Abstracts for the 2002 Lowell Workshop. The Outer Edges of Dwarf Irregular Galaxies: Stars and Gas

October 7, 2002

Oral presentations

Thursday, October 10

Eric M. Wilcots
University of Wisconsin

Extended HI Around Irregular Galaxies

The combination of wide-field HI imaging and sensitive single-pointing VLA observations over the past few years has uncovered a wealth of neutral gas lurking in the immediate environments of a number of irregular galaxies. Sorting through the various detections of gas around galaxies, one finds that it tends to come in three main flavors: very extended, but smooth HI disks or envelopes; very extended, but morphologically and kinematically chaotic distributions of gas; and discrete clumps of gas that seem to lack a stellar counterpart. I will review what we know (and don't know!) about the nature of extended HI around irregulars and what role it may play in the evolution of the host galaxy.

J.M. van der Hulst
Kapteyn Institute, Groningen, The Netherlands

The HI-edges of disk galaxies

The HI distribution of ten fairly face-on galaxies from the WHISP survey were examined to test the idea that the UV metagalactic radiation field ionizes the edges of the HI disks of galaxies. Though this idea works in a number of galaxies we do find that other effects also play a role. Some galaxies appear to have sharp edges in their HI distribution that set in at column densities too high to be explained as the effect of ionization.

This work has been done in collaboration with R. Boomsma, X. Tielens (Kapteyn Institute, Groningen) and R. Braun (ASTRON, Dwingeloo).

Fabian Walter
Caltech/NRAO

The Extent of Molecular Gas in Dwarf Irregular Galaxies

Until a few years ago, not much was known about the properties of the molecular gas content in dwarf galaxies. However, enormeous progress has been made in recent years to study this important phase of the ISM. In this talk I will summarize the results of our dwarf galaxy survey which was undertaken at the Caltech OVRO millimeter interferometer over the last 3 years. I will summarize the highlights of this survey and will in particular concentrate on the Local Group Dwarf Galaxy IC10, where we have recently completed an intensive high-resolution mosaicking campaign. Strikingly, this very sensitive search for molecular gas has recovered the presence of vast amounts of molecular gas in the very outskirts of this fascinating galaxy - far away from the central starforming regions. The high resolution of this study enables us for the first time to derive a possible change of the conversion factor of the molecular gas as a funciton of galactocentric distance. I will also discuss our OVRO observations of molecular gas in two tidal dwarf galaxies.

Erik Muller
University of Wollongong, ATNF

A study of the HI expanding shell population of the Magellanic Bridge

We have conducted high-resolution observations of the Neutral hydrogen (HI) in the Magellanic Bridge, a tidally extruded feature lying between the Small and Large Magellanic Clouds. This region represents the environment at the very extreme outer edges of Dwarf Irregular Galaxies, and these observations have revealed the chaotic and filamentary substructure of this region down to the smallest observed scales of 9 pc. A census of the expanding HI shell population of this region has been conducted and has allowed a direct comparison with a similar survey of the expanding shell population of the SMC, as well as that of other galaxies. It appears that shells within the Western part of the Bridge tend to fragment at an earlier age than those further east, possibly because western region is more susceptible to turbulence and wind shear originating from the SMC. A comparison of the spatial distributions of OB associations and expanding HI shells within the Magellanic Bridge do not show a satisfactory correlation. This finding casts doubt on the popular concept of a stellar wind as an expansion mechanism.

Carme Gallart
Instituto de Astrofisica de Canarias

The star formation histories of the outer parts of dwarf irregular galaxies.

In recent years, wide field observations of dwarf irregular galaxies have shown that they are substantially more extended that previously thought. The recent star formation, however, is concentrated in the central part of these galaxies, causing the central surface brightness to be much higher than that of the external parts. The information on the actual nature of these external regions is still scarce: in Local Group dwarf irregulars, the ones for which the most detailed information, through color magnitude diagrams, can be obtained, these tipically reach only a few magnitudes below the tip of the red giant branch (only for a few cases HST observations reach the horizontal branch). From this information, it can be stablished that an old population exist in these galaxies, but whether this is a true halo-like population (i.e. formed in a single burst and therefore mainly composed by an old population with little or no intermediate-age component and/or with a distinct kinematics) has not been unambiguously stablished yet. This information, namely color magnitude diagrams reaching the oldest main-sequence turnoffs, and kinematic information of the old stars, holds the key to understanding in detail the formation and evolution of dwarf galaxies, but new observations with state-of-the-art instruments are necessary. For the closest irregulars, the SMC and the LMC, wide field observations with 4m class telescopes are enough to provide deep color-magnitude diagrams. For all the other Local Group dwarf irregulars, HST with ACS is necessary. Kinematic information can be provided by multi-object spectrographs on 8m class telescopes. The feasibility of these observations will be discussed and some new photometric data on the LMC and Phoenix will be shown.

Sebastian L. Hidalgo
Instituto de Astrofísica de Canarias

The extended structure of the Phoenix dwarf galaxy revealed by HST.

We present preliminary results of VI HST imaging of Phoenix, a dE/dIrr transition galaxy, situated at about 450 kpc, close enough to reach the old main sequence turn-offs, but still far away from the Milky Way to be free from strong gravitational interactions. This makes Phoenix unique to test the origin and early evolution of dwarf galaxies through the detailed analysis of the properties of its oldest structures and stars. In particular, indications exist that dIrr galaxies are surrounded by extended, probably old structures which would be related to the early evolution of the galaxy. The accurate knowledge of the stellar population age distribution in these structures promises to be crucial to understand the formation of primeval dwarf galaxies.

Arna Karick
University of Melbourne

The Spatial Distribution of Star-Formation in Fornax Cluster Dwarf Galaxies.

Spectroscopic observations of dwarf galaxies in the Fornax Cluster reveal a surprising amount of star formation. Observations of 62 bright cluster dwarfs were taken with the Flair-II fibre spectrograph on the UKST. Dwarfs display a much higher rate of star formation than suggested by their morphological classification, 35emission indicative of star formation but only 19classified as late types. The most extreme star-forming dwarfs form part of a dynamically separate infalling sub-cluster, indicating that star-formation is largely influenced by the cluster environment.

