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Science with VLBI: the key to fundamental physics and fundamental astrophysics

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Overview

Some general considerations for VLBI

Cosmic reference frames

Stellar astrometry

Maser astrometry

Many classes of jets

Other VLBI facilities

Future of the field

VLBI constraints

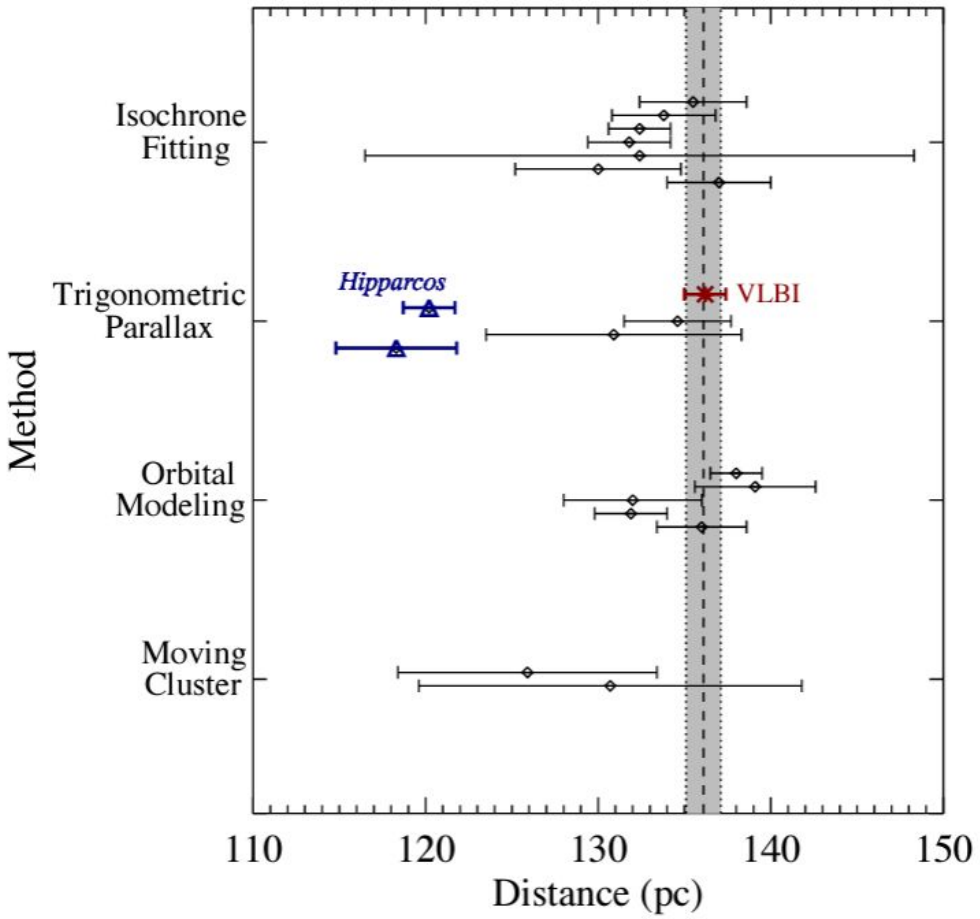
$$T = 1.222 \times 10^9 \frac{I}{\nu^2 \, \theta_{maj} \, \theta_{min}}$$

