Astronomy at the University of New Mexico

P.A. Henning
Associate Professor of Physics and Astronomy
Director, Institute for Astrophysics

http://panda.unm.edu

Astronomy at UNM

- Within Department, IfA has 7 full time faculty, 5 associate members (3 local), 2 emeritus faculty
- Degrees: B.S. Astrophysics, Physics; M.S., Ph.D. in Physics. Can do research in Astro to earn Physics Ph.D.
- UNM Astronomy - Comets to Cosmology!

The IfA at UNM

- H. Ahluwalia – Galactic, Solar Cosmic Rays 
- J. Brandt (adjunct) – Interaction of Solar Wind with Comets 
- H. Dickel (adjunct) – Dense Cores of Molecular Clouds 
- J. Dickel (adjunct) – Supernova Remnants, Interstellar Medium 
- P. Henning – Large-Scale Structure, HI in galaxies 

The IfA at UNM

- D. Loomba – Gravitational Lensing, Dark Matter, High-z Quasars 
- J. McGraw – Optical Instrumentation, Surveys 
- Y. Pihlström – AGN-Starburst Connection 
- R. Rand – Structure and Evolution of Galaxies 
- G. Taylor – VLBI Imaging of AGN, Galaxy Clusters 

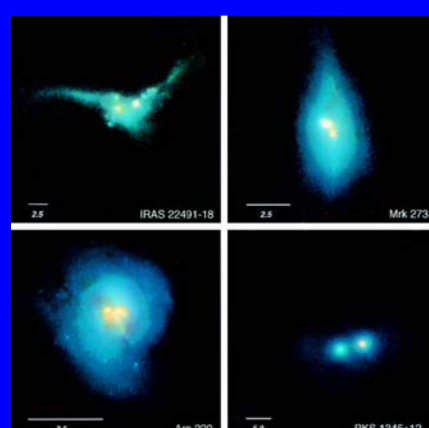
Some Research Highlights

Pihlström: AGN-Starburst Connection

Using radio and mm interferometry to study the properties of circumnuclear gas in AGN and starbursts, and the connection between AGN and starbursts.

Ultra Luminous Infrared Galaxies: by determining the distribution and kinematics of dense molecular gas and radio continuum we aim to:

- Compare the gas properties to those of high-z submm galaxies (galaxy evolution).
- To constrain the origin of OH megamasers.



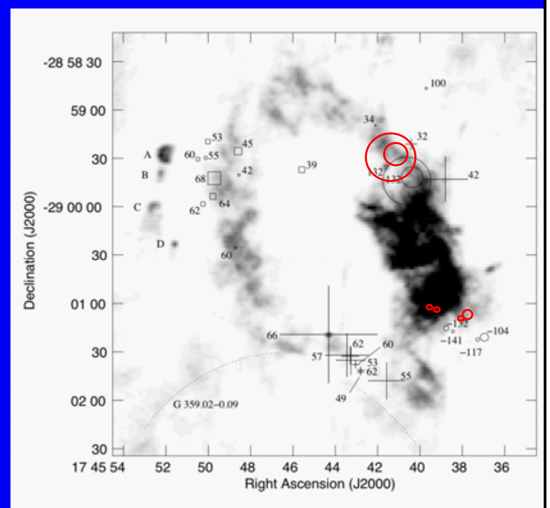
Scoville et al 2000

Pihlström: Masers in the Galactic Center

Probing the physical conditions in the ISM close to the nearest supermassive black hole.

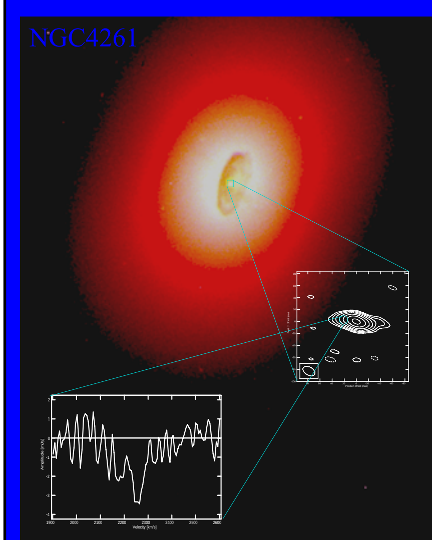
1720 MHz OH masers trace SNRs, but are also associated with the circumnuclear disc.

=> conditions at ~ 2 pc from SgrA*.



VLA monitoring work in progress by UNM student Robert Edmonds

Pihlström: Absorption studies with VLBI



van Langevelde et al. 2000

Absorption studies of gas close to the AGN central engine.

- What are the AGN radiation conditions at a few pc radius?
- What is the AGN feeding rate, and what triggers AGN activity?
- What are the plausible evolutionary scenarios for radio AGN?

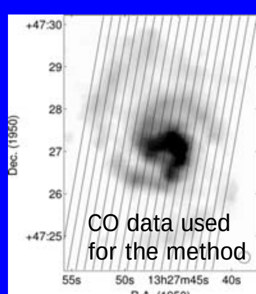
Rand: Spiral Structure, Interstellar Gas and Star Formation

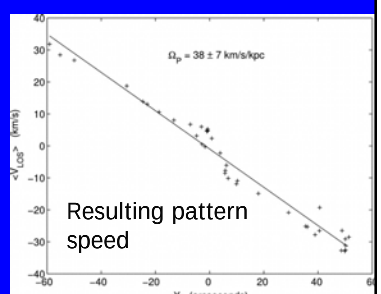
How do spiral density waves affect the growth of structure in the ISM and the mode, rate and efficiency of star formation?

Recent research focuses on determining angular speeds of spiral density wave patterns using the “Tremaine-Weinberg” (TW) method.

We have recently extended the method to allow for a *radially varying* pattern speed. This has the potential for answering the long-standing question of the winding and longevity of spiral structure.

The TW method allows pattern speeds to be found from 2-d kinematic maps of well-chosen components of spiral galaxies, and does not rely on identifying behavior associated with resonances (e.g. the Lindblad Resonances).