We now present an analysis of the spatial distribution of star formation within the Fornax dwarf galaxies based on a photographic UKST H-alpha image of the cluster. This allows us to probe individual star-forming regions for which fibres are not sensitive. High surface brightness dwarfs show multiple HII regions which tend to be located at the edges of galaxies. Galaxies with more centrally concentrated star forming regions are weakly correlated with the LSB dwarfs. We find no correlation between the distribution of star-forming regions and the infall direction of the galaxies. This may be naively expected if the star-formation of infalling dwarfs is stimulated by tidal interactions or induced by bow-shocks.

Walter Koprolin
Insitute for Astronomy, University of Vienna / Austria / Europe

Physical properties of the stellar population and the gas in Blue Compact Dwarf Galaxies

Blue Compact Dwarf (BCD) Galaxies are low-luminosity systems where active star formation is taking place either in one central or in several more outlying starburst regions. We study the physical properties of the stellar population of BCD galaxies in order to determine its nature and relation to the gaseous component which is concentrated in the starburst region(s) of these galaxies.

Deep long-slit spectra have revealed typical stellar absorption lines, which are used to extract line strength indices and kinematic data of the stellar component. Preliminary results indicate that the stellar population in BCD galaxies may be related to the population in Elliptical Galaxies and Galactic Globular Clusters.

IR surface photometry doesn't support the BCD classification from optical photometry as the optical data is starburst-dominated. Preliminary photometric results indicate that the old stellar population of several BCDs may resemble flattened disks.

Determining the properties of the stellar and gaseous components of BCDs should reveal important clues on the evolution of these interesting galaxies and finally solve the question wether they are young galaxies undergoing their first starburst or old systems in a period of active star formation.

Environment studies of the Blue Compact Dwarf Galaxies open another interesting field of research, since many of the BCD galaxies of our sample are located in groups or clusters.

Eon-Chang Sung[1,2], Kenneth C. Freeman[2] and Helmut Jerjen[2]
1) Korea Astronomy Observatory, Korea 2) RSAA, ANU, Australia

Searching for Super Star Clusters in Blue Compact Dwarf Galaxies (BCDGs)

We present a search for super star clusters (SSCs) in a sample of nearby blue compact dwarf galaxies based on groundbased JHK imaging and optical spectroscopy. We will discuss the f raction of SSCs present in BCDGs, the environmental conditions for the formation of SSCs, and their velocity dispersions.

Annette Ferguson
Kapteyn Institute, Groningen

The Evolution of the Outer Regions of Disk Galaxies: Spirals vs Irregulars

The outskirts of disk galaxies are low surface brightness and gas-rich: have these regions started to form stars only recently or have they continuously evolved at a very low rate over a Hubble time? I will discuss observational constraints on the evolution of disks at large radii from measurements of the gas-phase chemical abundance in these parts and from direct and indirect inferences about the ages of the constituent stellar populations. Whenever possible, comparisons will be made between the properties of stars and gas in the outskirts of massive spirals and dwarf irregulars.

Ralf-Juergen Dettmar
Ruhr-University Bochum

The outer edges of disk galaxies - what we can learn in comparison

Based on a large collection of deep CCD surface photometry for edge-on galaxies we have in a series of papers reconsidered the issue of radial truncations ("cut-offs") for the stellar distribution in the disks of galaxies. The spread in relevant parameters such as the ratio of "cut-off" radius to scalelength is much larger than found in previous studies with smaller samples. In order to verify the findings and to study the profile of the "cut-off" unaffected from the line-of-sight integration we have recently (Pohlen et al. 2002) analyzed the outer disks of three edge-on galaxies down to a surface brightness of μ_R=29 mag/arcsec^2. In these cases the "cut-off" region is best described by an exponential of shorter scale-length.

Observations of edge-on galaxies have also been used to quantify the frequency of warps and the thickening of the outer disks due to the heating by minor merger events.

Our results will be discussed with regard to models trying, e.g., to account for such truncations of the disk by a local star formation szenario or which quantify the effects of disk heating by numerical simulations. A comparison with later-type "Irr" galaxies will be attempted.

References: Pohlen, M., Dettmar, R.-J., Lútticke, R., Aronica, G. 2002: A&A accepted (astro-ph/0206419)

René Walterbos
New Mexico State University

Chemical abundances in M81's outer disk HII regions

The outer disk of the large nearby spiral M81 shows several faint HII regions located at large radial distances from the center. Only some of these coincide with known dwarf galaxies, such as HoIX, while others appear as isolated objects in the extended HI disk. The chemical abundances of these objects will provide valuable information on the evolutionary history of the outer HI disk. These objects may be signposts of faint dwarf galaxies in formation as a result of the gravitational interaction of M81 with M82 and NGC 3077, or they may be isolated star forming events in HI enhancements triggered by the interaction. We have obtained MMT 6.5-m spectroscopy data on these objects to measure their abundances and to establish the overall abundance pattern from inner to outer disk in M81.

Gaspar Galaz
P. Universidad Católica de Chile

Old stellar populations and gas content in low surface brightness galaxies

This talk summarize last results from an on-going research on old stellar populations in low surface brightness galaxies (LSBGs). The study is based on 88 LSBGs observed in the near-IR. Being able to detect a prominent population of old stars in many of these LSBGs, we use some models of galaxy evolution to compute stellar and baryonic masses, obtaining several results which suggests possible past and present evolutionary states of stars and gas in these galaxies.

Friday, October 11

Dave Strickland
The Johns Hopkins University

The connection between outflows from massive star feedback and the halos of star-forming galaxies.

The distribution and properties of gas in the halos of star-forming galaxies, both large and small, remains somewhat mysterious. Does it come from the galaxies themselves, driven outwards by SN heating, or does it come from the continued slow accretion of the IGM that the numerical cosmologists propose? Whatever the origin of halo gas, understanding its properties is vital for quantitatively assessing the long term fate of material in SN-driven galactic outflows. Halo gas can potentially play the dominant role in controlling whether SN-driven winds can eject energy and metals into the IGM. In addition, the observational signatures of superwinds are most likely due to the interaction of the invisible superwind with a pre-existing halo medium. I will discuss various observational and theoretical aspects of these issues, attempting to inventory both what we know, and what we don't know, about the gaseous components of the halo regions of star-forming galaxies.

