

Data Archives and Radio Surveys

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Multiwavelength Summer School

Layout

- Surveys and Radio Surveys
 - What is available – blind and targeted surveys
- Data Archives
 - How do you use them?
 - Virtual Observatory
 - Example case

Surveys

- Survey (noun): *1. a detailed examination or investigation, e.g., to find out public opinion or customer preference*
- For us: Astronomical Survey: *Study of regions of the sky using telescopes for imaging or mapping those* ⇒
Astronomical Catalogs

Surveys

- High-Energies
 - RASS
- Optical
 - Palomar
 - Digitized Sky Survey
 - [Sloan Digital Sky Survey](#)
 - ...
- Infra-Red
 - IRAS
 - 2-micron All-Sky Survey
 - Akari Survey
- Radio
 - NVSS
 - WENSS
 - CLASS
 - Ohio Sky Survey
 - ...
- Multi-Wavelength
 - GOODS
 - COSMOS
 - ...

Radio Surveys: History

- Optical astronomers have their catalogs since ages
 - Uranometria, Johann Bayer (1603)
 - Star Atlas, Flamsteed (1725)
 - Messier Catalog (1781): Mnnn
 - Bonner Durchmusterung ()
 - New General Catalogue (1880s): NGCnnnn
 - Henry Draper Catalogue (1918-1924): HDnnnnnn
 - Uppsala General Catalogue (1973), UGCnnnnn
 - Hipparcos Catalogue (1997) ...
- Radio Astronomy was born in the 1930s
- First images were performed by Grote Reber
- Construction of the first large telescopes. First surveys performed:
 - Cambridge (2C, 3C, 4C)
 - Parkes Telescope (PKSnnnn–nnn)
 - NRAO 300-ft Telescope (NRAOnnn)
- Advances in sensitivity, data acquisition, more specific surveys

Ingredients of the radio sky

- Galactic continuum radiation
 - Magnetic field and cosmic rays: synchrotron ($\alpha = -0.55$)
- Interstellar medium
 - Spectral lines: Neutral H (HI) at $\lambda 21$ cm, ionized H (HII), rotational and vibrational lines for another molecules (O_2 , N_2 , CH_4 , CO_2 , etc.)
 - Supernova remnants: synchrotron
- Stars
 - Circumstellar masers (SiO, H_2O , OH)
 - Novae
 - Binaries and flare stars (recurrent novae, X-ray binaries): non-thermal
- Pulsars
 - Neutron stars emitting coherent radiation with $\alpha = -2 \pm 1$
- Radio galaxies and quasars
 - Radio galaxy lobes: synchrotron
 - AGN cores: synchrotron, flat spectrum (parts self-absorbed)
- Cosmic microwave background
 - Thermal radiation from the Big Bang

The sky at 1.4 GHz at 45'' resolution

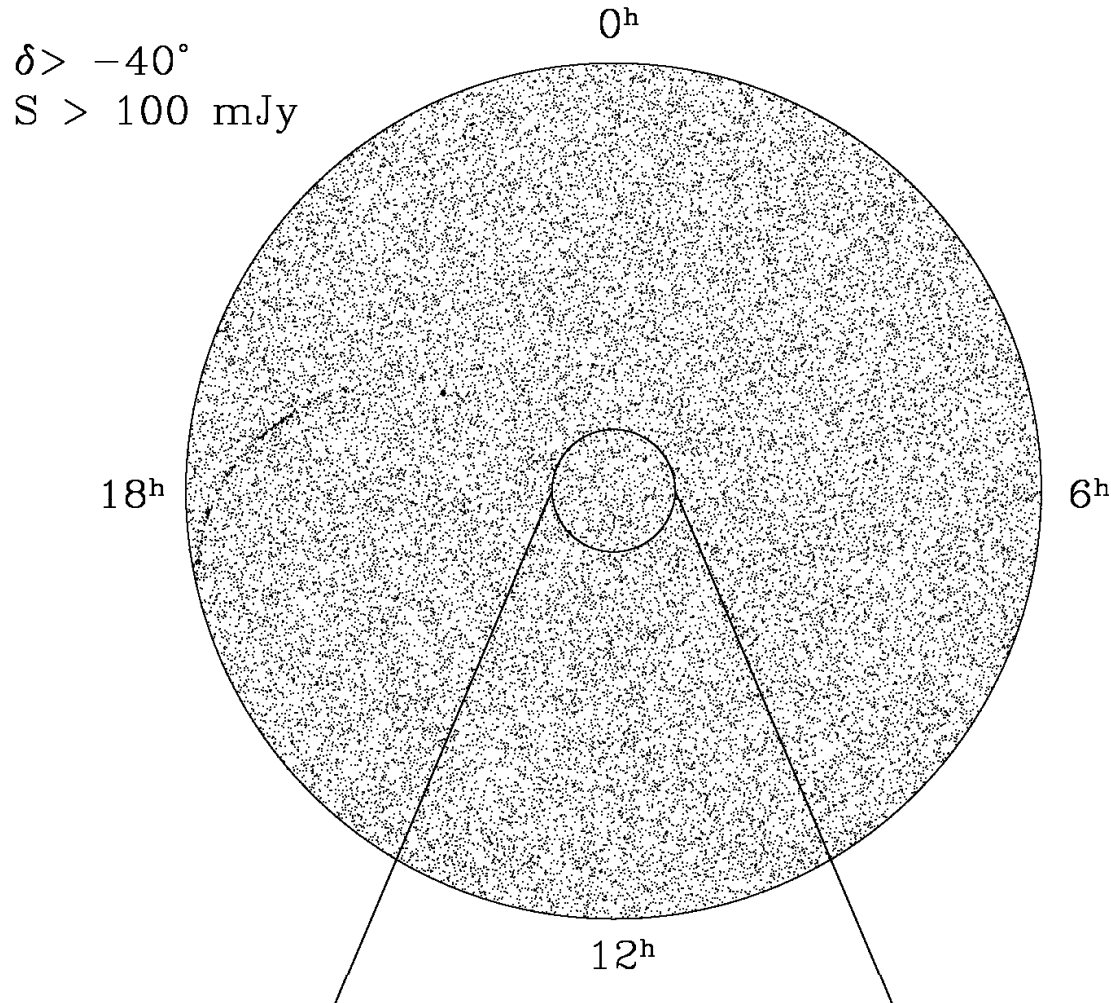


Image: Condon et al.

The sky at 1.4 GHz at 45'' resolution

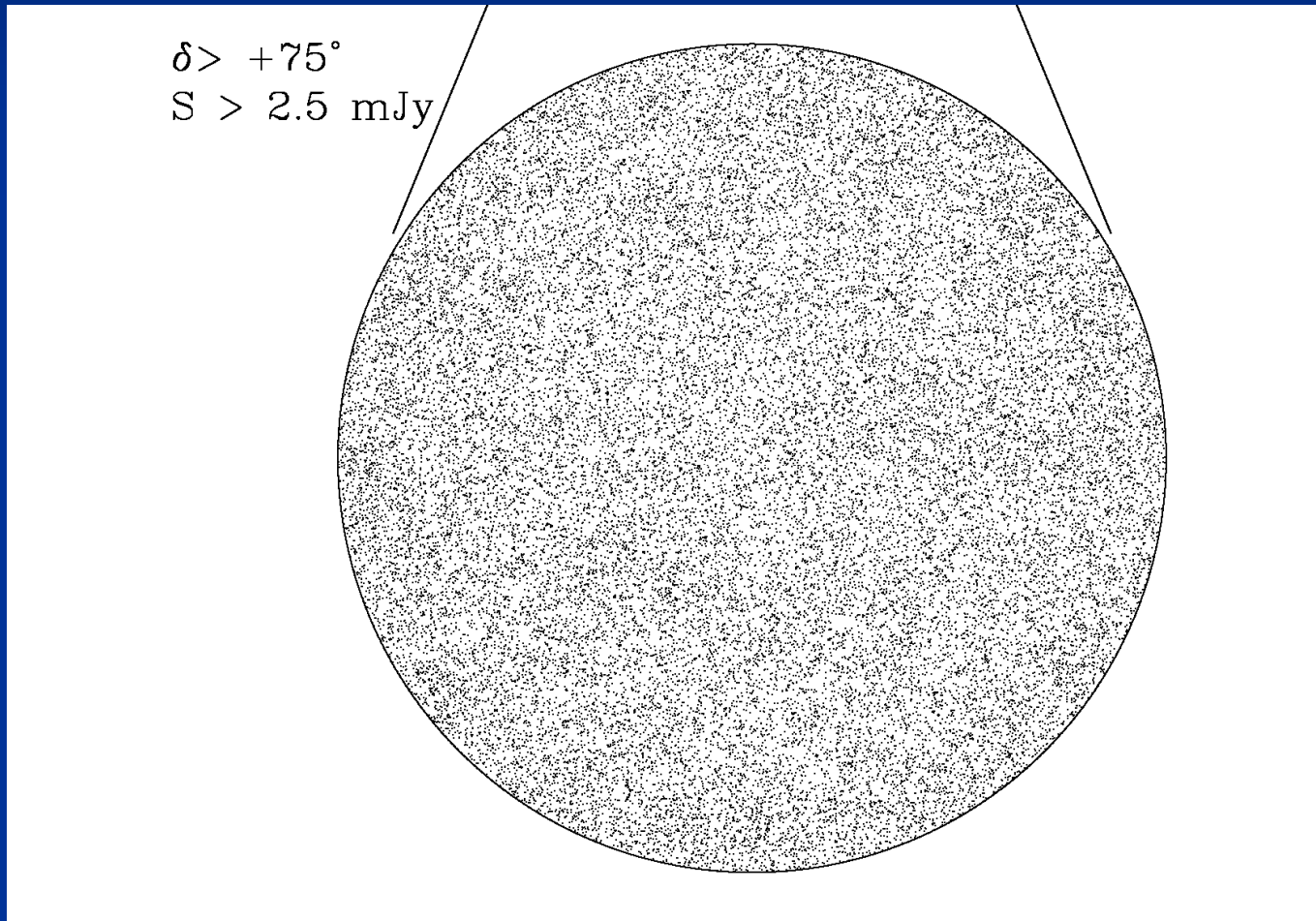
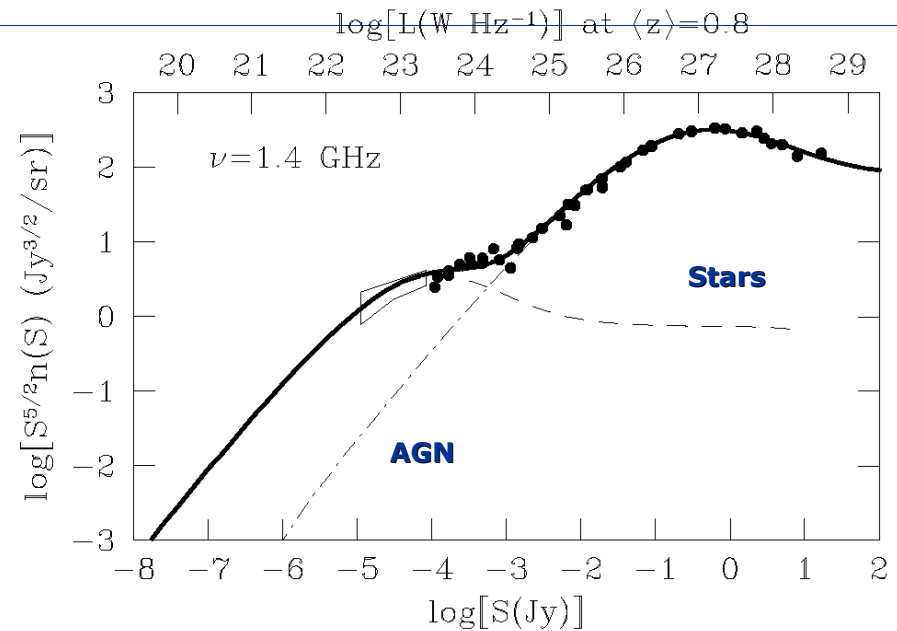
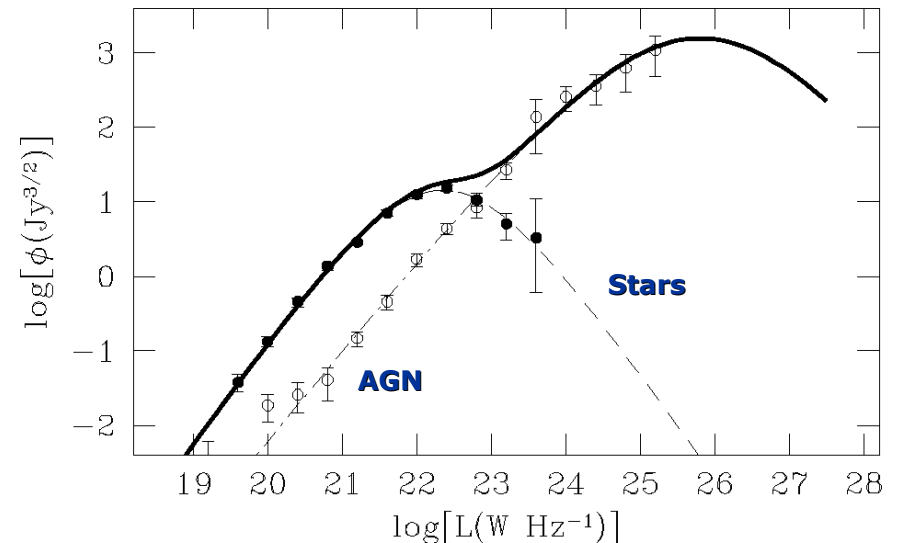


