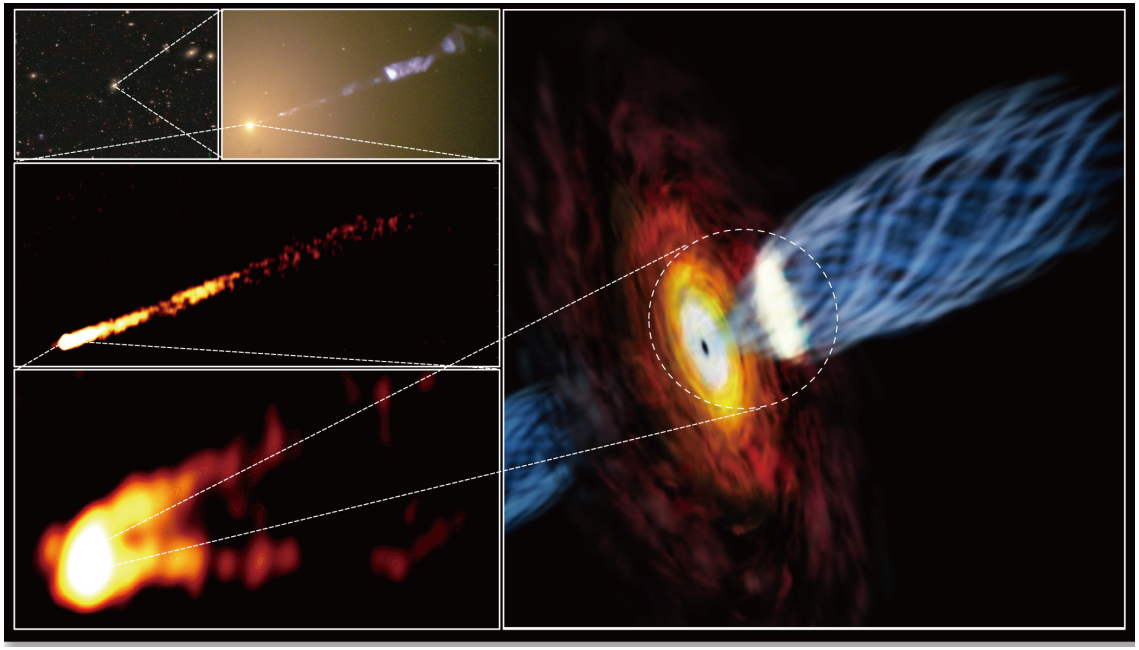
Multi-frequency VLBA observations of the jet base of M87



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Collaborators:

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Outline

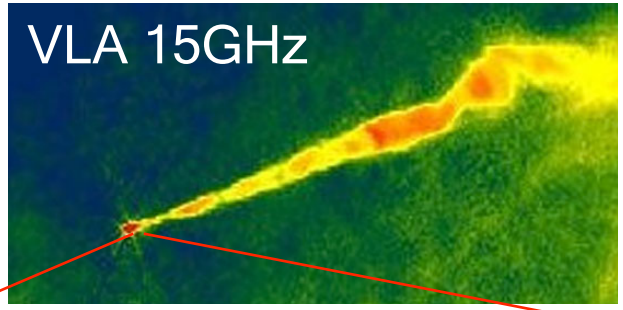
- Our multi-frequency VLBA observations of M87
  - Constraint on the central engine location (Hada+11)
  - Jet width(collimation) profile near the BH (preliminary)

