Starbursts

From 30 Doradus to Lyman Break Galaxies

Programme and Abstract book

An international conference held at the
Institute of Astronomy, University of Cambridge (UK)
6 – 10 September 2004

Edited by Richard de Grijs

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Monday 6 September 2004 *Page:*

09:20 – 09:30	Welcome and opening	Douglas Gough (Director, IoA)	

Session I: Local starbursts as benchmarks for galaxy evolution

Chair: Max Pettini

09:30 – 10:00	Tim Heckman **R**	Local Starbursts in a Cosmological Context	8
10:00 – 10:20	Jay Gallagher	Starbursts in an evolving Universe: a local perspective	9
10:20 – 10:40	James D. Lowenthal	Are there local analogs of Lyman break galaxies?	10
10:40 – 11:10	coffee		
11:10 – 11:30	Paul A. Crowther	Massive stellar content of the metal-rich starburst M83	11
11:30 – 11:50	Jason L. Melbourne	Laser Illuminates Blue Compact Galaxies	12
11:50 – 12:10	JD T. Smith	Mid-Infrared Spectra of SINGS Galaxies	13
12:10 - 14:10	lunch		

Chair: Linda Smith

14:10 – 14:30	Almudena Alonso-Herrero	Near-Infrared Super Star Clusters in Starburst and Luminous Infrared Galaxies	14
14:30 – 14:50	Marco Sirianni	High-Resolution Imaging of the Super Star Clusters in NGC 1569 and NGC 1705	15
14:50 – 15:10	Andrea M. Gilbert	Massive Star Clusters, Feedback, and Superwinds	16
15:10 – 15:30	Bernhard R. Brandl	The mid-IR Properties of Nearby Starbursts from Spitzer Spectroscopy	17
15:30 - 16:00	tea		

Session II: The initial mass function in starburst regions; environmental dependences?

Chair: Jay Gallagher

16:00 – 16:30	Bruce Elmegreen **R**	The initial mass function in starbursts	18
16:30 – 16:50	Ian Bonnell	Dynamical models of star formation and the IMF?	19
16:50 – 17:10	Mark McCaughrean	Cluster star formation in the Milky Way and Magellanic Clouds: Evidence for IMF variations?	20
17:10 – 17:30	Ariane Lançon	Red supergiants, mass segregation and M/L ratios in young star clusters	21
17:30 – 17:50	Nate McCrady	IMF Variation in M82 Super Star Clusters, A Population Study	22

Tuesday 7 September 2004 *Page:*

Session III: Starbursts as a function of wavelength

Chair: Bruce Elmegreen

09:00 – 09:30	Jürgen Knödlseder **R**	Colourful starbursts	23
09:30 – 09:50	Claus Leitherer	A Far-Ultraviolet View of Starburst Galaxies	24
09:50 – 10:10	Daniela Calzetti	Local starbursts as benchmarks for the high-redshift Universe: Perspectives from the optical	25
10:10 – 10:30	Nils Bergvall	The starburst phenomenon from the optical/near-IR perspective	26
10:30 – 10:50	Paul van der Werf	Dissecting starburst galaxies with infrared observations	27
10:50 – 11:20	coffee		
11:20 – 11:40	Neil Trentham	What fraction of stars formed in infrared galaxies at high redshift?	28
11:40 – 12:00	James Dunlop	SHADES – exploring dust-enshrouded star-formation in the young Universe	29
12:00 – 12:20	Jim Ulvestad	Compact extragalactic star formation – peering through the dust at centimeter wavelengths	30
12:20 – 14:10	lunch		

Chair: Cathie Clarke

14:10 – 14:30	Veronique Buat	Star formation in the nearby Universe: the ultraviolet versus the far-infrared point of view	31
14:30 – 14:50	Michael A. Dopita	Theoretical Pan-Spectral Energy Distributions of Starburst Galaxies	32

Session IV: Triggering and quenching of starbursts and the effects of galactic interactions

14:50 – 15:20	François Schweizer **R**	Interaction-Induced Starbursts	33
15:20 – 15:40	Chris Mihos	Interaction-Induced Starbursts: Modeling Different Environments	34
15:40 – 16:10	tea		
16:10 – 16:30	Richard de Grijs	Star and cluster formation in extreme environments	35
16:30 – 16:50	Curtis Struck	The Recurrent Nature of Central Starbursts	36
16:50 – 17:10	Françoise Combes	Efficiency of the dynamical mechanism	37
17:10 – 17:30	Luis Colina	ULIRGs: 2D kinematics and star formation	38
17:30 – 17:50	Matthew A. Bershady	Internal Kinematics of Luminous Compact Blue Galaxies at $0.2 < z < 0.6$	39

Wednesday 8 September 2004 *Page:*

Session V: Star-formation rates in relation to the host galaxy properties

Chair: Daniela Calzetti

Free afternoon

Thursday 9 September 2004 *Page:*

Session VI: Starburst tracers: gas, dust and star formation

Chair: Rob Kennicutt

09:00 – 09:30	N. Förster-Schreiber **R**	Starburst galaxies: an infrared perspective	50
09:30 – 09:50	Roberto Terlevich	The star-formation history of HII galaxies	51
09:50 – 10:10	David Elbaz	Dusty starbursts as a standard phase in galaxy evolution	52
10:10 – 10:30	Daniel Kunth	Is the interstellar gas of starburst galaxies well mixed?	53
10:30 – 10:50	Eva Schinnerer	Super Star Clusters in M51: Connection between Molecular Gas, Stars & Dust	54
10:50 – 11:20	coffee		

Session VII: Starbursts at intermediate redshifts, and the starburst versus AGN paradigm

11:20 – 11:40	Guinevere Kauffmann	The Formation of Bulges and Black Holes: lessons from a census of active galaxies in the SDSS	55
11:40 – 12:00	Clive Tadhunter	Starbursts associated with luminous AGN	56
12:00 – 12:20	Rosa González Delgado	Starbursts in Low Luminosity Active Galactic Nuclei: Implications for the Starburst-AGN connection	57
12:20 – 14:20	lunch		

Chair: Clive Tadhunter

14:20 – 14:50	Nick Scoville **R**	The COSMOS survey of Starburst and AGN Evolution in the Large-Scale Structure Context	58
14:50 – 15:10	David C. Koo	Studies of Luminous Blue Compact Galaxies at Redshifts $z \sim 1$ in the DEEP Project	59
15:10 – 15:30	François Hammer	Did most present-day spirals form during the last 8 Gyr?	60
15:30 – 15:50	Lin Yan	The Spitzer 24-micron Properties of optical/near-IR selected EROs	61
15:50 – 16:20	tea		
16:20 – 16:40	Philip N. Appleton	The Infrared and Radio Properties of Starburst Galaxies in the Spitzer First Look Survey out to $z = 1.5$: The effects of collisions and mergers	62
16:40 – 17:00	Jiasheng Huang	The Spitzer observation of Lyman Break Galaxies	63
17:00 – 17:20	Lee Armus	Observations of ULIRGs with the IRS on Spitzer	64
17:20 – 17:40	Emeric M. Le Floc'h	Spitzer discovery of luminous infrared galaxies at $1 < z < 2.5$	65

Friday 10 September 2004 *Page:*

Session VIII: Violent star formation and the properties of star-forming galaxies at high redshift

Chair: Guinevere Kauffmann

09:00 – 09:30	Daniel Schaerer **R**	Stellar populations and star-formation histories of distant starbursts	66
09:30 – 09:50	Casey Papovich	The Role of Infrared-Selected Starburst Galaxies in Galaxy Evolution	67
09:50 – 10:10	Rodger I. Thompson	Starbursts in the Ultra Deep Field	68
10:10 – 10:30	Johan Fynbo	The properties of Lyα and Gamma-ray burst selected starbursts at high redshift	69
10:30 – 10:50	Dörte Mehlert	The stellar population of high-z galaxies from medium-resolution spectra in the FORS Deep Field	70
10:50 – 11:20	coffee		
11:20 – 11:40	Dawn K. Erb	Kinematic and Stellar Masses of Star-forming Galaxies at $z \sim 2$	71
11:40 – 12:00	Lisa J. Kewley	Star Formation and Metallicity in Galaxies: Evolution Between $0 < z < 3$	72
12:00 – 12:20	Samantha A. Rix	New Metallicity Diagnostics for High-Redshift Star-Forming Galaxies	73
12:20 – 14:20	lunch		

Chair: Evan Skillman

14:20 – 14:40	Marcin Sawicki	The Differential Evolution of the Luminosity Function of Star-Forming Galaxies from $z \sim 4$ to $z \sim 1.7$ using Multi-wavelength Imaging	74
14:40 – 15:00	Kentaro Nagamine	Massive galaxies at $z = 2$	75
15:00 – 15:20	Duília de Mello	Metal Enrichment in Galaxies at $z \sim 2$	76
15:20 – 15:40	tea		
15:40 – 16:10	Malcolm Bremer	Properties of star-forming galaxies at $z > 5$	77
16:10 – 16:30	Fabian Walter	Resolved Molecular Gas Emission in a QSO host galaxy at $z = 6.4$	78
16:30 – 17:00	Bob O'Connell	Conference summary	

Local Starbursts in Cosmological Context

Timothy M. Heckman

Department of Physics & Astronomy, Johns Hopkins University, USA

In this talk I hope to introduce some of the major topics that will be the subjects of detailed discussion throughout the conference. I will begin by defining starbursts in several different ways, and discuss the merits and demerits of these definitions. Using these definitions, I will then evaluate the importance of starbursts at low- and high-redshift. I will compare and contrast local starbursts and the Lyman-Break and sub-mm galaxies populations, and speculate as to the underlying astrophysics that explains the similarities and differences between local and high-z starbursts. I will briefly summarize the properties of starburst-driven galactic superwinds and their possible implications for the evolution of galaxies and the inter-galactic medium. Finally, I will briefly describe our current understanding of the starburst-AGN connection and the relation between the growth of black holes and galaxy bulges.

Starbursts in an evolving Universe: a local perspective

John S. (Jay) Gallagher

Department of Astronomy, University of Wisconsin-Madison, USA

Beyond the stars themselves, the hierarchy of gravitationally related young stellar systems in the disks of most galaxies range from OB associations to open star clusters, often arranged along spiral arms. While a variety of types of nearby starbursts exist (interactions, nuclear, dwarf, BCD), their star formation displays systematically different patterns than in normal galactic disks. Many stars are born in very compact star clusters, including the super star clusters (SSCs), which extend in mass to the range of globulars. The clusters themselves frequently are grouped in starburst clumps. These patterns imply high degrees of baryonic dissipation in starbursts, which will affect the overall evolution of galaxies, e.g., globally through the Tully-Fisher relationship, and locally through building high densities in galactic centers. Extreme concentrations of OB stars within the clumps impact the state of the ISM, including driving of galactic winds, possibly into the IGM, and opening positive feedback channels that support further intense star formation. These features will be briefly illustrated from observations of nearby galaxies to show how starbursts contribute to the ongoing processes of galaxy building.

Are there local analogs of Lyman break galaxies?

James D. Lowenthal

Department of Astronomy, Smith College/Five College Astronomy Department, USA

To make direct comparisons in the rest-far-ultraviolet between LBGs at $z \sim 3$ and more local star-forming galaxies, we use *HST*/STIS to image a set of 12 nearby ($z > 0.05$) HII galaxies in the FUV and a set of 14 luminous compact blue galaxies (LCBGs) at moderate redshift ($z \sim 0.5$) in the NUV, corresponding to the rest-FUV. We then subject both sets of galaxy images and those of LBGs at $z \sim 3$ to the same morphological and structural analysis. We find many qualitative and quantitative similarities between the rest-FUV characteristics of distant LBGs and of the more nearby starburst samples, including general morphologies, sizes, asymmetries, and concentrations. Along with some kinematic similarities, this implies that nearby HII galaxies and LCBGs may be reasonable local analogs of distant Lyman break galaxies.

Massive stellar content of the metal-rich starburst M83

Paul A. Crowther

Department of Physics & Astronomy, University of Sheffield, UK

VLT/FORS imaging and spectroscopy has been obtained for the metal-rich spiral nuclear starburst galaxy M83, revealing an unprecedented 1000 Wolf-Rayet (WR) stars located in 135 regions in its disk. One remarkable cluster, located 1 kpc from the nucleus, contains $\frac{1}{4}$ of the entire galactic WR population, and is also revealed as a compact Super Star Cluster (mass 2×10^5 $M_\odot$, radius 4 pc) from *HST*/ACS images. In contrast with all other galaxies for which spatially resolved WR populations have been obtained, N(late WC)/N(early WC) $\gg$ 1. Such a WC subtype-metallicity dependence argues in favour of a mass-loss/metallicity scaling for WR stars, supporting the Smith et al. (2002) grid of ionizing fluxes for young starbursts.

Laser Illuminates Blue Compact Galaxies

Jason L. Melbourne

CfAO, University of California, Santa Cruz, USA

With absolute magnitudes comparable to M31 and radii similar to the dwarf ellipticals orbiting our neighbor, Luminous Blue Compact Galaxies (LBCGs) lie at the extreme end of starburst galaxies. At $z \sim 1$ they comprise on the order of 10% of galaxies and between then and now are a major contributor to the evolution of the star-formation rate of the universe. Despite this, not only are the triggers of these intense localized starbursts still in doubt, the evolutionary end state is also uncertain. This is in large part due to the rarity of these galaxies in the local Universe, and the difficulty of spatially resolving them at higher redshift. Although rare, local counterparts have been discovered in emission-line galaxy surveys such as KISS and UCM as well as in Sloan. Making use of the high spatial resolution available with the ground-based Lick Laser Adaptive Optics system, we image 6 low redshift LBCGs in the near-IR. The observations reveal morphologies ranging from disky to irregular and knotty. At least two of these LBCGs are not the bursting bulges proposed by Barton and van Zee (2001). For these two galaxies we combine the near-IR data with *HST*/STIS imaging in the UV to determine stellar populations, and population gradients.

Mid-Infrared Spectra of SINGS Galaxies

JD T. Smith

Steward Observatory, University of Arizona, USA

We present first results of Spitzer spectroscopy from SINGS, the Spitzer Infrared Nearby Galaxies Survey. Spitzer's Infrared Spectrograph (IRS) is used to spectrally map variously sized regions centered on the nucleus, and covering star-forming rings and extra-nuclear HII regions. We highlight the powerful diagnostic capabilities made possible by the sensitivity of the IRS for local samples of low, moderate, and very active star-forming galaxies, including [OIV] as a tracer of very massive stars, new PAH features in the 16–18 micron range, and molecular hydrogen lines tracing hot photo-dissociation regions. We demonstrate the versatility of the IRS spectral mapping mode in producing spatially resolved maps tracking variations of the physical parameters of the gas, dust and stars on kpc scales in star-forming galaxies.

Monday 6 September 2004, 14:10 – 14:30 **Session I**

Near-Infrared Super Star Clusters in Starburst and Luminous Infrared Galaxies

Almudena Alonso-Herrero

Departamento de Astrofísica Molecular e Infrarroja, IEM, CSIC, Spain

In the last few years, NICMOS on the *HST* has played a relevant role in the discovery of a population of near-infrared star super clusters (SSCs) and associated giant HII regions, not only in interacting galaxies, LIRGs, and ULIGs, but also in isolated starburst galaxies, groups of galaxies, and even dwarf galaxies. Theoretical and observational arguments suggest that giant HII regions and SSCs represent the dominant mode of recent star formation – younger (a few million years old) and "older" ($\sim 3 - 200$ Myr), respectively. In particular, Paα ($\lambda_{\rm rest} = 1.87$ micron) observations together with radio observations offer us an unprecedented view to the truly youngest (high-mass) star-formation activity, as it is plausible that a large fraction of the youngest SSCs in galaxies are hidden by dust in their natal HII regions. In this talk I will present results on the properties of near-infrared SSCs and associated giant HII regions in a variety of galaxy types.

High-Resolution Imaging of the Super Star Clusters in NGC 1569 and NGC 1705

Marco Sirianni

European Space Agency / Space Telescope Science Institute, USA

We observed the local starburst galaxies NGC 1569 and NGC 1705 with the *HST*/ACS High Resolution Camera in the U, V and I filters. The superb resolution of these images (0.017 arcsec pixels) shows, for the first time, the real morphology of the Super Star Clusters in these galaxies. The analysis of the Radial Color profiles is used to address the issue of whether SSCs suffer from early mass segregation. Without some mass segregation the velocity dispersions of SSCs suggest that they are deficient in low mass stars, and hence may not represent true proto-globular clusters. For the first time the brightest stars of the SSCs are nicely resolved and HRC high precision photometry allows us to investigate the upper end of the luminosity function for these powerful starbursts, the closest analogs to high-z galaxies.

Massive Star Clusters, Feedback, and Superwinds

Andrea M. Gilbert

Max-Plank-Institut für extraterrestrische Physik, Garching, Germany

Young massive star clusters return matter and energy to the ISM via cluster winds that ultimately combine to power superwinds in high-density starbursts. We present high-resolution near-IR spectroscopy of such clusters that dominate the current star formation in the nearby merger, the Antennae. By fitting outflow models to their broad hydrogen lines, we measure the mass-loss rates and mechanical luminosities of these cluster outflows. They are strongly mass-loaded with high thermalization efficiencies, two properties that also characterize superwinds. While the Antennae do emit large-scale diffuse X-rays, their present star cluster density may be too low to generate an M82-like superwind, but it is perfect for providing a resolved look at feedback mechanisms in a young merger.

Monday 6 September 2004, 15:10 – 15:30 **Session I**

The mid-IR Properties of Nearby Starbursts from Spitzer Spectroscopy

Bernhard R. Brandl

Leiden University, Netherlands

Starburst galaxies cover a wide range of luminosities that can exceed the closest starburst region, 30 Doradus, by orders of magnitude in luminosity. Are the constituents of the luminous starbursts still clusters like R136, or do they require a different mode of star formation?
I will discuss the star formation in, and the general properties of, the 30 Doradus region in the light of recent observations with the Spitzer Space Telescope. I will then compare 30 Doradus with more distant and luminous systems and discuss recent Spitzer spectra of nearby starburst galaxies for comparison.

The initial mass function in starbursts

Bruce Elmegreen

IBM Watson Research Center, USA

Twenty years of progress in our assessment of the IMFs in Starburst regions will be reviewed, starting with the early models of top-heavy IMFs and proceeding toward today's more conservative interpretations. General observations of the IMF will then be discussed to put the starburst results in perspective. These general observations include regions ranging from the LMC remote field to low surface brightness galaxies, the nearby field, normal galaxies, normal clusters, and super star clusters. Evidence for a top-heavy IMF is found for a few SSC, but the observations contain many systematic uncertainties. We conclude with an assessment of observed IMF variations, suggesting that the IMF probably does vary with environment in the sense that denser and more massive clusters produce proportionally more massive stars. We believe this shift is the result of enhanced accretion and coalescence in the pre-stellar condensation (PSC) phase, as proposed by many authors over the years. Low-density regions like Taurus probably produce relatively steep IMFs. A three-component IMF model is proposed in which solar-mass and intermediate-mass stars come from PSCs that form by gas processes like turbulence and gravitational collapse in molecular clouds; low-mass stars and brown dwarfs get their mass from gravitational instabilities inside the exposed cores, disks, and shocked interfaces of PSCs, where the pressure is extremely high, and many high-mass stars get their mass from the coalescence of and enhanced accretion onto PSCs. The relative importance of these three components should vary with environment in a way that explains the observed IMF variations.

Dynamical models of star formation and the IMF?

Ian Bonnell

School of Physics and Astronomy, University of St. Andrews, UK

I will review how competitive accretion in stellar clusters is a potential mechanism to explain the observed initial mass function (IMF) of stars. In this mechanism, stars attain their final masses by accreting gas within a clustered environment, with a few centrally located stars accreting significantly more than the rest to become high-mass stars. The IMF arises due to the detailed physics of the accretion process. In young, gas-dominated clusters, accretion is controlled by the tidal radius of individual stars. In contrast, where stars dominate the potential, as first occurs in the core of a cluster, the accretion is controlled by the Bondi-Hoyle radius. The combination of these two accretion processes results in a two power-law IMF with a shallow power-law, $\gamma \approx -1.5$, for low-mass stars which accrue their mass in the gas dominated regime whereas higher mass stars have a steeper, $\gamma \approx -2.5$, IMF as their mass is predominantly due to accretion in the core of a cluster. Numerical simulations of the fragmentation and formation of a stellar cluster show that the final stellar masses are due to competitive accretion and that this results in a realistic IMF. Competitive accretion also naturally results in a mass segregated cluster and in a direct correlation between the richness of a cluster and the mass of the most massive star therein.

Cluster star formation in the Milky Way and Magellanic Clouds: Evidence for IMF variations?

Mark McCaughrean

Astrophysikalisches Institut Potsdam, Germany

I will review recent studies of the stellar initial mass function (IMF) in regions of high-mass star formation in the Galaxy and Magellanic Clouds, considering to what extent these (mostly) resolved populations can be used as building block templates for understanding starbursts at much larger distances. In particular, I will examine whether or not there is significant evidence for variations in the IMF at the high- and low-mass ends of the spectrum, including upper and lower mass cutoffs, as a function of the ambient environment.