Daniela Calzetti
Space Telescope Science Institute

The Physical Conditions of Ionized Gas at the Edges of Starburst Regions

Star formation has a strong impact on the host galaxy over scales that can reach many kpc. I present a study of the conditions of the ionized gas located at the edges of starburst regions, based on HST/WFPC2 narrow-band imaging of hydrogen and metal lines. The sample consists of 4 starburst galaxies located at distances between 2 and 5 Mpc, and covering a range of metallicities and environmental conditions. The high-angular resolution afforded by HST allows us to investigate in detail the structures of the photo- and shock-ionized gas, and to infer relations between the local physical conditions and the global galactic parameters (e.g. metallicity).

Gerhard Hensler
Inst of Theor Physics and Astrophysics, Univ of Kiel

Star Formation and Gas Cycles in Dwarf Irregular Galaxies

Because of their low gravitational energies dwarf galaxies are greatly exposed to energetical influences from internal and external sources. In gas-rich dwarf irregular galaxies not only that star formation regulates itself due to the stellar energy release, but also supernova-driven galactic winds are accepted as a general explanation for their low metallicities. Chemodynamical models of dIrrs that take the dynamics of different gas phases and the stars as well as their energetic and materialistic interactions into account can show that strong evaporation of interstellar clouds embedded in the hot supernova gas leads to an almost perfect mixing of the interstellar gas. If circumgalactic HI envelops exist as it is observed with growing evidence around actively star-forming dIrrs, infalling gas clouds are poluted by metal-enriched hot outflows by means of condensation. This leads to a large range of timescales for the self-enrichment of the interstellar medium in dIrrs. In addition, the infalling gas feeds the formation of a gaseous disk until the star formation rate reaches a level of stellar energy release that compensates the gas accumulation. By this, also peculiar element abundances, like their low N/O ratios at also low O, that are difficult to understand otherwise, are self-consistently reproduced.

Alessandra Aloisi
Johns Hopkins University

FUSE Metal Abundance Measurements in the Interstellar Medium of IZw18

We present new FUSE observations of the metal-deficient star-forming dwarf galaxy IZw18. These data are characterized by a higher S/N and a better coverage of the full FUSE spectral range (900-1200 angstroms) if compared to previous published FUSE observations. They allow us to obtain tighter constraints on the metal and molecular content of IZw18 interstellar medium. A multi-component fitting technique is applied to derive heavy element abundances from absorption lines. We find an iron content similar to the one in the HII regions ([Fe/H] -1.99), and an alpha-element abundance from Si three times lower than the one inferred from nebular O in the ionized gas ([Si/H] -2.28). We can conclude that the HI gas in IZw18 has already been enriched in heavy elements from an old star-formation episode, and thus it cannot be considered primordial in its nature. Moreover IZw18 HII regions have been self-enriched only with the products (alpha-elements) of the most massive stars generated during the latest burst of star formation. We will discuss the implications of our findings in the context of the chemical evolution of IZw18 and dwarf star-forming galaxies in general.

P. Chris Fragile
Lawrence Livermore National Laboratory

Supernova Enrichment of Dwarf Spheroidal Galaxies: A Numerical Study

Many dwarf galaxies, including systems containing multiple generations of stars, exhibit sub-Solar metallicities, with little star-to-star variation. Such a lack of abundance variation across generations implies that enriched material from supernovae has been lost from the star- forming regions of these small galaxies. Such mass loss may have important consequences for the evolution of the intergalactic medium and for the evolution of massive galaxies, which themselves may have formed via the merger of smaller systems. Here we report results of three- dimensional simulations of the evolution of supernova-enriched gas within dwarf spheroidal galaxies (DSph's). We consider two model galaxies chosen to represent opposite ends of the DSph distribution. For each of these models we investigate a number of scenarios from a single supernova in a smooth gas distribution through multiple supernovae within a highly disturbed gas distribution. The results of these investigations suggest that, for low star-formation efficiencies, it is difficult to completely expel the enriched material from the galaxy. However, much of the enriched gas is lost from the core of the galaxy following multiple supernovae, especially if the interstellar medium is already highly disturbed. If subsequent star formation occurs predominantly within the core, then these results could explain the poor self-enrichment efficiency observed in dwarf galaxies.

This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

Stéphanie Côté
Herzberg Institute of Astrophysics, NRC

Dark Matter in Dwarf Irregulars: the Ins and Outs of Rotation Curves

Dwarf Irregular galaxies are dominated by dark matter, and their extended neutral hydrogen rotation curves have provided us with the most detailed and strongest evidence for dark matter in galaxies. I will review the issue of the discrepancy between the predicted Cold Dark Matter rotation curves and the observed ones, as well as the viability of MOND (Modified Newtonian Dynamics) for dwarf irregulars. The dark matter properties of dwarf irregulars will be put in context with respect to other galaxies, and the overall observational clues on the spatial extent and distribution of dark matter halos will be reviewed. I will describe ongoing work on extending rotation curves to very large galactocentric radii, using Lyα absorption lines in background QSOs, and the resulting constraints on cosmological models.

Arif Babul
University of Victoria

The Interaction between the IGM and Outflows from Dwarf Galaxies

Recent FUSE, Chandra and XMM-Newton observations of dwarf galaxies clearly show that the deposition of energy by stellar winds and supernovae during starbursts gives rises to structures such as superbubbles that in the case of dwarf galaxies, with their relatively shallow potential wells, can evolve into outflows. The subsequent evolution of these outflows depends strongly on the local environment of the galaxy. Here, I will review the physics underlying the outflows and the interaction between the outflows and the IGM. I will focus on two specific cases: In low density regions, the metal-enriched outflows from low-mass systems is likely to escape beyond the galactic halos and pollute the general IGM. Indeed, recent studies of the QSO absoption lines indicate that much of the intermediate redshift IGM is contaminated by heavy metals and starburst-powered outflow from dwarf galaxies is believed to be the source of the pollution. I will present some preliminary results of recent analyses of the distribution of QSO absorption lines that tests this hypothesis. In high-density regions, such as clusters of galaxies, the interaction between the IGM and the outflows is more complex. Thermal pressure of the IGM can easily confine the gas. On the other hand, the resulting structures are much more susceptible to gravitational instablity and ram pressure stripping, and may be responsible for comet-like low-surface brightness stellar tails, diffuse intracluster stars, and 'tidal dwarf galaxies'.