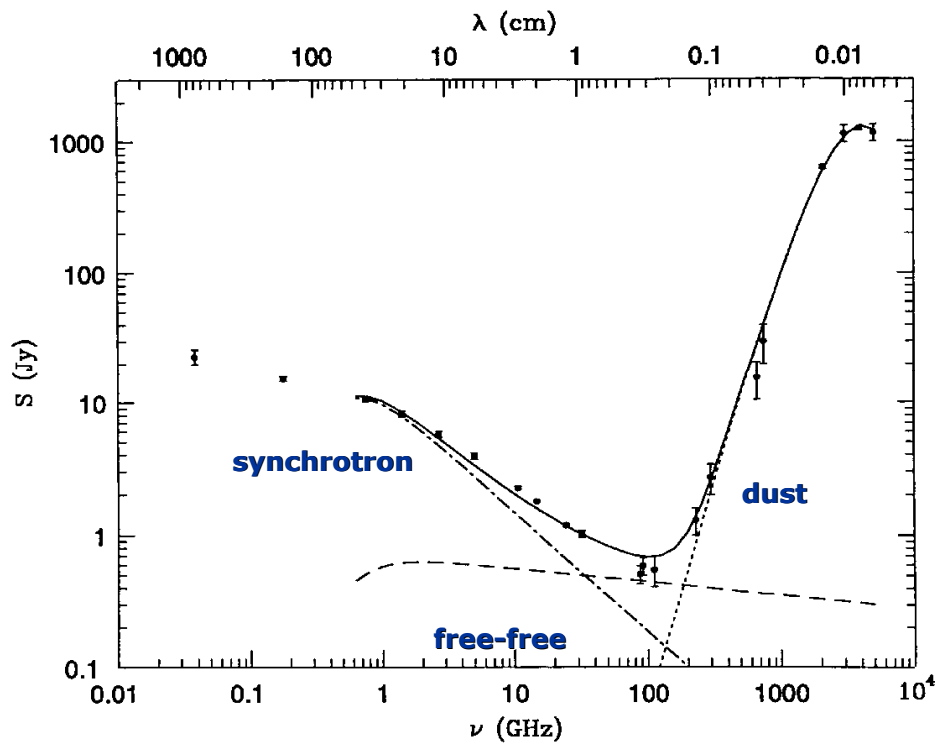
Image: Condon et al.

Flux density versus luminosity of radio sources

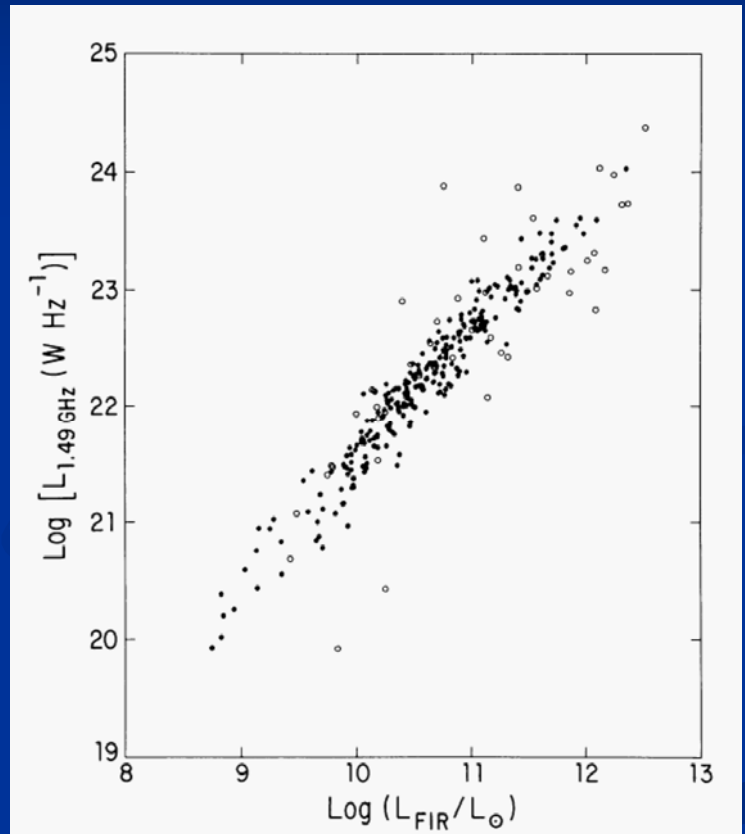
- Evolution $10\times$ in luminosity \rightarrow few nearby sources, $\langle z \rangle \sim 1$ (cosmic downsizing)
- "shell" $\rightarrow L \propto S$
- AGNs at high L, S
- Star-forming galaxies at low L, S



Low Luminosity: Star-forming Galaxies



M 82 spectrum



FIR/Radio Correlation
for Starburst Galaxies

Condon et al.

Classes of Radio Surveys

- Blind Surveys:
 - (parts of) all-sky surveys like NVSS, WENSS, etc.
- Targeted surveys:
 - deep surveys (ATLAS, CDF)
 - imaging of celestial fauna (HI)
 - most VLBI surveys (CJF, 2cmS/MOJAVE, TANAMI)

Toys



VLA



WSRT



VLBA



Effelsberg



MERLIN



GMRT

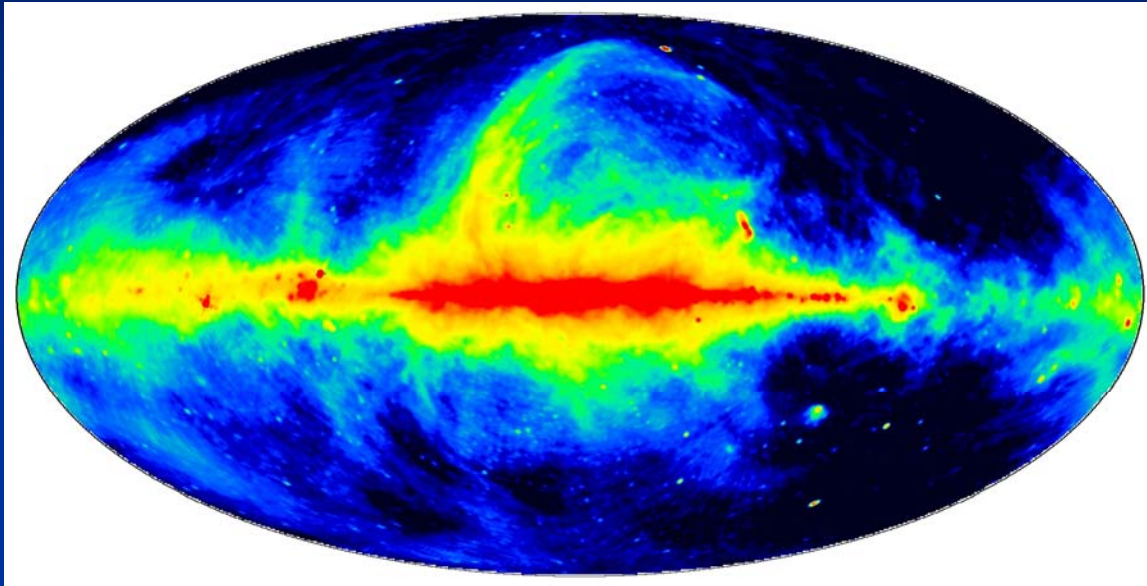


MOST

Blind Surveys

- Covering almost the entire sky below 1.4 GHz
- Typical resolution of 50"
- Root-mean-square noise of the order of mJy
- Provide post stamps (JPG/FITS files)

Bonn 408 MHz Survey



- Haslam et al. 1974; Jodrell Bank 250-ft + Effelsberg 100-m + Parkes 64-m
- “Classical” picture

<http://www.mpifr-bonn.mpg.de/survey.html>

The newer Cambridge Surveys



6C	151 MHz	0.3 Jy	4.2' × 4.2' cosec δ	2.8 Sr	Hales et al. 1993
7C	151 MHz	0.15 Jy	70" × 70" cosec δ	4 Sr	Visser et al. 1996
8C	38 MHz	1 Jy	4.5' × 4.5' cosec δ	0.8 Sr	Rees 1990
<u>9C</u>	15 GHz	0.01 Jy		0.15 Sr	Waldram et al. 2003

Main Blind Surveys of the Nearby Universe

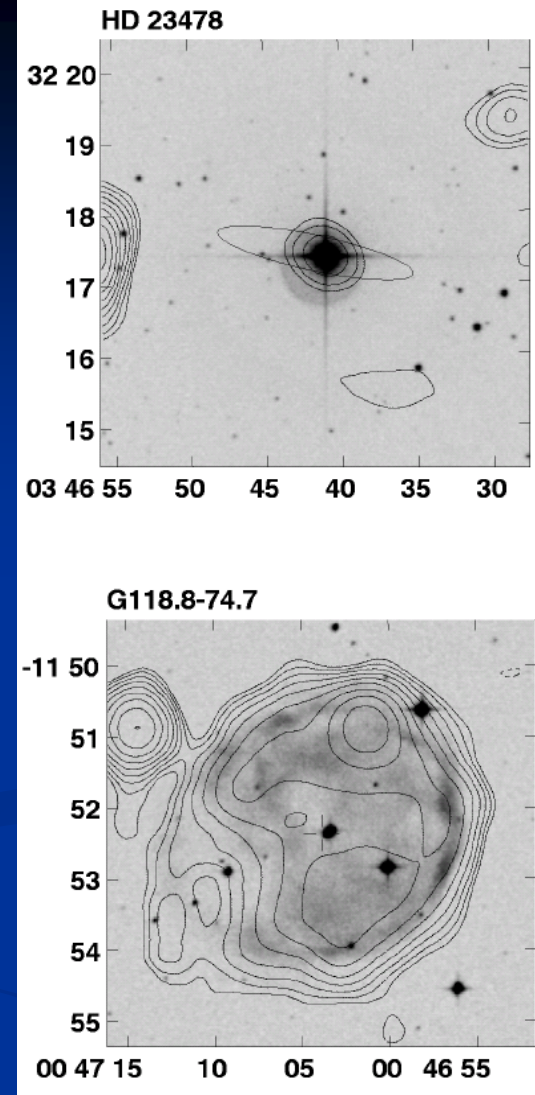
<u>NVSS</u>	1.4 GHz	2.5 mJy	10.3 Sr	Condon et al. 1998
<u>FIRST</u>	1.4 GHz	1 mJy	2.6 Sr	Becker et al. 1995
<u>SUMSS</u>	843 MHz	5 mJy	6 Sr	Bock et al. 1999
<u>WENSS</u>	330 MHz	18 mJy	3.1 Sr	Rengelink et al. 1997
WISH	352 MHz	18 mJy	1.6 Sr	De Breuck et al. 2002
<u>VLSS</u>	74 MHz	500 mJy	9.4 Sr	Cohen et al. 2006

- Low redshift surveys
- For distant sources, new instruments are needed to get the whole sky population (EVLA, SKA)
- Low freq. observations are biased towards

NVSS

NRAO VLA Sky Survey

- Entire sky north of -40° , at $45''$ resolution and 2.5 mJy/beam limit.
- 2326 $4^\circ \times 4^\circ$ continuum cubes (Stokes I, Q, V) and 1.8 Mio discrete sources
- Most used and complete sky survey



Example of postage-stamp images (NVSS contour, DSS grey)
Condon et al. 1998

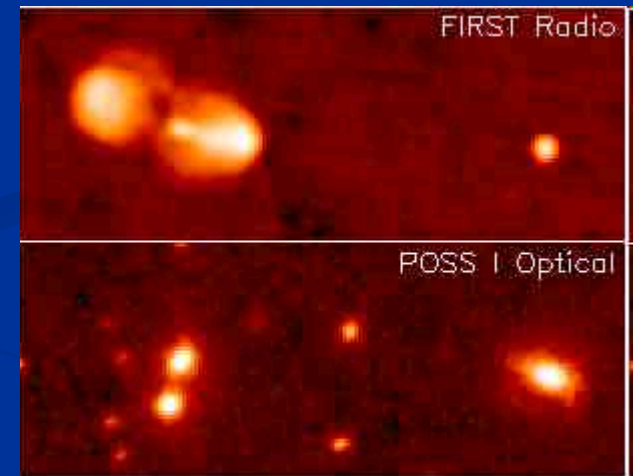
<http://www.cv.nrao.edu/nvss/postage.shtml>