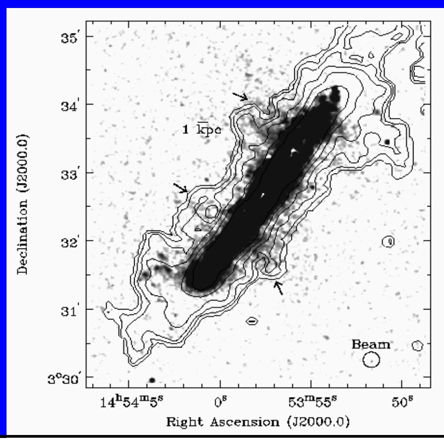


Zimmer, Rand & McGraw (2004)

Along each “aperture”, the intensity-weighted observed velocity and position coordinate are calculated. These are plotted against each other, and the slope yields the pattern speed. A faster speed for M51’s inner bar is also suggested.

Rand: Interstellar Disk-Halo Connection

Spiral galaxies have multi-phase ISMs in their halos as a result of injection of disk gas by stellar winds and supernovae. This research focuses on morphology, ionization and kinematics of halo gas.

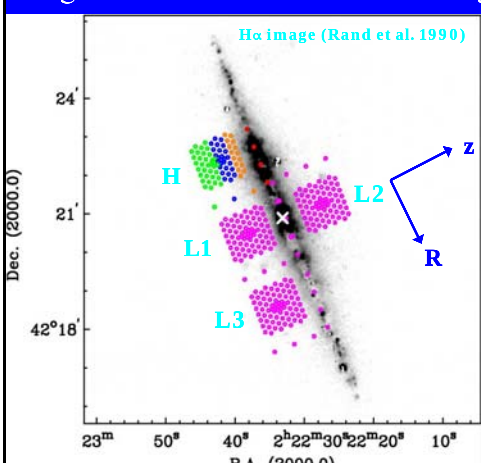


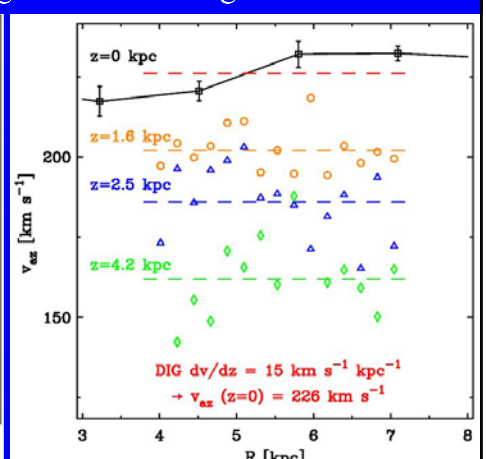
NGC 5775

Greyscale shows Hα emission from edge-on spiral NGC 5775. Contours show HI obtained with VLA. Correlated shells and filaments in both indicate sites of mass and energy input into gaseous halo.

Collins et al. (2000)
Irwin (1994)

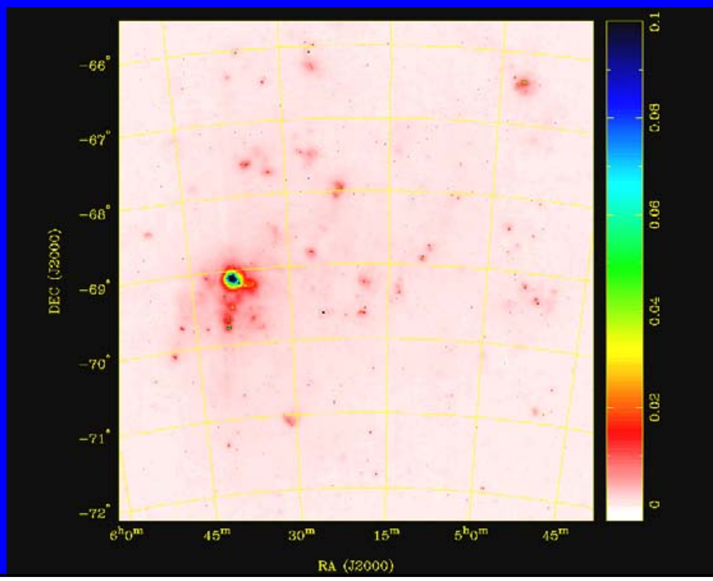
Recent work has focused on the kinematics of diffuse ionized gas halos and comparison with simple models of the flow. The rotation speed of the gas is found to decrease with height in all three edge-ons studied.





WIYN Sparsepak IFU obs. of NGC 891 (Heald et al. 2006b), and derived rotation speed vs. height for pointing H.

J. Dickel: Multiwavelength Radio Continuum Survey of LMC



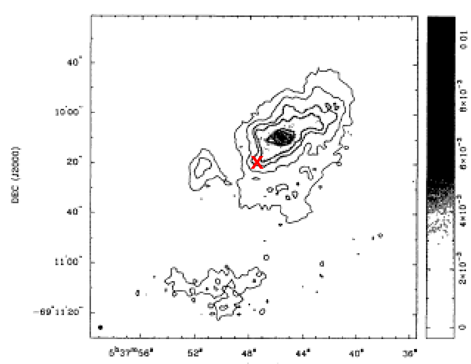


Fig. 1. Image of the SNR N157B at a wavelength of 6 cm with a half-power beamwidth of 1.7 arcsec. The contour levels are 0.5, 1.0, 1.6, 2.2, 3.8, and 4.3 mJy/beam.