Sergey Mashchenko
Department of Physics and Astronomy, McMaster University, Canada

Impact of UV Radiation from Giant Spirals on the Evolution of Dwarf Galaxies

We show that ultraviolet radiation, with wavelengths shorter than 2000 A, escaping from the disks of giant spirals could be one of the principal factors affecting the evolution of low mass satellite galaxies. We demonstrate, using a semi-qualitative model, that the Lyman continuum part of the radiation field can lead to ionization of the ISM of the dwarf galaxies through the process of photoevaporation, making the ISM virtually unobservable. The FUV part ($912< \lambda <2000$ A) is shown to dominate over the internal sources of radiation for most of the Galactic dwarf spheroidals. The proposed environmental factor could be at least partially responsible for the bifurcation of the low mass proto-galaxies into two sequences — dwarf irregulars and dwarf spheroidals. We discuss many peculiarities of the Local Group early-type dwarfs which can be accounted for by the impact of the UV radiation from the host spiral galaxy (Milky Way or M31).

Massimo Ricotti
Institute of Astronomy, University of Cambridge

Radiative feedback in the early universe: clues on the origin of Dwarf Spheroidals

The theory of galaxy formation predicts that the creation process is hierarchical: small objects form first, and large galaxies form later from mergers of smaller subunits. The first galaxies are believed to have formed 100 million years after the Big Bang, at redshift $z \sim 30$. In these primordial galaxies, the first stars emitted light into a previously dark universe. The radiation emitted at this time influenced the subsequent evolution of the universe in a still-unknown way. This process of self-regulation, in which the radiation emitted by galaxies influenced the surrounding intergalactic medium and the future formation of other galaxies, is termed "radiative feedback" from galaxy formation. Using 3D cosmological simulations with radiative transfer we find that the first galaxies are characterized by a bursting star formation that is self-regulated by a feedback process acting on cosmological scale. In contrast to massive galaxies, which

reionize voids first, small primordial galaxies partially ionize only the dense filaments, while leaving the voids neutral.

Preliminary results indicate similarities between the properties of simulated primordial galaxies and the bulk of dwarf spheroidal galaxies (dSphs) in the Local Group and Andromeda. I briefly discuss observational tests that could help in understanding the impact of a population of small primordial galaxies on the cosmic evolution.

Paul Hodge
University of Washington

Summary

A summary of the workshop will be presented.

Posters — Gas

Sylvie F. Beaulieu
University of Victoria
and Claude Carignan (U. Montréal), Ken C. Freeman (MSSSO)

Sculptor and Cen A Groups: HI Detection in dSph Galaxies

We present preliminary results of ATCA observations of two dwarf spheroidal galaxies, one in each of the Sculptor and Cen A groups. Our primary motivation was to detect and, if possible, put limits on their HI content.

Martin Bureau
Columbia University

On the Spiral Structure of NGC2915 and Dark Matter

NGC2915 is a blue compact dwarf galaxy embedded in an extended, low surface brightness HI disk exhibiting a two-armed spiral structure and a central bar-like component. Commonly accepted mechanisms are unable to explain the existence of these patterns and disk dark matter (scaling with the HI distribution) or a rotating triaxial dark halo were proposed as alternative solutions. In an attempt to explore these mechanisms, hydrodynamical simulations were run for each case and compared to observations using customized column density and kinematic constraints. The spiral structure can be accounted for both by an unseen bar or triaxial halo, the former fitting the observations slightly better. However, the large bar mass or halo pattern frequency required make it unlikely that the spiral wave is driven by an external perturber. In particular, the spin parameter lambda is much higher than predicted by current cold dark matter structure formation scenarios. The massive disk models show that when the observed gas surface density is scaled up by a factor about 10, the disk develops a spiral structure resembling closely the observed one, in perturbed density as well as perturbed velocity. This is consistent with more limited studies in other galaxies and suggests that the disk of NGC2915 contains much more mass than is visible, tightly linked to the neutral hydrogen. A classic (quasi-)spherical halo is nevertheless still required, as increasing the disk mass further to fit the circular velocity curve would make the disk violently unstable. Scaling the observed surface density profile by an order of magnitude brings the disk and halo masses to comparable values within the disk radius. The surface density remains under Kennicutt's star formation threshold for a gaseous disk and no stars are expected to form, as required by observations.

G. Lyle Hoffman & E. E. Salpeter
Lafayette College, Cornell University

Mini-HVC and Compact HVC: Galactic Fuel, Tidal Debris or Proto-Dwarf Galaxies?

Compact High Velocity Clouds (CHVC) are small in angular extent and relatively isolated, with peak neutral hydrogen column densities around 10^{20} atoms/cm^2 (Braun & Burton). There is controversy over their distances, with estimates ranging from 'circum-Galactic' 100-200 kpc (or even closer) up to Local Group distances of order 600 kpc. In the course of mapping four CHVC using the Arecibo telescope, we discovered three superimposed, still smaller, cloudlets (which we call Mini-HVC) with peak neutral column densities below 2×10^{19} atoms/cm^2. Subsequent mapping of some of the very low H I column density (when averaged over the 21' beam of the Green Bank 140 Foot telescope) gas that Lockman et al. found distributed over

37mini-HVC, with peak column densities as low as 3×10^{18} atoms/cm^2. Such low column densities in the face of the extragalactic photoionizing UV imply large ratios of H II to H I.

The first three mini-HVC discovered and one of the Lockman et al. sources are in the general direction of, and similar in velocity to, the Magellanic Stream. These might be tidal debris. However, the several other mini-HVC found in mapping Lockman et al. sources (some in reference beams) are ¿ 30 degrees from the Magellanic Stream, and one is in the opposite hemisphere. Many mini-HVC may turn out to be on the outskirts of major HVC complexes, quite close to the Milky Way, but some are well removed from the complexes and may be examples of low-mass dark matter halos continually merging with Local Group galaxies, as advocated by Blitz et al. Some questions remain unanswered by observations to date: Are similar mini-HVC and CHVC being accreted by other galaxies in the Local Group or other groups? Can an individual CDM halo, such as those that give rise to CHVC, accrete enough hydrogen gas in the intragroup medium (Burstein & Blumenthal), or contract appreciably through some dynamic instability, to raise its central column density above the threshold for star formation, thus becoming a Blue Compact Dwarf galaxy?