FIRST

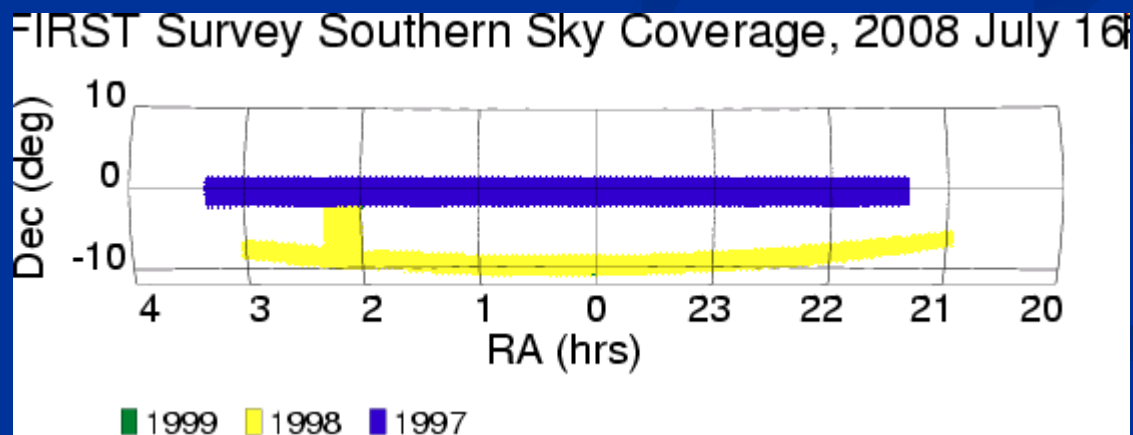
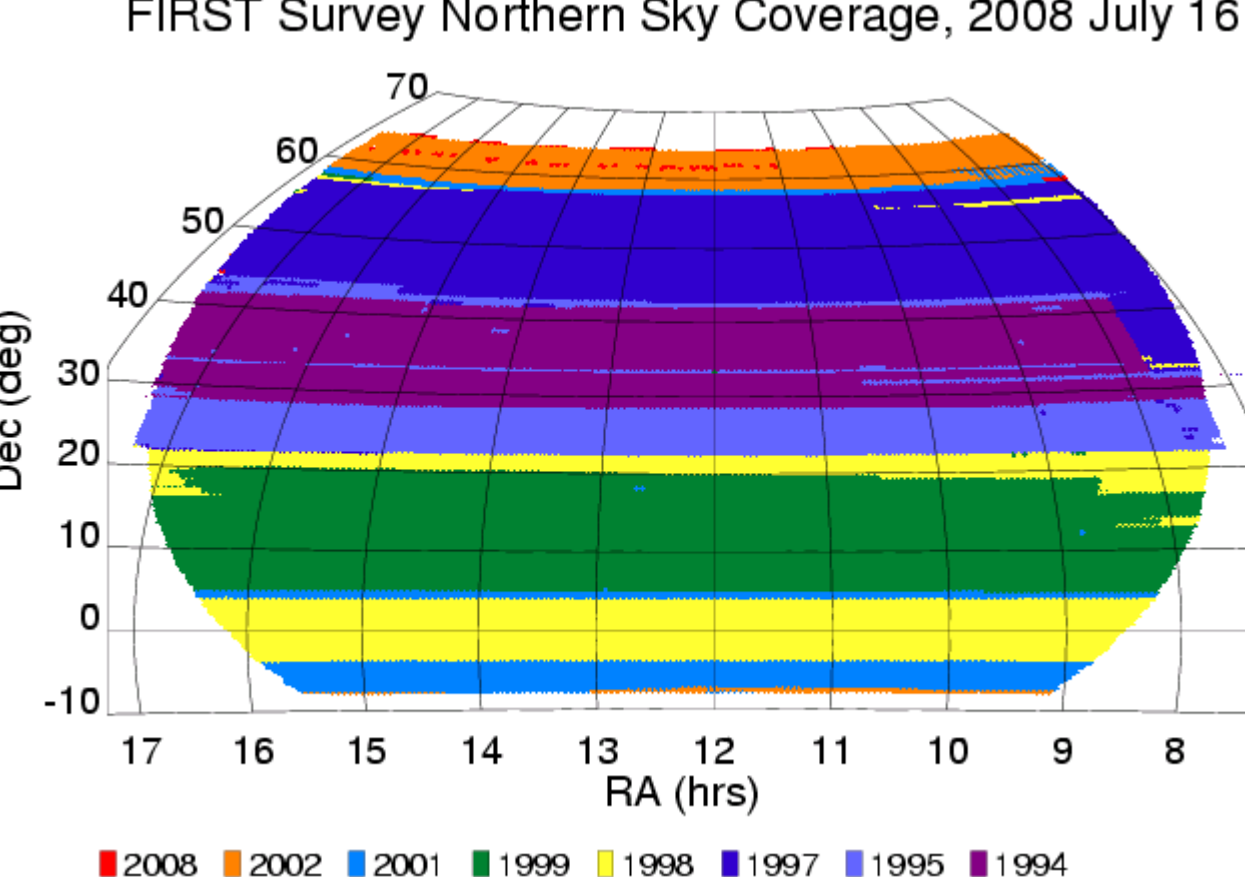
Faint Images of the Radio Sky at Twenty-cm

- High resolution ($5''$) of the north Galactic cap at 1400 MHz, above 1 mJy/beam
- 816000 sources
- Extension to South



<http://sundog.stsci.edu/top.html>

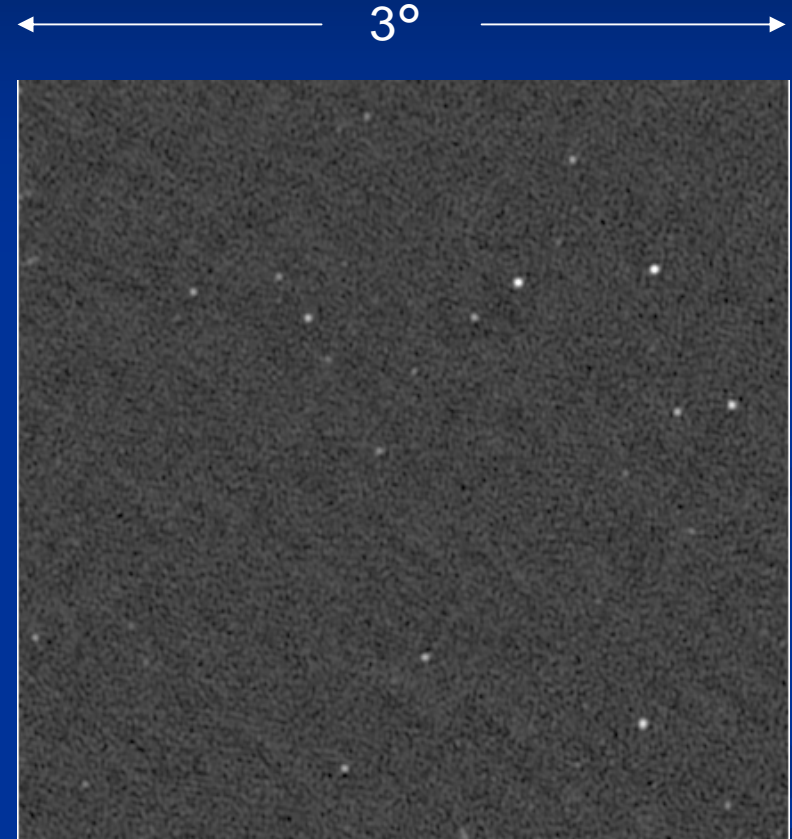
FIRST Sky Coverage



VLSS

VLA Low-Frequency Sky Survey

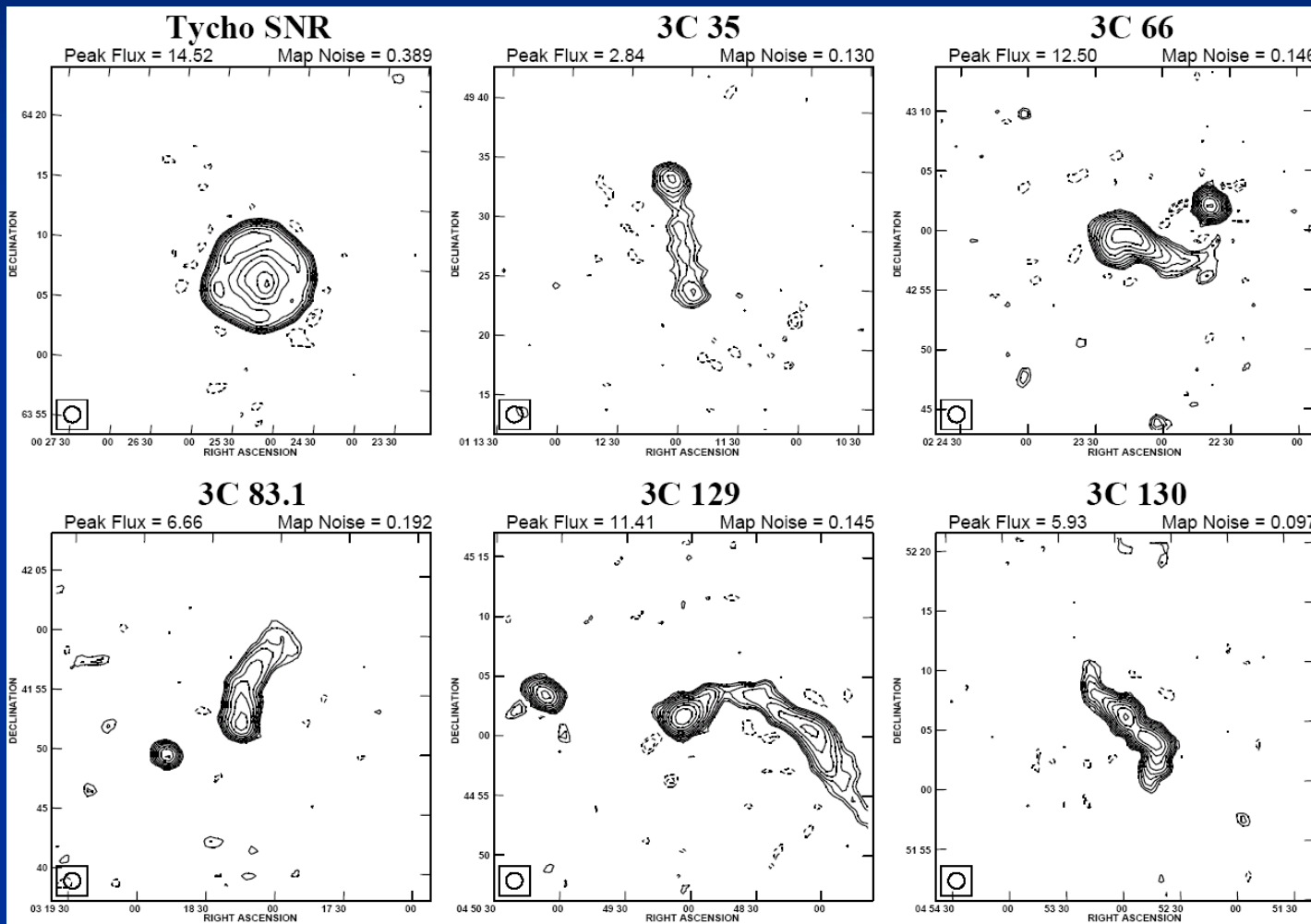
- Formerly known as 4MASS
- 74 MHz ($\lambda 4\text{m}$), 80" resolution, 0.1 Jy/beam noise
- 70000 sources
- Special analysis needed due to ionosphere; sidelobe confusion



<http://lwa.nrl.navy.mil/VLSS/>

VLSS Sample Images

Cohen et al. 2007, AJ, 134, 1245-1262



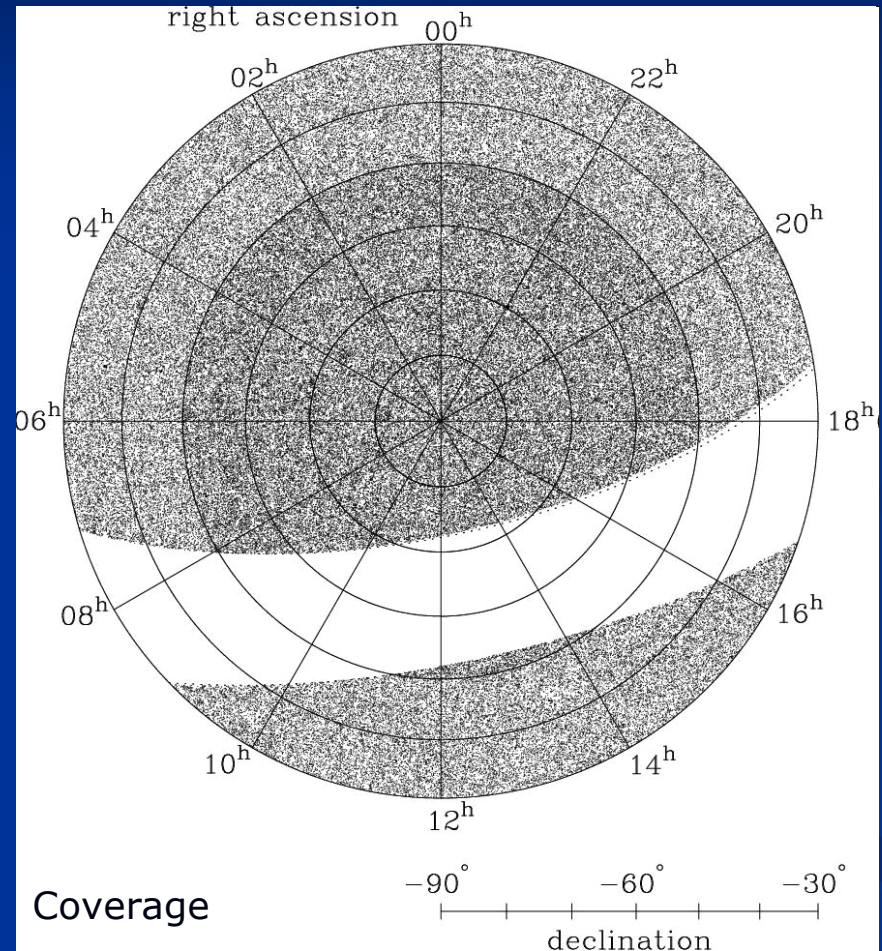
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SUMSS