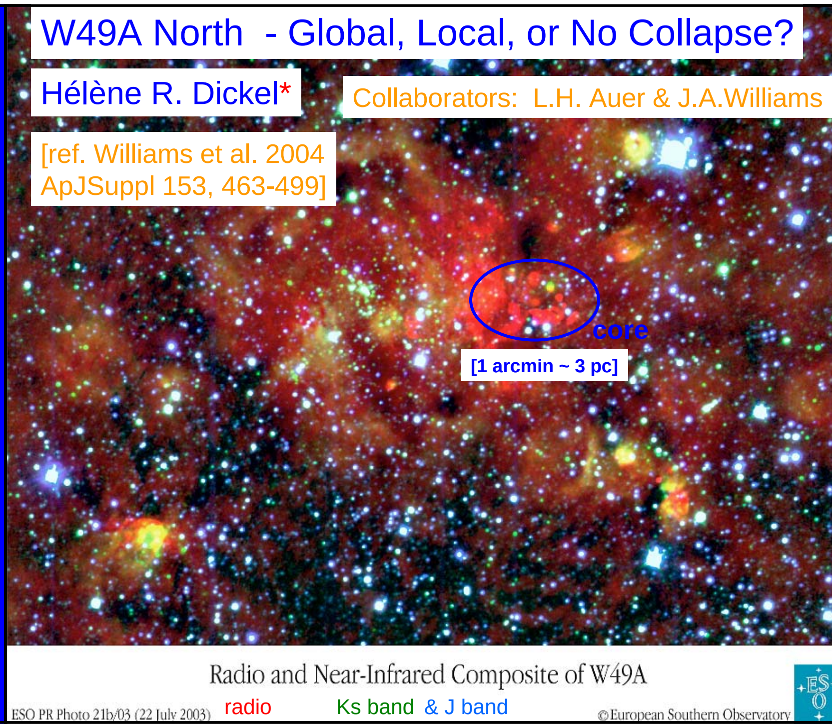
This supernova remnant is in transition from being a bow-shock pulsar wind nebula trailing behind the pulsar (x) to becoming a composite SNR with a faint shell seen in the south and the east around the PWN . J. Dickel et al.

W49A North - Global, Local, or No Collapse?

Hélène R. Dickel*

Collaborators: L.H. Auer & J.A.Williams

[ref. Williams et al. 2004 ApJSuppl 153, 463-499]



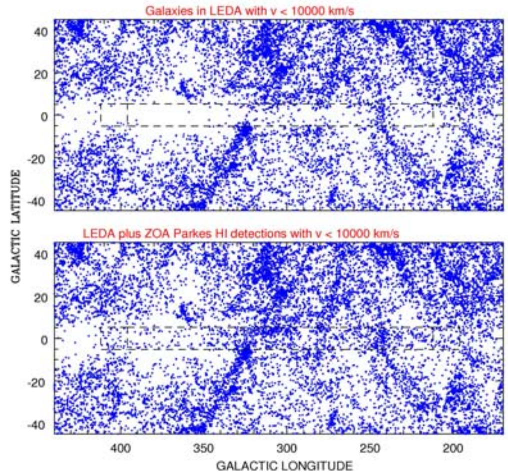
Radio and Near-Infrared Composite of W49A

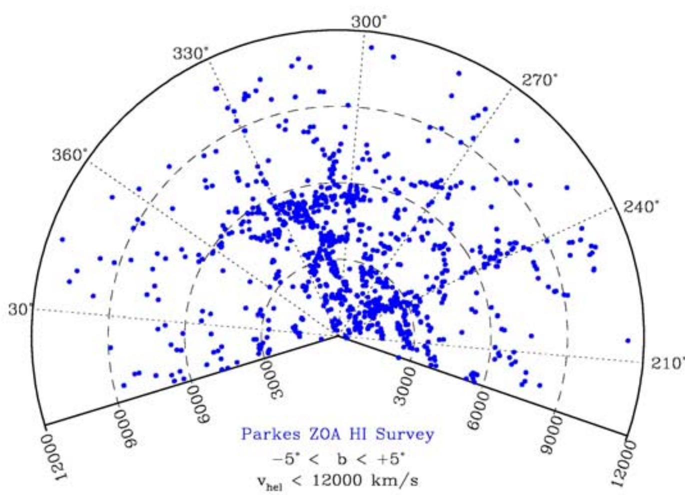
radio Ks band & J band

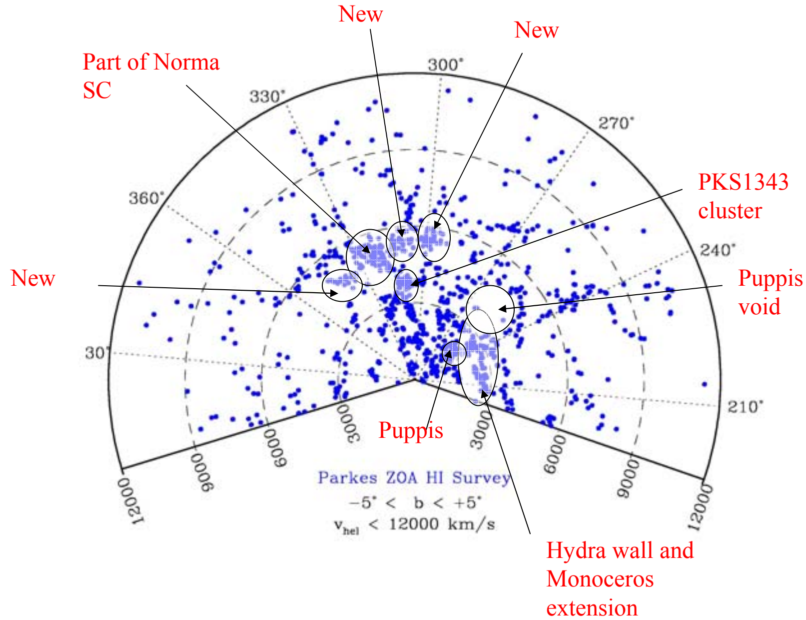
Henning: Large-Scale Structure Behind the Milky Way

- Milky Way blocks 20% of optical extragalactic Universe, somewhat less in IR
- Major mass concentrations affecting Milky Way motion wrt CMB are obscured, Eg. Great Attractor, Pisces-Perseus Supercluster,…
- Connectivity of other LSS across Galactic Plane
- Optically-obscured galaxies containing HI may be discovered at 21-cm, with radio telescopes


