Radioastronomical activities of AMIGA group

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OUTLINE

- Previous works
- AMIGA goals

Scientific work

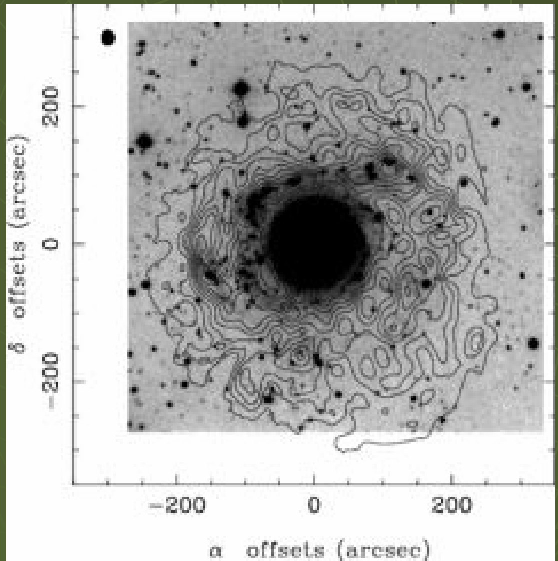
- Global study: radiocontinuum, CO, HI
- SF in inner and outer parts of disks
- Environment

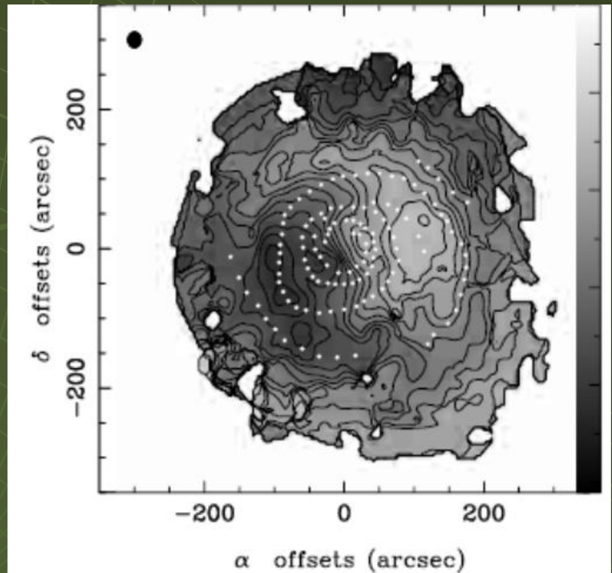
Technical development

- Calibration techniques
- Radio-VO archiving and tools

PREVIOUS WORK

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





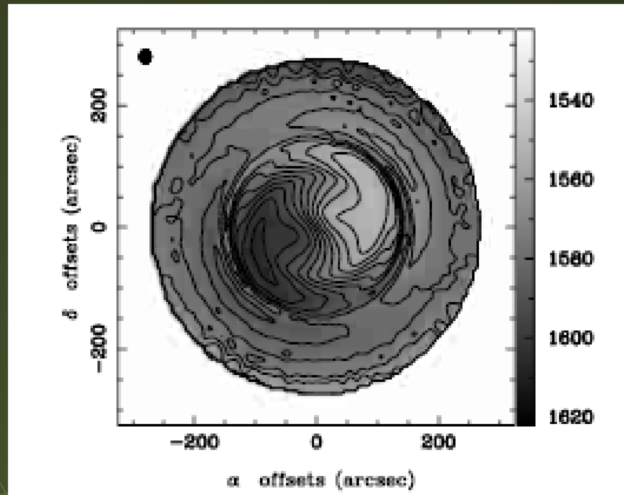
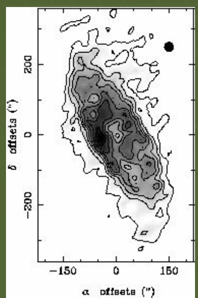
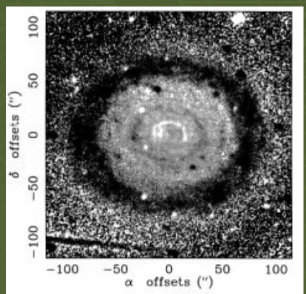
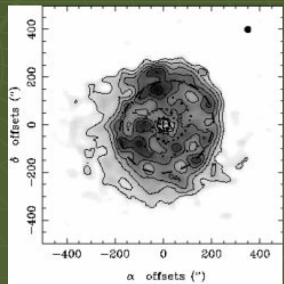


Fig. 10. First-order moment of the modeled channel maps obtained with the geometrical parameters plotted in Fig. 9.