Janice C. Lee
University of Arizona
and John J. Salzer (Wesleyan U.), Chris D. Impey (U. Arizona), Trinh X. Thuan (U. Virginia), and Caryl Gronwall (Pennsylvania State U.)

HI Properties of Low Luminosity Star-Forming Galaxies in the KPNO International Spectroscopic Survey

We present the results of new HI observations of a complete sample of low luminosity star-forming galaxies taken from the KPNO International Spectroscopic Survey (KISS), the first CCD-based wide-field objective-prism survey for emission-line galaxies. This sample (N = 109) consists of all star-forming galaxies with $M_B > -18.0$ and $cz < 11{,}000$ km s^{-1} from the first Hα-selected survey list. The galaxies in this list lie within a 1.3 deg wide strip centered on δ(B1950) = 29°30′ that spans the range α(B1950) = $12^{\rm h}15^{\rm m}$ to α(B1950) = $17^{\rm h}0^{\rm m}$. Overall, 97 out of 109 galaxies have been detected in HI. We confirm the weak trend of increasing gas richness with decreasing luminosity found by previous authors. Gas richness is also shown to be weakly anti-correlated with metallicity. The dependence of star formation rates (SFRs) and HI gas depletion timescales on metallicity is examined. The median solar metallicity based SFR and gas depletion timescale are 0.1639 $M_\odot$ yr^{-1} and 5 Gyrs, respectively. Corrections for variations in metallicity decreases SFRs by ~ 0.5 dex and increases gas depletion timescales by an average of $\sim$8 Gyrs. The majority of galaxies in this sample still have large reservoirs of HI gas, and despite their large current star formation rates, could have formed stars in a quasi-continuous manner for a Hubble time. Finally, we present the first HI mass function for low luminosity star-forming galaxies and show that this subpopulation contributes 10-15% of the overall HI density in the local universe. We conclude that if the HI mass function of the Universe does indeed have a steeply rising low-mass slope as suggested by previous authors, it is not due to the population of low luminosity star-forming galaxies. Comparison of the number densities from the HIMFs in the range $10^8 < M_{HI}/M_\odot < 10^9$ implies that 25-50% of galaxies in this regime are currently undergoing a strong episode of star formation.

Felix J. Lockman
NRAO

A New Population of HI Clouds in the Galactic Halo

The HI halo of the Milky Way at the tangent points in the inner Galaxy has been observed in the 21cm line with the new 100 meter Green Bank Telescope. At the resolution and sensitivity of this instrument a significant portion of the halo is seen to be composed of discrete clouds. The velocities of the clouds are determined largely by Galactic rotation. Their location near the tangent points means that their distance is known with reasonable accuracy, and thus it is possible to get good estimates of their size, mass, density and other properties. The HI clouds are found to at least 1.5 kpc from the plane. Their general distribution in R and z is not yet known.

V. J. McIntyre
Australia Telescope National Facility

Star Formation in the Disk of NGC 4214

I present detailed HI and optical imaging of the Magellanic Irregular galaxy NGC 4214. The data show a number of interesting sites of recent star formation associated with holes in the HI distribution, well out into the disk.

Stephen D. Murray
Lawrence Livermore National Lab.

Tidal Stripping of Gas from Dwarf Galaxies

In cosmological models dominated by cold dark matter, dwarf galaxies are the first objects to form, while large galaxies form via the merger of dwarf systems. The formation of, and star formation within dwarf galaxies may thus have important consequences for all galaxies. In addition, they represent important laboratories to study the physical factors that affect the formation of the first generations of stars. In this contribution, we examine the evolution of gas within dwarf systems which are subjected to tidal forces from a nearby large galaxy. Three-dimensional models are computed using COSMOS, an astrophysical radiation hydrodynamics code developed at Lawrence Livermore National Laboratory. We find that, when the gas within a dwarf galaxy is ionized, substantial mass loss may occur through the Lagrange points, thus limiting the ability of dwarf galaxies to form subsequent generations of stars following the formation of a nearby massive galaxy.

Sally Oey
Lowell Observatory

A star formation threshold for the escape of ionizing radiation from galaxies

The spatial distribution of star formation within galaxies strongly affects the resulting feedback processes. We consider ISM structuring by SNe originating in spatially distributed clusters having a cluster membership spectrum given by the observed HII region luminosity function. We derive a critical $SFR_{\rm crit}$ at which the ISM porosity is unity: this describes the case in which the SN mechanical energy output is comparable with the ISM "thermal" energy contained in random motions. We argue that ionizing radiation has a high escape fraction for the simple parameterization $SFR > SFR_{\rm crit}$.

Karen O'Neil
Arecibo Observatory

ALFA — The Arecibo L-band Feed Array

The Arecibo L-band Feed Array (ALFA) is a seven feed system that will allow large-scale surveys of the sky to be conducted with unprecedented sensitivity using the 305-m Arecibo telescope in Puerto Rico. The NAIC Arecibo Observatory telescope, operated by Cornell University for the National Science Foundation, is the largest and most sensitive single dish radio telescope in the world and is used to study large numbers of sources that are too faint to be seen with other telescopes. In the past, use of the telescope as a survey instrument has been limited by the relatively small field of view in a single observation. ALFA, operating near 1.4 GHz, will consist of a cluster of seven cooled dual-polarization feeds, a fiber-optical transmission system, and digital back-end signal processors. The system will enable deep surveys for a variety of objects in the Milky Way Galaxy and of other galaxies for probing cosmology. As such, the multibeam system will have a broad appeal to astronomers from all over the world.

Jan Palouš
Astronomical Institute, Academy of Sciences of the Czech Republic

The gravitational instability of expanding shells: the mass spectrum of fragments

We discuss the gravitational instability of expanding shells. Masses of individual fragments are in the range between $10^3 - 10^6$ solar masses for low density environment and between 0.1 - 100 solar masses for high density environment. The mass spectrum dN/dm_frag in both, low and high density environments, is approximated with the power law of the fragment mass m$_frag$ with the spectral index between -2.3 and -2.4. It may be explained as the result of the delay in the formation of high mass clumps compared to low mass clumps, thin shell geometry, and the expansion process, during which the slowly forming high mass fragments suffer more from stretching that the rapidly forming low mass clumps. The influence of the turbulent medium will also be discussed.

