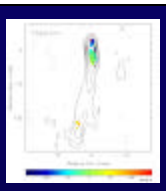




The Future of Very Long Baseline Interferometry and AGN surveys at milliarcsecond resolution

Greg Taylor
NRAO/KIPAC

GLAST Lunch talk, 2004 October 21

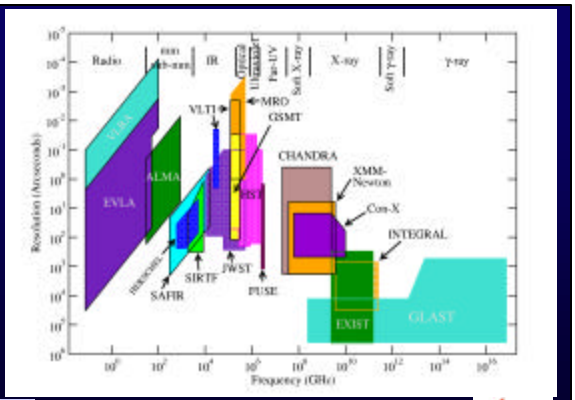
Very Long Baseline Array (VLBA)

Dedicated in 1993

10 antennas recording to tape

Correlator in Socorro, NM

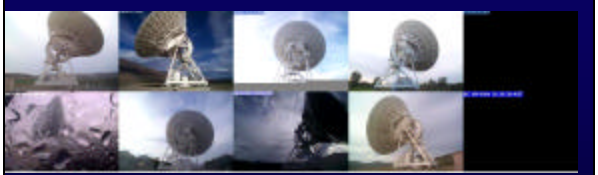
Combinable with Global Arrays



Discovery Space

The Very Long Baseline Array (VLBA)

VLBA Time Lapse Movie



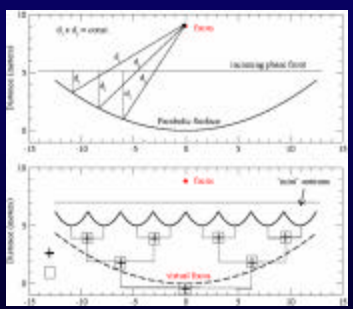
courtesy Enno Middelberg
and the NRAO site Techs

Aperture Synthesis – Basic Concept

If the source emission is unchanging, there is no need to collect all of the incoming rays at one time.

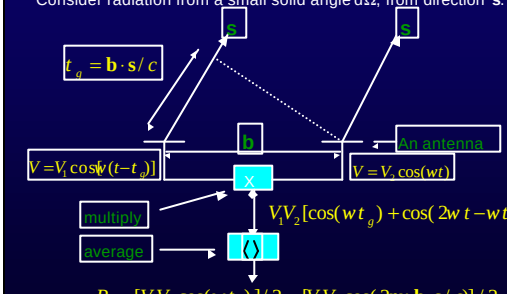
One could imagine sequentially combining pairs of signals. If we break the aperture into N sub-apertures, there will be N(N–1)/2 pairs to combine.

This approach is the basis of aperture synthesis.



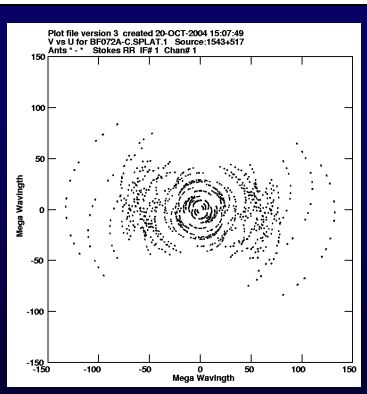
The Stationary, Monochromatic Interferometer

A small (but finite) frequency width, and no motion.
Consider radiation from a small solid angle dΩ, from direction **s**.