(Verdes-Montenegro et al 1995, 1997, 2000, 2002)

PREVIOUS WORK

Neutral gas in Compact groups, where low SF is found

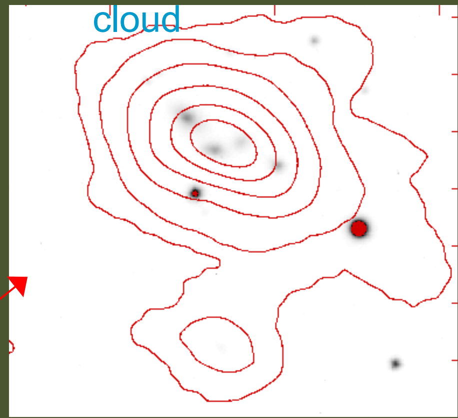
- Molecular gas content and mapping: CO deficiency
- Atomic gas content in 72 groups: 60% HI missing
- Atomic gas mapping of 26 CGs with VLA

(Verdes-Montenegro et al 1997ab, 2001, 2002, 2005; Perea et al 1997; Sulentic et al 2001; Williams et al 2002; Durbala et al 2007)

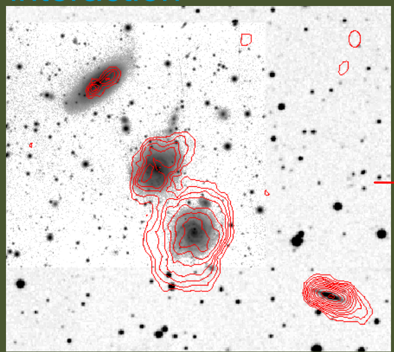
PREVIOUS WORK

Evolutionary model proposed

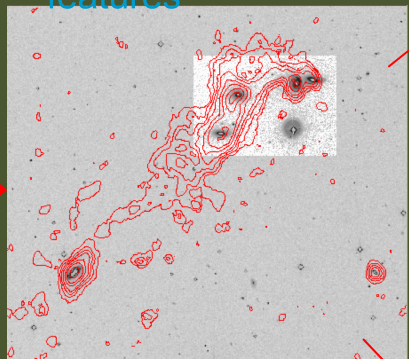
Phase 3b: Gas in a cloud



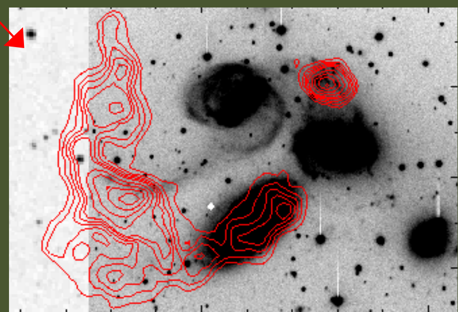
Phase 1: Low level of interaction



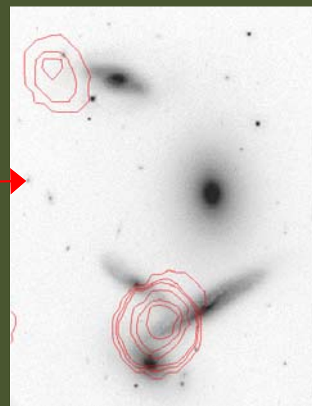
Phase 2: Gas in tidal features



Phase 3a. No HI in the galaxies



¿?



(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

PhDs: 1-2005, 1-2006, 2-2008, 1- 2009, 2- 2010

GLOBAL & DETAILED STUDY

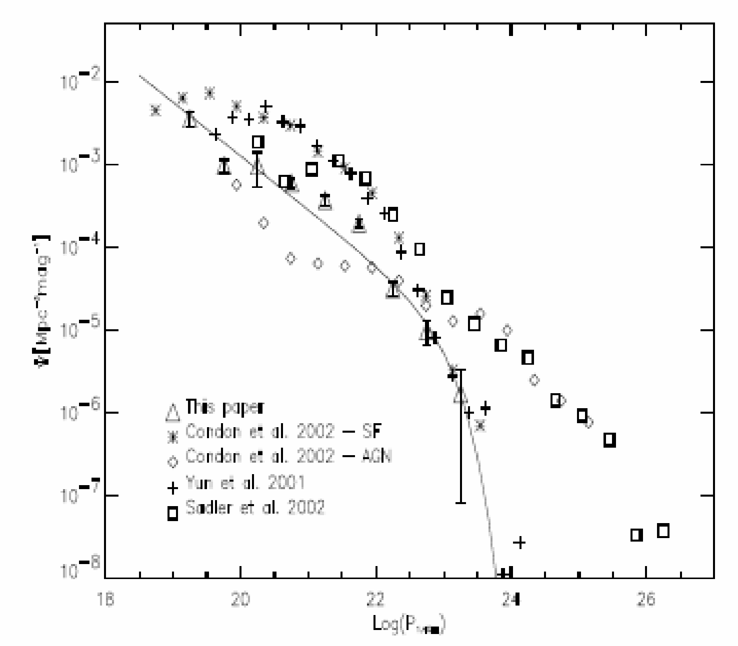
- Refinement of starting sample (CIG):
  - Positions, degree of isolation, optical characterization
- Global characterization:
  - MIR, FIR, radio-continuum
  - SDSS spectra for optical AGNs selection
  - Hα + R (200 galaxies)
  - Molecular gas & atomic gas content
- Test of galaxy formation models
  - 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