Caroline Simpson[1], Deidre Hunter[2], and Pat Knezek[3]
[1]Florida International Univ, [2]Lowell Obs, [3]WIYN Obs

DDO 88: Inner Turmoil, Outer Calm

We present an HI and optical study of the gas-rich dwarf irregular galaxy DDO 88. Although DDO 88's global optical and HI parameters are normal for its morphological type, it hosts a large (2-3 kpc diameter) and unusually complete ring of enhanced HI emission located at approximately one-third the total HI radius and one-half the optically-defined Holmberg radius. The ring surrounds a central depression in the HI distribution. The HI ring is not expanding and does not appear to be related to any recent large-scale star formation. The star-formation rate is modest and is normal for Im/Sm galaxies. There is no star formation in the outer regions of the galaxy beyond the ring. The normal appearance of this galaxy in the optical and in the outer regions of the HI, which exhibits no unusual features, give no hint of the presence of the striking HI ring in the inner regions. This may place constraints on what the outer regions of dIrr galaxies can tell us about their evolution.

Eon-Chang Sung[1,2], Kenneth C. Freeman[2] and Lister Staveley-Smith[3]
1) Korea Astronomy Observatory, Korea 2) RSAA, ANU, Australia 3) ATNF, CSIRO, Australia

Is there a long HI bridge between two BCDGs, ESO 435-IG20 and ESO 435-IG16 ?

Based on environmental criteria of BCDGs from optical, near infrared and HI data, we have suggested a new classification scheme for blue compact dwarf galaxies. We present a high spatial resolution HI synthesis observation of the BCDG pair, ESO 435-IG20 & ESO 435-IG16 which is in the detached interacting class of our new classification scheme. From optical observations, because these two gas-rich dwarf galaxies are more than 30 arcmin apart, they were not recognized as an interacting pair because of their large separation. Our HI synthesis observation shows that these two galaxies do appear to be interacting, with evidence for a long HI bridge or tail with a projected length of 130kpc (adopting a distance of 13Mpc). We will discuss the HI environment of the detached interacting BCDG pair ESO 435-IG20 & ESO 435-IG16.

Posters — Stars

Javier Alonso-Garcia
University of Michigan

RRLyrae in M 32

We report the first identification of RR Lyrae in a region $2'$–$4'$ from the center of M 32 based on Hubble Space WFPC2 images. We show their position in the Color Magnitude Diagram and their light curves. To show that this population is not attributable to M 31 we have also observed a field in the disk of M 31, far away from M 32. Comparative study of the two fields reveals an overpopulation of RRLyrae near M 32 that clearly reflects that these stars belong to M 32.

Javier Alonso-Garcia
University of Michigan

Intermediate-Age Dwarf Spheroidal Galaxies in the M 81 Group: UGC 4998 and DDO 44

We report results of a study of the dwarf members of the M 81 group UGC 4998 and DDO 44, using new HST data. The focus of this work is the study of the star formation history of intermediate age dwarf spheroidal galaxies located outside the Local Group. Also to identify radial population gradients as a funtion of time in both galaxies, to determine their basic chemical properties and to place the galaxies in the global relations for other early-type systems that relate metallicity, size, surface brightness and luminosity.

Nicola Caon
Instituto de Astrofisica de Canarias
and L.M. Cairos, J.A. Lopez-Aguerri, C. Munoz-Tunon, P. Papaderos

The structure of the underlying component in Blue Compact Dwarf Galaxies

We study the structure of the underlying component in a sample of Blue Compact Dwarf (BCD) galaxies by fitting a Sersic law to the outer parts of their light profiles. We describe in detail the problems that arise from the limited radial and surface brightness available for the fit. In fact, BCDs are dominated by the emission from the starburst at high and intermediate intensity levels, and the host component only becomes visible at very low surface brightness levels (¿ 24 B-mag arcsec^{-}2).

The relationships among the photometric parameters derived for this sample are compared to those of other dwarf classes, to look for possible physical and evolutionary links.

Igor Drozdovsky
University of Pittsburgh, USA

Stars as a Tracer of the Shape of Irregular Galaxies' Haloes

The presence of red extra light ("background sheet") outside of the main galaxy body and the spatial distribution of resolved old stellar populations suggest that irregular galaxies might have similar outer structures to spirals, consisting primarily of late-type stars out to large galactocentric radii. Further investigation of this claim is critical in constraining the origin and evolution of galaxies and the nature of dark matter haloes. We present the preliminary results of our study of nearby irregulars to: on the basis of analyzing of derived color-magnitude diagrams separate different stellar populations, constrain their spatial geometry, determine the connection between underlying stellar population and the host galaxy structure, and estimate the possible contribution of such stars to the dark matter mass.

Sebastian L. Hidalgo
Instituto de Astrofísica de Canarias

NGC3109: Extended Structures in Faint Galaxies

We present here preliminary results of our wide-field study of NGC 3109: a low luminosity galaxy in the outskirts of the Local Group. Its edge-on orientation (which simplifies the study of a possible halo) and the possibility that it could, in fact, be a small spiral (the smallest in the Local Group) makes its deep analysis of major relevance to understand the properties of dwarf galaxies and the transition from dwarf irregulars to spirals.

Deidre Hunter
Lowell Observatory

What's going on out there? The stellar edges of irregular galaxies

Motivated by the fact that the Holmberg radius in irregular galaxies is usually much larger than the obvious extent of star-forming regions seen in Halpha images, I will present the results of very deep optical imaging of two irregular galaxies. These data will be used to explore how far out the stellar populations extend, how the stars are distributed, and what the star formation history at the edges of the galaxies has been. These questions relate to the question of how irregular galaxies form and evolve.

Arna Karick
University of Melbourne

The Relationship between Nucleated Dwarf Elliptical Galaxies and Ultra-Compact Dwarf Galaxies in the Fornax Cluster.