Individual regions discussed will include the Trapezium Cluster in Orion, the nearest and best-studied example of ongoing star formation, along with the more massive and distant NGC 3603, the Arches and Quintuplet Clusters near the Galactic Centre, and the R136/30 Dor cluster in the LMC. In these latter clusters, *HST* and adaptive-optics observations at near-infrared wavelengths have enabled much more detailed looks at their contents than previously possible, hopefully yielding an improved basis for decomposing the properties of integrated starburst populations.

Red supergiants, mass segregation and M/L ratios in young star clusters.

Ariane Lançon

Observatoire de Strasbourg, France

Dynamical masses of star clusters are used to set constraints on the slope or lower mass cut-off of the stellar IMF. The measurements of dynamical masses rest on model-based relationships between mass, projected velocity dispersion and projected half-light radius. We have used dynamical models that account for stellar evolution to compute the evolution of this relationship, depending on the wavelengths at which radii and velocity dispersions are observed. The conversion factor varies significantly over a few $\times 10^7$ yr. In particular, we look at near-IR observations (highly reddened clusters), where red supergiants are dominant. These stars are initially among the most massive stars, but they lose mass rapidly and the resulting dynamical evolution is complex.

IMF Variations in M82 Superstar Clusters, A Population Study

Nate McCrady

University of California, Berkeley, USA

The nuclear starburst in M82 is host to over 20 infrared-bright, dense, young superstar clusters (SSCs). We use high-resolution near-infrared Keck/NIRSPEC echelle spectroscopy to measure the stellar velocity dispersions. The SSCs are resolved in *HST*/NICMOS and ACS images, from which we measure half-light radii and integrated luminosities. We calculate virial masses for the SSCs, and present the mass and luminosity distribution functions for the population. Comparing the observed light-to-mass ratios to population synthesis models constrains the IMF for individual clusters and demonstrates apparent variations within a single starburst galaxy. We present evidence for mass segregation despite the young ages (typically 10–50 Myr), and discuss implications for interpretation of the IMF and whether the clusters are a young globular cluster population. With a sample of over 20 clusters, this dataset represents the largest study of SSCs in a single galactic environment, providing a strong test of environmental dependency of the IMF.

Colourful starbursts

Jürgen Knödlseder

C.E.S.R., France

no abstract received

Tuesday 7 September 2004, 09:30 – 09:50 **Session III**

A Far-Ultraviolet View of Starburst Galaxies

Claus Leitherer

Space Telescope Science Institute, USA

I will discuss recent results on starburst galaxies obtained at wavelengths below 1200Å. The talk will cover stars, hot and cold gas, and dust. The wavelength region below 1200Å follows similar trends as seen at longer wavelengths, with several notable exceptions. Even the youngest stellar populations show a turn-over in their SEDs, and line-blanketing is much more pronounced. Furthermore, the OVI line allows us to probe gas at higher temperatures than seen at longer wavelengths. Molecular hydrogen lines (if detected) provide a glimpse of the cold phase. I will also briefly cover the crucial wavelength regime below 912Å and the implications of recent attempts to detect escaping ionizing radiation.

Local starbursts as benchmarks for the high-redshift Universe: Perspectives from the optical

Daniela Calzetti

Space Telescope Science Institute, USA

The optical regime is historically the best-studied wavelength range. Gas ionized by massive stars produces optical emission lines that have been used to get indicators of star-formation rate, metallicity, dust reddening, and the ionization conditions of the ISM. Absorption lines have been used to measure velocity dispersions, and the 4000Å break has been shown to be an indicator of the mean age of stellar populations. I briefly summarize recent work done on some of these indicators in nearby galaxies, in view of their importance for understanding star-forming galaxies at high redshift.

The starburst phenomenon from the optical/near-IR perspective

Nils Bergvall

Uppsala Astronomical Observatory, Sweden

The optical/near-IR spectral continuum carries unique information about the stellar population in a galaxy, including its mass function and star-formation history. Star-forming regions also display rich emission-line spectra from which we can derive dust extinction, metallicities and velocity fields. All this information is potentially very useful in the dissection of the starburst phenomenon. There are, however, several obstacles on the way. One is the dust obscuration, hindering us from the view of the most luminous starbursts. A second problem concerns the reliability of the spectral evolutionary models used in the analysis and the insufficiency of the constraints we are able to pose on the models. Moreover, when we try to understand the starburst triggering mechanism we sometimes face severe problems with selection biases. With focus on the relatively dust free starburst dwarfs, I will discuss a few of the advantages and limitations of observations in the optical/near-IR region. Special attention will be given to the role of interactions and mergers and the coherence among the results from different observers. I will also briefly discuss the properties of the progenitors of starburst dwarf galaxies and the red halo excess. A few new results will be presented.

Dissecting starburst galaxies with infrared observations

Paul van der Werf

Leiden Observatory, Netherlands

Stars form in dusty molecular clouds, and hence it is not surprising that starburst galaxies are often optically obscured. Infrared observations can not only help penetrate the dusty veil, but also allow the dust emission to be used as a diagnostic tool. Combined near-infrared and mid-infrared spectral line and continuum imaging at sub-arcsecond resolution thus provides unique insight into the physics of starburst galaxies. In this talk two case studies will be presented: the nearby moderate luminosity starburst galaxy NGC 253 and the ultraluminous infrared galaxy Arp 220. Focus will be on the diagnostic power of near-infrared emission lines (hydrogen and helium recombination lines tracing massive young stars, [FeII] lines tracing supernova shocks and H_2 vibrational lines tracing warm molecular gas), and ground-based N-band imaging tracing the starburst-heated dust at the highest available spatial resolution.

Tuesday 7 September 2004, 11:20 – 11:40 **Session III**

What fraction of stars formed in infrared galaxies at high redshift?

Neil Trentham

Institute of Astronomy, University of Cambridge, UK

Star formation happens in roughly two types of environment: ultraviolet-bright starbursts (examples: 30 Doradus and HII galaxies) and dust-enshrouded regions (which may be moderate like Orion in the Galaxy or extreme like the core of Arp 220). In this talk I will estimate how many of the stars in the local Universe formed in each type of environment, using observations of star-forming galaxies at different wavelengths at all redshifts and of the evolution of the field galaxy population down to redshift zero. Finally I try to uncover why the ratio of stars that formed in each type is equal to a particular value and identify the responsible cosmic processes at high redshift.

SHADES – exploring dust-enshrouded star-formation in the young Universe

James Dunlop

Institute for Astronomy, University of Edinburgh, UK

The sub-mm galaxy population continues to present a major challenge to theories of galaxy formation, as current semi-analytic models cannot naturally explain the existence of a substantial population of dust-enshrouded starburst galaxies. However, while now regarded as of key importance by theorists, the basic properties of sub-mm galaxies (such as redshift distribution, clustering, and mass) are still not well defined. SHADES, the Scuba HAlf Degree Extragalactic Survey was designed to remedy this situation. It aims to devote $\sim$ 50% of all UK time on the JCMT over 3 years to map 0.5 square degrees with SCUBA to an rms noise level of 2 mJy at 850 microns. Now 50% complete, the survey has yielded a complete sample of $\sim$ 150 bright sub-mm sources, with comprehensive supporting multi-frequency observations. I will summarize the current status of the survey, and highlight the key new results already emerging from the combination of SCUBA, VLA, and Spitzer observations of the survey fields.

Compact extragalactic star formation – peering through the dust at centimeter wavelengths

Jim Ulvestad

National Radio Astronomy Observatory, USA

Nearby galaxies presently undergoing starbursts cover a wide range of types, including metal-poor dwarfs, irregular and spiral galaxies, and classical mergers. These galaxies provide a window into the properties of distant galaxies in the early Universe, when massive star formation was much more prevalent. Centimeter radio interferometry supplies a unique capability for exploring the youngest star formation complexes, so-called "super star clusters" (SSCs) that ultimately may evolve into globular clusters. Imaging of thermal radio emission has revealed many SSCs, which often are invisible in the optical and near-infrared. These clusters contain the equivalent (in ionizing radiation) of a few tens of O7 stars in galaxies like NGC 253, up to a few thousand O7 stars or more in galaxies like the Antennae, in regions with sizes ranging from a few parsecs up to about 100 parsecs. Recent VLBI observations also detect young supernovae enshrouded by dust in some merging/starburst galaxies, possibly marking slightly older SSCs in which the most massive stars are just going supernova.

Tuesday 7 September 2004, 14:10 – 14:30 **Session III**

Star formation in the nearby Universe: the ultraviolet versus the far-infrared point of view

Veronique Buat

Laboratoire d'Astrophysique de Marseille, France

We make use of the on-going All Imaging Survey of the UV GALEX satellite cross-correlated with the IRAS all sky survey to build samples of galaxies truly selected in far-infrared or in ultraviolet. We will discuss the best way to derive dust extinction and star formation rates for these galaxies and will compare the properties of the galaxies selected in FIR or in UV. Implications for high-redshift studies will be discussed.

Theoretical Pan-Spectral Energy Distributions of Starburst Galaxies

Michael A. Dopita

Research School of Astronomy & Astrophysics, The Australian National University, Australia

We have combined the Starburst99 (for the stellar SED) and the MAPPINGS IIIq code (for the gas line and continuum, PAH molecular and dust re-emission spectrum) with self-consistent evolutionary models of HII regions. This produces purely theoretical synthetic spectral energy distributions (SEDs) for (solar metallicity) starbursts lasting some 10^8 yr. These self-consistent theoretical SEDs extend from the Lyman Limit to beyond 21 cm, and allow us to inter-compare the calibrations of the commonly-used star-formation indicators from UV to radio wavelengths. We find that two parameters exercise fundamental control over the SED, the mean pressure in the ISM and the characteristic timescale over which the HII regions destroy their surrounding placental molecular clouds. We present theoretical colour–colour diagrams for both IRAS and the Spitzer Space Observatory to show how these parameters can be separated observationally.

Interaction-Induced Starbursts

François Schweizer

Carnegie Observatories, USA

Extragalactic starbursts induced by gravitational interactions can now be studied from $z \simeq 0$ to $z \gtrsim 2$. The evidence that collisions and mergers of gas-rich galaxies tend to trigger galaxy-wide starbursts is strong, both statistically and in individual cases of major disk-disk mergers. Observed star-formation rates are enhanced by factors of a few to $\sim 10^3$ over normal. Detailed studies of NGC 3256, NGC 4038/39, and ULIRGs suggest that the main trigger for starbursts may be the rapidly mounting pressure of the ISM rather than exceptionally fast cloud motions or direct cloud-cloud collisions. Numerical simulations show that in colliding galaxies the SFR depends not only on the gas density, but crucially also on energy dissipation in shocks. An often overlooked characteristic of merger-induced starbursts is that the spatial distribution of the enhanced star formation extends over large scales ($\sim 10 - 30$ kpc). Thus, although most such starbursts do peak at or near the galactic centers, young stellar populations pervade merger remnants and explain why age gradients in descendant galaxies are mild. This talk will give an overview of interesting phenomena observed in galaxy-wide starbursts and will emphasize that such events continue to accompany the birth of elliptical galaxies to the present epoch.

Tuesday 7 September 2004, 15:20 – 15:40 **Session IV**

Interaction-Induced Starbursts: Modeling Different Environments

Chris Mihos

Department of Astronomy, Case Western Reserve University, USA

Starbursts in interacting galaxies are mediated by the dynamical response of the host galaxy to the collisional perturbation. Environmental effects may lead to systematic differences in the nature of the encounter and the structural properties of the interacting galaxies. The properties of induced starbursts are likely, therefore, to be different in cluster, group, and field environments. I will first discuss these differences in the context of numerical simulations of star formation in interacting galaxies, and then touch on systematic effects in the implementation of star-formation prescriptions in simulations.

Star and star cluster formation in extreme environments

Richard de Grijs

Department of Physics & Astronomy, University of Sheffield, UK

The currently available empirical evidence on the star-formation processes in the extreme, high-pressure environments induced by galaxy encounters, mostly based on high-resolution *Hubble Space Telescope* imaging observations, strongly suggests that star *cluster* formation is an important and perhaps even the dominant mode of star formation in the starburst events associated with galaxy interactions. The production of young massive star clusters (YMCs) seems to be a hallmark of intense star formation, particularly in interacting and starburst galaxies. Their sizes, luminosities, and mass estimates are entirely consistent with what is expected for young Milky Way-type globular clusters (GCs). YMCs are important because of what they can tell us about GC formation and evolution (e.g., initial characteristics and early survival rates). They are also of prime importance as probes of the formation and (chemical) evolution of their host galaxies, and of the initial mass function in the extreme environments required for cluster formation. Recent evidence lends support to the scenario that GCs, which were once thought to be the oldest building blocks of galaxies, are still forming today. In very recent developments, we have developed a novel empirical approach to assess the shape of the initial-to-current YMC mass functions, and hence their chances of survival for a Hubble time.

The Recurrent Nature of Central Starbursts

Curtis Struck

Department of Physics & Astronomy, Iowa State University, USA

Numerical hydrodynamical models with feedback terms suggest that at sufficiently high gas densities and SFR rates nuclear starbursts are inherently self-limiting, but also repetitive. Observations suggest that central starbursts have a wide range of time-scales, and provide tentative evidence of multiple bursts, in some cases. Studies of interacting galaxies show that before a merger the galaxy nuclei are frequently not in a burst phase, which suggests that the burst duty cycle is short. It is unlikely that either gas consumption or dispersal terminate individual bursts (galactic winds do not eject large masses of gas). The models suggest that this is accomplished by a combination of heating (increasing the warm/hot component), expansion into the vertical direction, and increasing the cloud velocity dispersion. These processes introduce cooling and expansion, or sonic time-scales, into the problem, in addition to the feedback timescale or massive star lifetime. Cycles of bursts may be triggered externally, e.g., by mass transfer or bars with their own time-scales. With the interplay of so many processes, it is difficult to sort out the role of each, and perhaps impossible to deterministically account for the triggering in the centers of interacting systems.

Efficiency of the dynamical mechanism

Françoise Combes

Observatoire de Paris, LERMA, France

The most extreme starbursts occur in galaxy mergers, and it is now acknowledged that dynamical triggering has a primary importance in star formation. This triggering is due partly to the enhanced velocity dispersion provided by gravitational instabilities, such as density waves and bars, but mainly to the radial gas flows they drive, allowing for large amounts of gas to condense on a short time-scale. Numerical simulations with several gas phases, taking into account the feedback to regulate star formation, have explored the various processes, using recipes like the Schmidt law, moderated by the gas instability criterion. The state of the art will be reviewed, and the detailed mechanisms governing gas infall in the inner parts of galaxy disks will be discussed.

Tuesday 7 September 2004, 17:10 – 17:30 **Session IV**

ULIRGs: 2D kinematics and star formation

Luis Colina

Instituto de Estructura de la Materia, CSIC, Spain

This talk will summarize the results of our Integral Field Spectroscopy survey of low-z ULIRGs being carried out using the INTEGRAL system on the WHT. The sample consists of 20 ULIRGs covering different phases of the interaction process and all types of activity from QSO-like to starbursts. Data allow to establish connections between the kinematics, ionization, and energy sources. Several topics will be covered: (1) 2D velocity fields: tidally induced motions, nuclear rotating disks, starburst-induced winds. (2) nuclear gas (and stellar) kinematics: mass estimates. (3) dust-enshrouded star formation: nuclear starbursts, differential extinction effects. (4) tidally induced star formation: extranuclear stellar clusters, tidal dwarf galaxies. (5) extended LINERs: gas kinematics, shocks, ionization. (6) implications for high-z dust-enshrouded starbursts.

Internal Kinematics of Luminous Compact Blue Galaxies at $0.2 < z < 0.6$

Matthew A. Bershady

Department of Astronomy, University of Wisconsin-Madison, USA

We describe the dynamical properties which may be inferred from *HST* and Keck spectroscopic observations of luminous compact blue galaxies at intermediate redshift. While the sample is homogeneous in blue rest-frame color, small size and line-width, and high surface brightness, their detailed morphology is eclectic. We use the available kinematic data to determine the amplitude of rotation versus random, or disturbed motions of the ionized gas. We also examine the correlation of their resolved kinematics with their distorted *HST* morphology at optical and infrared wavelengths. This information allows us to assess the accuracy of dynamical mass estimates, constrain their M/L ratios, and hence better glimpse the future of these unusual galaxies.

Wednesday 8 September 2004, 09:00 – 09:30 **Session V**

Star-Formation Demographics of Host Galaxies: Clues from the Local Universe

Rob Kennicutt (with Janice Lee, Jose Funes, and Sanae Akiyama)

Steward Observatory, University of Arizona, USA

An explosion of new multi-wavelength observations of local galaxies is allowing us to study the demographics of the local star-forming galaxy population in unprecedented depth, and characterize the properties, frequencies, and duty cycles of starbursts of different types. Such data provide a foundation for interpreting observations of high-redshift objects, and for exploring the underlying scaling laws that connect the properties of starburst galaxies to each other and to those of normal star-forming galaxies. This talk will review the integrated star-formation properties of the local galaxy population, including starbursts, with emphasis on what can be learned from large Hα and infrared surveys.

A morphological view of star-forming vs. recently star-forming vs. red-and-dead galaxies at $1 < z < 2$

Bob Abraham

Department of Astronomy & Astrophysics, University of Toronto, Canada

I present the star-formation history, evolving stellar mass function and morphological mix of galaxies identified spectroscopically from the Gemini Deep Deep Survey (GDDS). The GDDS is the deepest redshift survey ever undertaken, and is based on careful infrared selection coupled with unusually long (typically > 30 hour) integration times on Gemini. These long integrations are made possible by a new "Nod & Shuffle" mode added to the telescope by our survey team. The central conceit of the GDDS is that it probes a *mass-limited* sample at $1 < z < 2$ (the so-called "redshift desert") irrespective of star-formation history, picking up (for example) faint but massive red-and-dead galaxies missed by most other high-redshift galaxy surveys. Actively starbursting, recently star-forming (but now quiescent), and red-and-dead galaxies offer a study in contrasts over this redshift range; this talk will explore what their relative abundances tell us about galaxy formation, and more specifically, about the duty cycle of starburst activity, in the former redshift desert.

The global star-formation rate in different morphological types of galaxies

Joe Silk

Astrophysics, University of Oxford, UK

I will provide theoretical perspectives on global star-formation rates, with particular emphasis on the nature of starbursts, both minor and major.

Star formation in local galaxies and the abundance of starbursts in the local Universe

Jarle Brinchmann

Centro de Astrofisica da Universidade do Porto, Portugal

We have recently completed a comprehensive study of star formation in the local universe using SDSS data (Brinchmann et al 2004). We have re-analysed the SDSS spectra using a special-purpose pipeline which provides state-of-the-art continuum subtraction to extract emission lines down to very low flux levels. Coupled with careful emission-line modeling using the Charlot & Longhetti (2001) models this has allowed us to study star formation in galaxies spanning 4 orders of magnitude in stellar mass while carefully accounting for systematic effects. Here, we will outline the main results of this study and focus in particular on the abundance function of starbursts in the local Universe. We will discuss the distribution function of starbursts versus metallicity of the star-forming gas, stellar mass of the host galaxy, and the recent past star-formation history of the galaxy. One of the key results here is to show that a large fraction of the galaxies undergoing starbursts today show signs of activity over the last Gyr.

Star Formation in Gas-Rich Early-Type Galaxies

Annette Ferguson

Max Planck Institute for Astrophysics, Garching, Germany

Little is known about the current star-formation properties of the earliest-type galaxies, namely the ellipticals and S0s. Recent studies suggest that a non-negligible fraction of these systems actually possess substantial amounts of extended cold interstellar gas. Furthermore, the peak gas column densities observed are comparable to those seen in the outer parts of spirals, and in LSB galaxies, where low level massive star formation is often observed. I will present results from an Hα imaging survey to search for ongoing star formation in a sample of 35 field E/SOs with extended gas distributions. I will discuss the incidence and properties of HII regions in these systems, and the implications they have for understanding the star-formation process. Better statistics on star-forming early types is provided by the SDSS and I will present some preliminary results from a sample of ellipticals drawn from the public data release.

Star-Formation Efficiencies and Star Cluster Formation

Uta Fritze–v. Alvensleben

Universitäts-Sternwarte Göttingen, Germany

Starbursts produce large numbers of bright blue Young Star Clusters (YSCs). Evolutionary synthesis models show that the time evolution of M/L ratios is very strong in very early phases of a star cluster. Multi-color photometry in combination with a dedicated SED analysis tool allows us to derive masses for individual star clusters and, hence, mass functions for YSC systems that can significantly differ in shape from their luminosity functions. Both the luminosity and the mass of the most luminous cluster is found to scale with burst strength, star-formation rate, and the total number of YSCs present. Neither the mass function, which is known to be Gaussian for old Globular Cluster (GC) systems but still controversial for YSC systems, nor the mass range, however, allow to individually discriminate YSCs in terms of young GCs on one hand and less strongly bound and hence more short-lived clusters on the other. While the formation of GCs, i.e. of star clusters compact and strongly bound enough to be able to survive for $\geq$ 10 Gyr, is expected in massive gas-rich spiral – spiral mergers because of their – at least sometimes – high global star-formation efficiencies it has not yet been possible to identify young GCs among young star cluster populations. We define a compactness parameter involving masses and half-light radii of YSCs that need not yet be tidally truncated and investigate if young GCs are formed at all in starbursts in various types of systems and if the ratio of young GCs to more loosely bound star clusters depends on galaxy type, mass, environment, burst strength, etc.