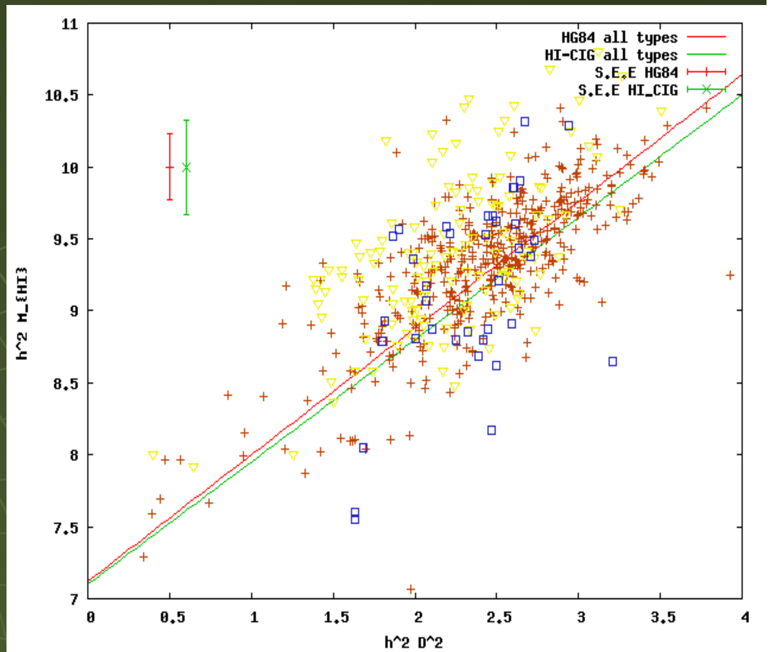
(Leon et al 2008, Sabater et al 2008)



Global study: Atomic gas

- Reference for M(HI) = f(LB, Ø, t) (previous: HG84, n = 324)
  - Single dish: for 910 CIG (Espada 2006, PhD)
    - > 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

Global study: Atomic gas

- Reference for M(HI) = f(LB, Ø, t) (previous: HG84, n = 324)
  - Single dish: for 910 CIG (Espada 2006, PhD)
    > 100 papers + own data (Arecibo, GBT, 100m, Nancay)
  - Improved quantity & quality
- 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 $M(H_2) = f(LB, Ø, t)$
  - 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

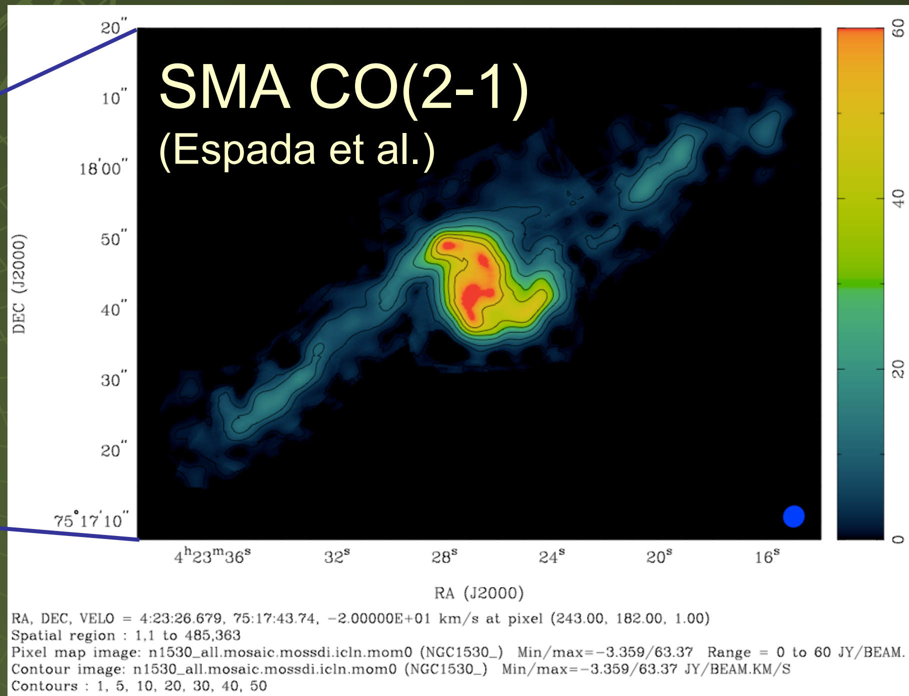
  CO data from AMIGA, and new CO data for 56 gal HCGs

  (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. Martinez Badenes, PhD)