A small sample of ultra-compact dwarf galaxies (UCDs) were discovered as part of the Fornax Cluster Spectroscopic Survey (FCSS). Assumed to be foreground stars, spectral analysis of these very faint objects gives radial velocities confirming them to be cluster members. Optical imaging indicates they are morphologically unlike any previously known cluster dwarf. The UCDs all lie within $30'$ of the central cD galaxy NGC 1399 at larger radii than its associated globular systems. The two most favoured hypotheses for their origin are: (1) globular cluster systems associated with the central cD galaxy NGC 1399, (2) the nuclei of tidally stripped infalling dE,Ns.

We present some preliminary results of deep multicolour imaging of the Fornax Cluster core. Images were taken with the CTIO 4m Blanco Mosaic-II telescope using Sloan filters (u' g' r' i' z'). We investigate the relationship between dE,Ns, UCDs and globular clusters in colour space ($g' - r'$ vs. $u' - g'$) in an attempt to constrain the origin of the UCDs.

Patricia M. Knezek & Barton J. Pritzl
WIYN Observatory & NOAO

Star Formation Histories of Three Gas-Rich dIrrs in the Centaurus A Group of Galaxies

We present HST V&I photometry of three gas-rich dwarf irregular galaxies discovered in the recent HI Parkes All-Sky Survey (HIPASS) and a follow-up deep pointing with the same telescope of the Centaurus A region. All three galaxies have M(HI)/L(B)¿3, have surface brightnesses in B $>$ 24 mag/arcsec^2, and are intrinsically as faint or fainter than any known dwarfs in the Local Group (M(V)   -11). Only two Local Group galaxies are potentially as extreme in their properties as the three Cen A dwarfs, but both galaxies lie in regions of significant foreground extinction. We find from our HST results that the three dIrrs differ significantly in both their spatial distribution of stars and in their star formation histories, as indicated by their color-magnitude diagrams. This is consistent with the wide range of star formation histories seen in Local Group dwarfs. We examine these results in the light of each galaxy's individual parameters, as well as their overall group environment.

Yutaka Komiyama
Subaru Telescope

Wide-field imaging survey of the dwarf irregular galaxy NGC6822

The dwarf irregular galaxy NGC6822 is one of well-studied galaxies in Local Group. Recently, de Blok & Walter found that HI gas is spread around the galaxy in large scale. Motivated by thier result, we observed NGC6822 with Suprime-Cam which is a wide-field CCD camera attached to the prime focus of the Subaru telescope. The observation was carried out in B,R,I bands and covers about 1700 arcmin^2. We will present the stellar distribution, correlation with HI gas and discuss the formation history of NGC6822.

Andrew Odell
Northern Arizona University
and Michael Maitzen (U. Vienna), James Schombert (U. Oregon), Karl Rakos (U. Vienna)

The Ages and Metallicities of Galaxies from Continuum Colors

We present the results of a narrow band imaging project of galaxies in the Fornax (z = 0.01), Coma (z = 0.02), A2218 (z = 0.17), and A2125 (z = 0.01) clusters. Differing from spectral line projects, we determine the mean age and metallicity of the underlying stellar populations in galaxies by measurement of the position of the RGB and MS turnoff through continuum colors (3500 Å, 4100 Å, 4675 Å, and 5500 Å in the rest system, i.e. modified Strömgren colors). Our sample includes 120 galaxies between $M = -16$ and -23 in Fornax and Coma plus over 300 galaxies in distant clusters. We find the color-magnitude relation to be linear for only the brightest galaxies with an increasing amount of scatter for low luminosity ellipticals. Bright ellipticals are found to have metallicity between -0.5 and $+0.5$, but low luminosity ellipticals have values that range from -2 to solar. Our age index finds a weak correlation between luminosity and mean stellar age in ellipticals such that bright ellipticals are 2 to 3 Gyrs younger than low luminosity ellipticals.

S. C. Odewahn
Arizona State University
and R. A. Jansen, R. A. Windhorst, V. Taylor, P. Eskridge (Minnesota State University)

HST/WFPC2 Analysis of the mid-UV — Optical Colors within the Disks of Nearby Galaxies

We have used WFPC2 in Cycle 9 (GO) and Cycle 10 (SNAP) programs to image 64 nearby galaxies in F300W and F814W for the primary purpose of studying the morphological properties of galaxies in the near-UV. Sample selection, described in Windhorst et al 2002 (ApJS, in press), was designed to include galaxies of all types, including dwarf systems, but was preferentially skewed towards the late Hubble types. Our ultimate goal is to use these data as a benchmark for comparing the morphological properties of nearby and high redshift systems, where the latter are observed predominantly in a restframe bandpass in the mid-UV. In this poster we present classical radial surface brightness profiles, as well as analyse images of 64 galaxies following the Fourier-based methodology of Odewahn et al 2002 (ApJ,568,539) and the pixel color map approach of Eskridge et al 2002 (ApJ submitted). Our near-ultraviolet and optical images reveal regions of strong on-going star formation that are sometimes associated with structures traced by the old stellar populations. We use our F300W-F814W pixel color-magnitude diagrams to quantify the level and character of star formation in the outer regions (beyond the effective radius) of our disk-dominated galaxies.

Michael Pohlen[1], Ralf-Juergen Dettmar[2]
[1]IAC, Tenerife (Spain), [2]AIRUB, Bochum (Germany)

Do low surface brightness galaxies exhibit outer stellar truncations? Case study of UGC7321, UGC9242, and ESO342-017.

We present results on the radial surface brightness profiles of three low surface brightness (LSB) galaxies. Normal disk galaxies are known to exhibit truncations in the radial light profiles towards larger galactocentric distances. These 'outer-edges' are associated either to global star-formation thresholds in the very outer parts of their disks or to the initial angular momentum distribution during their formation epoch. Our data confirm for the first time that the radial structure of LSB galaxies is qualitatively and quantitatively comparable to what we found for normal galaxies. This new results has to be taken into account while explaining the origin for the observed truncations and their application as characteristic parameters for galaxy formation and evolution models.

Violet Taylor
Arizona State U.

