



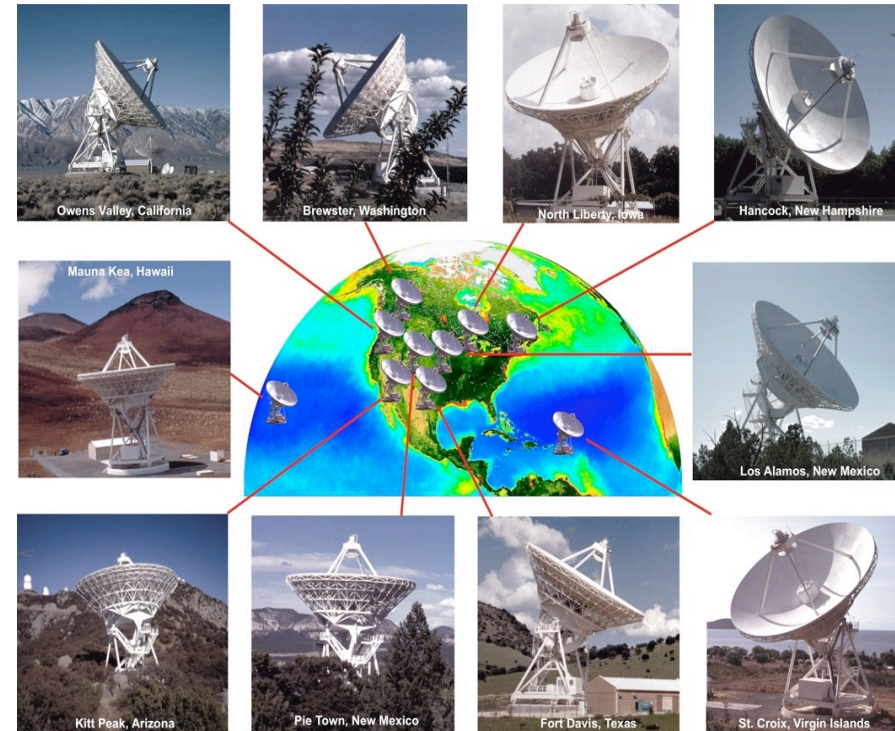
The Very Long Baseline Array

Amy Mioduszewski



Instrument Overview

- A 10 element interferometer radio telescope
 - Identical 25m diameter antennas
 - Array dedicated to Very Long Baseline Interferometry (VLBI)
- Antenna sites in US territory from Mauna Kea Hawaii to St. Croix, US Virgin Islands
 - Baseline lengths between 236 km and 8611 km
- Software Correlator (DiFX) in Socorro, NM



Instrument Overview II

Frequency coverage from 330 MHz (90 cm) to 90 GHz (3mm)

- In 10 frequency bands
- Current highest bandwidth 256MHz (dual polarization)
- Wide instantaneous spanned bandwidth:
 - S/X mode: simultaneous 2.4 GHz and 8.4 GHz observing
 - C-band receiver: simultaneous tunings anywhere in 4-8 GHz band

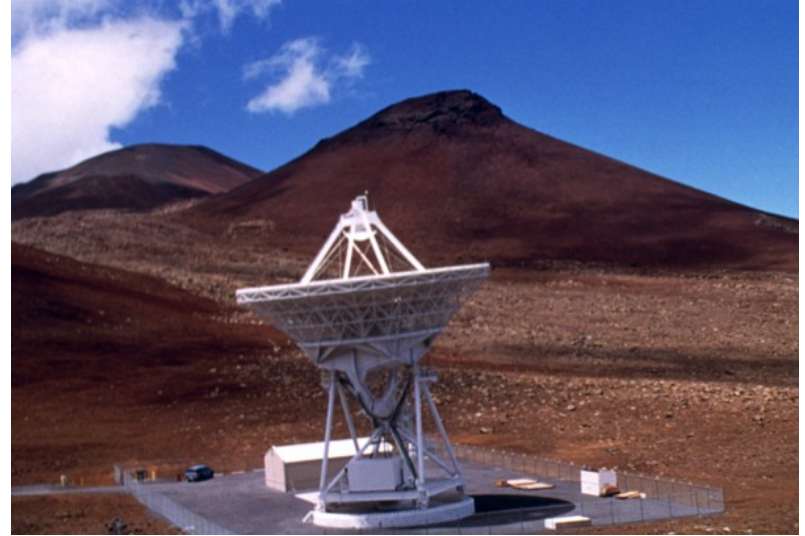
λ (cm)	ν (GHz)	σ (μ Jy/beam) in 8 hrs at 2Gbps
90 cm	0.312 - 0.342	266*
50 cm	0.596 - 0.626	681*
21 cm	1.35 - 1.75	10-12
13 cm	2.15 - 2.35	12
6 cm	3.9 - 7.9	6-9
4 cm	8.0 - 8.8	11-15
2 cm	12.0 - 15.4	18
1 cm	21.7 - 24.1	18-22
7 mm	41.0 - 45.0	40
3 mm	80.0 - 90.0	180†