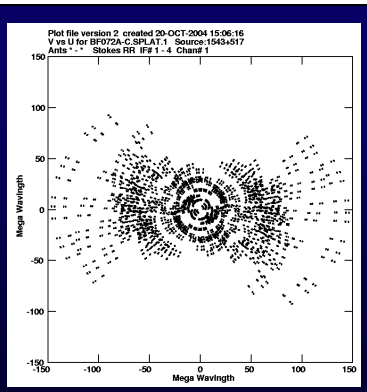
u,v coverage
for 1543+517
in VIPS

single
frequency



u,v coverage
for 1543+517
in VIPS

four
frequencies



Mapping the Future of VLBI Science in the U.S.

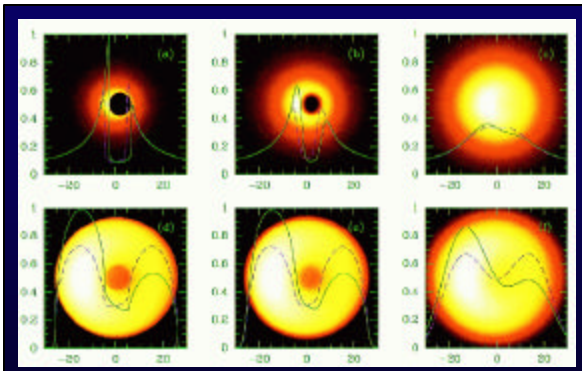
http://www.nrao.edu/VLBIfuture

VLBI Future Committee:

Shep Doeleman (Haystack Obs.)
Dave Hough (Trinity College)
Shri Kulkarni (Caltech)
Colin Lonsdale (Haystack Obs.) co-chair
Alan Marscher (Boston Univ.)
Chris O'Dea (STScI)
Greg Taylor (NRAO) co-chair
David Wilner (Harvard-Smithsonian CfA)
Joan Wrobel (NRAO)

Future Science Prospects

Imaging Massive Black Holes
Gravitational Lenses – Where is the Dark Matter?
Supernova Factories and nascent AGNs
Launching AGN Jets
Kinematics of the Local Group
Magnetism in Stars
Binary Black Holes
Imaging Cosmic Explosions from GRBs and SNe



Gravitational Radii (0.5 R_sch)

Falcke et al.

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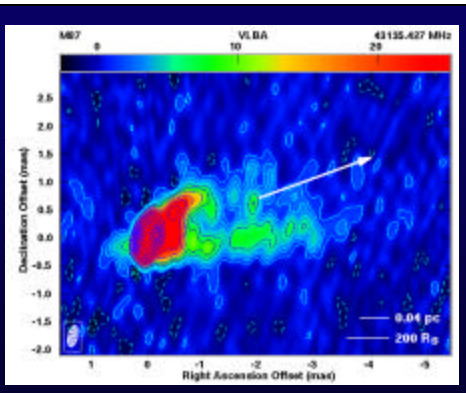

Ly, Walker & Wrobel 2003

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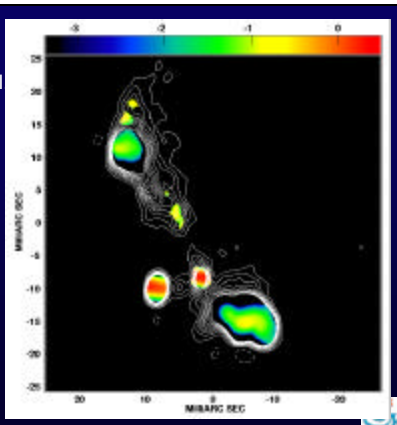
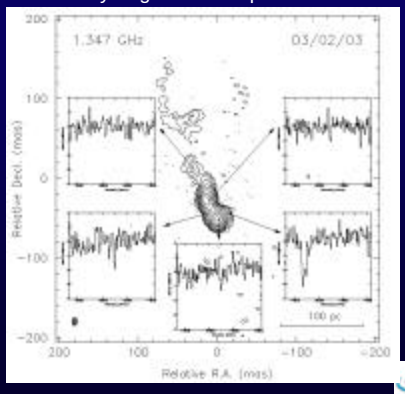
0402+379
Maness et al
2004

