Radioastronomical activities of AMIGA group

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OUTLINE

- Previous works
- AMIGA goals

Scientific work
- Global study: radiocontinuum, CO, HI
- SF in inner and outer parts of disks
- Environment

Technical development
- Calibration techniques
- Radio-VO archiving and tools
PREVIOUS WORK

Dynamical study of HI in isolated – ringed – non-barred galaxies

PREVIOUS WORK

Neutral gas in Compact groups, where low SF is found

- Molecular gas content and mapping: CO deficiency
- Atomic gas content in 72 groups: 60% HI missing
- Atomic gas mapping of 26 CGs with VLA

Evolutionary model proposed

Phase 1: Low level of interaction
Phase 2: Gas in tidal features
Phase 3a: No HI in the galaxies
Phase 3b: Gas in a cloud

(Verdes-Montenegro et al 2001)
AMIGA GOALS

AMIGA project:
Analysis of the interstellar Medium of Isolated Galaxies

Need for a reference sample of isolated galaxies to study denser environments
Either no strict isolation definition or, if well defined:

- Monochromatic observations of large samples/
- Multiwavelength observations of small samples

Multiwavelength statistical study of ISM ~1000 galaxies
Build & analyse the catalog (ISM – SF – AGN)
Make it public: VO interface with search utilities
AMIGA GOALS

Starts in 2003 @IAA with funding from National Funding (PNAYA)

Since 2006 Coordinated project (PI: L. Verdes-M)

IAA-group + IRAM-30m @ Granada

IAA: 1 staff, 3 postdocs, 3 PhD students, 2 software engineers

+ International collaboration:

Obs. Marseille, Obs. Paris, CfA, ASIAA-Taiwan, MPIfA (Bonn), Univ. Alabama, UMASS, Mc Donald Observatory, Arcetri, UNAM, IAC, Kapteyn Institute

GLOBAL & DETAILED STUDY

- Refinement of starting sample (CIG):
  - Positions, degree of isolation, optical characterization
- Global characterization:
  - MIR, FIR, radio-continuum
  - SDSS spectra for optical AGNs selection
  - Hα + R (200 galaxies)
  - Molecular gas & atomic gas content
- Test of galaxy formation models
  - Characterization of neighborhood: SDSS + GCs (VLT/GTC)
- Conditions for secular SF and AGN: inner & outer parts of disks
- Environment: minor interactions, dense groups
Global study: Radiocontinuum

- Comparison NVSS vs FIRST @21cm, Radio/LB (R)
  - disk-dominated SF emission in spirals vs dense env.
  - less than 3% of the sample with R > 100 (AGN)
- Radio-FIR correlation to select radio-excess galaxies
  - 0.4% of radio-excess galaxies
  - All types increase with environment density

Lowest rate of radio-excess galaxies among all samples

(Leon et al 2008, Sabater et al 2008)
Global study: Atomic gas

- Reference for $M(HI) = f(LB, \varnothing, t)$ (previous: HG84, n = 324)
  - Single dish: for 910 CIG
    > 100 papers + own data (Arecibo, GBT, 100m, Nancay)
  - Improved quantity & quality
- Origin of ISM in E/S0s
  - 27% isolated E/S0 detected in HI
  - $M_B$ not compatible with fossil group
  - HI with double horned profiles
- Shape of profiles quantified:
  - 21% of asymmetric profiles
- Discarded: Small companions in the beam, gas accretion

Espada 2006, PhD
Global study: Atomic gas

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Next step at Arecibo

- Observation with ALFA to improve accuracy in flux measurement for ~ 400 galaxies:
  - To improve reference for MHI-LB
  - HI mass function

Participating in ALFALFA consortium
Follow up observations with targeted proposal (2009)
Global study: Molecular content

- Complete reference sample for $M(H_2) = f(LB, \varnothing, t)$
  - CO single dish for 205 galaxies $1500 < v < 5000$ km/s
  - Major axis mapping for ~ 20 galaxies
    - IRAM 30m, FCRAO, Nobeyama 470h
- $M(H_2)$ conditioned at 1st order by morphology, and at second order by environment
- $M(H_2)/M(HI)$: Relative content increases for denser env.
- Applied to investigate HI deficiency vs SF in HCGs
  - CO data from AMIGA, and new CO data for 56 gal HCGs
    - Espada 2006, PhD
    - V. Martínez-Badenes, PhD
SF in the inner parts of disks

Mapping of individual galaxies from Verley’s sequence:
gas–bar–SF interplay, gas towards the center: bar destruction
- G: CIG 147, 347, 1004: CO(1-0), CO(2-1) @ PdB, CO(2-1) @ SMA, HCN @ 30m, public BIMA CO(1-0)

(V. Martínez-Badenes, PhD)

SMA CO(2-1)
(Espada et al.)

Arecibo meeting Granada

Analysis of the Interstellar Medium of Isolated Galaxies
Southern Galaxies @ SMA

Exploratory imaging of CO-bright southern galaxies:
- N=36 CO(2-1) at SMA (N=14 already observed)
- Not explored by any other mm interferometer up to date.
- From prototypical barred spirals to mergers.
- To explore role of molecular gas properties on existence of SB/AGN.