Sidney University Molonglo Sky Survey

- Southern sky below -30° and $|b| > 10^\circ$, 843 MHz
 - complemented by MGPS-2 at the galactic plane (Murphy et al. 2007, MNRAS, 382, 382)
- Similar to NVSS in resolution and sensitivity
- 211000 sources

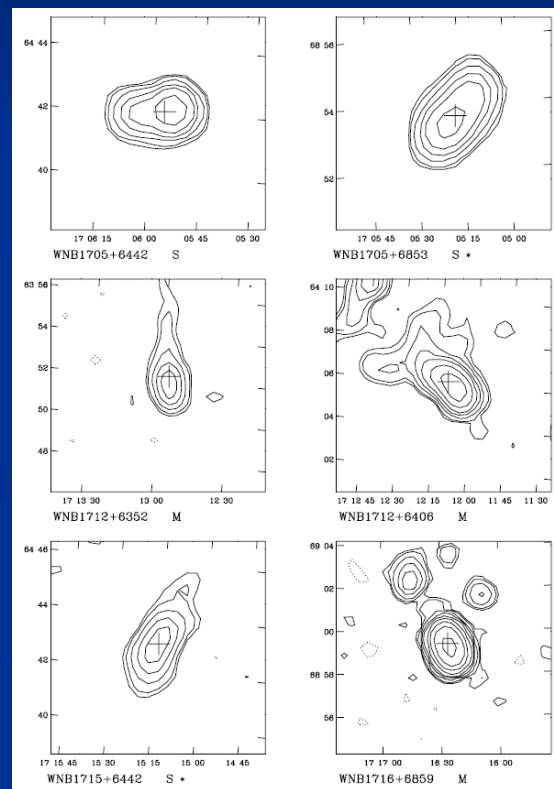


<http://www.physics.usyd.edu.au/sifa/Main/SUMSS>

WENSS

Westerbork Northern Sky Survey

- Northern sky, $\delta > +30^\circ$, 326 MHz, ($54'' \times 54'' / \sin \delta$) resolution, 230000 sources stronger than 18 mJy
- Extended to the South (WISH)



Extended sources
Rengelink et al. 1997

<http://www.astron.nl/wow/testcode.php?survey=1>

WISH

Westerbork in the Southern Hemisphere survey

- Extension of WENSS to the South, $-26^\circ < \delta < -9^\circ$, $|b| > 10^\circ$, resolution of $(54'' \times 54'' / \sin \delta)$, flux density limit at 18 mJy

<http://www.astron.nl/wow/testcode.php?survey=2>

Targeted Surveys

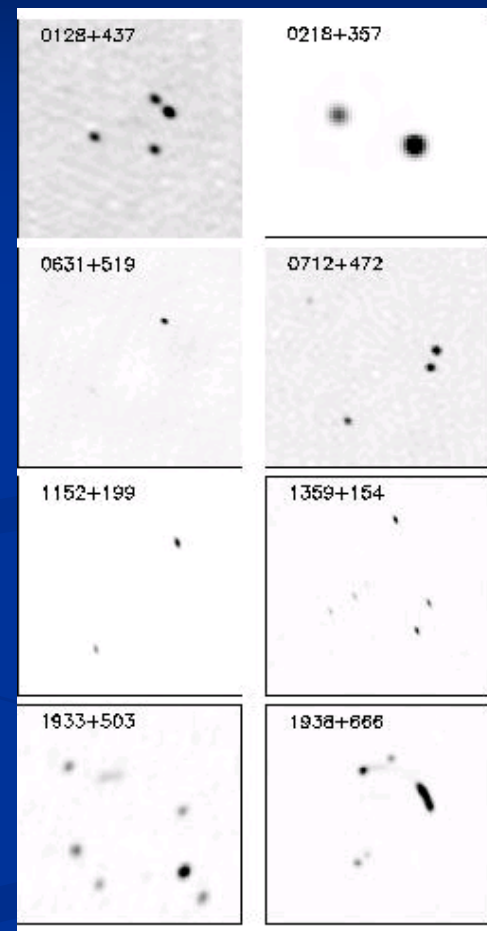
- Deep field surveys: commonly with a multi-band approach
- Stamp collection (and movie making): VLBI monitoring surveys, HI images, polarisation
- Examples...



CLASS

Cosmic Lens All-Sky Survey

- 11000 VLA snapshots at 8.4 GHz of sources with flat radio spectra ($\alpha_{(1.4-5)\text{ GHz}} > -0.5$) and $S > 30$ mJy at 5 GHz; resolution of $0.2''$
- Sources checked for evidence of grav. lensing (22 were found)
- Extension of JVAS (1992)
- Follow-up observations with MERLIN and the VLBA



MERLIN images of CLASS sources

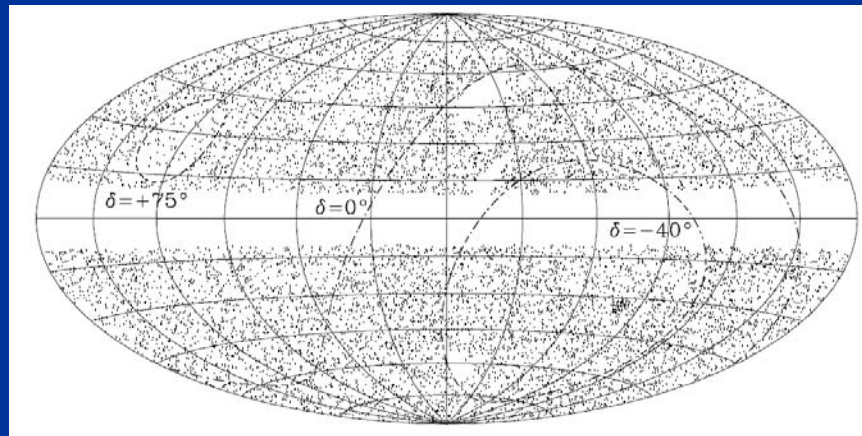
<http://www.jb.man.ac.uk/research/gravlens/class/class.html>

CRATES

Flat Spectrum Radio Source Catalog

- 8.4 GHz survey of 11000 bright flat-spectrum sources above 65 mJy (at 4.8 GHz) with VLA & ATCA
- Positions, sub-arcsecond structures and spectral indices

Healey et al. 2007



<http://astro.stanford.edu/CRATES/>

VLA-COSMOS

Cosmic Evolution Survey with the HST

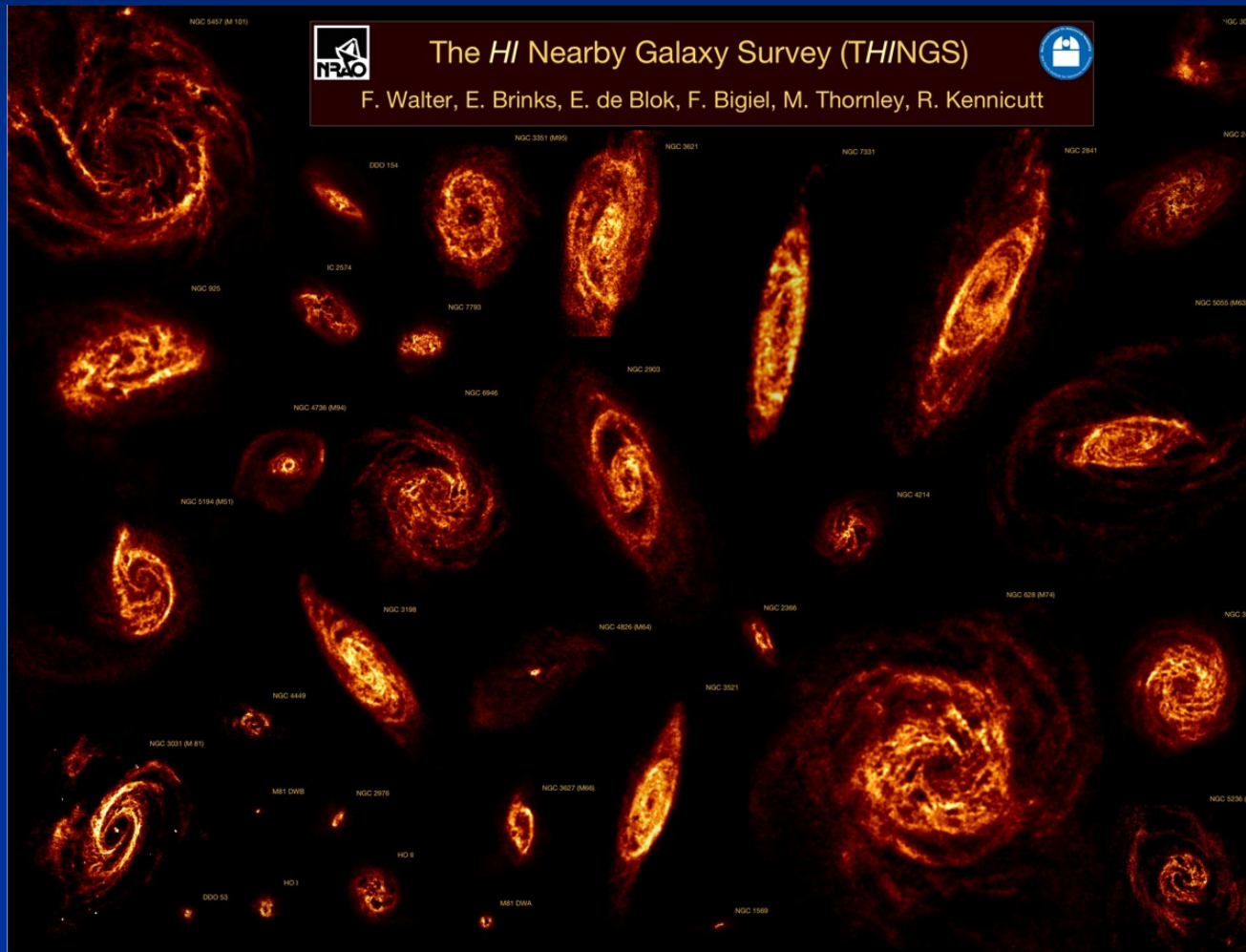
- COSMOS field:
X-ray to mm
survey
including VLA
observations:
 - 1.5" resolution,
10 μ Jy, 1.4 GHz
 - 2 square degree
deep field
 - 3500 sources



<http://www.mpia-hd.mpg.de/COSMOS/>

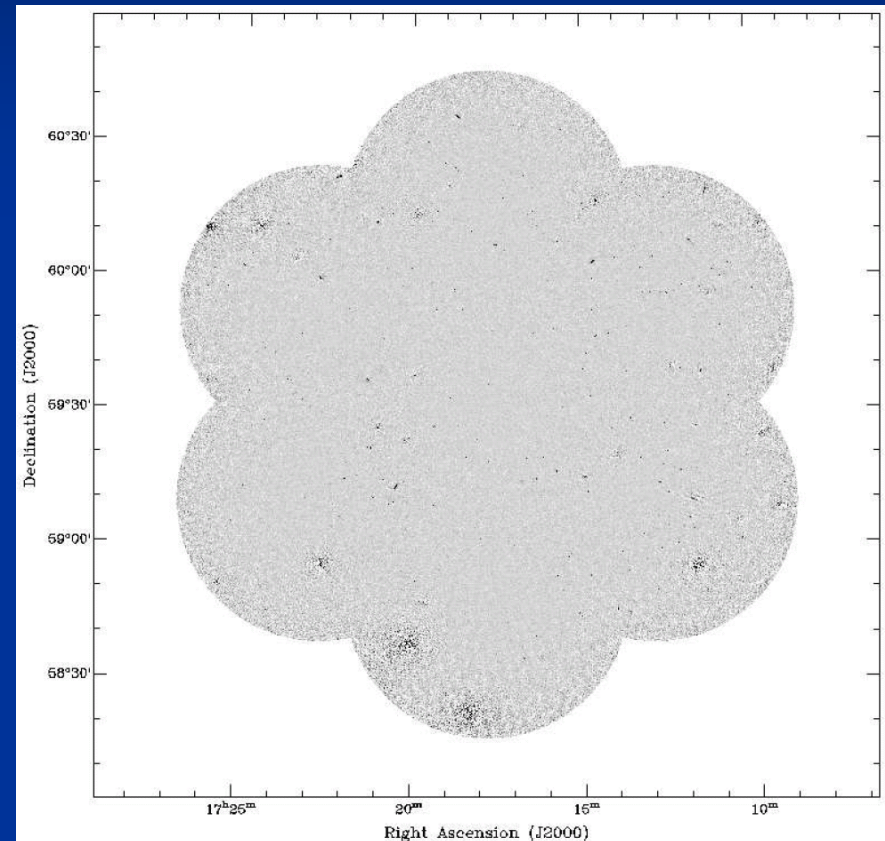
THINGS

The HI Nearby Galaxy Survey



Spitzer Extragalactic first-look Survey

- GMRT 610-MHz observations
- 4 sq. deg, $5.8'' \times 4.7''$ resolution at P.A. 60° , $30 \mu\text{Jy}$ rms noise
- 3944 sources