A Close
Binary
Black
Hole
Candidate



0402+379 neutral hydrogen in absorption



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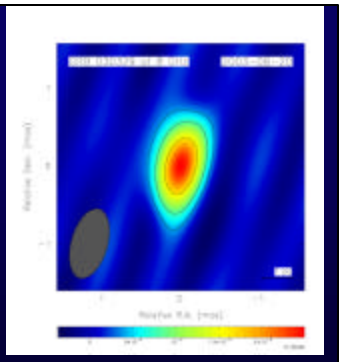
Imaging Cosmic Explosions from GRBs and SNe

June 20, 2003

+83 days

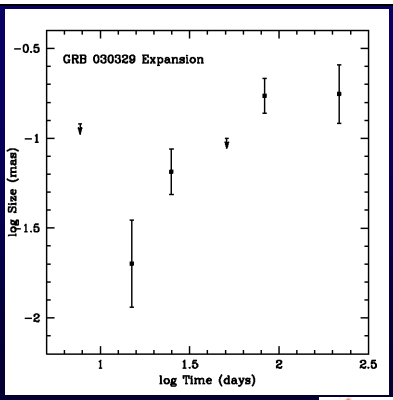
Peak ~ 3 mJy
Size 0.172 +/- 0.043 mas
0.5 +/- 0.1 pc
average velocity = 3c



VLBA+Y27+GBT+EB+AR+WB = 0.11 km^2

R ~ (E/n)**1/8

E ~ 10**53 ergs
(isotropic equivalent)



Resolving the Afterglow

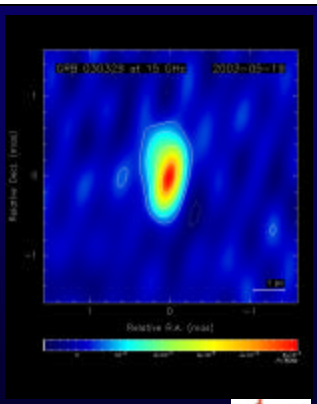
4th Epoch – May 19, t +51 days
VLBA+EB+GBT+Y27

Beam is 0.67 x 0.24 mas

Jet component at 0.28 +/- 0.05 mas

Not consistent with standard model prediction of 0.12 mas expansion

average expansion velocity of 19c



Recommendations

Hardware

- Implement Mark 5 disk-based recording
- Increase VLBI participation of GBT and Arecibo
- Upgrade the 22-86 GHz performance of the VLBA
- Investigate connections with EVLA and future facilities
- Support VLBI at mm wavelengths on new facilities

Recommendations

Software

- Dedicate new resources in order to:
  - Improve ease-of-use
  - Provide new capabilities
- Coordinate with activities in the U.S., Europe, and abroad

Recommendations

Astronomical Community

- Support graduate students at U.S. Universities
- Investigate financial support for time awarded on VLBI networks
- Send Greg on sabbatical to SLAC/Stanford

Previous AGN surveys at mas resolution

Pearson-Readhead (PR - 1988): 5 GHz, 35 sources
Caltech-Jodrell Bank (CJ1 - 1995): 1.7 and 5 GHz, 65 sources
Second Caltech-Jodrell Bank (CJ2 - 1994): 5 GHz, 192 sources
CJ Flat spectrum (CJF – 1996): 5 GHz, 293 sources
VLBA 2cm survey (2000): 15 GHz, 132 sources
VSOP pre-launch survey (1998): 5 GHz, 374 sources
USNO geodetic survey (2004): 2.2 and 8GHz, 452 sources

Polarization: partial observations at a single frequency for PR and CJF
Multi-epoch: PR, CJ, VLBA 2cm, USNO

CJF Survey

Caltech-Jodrell Bank flat-spectrum survey

- 293 extragalactic radio sources
- Parent samples include: PR ('81, '88), CJ1 ('95), CJ2 ('94) surveys
- Criteria: $S_{4850} \geq 350$ mJy