Cluster Populations in Nearby Starburst Galaxies

Jason Harris

Steward Observatory, University of Arizona, USA

I present broad- and narrow-band *HST* photometry of young star clusters in the nearby starburst galaxies M83, NGC 3077 and NGC 5253. By comparing the photometry to population synthesis models, we are able to constrain the age and mass of each cluster. The distribution of cluster ages illuminates the recent star-formation history of the host galaxy. Comparing the star-formation histories of these galaxies provides a new look at understanding the starburst phenomenon, and in particular, how starburst events shape (and are shaped by) the properties of the host galaxy.

Massive Star Clusters in Non-Interacting Galaxies

Søren S. Larsen

ESO / ST-ECF, Germany

Much attention has been given to starbursts and formation of massive clusters as a result of galaxy interactions and mergers. However, there are several examples of apparently normal, undisturbed galaxies with elevated levels of star formation, which are also forming large numbers of luminous young star clusters. This implies that galaxy interactions, while seemingly effective at stimulating enhanced star-formation activity, are not a necessary condition for the formation of massive star clusters. I will discuss observations of massive clusters in several nearby galaxies, including new estimates of their dynamical masses and corresponding mass-to-light ratios which appear to be consistent with a "standard" (Salpeter- or Kroupa-like) stellar initial mass function.

Nascent starbursts in synchrotron-deficient galaxies

Hélène Roussel

California Institute of Technology, USA

We have identified a rare category of galaxies deviating from the universal infrared-radio correlation of star-forming galaxies in being significantly deficient in synchrotron radiation at 20 cm. The selected objects also have high dust temperatures, indicating intense radiation fields. From a detailed study of the three closest such objects, the most likely scenario accounting for all their properties is a starburst breaking out in the last few Myr in a host previously quiescent for at least 100 Myr. The prototype of this class, NGC 1377, is the only member of the IRAS Bright Galaxy Sample undetected at all radio wavelengths at the 1 mJy level, and has very intriguing properties: the color temperature in the far-infrared is 80 K; the peculiar mid-infrared spectrum suggests a transient dust species other than PAHs; the only detected line emission in the optical-infrared range is from hot, shock-excited molecular hydrogen; nearly all ionizing photons must be absorbed by dust. All evidence points to a very compact starbursting region that could be as young as 0.1 Myr. Yet, the morphology of NGC 1377 (low mass lenticular) does not reveal any disturbance nor hint at any tidal interaction. We have selected a statistical sample of candidate nascent starbursts from the cross-correlation of the IRAS Faint Source Catalog with the NVSS and FIRST VLA radio surveys. They constitute only 1–2% of an infrared flux-limited sample, but make up 17% of galaxies whose infrared spectrum peaks at 60 microns. Due to the extreme brevity of their presumed evolutionary stage, they have been largely overlooked, but are of crucial importance to understanding the triggering mechanisms, initial conditions and early development of starbursts. I will first describe the characteristics of the prototype nascent starburst, NGC 1377, and discuss the analogy with Becklin-Neugebauer objects. I will then present the selected sample and results obtained from a recent multi-wavelength VLA campaign, and other diagnostics of interstellar medium excitation. I will conclude with the prospects for a detailed study with the Spitzer telescope.

HST/STIS Spectroscopy of the Starburst Core of M82

Linda J. Smith

Department of Physics & Astronomy, University College London, UK

We present *HST*/STIS spectroscopy for one slit position crossing the starburst core of M82, sampling both clusters and ionized gas at optical wavelengths. The spectra have a spatial resolution of 2 pc at M82, allowing us to uniquely probe the conditions within a starburst environment in unprecedented detail. We present measurements of densities, abundances and kinematics for the ionized gas component. We find that, overall, the ionized gas has high turbulent and thermal pressures ($P/k \sim 10^7$), reflecting the intense energy input from supernovae concentrated in super star clusters. The data also provide new insights into the immediate environments of SSCs. We identify one such 5–8 Myr old cluster which is embedded in a high pressure H II region that appears to be interacting with the superwind from the starburst core.

Starburst galaxies: an infrared perspective

Natascha M. Förster-Schreiber

Max-Planck-Institut für extraterrestrische Physik, Garching, Germany

I will discuss various tracers of the gas, dust, and star-formation activity in starburst galaxies, with an emphasis on the infrared regime. I will review results in recent years from studies of nearby starbursts based on these diagnostics, which significantly enhanced our understanding of the star-formation process in starburst environments, and of the evolution and feedback effects of starburst activity, and which enabled us to establish novel empirical tools to constrain the properties of star-forming galaxies from infrared observations. I will highlight some of the promising applications of such tracers in investigations of galaxies near and far with current and future facilities such as Spitzer and Herschel.

Thursday 9 September 2004, 09:30 – 09:50 **Session VI**

The star-formation history of HII galaxies

Roberto Terlevich

INAOE, Mexico

no abstract received

Dusty starbursts as a standard phase in galaxy evolution

David Elbaz

Service d'Astrophysique, CEA Saclay, France

The apparently anomalous objects discovered by IRAS and classified as LIRGs and ULIRGs, which radiate the bulk of their luminosity through dust re-radiated stellar light, appear to be much more common in the distant Universe than locally. Their fast evolution revealed by ISO and SCUBA is now confirmed also by Spitzer. The contribution of these galaxies to the cosmic star-formation history as well as to the cosmic stellar mass building history is such that they should be considered as a standard phase experienced by most galaxies instead of a peculiar population of galaxies.
Are these distant LIRGs similar to local ones? What is the triggering mechanism for these starbursts? How many stars do they form, how long does this phase last? What is the role of the environment? Using data gathered on these galaxies using *HST*/ACS, VLT-FORS2 and VIMOS, ISOCAM, Spitzer, XMM and Chandra, we will address these questions.

Is the interstellar gas of starburst galaxies well mixed?

Daniel Kunth

Institut d'Astrophysique de Paris, CNRS, France

It is now possible to observationally study the chemical composition of the interstellar gas in starburst galaxies. Compositions can now be obtained for the ionized gas (HII), the neutral gas (HI) and the hot gas (from OVI, etc...). I will show that this sheds some new light onto the problem of dispersal and mixing of the heavy elements, both in the ISM and the IGM.

Super Star Clusters in M51: Connection between Molecular Gas, Stars & Dust

Eva Schinnerer

Max Planck Institute for Astronomy, Heidelberg, Germany

Due to its almost face-on orientation, the nearby grand-design spiral galaxy M51 is a prime target to study the connection/interplay between (molecular) gas, dust and massive star formation. I will report on a ongoing multi-wavelength (UV to radio) study focusing on the (cor)relation between the physical properties of dense molecular gas and ongoing massive star formation (including super star clusters) within the spiral-arm environment. Our observations of key molecular transitions (^{12}CO, ^{13}CO, C^{18}O, HCN, HCO$^+$) with the OVRO mm-interferometer and the IRAM 30m telescope allow, for the first time, to constrain the physical properties (temperature, density) of the molecular gas at high spatial resolution ($\sim$ 100 pc). This information is combined with new high-resolution radio continuum VLA data, archival *HST* imaging (Hα, Paα, B, V, R, I, J, H, K) and GALEX UV data tracing the ongoing star (cluster) formation. Preliminary analysis suggests that the physical conditions of the giant molecular cloud complexes (GMCs) are similar to those in the Milky Way, with little evidence for cloud heating by the massive star formation. However, we find varying conditions in the molecular gas across the spiral arms which is likely linked to the onset of star formation along the leading side of the spiral arms.

The Formation of Bulges and Black Holes: lessons from a census of active galaxies in the SDSS

Guinevere Kauffmann

Max Planck Institute for Astrophysics, Garching, Germany

We have used a sample of 22,000 AGN drawn from the Sloan Digital Sky Survey (SDSS) to examine the relationship between galaxies, starbursts, supermassive black holes and AGN in the present-day Universe. We have studied how AGN host properties compare to those of normal galaxies and how they depend on the luminosity of the active nucleus. We find that AGN reside almost exclusively in massive galaxies and have distributions of sizes, stellar surface mass densities and concentrations that are similar to those of ordinary early-type galaxies in our sample. The host galaxies of low-luminosity AGN have stellar populations similar to normal early-types. The hosts of high-luminosity AGN have much younger mean stellar ages and a significant fraction have experienced recent starbursts. We use the velocity dispersion of each AGN host galaxy to infer its black hole mass and its [OIII] luminosity to derive the mass accretion rate of the black hole. We find that the volume-averaged ratio of star formation to black hole accretion is ~ 1000 for the bulge-dominated galaxies in our sample. This is remarkably similar to the observed ratio of stellar mass to black hole mass in galaxy bulges. Most of the present-day black hole growth is occurring in black holes with masses less than 3×10^7 $M_\odot$. Our estimated accretion rates imply that low-mass black holes are on average growing on a timescale that is comparable to the age of the Universe. We have also cross-correlated our sample with the IRAS catalog and we will present new results on how the morphologies and stellar populations of AGN differ from those of ordinary starburst galaxies as a function of L(FIR).

Starbursts associated with luminous AGN

Clive N. Tadhunter

Department of Physics & Astronomy, University of Sheffield, UK

The starburst components detected in the host galaxies of luminous AGN have the potential to provide key information about the link between the evolution of the hosts and the triggering of the nuclear activity. I will review the properties of the starburst components in powerful radio galaxies, concentrating on new results derived from wide spectral coverage optical spectroscopic observations. The spectra show that the starbursts are massive, have intermediate ages, and are often highly extinguished. The results are discussed in the context of models for the triggering of the activity.

Starbursts in Low Luminosity Active Galactic Nuclei: Implications for the Starburst-AGN connection

Rosa M. González Delgado

Instituto de Astrofísica de Andalucía, Spain

We present a study of the stellar populations in Low Luminosity Active Galactic Nuclei (LLAGN). Our goal is to search for spectroscopic signatures of starbursts, and to investigate their relationship with the ionization mechanism in LLAGN. The method used is based on the stellar population synthesis of the optical continuum of the innermost ($20 - 100$ pc) regions in these galaxies. For this purpose, we have collected high spatial resolution optical ($2900 - 5700$Å) STIS spectra of 28 nearby LLAGN, plus UV-optical SEDs of a few LLAGN that are available in the *Hubble Space Telescope* archive, in addition to 51 ground-based optical spectra of LLAGN. Our main findings are: (1) No features due to Wolf-Rayet stars were convincingly detected in the STIS spectra. (2) Young starbursts contribute very little to the optical continuum in the ground-based apertures. However, the fraction of light provided by young stars is higher than 10% in most of the weak-[OI] ([OI]/H$\alpha \leq 0.25$) LLAGN STIS spectra. (3) Intermediate-age stars contribute significantly to the optical continuum of these nuclei. This population is more frequent in objects with weak than with strong [OI]. Weak-[OI] LLAGN that have young stars stand out for their intermediate-age population. (4) Most of the strong-[OI] LLAGN have predominantly old stellar populations. Few of these objects also show a featureless continuum that contributes significantly to the optical continuum. These results suggest that young and intermediate-age stars do not play a significant role in the ionization of LLAGN with strong [OI]. However, the ionization in weak-[OI] LLAGN with young and/or intermediate-age populations could be due to starburst processes. A comparison of the properties of these objects with Seyfert 2 galaxies that harbor a nuclear starburst suggests that weak-[OI] LLAGN are the lower-luminosity counterparts of the Seyfert 2 composite nuclei.

The COSMOS survey of Starburst and AGN Evolution in the Large-Scale Structure Context

Nick Z. Scoville

California Institute of Technology, USA

The Cosmic Evolution Survey (COSMOS) is specifically designed to elucidate the formation and evolution of galaxies, their stellar populations and AGN, correlated with the large-scale structure environment. The project involves imaging with *HST*/ACS and many large ground-based telescopes, in addition to spectroscopy. The goals and preliminary results from COSMOS are reviewed.

Studies of Luminous Blue Compact Galaxies at Redshifts $z \sim 1$ in the DEEP Project

David C. Koo

UCO/Lick Observatory, University of California, Santa Cruz, USA

Luminous blue compact galaxies are an important class of starburst galaxies that appear to increase dramatically in numbers and luminosity back in time to at least redshift $z \sim 1$. They may well be the lower redshift counterparts to high-redshift "Lyman Break Galaxies". Whether they are the progenitors of local dwarf ellipticals or bulges of local late-type spirals or even just starbursting nuclei, perhaps with an AGN, of interacting galaxies remains controversial. Early results from continued studies of these galaxies within the DEEP program, which uses Keck spectroscopy and *HST* imaging, are presented. Beyond the common use of luminosity, colors, size, and star-formation rate data, we highlight the advantages of kinematics, chemical abundance, and multi-wavelength data to probe their nature and likely evolution.

Did most present-day spirals form during the last 8 Gyr?

François Hammer

GEPI, Observatoire de Paris, France

The present study is based on follow-up observations which have been made using *HST*, ISO, VLA and VLT. It targets 195 $z > 0.4$ galaxies, mostly from the sample of the CFRS, within an intermediate stellar mass range of $(3 - 30) \times 10^{10}$ $M_{\odot}$. The study leads to a considerable re-evaluation of the star-formation rates, using mid-IR photometry and/or Balmer emission-line luminosity, after a proper correction for extinction effects. It shows that gas phases of intermediate-redshift galaxies are metal deficient by a factor of 2, compared to those of local spirals. We find that for intermediate-mass galaxies, the bulk of their stars was likely formed during multiple and short episodes of violent star formation, during which they appear as luminous infrared galaxies (LIRGs). Recent formation of bulges and disks in spirals accounts for the simultaneous decrease, during the last 8 Gyr, of the cosmic star-formation density, of the merger rate, and of the number densities of LIRGs and of compact galaxies.

The Spitzer 24-micron Properties of optical/near-IR selected EROs

Lin Yan

Spitzer Science Center, California Institute of Technology, USA

Optical/near-IR colors have been widely used by recent surveys for selecting galaxies with old stellar populations at $z \sim 1$. However, the relative contribution from the early-type versus dust-reddened systems to the total sample is not well determined by any of the previous data. We present the first, direct measurement of the dust-enshrouded systems using the 24μm mid-infrared data from the Spitzer Space Telescope. Our 24-micron detections of previously thought "early-type galaxies" at $z \sim 1$ demonstrate the superb sensitivity of the Spitzer 24-micron band. Combining the deep Spitzer 24-micron data with Keck DEIMOS spectroscopy of a sample of ($R - K_{\rm s} > 5.3$) EROs, we discuss the physical nature of this population and the significant implication of our results to the studies of early-type galaxies at $z \sim 1$, and the measurements of the evolution of mass functions out to $z \sim 1-2$.

The Infrared and Radio Properties of Starburst Galaxies in the Spitzer First Look Survey out to $z = 1.5$: The effects of collisions and mergers

Philip N. Appleton

Spitzer Science Center, California Institute of Technology, USA

Based on an extensive redshift survey of mid- and far-infrared emitting galaxies in the 4 square-degree field of the Spitzer First Look Survey, we investigate the luminosity evolution of this population as a function of redshift. Using redshifts obtained at WIYN, Keck and archival SDSS data, we study the radio and IR luminosity evolution, and the magnitude and scatter in the well-known IR/radio correlation with redshift (to $z \sim 1.5$). Of particular interest are the effects of collisions and mergers on the IR properties of the sample. Using 50 orbits of recently acquired I-band *HST*/ACS imaging, we explore the influence of the "merger state" (based on two independent *HST* morphology indicators) on the Mid- and Far-IR colors and luminosities. The work is part of a larger project to study the mass deposition rate in galaxies in IR- and optically-selected galaxy samples out to $z = 1.5$.

Spitzer observations of Lyman Break Galaxies

Jiasheng Huang

Harvard-Smithsonian Center for Astrophysics, USA

In this talk, I will present the IRAC and MIPS observations of the spectroscopically confirmed LBGs in one of the Spitzer GTO deep survey fields. The MIR colors show that LBGs are clearly divided into two populations characterized by the 8μm flux. The 8μm-bright LBGs could be powered by AGN. The average 24μm flux will be used to derive star-formation rates for those LBGs that may not have any AGN features. I will present the MIR color and luminosity functions for both populations.

Observations of ULIRGs with the IRS on Spitzer

Lee Armus

Spitzer Science Center, California Institute of Technology, USA

Ultraluminous Infrared Galaxies (ULIRGs) have power outputs rivalling quasars, yet they emit nearly all of their energy in the mid- and far-infrared. Both starbursts and dust-enshrouded AGN have been implicated as the power sources in ULIRGs. While rare in the local Universe, ULIRGs may play a dominant role in producing the far-infrared background as well as the star-formation energy density at high redshifts. We are conducting a large survey with the IRS on Spitzer to obtain mid-infrared spectra of over 100 ULIRGs with redshifts of $0.02 < z < 0.80$. We will present the first results from this survey, concentrating on the superb sensitivity of the IRS for uncovering hidden AGN, measuring warm molecular gas, and detecting organic ices in the nuclei of these remarkable galaxies. We will also discuss the use of the IRS low-resolution ULIRG spectra as templates for untangling the energy sources in high-redshift, dusty galaxies.

Spitzer discovery of luminous infrared galaxies at $1 < z < 2.5$

Emeric M. Le Floc'h

Steward Observatory, University of Arizona, USA

The successful launch of Spitzer is now providing a unique opportunity to tackle the evolution of dust-enshrouded star formation and black hole accretion activity within infrared-luminous galaxies in the distant Universe. Our team is conducting a Guaranteed Time Observer program on deep infrared surveys with the Multi-band Imager and Photometer for Spitzer at 24, 70 and 160μm. I will present our first results, such as galaxy number counts in the infrared, redshift distribution and the relation between the infrared-selected high-redshift sources and other populations such as the SCUBA/VLA galaxies and the X-ray luminous active nuclei. I will particularly emphasize the first identification of luminous-infrared galaxies in the redshift desert (i.e., $1 < z < 2.5$), and show that our data suggest a contribution of the latter that is more important than is predicted by the current models on galaxy evolution.

Stellar populations and star-formation histories of distant starbursts

Daniel Schaerer

Geneva Observatory, Switzerland

I will review our current knowledge on the properties of distant ($z \gtrsim 3-6$) starburst galaxies in terms of stellar populations, star-formation histories, extinction and related properties as derived from panchromatic photometric and spectroscopic observations. In particular, recent results from searches for starbursts at $z \gtrsim 7-10$ – using ground-based and space observations – will also be discussed. Finally, a detailed analysis of some strongly lensed $z \gtrsim 6-10$ galaxies including optical, near-IR, and Spitzer observations will be presented.

The Role of Infrared-Selected Starburst Galaxies in Galaxy Evolution

Casey Papovich

Steward Observatory, University of Arizona, USA

With the launch of the Spitzer Space Telescope, we can now study the evolution of starburst and infrared-luminous galaxy populations to high redshifts. I will discuss the goals of the Spitzer GTO far-infrared deep surveys. Early Spitzer results show that the number density of infrared-luminous sources increases rapidly with redshift – significantly greater than that implied from optical surveys. I will describe the properties of starburst and infrared-luminous galaxies selected from recent Spitzer far-infrared images that overlap with fields imaged by the *Hubble Space Telescope*. The combined *Hubble*-Spitzer datasets illustrate the important connection between galaxy morphology and the interaction rate with the production of starburst activity and high infrared luminosity, and their evolution with increasing redshift. I will discuss the need for timely, deep, large-area, Spitzer-*Hubble* fields, in order to realize the dream of the Great Observatories, and answer key questions in galaxy evolution as a function of luminosity, environment, and redshift.

Starbursts in the Ultra Deep Field

Rodger I. Thompson

Steward Observatory, University of Arizona, USA

We have completed the NICMOS *HST* Treasury Program observations in the Ultra Deep Field, centered on the Chandra Deep Field South. This data, combined with the recently released ACS optical data, allows us to chart the star-formation history to redshifts of 6 and beyond. The contribution will present the results of this study with concentration on starburst galaxies at high redshift. A primary question is whether starburst galaxies exist at all redshifts or whether there is a peak epoch when they dominate. A parallel question is whether the bulk of star formation occurs in starburst galaxies or whether galaxies with normal star-formation rates produce the majority of stars. Results from a similar study in the HDF-N indicated that the numbers of stars produced by each type were roughly equal. The UDF provides an important check on that result in an area that is completely uncorrelated with the HDF-N.

The properties of Lyα and Gamma-ray-burst selected starbursts at high redshift

Johan P.U. Fynbo

Astronomical Observatory, University of Copenhagen, Denmark

Selection of Lyα-emitting starbursts from deep narrow-band imaging and Gamma-Ray Bursts (GRBs) both allow the study of starburst galaxies that are significantly fainter than what is currently available for selection techniques based on the continuum (such as Lyman-break galaxies). I present results from a survey for Lyα emitters at $z = 3$ conducted at the VLT. Furthermore, I briefly describe the properties of host galaxies of GRBs at $z = 2 - 4$, and discuss how the Lyα-selected starbursts and the GRB host galaxies compare to the Lyman-break galaxies.