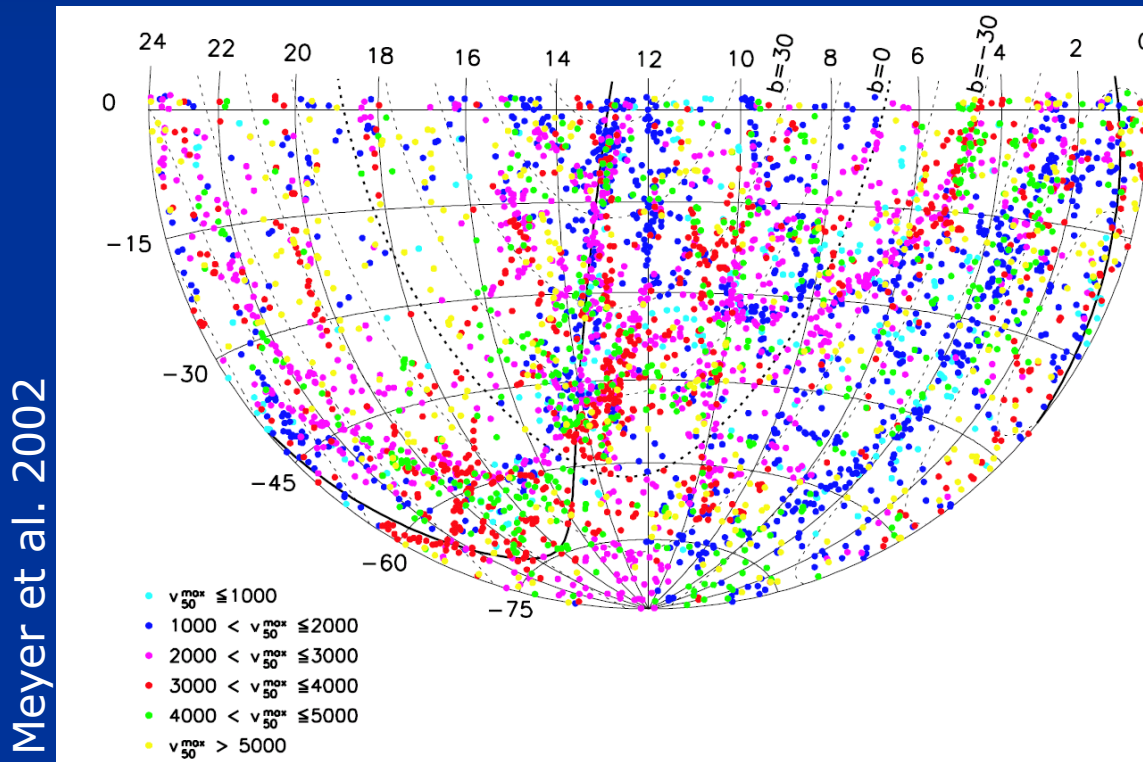


<http://www.mrao.cam.ac.uk/surveys/GMRT/FLS/>

HIPASS

HI Parkes Archive Sky Survey

■ Neutral Hydrogen survey in the South



<http://www.atnf.csiro.au/research/multibeam/release/>

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VLBI Surveys

- Designed to provide milliarcsecond resolution images of compact sources (usually AGN)
- Extensive surveys to get one image of a large sample of sources (ICRF, VIPS, VCS)
- Intensive surveys to monitor the structural evolution of selected sources (CJF, MOJAVE, TANAMI)

VLBI Surveys

CJF	18/6 cm	293	Complete	Pollack et al. 2003
ICRF/RDV	13/3.6 cm	~500		Ojha et al. 2004
VLBA Cal. Surv.	13/3.6 cm	>3400	Open, complete	Kovalev et al. 2007
VSOP/VLBA	6 cm	374		Fomalont et al. 2000
VSOP Survey	6 cm	~300		Dodson et al. 2008
VIPS	6 cm	1127	Open	Helmboldt et al. 2007
2 cm Survey	2 cm	250	Open, complete	Kellermann et al. 1998
MOJAVE	2 cm	≥ 133	Open, complete	Lister et al. 2009
VERA FSS / GaPS	1.35 cm	>500		Petrov et al. 2007
ICRFext	1.35 / 0.7 cm	~100		Lanyi et al. 2005
GMVA	3 mm	123		Lee et al. 2008

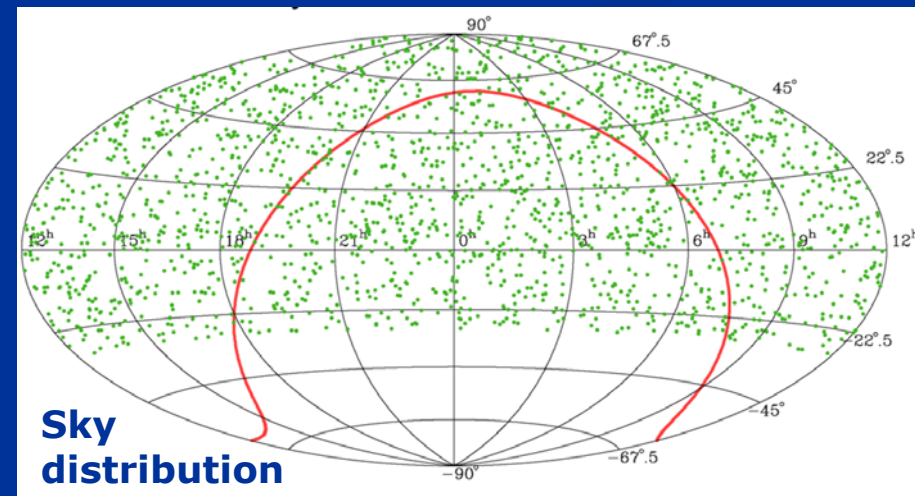
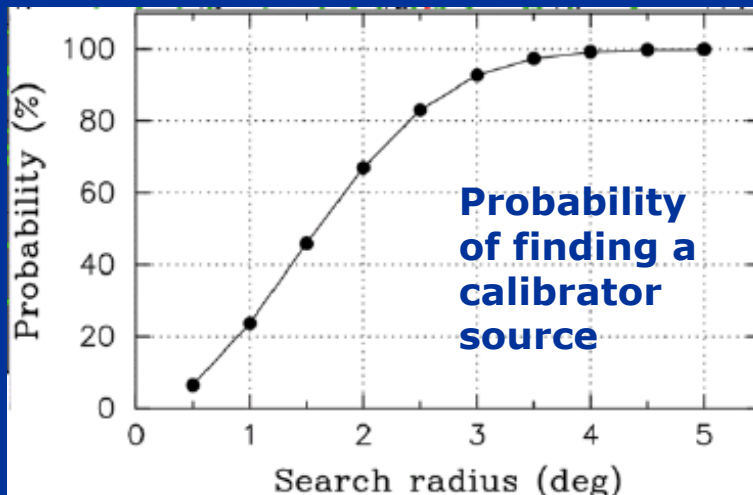
List compiled by Y.Y.Kovalev (2008)

VCS

NRAO VLBA Calibrator Source Survey

- Sample of compact radio sources in the Northern sky
- Needed for astrometrical, geodetical and astrophysical applications

Kovalev et al.



<http://astrogeo.org/vcs/>



The VLBA Imaging and Polarimetry Survey

- 5 GHz and 15 GHz imaging of 1100 AGN with the VLBA
- Parent sample: CLASS crossed with SDSS
- One-epoch survey, paving the way to Fermi observations

(Taylor et al. 2007, ApJ 658, 203)

<http://www.phys.unm.edu/~gbtaylor/VIPS/>

2cm Survey / MOJAVE

- Study of over 200 sources at 15 GHz with the VLBA at 1-mas resolution
- Database collected since 1994
- Data on the brightest radio AGN in the Northern sky available in the web
 - Images, visibility data, movies
 - Radio flux densities and spectra
 - Kinematics plots

See Lister et al. 2009

<http://www.physics.purdue.edu/MOJAVE/>

TANAMI

Tracking AGN with Austral Milliarcsecond Interferometry

- Monitoring of Southern Sources at 8.4 GHz and 22 GHz
- 40 initial sources observed, adding up to 80 new ones
- Observations started in November 2007 with the Australian Long Baseline Array and some additional antennas

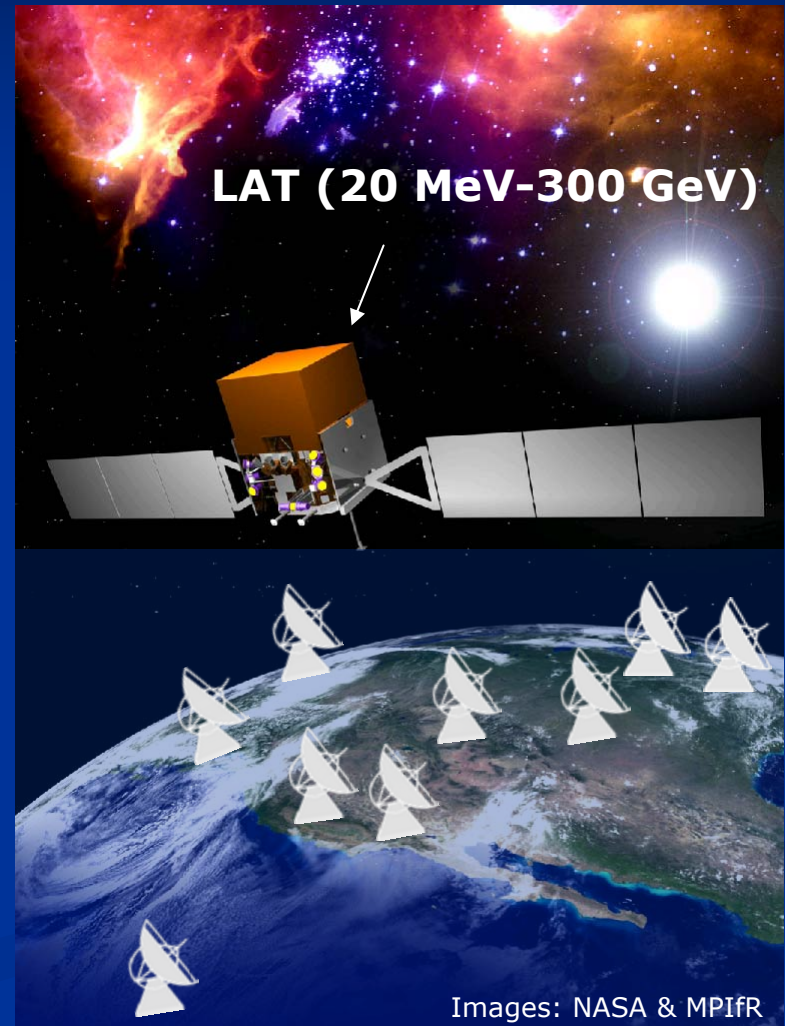
(Ojha et al. 2009, A&A submitted)



<http://pulsar.sternwarte.uni-erlangen.de/tanami/>

VLBI Surveys in the Fermi era

- AGN nature, compact jet emission
- Cross-correlation: compactness/ variability/ viewing angle vs. γ -ray emission
- Relating the γ -ray flares (detection, light curves) with the feature ejection in AGN jets
- See Lister et al. (2009), Kovalev et al. (2009), Savolainen et al. (in preparation)



Images: NASA & MPIfR

Using Data Archives

- Categories:
 - Publication archive (ADS, arXiv)
 - Data interface (Simbad, NED)
 - Data archives (Observatories, Virtual Observatory)
- If you know which data you need, go directly to the facility portal (see next slide)
- One step above: use the Virtual Observatory

Direct data archives

- **EVN**
 - <http://archive.jive.nl/scripts/listarch.php>
 - <http://db.ira.inaf.it/evn/>
- **VLBA**
 - <http://vlba.nrao.edu/astro/archive>
- **MERLIN**
 - <http://www.merlin.ac.uk/archive>
- **VLA**
 - <http://www.vla.nrao.edu/astro/#D9>
- **GMRT**
 - <http://neptune.gmrt.ncra.tifr.res.in/obsastro/>
- **WSRT**
 - <http://www.astron.nl/p/WSRT4.htm>
- **ATCA**
 - <http://atoa.atnf.csiro.au/>
- **IRAM**
 - <http://iram.fr/IRAMFR/PDB/arch.html>



SIMBAD



- Astronomical database providing
 - Basic data
 - Cross-identifications
 - Bibliography
 - Measurements
- Web interface and batch mode possible
- Linked to VizieR (Catalogue Service) and Aladin (Sky Atlas Viewer)
- All objects outside the Solar System

<http://simbad.u-strasbg.fr/>

SIMBAD



SIMBAD Astronomical Database

Queries

[basic search](#)

[by identifier](#)

[by coordinates](#)

[by criteria](#)

[reference query](#)

[scripts](#)

Documentation

[User's guide](#)

[Query by urls](#)

[Nomenclature Dictionary](#)

[Object types](#)

[List of journals](#)

[Measurement description](#)

[Spectral type coding](#)

Information

[Presentation](#)

[Release history](#)

[Acknowledgment](#)

Release:

SIMBAD4 1.123 - 25-May-2009

Content

The SIMBAD astronomical database provides basic data, cross-identifications, bibliography and measurements for astronomical objects outside the solar system.

SIMBAD can be queried by object name, coordinates and various criteria. Lists of objects and scripts can be submitted.

Links to some other on-line services are also provided.