21 Jan 1997

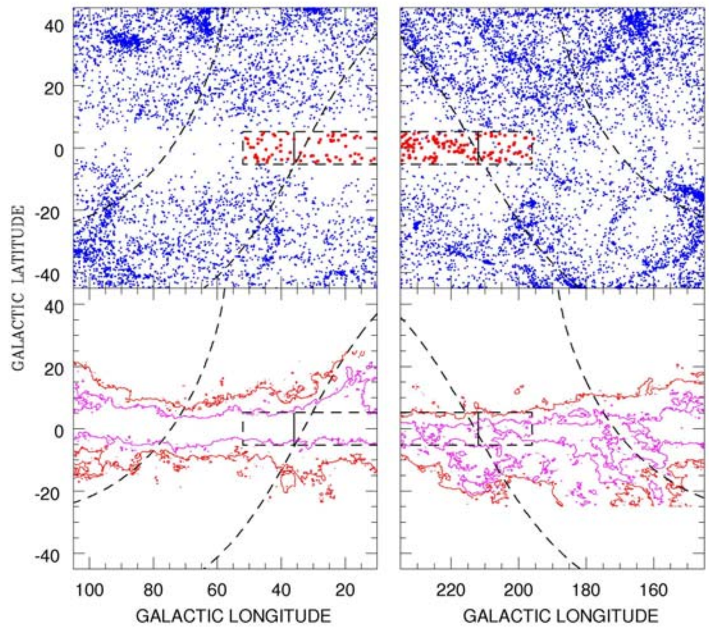

Galaxies in LEDA with v < 10000 km/s
LEDA plus ZOA Parkes HI detections with v < 10000 km/s
GALACTIC LATITUDE
GALACTIC LONGITUDE
40
20
0
-20
-40
400
350
300
250
200

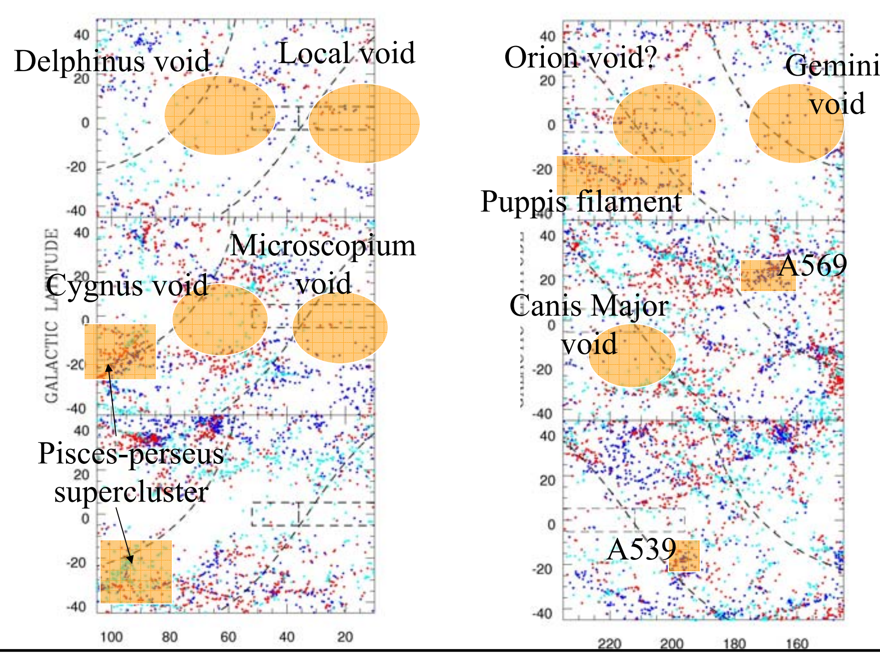

300°
330°
270°
360°
240°
30°
210°
3000
6000
9000
12000
Parkes ZOA HI Survey
−5° < b < +5°
v_hel < 12000 km/s



- The next step: extend maps of hidden galaxies and large-scale structures to the north, using the 305-m Arecibo radio telescope

Arecibo can't see the whole sky

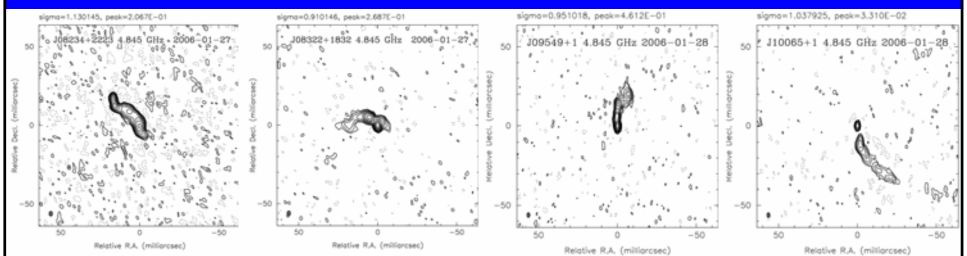




Taylor: VLBI Imaging of Active Galactic Nuclei

VLBA Imaging Polarimetry Survey (VIPS)

- 1127 sources: S > 85 mJy, 65 > dec > 20, |b|>10 at 5 GHz in SDSS northern cap
- First epoch observations on the VLBA in 2006
- Identifications and redshifts from SLOAN, HET, Palomar, …
- Goals:
  - Characterize GLAST sources
  - Understand polarization properties of AGN classes
  - Study AGN environments
  - Find close binary black hole systems