  α^{4850} and $\alpha_{1400} \geq -0.5$

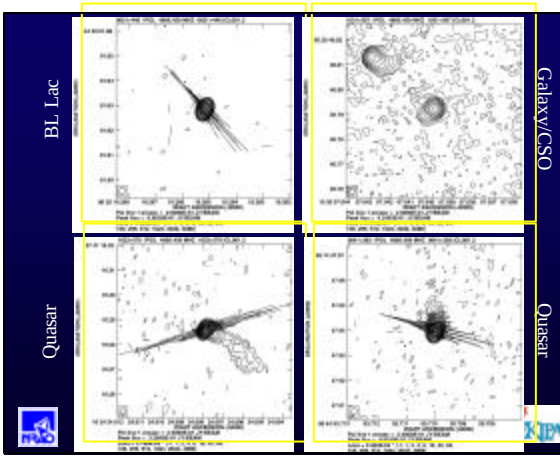
  $\delta_{B1950} \geq 35^{o}$

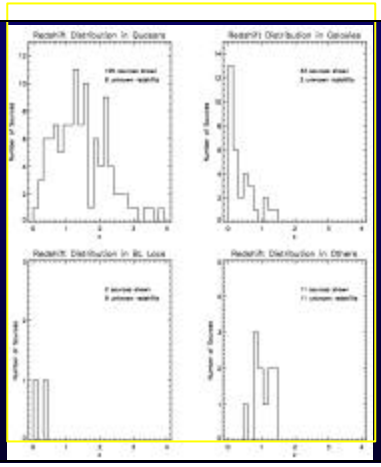
  $|b| \geq 10^{o}$

CJF Polarimetry

Characteristics, Classifications & Completeness

- 182 CJF sources imaged with the VLBA on 1998 February, 1999 November and 2000 December
- ~300 hours of observation over 15 days
- Optical classifications by Henstock, Vermeulen & Taylor, 1995 give:
  - 113 Quasars
  - 36 Galaxies
  - 11 BL Lacs
  - 22 'others'
- Redshift completeness: 151/182





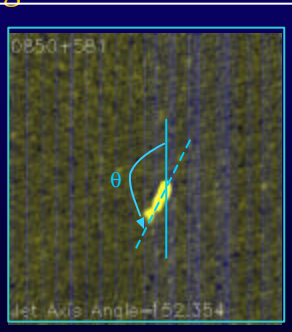
~~Defining the Source Characteristics~~

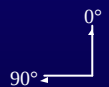
- Morphologies based on total intensity give: 37 naked cores, 137 core-jets and 8 compact symmetric objects
- Define jet angle (?) using closest component to core
- Define jet length as distance to farthest component (irrespective of jet bend)
- Measure: I_{tot} , p_{tot}

  I_{core} , p_{core} (peak flux at core position in Jy beam^{-1})

  average m_{core} , m_{jet}

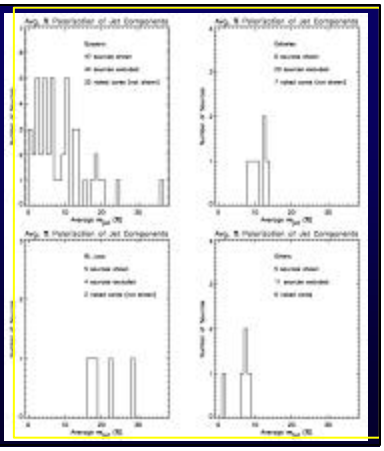
Defining the Source Characteristics





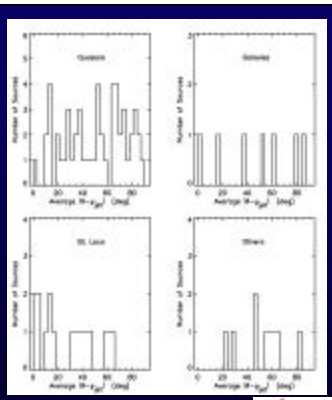
Discussion

•K-S test says says m_{jet} for BL Lacs is drawn from different parent distribution than Qs or Gs.