The stellar population of high-z galaxies from medium-resolution spectra in the FORS Deep Field

Dörte Mehlert

Landessternwarte Heidelberg, Germany

For ~ 20 starburst galaxies in the FORS Deep Field with redshifts between $2.3 < z < 3.5$, we obtain medium-resolution spectra ($R \sim 2000$) with the VLT and the FORS2 instrument. Using the two holographic grisms 1200R and 1400V at these redshifts, we covered the rest-frame UV of our selected galaxies which is the predestined wavelength range to investigate the formation and stellar population of high-redshift starburst galaxies. The comparably high resolution of our data gives us the unique possibility to derive the stellar age, metallicity and composition of these galaxies not only from strong stellar-wind lines like CIV, but also from weaker, purely photospheric stellar lines. First results, which are mainly based on comparisons with the Starburst99 models from Leitherer et al. (1999, 2001), will be presented here.

Kinematic and Stellar Masses of Star-forming Galaxies at $z \sim 2$

Dawn K. Erb

Department of Astronomy, California Institute of Technology, USA

We have assembled a sample of several hundred star-forming galaxies at $z \sim 2$, selected by their rest-frame UV colors and with spectroscopically confirmed redshifts. I will present the results of the modeling of their stellar populations using $UGRJK$ (and in one field, mid-IR data from the Spitzer Space Telescope) photometry, and a comparison of the stellar masses derived from this modeling with dynamical masses from the width of the Hα emission line. I will also discuss correlations between the rest-frame optical luminosity and Hα line widths and nebular chemistry. The sample shows considerable diversity in mass, age and metallicity, and intriguing differences with respect to the Lyman break galaxies at $z \sim 3$, including a $\sim 50\%$ larger average velocity dispersion at $z \sim 2$.

Star Formation and Metallicity in Galaxies: Evolution Between $0 < z < 3$

Lisa J. Kewley[1]

Institute for Astronomy, University of Hawaii, USA

Observing the star-formation rate since the earliest times in the Universe is crucial to understanding galaxy formation and evolution. Metallicity is intricately related to star formation because metals are injected into the interstellar medium by stellar mass-loss processes. Theory suggests that metallicity changes less rapidly than star-formation rate as a function of redshift, but until now, there has been no solid observational foundation for the cosmic metallicity history of star-forming galaxies. I will present the first results of our new investigation into the star formation and metallicity history of galaxies between redshifts $0 < z < 3$. Our local comparison samples include the Nearby Field Galaxy Survey (NFGS) and an objectively selected sample of galaxy pairs. We find that the galaxy pairs contain a broader range of star formation and metallicity properties than observed in the NFGS, providing an important local benchmark for comparisons with high-z samples. I compare the star formation and metallicity properties of our local samples with a large sample of galaxies from the Hubble Deep Field North and the Gemini Deep Deep Survey. This analysis provides insight into the simultaneous evolution of star formation and metallicity for star-forming galaxies spanning the redshift range $0 < z < 3$.

[1]Hubble fellow

New Metallicity Diagnostics for High-Redshift Star-Forming Galaxies

Samantha A. Rix

Isaac Newton Group of Telescopes, Spain

Information on the chemical composition of high-redshift star-forming galaxies, such as Lyman Break Galaxies, provides important clues as to their current evolutionary status, their past history of star formation, their evolutionary link to today's galaxies and their interplay with their environment. The limited applicability, at high redshifts, of well-established metallicity indicators has highlighted the need for new diagnostics, particularly ones that can be applied to large samples of galaxies. By bringing together techniques from the fields of hot massive stars, local starbursts and high-redshift galaxies, we have married the output of the hot star code "WM-basic" with the spectral synthesis code "Starburst99". Our new code is capable of modeling the UV stellar spectra of star-forming regions at metallicities between $\frac{1}{20}$ and twice solar. We have used our models to investigate the influence of metallicity on the strength of photospheric spectral features and propose a new metallicity indicator, based on the equivalent width of a broad blend of Fe III lines from O and B stars near 1978Å. The first application of the 1978 Å index to Keck observations of two well-studied high-redshift star-forming galaxies suggests that our method provides a promising alternative, or at least complement, to established techniques.

The Differential Evolution of the Luminosity Function of Star-Forming Galaxies from $z \sim 4$ to $z \sim 1.7$ using Multi-wavelength Imaging

Marcin Sawicki

Dominion Astrophysical Observatory/HIA/NRC, Canada

I will present results from an extremely deep *ugri* ground-based imaging survey on Keck. These multi-wavelength observations use the identical filter set and well-characterized selection techniques employed by Steidel and collaborators to select star-forming Lyman Break Galaxies at $z \sim 4$ and $z \sim 3$, and include a very recent extension of the technique into the "redshift desert" at $z \sim 2.2$ and $z \sim 1.7$. In contrast to previous work, our survey reaches typically ~ 1.5 magnitudes deeper, and thus probes well into the faint end of the galaxy population. We present the first robust measurements of the UV galaxy luminosity function at $z \sim 2$, and of the faint end of the luminosity function at $z \sim 4$. Our data show that the faint end of the luminosity function is evolving with lookback time, while the bright end remains virtually unchanged. Because this evolution is differential with luminosity, it points to new avenues for studying how galaxies form at high redshift. I will describe our survey, the evolution of the LF from $z \sim 4$ to $z \sim 1.7$, and discuss the possible mechanisms that can be responsible for this differential evolution.

Massive galaxies at $z = 2$

Kentaro Nagamine

Harvard-Smithsonian Center for Astrophysics, USA

We study the properties of galaxies at $z = 2$ in a ΛCDM universe using two different types of hydrodynamical simulations (Eulerian TVD and SPH), with particular emphasis on a selection based on the U_n, G, R filter set. The galaxies at $z = 2$ in our simulations satisfy well the color-selection criteria proposed by Adelberger et al. (2004) and Steidel et al. (2004) when we assume Calzetti extinction with $E(B-V) = 0.15$ mag. We find that the number density of galaxies brighter than $R = 25.5$ mag at $z = 2$ is about $5 \times 10^{-2} h^3$ Mpc^{-3}, roughly one order of magnitude larger than that of Lyman-break galaxies at $z = 3$. The most massive galaxies at $z = 2$ have stellar masses $\gtrsim 10^{11}$ M$_\odot$, and their observed-frame $G - R$ colors lie in the range $0.0 < G - R < 1.0$ mag. They have been continuously forming stars with a rate exceeding 30 M$_\odot$ yr^{-1} over a few Gyr from $z = 10$ to $z = 2$, although the TVD simulation indicates a more sporadic star-formation history than the SPH simulations. Typically of order half of their stellar mass was already assembled by $z \sim 4$. The bluest galaxies with colors $-0.2 < G - R < 0.0$ mag at $z = 2$ are somewhat less massive, with $M_* < 10^{11}$ M$_\odot h^{-1}$, and are less dominated by an old stellar population. On the other hand, the reddest massive galaxies at $z = 2$ with $G - R \gtrsim 1.0$ mag and $M_* > 10^{10}$ M$_\odot h^{-1}$ finished the build-up of their stellar mass by $z \sim 3$. Our study suggests that the majority of the most massive galaxies at $z = 2$ could be detected at rest-frame ultra-violet wavelengths, contrary to some of the recent claims made on the basis of near-infrared studies of galaxies at the same epoch, if the median extinction is $E(B-V) < 0.3$ mag as indicated by surveys of Lyman-break galaxies at $z = 3$. However, the fraction of stellar mass contained in galaxies that pass the color-selection criteria used by Steidel et al. (2004) could be as low as 50% of the total stellar mass in the Universe at $z = 2$. The observed-frame R-band luminosity function of $z = 2$ galaxies for the combined result of the SPH simulations can be well-fitted by a Schechter function with parameters $(\Phi^*, M_R^*, \alpha) = (1 \times 10^{-2}, 21.0, -1.4)$, and the TVD simulation also supports a faint-end slope of $\alpha = -1.4$. A comparison with $z = 3$ indicates that the luminosity functions have brightened by about half a magnitude from $z = 3$ to $z = 2$ without much change in their shape.

Metal Enrichment in Galaxies at $z \sim 2$

Duília de Mello

LASP, NASA's GSFC, USA

I will present the recent results from the analysis of the composite spectrum of 5 near-IR luminous ($K < 20$) galaxies at $z \sim 2$. The composite spectrum is characterized by strong absorption lines over the UV continuum, as in Lyman Break Galaxies (LBGs). However, several among the strongest absorptions are not seen in LBGs. They were identified as SiIII$\lambda \sim 1296$Å, CIII$\lambda \sim 1428$Å, SiII$\lambda \sim 1485$Å, and $\sim$1380Å, which is probably a blend of several Fe photospheric lines in the region 1360–1390Å. The pure photospheric lines as the UV continuum resemble the spectrum of the starburst galaxy NGC 6090, a luminous infrared galaxy classified as a merger in progress. A metallicity higher than solar is suggested by comparing the pure photospheric lines known as the 1425Å index (SiIII, CIII, FeV) with Starburst99 models. The evidence of high metallicity, together with the high masses, high star-formation rates, and possibly strong clustering, suggests that these galaxies are progenitors of local massive ellipticals.

Properties of star-forming galaxies at $z > 5$

Malcolm Bremer

H.H. Wills Physics Laboratory, University of Bristol, UK

I present results from several surveys of Lyman break galaxies at $z > 5$ including photometrically identified samples drawn from the HUBBLE CDF-S and UDF data, and from ground-based imaging of 10 $z = 0.4 - 0.8$ cluster fields (where lensing aids identification). A total sample of over 150 objects drawn from these surveys allows me to discuss the general properties of these distant star-forming galaxies. In addition I present results on a spectroscopically confirmed sample of 25 objects at $z > 5$ drawn from a survey of 160 square arcmin. This sample will allow me to discuss the clustering properties of these sources and determine of the star-formation properties from comparison of their Lyα emission and broad-band SEDs. Finally I will discuss how these objects contribute to the reionization of the Universe.

Resolved Molecular Gas Emission in a QSO host galaxy at $z = 6.4$

Fabian Walter

Max Planck Institute for Astronomy, Heidelberg, Germany

We present the first resolved map of molecular gas emission in the host galaxy of the QSO J1148+5251 at a redshift of 6.42. This enigmatic object has been discovered by the SDSS, is located in the Epoch of Reionization and is the highest-redshift QSO known to date. Using the VLA and the Plateau de Bure interferometer we recently reported the detection of abundant molecular gas, as traced through line emission from Carbon Monoxide, in this object (total gas mass: $\sim 2 \times 10^{10}$ $M_\odot$). This finding demonstrates that molecular gas, the requisite fuel for star formation is already present ~ 0.9 Gyr after the Big Bang. Here we present the first resolved VLA maps of the molecular gas distribution at a resolution of 0.15 arcsec (corresponding to only ~ 1 kpc at a redshift of $z = 6.4$). The observations show extended (~ 5 kpc) molecular gas emission and the presence of 2 molecular gas peaks (separation: ~ 2 kpc) and enable us to constrain the gas properties and the dynamical mass of a system in the Epoch of Reionization.

Starbursts

From 30 Doradus to Lyman Break Galaxies

Poster Abstracts

Paul Alexander

Cavendish Astrophysics, University of Cambridge, UK

no abstract received

Stellar and Gas Kinematics in the Core of M100

Emma L. Allard

STRC, University of Hertfordshire, UK

The stellar and gas kinematics of the bar and circumnuclear regions in the barred spiral galaxy M100 have been measured and are presented here as two-dimensional maps. The data have been obtained using the SAURON integral field spectrograph on the William Herschel Telescope. In this progress report, we present maps of the total intensity, mean velocity, and velocity dispersion for the stars and the gas. The gas velocity field shows significant deviations from circular motion, which can be interpreted as the kinematic signatures of gas streaming along the inner part of the bar, and of density wave streaming motions across the miniature spiral arms in the nuclear pseudo-ring. The stellar velocity field, presented here for the first time, shows similar non-circular motions. The gas velocity dispersion is notably smaller where the star formation occurs in the nuclear zone. We outline our further plans with the data set.

Metals in the Neutral ISM of Starburst Galaxies

Alessandra Aloisi

ESA/STScI, USA

Thanks to their proximity, local starbursts are perfectly suited for high-resolution and sensitivity multi-wavelength observations aimed to test our ideas about star formation, the evolution of massive stars, and the physics and chemical evolution of the ISM. High-resolution UV spectroscopy with FUSE and STIS has recently given the possibility to characterize, in great detail, the gaseous component in local starbursts thanks to the presence in this spectral range of many absorption lines from molecular hydrogen and heavy chemical elements (e.g., O, N, C, and Fe). I will concentrate on the determination of the metal content in the neutral ISM of some nearby starburst galaxies (e.g., I Zw 18 and NGC 1705), how it relates to the metals observed in the ionized gas, and what it tells us about the star-formation history of the galaxy and the evolutionary state of local starbursts in general. I will also show how this analysis allows us to better address many of the open issues (e.g., depletion and ionization) affecting similar studies on more distant star-forming galaxies and absorption-line systems (e.g., Lyman Break Galaxies and DLAs). I will finally compare our results to the chemical properties of more distant galaxies in order to better investigate the connection between nearby starbursts and the high-redshift Universe.

Measuring sizes and compactnesses of young star clusters

Peter Anders

Universitäts-Sternwarte Göttingen, Germany

We will present our recent efforts to improve the size determinations and photometry of star clusters. This also involves size-dependent aperture corrections, which turn out to depend considerably on the structural properties of the young star clusters. On the basis of these reliably measured sizes, we define a useful observable measure of the compactness of a star cluster, which also describes how strongly it is bound and hence governs its survivability during the evolution of the host galaxy. This compactness and survivability is of major importance for the studies of young star clusters in interacting/merging and starburst galaxies, since it will significantly help our understanding as to which of these clusters will eventually resemble Milky Way globular cluster-type objects. From our studies we can draw conclusions, e.g., about the relation between the cluster properties (compactness, masses, ...) and the properties of the starburst in which they are born. This will also deepen our understanding about the evolution of galaxies from high redshifts to the present. We will show applications of our new tools to young star cluster systems in nearby starburst galaxies.

The Complex Star-Formation History of NGC 1569

Luca Angeretti[1], M. Tosi[2], L. Greggio[3], E. Sabbi[1], A. Aloisi[4], C. Leitherer[4]
[1]*Dipartimento di Astronomia, Università di Bologna, Italy;* [2]*INAF – Osservatorio Astronomico di Bologna, Italy;* [3]*INAF – Osservatorio Astronomico di Padova, Italy;* [4]*Space Telescope Science Institute, USA*

We present new results on the star-formation (SF) history of the dwarf irregular galaxy NGC 1569, derived from *Hubble Space Telescope* NICMOS/NIC2 data in the F110W (J) and F160W (H) near-infrared (NIR) filters, using the synthetic Color-Magnitude Diagram method. The galaxy experienced a complex star-formation activity. The best fit to the data is found assuming 3 episodes of activity in the last 1–2 Gyr. The most recent and strong episode constrained by these NIR data started 37 Myr ago and ended 13 Myr ago, although we cannot exclude that there were up to three SF episodes in this time interval. The average star-formation rate (SFR) of the episode is ~ 3.2 $M_\odot$ yr^{-1} kpc^{-2}, in agreement with literature data. A previous episode produced stars between 150 Myr and 40 Myr ago, with a mean SFR about $\frac{2}{3}$ lower than the mean SFR of the youngest episode. An earlier star-formation episode occurred about 1 Gyr ago. All these SFRs are 2–3 orders of magnitude higher than those derived for the late-type dwarfs in the Local Group. In all cases, a Salpeter-type initial mass function allows for a good reproduction of the data, but we cannot exclude flatter mass functions. We have explored some possible scenarios using the astrated mass in the best-fit model, in order to constrain the past star-formation history. We cannot rule out a low star-formation rate in the past, but we can safely conclude that the last 1–2 Gyr have been peculiar.

Herschel Space Observatory

Peter D. Barthel[1] (on behalf of the Herschel Science Team)
[1]*Kapteyn Astronomical Institute, University of Groningen, Netherlands*

A short summary is given of the ESA Cornerstone Mission *Herschel*, to be launched in 2007. The 3.5m *Herschel* telescope will explore the as yet unexplored far-infrared/submm Universe, and the poster will briefly summarize the observatory capabilities and status, operational aspects and data processing and products, as well as proposal planning and time line.

Sylvie F. Beaulieu

Departement de Physique, Université Laval, Canada

no abstract received

Recent Imaging Results from SINGS

George J. Bendo

Steward Observatory, University of Arizona, USA

The Spitzer Infrared Nearby Galaxy Survey (SINGS) is a comprehensive infrared imaging and spectroscopic survey of 75 nearby galaxies. One of the primary goals of SINGS is to compare star-formation rates derived from far-infrared emission with rates derived from other generally accepted star-formation indicators, specifically ultraviolet emission, Hα emission, and radio synchrotron emission. A related secondary goal is the search for other emission mechanisms, such as mid-infrared PAH emission, that may correlate with these star-formation indicators. Further study of both of these star-formation tracers will give us better understanding of the physical processes that link them all together. We present recent results from SINGS observations of NGC 7331 and M81 that relate to this work, and we also show some of the IRAC and MIPS images recently obtained by SINGS.

Galactic winds and the transport of metals into the IGM in semi-analytic simulations

Serena Bertone

Max Planck Institut für Astrophysik, Garching, Germany

We use a semi-analytic treatment of galactic winds within high-resolution, large-scale cosmological N-body simulations of a ΛCDM Universe to investigate the chemical enrichment history of the intergalactic medium (IGM). We follow the evolution of superbubbles and supershells powered by supernova explosions in a spherical region of space with diameter 52 h^{-1} Mpc and mean density close to the mean density of the Universe, from $z = 20$ down to $z = 0$. The volume filling factor and the fraction of IGM mass affected by winds are calculated as a function of redshift, and of the two model parameters. Our results suggest that galactic winds may not significantly affect the global properties of the Lyα forest. The mass-loading efficiency of the outflows is a key factor to determine the evolution of winds and their global impact on the IGM: the higher the mass loading, the later the IGM is enriched with metals. Galaxies with $10^9 < M_\star < 10^{10}$ M$_\odot$ are responsible for most of the metals ejected into the IGM at $z = 3$, while galaxies with $M_\star < 10^9$ M$_\odot$ give a non-negligible contribution only at higher redshifts, when larger galaxies have not yet assembled.

$UBViz$ dropouts: Galaxy Evolution from $z \sim 2$ to $z \sim 6$ and beyond

Rychard J. Bouwens

Department of Astronomy & Astrophysics, University of California, Santa Cruz, USA

The deep multi-wavelength data over the wide-area GOODS and deep UDF (plus parallel fields) provides us an unprecedented data set from which to study the extragalactic Universe. Using the combined optical and infrared data available for different segments of these fields, it is possible to select large statistically significant samples of $UBViz$ dropouts, from $z \sim 2$ all the way back to $z \sim 10$, allowing us to draw conclusions about global trends in galaxy formation and evolution during the first few billion years of the Universe. Here, we report on a few of those trends, discussing the evolution of the star-formation rate density, the evolution in size, and evolution in UV color – using sophisticated cloning simulations to set our high-redshift expectations and cope with the formidable selection biases (16× increase in surface brightness dimming from $z \sim 2.5$ to $z \sim 6$). While early results from the GOODS + UDF parallel data sets point toward modest increases in the star-formation rate, size, and reddening from $z \sim 6$ to $z \sim 2$, data available with the UDF promises to push these trends to even higher redshift and fainter magnitudes. We summarize the early results.

Spitzer Imagery of Embedded Ultra-Young Star Clusters in M33

Brent A. Buckalew[1], H. Kobulnicky, R. Gehrz, C.E. Woodward, M. Ashby, P. Barmby, B. Brandl, N. Devereux, C. Engelbracht, G. Fazio, K. Gordon, J. Hinz, R. Humphreys, K. Misselt, M. Pahre, P. Pérez, E. Polomski, G. Rieke, T. Roellig, J. van Loon, S. Willner

[1] *University of Wyoming, USA*

The natal environments of massive star clusters in starburst galaxies have not been studied well even though such information would be vital to explain the contribution (or lack thereof) of these systems to the feedback mechanisms of star formation in galaxies. Fourteen embedded star clusters in M33 were first detected in radio imagery and are thought to be extremely young ($\sim$ 1 Myr) because of their non-optical nature. The radio provided a list of sources, but mid-infrared data provides the clues into their natal environment. We present the IRAC and MIPS imagery of these fourteen clusters and their associated spectral energy distributions from $3.6 - 160\mu$m. We discuss the various spectral energy distributions and what they tell us about their environments. From the imagery, we show that a surprising similarity exists between the morphology of these systems and those of Ultra-Compact HII regions. We find that these clusters have shell, cometary, core-halo, and irregular PAH/dust morphologies in the IRAC 8μm imagery.