Statistics

Simbad contains on 2009.06.18

4,602,519 objects

13,124,663 identifiers

232,322 bibliographic references

6,538,203 citations of objects in papers

Acknowledgment

If the Simbad database was helpful for your research work, the following acknowledgment would be appreciated:

This research has made use of the SIMBAD database, operated at CDS, Strasbourg, France

Basic search

identifier, coordinates (radius=10 arcmin), or bibcode

[help](#)

[Install the Simbad basic search in your tool bar](#)

SIMBAD query



SIMBAD: Query by identifiers

other query Identifier query Coordinate query Criteria query Bibliography query Basic query Script submission Output options Help

Query an identifier

Identifier :

Examples
sirius, M31, MCG+02-60-010
How to write an identifier can be found in the [dictionary of nomenclature](#)
IAU format can also be used, with the following format:
iauc [J]B]1230+08 [* enlarging-factor] [= Object-type]

you can choose to query :

around the object, define a radius :

Query a list of identifiers

Enter the name of an ASCII file produced by a text editor containing one identifier per line:

No file chosen

list display full display

query around the objects with radius :

Only the list display applies here

Query by identifiers can be done by

- full identifiers
- partial identifiers using wildcards ('?' = one char, '*' = any string, including an empty one (no char), '[xyz]' = one char among the list).
Examples:
HD *0000 returns all HD objects having the HD identifier ending with 4 zeros
HD 10? returns HD 100, 101, ..., 109.
- query around an object, with a radius definition
- a whole catalogue.
- Query by lists of objects



SIMBAD



Source Query: M 87

Basic data

Identifiers

Plots and images

Bibliographical references

Measurements

External archives



SIMBAD query result

other query modes: [Identifier query](#) [Coordinate query](#) [Criteria query](#) [Bibliography query](#) [Basic query](#) [Script submission](#) [Output options](#) [Help](#)

Object query: m87 C.D.S. - SIMBAD4 ed 1.123 - 2009.06.19CEST01:32:31

[Available data](#) [Basic data](#) [Identifiers](#) [Plots and images](#) [Bibliography](#) [Measurements](#) [External archives](#) [Notes](#)

Basic data: with radius arcmin

M 87 -- LINER-type Active Galaxy Nucleus

Other object types: [LIN 0](#) [Rad 1](#) [IC 4](#) [ICP](#) [CTA](#) [Cn1](#) [CA](#) [DR](#) [ICRF](#) [TERR](#) [12y_M11x](#) [NGC](#) [NGA0](#) [NG1](#) [NG5](#) [NG6](#) [NG7](#) [NG8](#) [NG9](#) [NG10](#) [NG11](#) [NG12](#) [NG13](#) [NG14](#) [NG15](#) [NG16](#) [NG17](#) [NG18](#) [NG19](#) [NG20](#) [NG21](#) [NG22](#) [NG23](#) [NG24](#) [NG25](#) [NG26](#) [NG27](#) [NG28](#) [NG29](#) [NG30](#) [NG31](#) [NG32](#) [NG33](#) [NG34](#) [NG35](#) [NG36](#) [NG37](#) [NG38](#) [NG39](#) [NG40](#) [NG41](#) [NG42](#) [NG43](#) [NG44](#) [NG45](#) [NG46](#) [NG47](#) [NG48](#) [NG49](#) [NG50](#) [NG51](#) [NG52](#) [NG53](#) [NG54](#) [NG55](#) [NG56](#) [NG57](#) [NG58](#) [NG59](#) [NG60](#) [NG61](#) [NG62](#) [NG63](#) [NG64](#) [NG65](#) [NG66](#) [NG67](#) [NG68](#) [NG69](#) [NG70](#) [NG71](#) [NG72](#) [NG73](#) [NG74](#) [NG75](#) [NG76](#) [NG77](#) [NG78](#) [NG79](#) [NG80](#) [NG81](#) [NG82](#) [NG83](#) [NG84](#) [NG85](#) [NG86](#) [NG87](#) [NG88](#) 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[NG1000](#)

ICRS coord. (ep=2000): 12 30 49.42308 +12 23 28.0439 (Radio) | l 0.250 0.017 0 | b 200.643 ... 127.3587P

FK4 coord. (ep=1950 ep=1950): 12 30 49.423 +12 23 28.04 (Radio) | l 0.250 0.017 0 | b 200.643 ... 127.3587P

Gal coord. (ep=2000): 283.7797 +74.4312 (Radio) | l 0.250 0.017 0 | b 200.643 ... 127.3587P

Radial velocity / Redshift / cz: km/s 1266 (43) / z 0.004233 (0.000143) / cz 1269.02 [42 87] D 2002LBA 0P

Morphological type: E 0 -

Angular size (arcmin): 8.317 5.754 3.60 (-) - D -

Fluxes (J): B 10.4 (-) D 1995PASP 111. 438P
V 12.86 (-) D -
J 6.719 (0.071) C 2006AJ 131. 1

NED

NASA/IPAC Extragalactic Database

- Database of extragalactic objects including:
 - Cross-identifications of names
 - Positions, redshifts
 - Basic data
 - Bibliographical references
 - Images from 2MASS, DSS, etc.
- Web interface, batch mode

<http://ned.ipac.caltech.edu/>

NASA/IPAC EXTRAGALACTIC DATABASE



- ▶ Latest Updates to NED and Level 5 Knowledgebase
- ▶ **NEW** Query Redshift-Independent Distances by Object Name
- ▶ **NEW** Redshift-Independent Distances in query reports
- ▶ **NEW** Query volumes of space around objects in query reports
- ▶ **NEW** Improved query reports including Index and SED preview
- ▶ **NEW** 450,000 object Associations between SDSS and other surveys

Notice: Ongoing upgrades to the user interface include changes to the HTML query reports. Automated queries should use XML (VOTable) output. [Details](#)

OBJECTS	DATA	LITERATURE	TOOLS	INFO
By Name	Images By Object Name or By Region	References by Object Name	Coordinate Transformation & Extinction Calculator Velocity Calculator	FAQ Introduction
Near Name	Photometry & SEDs	References by Author Name	Cosmology Calculators Extinction-Law Calculators	Features Graphical Overview
Near Position	Spectra	Text Search	FTP	NED Source List
Advanced All-Sky	Redshifts	Knowledgebase	X/Y offset to RA/DEC	NED Team
IAU Format	Redshift-Independent Distances NEW	Galaxy Distance Tabulations (NED-D)	Batch Job Submission	Comment
By Refcode	Positions	Abstracts	Pick Up Batch Job Results	Web Links
Object Notes	Diameters	Thesis Abstracts	Skyplot	Glossary & Lexicon

Interface last updated: 2 June 2009

- 163 million objects
- 170 million multiwavelength object cross-IDs
- 636 thousand associations (candidate cross-IDs)
- 1.5 million redshifts
- 1.7 billion photometric measurements
- 609 million diameter measurements

Database last updated: 2 June 2009

- 5.1 million objects linked to 71,596 journal articles
- 2.3 million images, maps and external links
- 56,405 spectra
- 18,150 redshift-independent distances for 5,049 galaxies
- 64,956 object notes
- 48,661 journal article abstracts

If your research benefits from the use of NED, we would appreciate the following acknowledgement in your paper: *This research has made use of the NASA/IPAC Extragalactic Database (NED) which is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.*

NED



JPL

You have selected the following parameters to search on:
Parameters for Distances and Cosmology: $H_0 = 73.0$, $\Omega_{matter} = 0.27$, $\Omega_{vacuum} = 0.73$.
Derived Quantities use a Redshift corrected to a Reference Frame defined by the 3K CMB.
NED results for object MESSIER 087

1 object found in NED. Skyplot(s): 100

RA	Dec	Obj	Class	Image	Spectra
13:07:00.0	+01:02:00.0	M87	Galaxy		

Source list

Object No. 1: MESSIER 087

Essential Data (Jump to sub-section of this query report) | Detailed Data (NED queries)

Normal Name	RA	Dec	Obj	Class	Image	Spectra
M87	13:07:00.0	+01:02:00.0	M87	Galaxy		

Index, SED

ESSENTIAL NOTE for MESSIER 087 (Back to NED)

COORDINATES for MESSIER 087 (Back to NED)

Reference Frame	Longitude (J2000)	RA	Dec (J2000)	Dec (J2000) (degrees)
Equinox J2000.0	197.072218	13:07:00.0	01:02:00.0	1.034500
Equinox J1950.0	197.070200	13:06:59.9	01:01:59.9	1.034499
Equinox J1900.0	197.068182	13:06:59.8	01:01:59.8	1.034498
Equinox J1850.0	197.066164	13:06:59.7	01:01:59.7	1.034497
Equinox J1800.0	197.064146	13:06:59.6	01:01:59.6	1.034496
Equinox J1750.0	197.062128	13:06:59.5	01:01:59.5	1.034495
Equinox J1700.0	197.060110	13:06:59.4	01:01:59.4	1.034494
Equinox J1650.0	197.058092	13:06:59.3	01:01:59.3	1.034493
Equinox J1600.0	197.056074	13:06:59.2	01:01:59.2	1.034492
Equinox J1550.0	197.054056	13:06:59.1	01:01:59.1	1.034491
Equinox J1500.0	197.052038	13:06:59.0	01:01:59.0	1.034490
Equinox J1450.0	197.050020	13:06:58.9	01:01:58.9	1.034489
Equinox J1400.0	197.048002	13:06:58.8	01:01:58.8	1.034488
Equinox J1350.0	197.045984	13:06:58.7	01:01:58.7	1.034487
Equinox J1300.0	197.043966	13:06:58.6	01:01:58.6	1.034486
Equinox J1250.0	197.041948	13:06:58.5	01:01:58.5	1.034485
Equinox J1200.0	197.039930	13:06:58.4	01:01:58.4	1.034484
Equinox J1150.0	197.037912	13:06:58.3	01:01:58.3	1.034483
Equinox J1100.0	197.035894	13:06:58.2	01:01:58.2	1.034482
Equinox J1050.0	197.033876	13:06:58.1	01:01:58.1	1.034481
Equinox J1000.0	197.031858	13:06:58.0	01:01:58.0	1.034480
Equinox J0950.0	197.029840	13:06:57.9	01:01:57.9	1.034479
Equinox J0900.0	197.027822	13:06:57.8	01:01:57.8	1.034478
Equinox J0850.0	197.025804	13:06:57.7	01:01:57.7	1.034477
Equinox J0800.0	197.023786	13:06:57.6	01:01:57.6	1.034476
Equinox J0750.0	197.021768	13:06:57.5	01:01:57.5	1.034475
Equinox J0700.0	197.019750	13:06:57.4	01:01:57.4	1.034474
Equinox J0650.0	197.017732	13:06:57.3	01:01:57.3	1.034473
Equinox J0600.0	197.015714	13:06:57.2	01:01:57.2	1.034472
Equinox J0550.0	197.013696	13:06:57.1	01:01:57.1	1.034471
Equinox J0500.0	197.011678	13:06:57.0	01:01:57.0	1.034470
Equinox J0450.0	197.009660	13:06:56.9	01:01:56.9	1.034469
Equinox J0400.0	197.007642	13:06:56.8	01:01:56.8	1.034468
Equinox J0350.0	197.005624	13:06:56.7	01:01:56.7	1.034467
Equinox J0300.0	197.003606	13:06:56.6	01:01:56.6	1.034466
Equinox J0250.0	197.001588	13:06:56.5	01:01:56.5	1.034465
Equinox J0200.0	196.999570	13:06:56.4	01:01:56.4	1.034464
Equinox J0150.0	196.997552	13:06:56.3	01:01:56.3	1.034463
Equinox J0100.0	196.995534	13:06:56.2	01:01:56.2	1.034462
Equinox J0050.0	196.993516	13:06:56.1	01:01:56.1	1.034461
Equinox J0000.0	196.991498	13:06:56.0	01:01:56.0	1.034460

REDSHIFT-INDEPENDENT DISTANCES for MESSIER 087 (Back to NED)

17 Distances found in NED (Detailed Listing)

Class	Distance (Mpc)	Quanta	Ω_{matter}	Ω_{vacuum}
Min	11.63	0.27	0.73	
Max	31.43	0.27	0.73	

FOREGROUND GALACTIC EXTINCTION for MESSIER 087 (Back to NED)

RA	Dec	A_V	A_B	A_I	$A_{H\alpha}$	A_{K_s}	A_{K}	A_{L}	A_{M}	A_{N}	A_{O}	A_{Q}	A_{R}	A_{S}	A_{U}	A_{VIS}	A_{Z}
13:07:00.0	+01:02:00.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

CROSS-IDENTIFICATIONS for MESSIER 087 (Back to NED)