UV–Optical light-profiles and color gradients of late-type, irregular, and peculiar galaxies

We present light-profiles and color gradients for a sample of late-type, irregular, and peculiar galaxies imaged with the Hubble Space Telescope (HST) Wide Field Planetary Camera 2 (WFPC2) in the UV filter F300W (as well as in the F814W filter) and with the Vatican Advanced Technology Telescope (VATT) in the UBVR filters. These galaxies are important local benchmarks to study the numerous faint blue galaxies that dominate the galaxy population seen in the deep fields at high redshifts, and it is therefore critical that this local population is studied at the shortest possible wavelengths.

These UV–Optical light-profiles are analysed to determine the color gradients of these galaxies from their centers to their outer regions. We will examine the dependence of color and color gradient trends of late-type, irregular, and peculiar galaxies on global galaxy properties, such as Hubble type, average surface brightness, and interaction with neighbors, etc.

Matthew G. Walker
University of Michigan

Stellar Radial Velocity Profile for the Fornax Dwarf Galaxy

We present precise radial velocities for over 200 stars in 31 fields in the Fornax dwarf spheroidal galaxy, obtained using echelle spectroscopy. Our sample population spans the region $R = 0$ to just beyond best estimates of the Fornax tidal radius. We also present $V - I$ CCD photometry of the giant branch from each Fornax field.

We use both the velocities and photometry to identify and eliminate probable non-members, leaving us with one of the largest samples to date of stellar radial velocities for a single dwarf galaxy. This allows the calculation of a radial velocity profile, as well as a more robust estimate of the central velocity dispersion of Fornax.

Most importantly, these data represent a mere prelude to what we expect to obtain later this year, when we will employ newly developed instrumentation at the Magellan 6.5 m telescope to observe the dwarf galaxies Carina, Fornax, Leo I, Sextans, and Sculptor. The brand new MIKE fiber echelle spectrograph will allow measurement of radial velocities to greater than 1 km/s precision for over 100 target stars simultaneously. Preliminary goals include samples of an average of 1500 stars per galaxy, which will raise the bar in dwarf galaxy radial velocity sample population by an order of magnitude.

Rogier A. Windhorst[1], Seth H. Cohen[1], Rolf A. Jansen[1], Stephen C. Odewahn[1], Simon P. Driver[2], Daisuke Kawata[3], Brad K. Gibson[3], and Andrew Hopkins[4]
[1]Arizona State University, [2]Australian National Univeristy, [3]Swinburne University, [4]University of Pittsburgh

Fundamental Limitations to the Observability of the Outskirts of Galaxies at High Redshifts: The Natural Confusion limit in Ultradeep Optical–IR and Radio Surveys

We discuss the natural confusion limit in the red/near-IR for the 6.0 meter Next Generation Space Telescope (NGST) — now called the James Webb Space Telescope (JWST) and planned for launch to an L2 orbit in 2010 — and for the Square Kilometer Array (SKA) at radio wavelengths, that would become reality in the next decade. The classical instrumental confusion limit occurs when the typical sources are unresolved by a telescope, but the telescope sensitivity is so good that the faint source surface density results in significant source overlap. However, the natural confusion limit occurs when the faint source population is significantly resolved by the telescope and their surface density is so high that one has fewer than a minimum number of typical "object-areas" per detected object.

First, we summarize the observed half-light radius vs. magnitude relation for the entire galaxy population from the RC3 level to the HDF limit. Together with estimates of this relationship in hierarchical models at flux levels fainter than J(1.25 micron)$_{AB}$ = 28 mag and model extrapolations of the faint galaxy counts at J$_{AB}$ = 28–34 mag, we estimate the natural confusion limit for JWST at 1.25 microns. At J$_{AB}$ = 34 mag, the surface density could be several tens of millions of objects per square degree, or several detected objects per square arcsecond.

A rather unexpected scientific result of this study is that in ultradeep surveys, the natural confusion limit becomes as important in the definition of faint source samples as the traditional surface brightness limits. In particular, for resolutions of $\sim 0.08''$ FWHM, it appears that for J$_{AB}$ > 25 mag (or B>27 mag) both HST and the JWST may be more affected by natural confusion than by the traditional surface brightness limits. We suggest that this may already be visible in the deepest HDF images. This does however not mean that the deepest JWST samples will be fundamentally limited by natural confusion. Instead, we expect that for J$_{AB}$ > 28–30 mag, the faint objects seen by JWST will be largely point sources at 0.08" FWHM, which we begin to address with hierarchical simulations. In this case, the deepest JWST images will be limited only by the instrumental confusion limit, which doesn't set in until around J$_{AB}$ > 33.5 mag.

Last, we use the JWST results to estimate the natural confusion limit for the SKA at GHz frequencies, arguing that the same population of faint irregular, peculiar and merging/star-forming objects that dominates the faint optical/IR galaxy counts will likely dominate the radio source counts at nanoJansky levels. If so, the SKA will need to have better than 50–100 m.a.s. FWHM in order to not run into the instrumental confusion limit at 100 nanoJy at 1.4 GHz. At 10 nanoJy, the SKA may reach similar object surface densities as the JWST at $J_{AB} = 33$ mag, and — like the JWST — may not run into the natural confusion limit, if the slope of the nanoJy source counts remains below $\gamma < 1.7$, and if the ratio of radio to optical–near-IR sizes remains close to unity at nanoJy levels.

Ted K. Wyder and Paul W. Hodge
California Institute of Technology; University of Washington

The Stellar Populations in the Outer Regions of NGC 6822

We present VI color-magnitude diagrams obtained with the WFPC2 aboard the Hubble Space Telescope of four fields in the Local Group dwarf irregular galaxy NGC 6822. Among the brighter Local Group dwarfs with $M_B = -15.5$, NGC 6822 is dominated in its central regions by a North-South bar containing most of the sites of recent star formation in this galaxy. The central bar is surrounded by a lower surface brightness area containing a higher proportion of somewhat redder, fainter stars. The four fields observed lie approximately along the bar's minor axis with the outermost two fields at projected distances of 700 and 900 pc East and West of the bar, respectively. The color-magnitude diagrams reach down to V=26 mag, a level well below the red clump, allowing us to investigate both the young and older stellar populations in the outer regions of this galaxy and how it differs from the central regions. Assuming an initial mass function, chemical enrichment history, distance and a set of theoretical stellar isochrones, we derive the star formation history in each field by fitting the observed color-magnitude diagrams.