Star formation at $z \sim 6$ from the *Hubble* Ultra Deep Field

Andrew Bunker

Astrophysics Group, University of Exeter, UK

We determine the abundance of i'-band drop-outs in the recently-released *HST*/ACS *Hubble* Ultra Deep Field (UDF). Since the majority of these sources are likely to be $z \sim 6$ galaxies whose flux decrement between the F775W i'-band and F850LP z'-band arises from Lyα absorption, the number of detected candidates provides a valuable upper limit to the unextincted star-formation rate at this redshift. We demonstrate that the increased depth of UDF enables us to reach an 8σ limiting magnitude of z'(AB)=28.5 (equivalent to $1.5h_{70}^{-2}$ M$_\odot$ yr^{-1} at $z = 6$, or $0.1L^*$(UV) for the $z \sim 3$ U-drop population), permitting us to address earlier ambiguities arising from the unobserved form of the luminosity function. We identify 54 galaxies (and only one star) at z'(AB) < 28.5 with $(i' - z') > 1.3$ over the deepest 11 arcmin^2 portion of the UDF field. The characteristic luminosity (L^*) is consistent with values observed at $z \sim 3$. The faint end slope (α) is less well constrained, but is consistent with only modest evolution. The main change appears to be in the number density (Φ^*). Specifically, and regardless of possible contamination from cool stars and lower redshift sources, the UDF data support our previous result that the star-formation rate at $z \sim 6$ was at least $6\times$ *less* than at $z \sim 3$ (Stanway, Bunker & McMahon 2003). This declining comoving star-formation rate ($0.005h_{70}$ M$_\odot$ yr^{-1} Mpc^{-3} at $z \sim 6$) poses an interesting challenge for models which suggest that the bulk of star-forming galaxies that reionized the Universe lie at redshifts just beyond $z \sim 6$.

UV Spectroscopy of Luminous IR Galaxies

Denis Burgarella

Observatoire Astronomique Marseille Provence – LAM, France

The ELAIS S1 field was spectroscopically observed by the UV satellite GALEX. This field was already observed at 15 microns and 90 microns by ISO. We cross-correlated the UV database with the IR one to get 21 objects with luminosities in the range $10 < \log L(\mathrm{IR}) < 13$ (i.e., normal galaxies to ULIRGs) and $10 < \log L(\mathrm{UV}) < 12.5$ in the redshift range $0 < z < 1.6$. This constitutes unique data to study the characteristics of IR-bright galaxies in UV. We will discuss the nature of the two $z > 1$ objects which are likely to be AGN (one BAL QSO). The remainder of the sample is at $z < 0.35$. It is used 1) to compare UV dust attenuations evaluated from the spectroscopic UV slope β and from the FIR/UV ratio and 2) to compare the UV and IR estimates of the SFR. We finally present how this applies to high-redshift observations in the rest-frame UV.

Starbursts in Dwarf Galaxies: A Multi-wavelength Case Study of NGC 625

John M. Cannon

MPIA, Heidelberg, Germany

The results of a multi-wavelength case study of the nearby dwarf starburst galaxy NGC 625 are presented. This low-mass galaxy hosts a massive starburst comparable in luminosity to 30 Doradus in the Large Magellanic Cloud; its proximity and high galactic latitude provide an ideal opportunity to investigate the starburst phenomenon and its impact on the ISM and IGM. We use Chandra, FUSE, *HST*, CTIO, ATCA, and VLA data to investigate the nature of the stellar population and multi-phase ISM. Our principal findings are summarized as follows: 1) Ground-based optical spectroscopy finds a prominent Wolf-Rayet (W-R) feature arising from the major starburst region, implying a brief burst duration (4–6 Myr); 2) A spatially resolved star-formation history analysis using *HST*/WFPC2 data shows that the duration of the burst is actually much longer than the W-R features would imply (duration $>$ 50 Myr), and that the star formation has been widespread throughout the disk over this interval; 3) This extended starburst has input sufficient kinetic energy into the ISM to create a large-scale outflow; 4) HI observations from the ATCA show complex kinematics that are consistent with a minor-axis outflow of large amounts of neutral gas; 5) This outflow is verified by FUSE spectroscopy, where strong OVI coronal gas absorption is blueshifted with respect to the neutral and diffuse H_2 absorption lines; 6) FUSE spectra also reveal an abundance offset between the neutral and nebular gas regions that may be a common component of the ISM of low-metallicity dwarf galaxies; 7) The ROSAT detection of diffuse soft X-ray emission is verified by new Chandra imaging of NGC 625; 8) VLA radio continuum data shows a thermal global spectral index and a mix of thermal and non-thermal indices for the individual major star-formation regions, suggesting vigorous and (temporally and spatially) extended star formation throughout the disk. We interpret these results in the context of low-mass galaxy evolution and compare our results to those found for other well-studied dwarf starburst systems.

A multi-wavelength study of the starburst galaxy NGC 7673

Paola Castangia[1], Anna Pasquali[2]

[1] *Università di Cagliari/INAF–Osservatorio Astronomico di Cagliari, Italy;* [2] *ETH Zürich, Switzerland*

We have compared the archival International Ultraviolet Explorer spectrum of the starburst galaxy NGC 7673 with the predictions of stellar population synthesis, in order to investigate the star-formation history of this galaxy at different wavelenghts. *HST*/WFPC2 images resolved NGC 7673 into a large number of star clusters, of which the ages, masses, and reddenings have been derived from optical colours. Fifty of these clusters were detected through the ultraviolet filter F255W and 31 were found to fall inside the IUE large aperture, which was used to acquire the integrated ultraviolet spectrum of the galaxy.
We then used the Starburst99 evolutionary synthesis models to generate the ultraviolet spectra of the clusters, based on the ages and masses derived from optical colours, and fitted the sum of these spectra to the observed IUE spectrum of NGC 7673.
We have discovered that the star clusters account for about two thirds of the UV emission of the galaxy, thus being the main sources of the UV flux. However, because of the large uncertainty in the derivation of the cluster parameters, a significant contribution to the UV emission from other sources cannot yet be ruled out entirely.

UV star-formation rates of GRB host galaxies

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Recently, it has been established that at least some long-duration gamma ray bursts (GRBs) are associated with supernova explosions. Studying galaxies that host GRBs yields insight into the properties of star-forming galaxies at high redshifts. We investigate the broad-band spectral energy distribution of a sample of GRB host galaxies at redshifts $0.4 < z < 2$. They are all consistent with being starburst galaxies. Their global star-formation rates (SFR) derived from the UV fluxes are not extreme, but when normalising the SFR to the galaxy luminosity, differences from field galaxy populations at similar redshifts appear. The specific SFRs of GRB hosts are slightly larger, while the starburst ages and global extinctions are similar.

Magnetic fields and starbursts: from irregulars to mergers

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From a theoretical point of view, various magnetic instabilities, e.g., magneto-gravitational, magneto-rotational and Parker instabilities can trigger star formation, take part in the formation of giant molecular clouds and in forming gaseous spurs and bubbles. All these processes require regular magnetic fields. Such fields are not only observed in spirals but we also discovered them in the nearby irregular dwarf starburst galaxies NGC 4449 and IC 10. Coherent magnetic fields following the global gas motions provide a sensitive tracer of the velocity field in star-forming regions in the sky plane, adding two more dimensions to the radial velocity data. We found that strong magnetic fields (twice stronger than in normal spirals) accompany the interaction-triggered star formation in the "Antennae" pair of galaxies. Extremely strong (30 μG), largely chaotic fields allowed us to reveal a heavily dust-obscured recent starburst, hidden in the southern part of the huge gas and dust complex probably formed during the collision. However, its northern, cool part houses highly coherent magnetic fields, tracing the line of collision between the arms of merging spirals. Our polarization and radio spectral data are also suggestive of the magnetized gas outflow along the southern tidal tail, against frequent suggestions of the gas infall from these structures. We discuss in detail the associations of magnetic fields with different gas phases using available data in radio continuum, HI, optical, Hα, X-ray, and dust emission. Dwarf irregulars as well as merging galaxies belong to objects potentially responsible for supplying magnetic fields to the intergalactic space in the early Universe. Studying them is thus very important also in the context of modern cosmology.

Search for R-band Dropout High-Redshift Galaxies

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I report on ongoing work searching for populations of galaxies at $z > 5$, using very deep images in V, R, I, J and Ks obtained with the VLT and the NTT, and I-band data from the ACS on the *HST*. These data were used to identify R-dropout Lyman Break galaxies and separate them from any lower redshift or Galactic contaminants. An initial list of two hundred good $z > 5$ candidates were found in ten separate fields, totalling an area of about 400 square arcmin. The eventual sample will be drawn from the full data set, a factor two larger. Based on this and previous work, most of these candidates will be real $z > 5$ galaxies, as opposed to lower-redshift interlopers and Galactic objects. I discuss the individual and statistical properties of these sources.

An ultraviolet spectral library of metal-poor OB stars

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We present new *HST*/STIS spectroscopy of 12 B-type stars in the Small Magellanic Cloud. As a consequence of the SMC metal deficiency, the spectra are distinctly different from Galactic analogues, and a morphological comparison is made using archival IUE data. The intensity of the P Cygni emission in the UV resonance lines is greater, and seen to later spectral types, in the Galactic spectra than in their SMC counterparts. We attribute these effects as arising from weaker stellar winds in the SMC targets. Combined with previous *HST* observations of O stars, we now have metal-poor template spectra for a large part of the upper H-R diagram, of use in interpreting the stellar populations in starbursts and high-redshift systems.

A Possible Formation Scenario for the Heavy-Weight Young Cluster W3 in NGC 7252

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The young star cluster W3 (age 500 Myr) in NGC 7252 is the most luminous star cluster known to date. Dynamical mass estimates result in $(8-2) \times 10^8$ $M_\odot$. With an effective radius of about 18 parsec and a velocity dispersion of 45 km s^{-1}, this object is rather one of the recently discovered ultra-compact dwarf galaxies than a star cluster. Even though the galaxy NGC 7252 is a merger remnant – was there a starburst strong enough to form a single star cluster that heavy? In our model, we propose an alternative formation scenario. Observations of interacting galaxies reveal regions of strong star formation forming dozens to hundreds of star clusters in confined regions of several hundred parsec in diameter. The total mass of new stars in these regions can reach 10^7 or even 10^8 $M_\odot$. By means of numerical simulations we have shown that the star clusters in these regions merge on short time-scales. In the context of W3 our models show a possible formation scenario for this heavy-weight star cluster. We discuss the properties, which could be observable if our formation scenario were right.

Integral-Field Spectroscopy and imaging of ULIRGs at low and high redshift: IRAS 16007+3743

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We present results of the Ultraluminous Infrared Galaxy (ULIRG) IRAS 16007+3743 ($z = 0.18$), as part of an ongoing program aimed at studying the internal physical structure and kinematics of a representative sample of ULIRGs (see Colina et al., 2004, and references therein). The program is based on integral-field spectroscopy data from the INTEGRAL system (WHT), and *HST* imaging. With these data we characterize this system and perform preliminary high-redshift simulations of future instruments such as JWST NIRSpec, MIRI and NIRCam, which will be useful to establish the connection between the local ULIRGs and high-z galaxies (LBGs, SMGs).

A Kinematic Study of the Nuclear Stellar Populations in Seyfert Galaxies

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Recent studies in the optical and in the UV have detected circumnuclear starbursts in 40% of nearby Seyfert 2 galaxies; about half of the remaining 60% present a UV excess whose nature is not well known, mainly because of the limitations of the current stellar population analysis techniques in the optical and UV domains. A possible way to circumvent these difficulties is to use a determination of the Mass-to-Light (M/L) ratio, obtained with a combination of velocity dispersion measurements and photometric information. Dynamical information in AGN (particularly in type 2) is better determined from NIR spectroscopic data, where the stellar absorption features are less affected by the nuclear continuum dilution. In this work, we present preliminary results of a spectroscopic survey of more than 60 Seyfert nuclei (mainly Seyfert 2's), conducted at ESO/La Silla and KPNO. For many of these objects we have complementary data, such as *HST* images, optical and (in some cases) UV spectroscopy. Long-slit spectroscopy was performed around the NIR CaII triplet lines at 8498, 8542 and 8662Å. Here, we describe the analysis steps taken so far, and present the first results concerning velocity dispersion measurements in nuclear and off-nuclear regions. With these data we aim to investigate the ambiguous Sy 2 nuclei nature, thus contributing to a better understanding of the AGN-starburst connection.

• This work is supported by CNPq and Capes.

Star Formation with Chandra: From ULIRGs to Dwarf Starbursts

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We have analyzed Chandra observations of the diffuse X-ray emission in 7 dwarf starburst galaxies, 6 starbursts, and 9 ULIRGs. These cover a wide range of X-ray luminosities (5 magnitudes) and star-formation rates. We find a variety of similarities within the sample. The ratio of the thermal X-ray to infrared emission is roughly constant. The X-ray surface brightness also does not vary significantly within the sample. All three galaxy types have enriched α element to Fe abundances and each shows correlations in their Hα and diffuse X-ray emission morphologies. These findings suggest that the same physical mechanism is producing the diffuse X-ray emission in the three galaxy types.

Westerlund 1: A Super-Star Cluster within the Milky Way

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We present optical and IR photometric and spectroscopic observations of the young open cluster Westerlund 1 (Wd1) which indicate it is the first Super Star Cluster identified in the Milky Way. Wd1 hosts a rich population of OB supergiants, Wolf-Rayet stars, Luminous Blue Variables, Yellow Hypergiants and Red Supergiants, from which we infer an age of 5 Myr. For an adopted Kroupa IMF we derive a mass of 10^5 $M_\odot$ and radius of 0.2 pc for an estimated distance of 2.5 kpc. As such, Wd1 is the most massive, and densest, young cluster in the Local Group, exceeding NGC 3603 and the Arches cluster in the Milky Way and R136 in the LMC.

Clustering of Simulated Galaxies at Redshift 4

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We have investigated the structures formed in our hydrodynamic cosmological simulation of reionization and its aftermath. We have identified dark matter haloes and peaks of I-band luminosity. We relate the clustering of these structures to the observed angular correlation of galaxies at redshift 4. The observed correlation is best modelled by the multiple occurrence of luminosity peaks in individual dark matter haloes. Examination of earlier stages of the simulation suggests the importance of disruptive interactions between dark matter haloes.

Does size matter (in the SFRs)?

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The star-formation rate (SFR) of spiral galaxies seems to follow a relationship with their morphological type: the later the type of the galaxy, the larger the SFR becomes. Here, we will present SFRs, derived from Hα images, of a sample of late-type, inactive, non-peculiar spirals. The common property is that all these galaxies have radii smaller than 5 kpc. Two important (and shocking!) results come out: the SFRs of dwarf late-type spirals are lower than expected. Moreover, the number of HII regions as well as the SFRs is larger for barred dwarf galaxies. Therefore, the question arises: is size a key parameter in Star-Formation Rates of spiral galaxies?

Infrared Observations Of The $z = 2.3$ Coup Fourre Galaxy Cluster

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We have used the Wide Field Infrared Camera (WIRC) on the Hale 200" telescope to obtain deep broad-band J (1.250 μm) and Ks (2.150 μm), and ultra-deep narrow-band Brγ (2.166 μm) maps of a 23 Mpc^2 region centered on the $z = 2.313$ starbursting Coup Fourre galaxy (CFg). At this redshift, the Hα line is near the center of the Brγ filter, allowing us to measure the distribution and intensity of massive star formation (SFR > 18 M$_\odot$ yr^{-1} ($3\sigma, A_V = 0$ mag) over a galaxy cluster-sized volume, while the J and Ks WIRC maps probe the rest-frame blue and red continuum emission. We use these maps to determine basic properties of robustly star-forming companion galaxies within 2 Mpc of the CFg, including their SFR, absolute red and blue luminosities, and Hα equivalent widths. We also outline important follow-up observations to be carried out with the Spitzer Space Telescope.

The Molecular Interstellar Medium in Ultraluminous Infrared Galaxies

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We are conducting a large survey of Ultraluminous Infrared Galaxies (ULIRGs) with the Infrared Spectrograph on the Spitzer Space Telescope, which will result in low ($R \sim 90$) and high ($R \sim 600$) spectral resolution spectra from 5 to 38.5 μm of 110 sources with redshifts of $0.02 < z < 0.90$. Although rare in the local Universe, it is thought that ULIRGs make a significant contribution to the star-formation energy density at high redshifts, and typically contain large quantities of molecular gas which fuels their enshrouded energy source. In this poster, we present our analysis of direct detections of molecular hydrogen in ten ULIRGs also found in the IRAS Bright Galaxy Sample. Observations of the pure rotational H_2 emission lines, S(3) 9.665 μm, S(2) 12.279 μm, S(1) 17.035 μm and S(0) 28.218 μm, are used to derive the temperature and mass of the "warm" molecular hydrogen gas. This is compared to the total molecular gas mass inferred from published CO observations.

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no abstract received

New Frontiers Opened by Chandra in Cosmological Studies of Galaxies

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The deepest extragalactic X-ray surveys with Chandra show that galaxies are beginning to rival AGN as the most numerous point source populations at the faintest X-ray fluxes. These X-ray detected galaxies provide probes of X-ray binaries and hot gas in galaxies over important Gyr time-scales that simply were not accessible before the Chandra mission. However, most distant ($z > 0.2$) Chandra studies of the evolution of X-ray emission from star-forming galaxies are severely limited by the lack of highly complete observed X-ray samples in the local Universe. This poster reviews recent progress in X-ray studies of star-forming galaxies and discusses new results arising from archival Chandra studies of galaxies in the Sloan Digital Sky Survey Data Release 2 (SDSS DR2) and of pointed X-ray observations in the Coma cluster of galaxies. These projects are filling in the "local" observational needs of deep X-ray surveys.

A *Hubble Space Telescope* trip to the stellar populations present in Luminous Blue Compact Galaxies at Intermediate Redshift

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We present a spatially resolved spectroscopic/photometric study of 4 blue ($(B - V) \leq 0.6$ mag) compact field galaxies at redshifts $0.436 \leq z \leq 0.525$. The observed objects are very luminous, with absolute magnitudes $M_V \sim -20$. These galaxies are compact, having apparent half-light radii ($r_{1/2}$) less than 0.5 arcsec and high surface brightnesses. The spectra, taken with the STIS spectrograph on board of the *HST*, show very prominent emission lines. These spectra were used to derive oxygen abundances, areal star-formation rates and dust contents. The imaging data were taken with the WFPC2 instrument on *HST*. The observed galaxies present a very bright and blue central core, and a very faint extended component. With this work, we try to address the following questions.
(1) Can the blue, central component observed in the *HST* images be mapped in a one-to-one fashion to the line-emitting region observed with STIS?
(2) What is the origin of the color gradients observed in the *HST* images? Age, metallicity or dust?
Overall, it is very difficult to establish unambiguously a color gradient in the very central regions of the star-forming knot. However, it is possible to investigate line ratio changes within this narrow region.

Constraints on Lyman continuum flux escaping from galaxies at $z \sim 3$ using VLT narrow-band photometry

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We performed narrow-band imaging observations with the Very Large Telescope, aimed at detecting the Lyman continuum (LyC) flux escaping from galaxies at $z \sim 3$. We have not found any significant LyC flux from our sample of two galaxies in the *Hubble* Deep Field South, at $z = 3.170$ and 3.275. The corresponding lower limits on the F_{1400}/F_{900} flux density ratio (per Hz) are 24.4 and 14.6 (2σ confidence level). After correction for the intergalactic hydrogen absorption, the resulting limits on the relative escape fraction of the LyC flux are compared with those obtained by different approaches, at similar or lower redshifts. We include one additional object with a relative escape fraction lower than the detection reported by Steidel et al. in the composite spectrum of $z \sim 3$ galaxies. In addition, we will present constraints based on fitting the multi-band spectral energy distribution.

Near-Infrared Spectral Properties of Metal-Poor Red Supergiants

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The insufficient abundance range is one of the major obstacles for creating a realistic population synthesis models for starburst galaxies, in particular for the metal-poor dwarf irregulars.
We have embarked on a project to obtain medium/high-resolution spectra of stars spanning the relevant abundance range (Ivanov et al. 2004). Here we report ISAAC@VLT spectroscopy of metal-poor supergiants from the Magellanic Clouds, covering the H and K atmospheric windows. The spectral resolution is about $R = 9000$, making the new spectra excellent templates for measuring the velocity dispersion in external galaxies. The typical signal-to-noise ratio is 30-50. We report the strengths of metal and molecule features.

Wide and Deep Survey of LBGs at $z \sim 5$

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We present results of our surveys for Lyman Break Galaxies (LBGs) at $z \sim 5$. Our target field covers about 500 square arcmin and includes the whole area of the Hubble Deep Field-North and GOODS-North. The image depths reach to 28.2 in V, 26.9 in I and 26.6 in the z' band (AB mag). These exceptional wide and deep images obtained by the 8.2m Subaru telescope, as well as plenty of redshift information in the HDF-N enabled us to construct a reliable sample of V-band dropout LBGs. We found that the rest-frame UV luminosity function of LBGs at $z \sim 5$ is similar to those for lower redshift LBGs ($z \sim 3-4$), especially for the brighter part. In the fainter part, the number density at $z \sim 5$ decreases by about factor of 2 compared to $z \sim 3$. So far, seven bright LBGs among these candidates have been confirmed spectroscopically to be at $z \sim 5$. All of them show weaker Lyα emission or Lyα absorption features, which are significantly weaker than those for LBGs at $z \sim 3$. This might indicate a sign of evolution in the star-formation activity in LBGs at different epochs. We will also report the results of near-infrared imaging observations recently made for spectroscopically confirmed LBGs at $z \sim 5$, aiming to clarify the state of star-formation activity in these galaxies.