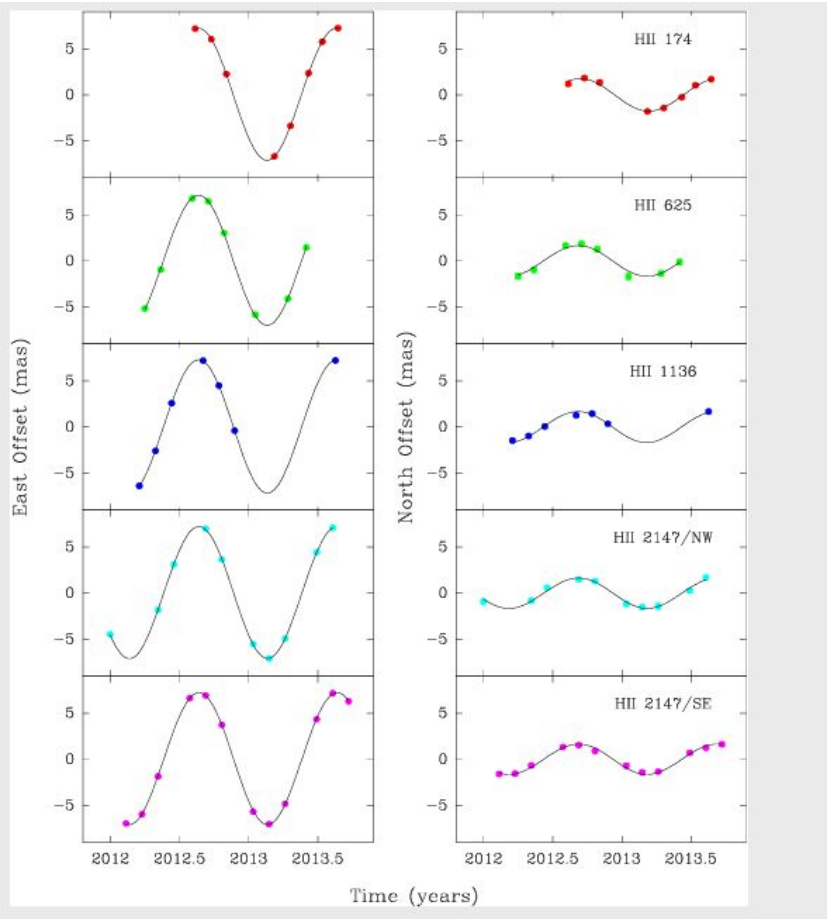
in units of K, GHz, mJy, milliarcsec

- VLBA has 10+3 elements (extra 3 are VLA, GBT, Effelsberg), 1 GHz bandwidth
- Without adding non-VLBA dishes, much less sensitive than VLA (~20 times less sensitive for continuum)
- Need higher signal to noise than VLA to get good detection
- *Predominantly nonthermal and/or coherent source analysis*

Fundamental astronomy: cosmic reference frames

Fundamental astronomy: setting the stellar parallax scale



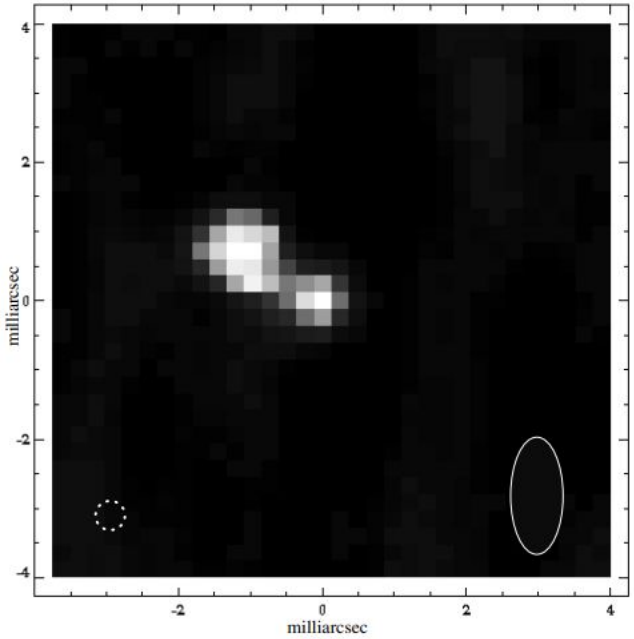


Melis et al. 2014 solves the Pleiades controversy

VLBA versus Gaia for parallaxes

1) VLBA sets the ground-truth and can be much more precist
2) Supernova can “move” quasar positions in optical but not in radio
3) Crowding is a problem in the Galactic Plane for Gaia
4) Highly reddened objects and pulsars are better in radio
5) Gaia’s advantage is its all-sky nature, not its quality for the best-studied objects