Instrument Overview III

- The RDBE (ROACH Digital Back End) has two systems: the PFB and the DDC
- The PFB has
 - 8 X 32MHz dual pol channels (or subbands in VLA terminology, or IF in AIPS terminology), or 16 X 32 MHz single polarization.
 - these result in 2Gbps recording, the current highest data rate.
 - generally recommended for continuum observations.
- The DDC is (assuming dual pol)
 - either 2 or 4 data channels (subbands) range downward from 128MHz to 1MHz in binary steps.
 - again (current) maximum of 256MHz dual pol (2Gbps)
 - generally used for spectral line.
- Starting in Semester 2019A: Mark6 - 4 Gbps recording (shared risk)

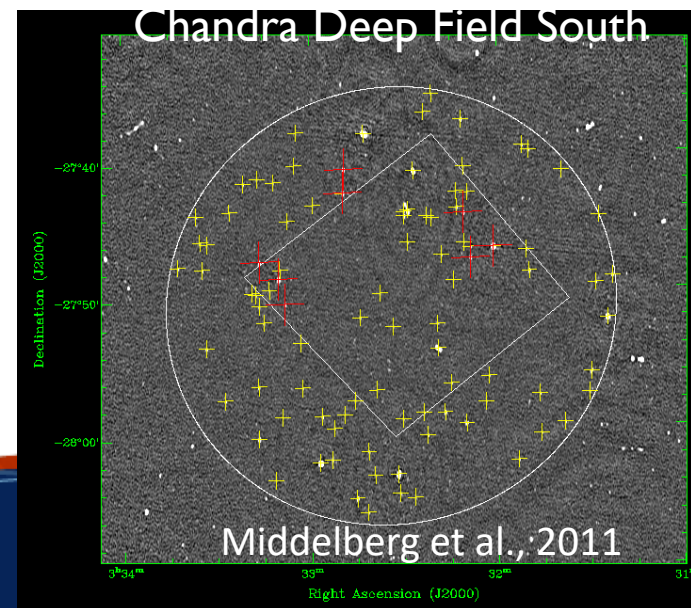
Science applications of VLBA and VLBI

- VLBI provides a tool to study mas-level structure in radio sources.
 - Active Galactic Nuclei (AGN)
 - Pulsars
 - Masers
 - Supernova/Supernova Remnants
 - Magnetically active stars
 - X-ray binaries
 - Nova
- A VLBI detection instantly identifies a compact non-thermal source
 - Synchrotron/cyclotron radiation (electrons in a magnetic field)
 - Maser emission (stimulated emission)
 - Thermal lines seen in absorption against non-thermal background



Special correlator capabilities (DiFX)

- Pulsar gate
 - Synchronous correlator gate to improve signal to noise ratio of repeating signals, such as pulsars
- Multi-phase-center capability
 - Can simultaneously correlate at 100s of points in the antenna primary beam
 - Especially effective w/ VLBA due to identical antennas
- Ultra-high spectral resolution
 - Using “zoom” modes, can achieve 1 Hz
 - Up to 132096 channels if justified.
 - Used in some asteroid radar observing



Resident Shared Risk Observing (RSRO)

Some possible RSRO projects:

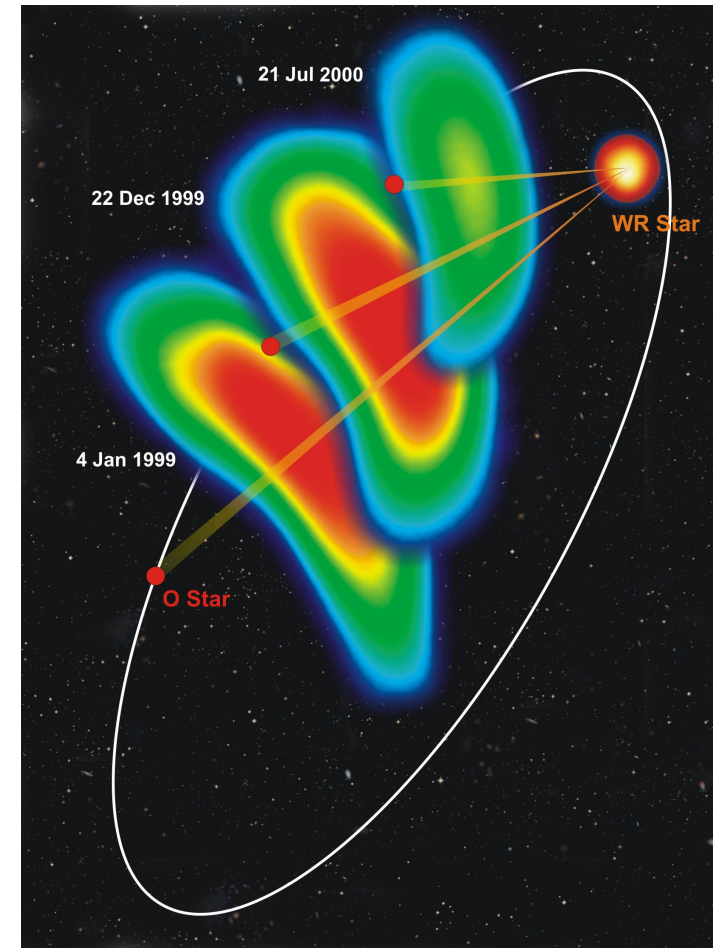
- VLA (Y1) single dish VLBI
- DDC-4 capability at Arecibo
- Rapid response capability
- 3mm VLBI with the LMT

Strengths of the VLBA

High dynamic range imaging at milliarcsecond resolution

- Locations of 10 antennas carefully chosen for optimal “UV coverage”
- Imaging resolution in different observing bands:
 - L-band (~ 1.6 GHz / 20 cm): 5 mas
 - X-band (~ 8 GHz / 4 cm): 0.85 mas
 - Q-band (~ 50 GHz / 7mm): 0.17 mas
- E.g. for ~ 1 mas resolution
 - 1 AU at 1 Kpc
 - Few-10 stellar radii at 100pc