Centaurus A

NGC613
SF beyond R25

- XUV disks challenge our current ideas on SF law
  - To identify gas reservoir: no study so far of isolated XUV disks
  - Kinematics, relative ratio of atomic and molecular component
  - e-VLA, IRAM-30m, best candidates for ALMA

CIG 96 (UV: Gil de Paz; HI: Espada et al)
VLA mapping of 12 isolated/asymmetric galaxies
- Asymmetries in the velocity field
- Few HI companions (mass limit $5 \times 10^6 M_{\odot}$)
- Upper limit to cloud accretion
- No tidal tails

Detailed study of extreme case CIG 96

Accretion of small companions favoured, longer-lived in the velocity field

(Espada et al 2005)
### HI data parameters

**Channel maps**
- Field size, channels: \(17.0 \times 17.0, 22 - 46\)
- Velocities: 1436.7 - 1686.6
- rms noise channel: 0.66 mJy/beam
- Contours: 3, 10, 21, 42, 56, 70, 84, 98, 112

**Global HI profile**
- VLA — GB43m (HG98)

**HI flux**
- (Jy km s\(^{-1}\)): 103 — 1023

**Helio-centric velocity**
- (km s\(^{-1}\)): 1557 — 1562

**HI profile width 20%**
- (km s\(^{-1}\)): 238 — 239

**MHI**
- \(10^9 M_\odot\): 7.24 — 7.53

**HI maps**
- Field size: \(5.6 \times 5.6\)
- HI map contours: 1, 100, 250, 750, 1000, 1250, 1500, 1750, 2000, 2250, 2400, \(10^{20}\) cm\(^{-2}\)
- Velocity contours: \(v_{max} - v_{min}\), \(\delta v\)

**Comments**
- Companion \(\alpha=02:16:26.90, \delta=05:56:24.0, v=1605\) (1572—1655), \(M_{HI} \geq 10^8 M_\odot\)
Environment: where is the missing HI?

- Chandra & XMM observations: no general diffuse gas
- HI distribution (VLA): few tidal tails
- Diffuse HI in IGM (GBT): to be proposed for ALFA@Arecibo
Technical development

Calibration tests in collaboration with SMA: the ALMA pathfinder  (D. Espada, V. Martínez)

Phase transfer: Calibration of high-freq data with low freq.
- Phase drifts and jumps due to electronics.
- Inspecting problems with simultaneous 300/400 GHz Rx’s
- Problems identified: Temperature diff. inside ant. cabine, cable tension (azimuth). Can we predict phase diff.?

Fast switching:
- Observe one bright quasar for long time, and study atmosph.
- Test with 3 quasars (1 as calib) changing t for calib. cycle.
  S/N ↓ & position offsets ↑ with calib. cycle.
- Needed calib. cycles < 1min in Mauna Kea site to improve phase fluctuacions under normal weather conditions.

Joined ALMA Comissioning & Science Verification group
Virtual Observatory: archiving & tools

We find:

- Few radio data available in archives (not to mention in the VO… ALFALFA being an exception!)
- Optical/IR data more often available, too diverse queries
- VO Essential for multi-\(\lambda\) astronomy
- Need for VO-enabled radio oriented analysis tools

**Solution:** INTEROP

Not producing new soft but adding VO functionalities

Started working on radio-VO: access + tools

Got funding for 3 FTE x 3 years software engineers

1 PhD in 2008 to be followed by a postdoc, 1 PhD starting
Virtual Observatory: IRAM-30m archive

Development of RADAMS
(Radio Astronomy DAta Model for Single-dish telescopes)

First VO-compliant data model for radioastronomy

Extensible: additional metadata can be provided for different instruments, observing modes, switching modes…

Applied to the IRAM-30m antenna:
archive to be finished end 2008 and integrated in the VO

Membership to IVOA DM Working Group

(J. Santander 2006, DEA; IVOA Note 0.66)
Key to the success of ALMA:
data accessible to the community at large, not only domain of 
experienced radio astronomers.

This requires access to:
- well documented+intuitive tools to inspect+analyse 3D data
- existing VO tools widely accepted by the community (e.g. 
  Aladin, VOSpec, Topcat, etc)
- complementary data sets at same or different wavelengths

Planned collaboration with ESO-ALMA archive team
- Development of a Radio Data Cube Data Model (RDCDM) suitable for the ASA, to be submitted for approval and discussion to the DMWG

Development of a suitable IVOA data model for radio-astronomical data cubes

- VO services:
  - analysis of ASA Requirements draft Use Cases stating which use cases can be provided by already existing VO services
  - VO spectral and image services will be deployed and tested
MOVOIR Development

MOdular Virtual Observatory Interface for Radio-astronomy

Tools: MASSA/MADCUBA (Herschel packages for HIFI, usable with 30m data developed by J. M. Pintado’s group)

Data services:
Access to standard FITS imported by the MOVOIR from VO SDSS, HST, MAST, FUSE, IUE, ISO, XMM-Newton, VizieR, AMIGA*, IRAM 30m*, Robledo*…

Applications
Aladin, Topcat, VOPlot, Mirage…
High-level analysis tools for 3D data
- ALMA not expected to have them (ALMA community day 2007, 3D-2008 meeting)
- GIPSY (Groningen Image Processing System, developed at Kapteyn AI) one of oldest + most powerful systems available

GIPSY upgrade and integration in the VO, full compatibility with ALMA data, usability in order to make it available to a larger user base

Collaboration IAA, Kapteyn Institute, SVO and Obs. Paris
CONCLUSIONS

- Solid scientific knowledge of the ISM neutral component
- Regular access to worldwide first line radio-facilities
- Development of gain calibration techniques for mm/submm
- Pioneering work in integration of radio-archives & tools in VO

Privileged position to

Contribute to the ALMA commissioning phase
Exploit ALMA from its very early stages
Produce technical contributions for ALMA until its full operation & extremely high-throughput instruments, such as SKA-pathfinders & SKA