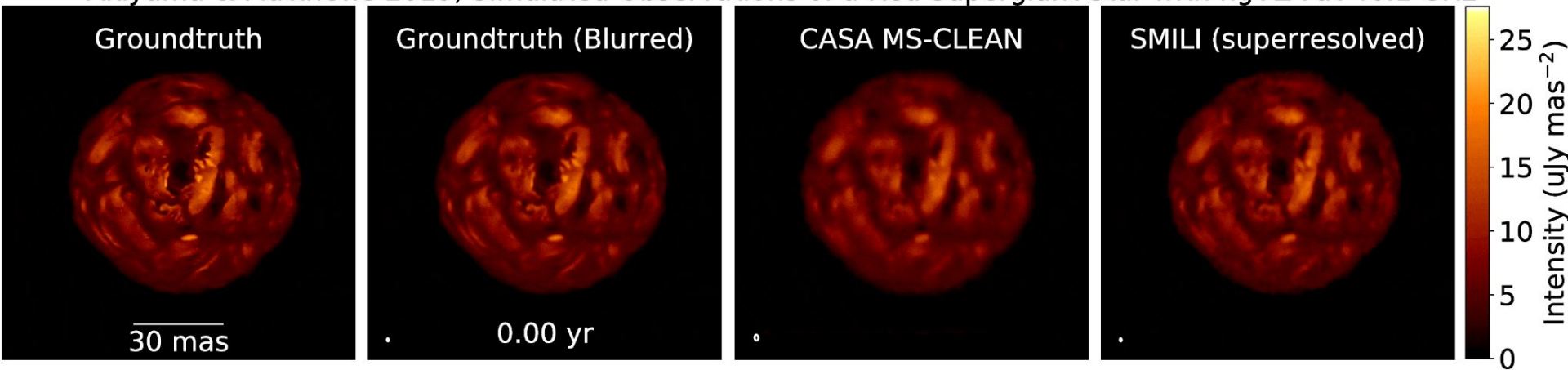
Stellar imaging



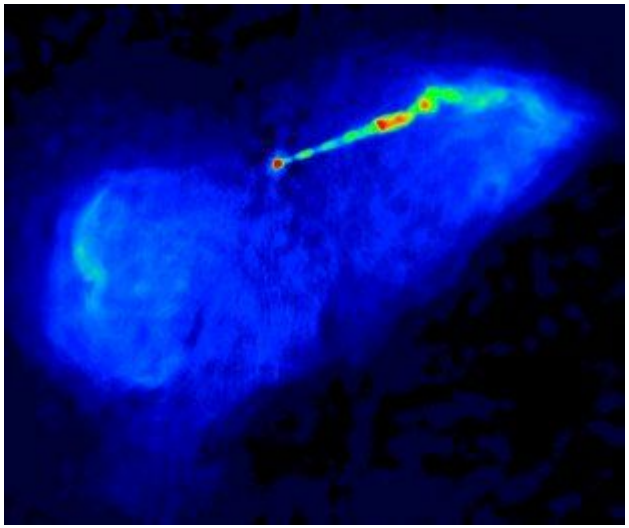
Left: VLBA observations of UV Ceti when flaring (Benz et al. 1998)

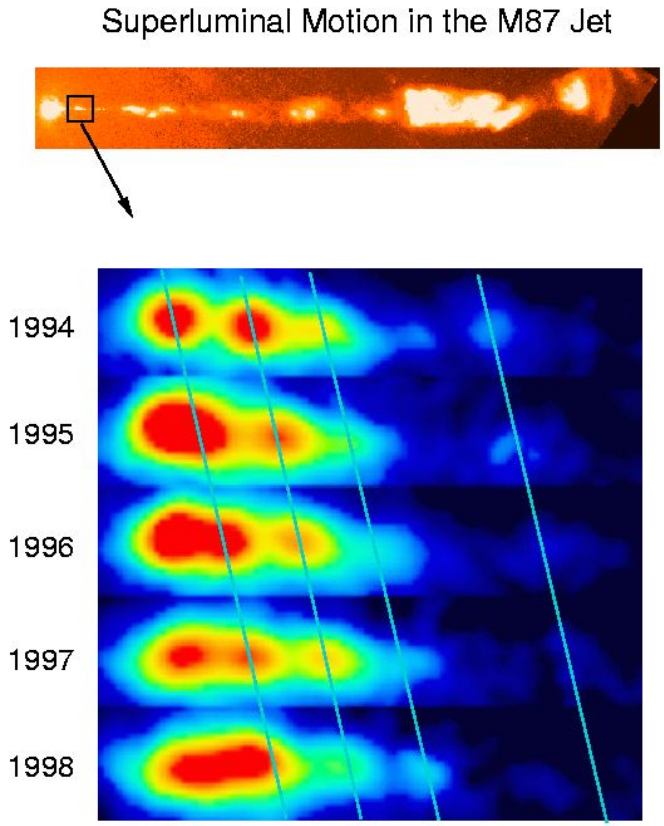
Right: Simulations of ngVLA observations of nearby red supergiants

Akiyama & Matthews 2019, Simulated Observations of a Red Supergiant Star with ngVLA at 46.1 GHz