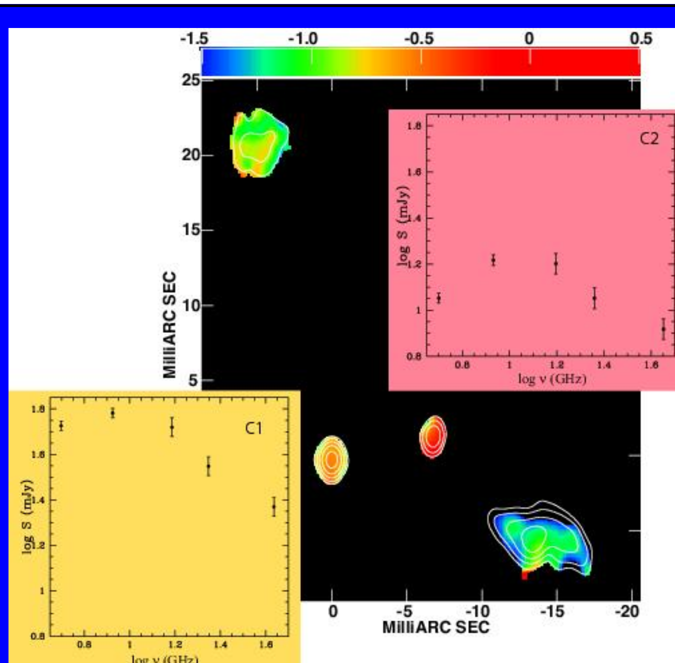


http://www.phys.unm.edu/~gbtaylor/VIPS/

A Compact Binary Black Hole

0402+379

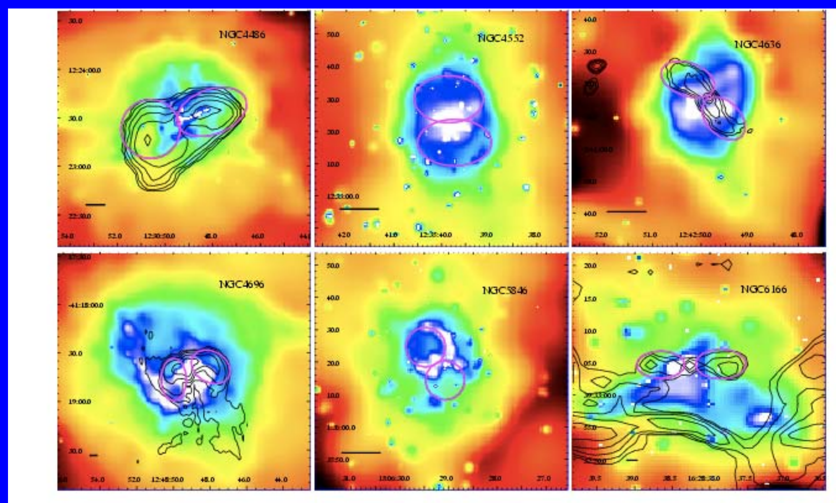
Rodriguez et al. 2006



Taylor: Galaxy Clusters

- Exploring the evolution Radio Galaxies
- Studying Cluster Magnetic Fields

Chandra + VLA



The Long Wavelength Array

Greg Taylor (UNM)

Summer Synthesis Imaging Workshop

June 15, 2006

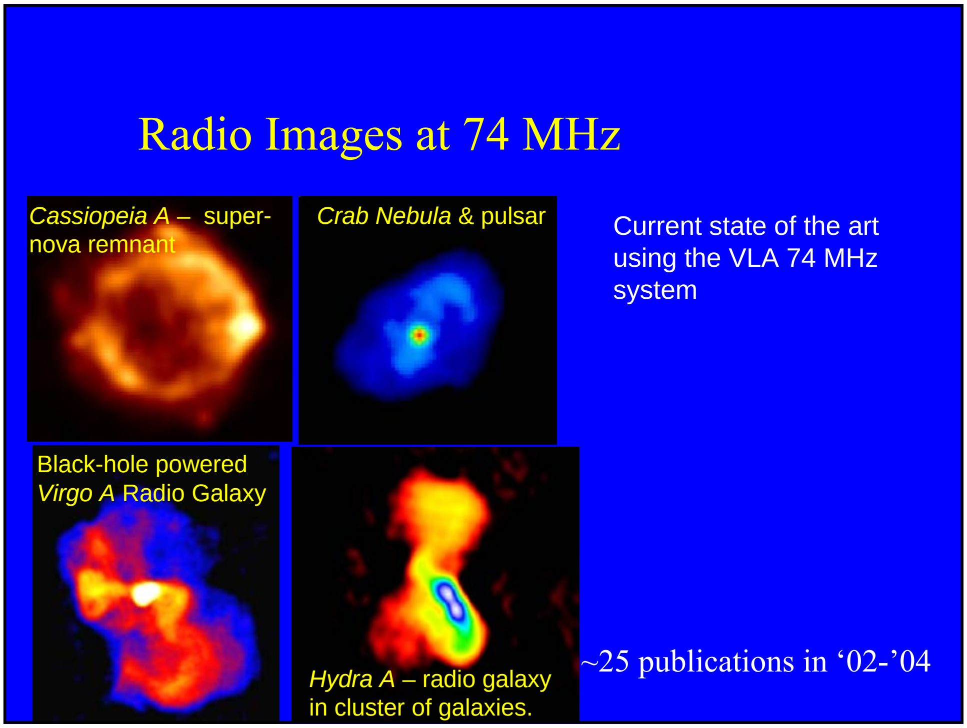
(LWA: http://lwa.unm.edu)