IMF statistical sampling: the ionizing cluster of NGC 588

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Most OB associations are modelled by fitting spatially integrated observational properties, such as the equivalent widths of Hβ and the UV stellar lines. This implies assumptions regarding the detailed stellar content of the objects modelled, in particular the initial mass function (IMF). In standard models, the IMF is a continuously sampled power law. However, Cerviño et al. (2002) showed that in clusters less massive than a few $\times 10^4$ $M_\odot$, the number of massive stars is low to moderate ($\sim$ 15 per 10^4 $M_\odot$ for a Salpeter slope), and the discrete nature of the IMF causes the observational properties to deviate significantly from those that are derived from a continuous IMF. I will discuss this issue of IMF statistical sampling in the framework of a double analysis of NGC 588, a giant HII region in the nearby galaxy M33. The first analysis consisted of fitting a usual massive star cluster model, with a fully sampled IMF. This model unsatisfactorily fits the data. The second model was based on *HST* images, where the individual stars of the cluster are resolved. From the latter, we inferred a reliable discrete IMF of the cluster, and derived an average power-law IMF from which the discrete IMF is a possible sample. We studied the difference between these two forms of IMF in terms of spectral properties. These effects are large, and I will use them to assess the necessity to account for IMF fluctuations in the study of moderately massive young clusters.

Non-isothermal gravoturbulent fragmentation: effects on the IMF

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Identifying the processes that determine the initial mass function (IMF) of stars is a fundamental problem in star-formation theory. One of the major uncertainties is the exact chemical state of the star-forming gas and its influence on the dynamical evolution. Most simulations of star-forming clusters use an isothermal equation of state (EOS). However, this might be an oversimplification given the complex interplay between heating and cooling processes in molecular clouds. Theoretical predictions and observations suggest that the effective polytropic exponent γ in the EOS changes with density. We study the effect of a piecewise polytropic EOS on the formation of stellar clusters in turbulent, self-gravitating molecular clouds using three-dimensional, smoothed particle hydrodynamics simulations. We increase the polytropic exponent γ from 0.7 to 1.1, at some chosen density. This change in the EOS selects a characteristic mass scale, which we relate to the peak of the observed IMF.
Primordial gas may have effective $\gamma > 1.0$. Our results then suggest that population III stars should have formed as isolated, massive objects.

A Study of the Strong Near-IR [SIII] Lines in HII Galaxies

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We have analysed long-slit spectrophotometric observations of a sample of 35 HII galaxies in the red (between 6000Å and 1 μm), including the nebular [SIII]$\lambda\lambda$9069,9532Å lines. For 6 of the 35 objects observed it has been possible to measure the auroral [SIII] line at 6312Å. All of these galaxies were observed previously in the blue, and it has therefore been possible to derive two line temperatures directly: t([OIII]) from the [OIII]λ4363Å line and t([SIII]) from the [SIII]λ6312Å line. Both spectra, red and blue, were obtained on the 1.52m telescope with the Boller & Chivens spectrograph at La Silla, ESO. In this work, we present the physical conditions and chemical abundances of these 6 galaxies derived from the measured [SIII]λ6312Å line, with particular emphasis on the S/H abundance. Despite the observed dispersion in the temperatures, the final result for the abundances is in accordance with the expected values for HII galaxies. In addition, we have added our observed HII galaxies to the empirical calibration of the metallicity parameter, S_{23} = ([SII]+[SIII])/Hα (Pérez-Montero & Díaz 2003). This calibration presents two important advantages with respect to the R_{23} parameter, which is based on the optical oxygen lines: it remains single-valued up to abundances close to solar and is almost independent of the ionization parameters of the nebula.

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no abstract received

Star formation at $z = 6.5$

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With respect to the formation of the first stars from primordial material and the sources of reionization, the observations of galaxies at $z = 6.5$, where Lyα is observable through an atmospheric window in the z' band, are of great interest. Employing slitless spectroscopy with FORS at the VLT, we have found a Lyα-emitting galaxy at $z = 6.5$ with a SFR(UV) of 70 $M_\odot$ yr^{-1}. Together with the small sample of currently known Lyα emitters at $z = 6.5$, this object puts constraints on the global star-formation history and the epoch of reionization.

Chemical Abundances in M33: toward NGC 604

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The Far Ultraviolet Spectroscopic Explorer (FUSE) offers the possibility to study the extragalactic interstellar medium (ISM) in sightlines toward UV-bright HII regions where stars are forming. From the absorption lines of species such as HI, OI, NI, ArI, or FeII we are able to derive the chemical composition of the diffuse neutral gas and compare it to the HII region composition. A major aim is to know whether HII regions truly reflect the ISM abundances of a galaxy or whether these regions are self-polluted with metals ejected by massive stars during the present starburst episode.

Five Blue Compact Dwarfs galaxies (BCDs) have been investigated so far. The situation remains, however, still unclear. For instance, the oxygen abundance is either the same within the neutral and ionized ISM (in I Zw 18, I Zw 36 and SBS 0335-052) or 10× lower in the neutral ISM (in Markarian 59). It seems, however, that nitrogen (using NI as a tracer in the neutral gas) and argon (using ArI) are systematically lower in the neutral phase.

Conscious of the uncertainties due to the complexity of the sightlines and the ionization structure, we have obtained high-quality spectra of individual HII regions in spiral galaxies. There, the situation is much easier to understand, allowing us to model HII regions with photoionization models. This study on NGC 604 provides a test on the method used for the BCDs. In NGC 604, we find a global underabundance in the neutral gas of N, O, Ar, and Fe as compared to the ionized gas, suggesting the presence of primordial gas in the line of sight. Furthermore, it appears that NI and ArI are good tracers, respectively of nitrogen and argon, in the diffuse neutral gas surrounding NGC 604.

Revealing the HII Regions of NGC 1705: Nebular Abundances and Extinction Variations

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NGC 1705 is a well-studied dwarf galaxy, exhibiting evidence of gas outflows driven by a very recent burst of star formation. Literature values of the nebular oxygen abundance span a range between 12+log(O/H) = 8.0 and 8.5. Here, we present new EFOSC2 spectra of 16 HII regions in NGC 1705. For the first time, [OIII]λ4363 was detected in five HII regions. The mean oxygen abundance derived directly from measured electron temperatures is 12+log(O/H) = 8.21 $\pm$ 0.05, which corresponds to 35% of the solar value. From Balmer emission flux ratios, we have observed variations in the extinction (between zero and 0.9 mag in V) on spatial scales of about 10 arcsec (250 pc) in radius from the super star cluster. One should therefore be cautious about possible spatial variations of the extinction along different lines of sight in the galaxy, and about how extinction corrections are applied to studies of resolved stellar populations. NGC 1705 has the appearance of a normal dwarf galaxy, on which is superposed a recent intense episode of star formation. There appears to be no evidence of any external trigger for the starburst.

The Dwarf Galaxy Duty Cycle: Measurements from a Complete Sample Within the Local Volume

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With the goal of fully characterizing the star-formation properties of complete samples of galaxies in the local Universe, we have carried out an Hα and R-band imaging survey of a volume-limited sample of 340 spiral and irregular galaxies within a distance of 11 Mpc. In particular, we are using this dataset to understand the importance of starbursts in dwarf galaxies. We present preliminary results regarding the duty cycle of starbursts in low-luminosity galaxies through an analysis of the Scalo birth-rate "b" parameter, and constrain the fractional stellar mass formed during burst phases. General properties of the overall sample, with an emphasis on the survey's completeness, are also discussed. The snapshots of the ongoing star formation provided by our Hα imaging will be complemented by UV imaging through a recently approved GALEX Legacy program. The combined Hα and UV volume complete dataset, which will be built up over the next year, will provide a more robust measurement of the duty cycle, powerful constraints on the systematic errors in the inferred star formation related quantities, and also allow for the systematic investigation of the poorly understood star formation propagation mechanism in dwarf irregular galaxies.

Optical and Near-IR Luminosity-Metallicity Relations of KISS Star-Forming Emission-Line Galaxies

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Using nebular oxygen abundances computed through the direct electron temperature method (T_e) for 23 star-forming emission-line galaxies from the KPNO International Spectroscopic Survey (KISS) in conjunction with other T_e-based measurements from the literature, we demonstrate that HII galaxies and more quiescent dwarf irregular galaxies follow similar metallicity-luminosity (L-Z) relationships. The primary difference is a zero-point shift between the correlations such that HII galaxies are brighter by an average of 0.8 B magnitudes at a given metallicity. This offset can be used as evidence to argue that low-luminosity HII galaxies typically undergo a factor of two luminosity enhancements, and that starbursts that elevate the luminosities of their host galaxies by 2 to 3 magnitudes are not as common. We also demonstrate that the inclusion of interacting galaxies can increase the scatter in the L-Z relation and may force the observed correlation toward lower metallicities and/or larger luminosities. This must be taken into account when attempting to infer metal abundance evolution by comparing local L-Z relations with ones based on higher-redshift samples since the fraction of interacting galaxies should increase with look-back time. The 23 KISS T_e-based measurements are further used to calibrate a strong-line abundance estimator, which allows us to compute metallicities for a much larger set of galaxies in the local Universe ($z < 0.09$) and to study the L-Z relationship in 5 different bandpasses over a luminosity range spanning 8 magnitudes.

Physical properties of low-luminosity high-redshift galaxies

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We report the results obtained from NIR ISAAC/VLT and optical FORS/VLT spectroscopy of lensed low-luminosity $1.3 \leq z \leq 2.3$ galaxies located in the core of the lensing clusters AC114, CL2244-02, and A370. The amplification factor allowed to obtain, for the first time, physical properties (SFR, abundance ratios, mass, age of the burst, dust content, etc) of star-forming galaxies, 1 to 2 magnitudes fainter than in previous studies of Lyman Break Galaxies at $z \sim 3$.

Control of Star Formation in Galaxies by Gravitational Instability

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We present high-resolution (up to 3 million particles) simulations of star formation for a wide range of disk galaxies consisting of a dark matter halo, a stellar disk, and isothermal gas. We use a three-dimensional, smoothed particle hydrodynamics (SPH) code implemented with sink particles, which represent collapsing star clusters. Our results show that, both the global Schmidt Law for star formation (Kennicutt 1998), and the star-formation threshold (Martin & Kennicutt 2001), can be reproduced excellently by gravitational collapse and an isothermal EOS, suggesting that the dominant physical mechanism determining the star-formation rate is just the strength of the gravitational instability. We find a strong correlation between star formation and the value of the Toomre instability parameter Q for stars and gas together (Rafikov 2001): the star-formation rate (SFR) decreases exponentially with Q. This suggests that vigorous starbursts occur where Q is small, while quiescent star formation takes place where Q is large. Massive galaxies, or galaxies with large gas fractions, tend to have low initial Q (smaller than unity), which leads to fast star formation in a very short time; while low-mass galaxies, or galaxies with small gas fractions, tend to have high initial Q, which maintains slow star formation over a long time. Q increases as the galaxies evolve. Feedback from massive stars probably increases Q and speeds up the cut-off of star formation.

The Luminosity-Metallicity Relation of distant luminous infrared galaxies

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A large sample (64 out of 105 objects) of distant ($z > 0.4$) luminous infrared galaxies (LIRGs) selected from ISOCAM deep survey fields (CFRS and Marano fields) have been studied in detail (on the basis of their high-quality optical spectra from VLT/FORS2), including the dust extinction, diagnostics, star-formation rates and metallicities in the interstellar medium, etc. The extinction coefficients estimated from two independent methods, e.g., Balmer line ratios and the energy balance between infrared and Hβ luminosities, are fully consistent, with a median value of 2.36. These distant LIRGs show many properties (IR luminosity, continuum color, ionization and extinction) strikingly in common with those of the local (IRAS) LIRGs studied by Veilleux et al. (1995). They can provide a good representation of LIRGs in the distant Universe. Oxygen abundances in the interstellar medium (12+log(O/H)) in the sample galaxies have been estimated from the extinction corrected "strong" emission-line ratios ([OII]/Hβ, [OIII]/Hβ and [OIII]/[OII]), and show a range from 8.36 to 8.93, with a median value of 8.67, which is half lower than that of the local bright disks (i.e. L^*) at the given magnitude. The PÉGASE2 models predict that total masses (gas + stars) of the distant LIRGs are from 10^{11} $M_\odot$ to $\leq 10^{12}$ $M_\odot$. A significant fraction of distant large disks are indeed LIRGs. Such massive disks could have formed $\sim 50\%$ of their metals and stellar masses since $z \sim 1$.

Globular Cluster Systems as the link between nearby and high-redshift galaxies: New tools for tracing ancient starbursts

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We present mathematically advanced tools for the determination of age, metallicity, and mass of old Globular Clusters (CGs) using both broad-band colors and spectral indices, and we present their application to the Globular Cluster Systems (GCSs) of elliptical galaxies. Since one of the most intriguing questions of today's astronomy aims at the evolutionary connection between (young) violently interacting galaxies at high-redshift and the (old) elliptical galaxies we observe nearby, it is necessary to reveal the possibly violent star-formation history of these old galaxies. By means of evolutionary synthesis models, we can show that, using the integrated light of a galaxy's (composite) stellar content alone, it is impossible to date (and, actually, to identify) even very strong starbursts if these events took place more than two or three Gyr ago. However, since large and violent starbursts are associated with the formation of GCs, GCSs are very good tracers of the most violent starburst events in the history of their host galaxies. Using our well-established Göttingen SED (Spectral Energy Distribution) analysis tool, we can reveal the age, metallicity, mass (and possibly extinction) of GCs by comparing the observations with an extensive grid of SSP model colors. This is done in a statistically advanced and reasonable way, including their 1σ uncertainties. However, since for all colors the evolution slows down considerably at ages older than about 8 Gyr, even with several passbands and a long wavelength base line, the results are severely uncertain for old clusters. Therefore, we incorporated empirical calibrations for Lick indices in our models and developed a Lick indices analysis tool that works in the same way as the SED analysis tool described above. We compare the theoretical possibilities and limitations of both methods as well as their results for the example of the cD galaxy NGC 1399, for which both multi-color observations and, for a subsample of clusters, spectral indices are available, and address implications for the nature and origin of the observed bimodal color distribution.

The far-UV morphologies of high-redshift galaxies

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We compare the rest-frame far-UV morphologies of Lyman break galaxies at $z \sim 3-5$, sub-mm sources at $z \sim 2$, and galaxies at $z \sim 1.5$ in the GOODS and UDF fields. New non-parametric morphological quantities (the Gini coefficient and M_{20}) are used to identify mergers and interacting galaxies. We examine the star-formation properties as a function of morphology, stellar mass, and redshift, and discuss the implications for merger-induced star formation at high redshift.

Oxygen Abundances, SFRs and Dust of CFRS Galaxies at Intermediate Redshift

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Measurements of the metallicity of galaxies at substantial look-back times is important for tracing the chemical evolution of galaxies and for modeling galaxy properties. Using near-infrared spectroscopy with ISAAC at the VLT and NIRSPEC at Keck, we measured the Hα and [NII]λ6584 lines of 27 CFRS galaxies at $0.47 < z < 0.92$, an approximately rest-frame-B selected sample of galaxies extending down to about $0.1L^*$. The [OII]λ3727, Hβ and [OIII]λ5007 lines of these 27 galaxies have been measured from CFHT optical spectra. We have developed a code to simultaneously fit [OII], Hβ, [OIII], Hα, and [NII] in terms of the extinction parameter, A_V, ionization parameter, q, and oxygen abundance, [O/H], based on a set of ionization parameter and oxygen abundance diagnostics developed by Kewley & Dopita (2002). Thus, we can determine, for each individual galaxy: a) the extinction, A_V, b) the SFR from the extinction-corrected Hα flux, and c) [O/H], with a precision of, typically, around 0.1 dex. We compare the SFRs, [O/H] and A_V's of these intermediate-redshift galaxies with the properties of local galaxies (e.g., the NFGS sample). Moreover, the metallicity-luminosity relation at intermediate redshift is studied by comparing the oxygen abundances of CFRS galaxies and of other galaxies at intermediate redshift (e.g., emission-line galaxies with faint absolute luminosities found by the Calar Alto Deep Imaging Survey (CADIS)).

Star-formation history of distant luminous infrared galaxies

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The detection of the Cosmic Infrared Background (CIRB; Puget et al. 1996) and the excess of faint galaxies that are ten times more numerous than expected from models without evolution in the 15-micron ISOCAM number count excess (Elbaz et al. 1999, Metcalfe et al. 2003, Aussel et al. 1999, Gruppioni et al. 2002) revealed a population of dusty galaxies that must play a crucial role in galaxy evolution. These luminous infrared galaxies (LIRGs) are now mostly associated with dust-enshrouded star formation (80%) rather than AGN activity (20%) (Fadda et al. 2002). We obtained about one hundred high-resolution spectra ($R = 2000$ in the rest frame) on the ESO VLT of distant LIRGs, located at $z \sim 0.7$, and which are known to be partially responsible for both the 15-micron ISOCAM number count excess and the high value of the cosmic infrared background.
Our goal was to study the star-formation history of these galaxies, which are experiencing a burst of star formation. Following the same strategy as Kauffmann et al. (2003), we used the latest version of GALAXEV (Bruzual & Charlot 2003), which uses the spectral library STELIB, whose spectral resolution is 3Å in the [3200, 9500]Å range, to quantify several parameters linked to what happened to LIRGs in the last few Gyr. We have quantified:

- the duration of the burst of star formation, which is about 0.1 Gyr.
- the amount of stars created in the burst for 7 galaxies, and we can say that it is lower than 10% of the mass of the galaxy.
- the M/L ratio, which is weaker than the M/L ratio used for field galaxies.
- the probability for these galaxies to have undergone a previous burst in the previous few $\times 0.1$ Gyr.

Since the CIRB is as strong as the optical background, which implies that a large part of stars in the local Universe are thought to be born in dusty environments, we can conclude that a typical galaxy must have experienced several phases, such as the LIRG phase.

Dynamics and emissivity of conductive gas clouds embedded in supernova-driven galactic superwinds

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Observationally, the soft X-ray and the ultraviolet OVI radiation in the halo of starburst galaxies have comparable intensities and are spatially related one to another and to the Hα emission. This is indicative of cold gas embedded into the hot superwind. Such cold gas may be representative of pre-existing clouds overrun by the wind, and/or fragments of the superbubble shell powered by the wind and fragmented at the breakout. As a first step, we present hydrodynamical simulations of a spherical, dense ($n = 1$ cm^{-3}) cold (10^4 K) cloud initially at rest and embedded into an hot ($10^6 - 10^7$ K) tenuous ($n = 10^{-2} - 10^{-3}$ cm^{-3}) uniform gas flowing supersonically ($440 - 2000$ km s^{-1}). We study the emission originating at the heat conduction front which develops at the edge of the cloud. In this model the X-ray and the OVI emission originates naturally at the conductive front. They are strictly spatially connected, have the same order of magnitude ($\sim 10^{33} - 10^{34}$ erg s^{-1} for a cloud mass of 200 M$_\odot$). According to McKee and Cowie (1975, ApJ, 195, 71) we find that, in presence of strong temperature gradients (such as present at the interface between the cloud and the superwind), dynamical effects related to the thermal conduction become important and modify the cloud evolution. In particular, the cloud size oscillates with a period of 0.3–1 Myr, inducing analogous oscillation in the intensity of the emitted X-ray and OVI radiation and in the mass-loss rate.

The Dynamics of Blue Compact and HII Galaxies from new Fabry-Perot Observations: Clear Signatures for Merging?

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Blue Compact Galaxies (BCGs) and HII galaxies comprise starbursts (SBs) of the most extreme type: very young stellar populations, high star-formation rates (SFRs), short gas consumption time-scales and often a very metal-poor environment. Although merging and interactions are widely accepted as a triggering mechanism, it is still unclear to what extent these factors play a role and which other aspects are important. We present new Fabry-Perot observations of the Hα emission line in a sample of HII galaxies, taken at the ESO 3.6m telescope with the CIGALE instrument. Velocity fields are presented and analysed and the importance of mergers and interactions is discussed.

Secular Evolution of Stellar Bars, Vertical Instabilities and Starbursts

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Vertical instabilities, buckling, in stellar bars weaken and shorten the bar. This can interrupt the bar-induced gas inflow into the central kpc of a galaxy for $\sim$ 1 Gyr. The subsequent bar growth in length and in amplitude can lead to a recurrent buckling. The first buckling results in the formation of a peanut/boxy-shaped bulge when viewed edge-on, and the second buckling forms an X-shaped bulge. The secular growth of the bar and the recurrent buckling can lead to important observational corollaries in bar fraction, bar detection, offset dust lanes, bar size-to-corotation ratio, etc.

