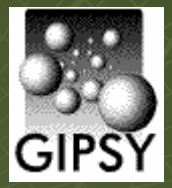
ALMA 3D: Analysis, visualization and VO tools for datacubes



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OUTLINE

- **Context:** AMIGA project
- **Motivation:** ALMA
- **Complementary work:** VO-archives & tools
- **ALMA exploitation:**
  - VO-compliant Archive
  - VO-Tools for high level analysis of cubes, special emphasis on kinematics/dynamics

CONTEXT

AMIGA project:

Analysis of the interstellar Medium of Isolated GAlaxies

Starts in 2003 @IAA with funding from PNAYA

Since 2006 Coordinated project (L. Verdes-M)

IAA-group + IRAM-30m @ Granada

January 2009: **AMIGA^3** starts

International collaboration:

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

CONTEXT

Need for a reference sample of isolated galaxies

Multiλ statistical study of ISM ~1000 galaxies

Build & analyse the catalog (ISM – dynamics - SF – AGN - bars)

(see Dani Espada's talk)

Make it public: VO interface with search utilities

Observational expertise:

- single dish + interferometry
- cm, mm, extension to submm:

Intensive use of SMA, submm-calib, ALMA CSV

Since 2005 formation of a team of 3 software developers with complementary profiles

(see V. Martínez's poster)

MOTIVATIONS

AMIGA is based on

multi-λ astronomy, with emphasis at radioλ

intensive analysis of 3D data:

- Few radio data available in archives (not to mention VO…)
- Optical/IR data more often available, but too diverse queries
- VO:

  essential for multi-λ astronomy

  uniform access to the data
- Need for powerful soft package for datacube analysis

Actions: radio-VO

Access	Exploitation
Archives	Tools

ARCHIVES

RADAMS:

Radio Astronomy DAta Model for Single-dish telescopes

1st VO data model for single dish

- VO-compliant: based on existing IVOA data models + development of new specific standards
- Extensible: additional metadata can be provided for different instruments, observing modes, switching modes…

- Conceived for DSS-63 Robledo antenna (+LAEFF-INTA)
- Revised, extended and implemented for IRAM-30m

(J. Santander 2006, DEA; IVOA Note 0.66, Sep 07)

TOOLS

- Existing VO-enabled analysis tools are mostly optical
- Existing radio astronomy tools not VO-aware

Need for VO-enabled radio oriented analysis tools

Solution: INTEROP

Not producing new soft but adding VO functionalities

Intercommunication in the least intrusive way

TOOLS

MOVOIR Development (J. D. Santander, PhD)

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, VOspec…

DEVELOPMENTS FOR ALMA

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

DEVELOPMENTS FOR ALMA

Already planned developments

- ALMA Science Archive Requirements Document:
  ASA will be VO-compliant.
- Support for proposals preparation via the ARCs
- Automatic processing: fully calibrated science products
- Data reduction: CASA (AIPS++ evol for ALMA; Python)

  Transformation UV-image

  Spectral line analysis, fitting, catalogs

  Fundamental image structure: cubes

  Processing of cubes (integration, rotation, filtering, clipping)

  Visualization + specific tools for SS objects and pulsars

DEVELOPMENTS FOR ALMA: ARCHIVE

AMIGA^3 developments:

ALMA archive in the VO

Collaboration with ESO-Archive team (G. Raffi, A. Wicenec):

- support from head of the Archive
- inputs from Archive Users
- interaction with IVOA Data Modeling Working Group

Characterization of the ALMA Archive:

- Study the mapping between the ALMA data model, the database implementation, and the VO data models

(see J. D. Santander's poster)

DEVELOPMENTS FOR ALMA: ARCHIVE

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

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

(see J. D. Santander's poster)

DEVELOPMENTS FOR ALMA: TOOLS

AMIGA^3 developments:

High-level analysis tools for 3D data

ALMA not expected to have them

GIPSY (Groningen Image Processing System)