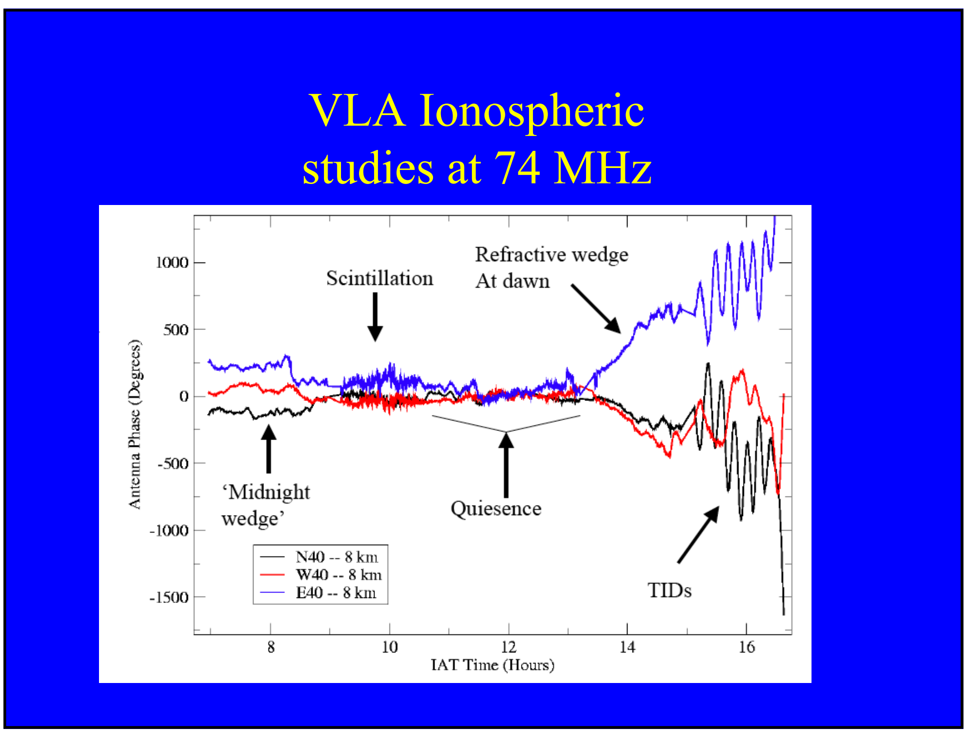
A project of the Southwest Consortium

Los Alamos NATIONAL LABORATORY

The University of New Mexico

ARL The University of Texas at Austin


Radio Images at 74 MHz
Cassiopeia A – super-nova remnant
Crab Nebula & pulsar
Current state of the art using the VLA 74 MHz system
Black-hole powered Virgo A Radio Galaxy
Hydra A – radio galaxy in cluster of galaxies.
~25 publications in '02-'04


VLA Ionospheric studies at 74 MHz
Scintillation
Refractive wedge At dawn
'Midnight wedge'
Quiesence
TIDs
N40 -- 8 km
W40 -- 8 km
E40 -- 8 km
Antenna Phase (Degrees)
IAT Time (Hours)
1000
500
0
-500
-1000
-1500
8
10
12
14
16

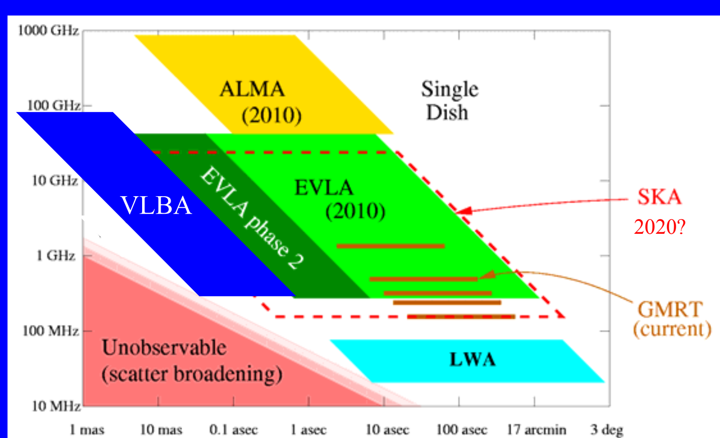
Key Limitation:
Need Something *Much Larger*

- The VLA not designed to provide good sensitivity below 100 MHz
  - ε ~15%
  - Single ν insufficient – need to go to lower frequencies with broad-band system

- Below 100 MHz, we need
  - Increased collecting area – currently limited to rms~25 mJy
  - Longer baselines – currently limited to θ~ 20" (θ ~ λ/D – D limited to 35 km)
  - Broad-band system – currently limited to 1.6 MHz bandwidth

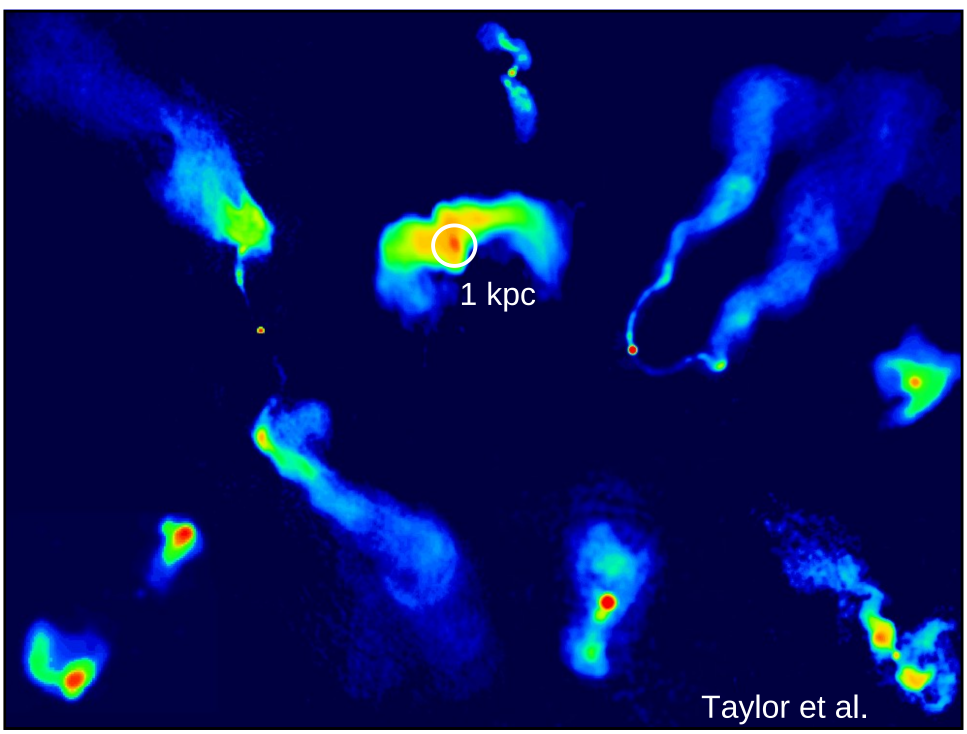
- New Technology Development
  - Beam forming
  - Buffering to allow for looking back in time
  - Wide field imaging/Improved Ionospheric Calibration

LWA Discovery Space
in frequency and resolution



Key LWA Science Drivers

1. Acceleration of Relativistic Particles in:
   - Hundreds of SNRs in normal galaxies at energies up to 10^{15} ev.
   - In thousands of radio galaxies & clusters at energies up to 10^{19} ev
   - In ultra high energy cosmic rays at energies up to 10^{21} ev and beyond.
2. Cosmic Evolution & The High Redshift Universe
   - Evolution of Dark Matter & Energy by differentiating relaxed & merging clusters
   - Study of the 1st black holes & the search for HI during the EOR & beyond
3. Plasma Astrophysics & Space Science
   - Ionospheric waves & turbulence
   - Acceleration, Turbulence, & Propagation in the ISM of Milky Way & normal galaxies.
   - Solar, Planetary, & Space Weather Science
4. Transient Universe
   - ***Possible new classes of sources (coherent transients like GCRT J1745-3009)***
   - ***Magnetar Giant Flares***
   - ***Extra-solar planets***
   - ***Prompt emission from GRBs***