Object Name	Type	Object Name	Type
MESSIER 087	Galaxy	NGC 4486	Galaxy
M87	Galaxy	NGC 4486	Galaxy
M87	Galaxy	IC 3639	Galaxy
M87	Galaxy	IC 3640	Galaxy
M87	Galaxy	IC 3641	Galaxy
M87	Galaxy	IC 3642	Galaxy
M87	Galaxy	IC 3643	Galaxy
M87	Galaxy	IC 3644	Galaxy
M87	Galaxy	IC 3645	Galaxy
M87	Galaxy	IC 3646	Galaxy
M87	Galaxy	IC 3647	Galaxy
M87	Galaxy	IC 3648	Galaxy
M87	Galaxy	IC 3649	Galaxy
M87	Galaxy	IC 3650	Galaxy
M87	Galaxy	IC 3651	Galaxy
M87	Galaxy	IC 3652	Galaxy
M87	Galaxy	IC 3653	Galaxy
M87	Galaxy	IC 3654	Galaxy
M87	Galaxy	IC 3655	Galaxy
M87	Galaxy	IC 3656	Galaxy
M87	Galaxy	IC 3657	Galaxy
M87	Galaxy	IC 3658	Galaxy
M87	Galaxy	IC 3659	Galaxy
M87	Galaxy	IC 3660	Galaxy
M87	Galaxy	IC 3661	Galaxy
M87	Galaxy	IC 3662	Galaxy
M87	Galaxy	IC 3663	Galaxy
M87	Galaxy	IC 3664	Galaxy
M87	Galaxy	IC 3665	Galaxy
M87	Galaxy	IC 3666	Galaxy
M87	Galaxy	IC 3667	Galaxy
M87	Galaxy	IC 3668	Galaxy
M87	Galaxy	IC 3669	Galaxy
M87	Galaxy	IC 3670	Galaxy
M87	Galaxy	IC 3671	Galaxy
M87	Galaxy	IC 3672	Galaxy
M87	Galaxy	IC 3673	Galaxy
M87	Galaxy	IC 3674	Galaxy
M87	Galaxy	IC 3675	Galaxy
M87	Galaxy	IC 3676	Galaxy
M87	Galaxy	IC 3677	Galaxy
M87	Galaxy	IC 3678	Galaxy
M87	Galaxy	IC 3679	Galaxy
M87	Galaxy	IC 3680	Galaxy
M87	Galaxy	IC 3681	Galaxy
M87	Galaxy	IC 3682	Galaxy
M87	Galaxy	IC 3683	Galaxy
M87	Galaxy	IC 3684	Galaxy
M87	Galaxy	IC 3685	Galaxy
M87	Galaxy	IC 3686	Galaxy
M87	Galaxy	IC 3687	Galaxy
M87	Galaxy	IC 3688	Galaxy
M87	Galaxy	IC 3689	Galaxy
M87	Galaxy	IC 3690	Galaxy
M87	Galaxy	IC 3691	Galaxy
M87	Galaxy	IC 3692	Galaxy
M87	Galaxy	IC 3693	Galaxy
M87	Galaxy	IC 3694	Galaxy
M87	Galaxy	IC 3695	Galaxy
M87	Galaxy	IC 3696	Galaxy
M87	Galaxy	IC 3697	Galaxy
M87	Galaxy	IC 3698	Galaxy
M87	Galaxy	IC 3699	Galaxy
M87	Galaxy	IC 3700	Galaxy
M87	Galaxy	IC 3701	Galaxy
M87	Galaxy	IC 3702	Galaxy
M87	Galaxy	IC 3703	Galaxy
M87	Galaxy	IC 3704	Galaxy
M87	Galaxy	IC 3705	Galaxy
M87	Galaxy	IC 3706	Galaxy
M87	Galaxy	IC 3707	Galaxy
M87	Galaxy	IC 3708	Galaxy
M87	Galaxy	IC 3709	Galaxy
M87	Galaxy	IC 3710	Galaxy
M87	Galaxy	IC 3711	Galaxy
M87	Galaxy	IC 3712	Galaxy
M87	Galaxy	IC 3713	Galaxy
M87	Galaxy	IC 3714	Galaxy
M87	Galaxy	IC 3715	Galaxy
M87	Galaxy	IC 3716	Galaxy
M87	Galaxy	IC 3717	Galaxy
M87	Galaxy	IC 3718	Galaxy
M87	Galaxy	IC 3719	Galaxy
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M87	Galaxy	IC 3721	Galaxy
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M87	Galaxy	IC 3727	Galaxy
M87	Galaxy	IC 3728	Galaxy
M87	Galaxy	IC 3729	Galaxy
M87	Galaxy	IC 3730	Galaxy
M87	Galaxy	IC 3731	Galaxy
M87	Galaxy	IC 3732	Galaxy
M87	Galaxy	IC 3733	Galaxy
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M87	Galaxy	IC 3735	Galaxy
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M87	Galaxy	IC 3742	Galaxy
M87	Galaxy	IC 3743	Galaxy
M87	Galaxy	IC 3744	Galaxy
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M87	Galaxy	IC 3746	Galaxy
M87	Galaxy	IC 3747	Galaxy
M87	Galaxy	IC 3748	Galaxy
M87	Galaxy	IC 3749	Galaxy
M87	Galaxy	IC 3750	Galaxy
M87	Galaxy	IC 3751	Galaxy
M87	Galaxy	IC 3752	Galaxy
M87	Galaxy	IC 3753	Galaxy
M87	Galaxy	IC 3754	Galaxy
M87	Galaxy	IC 3755	Galaxy
M87	Galaxy	IC 3756	Galaxy
M87	Galaxy	IC 3757	Galaxy
M87	Galaxy	IC 3758	Galaxy
M87	Galaxy	IC 3759	Galaxy
M87	Galaxy	IC 3760	Galaxy
M87	Galaxy	IC 3761	Galaxy
M87	Galaxy	IC 3762	Galaxy
M87	Galaxy	IC 3763	Galaxy
M87	Galaxy	IC 3764	Galaxy
M87	Galaxy	IC 3765	Galaxy
M87	Galaxy	IC 3766	Galaxy
M87	Galaxy	IC 3767	Galaxy
M87	Galaxy	IC 3768	Galaxy
M87	Galaxy	IC 3769	Galaxy
M87	Galaxy	IC 3770	Galaxy
M87	Galaxy	IC 3771	Galaxy
M87	Galaxy	IC 3772	Galaxy
M87	Galaxy	IC 3773	Galaxy
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M87	Galaxy	IC 3777	Galaxy
M87	Galaxy	IC 3778	Galaxy
M87	Galaxy	IC 3779	Galaxy
M87	Galaxy	IC 3780	Galaxy
M87	Galaxy	IC 3781	Galaxy
M87	Galaxy	IC 3782	Galaxy
M87	Galaxy	IC 3783	Galaxy
M87	Galaxy	IC 3784	Galaxy
M87	Galaxy	IC 3785	Galaxy
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M87	Galaxy	IC 3788	Galaxy
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M87	Galaxy	IC 3790	Galaxy
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M87	Galaxy	IC 3793	Galaxy
M87	Galaxy	IC 3794	Galaxy
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M87	Galaxy	IC 3797	Galaxy
M87	Galaxy	IC 3798	Galaxy
M87	Galaxy	IC 3799	Galaxy
M87	Galaxy	IC 3800	Galaxy
M87	Galaxy	IC 3801	Galaxy
M87	Galaxy	IC 3802	Galaxy
M87	Galaxy	IC 3803	Galaxy
M87	Galaxy	IC 3804	Galaxy
M87	Galaxy	IC 3805	Galaxy
M87	Galaxy	IC 3806	Galaxy
M87	Galaxy	IC 3807	Galaxy
M87	Galaxy	IC 3808	Galaxy
M87	Galaxy	IC 3809	Galaxy
M87	Galaxy	IC 3810	Galaxy
M87	Galaxy	IC 3811	Galaxy
M87	Galaxy	IC 3812	Galaxy
M87	Galaxy	IC 3813	Galaxy
M87	Galaxy	IC 3814	Galaxy
M87	Galaxy	IC 3815	Galaxy
M87	Galaxy	IC 3816	Galaxy
M87	Galaxy	IC 3817	Galaxy
M87	Galaxy	IC 3818	Galaxy
M87	Galaxy	IC 3819	Galaxy
M87	Galaxy	IC 3820	Galaxy
M87	Galaxy	IC 3821	Galaxy
M87	Galaxy	IC 3822	Galaxy
M87	Galaxy	IC 3823	Galaxy
M87	Galaxy	IC 3824	Galaxy
M87	Galaxy	IC 3825	Galaxy
M87	Galaxy	IC 3826	Galaxy
M87	Galaxy	IC 3827	Galaxy
M87	Galaxy	IC 3828	Galaxy
M87	Galaxy	IC 3829	Galaxy
M87	Galaxy	IC 3830	Galaxy
M87	Galaxy	IC 3831	Galaxy
M87	Galaxy	IC 3832	Galaxy
M87	Galaxy	IC 3833	Galaxy
M87	Galaxy	IC 3834	Galaxy
M87	Galaxy	IC 3835	Galaxy
M87	Galaxy	IC 3836	Galaxy
M87	Galaxy	IC 3837	Galaxy
M87	Galaxy	IC 3838	Galaxy
M87	Galaxy	IC 3839	Galaxy
M87	Galaxy	IC 3840	Galaxy
M87	Galaxy	IC 3841	Galaxy
M87	Galaxy	IC 3842	Galaxy
M87	Galaxy	IC 3843	Galaxy
M87	Galaxy	IC 3844	Galaxy
M87	Galaxy	IC 3845	Galaxy
M87	Galaxy	IC 3846	Galaxy
M87	Galaxy	IC 3847	Galaxy
M87	Galaxy	IC 3848	Galaxy
M87	Galaxy	IC 3849	Galaxy
M87	Galaxy		



Virtual Observatory



- Idea: all the World's astronomical data are transparently useable as the WWW
- Metadata standards needed (VOTables replacing FITS)
- Coordinated by the International Virtual Observatory Alliance
- European Virtual Observatory: Euro-VO
- National Sites:
 - German Astron. VO (GAVO: <http://www.g-vo.org>)
 - Australian VO (AVO: <http://aus-vo.org/>)
 - USA Natnl. VO (NVO: <http://www.virtualobservatory.net/>)
 - ...



Virtual Observatory



- Idea: all the World's astronomical data and services transparently useable as though they were a single entity
- Metadata standards needed (e.g. VOTable replacing FITS)
- Coordinated by the International Virtual Observatory Alliance (IVOA)
- European Virtual Observatory: Euro-VO
- National Virtual Observatories:
 - Germany (GAVO: <http://www.g-vo.org>)
 - Australia (AVO: <http://aus-vo.org/>)
 - USA (NVO: <http://www.virtualobservatory.net/>)

See M. Allen Lecture on July 9th



AstroGrid

- Portal to the Virtual Observatory
- Desktop Applications Suite
- TOPCAT
- AstroGrid Python available, so you can create your own applications

<http://www.astrogrid.org>

Virtual Observatory: Viewers

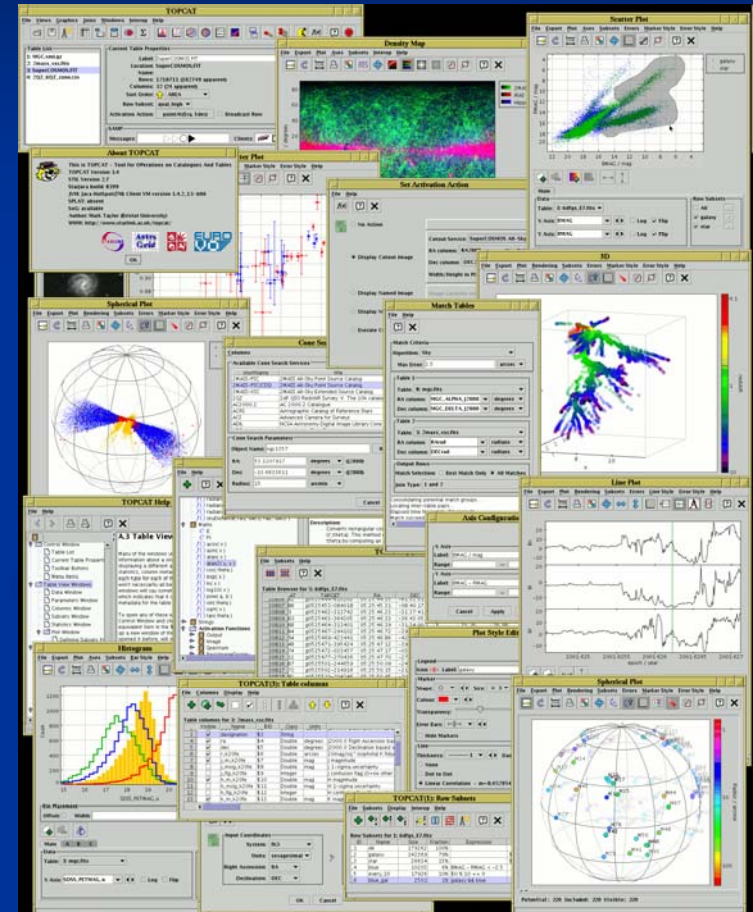
TOPCAT	http://www.star.bris.ac.uk/~mbt/topcat/
Aladin	http://aladin.u-strasbg.fr/
VOSpec	http://esavo.esa.int/vospec/
SkyView	http://skyview.gsfc.nasa.gov/
DataScope	http://heasarc.gsfc.nasa.gov/cgi-bin/vo/datascope/init.pl



TOPCAT

Tool for OPerations on Catalogues And Tables

- Interactive graphical viewer and editor for tabular data
- JAVA script as part of AstroGrid
- Fast access to large data sets, manipulation, plotting features, statistical tools, interface with other applications (SAMP, PLASTIC)



<http://www.star.bris.ac.uk/~mbt/topcat/>

Things you can do

- Finding data for a new source
- Checking all available data in all wavelength and resolution available observations
- Cross correlating catalogs
- Visualizing a catalog

Finding radio data: choosing the telescope

- North or south?
 - Dec $> -40 \rightarrow$ VLA/VLBA
 - Dec $> 0 \rightarrow$ MERLIN
 - Dec $< -30 \rightarrow$ ATCA
- Desired resolution & source size?
 - VLA/ATCA: arcsecond to arcmin resolution over few to 10s of arcminutes
 - MERLIN: 10s of milliarcseconds resolution over arcmin
 - VLBA: milliarcsecond resolution over arcseconds

Example: data extraction

- Use the VLA (NRAO's workhorse, with 3 Tb data)

NRAO National Radio Astronomy Observatory

Data Vault Home Search Download Google Sky

VLA VLBA GBT

NRAO Archive Search

Enter search criteria to search for data in the archive.