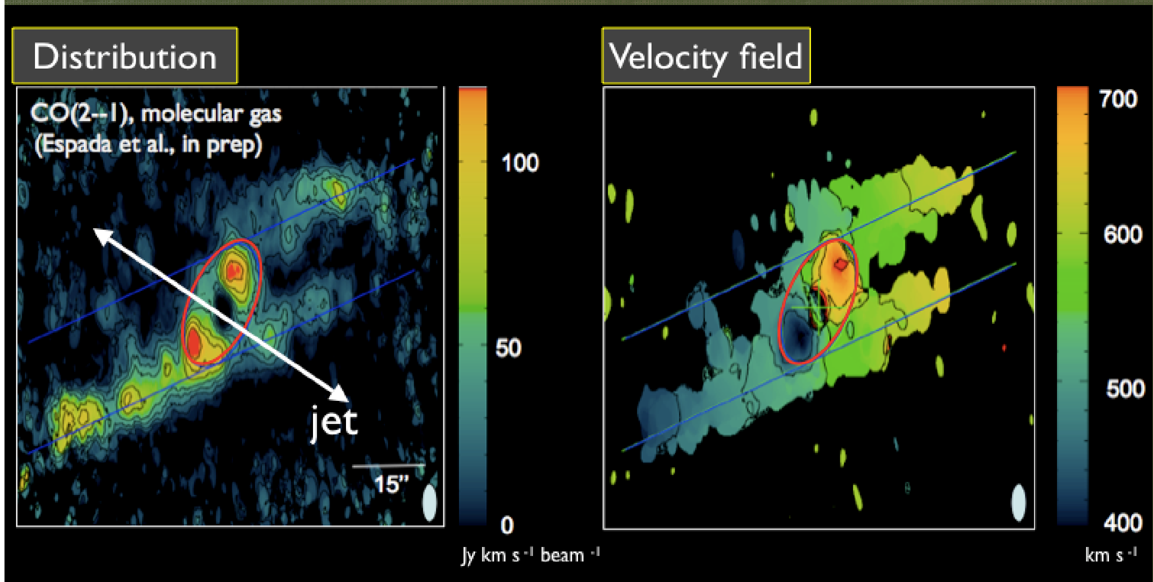


Southern Galaxies @ SMA

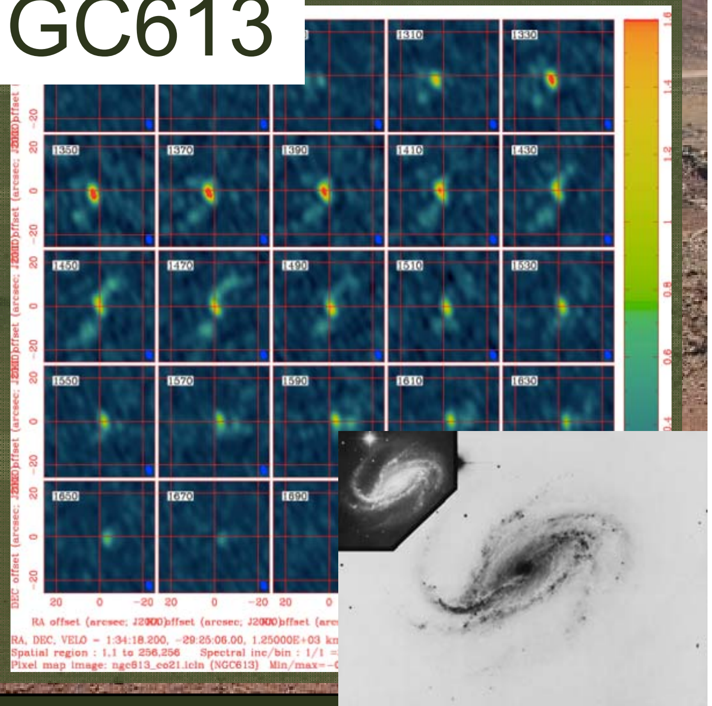
Exploratory imaging of CO-bright southern galaxies:

- -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

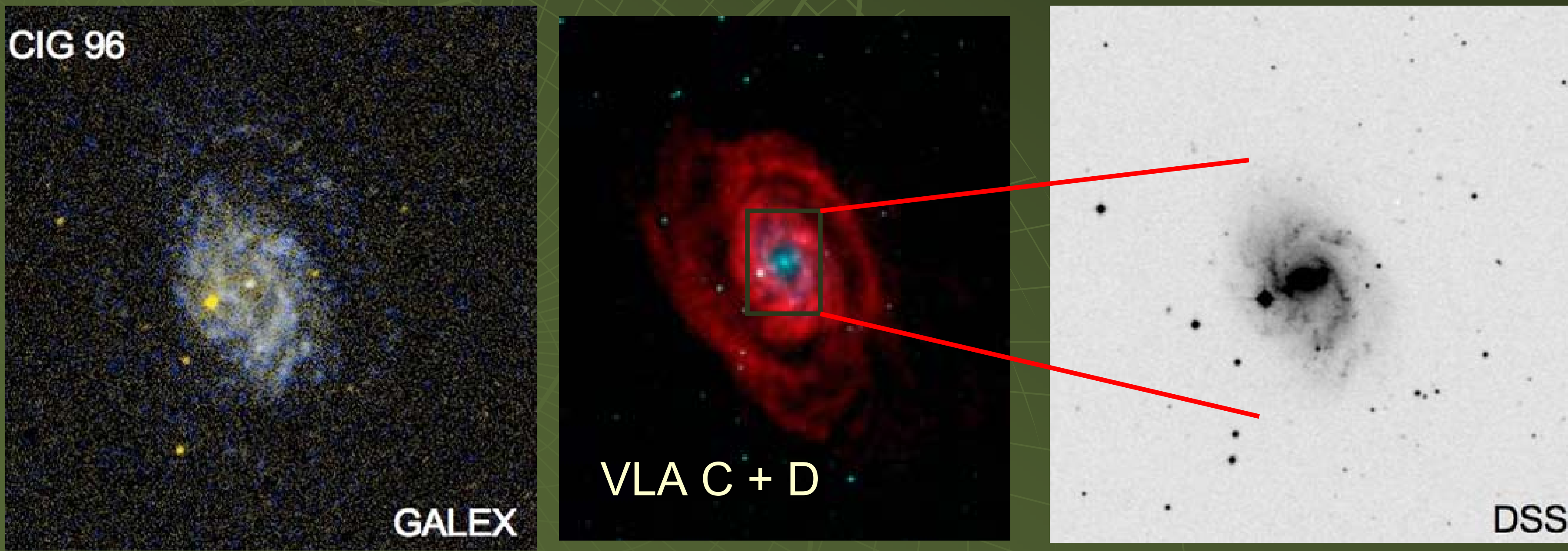


NGC613



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



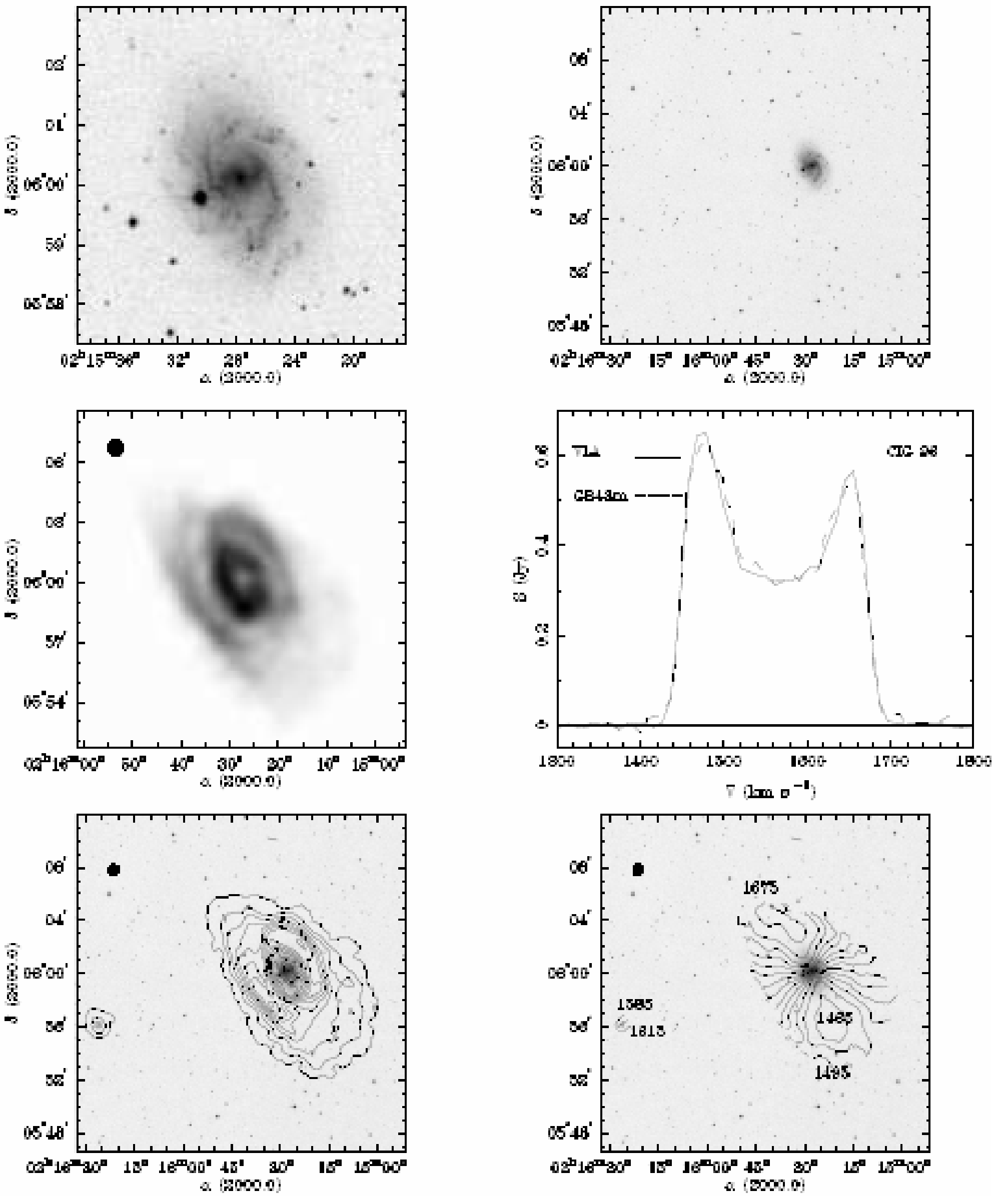
CIG 96 (UV: Gil de Paz; HI: Espada et al)