IMF variations in the Antennae star clusters

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The Antennae galaxies with their wealth of star clusters are an ideal target to search for IMF variations and their origin. We performed near-infrared broad- and narrow-band imaging, which together with the *HST* optical data provides a broad wavelength coverage to determine age and extinction of individual clusters, as well as the size information, which is one ingredient for a dynamical mass estimate. Our VLT-ISAAC, UVES and new FLAMES high resolution spectra allowed us to determine velocity dispersions and hence dynamical masses for roughly 20 clusters in this merger starburst. Comparing those to estimates of the photometric cluster mass obtained from evolutionary synthesis models reveals IMF variations between the clusters.

Enhanced tidally-induced starbursts in cluster galaxies: the relation to processes of cluster virialisation

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An Hα survey of 843 CGCG galaxies in 8 low-redshift Abell clusters has found evidence for enhanced gravitationally tidally-induced circumnuclear starbursts in cluster galaxies as compared to the field. The subset of tidally-disturbed galaxies with starbursts comprise the non-virialised component of later-type cluster galaxies, and appear to be concentrated in a shell, approximately 0.6 Mpc from the cluster centre.

NGC 1569 – A Dwarf Galaxy with a Giant Starburst

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The recent, very strong starburst in the nearby dwarf galaxy NGC 1569 has had a tremendous impact on both the ionized and the neutral interstellar gas in the galaxy and has led to the formation of a powerful galactic wind. In this contribution, we discuss the distribution and kinematics of the neutral atomic hydrogen using a high-resolution HI data cube and results from Chandra observations. We also report on our recent observations of the molecular gas morphology and velocity structure in the region near two very bright super star clusters and compare it to the distribution of the atomic gas. The spectra of several ^{12}CO and ^{13}CO transition lines have been used to derive an average kinetic temperature and gas density in the most prominent giant molecular association west of the super star clusters.

In addition, we present evidence for an extended HI structure in the halo of NGC 1569. This, and several peculiar features in the disk of NGC 1569, leads us to suggest that NGC 1569 is currently merging with an intergalactic HI cloud, which may have been the trigger and a gas reservoir of the recent starburst.

The Unusual Tidal Dwarf Candidate in the Merger System NGC 3227/6: Star Formation in a Tidal Shocks?

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We report the discovery of active star formation in the HI cloud associated with the interacting Seyfert system NGC 3227/NGC 3226 that was originally identified as a candidate tidal dwarf galaxy (TDG) by Mundell et al. and that we name J1023+1952. We present the results of broad-band $BRIJHK$ and ultraviolet imaging that show the HI cloud is associated with massive on-going star formation seen as a cluster of blue knots ($M_B < -15.5$ mag) surrounded by a diffuse ultraviolet halo and co-spatial with a ridge of high column density neutral hydrogen in its southern half. We also detect Hα emission from the knots with a flux density corresponding to a star-formation rate of SFR ~ 0.011 $M_\odot$ yr^{-1}. Although J1023+1952 spatially overlaps the edge of the disk of NGC 3227, it has a mean HI velocity 150 km s^{-1} higher than that of NGC 3227; comparison of ionized and neutral gas kinematics in the star-forming region show closely matched velocities, providing strong evidence that the knots are embedded in J1023+1952 and do not merely lie behind in the disk of NGC 3227, thus confirming J1023+1952 as a gas-rich dwarf galaxy. We discuss two scenarios for the origin of J1023+1952; as a third, pre-existing dwarf galaxy involved in the interaction with NGC 3227 and NGC 3226, or a newly-forming dwarf galaxy condensing out of the tidal debris removed from the gaseous disk of NGC 3227. Given the lack of a detectable old stellar population, a tidal origin is more likely. If J1023+1952 is a bound object forming from returning gaseous tidal tail material, we infer a dynamically young age consistent with its star-formation age, and suggest it is in the earliest stages of TDG evolution. Whatever the origin of J1023+1952, we suggest that its localized star formation is shock-triggered by collapsing tidal debris – a possible formation mechanism for the recently-discovered population of young extragalactic HII regions.

CO ($J = 7 - 6$) and [CI] Observations using SPIFI on JCMT: Investigation of Star Formation in Galaxies

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We present results of the CO ($J = 7 - 6$), 371 micron, and [CI], 370 micron, observations of the galaxies NGC 253, M82, M51, NGC 6946, and NGC 4038/39. The observations were carried out with our submillimeter spectrometer SPIFI at the JCMT. The line ratio probes the excitation mechanism and the physical conditions of the molecular gas in the star-forming regions in the galaxies. While the [CI] line is relatively easy to excite ($T_{\rm level} = 63$ K, $n_{\rm crit} = 10^3$ cm^{-3}), the CO(7-6) line has much higher excitation requirements ($T_{\rm level} = 155$ K, $n_{\rm crit} = 4 \times 10^5$ cm^{-3}). Thus, the [CI] line is strong in quiescent spiral galaxies, such as NGC 6946 and the Milky Way, while the CO(7-6) line is only strong in starburst nuclei or regions with enhanced star formation. For starburst galaxies, the C/CO abundance ratio is often enhanced. Since the [CI] emission has been observed to be co-extensive with [CII] emission, strong [CI] emission indicates PDRs. No other excitation mechanism (e.g., cosmic rays) would lead to enhanced [CI] emission. The brightness of the [CI] line that we detect in M82, NGC 253, and M51 favors a PDR origin. In contrast, the CO(7-6) emission line can result from several excitation mechanisms, e.g., shocks or cosmic rays or PDRs. The CO(7-6) line we observed in the nuclear region of NGC 253 strongly suggests cosmic rays as the excitation mechanism and main heat source inside the molecular clouds. The enhanced cosmic-ray flux required to explain the brightness of the CO(7-6) emission is consistent with the supernovae rate observed in NGC 253.

Stellar host galaxies and starburst mechanisms in Blue Compact Galaxies: Surprises from the Near Infrared and the Ultra Deep Field

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We analyze local Blue Compact Galaxies (BCGs), and BCGs at intermediate redshifts in the UDF with respect to extended stellar host galaxies. The light and mass distributions of these components, containing almost all stellar mass, hold clues to the starburst activity and evolution of BCGs. A deep NIR study of local BCGs is less affected by the starburst emission than previous optical work, and reveals unexpected central structure for many BCG host galaxies. This affects current concepts of BCGs, e.g., their post-burst fading. Surprisingly, burst-like star formation in typical local BCGs may occur above a threshold stellar mass density of the host galaxy; this new finding can explain various relations between the starburst and the host galaxy, and the difference in star-formation modes between dwarf irregulars and BCGs. Using BCGs in the UDF, we address evolutionary relations between BCGs at higher redshift, and galaxies in the local Universe, and whether starbursts in local and distant BCGs are due to the same mechanism.

The FORS Deep Field spectroscopic survey – Exploring galaxy evolution at high redshift

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Using the FORS instrument at the ESO VLT we obtained low-resolution spectra of the galaxy population in the FORS Deep Field. 98 out of 341 objects with reliable spectroscopic redshifts are starburst galaxies and QSOs at $2 < z < 5$. Using this data set we investigated the evolution of the characteristic spectral properties of bright starburst galaxies and their mutual relations as a function of redshift. Significant evolutionary effects were found for $2 < z < 4$. Most conspicuous are the increase of the average CIV absorption strength, of the dust reddening, and of the intrinsic UV luminosity, and the decrease of the average Lyα emission strength with decreasing redshift. In part, the observed evolutionary effects can be attributed to an increase of the metallicity of the galaxies with cosmic age. Moreover, the increase of the total star-formation rates and the stronger obscuration of the young stellar population by dusty gas clouds suggest the occurrence of more massive starbursts at later cosmic epochs.

On the X-ray contribution from young Supernovae in Starbursts

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We have collected, from the literature, X-ray fluxes of young supernovae measured with various instruments. After converting the data to one energy range, we have compared the X-ray light curves of these objects. We show that the X-ray luminosities of early supernovae show coherent trends with supernova type and provide significant, though short-lived contributions to the X-ray luminosity of starbursts.

ISO observations of the interacting galaxy Markarian 297

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Observations of the complex interacting system, Mrk 297, were made with the Infrared Space Observatory (ISO) using the ISOCAM, ISOPHOT and ISOLWS instruments. The ISO observations reveal that the strongest peak of star formation, i.e., the strongest ISOCAM source in the system in the four bands, is at a location completely unremarkable at visible wavelengths, and does not coincide with the nuclear region of either colliding galaxy. This striking characteristic has also been observed in the Antennae system, NGC 4038/4039, and again underlines the importance of infrared observations in understanding star formation in colliding/merging systems. ISOCAM maps of Mrk 297 at 6.7, 7.7, 12, and 14.3 microns are presented, which, together with PHT-S spectrometry of the central interacting region, probe the dust-obscured star formation and the properties of the organic dust. LWS spectroscopy yields a measure of the cold dust component in the system. A supernova that exploded in 1979 is one of the most powerful known radio remnants and lies on the periphery of the strongest mid-infrared source and site of the hidden starburst. This supernova explosion may have been accompanied by a gamma-ray burst (GRB), consistent with the idea that GRBs are associated with supernovae in star-forming regions, and a search for a GRB consistent with the direction to Mrk 297, in satellite data from July to December 1979, is recommended.

Chemical Abundances in Starburst Galaxies

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Detailed abundances and abundance patterns of key metals like Fe, C, O and other α elements in starburst galaxies, as obtained from high-resolution infrared and X-ray nuclear spectra, are presented. The metals locked in stars give a picture of the galaxy metallicity prior to the last burst of star formation. The enrichment of the new generation of stars born in the last burst can be traced by measuring the hot gas in X-rays. Comparison of stellar and gaseous abundances provides important clues on the galaxy history of star formation and chemical enrichment.

Galactic Starbursts as a Manifestation of a General Equipoise Dynamic

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Starburst dynamics demonstrate the principle of equidynamics. Equidynamics is one underlying dynamic that creates complexity, for it allows both construction and destruction and chaos transitions to complex systems in a re-distributive dynamic. Equidynamics is the process by which energy self-organizes. Self-organization is the process whereby each unit of energy self-equalizes its state by movement to resolve differentially toward a local average through the local summing of itself and related forces and energies. If the universe summed to an average globally, we would have only an amorphous condition. However, convergent, constructive phenomena such as starbursts and the fact that forces decrease with distance tell us that units of energy sum to their local average condition, not to the global condition, allowing one dynamic to produce both dissipation and convergence of energies. Starburst formation is of particular interest in demonstrating equidynamics because, rather than being a dissipation of energies, it is a colossal self-organizing primal convergence of energies that can be observed in many variations; yet, for all the varied instances, exhibited are recurring patterns and states of threshold pre-conditions. Equidynamics is defined as follows: the predicted state of a given unit of energy is equal to the sum of itself and the local sum of its relationships to interactive energies. Forces are subordinate as manifestations of relationships and are subsets of the over-arching principle of equidynamics. Investigation of the dynamic flow resulting in starburst formation and comparing it to similarities in other interactions, both dissipative and convergent – at the Galactic, earthly, cosmological and quantum scales – results in a conclusion, presented herein, that suggests an equidynamic law as a basic principle of energy that is fundamental to all forces at each scale of the Universe. This paper takes the equidynamic physics of starbursts as an observational phenomenon to inform us about physics as a whole.

The Temperature Distribution of Dense Gas in Starburst Cores

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We present the first interferometric survey of ammonia in the cores of prominent, southern starburst galaxies. Six starburst galaxies were observed with the Australia Telescope Compact Array in both, the ammonia (1,1) and (2,2) metastable inversion lines: NGC 253, NGC 4945, M83, Cen A, NGC 1365, and Circinus. In all galaxies but Circinus ammonia is detected either in emission, in absorption, or both. The ratio of these ammonia lines is a powerful diagnostic to derive the rotational temperature and thus to constrain the excitation of the cool and dense molecular gas component – the material which ultimately fuels starburst activity. We compare the total amount of dense molecular gas and its temperature distribution to the starburst and AGN activity in our sample of galaxies.

The photometric structure of young BCD candidates

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A tiny fraction of blue compact dwarf (BCD) galaxies exhibits a nearly galaxy-wide starburst activity and no signatures of an old underlying host galaxy. The evolutionary status and formation history of these most metal-deficient BCDs are still a subject of debate. Various lines of evidence suggest, however, that these systems do not contain a substantial population of stars older than ~ 1 Gyr and hence qualify as nearby young-galaxy candidates. Elaborated multi-wavelength investigations of such systems may therefore provide crucial insights into the formation and starburst-driven evolution of low-mass galaxies in the early Universe. I will discuss the photometric structure of these rare systems and emphasize the crucial importance of a correction for extended nebular emission when studying their evolutionary state.

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no abstract received

Luminous Compact Blue Galaxies in the Local Universe: a key reference for high-redshift studies

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Luminous Compact Blue Galaxies (LCBGs) are high surface brightness starburst galaxies, bluer than a typical Sbc and brighter than $\sim 0.25L^{\star}$. LCBGs have evolved more than any other galaxy class in the last $\sim$ 8 Gyr, and are a major contributor to the observed enhancement of the UV luminosity density of the Universe at $z \leq 1$. Despite the key role LCBGs may play in galaxy evolution, their statistical properties are still largely unknown. We have selected a complete sample of $\sim$ 25 LCBGs within 100 Mpc, after investigating over 10^6 nearby galaxies from the DR1 of the SDSS database. This sample, although small, provides an excellent reference for comparison with current and future surveys of similar galaxies at high redshift, including the population of Lyman-break galaxies. In this conference, we present preliminary results of this study using 3D spectroscopic observations obtained over a very wide range in wavelength, using WIYN/DENSEPAK in the optical, FISICA in the infrared, and the VLA at cm wavelengths.

Ionizing stellar populations in circumnuclear star-forming regions

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We present a study of the stellar populations and gas physical conditions in Circumnuclear Star-Forming Regions (CNSFRs) based on spectrophotometric data, including the 7000Å – 1 micron spectral range, which is of great interest to the whole diagnostic of the ionized gas. The properties of CNSFRs as a class are inferred from a comparison with those of other star-forming emission-line objects: low-excitation disc HII regions and HII galaxies.

Mid-Ultraviolet Spectral Templates for Single-Age, Single-Metallicity Systems

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This is a progress report for our *Hubble* Treasury program GO-10094. Our goal is to provide both theoretical and observational spectral templates for the mid-ultraviolet, from 2200Å to 3150Å and beyond, for a quantitative interpretation of the spectrum of a stellar system such as a globular cluster or elliptical galaxy. This is aimed at determining the age and metallicity of systems as young as 1 Gyr.

We are now calculating grids of theoretical spectral templates for stars all across the color-magnitude diagram, from red giants to turn-off stars to blue stragglers to extreme blue horizontal branch stars. The grids span a wide range of metallicities, and incorporate both the solar mix of elemental abundances and mixes with enhanced abundances of light elements such as magnesium. At the same time we are calculating stellar tracks and isochrones for these metallicities and mixtures. We will then generate theoretical spectral templates for single-age, single-metallicity systems by coadding the stellar spectra with weights derived from the isochrones. We will make public the stellar and composite grids, as well as broad-band indices and colors derived from them.

We present examples of the excellent matches between observed and theoretical spectra achieved to date, in both the ultraviolet and the optical spectral regions. We also illustrate the application of these theoretical spectra to several problems, from the determination of very heavy elements produced by the s- and r-process in individual stars, to the age and metallicity of extragalactic globular clusters and remote galaxies.

Luminous Blue Compact Galaxies in the GOODS-N Field

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We present a preliminary analysis of small, high surface brightness galaxies in the GOODS-N Field using spectra from the Team Keck Treasury Redshift Survey combined with *HST*/ACS images from the GOODS project. The galaxies span a range of redshifts, from $\sim 0.2 < z < 1.5$. Compact galaxies at similar redshifts were studied by Phillips et al. (1997) and Guzman et al. (1997), whose findings indicated that a significant portion of these galaxies are strongly bursting systems, that their space density evolves rapidly from $z \sim 1$ to the present, and that compact galaxies contribute disproportionately to the star-formation density at intermediate redshifts. Unlike the earlier sample, the current sample is defined by rest-frame parameters and is more homogeneous. While we confirm that the density of these galaxies appears to evolve rapidly with redshift, the interpretation is currently ambiguous. We also examine evolution in morphology, star-formation rates and O/H abundances, and discuss incorporating mass estimates in future work.

Optical and near-IR properties of submillimetre galaxies in the GOODS-North field

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We present a new "Super-map" in the GOODS-North field containing 42 statistically robust sources at 850 μm. We have used the *HST*/ACS images and ground-based near-IR observations from GOODS to study these sources. With the depth achieved by this survey, optical counterparts have been found for all of the radio-detected sub-mm sources. We have used the colours, morphologies and photometric redshifts of these secure identifications to help identify counterparts to the radio-undetected sources. We have found that certain combinations of optical properties can be used to successfully identify the counterpart to a sub-mm source. 75% of our sources have a unique optical counterpart, using our new techniques for counterpart identification, and an additional $\sim 15\%$ have several possibilities that meet our criteria in the ACS images. We have found a much higher ERO rate than other sub-mm surveys thanks to the increased depth in the optical images. The median redshift from optical photometric redshifts for the bright radio-detected sources is around 2, and rises to ~ 2.6 for the bright radio-undetected sources. While the quantitative morphologies span a range of values, in general the sub-mm galaxies show much larger sizes and more asymmetries than other galaxy populations at the same redshifts, and we can rule out the possibility that these galaxies have normal morphologies. With the current and upcoming data from Spitzer of GOODS-North, we will be able test our counterpart selection techniques and use the additional IR photometric points to study the optical/IR SED of an unbiased sample of sub-mm galaxies.

Probing star formation at high redshifts with X-ray surveys: number counts and luminosity

Piero Ranalli

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Thanks to the linear relations among radio, infrared and X-ray luminosities of non-active spiral galaxies, we have recently calibrated a new star-formation rate (SFR) indicator based on X-ray luminosity, which is largely unaffected by absorption, and has been tested in both local and high-redshift ($z = 1$) galaxies. Coupled with the deepest Chandra observations of the Chandra Deep Fields, this opens up the possibility to determine the number counts and luminosity function of high-redshift star-forming galaxies. We show how the X-ray number counts are quite well determined in a wide flux interval ($-17.5 < \log F_X < -15$). We also discuss the links between the luminosity functions in the radio, far infrared, blue and X-ray bands and the possibilities for the evolution of the luminosity function.

X-Ray and Radio Emission from UV-Selected Star-Forming Galaxies at $z \sim 2$

Naveen A. Reddy

California Institute of Technology, USA

We have examined the stacked radio and X-ray emission from UV-selected galaxies spectroscopically confirmed to lie between redshifts $1.5 < z < 3.0$ in the GOODS-North field to determine their average extinction and star-formation rates (SFRs). The X-ray and radio data are obtained from the Chandra 2 Ms survey and the Very Large Array, respectively. There is a good agreement between the X-ray, radio, and de-reddened UV estimates of the average SFR for our sample of $z \sim 2$ galaxies of ~ 50 $M_\odot$ yr^{-1}, indicating that the locally-calibrated SFR relations appear to be statistically valid from redshifts $1.5 < z < 3.0$. We find that UV-estimated SFRs (uncorrected for extinction) underestimate the bolometric SFRs as determined from the 2-10 keV X-ray luminosity by a factor of $\sim 4.5 - 5.0$ for galaxies over a large range in redshift from $1.0 < z < 3.5$.

Daniel Reverte-Payá

Instituto de Astrofísica de Andalucía–CSIC, Spain

no abstract received

Chemical Evolution of Late-Type Dwarf Galaxies

Donatella Romano

INAF, OA Bologna, Italy

We present results of chemical evolution models for both dwarf irregular and blue compact dwarf galaxies with recent star-formation histories inferred from colour-magnitude diagrams resulting from *HST* photometry. We constrain their early evolution and assembly history by comparing model predictions with their present-day chemical properties. The stellar feedback determining the occurrence of galactic outflows still remains the most uncertain mechanism driving the evolution of these galaxies.

The Spitzer properties of ISO+VLA+SCUBA sources in ELAIS-N1

Anna Sajina[1], D. Scott, M. Lacy, M. Dennefeld, H. Dole, G. Lagache

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We present a study of the $2-850\mu$m SEDs of a sample of 30 star-forming galaxies originally selected by the FIRBACK survey at 170μm and with positions determined from 1.4 GHz imaging. The sample consists of predominantly local, quiescent spirals ($z \lesssim 0.3$), with a tail of ULIGs extending up to $z \sim 1$. Their exceptional spectral coverage make this sample ideal for understanding the infrared SEDs of star-forming galaxies, with the higher-z ULIGs acting as a bridge to the more distant SCUBA-selected population.