jet axis – Jet EVPA

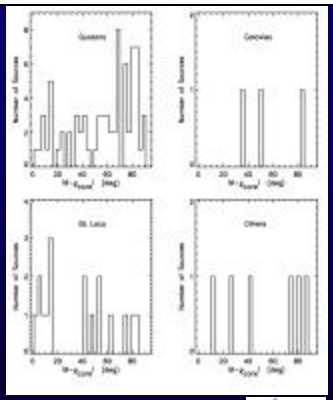
all consistent with flat distribution , no preferred orientation



jet axis – Core EVPA

•K-S test says 2% chance that $|\theta-\chi_{core}|$ is flat or randomly distributed

•Faraday rotation may conceal correlation

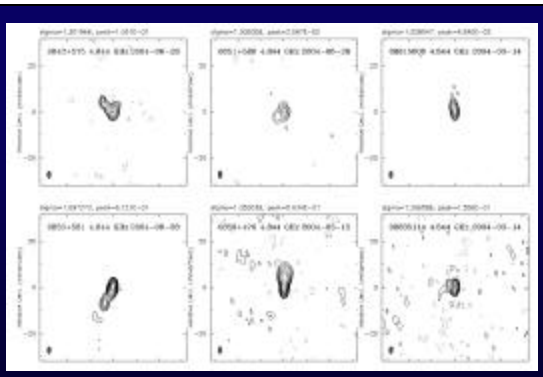


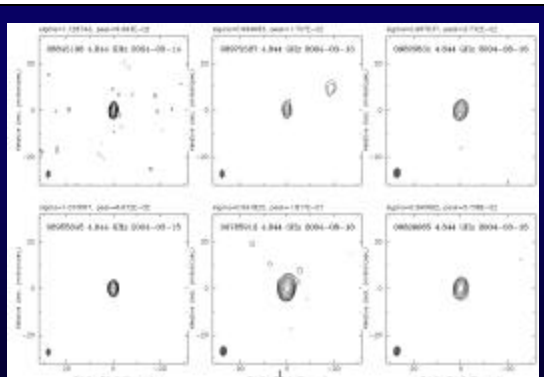
VLBA Imaging Polarimetry Survey (VIPS)

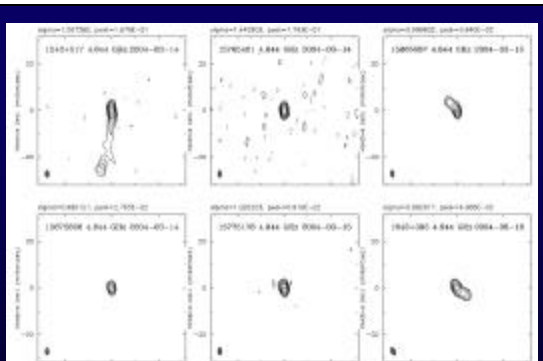
Parent Sample: CLASS
1000 sources: S > 50 mJy, dec > 20, |b|>10 at 5 & 15 GHz
Will require 1500 hours on the VLBA (63 days) @ 128 Mbps
or 750 hours @ 256 Mbps
Identifications and redshifts from SLOAN
Goals: Characterize GLAST sources
Understand polarization properties of AGN classes
Study AGN environments via Faraday rotation
Find new Compact Symmetric Objects
Find (possibly) the first milli-lenses

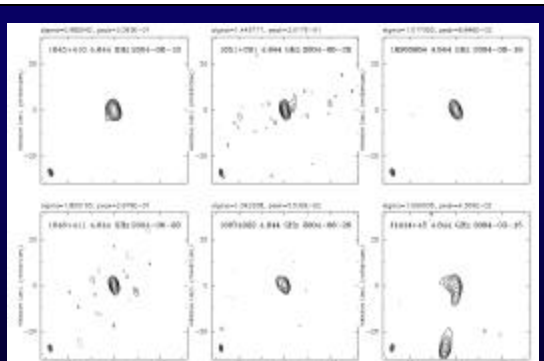
VIPS Pilot Project

4 x 12 hours with the VLBA on Mar 13, 14, Jun 28, Aug 18
24 target sources at 5 and 15 GHz
16 GB of data
All data reduced by new pipeline procedures