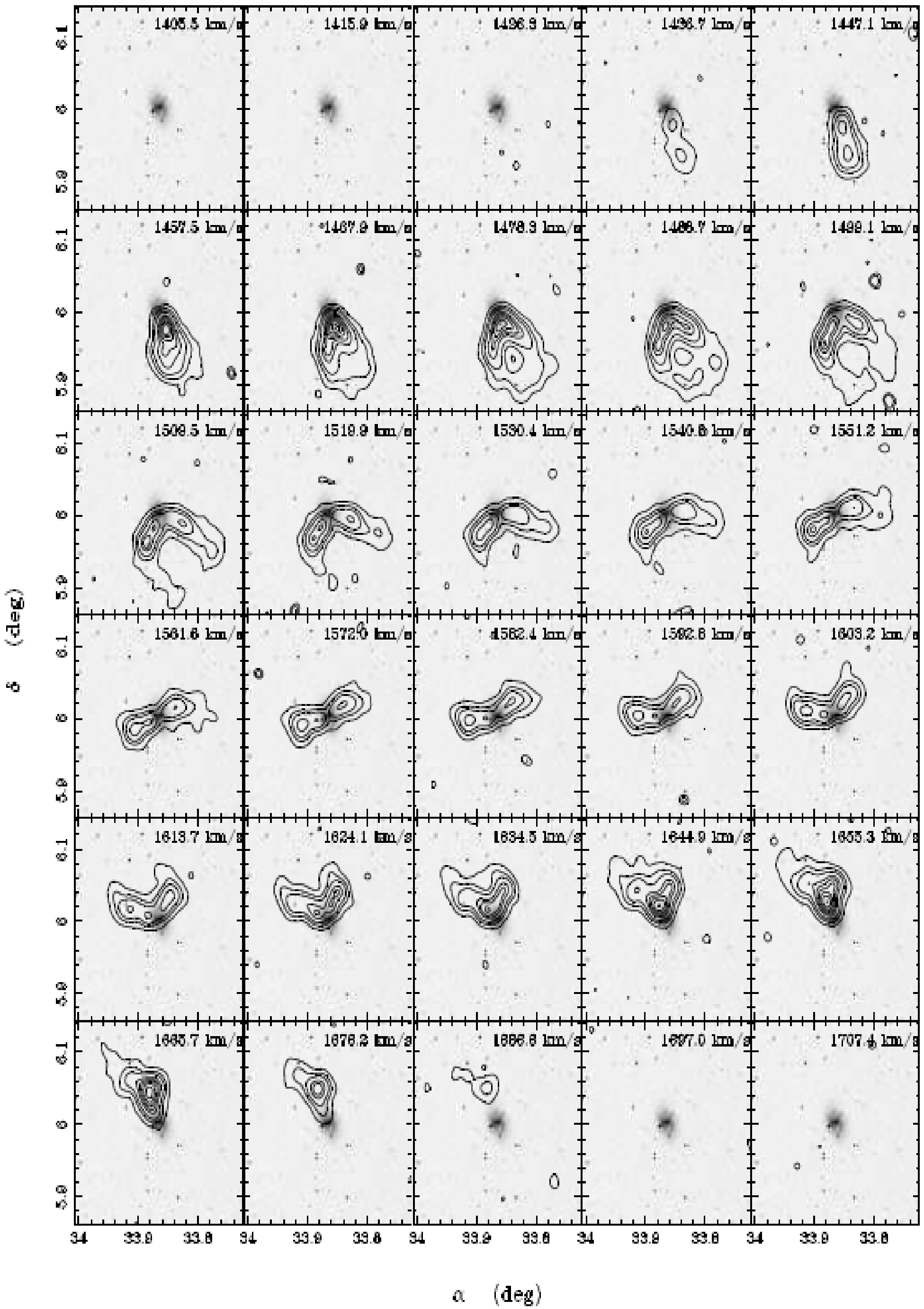
Environment

- VLA mapping of 12 isolated/asymmetric galaxies
  - Asymmetries in the velocity field
  - Few HI companions (mass limit $5x10^6 M_{sol}$)
  - 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