New Constraints on the Star-Formation Histories and Dust Attenuation of Galaxies in the Local Universe from GALEX

Samir Salim

Division of Astronomy & Astrophysics, UCLA, USA

We derive physical parameters including stellar mass, star-formation rates (SFRs), dust attenuation and burst mass fractions for 6472 galaxies observed recently by the Galaxy Evolution Explorer (GALEX), and present in the SDSS DR1 main spectroscopic sample. Parameters are estimated by comparing each observed broad-band SED (two GALEX and five SDSS bands) with an extensive library of model galaxy SEDs. We compare the constraints derived using SDSS bands *only* with those derived using the combination of SDSS and GALEX photometry and find that the addition of the GALEX bands leads to significant improvement in the estimation of both the dust optical depth and the star formation rate over timescales of 100 Myr to 1 Gyr. We are sensitive to SFRs as low as 10^{-3} $M_\odot\,yr^{-1}$, which are mostly associated with early-type, red galaxies. The least massive galaxies have ratios of current to past-averaged SF rates (b-parameter), consistent with constant SF over a Hubble time. For late-type galaxies, this ratio (on average) decreases with mass. We find that b correlates tightly with NUV$-r$ color, implying that the SF history of a galaxy can be constrained on the basis of the NUV$-r$ color alone. The fraction of galaxies that have undergone a significant starburst episode within the last Gyr steeply declines with mass – from $\sim 20\%$ for galaxies with $\sim 10^8$ $M_\odot$ to $\sim 5\%$ for $\sim 10^{11}$ $M_\odot$ galaxies.

Evolution of the chemical properties of galactic systems in ΛCDM universes

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The chemical evolution of galaxies is directly linked to the dynamical and astrophysical evolution of the systems. Hence, the chemical properties of the stars and the interstellar medium could be used as fossil records of the history of galaxy formation. The treatment of metal enrichment in cosmological simulations opens up the possibility of consistently studying the formation of galaxies and their chemical history. In this poster, we present first results on the study of the luminosity-metallicity relation (LMR) in galactic systems formed in a ΛCDM scenario. We use a chemodynamical model coupled to the entropy conservation code *Gadget2*, which includes the chemical production of SNII and SNIa. We found evolution in the zero point and slope of the luminosity-metallicity relation, in agreement with observations. We discuss the origin of the change of the LMR and the relation between the LMR and mass-metallicity relation. We also assess the possible impact that energy feedback might have on these relations.

Multi-wavelength Star-Formation Indicators

Henrique R. Schmitt[1], D. Calzetti, L. Armus, K.D. Gordon, T.M. Heckman, R.C. Kennicutt, Jr., C. Leitherer, G.R. Meurer

National Radio Astronomy Observatory, Charlottesville, USA

We present the results of a multi-wavelength study of star-formation indicators for a sample of nearby galaxies. The sample spans a wide range in luminosity, star-formation rate, metallicity, and morphology. We will discuss our high resolution far-ultraviolet *HST*/STIS images, ground-based Hα, and VLA 8.46 GHz radio images, as well as integrated mid/far-IR properties. We compare these star-formation indicators, present empirical calibrations between them and discuss the effects of reddening. We also use this dataset to analyze the relation between star-formation rate and the UV/far-IR ratio, and the distribution of ULIGs, SCUBA sources and Lyman Break galaxies relative to our sources in this diagram.

High-resolution near-UV imaging of Seyfert Galaxies

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National Radio Astronomy Observatory, Charlottesville, USA

We present the preliminary results of a near ultraviolet (3300Å) *HST*/ACS imaging survey of 73 nearby Seyfert galaxies. These images are used to study the structure and frequency of circumnuclear star formation in these objects. We find a wide range of morphologies in these images, from Seyfert 1's where only a single point source was detected, to galaxies with a large number of circumnuclear star clusters, as well as objects where only diffuse emission could be seen. We find that circumnuclear star formation can be found around both Seyfert types, and not only around Seyfert 2's, as suggested by previous studies. We confirm previous ground-based results, which indicate that circumnuclear star formation is common in Seyfert galaxies.

Integral-field spectroscopy in the IR: Gemini-CIRPASS observations and the star-formation history in the nucleus of M83

Rob G. Sharp[1], S.D. Ryder, J.H. Knapen, L.M. Mazzuca, I.R. Parry

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We present Gemini-South observations of the nuclear starburst region of M83, using the CIRPASS near-IR integral-field spectrograph. Spectroscopic diagnostics are used to overcome many of the uncertainties inherent to photometric studies of the star-formation history of the central region of M83. We use Paβ and [FeII] emission, and absorption in the CO(6,3) band head, to infer an age gradient, as opposed to stochastic star formation, across the nuclear star-forming region of M83.

The Massive Star Population of the Wolf-Rayet Galaxies He 2-10, Mrk 1259, NGC 5253 and Tol 89

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We present VLT/UVES high-resolution spectra of a sample of young massive clusters in the Wolf-Rayet (WR) phase in four WR galaxies (He 2-10, Mrk 1259, NGC 5253 and Tol 89) ranging from $0.2 - 1Z_{\odot}$. We compare the observed WR line profiles to new evolutionary synthesis models which can synthesize the WR spectral features for the first time. Using this new technique, we determine the age, slope of the upper initial mass function, and WR/O and WN/WC ratios for our sample of young massive clusters. We use these results to discuss the correctness of massive star evolutionary theory over a range of metallicities.

Extended Tidal Structure in Two Lyα Emitting Starburst Galaxies

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We present new VLA C-configuration HI imaging of the Lyα emitting starburst galaxies Tol 1924-416 and IRAS 08339+6517. The effective resolution probes neutral gas structures larger than 4.7 kpc in Tol 1924-416, and larger than 8.1 kpc in IRAS 08339+6517. Both systems are revealed to be tidally interacting: Tol 1924-416 with ESO 338-IG04B (6.6 arcmin = 72 kpc minimum separation), and IRAS 08339+6517 with 2MASX J08380769+6508579 (2.4 arcmin = 56 kpc minimum separation). The HI emission is extended in these systems, with tidal tails and debris between the target galaxies and their companions. Since Lyα emission has been detected from both of these primary systems, these observations suggest that the geometry of the ISM is one of the factors affecting the escape fraction of Lyα emission from starburst environments. This could be a very important factor to take into account when calculating the escape fraction of ionizing radiation from starbursts in the early Universe. Furthermore, these observations argue for the importance of interactions in triggering massive star-formation events.

Obscured star formation in the Antennae

Leonie Snijders

Leiden Observatory, Netherlands

The young super star clusters in the Antennae (NGC4038/39) are unique laboratories for the study of individual coeval, young stellar populations. Because of their young ages, they offer ideal probes of the upper main sequence in such regions. We studied several of the youngest star clusters (< 10 Myr) combining near-infrared medium-resolution spectroscopic data obtained with ISAAC at the VLT ($R = 3000$) with seeing-limited JHK imaging data from SOFI at the NTT. Here, we present the first results on the properties of the upper main sequence and the evolutionary state of the clusters.

Near-Infrared Properties of Starbursts at $z = 6$

Elizabeth R. Stanway

Institute of Astronomy, University of Cambridge, UK

The Hubble Ultra Deep Field (HUDF), and its accompanying observations in the near-infrared using NICMOS, have provided the astronomical community with an exceptionally valuable resource. For the first time, it has been possible to obtain a large sample of $z = 6$ candidate galaxies, probing faint magnitudes, and to explore their properties in the near infrared. We find that the starbursting i'-drop population at $z = 6$ has blue near-IR colours, suggesting that they may be very young, may have an IMF top-heavy in massive stars or may be metal poor.

The Morphologies of Extremely Red Galaxies from the Spitzer First Look Survey

Lisa J. Storrie-Lombardi[1], L. Yan, J. Colbert, I. Drozdovsky, P. Choi, P. Appleton, D. Fadda, M. Marleau, M. Lacy, H. Teplitz, M. Im

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We have obtained NICMOS observations of 50 EROs ($i-K > 4.5$), selected in the verification survey of the Spitzer First Look Survey. 13 of the 50 sources are detected at 24μm ($3\sigma = 90\mu$Jy). The Spitzer 24μm observations correlate extremely well with the observed morphologies. Clear morphological differences are apparent in the NIC2/F160W observations for the 24μm-detected sample compared to the 37 not detected at the longer wavelength. Over 80% of the non-24μm detected sources show elliptical or S0 morphologies. The EROs detected at 24μm show a broader range of disky and disturbed morphologies. The NICMOS observations measure the morphology at rest frame $R-I$ and reveal the stellar mass distribution. The Spitzer observations clearly detect the actively star-forming systems.

Are Gamma Ray Bursts Good Star-Formation Indicators?

Nial R. Tanvir

University of Hertfordshire, UK

Since long-duration GRBs are associated with the deaths of massive stars, they are also indicators of star-formation activity. Advantages they have over conventional methods are that they are extremely bright, and hence visible to high redshifts, and detectable in gamma-rays through very high columns of dust and gas. If they are unbiased tracers of star-formation activity, then the GRB host galaxies should contain all populations of star-forming galaxies, in proportion to their contribution to the global star-formation rate. In particular, if a high proportion of star formation occurs in obscured mode, then a similar proportion of GRBs and their hosts should also show signs of dusty environments. We describe progress towards testing this prediction.

Elizabeth J. Tasker

Astrophysics, University of Oxford, UK

no abstract received

Tracing the Inner Gas Disks in Starbursts and Radio Galaxies

Greg B. Taylor

NRAO, USA

Images of neutral hydrogen 21-cm absorption and radio continuum obtained at milli-arcsecond resolution using the Very Long Baseline Interferometry (VLBI) technique can trace gas disks on sub-kiloparsec scales in distant galaxies. Such disks may be common in the high-density environment conducive to starbursts. For example, in Mrk 273a, a gas disk with a diameter of 370 pc and an enclosed mass of 2×10^9 $M_\odot$ is found by HI absorption. We also report on searches for gas disks in the starburst Mrk 231, in the radio galaxy 3C293, and in the gigamaser galaxy TXS2226-184.

The $L - \sigma$ relation for local HII galaxies

Eduardo Telles

Observatorio Nacional, Rio de Janeiro, Brazil

HII galaxies present empirical parametric relations of size and luminosity versus their supersonic line widths, where the origin of the internal motions are not clear. The two more popular competing models are the gravitational model and the effect of massive-star evolution through winds and supernova explosions. In any case, the existence of the empirical relations by themselves justifies their calibration and possible use as a powerful distance indicator of cosmological interest, since HII galaxies are easy to find at great distances. We have pursued a more detailed investigation of the $[L - \sigma]$ relation for a homogeneous sample of about one hundred local HII galaxies ($z < 0.1$). Emission-line profiles were classified as: Gaussian – regular lines, very well represented by a single Gaussian fit; Irregular – showing wings, generally sharp and asymmetric; Profile with Components – showing two or more components, possibly suggesting systematic motions, or multiplicity. We have found that hydrogen-line widths are marginally greater than oxygen-line widths favouring turbulence as the interpretation for the motions. We have examined the possible existence of a Fundamental Plane for H*ii* galaxies. Using the method of Principal Component Analysis we have found that either the equivalent width of Hβ or the metallicity contributes about 30% to the variance as a second principal component and either may be responsible for the scatter in the $[L - \sigma]$ relation, indicating that it may be sensitive to evolution. There are still remaining issues to be cautious, for instance, the different emission-line profiles, shown by our high-resolution spectroscopy, indicate that different broadening mechanisms may be at play and may also be a source of scatter in the $[L - \sigma]$ relation. Furthermore, one needs to worry about systematic effects such as the M/L ratio of starbursts, inflow and outflow of gas, dust, and the validity and application to high-redshift galaxies.

Star formation in three nearby interacting galaxy systems

Sonia G. Temporin

Institute of Astrophysics, University of Innsbruck, Austria

Galaxy interactions have been known for a long time to trigger star formation, although both observations and numerical simulations have shown that the enhancement of star formation depends, among other things, on the orbital geometry of the encounter. In some situations, interactions might even suppress star formation. Here, we present an analysis of the distribution and strength of star formation in three nearby small galaxy systems, which are undergoing a weak interaction, a strong interaction, and a merging process, respectively. The galaxies in all systems present widespread star-formation enhancements, as well as, in some cases, nuclear activity. In particular, for the two closest systems, we study the number count, size, and luminosity distribution of HII regions within the interacting galaxies, while for the more distant, merging systems we analyze the general distribution of the Hα emission across the system and its velocity field. We compare our results with both similar results on isolated galaxies and numerical simulations of interacting galaxies from the literature, in order to single out HII region properties related to the interaction processes and infer a possible interaction scenario for these galaxy systems.

FUV Imaging of Starbursts in the Hubble Deep Field North

Harry I. Teplitz

Spitzer Science Center, California Institute of Technology, USA

We present far-UV imaging of the Hubble Deep Field North (HDF-N) taken with the Solar Blind Channel of the Advanced Camera for Surveys (ACS/SBC) on board *HST*. Combined with archival STIS imaging, the full WFPC2 deep field has now been observed at 1500 Å. We detect 111 objects, with redshifts $0.07 < z < 0.85$. A high fraction of galaxies previously identified as "blue-core ellipticals" show significant UV flux, presumably due to star-formation activity. Number counts to AB= 29 have a surprisingly flat slope, consistent with a larger-than-predicted population of starburst galaxies at intermediate redshift. We examine the morphology of starburst galaxies as a function of redshift, and compare FUV, optical and NIR properties.

Elena Terlevich

INAOE, Mexico

no abstract received

What Shuts off Star Formation? Post-burst Galaxies from $z = 0$ to 1

Christy A. Tremonti

Steward Observatory, University of Arizona, USA

The physical processes that govern star formation are not well understood. An open question is whether starbursts proceed until the gas supply is exhausted or whether supernova feedback serves to regulate bursts. We investigate this question by examining the kinematics of the neutral gas (as traced by the Na D interstellar absorption line) in galaxies that have experienced strong starbursts. We use the SDSS DR2 sample of over 200,000 galaxy spectra to select galaxies in various stages of a starburst. We use the Bruzual & Charlot (2003) models to subtract the stellar contribution to the Na D absorption line. We measure the residual equivalent width and the kinematic offset of the interstellar component. Of particular interest are the extreme post-burst or "E+A" galaxies. For these galaxies, we can age-date the burst to within a few 100 Myr using the stellar spectrum. With these data we are able to probe the temporal evolution of neutral gas in a starburst.

The Tully-Fisher Relations at high redshift

Lottie van Starkenburg

Leiden Observatory, Netherlands

no abstract received

The Dust in Lyman Break Galaxies

Uma Vijh

Ritter Astrophysical Research Center, University of Toledo, USA

I will present our analysis of UV attenuation by internal dust of a large sample ($N = 906$) of Lyman Break Galaxies (LBGs). Using spectral energy distributions (SEDs) from the PÉGASE galaxy spectral evolution models, we apply dust attenuation corrections to the $G-\mathcal{R}$ colours using the Witt & Gordon (2000) models for radiative transfer in dusty galactic environments to arrive at the UV attenuation factors. We show that the dust in the LBGs exhibit SMC-like characteristics rather than MW-like, and that the dust geometry in these systems is most likely represented by a clumpy shell configuration. We show that the attenuation factor exhibits a pronounced dependence on the luminosity of the LBG, $a_{1600} \propto (L/L_{\odot})^{\alpha}$, where $0.5 \leq \alpha \leq 1.5$. The exponent α depends on the initial parameters of the stellar population chosen to model the galaxies and the dust properties. We find that the luminosity-weighted average attenuation factor is likely to be in the range from $5.7-18.5$, which is consistent with the upper limits to the star-formation rate at $2 < z < 4$ set by the FIR background. This implies that the current UV/optical surveys do detect the bulk of the star formation during the epoch $2 < z < 4$, but require substantial corrections for internal dust attenuation.

Implications for the formation of star clusters from extra-galactic star-formation rates

Carsten Weidner

University Observatory Bonn, Germany

Observations indicate that young massive star clusters in spiral and dwarf galaxies follow a relation between luminosity of the brightest young cluster and the star-formation rate (SFR) of the host galaxy, in the sense that higher SFRs lead to the formation of brighter clusters. Assuming that the empirical relation between maximum cluster luminosity and SFR reflects an underlying similar relation between maximum cluster mass ($M_{\rm ecl,max}$) and SFR, we compare the resulting SFR($M_{\rm ecl,max}$) relation with different theoretical models. The empirical correlation is found to suggest that individual star clusters form on a free-fall time-scale with their pre-cluster molecular-cloud-core radii typically being a few pc, independent of mass. The cloud cores contract by factors of 5 to 10 while building up the embedded cluster. A theoretical SFR($M_{\rm ecl,max}$) relation in very good agreement with the empirical correlation is obtained if the cluster mass function of a young population has a Salpeter exponent $\beta = 2.35$ and if this cluster population forms within a characteristic time-scale of a few $\times 10$ Myr. This short time-scale can be understood if the interstellar medium is pressurised, thus precipitating rapid local fragmentation and collapse on a galactic scale. Such triggered star formation on a galactic scale is observed to occur in interacting galaxies. With a global SFR of $3-5$ M$_\odot$ yr^{-1}, the Milky Way appears to lie on the empirical SFR($M_{\rm ecl,max}$) relation, given the recent detections of very young clusters with masses near 10^5 M$_\odot$ in the Galactic disk. The observed properties of the stellar population of very massive young clusters suggests that there may exist a fundamental maximum cluster mass, $10^6 < M_{\rm ecl,max*}/{\rm M}_\odot < 10^7$.

Neutral Carbon, the CO Ladder, and Dust Emission in Dusty Quasars at $z = 2.5$

Axel Weiss

IRAM, Spain

Detections of large amounts of dust and gas in distant quasars have opened up the possibility of studying molecular gas properties in the early epoch of galaxy formation and of providing fundamental constraints on galaxy evolution. Molecular gas masses in excess of 10^{10} $M_\odot$ have led to the hypothesis that the tremendous far-infrared luminosities ($> 10^{12} L_\odot$) of these objects are powered not only by black holes but also by major starbursts which might be forming cores of elliptical galaxies or bulges of massive spiral galaxies. We report on an in-depth study of the molecular gas properties of the two brightest dusty quasars at redshifts > 2, the Cloverleaf quasar and IRAS F10214. Our analysis is based on observations at the IRAM interferometer and the IRAM 30m telescope of both of the neutral carbon fine structure lines, of the complete CO ladder between CO(3-2) and CO(8-7), and of the dust continuum. We discuss the excitation conditions, the distribution of the molecular gas and the implications for the quasar-starburst connection in the early epoch of galaxy formation. Up to now, comparable data sets exist only for the Milky Way and the central region of M82. It will be a primary task of ALMA to observe these important tracers of the molecular gas routinely, both in nearby galaxies and in high-redshift objects.

Revealing the Complex Structure of the M82 Superwind

Mark S. Westmoquette[1], J.S. Gallagher III[2], L.J. Smith[1]

[1]*Department of Physics & Astronomy, University College London, UK;* [2]*Department of Astronomy, University of Wisconsin-Madison, USA*

We present new and unique imaging of the archetypal starburst galaxy M82, showing – for the first time – the true extent and complexity of the starburst-driven superwind. The images have been formed from a combination of *HST* and WIYN Hα and [NII] observations. This partnership has enabled a wide range in dynamic response to be studied, and allowed the wind structure to be traced directly from the roots out to a distance of ~ 5 kpc. Prominent features include loops and filaments, reflection nebulae, and "search-light" formations. We discuss the newly-revealed structure of the superwind in the context of interacting winds from clumps of super star clusters.

Modeling the Red Halos of Blue Compact Galaxies

Erik Zackrisson

Uppsala Astronomical Observatory, Sweden

Optical/near-IR broadband observations of the faint halos of blue compact galaxies have revealed a red excess that is difficult to reconcile with normal, low-metallicity stellar populations. Here, various alternative explanations are explored: very high metallicities, abnormal IMFs and contamination by nebular emission. We find that a stellar population with a low to intermediate metallicity and an extremely bottom-heavy IMF succeeds not only in explaining the colours of blue compact galaxy halos but also the colours of halos detected around edge-on disk galaxies in the Sloan Digital Sky Survey.

X-ray binary populations in star-forming galaxies

Andreas Zezas

Harvard-Smithsonian CfA, USA

Chandra has revolutionized the study of X-ray binaries in nearby galaxies by allowing the detection of large populations in a wide range of galactic environments. We present results on the discrete X-ray source populations of a sample of nearby galaxies (NGC 55, NGC 1569, NGC 4214 and NGC 5253), which span a range of star-formation histories, from young to post-starbursts. We then compare these X-ray source populations with predictions from state-of-the art X-ray binary population synthesis models. We also compare the X-ray luminosity functions (XLFs) of the discrete sources in these nearby galaxies with the XLF of the more actively star-forming Antennae galaxies, which exhibit a large number of ultraluminous X-ray sources. Finally, we present results from our Chandra survey of the central part of the SMC, which extends the population of detected sources down to the levels of quiescent Be X-ray binaries.

The Enigmatic Local Group Starburst Galaxy IC 10

Daniel B. Zucker

Max Planck Institute for Astronomy, Heidelberg, Germany

IC 10 is the nearest starburst galaxy, but its study is hampered by widely varying estimates of its distance and line-of-sight extinction in the literature. Using both ground-based and *HST* data I derive a mean foreground reddening and a distance modulus which are consistent with previously published values based on Cepheids, but inconsistent with certain results in the literature. I discuss a number of possible reasons for this discrepancy, and the implications for work on nearby, i.e., resolved, galaxies. An analysis of color-magnitude diagrams reveals that, in addition to its current starburst, IC 10 has been actively forming stars for at least the past 100 Myr, and moreover has substantial stellar populations as old as 10 Gyr.

Conference Participants and their Contributions: *Page*

Conference Participants (continued) *Page*

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Conference Participants (continued)

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