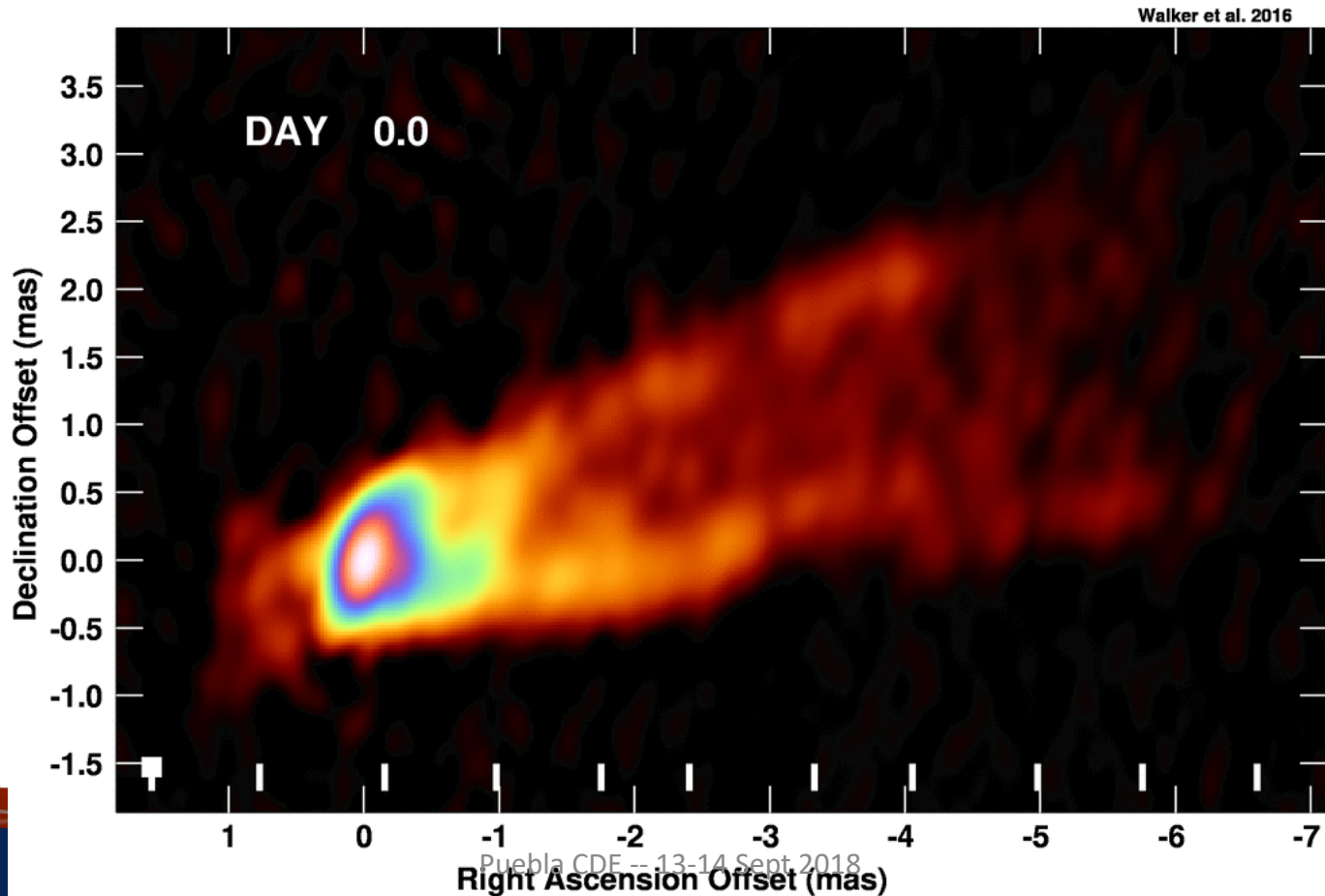
Example: WR140, imaging the evolution of the colliding wind region in Wolf-Rayet + O binary star system. Separation between stars between ~ 5 -15 mas or 9-27 AU (Dougherty et al. 2010).



Strengths of the VLBA

High dynamic range imaging at milliarcsecond resolution

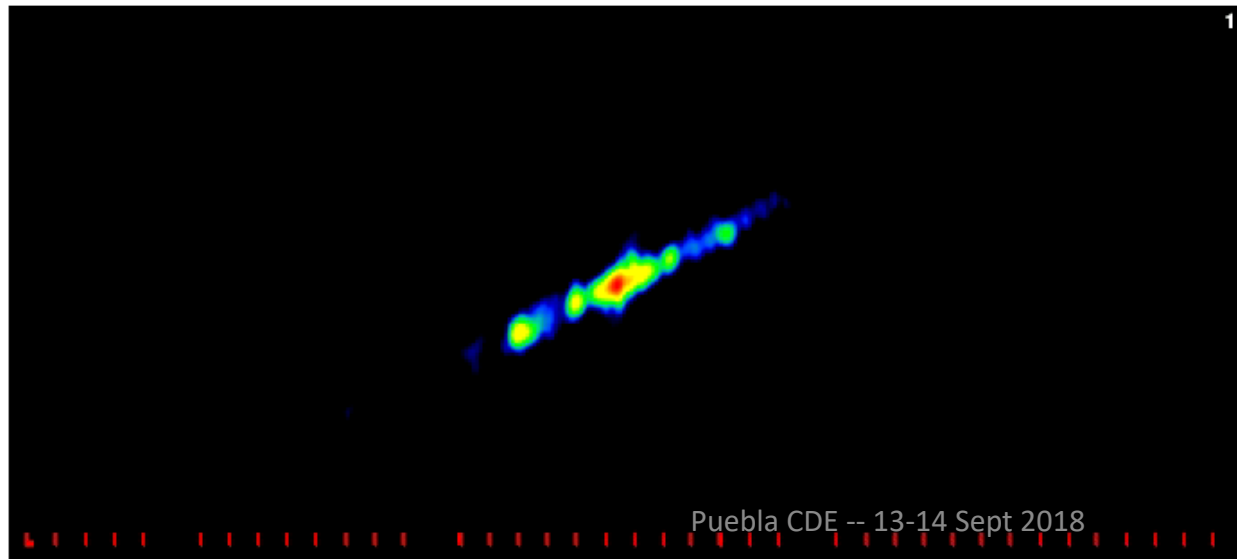
- M87 Jet at 43 GHz (R.C. Walker)
- Challenging: structure changes over time, high contrast