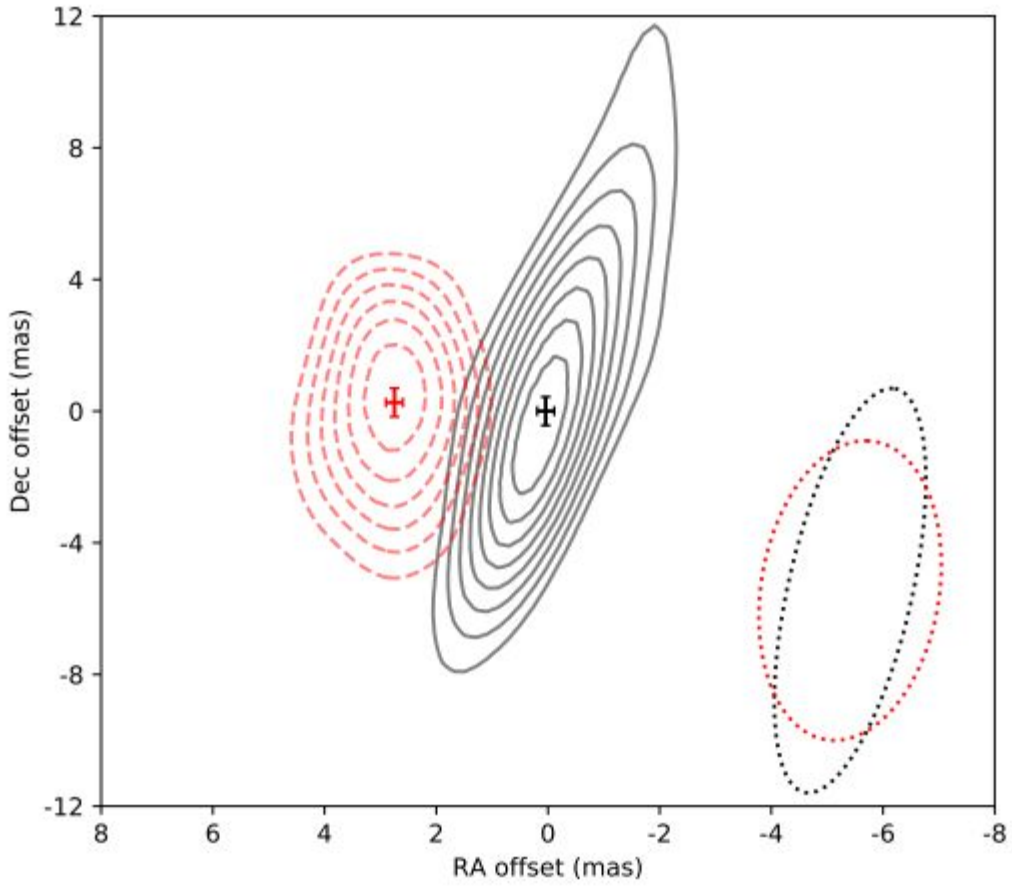
Jets from active galactic nuclei





How are jets accelerated? Where do neutrinos come from?

Kilonova jets



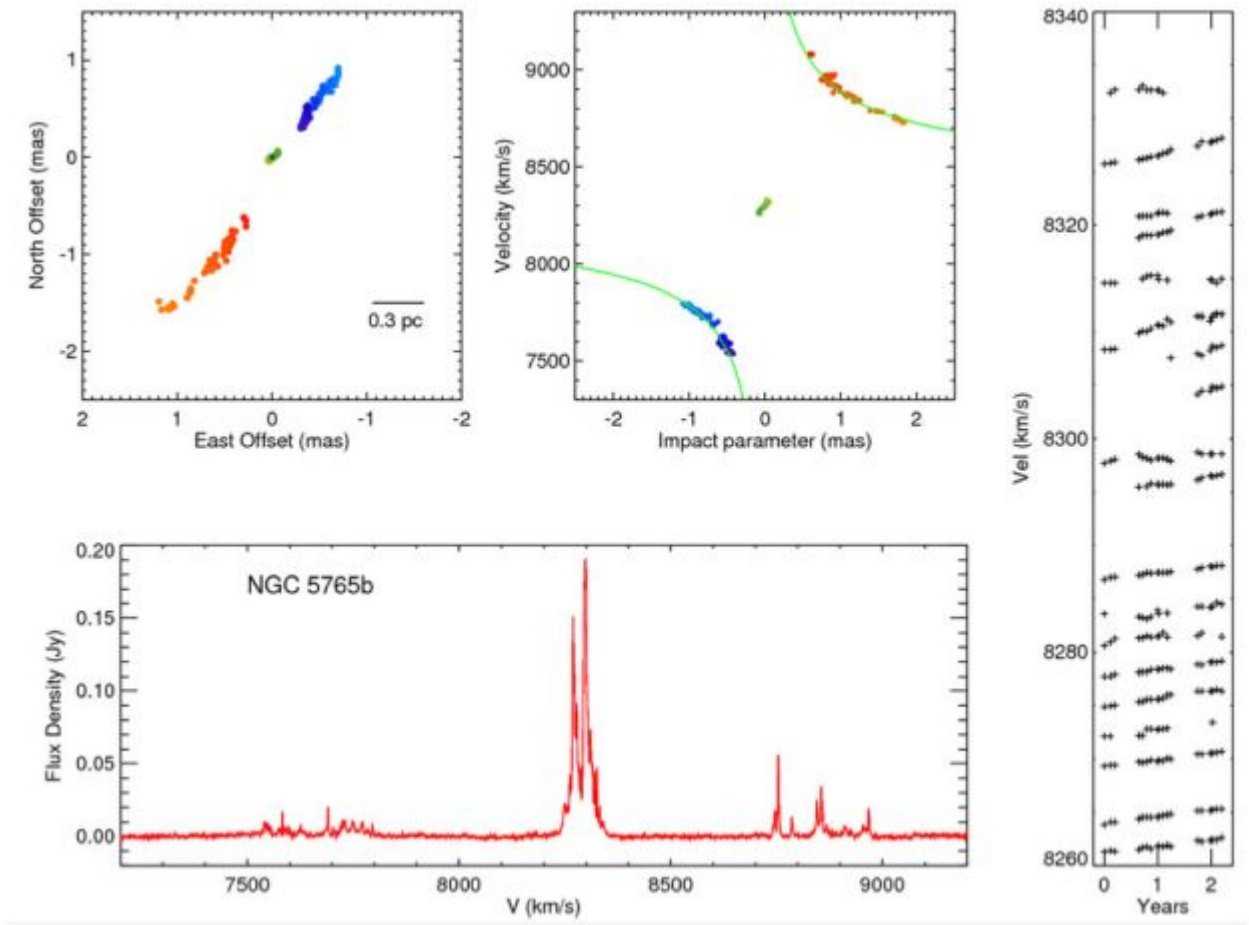
Superluminal motion!