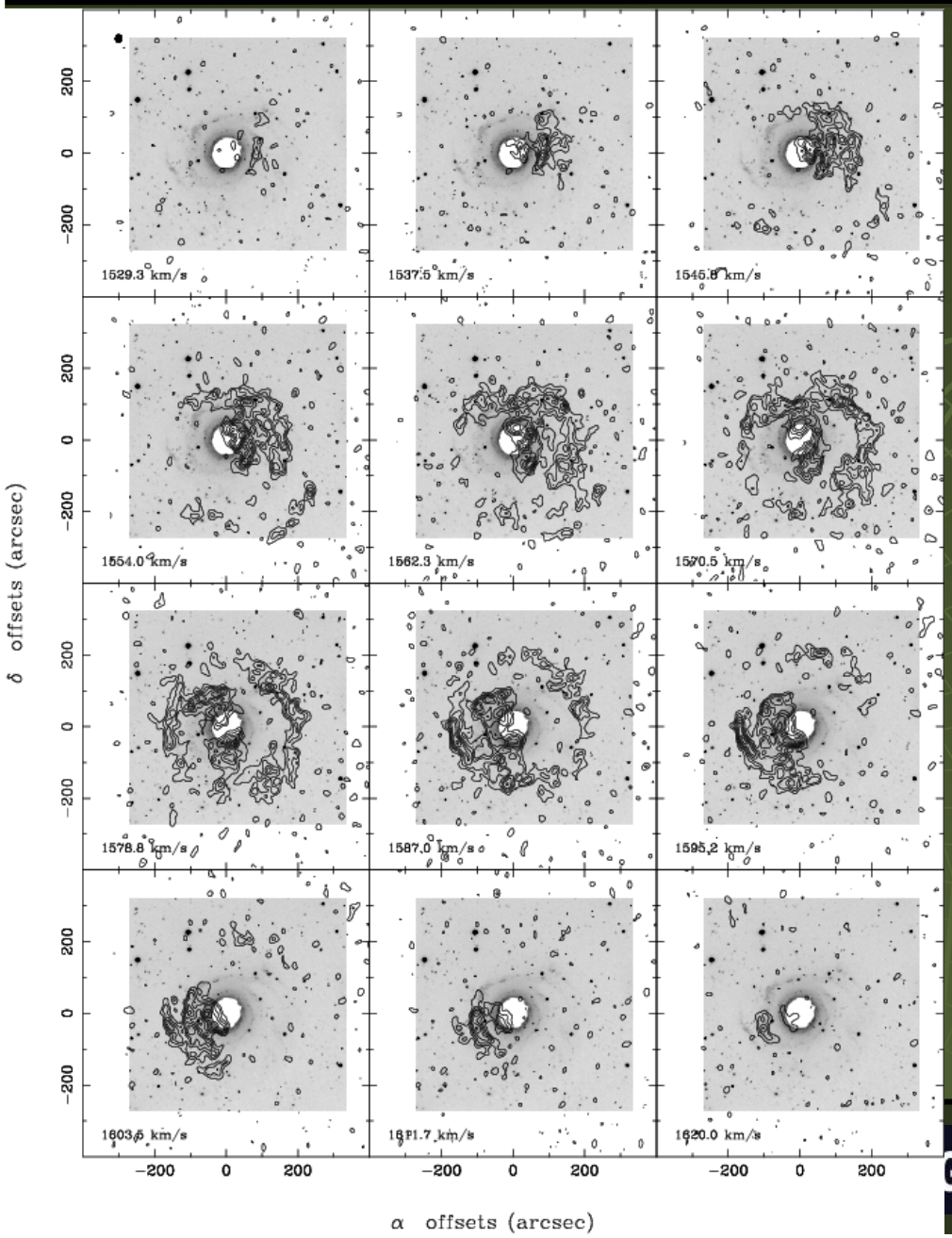
One of oldest + most powerful packages available to visualize and analyze multiD data

Developed at Kapteyn Astronomical Institute for WSRT

Oldest, but:

Ha kinematics of the SINGS nearby galaxy survey (Dicaire et al 2009)

DEVELOPMENTS FOR ALMA: TOOLS



Channel maps

(Verdes-Montenegro et al 2002)