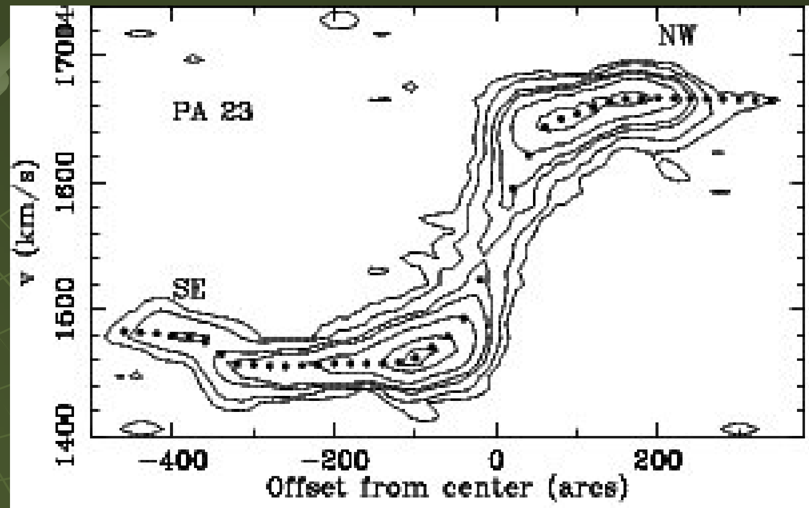
(Espada et al 2005)

Source: CIG 96		
Morphology		SBc
α(2000)	(hh:mm:ss)	02:15:27.6
δ(2000)	(dd:mm:ss)	06:00:09.0
Optical field sizes	($' \times '$)	5.6 $\times$ 5.6, 25.4 $\times$ 25.4
Observing time	(hours)	4
Central velocity	(km s^{-1})	1572
Spatial resolution	($''$)	15
Number of channels		64
Velocity resolution	(km s^{-1})	10.4
Beam size	($\alpha \times \delta$, $'' \times ''$)	49.8 $\times$ 46.0
Conv. beam size	($\alpha \times \delta$, $''$)	70.4 $\times$ 65.3
PA (N to E)	($^\circ$)	-6
HI data parameters		
Channel maps		
Field size, channels	($'$)	17.0 $\times$ 17.0, 22 - 46
Velocities	(km s^{-1})	1436.7 - 1686.6
rms noise channel	(mJy/beam)	0.66
Contours	(mJy/beam)	3, 10, 21, 42, 56, 70, 84, 98, 112
Global HI profile		
		VLA — GB43m (HG98)
HI flux	(Jy km s^{-1})	103 — 102.8
Heliocentric velocity	(km s^{-1})	1557 — 1562
HI profile width 20%	(km s^{-1})	238 — 239
M_{HI}	(10^9 $M_\odot$)	7.24 — 7.53
HI maps		
Field size	($' \times '$)	5.6 $\times$ 5.6
HI map contours	(mJy/beam km s^{-1})	1, 100, 250, 750, 1000, 1250, 1500, 1750, 2000, 2250, 2500
	(10^{20} cm^{-2})	0.1, 6, 15, 45, 60, 75, 90, 105, 120, 135, 150
Velocity contours	(v_{max} - v_{min}, δv) (km s^{-1})	1465 - 1675, 15
Comments		
Companion α=02:16:26.90,	δ=05:56:24.0, v=1605	(1572-1655), $M_{HI} \simeq 10^8$ $M_\odot$