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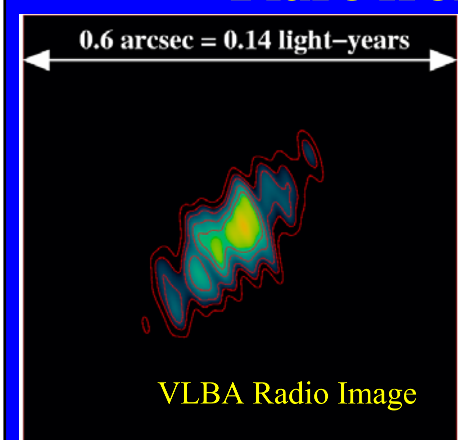
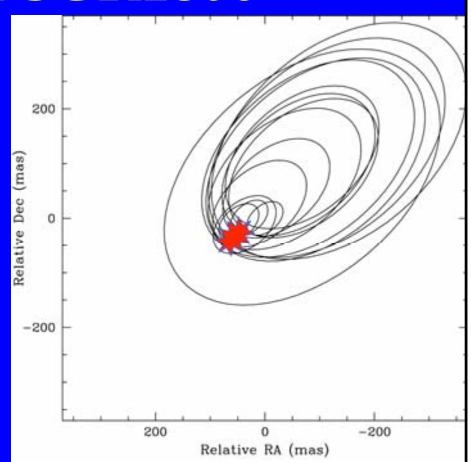
The 2004 Dec. 27 Giant Flare from SGR1806



VLBA Radio Image

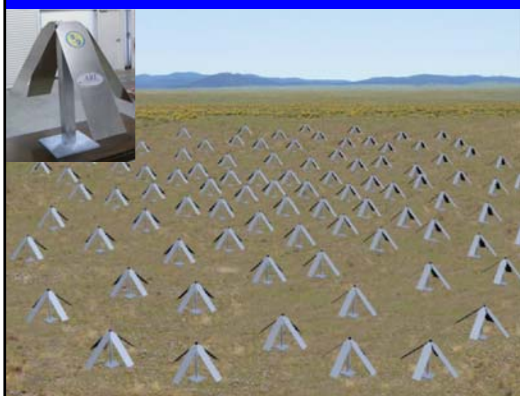


VLA monitoring over 80 days

- distance ≈ 15 kpc
- $E_{iso} \sim 10^{46}$ erg

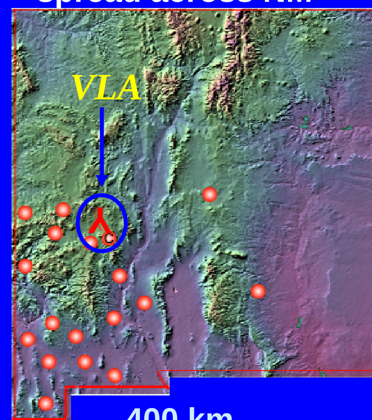
LWA Overview: Far Larger than the VLA

1 "LWA Station" = 256 antennas



100 m

Full LWA: 50 stations spread across NM



State of New Mexico

400 km

Phased Development

Time	Phase	Description	Acronym
2004	0	Existing 74 MHz VLA	VLA74
2006-2008	I Funded!	Long Wavelength Development Array +Long Wavelength Array Station #1	LWDA LWA1
2007-2010	II	9 station Long Wavelength Intermediate Array	LWIA
2010-2012	III	LWA Core	LWAC
2012-2014	IV	High Resolution LWA	LWA
2009-	V	LW Operations and Science Center	LWOSC

Technical Specifications: Summary

	Required	Desirable
• Frequency Range:	20 MHz to 80 MHz	10 MHz to 88 MHz
• Angular resolution:	$\theta \leq [8,2]$"	$\theta \leq [7,1.4]$"
• LAS at [20,80] MHz	$\geq [8,2]°$	$\geq [16,4]°$
• Baseline range:	100 m to 400 km	50 m to 600 km
• Sensitivity [20,80 MHz]:	$\sigma \leq [1.0,0.5]$	$\sigma \leq [0.5,0.1]$
• Collecting Area (m^2)	$A_e = 1 \times 10^6$	$A_e = 4\times10^6$
• Dynamic range:	$DR \geq [1\times10^3, 2\times10^3]$	$DR \geq [2\times10^3, 8\times10^3]$
$\Delta\nu_{max}$ (per beam)	$\Delta\nu \geq 4$ MHz	$\Delta\nu \geq 8$ MHz
$\Delta\nu_{min}$	$\Delta\nu \leq 100$ Hz	$\Delta\nu \leq 10$ Hz
• Temporal Res	$\Delta\tau = 10$ msec	$\Delta\tau \leq 0.1$ msec
• Polarization:	1 circular	Full
• Sky Coverage:	$z \geq 40°$	$z \geq 15°$
• FoV [20,80] MHz	$[8,2]°$	$\leq [16,4]°$
• # of beams:	4 single pol.	≥ 4 single pol.
• Configuration:	2D array, N = 53 stations	2D array, $N \geq 53$
• Philosophy:	User-oriented, open facility; proposals solicited from entire community	
• Mechanical lifetime	≥ 15 years for potentially long lifetime	