DEVELOPMENTS FOR ALMA: TOOLS

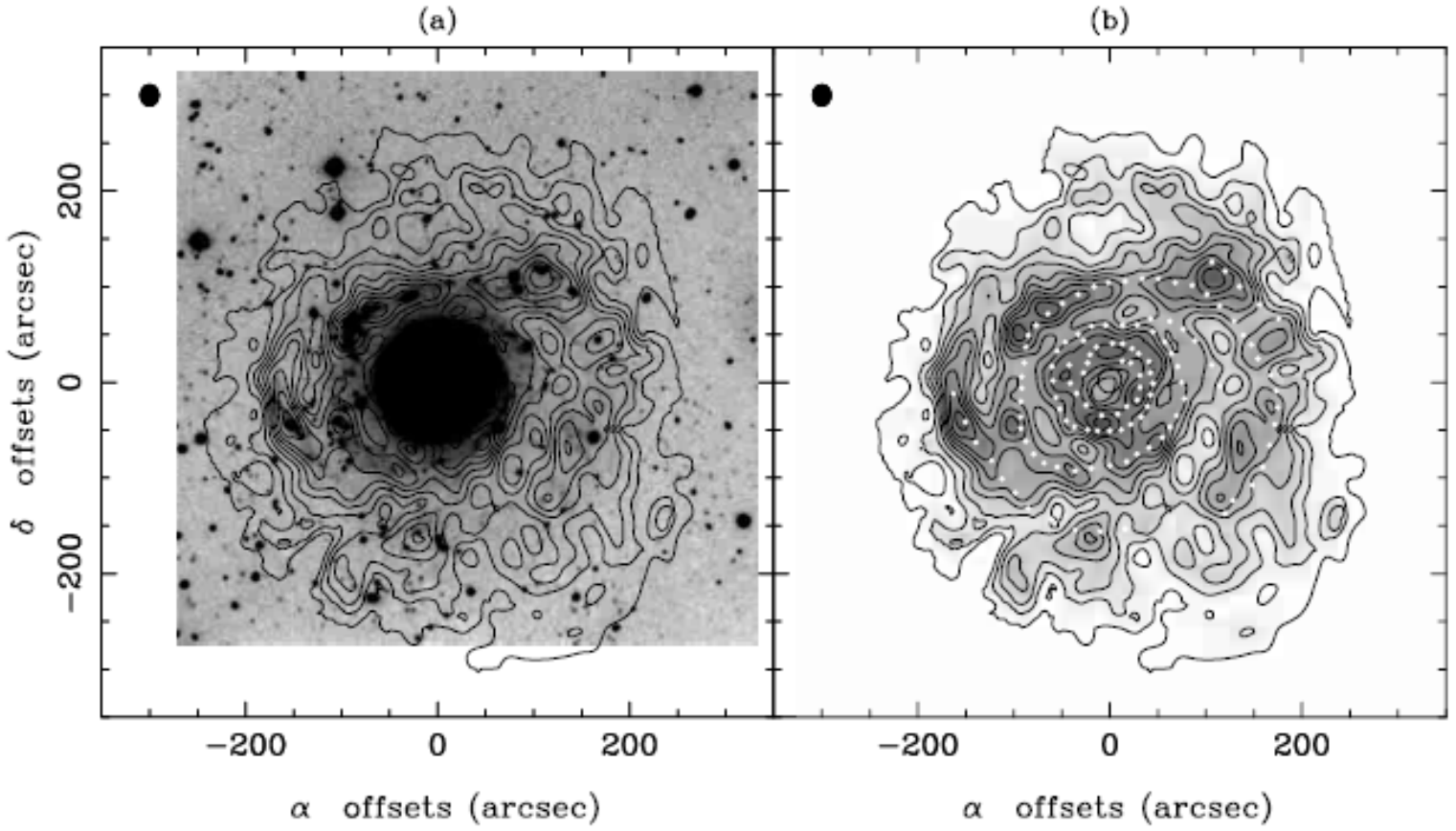


Fig. 6. a) Contour map of the HI column density distribution in NGC 3642 overlapped on the R image. The contours are 1.1, 3.4, 5.6, 7.9, 10.2, 12.4, 14.7, 16.9, 19.2 and 21.4×10^{20} atoms cm^{-2}. b) Greyscale map of the HI column density distribution with contours as in a). The main features are marked as dots. The synthesized beam ($21\farcs4 \times 18\farcs4 - \alpha \times \delta$) is plotted in the upper left of both panels.

HI column density distribution

DEVELOPMENTS FOR ALMA: TOOLS

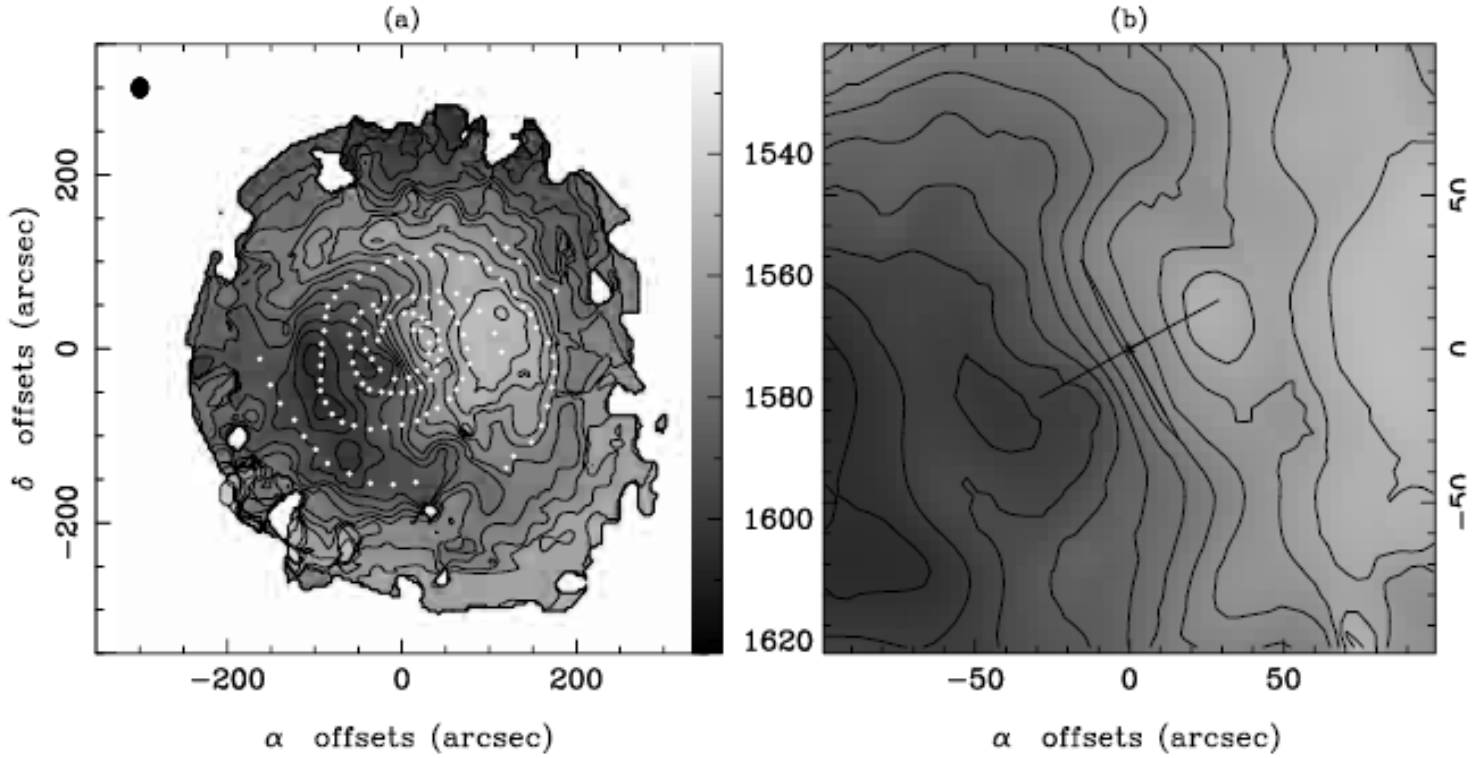


Fig. 7. a) Map of the first–order moment of the radial velocity field where both iso-velocity contours and greyscale are shown for clarity. The scale goes as in the wedge, where the numbers indicate heliocentric velocities in km s^{-1}. The contours go from 1532 to 1602 km s^{-1} with a step of 5 km s^{-1}. The main spiral features are marked as dots. The straight line indicates the direction of the position-velocity cut shown in Fig. 8. The beam size is $21.''4 \times 18.''4$ and is plotted in the upper left. b) Central part of the velocity field shown in a). The major and minor axis directions are indicated, and a cross indicates the optical center position (see Sect. 3.2).

Velocity field

(Verdes-Montenegro et al 2002)

DEVELOPMENTS FOR ALMA: TOOLS

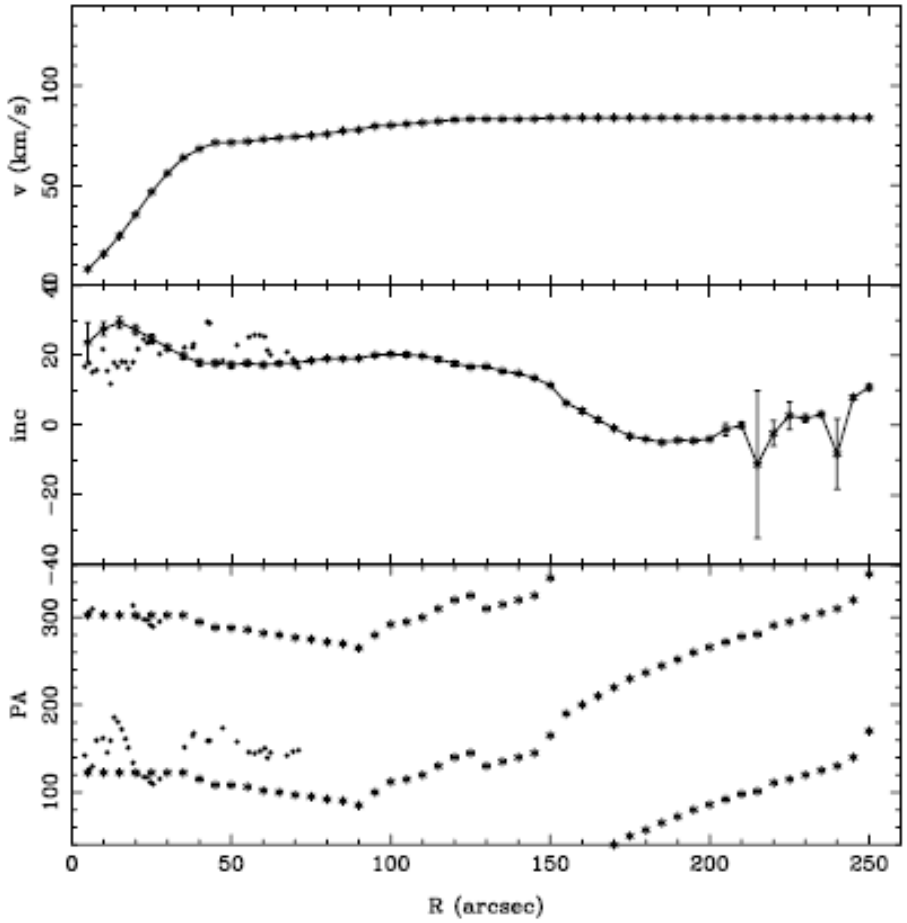


Fig. 9. a) Rotation curve assumed for the modelling of the velocity field. The best fit to this curve and to the observed velocity field is given by the combination of inclination and position angle plotted in b) and c) [illegible] the isophotal fitting of the optical *R* image (Fig. 4). Angles are measured from North

Parameters of the modelled velocity field

(Verdes-Montenegro et al 2002)