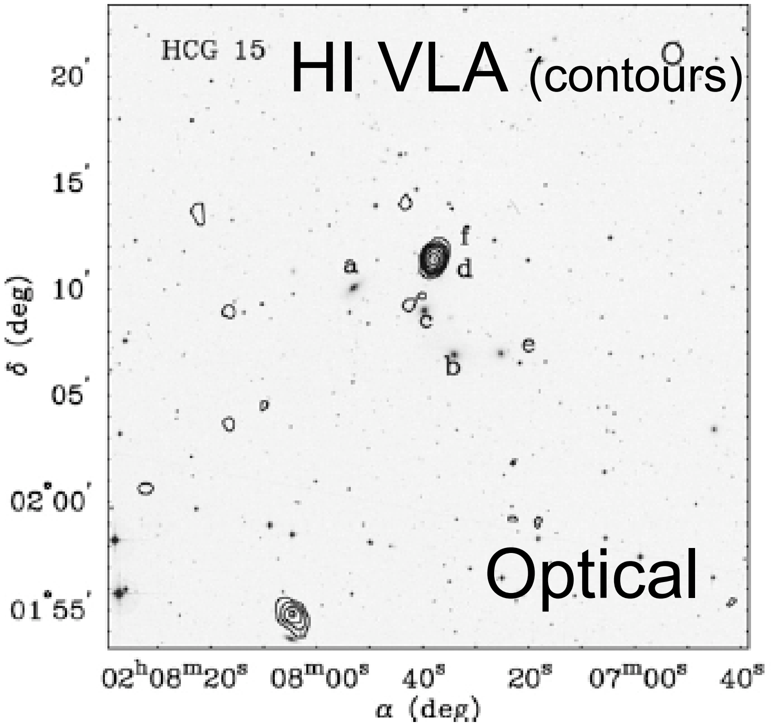


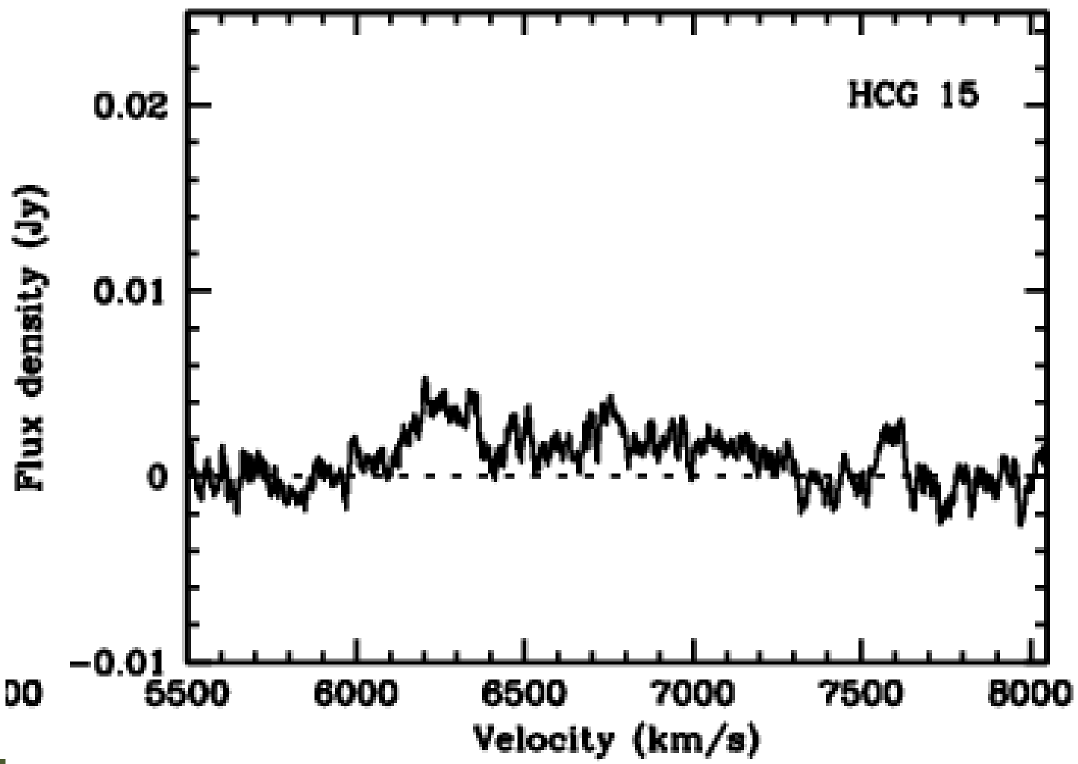
1405.5 km/s
1415.9 km/s
1426.3 km/s
1436.7 km/s
1447.1 km/s
1457.5 km/s
1467.9 km/s
1478.3 km/s
1488.7 km/s
1499.1 km/s
1509.5 km/s
1519.9 km/s
1530.4 km/s
1540.8 km/s
1551.2 km/s
1561.6 km/s
1572.0 km/s
1582.4 km/s
1592.8 km/s
1603.2 km/s
1613.7 km/s
1624.1 km/s
1634.5 km/s
1644.9 km/s
1655.3 km/s
1665.7 km/s
1676.2 km/s
1686.6 km/s
1697.0 km/s
1707.4 km/s
6.1
6
5.9
δ (deg)
34
33.9
33.8
α (deg)



NW
PA 23
SE
v (km/s)
1700
1600
1500
1400
-400
-200
0
200
Offset from center (arcs)

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-λ 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)

Virtual Observatory: ALMA archive/tools

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

Virtual Observatory: ALMA archive/tools

-Development of a Radio Data Cube Data Model (RDCDM) suitable for the ASA, to be submitted for approval and discussion to the DMWG

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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

Virtual Observatory: MOVOIR TOOL

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…

ALMA EXPLOITATION: TOOLS

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