Strengths of the VLBA

Time-dependent phenomena

- VLBA available 24 hours per day, all year
- Can probe phenomena ranging from hours to years in duration
- VLBI sources tend to be variable in brightness, structure, and polarization
- Perfect instrument for wide range of science within graduate student's thesis timescale!



Example: Daily observations of X-ray binary SS433 over 40 days.
(Mioduszewski et al)

Strengths of the VLBA

High precision relative astrometry

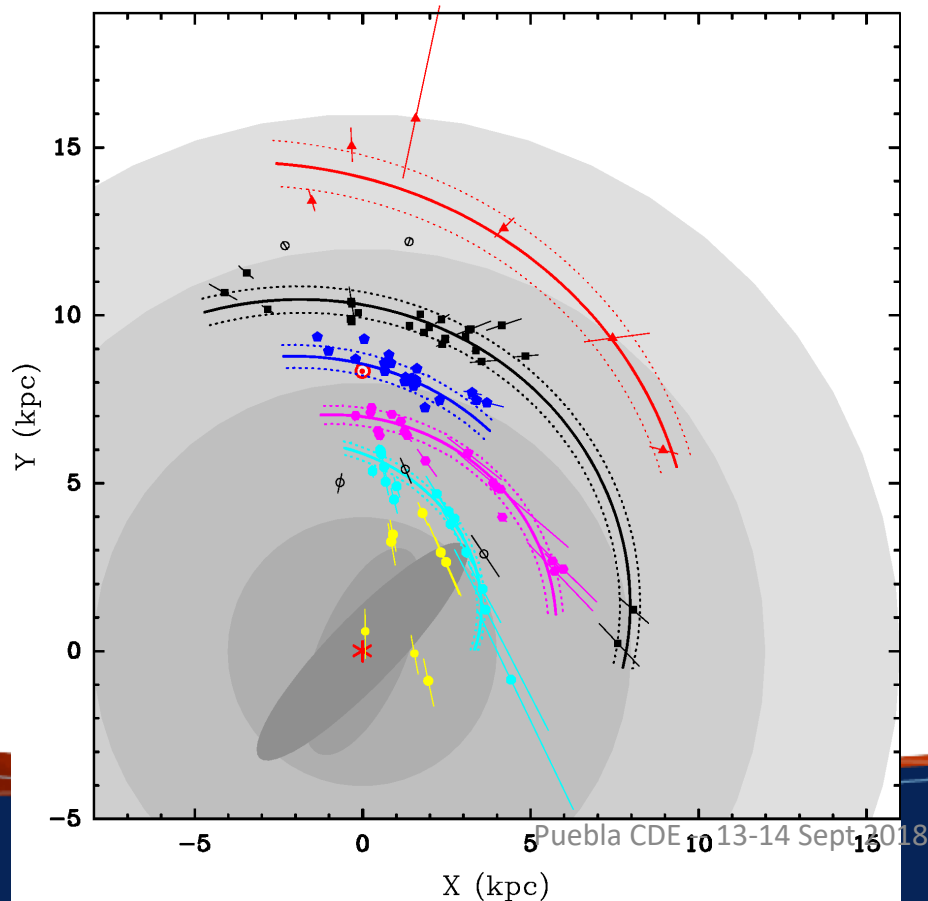
- Astrometry of a target object relative to a background quasar
 - Usually tied to ICRF to 0.25 mas
- Routinely repeatable at 0.1 mas precision
- Best astrometry to date better than 0.01 mas
- Can be performed on continuum or spectral line sources
 - E.g., pulsars, stars, masers



Strengths of the VLBA

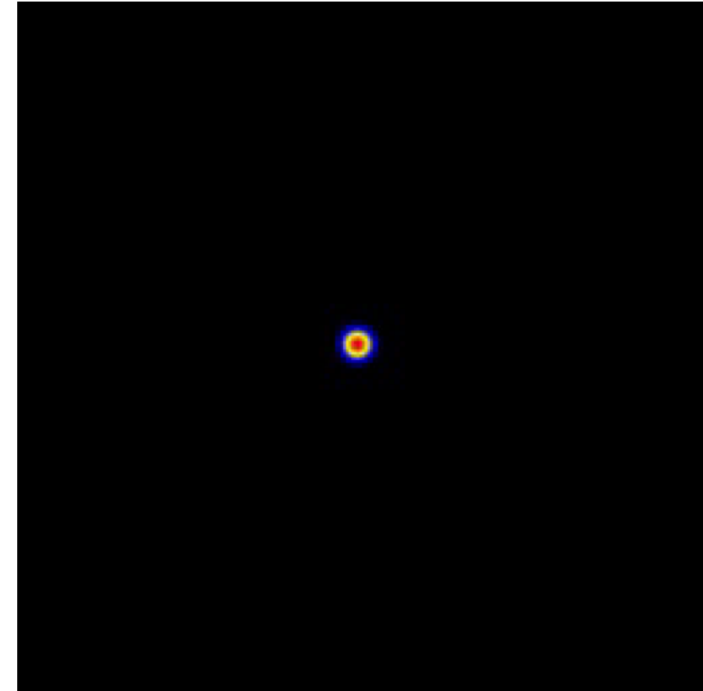
High precision relative astrometry

- BeSSeL project measures distances to star forming regions through methanol masers (Reid et al.), determining the structure of the spiral arms of the Galaxy.

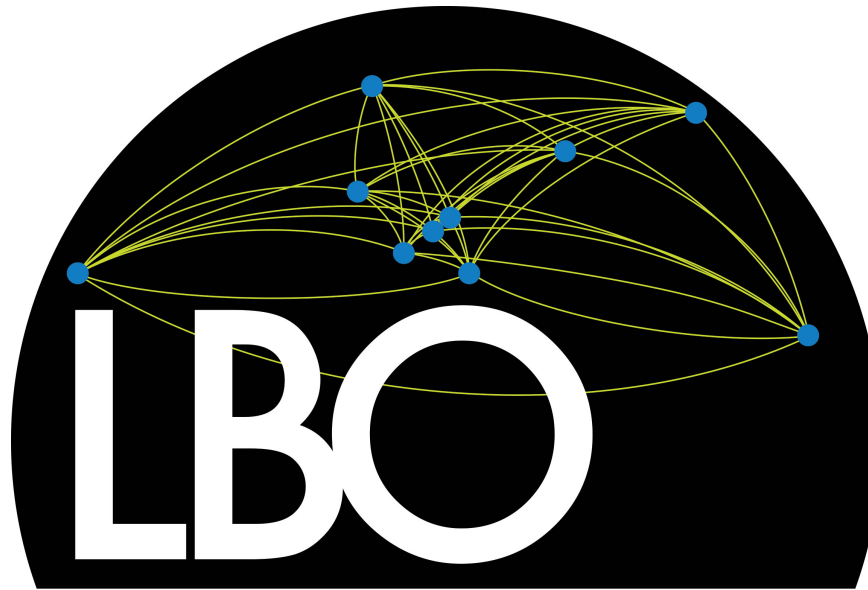


Extended arrays

- VLBA uses data formats and setups compatible with other VLBI antennas
- Routinely involved in High Sensitivity Array (HSA) with Arecibo, phased VLA, Green Bank Telescope and Effelsberg
 - Increases sensitivity by an order of magnitude
- Participates with European VLBI Network in the “Global VLBI Array”
- Joins the Global mm VLBI Array (GMVA) for 86-90 GHz (3mm) observations twice per year. Now with ALMA!
- Participates in global array of geodetic antennas for reference frame measurements.



Example: SNI 993J imaged over 10 years with VLBA+DSN+EVN (Bietenholz et al.)



LONG BASELINE OBSERVATORY

www.lbo.us

*The Long Baseline Observatory is a facility of the National Science Foundation
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