DEVELOPMENTS FOR ALMA: TOOLS

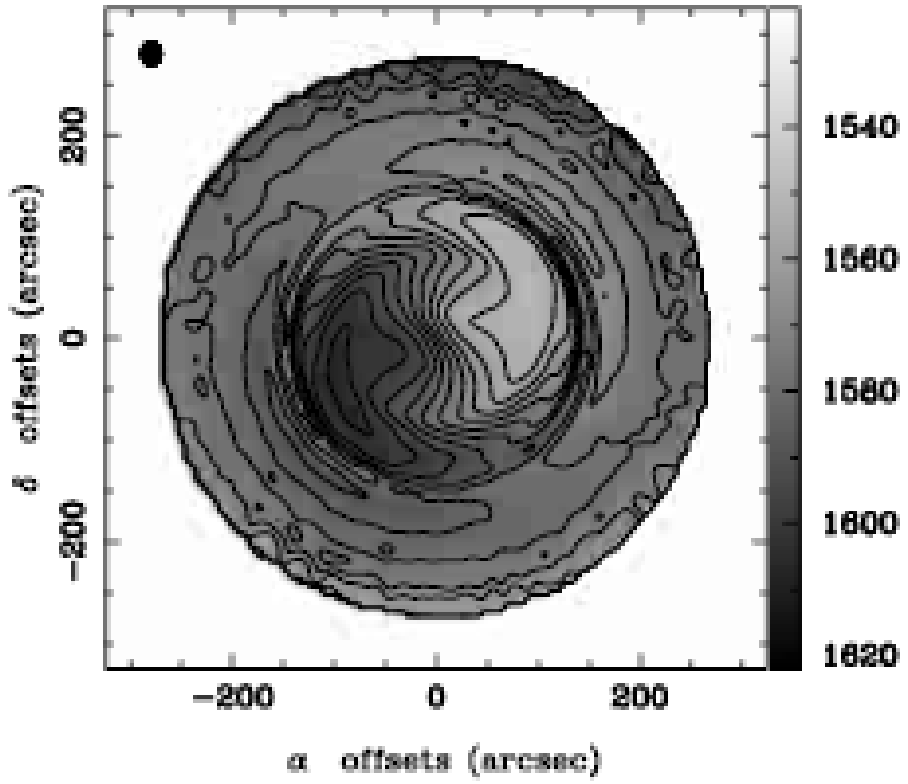


Fig. 10. First-order moment of the modeled channel maps obtained with the geometrical parameters plotted in Fig. 9.

Map of the first-order moment of the modeled channel maps

DEVELOPMENTS FOR ALMA: TOOLS

AMIGA^3 development, in collaboration with Kapteyn Institute and Spanish VO group

GIPSY upgrade

- Integration in the VO
- Full compatibility with ALMA data
- Usability in order to make it available to a larger user base
- Not only ALMA but other radiointerferometers, FP, IFUs

DEVELOPMENTS FOR ALMA: TOOLS

Definition of functional and technical specifications:

Use cases will be elaborated by scientists via a survey:

please, FQ user of 3D data in the conference contact us if you would like to contribute to the survey (5 min to fill it)

- Documentation
- Easily installable and maintainable
- Intuitive graphical user interfaces:

to fully exploit the (wealth) of input parameters in GIPSY (e.g: vsys, pa, I, vrot, vexp, center, side, weigth, etc)

DEVELOPMENTS FOR ALMA: TOOLS

Ensure data compatibility:

- Integration in the data environment of ALMA
- In the CASA core system

Implementation of VO access and tools:

- Available to a larger scientific user base
- Enables efficient multiwavelength comparisons

Study of implementing GIPSY on the server:

- In order to supply VO services based on distributed computing analysis (GRID).

DEVELOPMENTS FOR ALMA

- Collaboration with ESO to produce an ALMA VO-compliant archive:
  - Access to common VO services
  - More efficient multiwavelength comparisons
  - Implies Spanish contribution to (now unenxistent) IVOA standards for cube data models
- First high-level, friendly, VO-aware analysis package for radio 3D data, applicability to multiλ, fully compatible with ALMA

Coordinated integration of GIPSY + ALMA archive in VO

SUBNODE

- Spanish VO radio expertise
- Software developments for high-level exploitation of ALMA cubes
- Contribution to submm calibration (SMA, ALMA CSV)
- Large extragalactic program running at SMA

(so far 40 galaxies,

end 2009 100 gal)