Before this discovery, wasn't clear if there was a choked jet.

Also gives important evidence about inclination angles.

Mooley et al. 2018

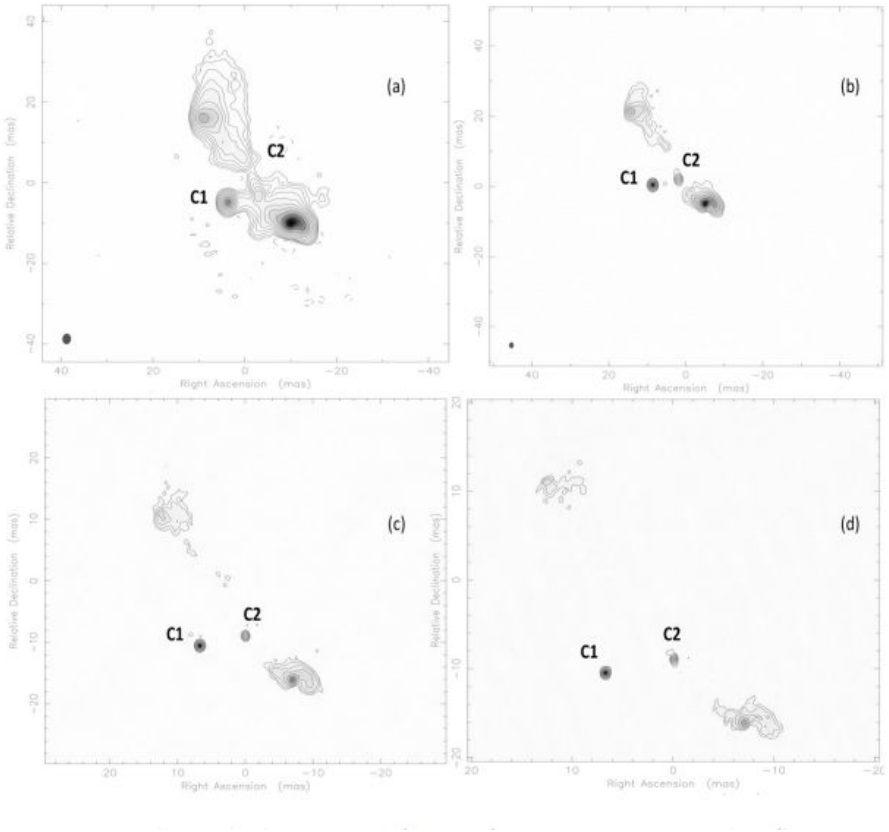
Extragalactic astrometry: masers

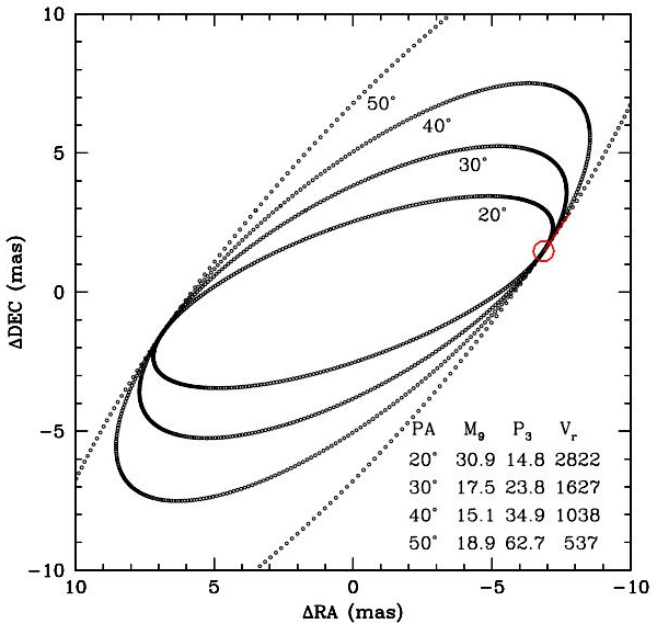


Precise mass and distance estimates for AGN with masers!

Braatz et al. 2019

Extragalactic astrometry: binary black holes

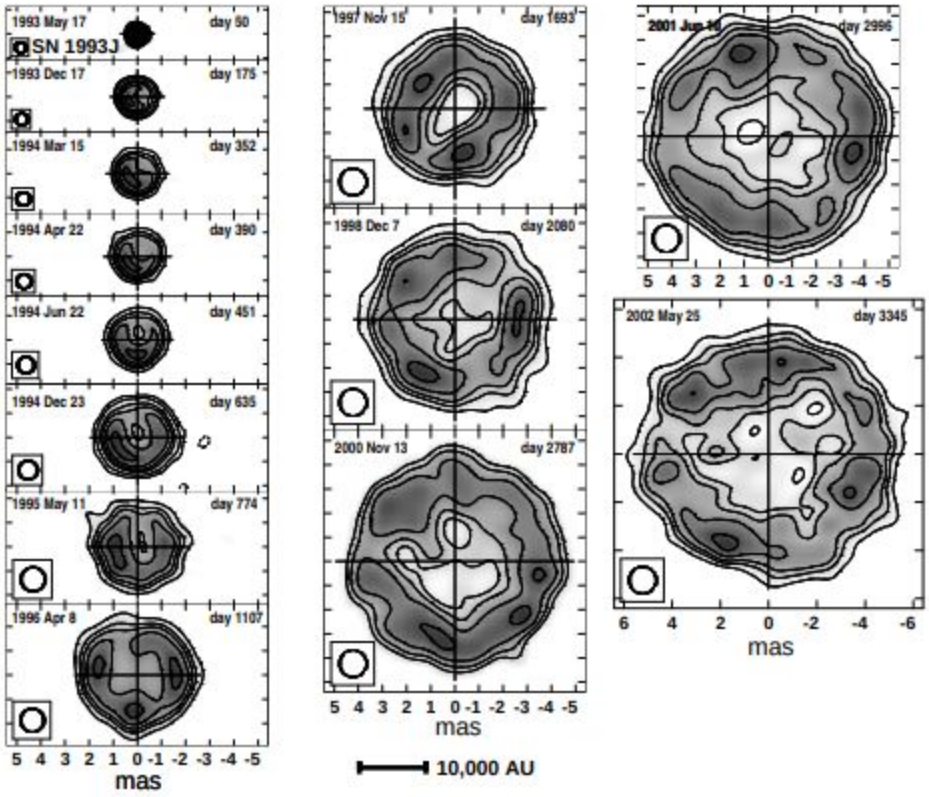




10 years of data, binary orbit ~30000 years

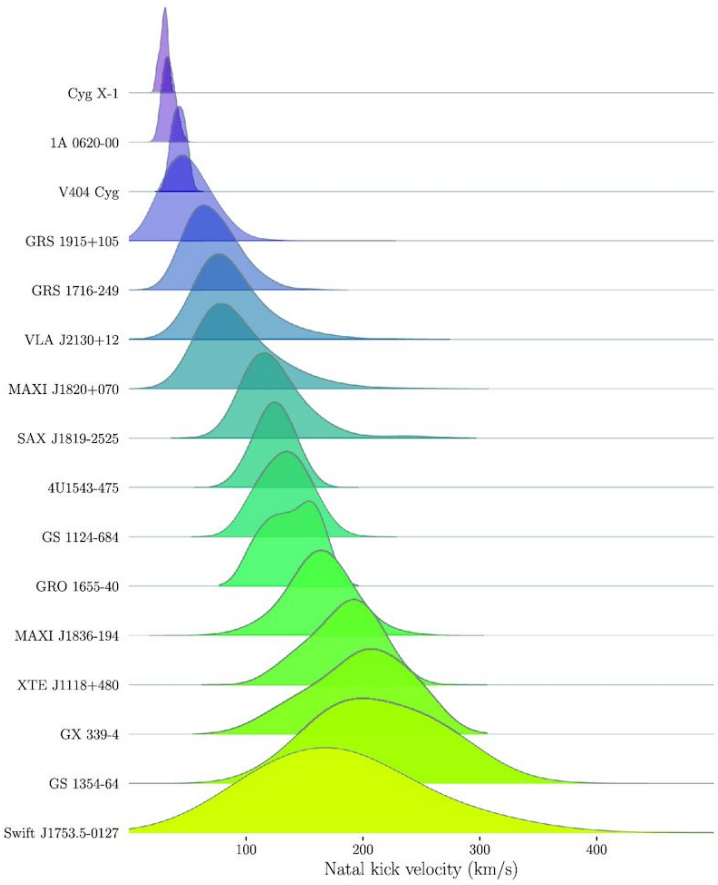
From Bansal et al. 2017

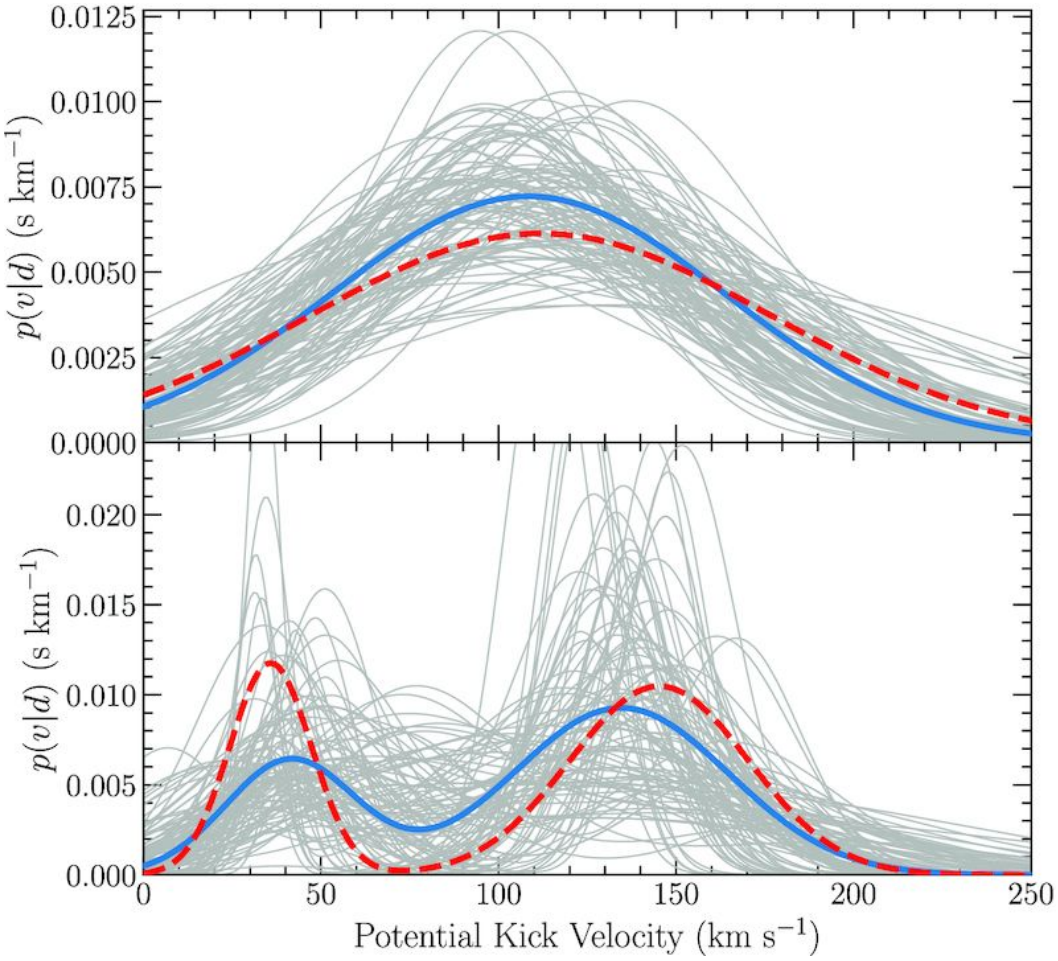
Supernova expansion



From Bietenholtz et al. 1993

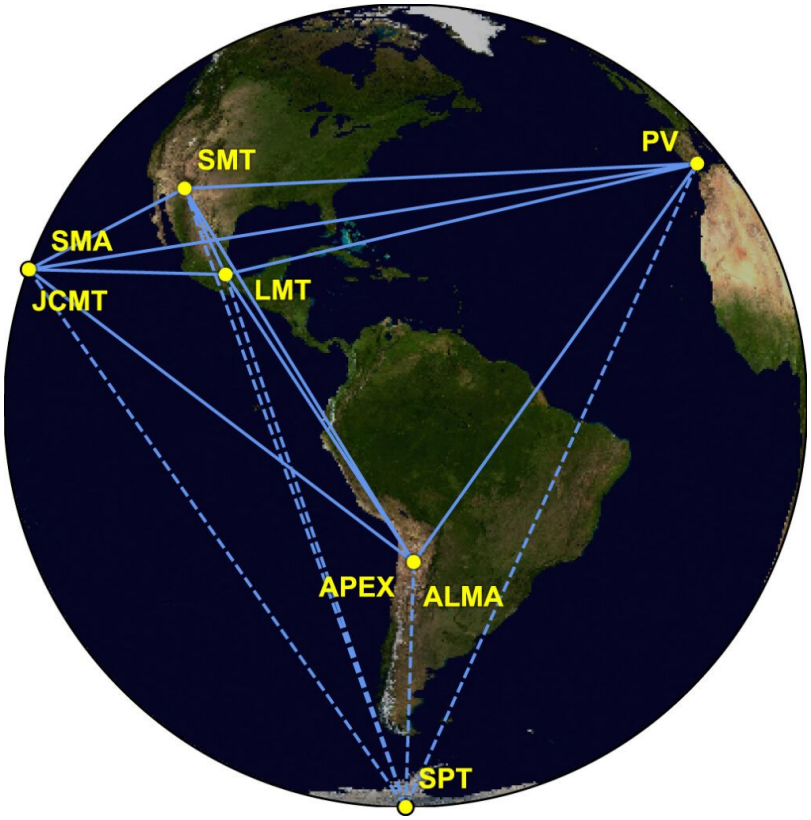
Compact object astrometry

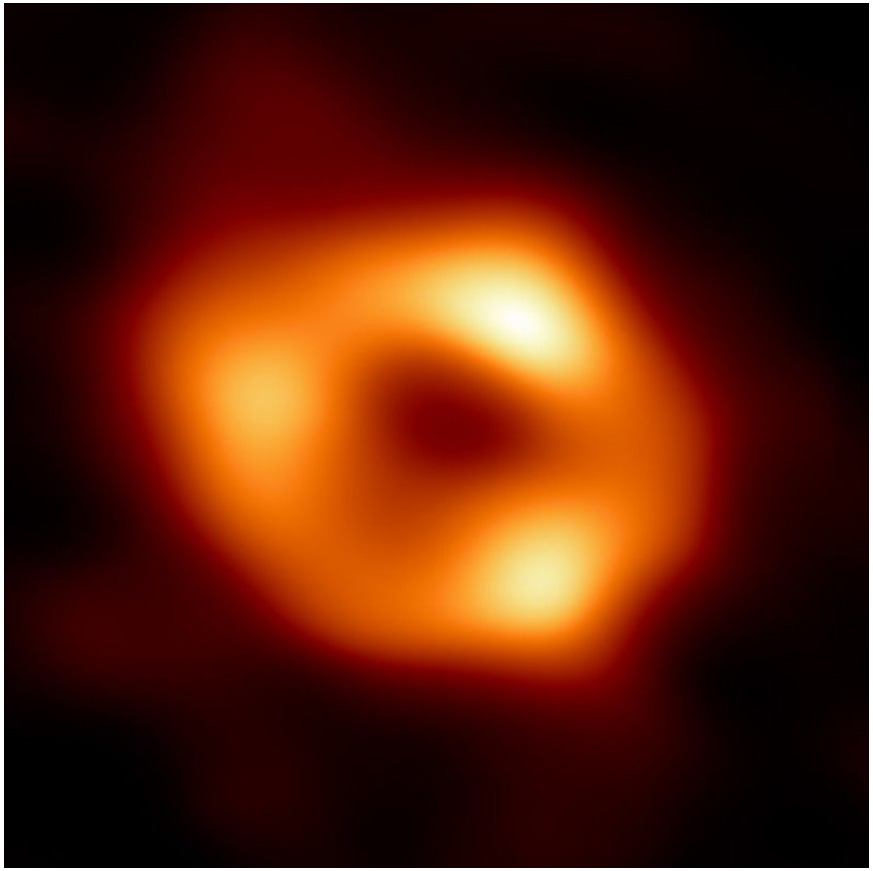




From Atri et al. 2019

Event Horizon Telescope





VLBI from other facilities

- Long Baseline Array (Australia) - best current Southern facility
- European VLBI Network (Europe + Asia + Africa) - high sensitivity, lower availability
- African VLBI Network (in construction phase)
- Event Horizon Telescope (worldwide, submm)
- MERLIN - UK only, intermediate baselines

Summary

VLBA and other VLBI facilities give the sharpest views in astronomy

This is vital for fundamental physics and fundamental astronomy