[Data Archive Policy](#)

Downloading NRAO Data - Public & Proprietary

For all available NRAO data, including VLA, VLBA, and GBT data, you can also use the search box above. You may also use the basic retrieval tool (linked to the right) to select and retrieve archived data from the VLA and VLBA. Note that during the proprietary period, downloading will require an access key, obtained from the [NRAO Data Analysts](#) office in Socorro.

[Basic VLA & VLBA Data Retrieval Tool](#)

Detailed VLA & VLBA Archive Search Tool

This tool (linked to the right) provides more advanced query parameters for searching the VLA and VLBA archives. Please see [Archive Status](#) for details on completeness of the archive contents and send feedback to your NRAO data archive contact, or use the survey linked below.

[Advanced Query Tool](#)

Image Archive Tool

A collection of images produced by VLA and VLBA observations are available for browsing and downloads. The image collection consists of results from surveys and the VLA Imaging Pipeline Project. There are approximately 130,000 images in the archive.

[Image Archive Tool](#)

<http://archive.cv.nrao.edu/>

The VLA Archive

- Returns:
 - Date
 - Obs. Frequency
 - Configuration
 - Field of View
 - Resolution
 - Largest angular scale
 - Time on source
 - Theor. rms noise
 - No of channels
 - Bandwidth
 - Stokes

NRAO Archive - Observing Summary

[Show Query Parameters](#)

Displaying rows : 1279

Transfer uv file for that table row to the Download Page - click the UV button

Search for archived image files for a table row - click the I button

Return a list of observing scans for a table row - click the S button

UV Data	Image Search	Scan List	Source	Project	Frequency MHz	Distance arcmin	TOS sec	rms mJy/b	resolution arcsec	FOV arcmin	Tele:config :sub:nants	Chans #	BW MHz	Polar	First Time	Last Time	RA(J2000)	DEC(J2000)
<input type="button" value="UV"/>	none	<input type="button" value="S"/>	C274	AD0094-public	4835.100	0.008	410	0.117	0.4	9.0	VLA:A:1.26	1	50.000	RR,LL,RL,LR	83-Sep-17 21:37:10	83-Sep-17 21:43:49	12h30m49.397s	+12d23'27.78"
			C274	AD0094-public	4885.100	0.008	410	0.117	0.4	9.0	VLA:A:1.26	1	50.000	RR,LL,RL,LR	83-Sep-17 21:37:10	83-Sep-17 21:43:49	12h30m49.397s	+12d23'27.78"
<input type="button" value="UV"/>	none	<input type="button" value="S"/>	C274	AD0094-public	14914.900	0.008	400	0.3	0.14	3.0	VLA:A:1.26	1	50.000	RR,LL,RL,LR	83-Sep-17 21:44:20	83-Sep-17 21:50:50	12h30m49.397s	+12d23'27.78"
			C274	AD0094-public	14964.900	0.008	400	0.3	0.14	3.0	VLA:A:1.26	1	50.000	RR,LL,RL,LR	83-Sep-17 21:44:20	83-Sep-17 21:50:50	12h30m49.397s	+12d23'27.78"
<input type="button" value="UV"/>	none	<input type="button" value="S"/>	C274	AD0094-public	1464.900	0.008	280	0.194	1.4	30.0	VLA:A:1.26	1	50.000	RR,LL,RL,LR	83-Sep-17 21:51:20	83-Sep-17 21:55:50	12h30m49.397s	+12d23'27.78"
			C274	AD0094-public	1514.900	0.008	280	0.194	1.4	30.0	VLA:A:1.26	1	50.000	RR,LL,RL,LR	83-Sep-17 21:51:20	83-Sep-17 21:55:50	12h30m49.397s	+12d23'27.78"
<input type="button" value="UV"/>	none	<input type="button" value="S"/>	228+126	AW0087-public	4885.100	0.005	310	0.28	0.4	9.0	VLA:A:3.6	1	50.000	RR,LL,RL,LR	83-Oct-10 15:56:10	83-Oct-10 20:04:49	12h30m49.407s	+12d23'28.18"
			228+126	AW0087-public	4835.100	0.005	310	0.28	0.4	9.0	VLA:A:3.6	1	50.000	RR,LL,RL,LR	83-Oct-10 15:56:10	83-Oct-10 20:04:49	12h30m49.407s	+12d23'28.18"

Eduardo Ros

Multiwavelength Summer School

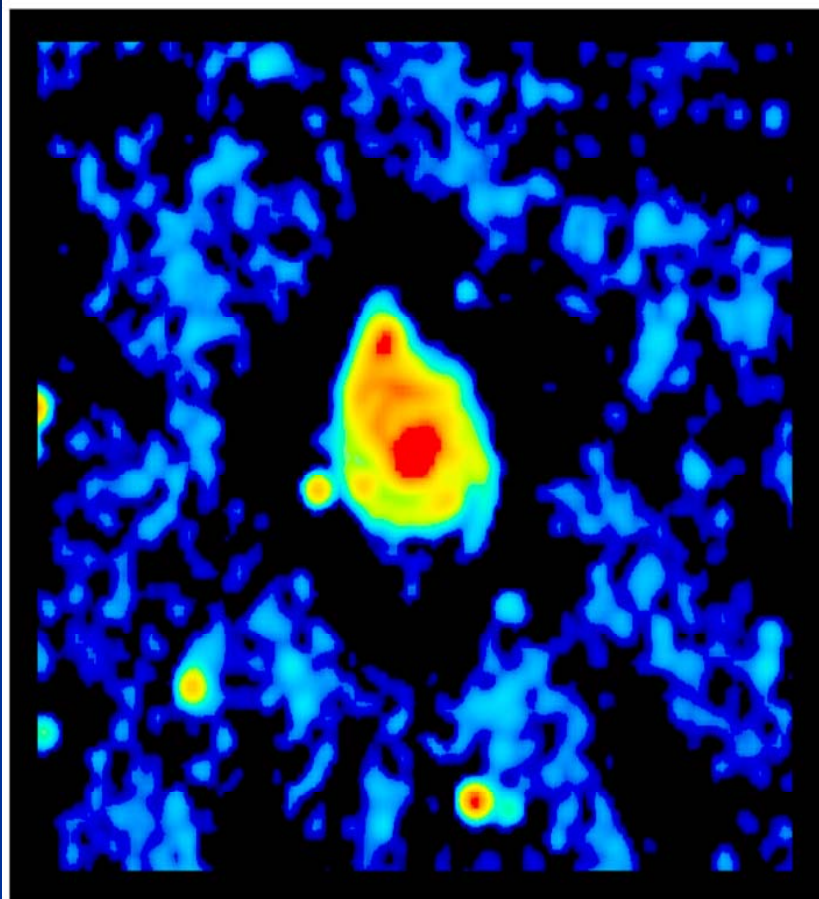
Dealing with data: a first look

- The archives send raw uv-data, not images
- Quick & dirty processing: VLARUN, VLBARUN
 - can get reasonable quick-look images in a few minutes, with no special black-belt qualification
- Steps:
 - AIPS
 - Load in data (FILLM)
 - Set array configuration; image size; depth of deconvolution
 - VLARUN → calibrated data & images
 - Write them out (FITTP)

Checking which data

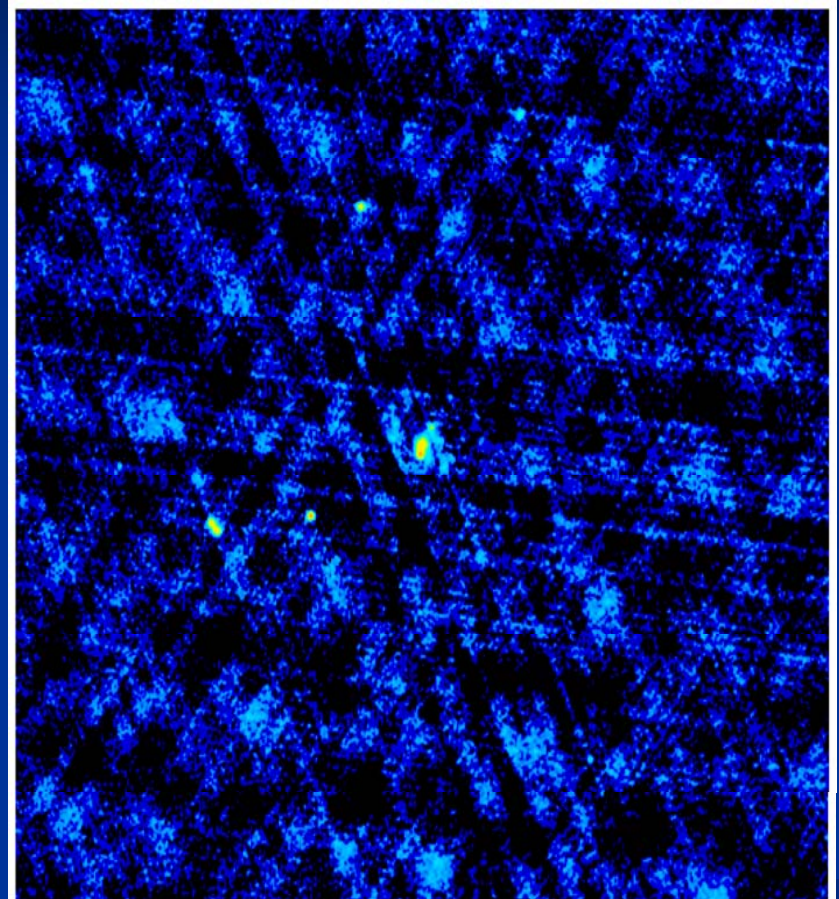
- Resolution vs missing structure
 - VLA array configuration choice to be made carefully (A to D)
- Sensitivity
 - Longer observations are better (interferometers!)
 - More bandwidth is better
 - Some frequency bands are more sensitive (5, 8 GHz)
- Special purposes
 - Spectroscopy: total bandwidth covers entire line
 - Polarization: Stokes field carefully checked, long runs needed
- Make your life easier
 - Continuum is easier than spectral line
 - "Center" frequencies (1-15 GHz) are easier than edges
 - VLBI is more challenging than VLA/ATCA
 - New data are better than old

M51: Surveys...



NVSS: 45"

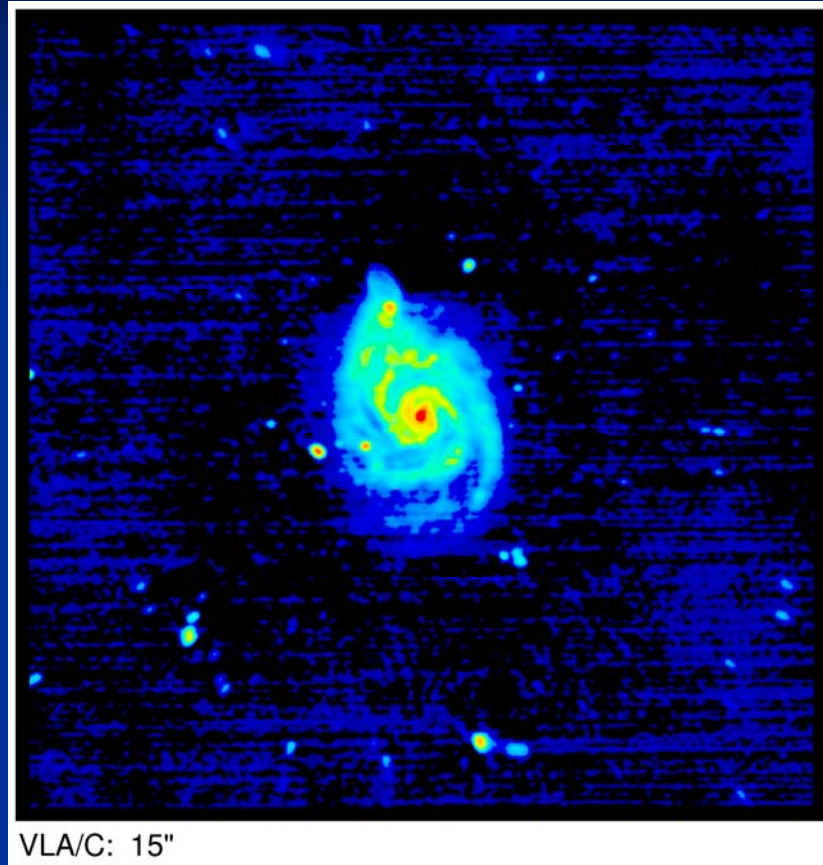
NVSS: 45" resolution



FIRST: 5.4"

FIRST: 5.4" resolution

...and the archive



VLA/C @ 20cm:
15" resolution

Some remarks

- Please refer to the original publications and not to databases in your publications
- Use requested acknowledgments for open, unpublished data
- Please give credit to the people who put hard work on it
- If doing survey work, design it to become a public data base and put it online as soon as possible

The future

- The archives are growing, getting better, merging into the VO...
- Lots of new radio telescopes coming this decade: SMA, EVLA, ALMA, eMERLIN, ...
→ great times to be an astronomer!