Engaging Universities

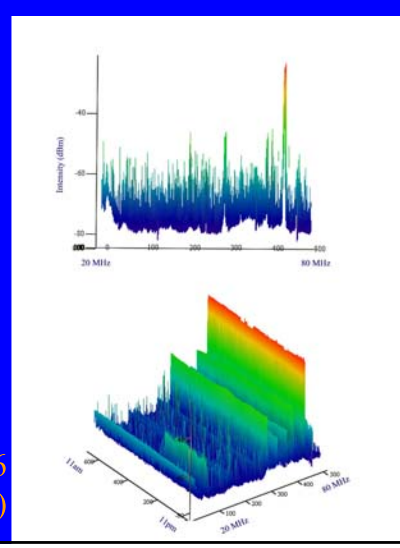
- The Long Wavelength Array R&D planned
  - Four Scientific Testing and Evaluation Teams:
    1) High Resolution Imaging / Particle Acceleration
       Caltech, Colorado, Minnesota, UNM, UT
    2) Wide Field Imaging / Cosmic Evolution
       NMT, Stanford, UNM, UVA
    3) Ionosphere / Ionsopheric Physics
       UT
    4) RFI Mitigation and Excision / Transients□□
       Berkeley, Caltech, Iowa, Sweet Briar, UNM, VT
- R&D in progress at UNM
  - Three UNM students: Eduardo Ros, Robert Edmonds, Steve Tremblay
  - Two UNM postdocs: Joe Helmboldt and Gianfranco Gentile
  - Another UNM/NRAO postdoc now being advertised

Students at work

Student Projects

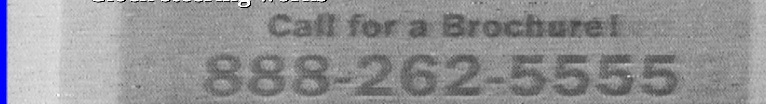
- Characterize RFI environment at proposed LWA sites
- Emissions shielding of LWA electronics
- Interfacing the LWDA with the VLA
- Testing and evaluation of LWA electronics
- Testing performance of LWA dipoles
- Command & Control Software development
- Post-processing software development

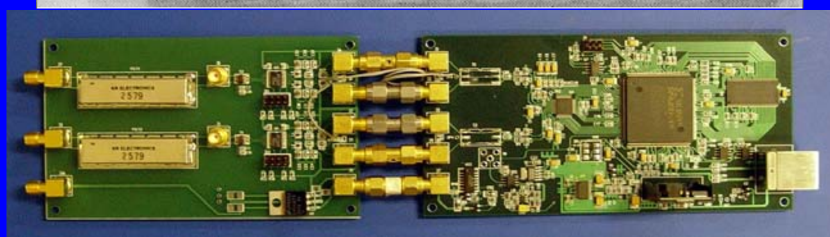
RFI on Feb 10, 2006
Courtesy T. Jaeger (Iowa)



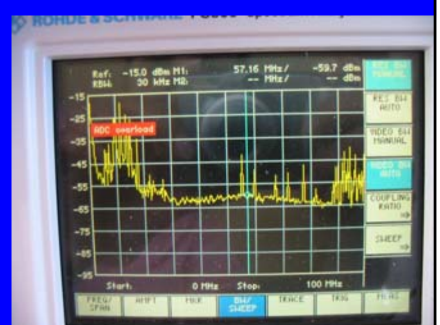
Receiver Rev. 2 Status

- **Verified capabilities**
  - **Powers on**
  - **FPGA remotely configurable**
  - **Clock steering works**
  - **LVDS transfer over 30m Cat5e works**
  - **Data collection has occurred => successfully hosts limited DSP firmware**
  - **Cost per Unit: $900**





LWDA site - 1



First Light!

First antenna in September 05

LWDA site - 2

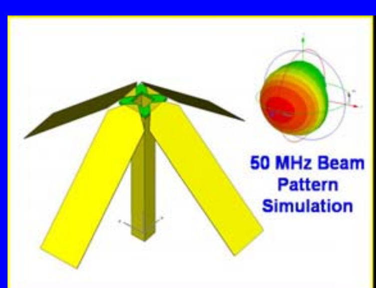
LWDA site - 3

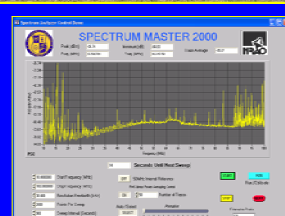
LWDA site - 4

LWDA site - 5

LWDA site

Active Antenna Field Testing
Green Bank, WV





Nagini Paravastu & Brian Hicks

Active Antenna Field Testing
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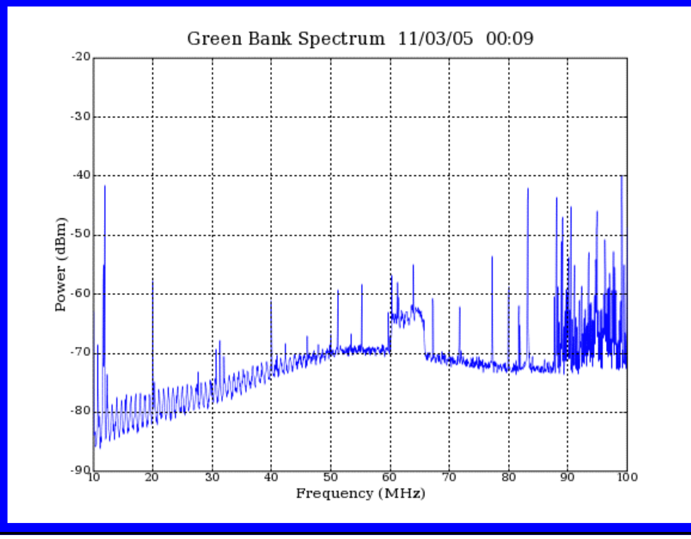

SUMMARY

- The LWA will open one of the last and most poorly explored regions of the EM spectrum below 100 MHz
  - Multi-beam, multi-frequency electronic array will herald revolutionary new approach to astronomical observations
  - Key science drivers include important topics in Ionospheric Physics, Cosmology, Acceleration physics, Plasma Astrophysics, & Solar and Space Weather Physics
- A great potential of the LWA is one for exploration, especially of the most poorly explored transient universe.
  - Other new LF instruments are also emerging: LOFAR, MWA, PAST
  - By going to the longest baselines and the lowest frequencies, the LWA ensures its uniqueness in the exciting search for new discoveries with the emerging suite of powerful, low frequency instruments.