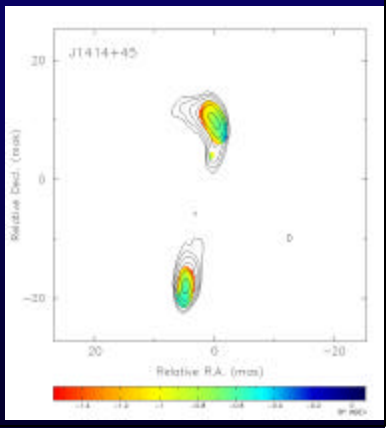






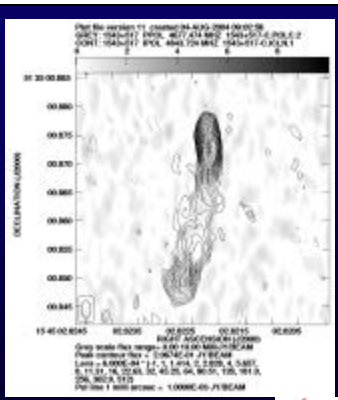


Spectral Indices



Polarization

detected in 9/24 sources (38%)



Faraday Rotation

Polarised Source

Plasma

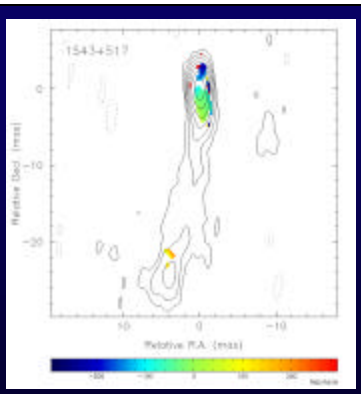
$n_e = n_i$

$B_{||}$

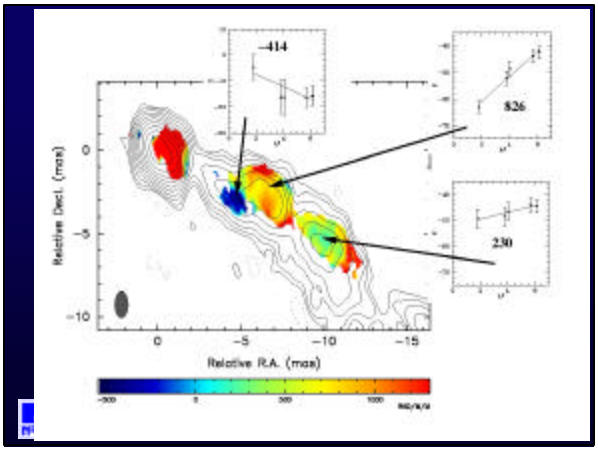
$\chi = \chi_0 + RM\,\lambda^2$

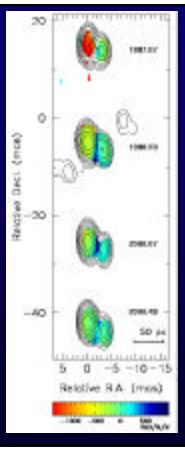
$RM = 812 \int_0^L n_e B_{||}\, dl$ radians/m^2

(n_e in cm^{-3}, $B_{||}$ in mGauss, L in pc)



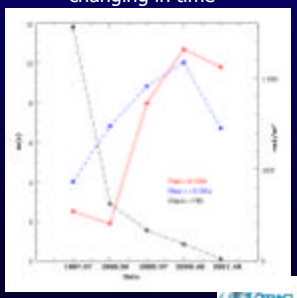
Faraday Rotation Measures

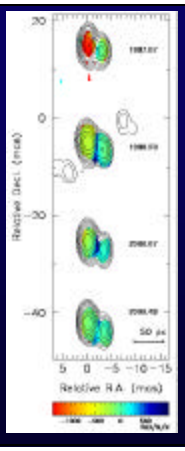




Zavala & Taylor (2002)

3C279 Rotation Measures changing in time





Zavala & Taylor (2002)

Source

Screen

Observer

Summary

Exciting time for VLBI:

- Major scientific results being made possible by new technologies
- Increased synergy with other wavelengths

Good time for a big AGN survey: