Astronomy at the University of New Mexico

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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

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?

van Langevelde et al. 2000
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).

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.

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

- Delphinus void
- Local void
- Cygnus void
- Microscopium void
- Pisces-perseus supercluster
- Orion void?
- Gemini void
- Puppis filament
- Canis Major void
- A569
- A539
Taylor: VLBI Imaging of Active Galactic Nuclei

VLBA Imaging Polarimetry Survey (VIPS)

- 1127 sources: $S > 85$ mJy, $65 > \text{dec} > 20$, $|b|>10$ 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
Radio Images at 74 MHz

- Cassiopeia A – supernova remnant
- Crab Nebula & pulsar
- Black-hole powered Virgo A Radio Galaxy
- Hydra A – radio galaxy in cluster of galaxies.

Current state of the art using the VLA 74 MHz system

~25 publications in ‘02-’04

VLA Ionospheric studies at 74 MHz

- Scintillation
- Refractive wedge
- At dawn
- ‘Midnight wedge’
- Quiescence
- TIDs
Key Limitation: Need Something Much Larger

- The VLA not designed to provide good sensitivity below 100 MHz
  - $\epsilon \sim 15\%$
  - Single $v$ 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 $\theta \sim 20''$ ($\theta \sim \lambda/D$ – $D$ 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

Taylor et al.
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The 2004 Dec. 27 Giant Flare from SGR1806

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

VLBA Radio Image

VLA monitoring over 80 days
**LWA Overview:**
Far Larger than the VLA

1 “LWA Station” = 256 antennas
Full LWA: 50 stations spread across NM

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**Phased Development**

<table>
<thead>
<tr>
<th>Time</th>
<th>Phase</th>
<th>Description</th>
<th>Acronym</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>0</td>
<td>Existing 74 MHz VLA</td>
<td>VLA74</td>
</tr>
<tr>
<td>2006-2008</td>
<td>I</td>
<td>Long Wavelength Development Array + Long Wavelength Array Station #1</td>
<td>LWDA LWA1</td>
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<tr>
<td>2007-2010</td>
<td>II</td>
<td>9 station Long Wavelength Intermediate Array</td>
<td>LWIA</td>
</tr>
<tr>
<td>2010-2012</td>
<td>III</td>
<td>LWA Core</td>
<td>LWAC</td>
</tr>
<tr>
<td>2012-2014</td>
<td>IV</td>
<td>High Resolution LWA</td>
<td>LWA</td>
</tr>
<tr>
<td>2009-</td>
<td>V</td>
<td>LW Operations and Science Center</td>
<td>LWOSC</td>
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### Technical Specifications:

#### Summary

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Required</th>
<th>Desirable</th>
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</thead>
<tbody>
<tr>
<td>Frequency Range:</td>
<td>20 MHz to 80 MHz</td>
<td>10 MHz to 88 MHz</td>
</tr>
<tr>
<td>Angular resolution:</td>
<td>$\theta \leq [8.2]^\circ$</td>
<td>$\theta \leq [7.1.4]^\circ$</td>
</tr>
<tr>
<td>LAS at [20,80] MHz</td>
<td>$\geq [8.2]^\circ$</td>
<td>$\geq [16.4]^\circ$</td>
</tr>
<tr>
<td>Baseline range:</td>
<td>100 m to 400 km</td>
<td>50 m to 600 km</td>
</tr>
<tr>
<td>Sensitivity [20,80 MHz]:</td>
<td>$\sigma \leq [1.0,0.5]$</td>
<td>$\sigma \leq [0.5,0.1]$</td>
</tr>
<tr>
<td>Collecting Area (m$^2$)</td>
<td>$A_e = 1 \times 10^6$</td>
<td>$A_e = 4 \times 10^6$</td>
</tr>
<tr>
<td>Dynamic range:</td>
<td>$\Delta v \geq 1 \times 10^3 \times 2 \times 10^3$</td>
<td>$\Delta v \geq 2 \times 10^3 \times 8 \times 10^3$</td>
</tr>
<tr>
<td>Temporal Res</td>
<td>$\Delta \tau = 0.1$ msec</td>
<td>$\Delta \tau \leq 0.1$ msec</td>
</tr>
<tr>
<td>Polarization:</td>
<td>Full</td>
<td>Full</td>
</tr>
<tr>
<td>Sky Coverage:</td>
<td>$z \geq 40^\circ$</td>
<td>$z \geq 15^\circ$</td>
</tr>
<tr>
<td>FoV [20,80 MHz]</td>
<td>$[8,2]^\circ$</td>
<td>$\leq [16,4]^\circ$</td>
</tr>
<tr>
<td># of beams:</td>
<td>4 single pol.</td>
<td>$\geq 4$ single pol.</td>
</tr>
<tr>
<td>Configuration:</td>
<td>2D array, $N = 53$ stations</td>
<td>2D array, $N \geq 53$</td>
</tr>
<tr>
<td>Philosophy:</td>
<td>User-oriented, open facility; proposals solicited from entire community</td>
<td></td>
</tr>
<tr>
<td>Mechanical lifetime</td>
<td>$\geq 15$ years for potentially long lifetime</td>
<td></td>
</tr>
</tbody>
</table>

### 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 / Ionospheric 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
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 on March 5
LWDA site

LWDA Site on March 15, 2006

Active Antenna Field Testing
Green Bank, WV

Data Acquisition System

Nagini Paravastu & Brian Hicks
Active Antenna Field Testing
Green Bank, WV

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.