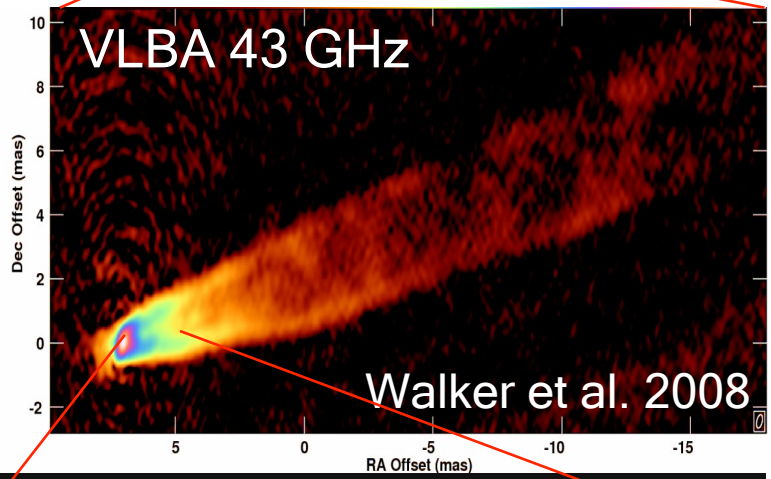
- Dense monitoring program of γ-ray blazars/ radio galaxies (incl. M87) with VERA

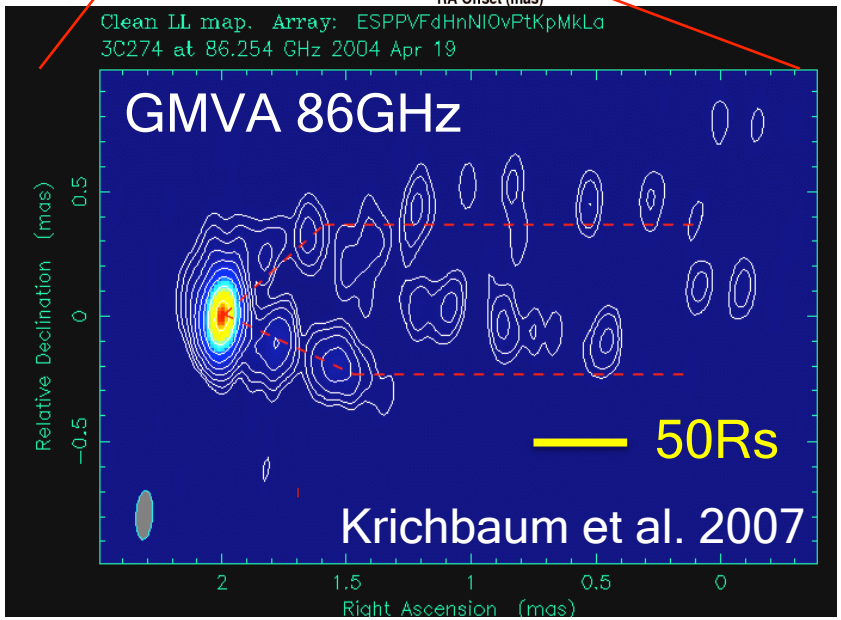
Radio galaxy M87

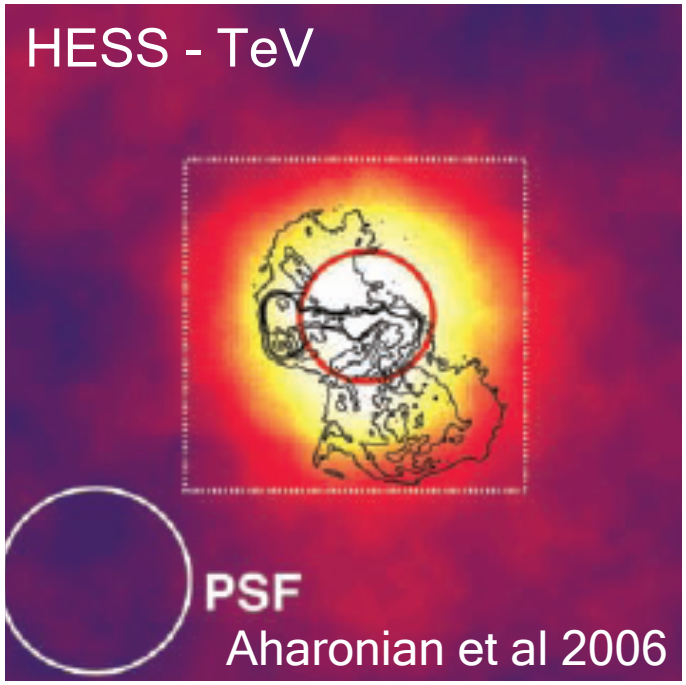
(D∼16.7Mpc, M_{BH}∼6・$10^9 M_{sun}$)

- 1mas∼0.08pc∼140R_s
- Horizon-scale study of
  - Jet formation/production
  - Origin of γ-ray emission

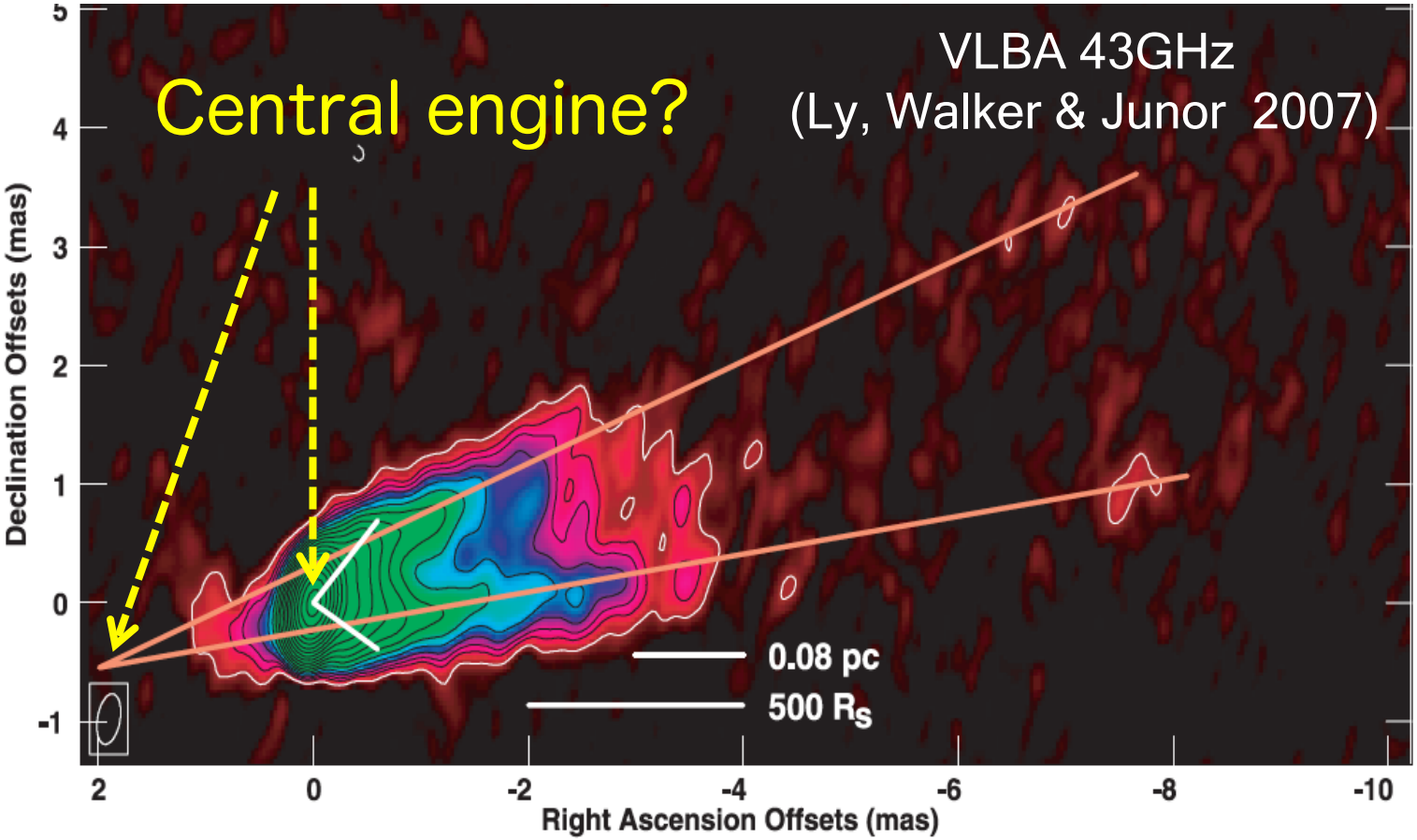






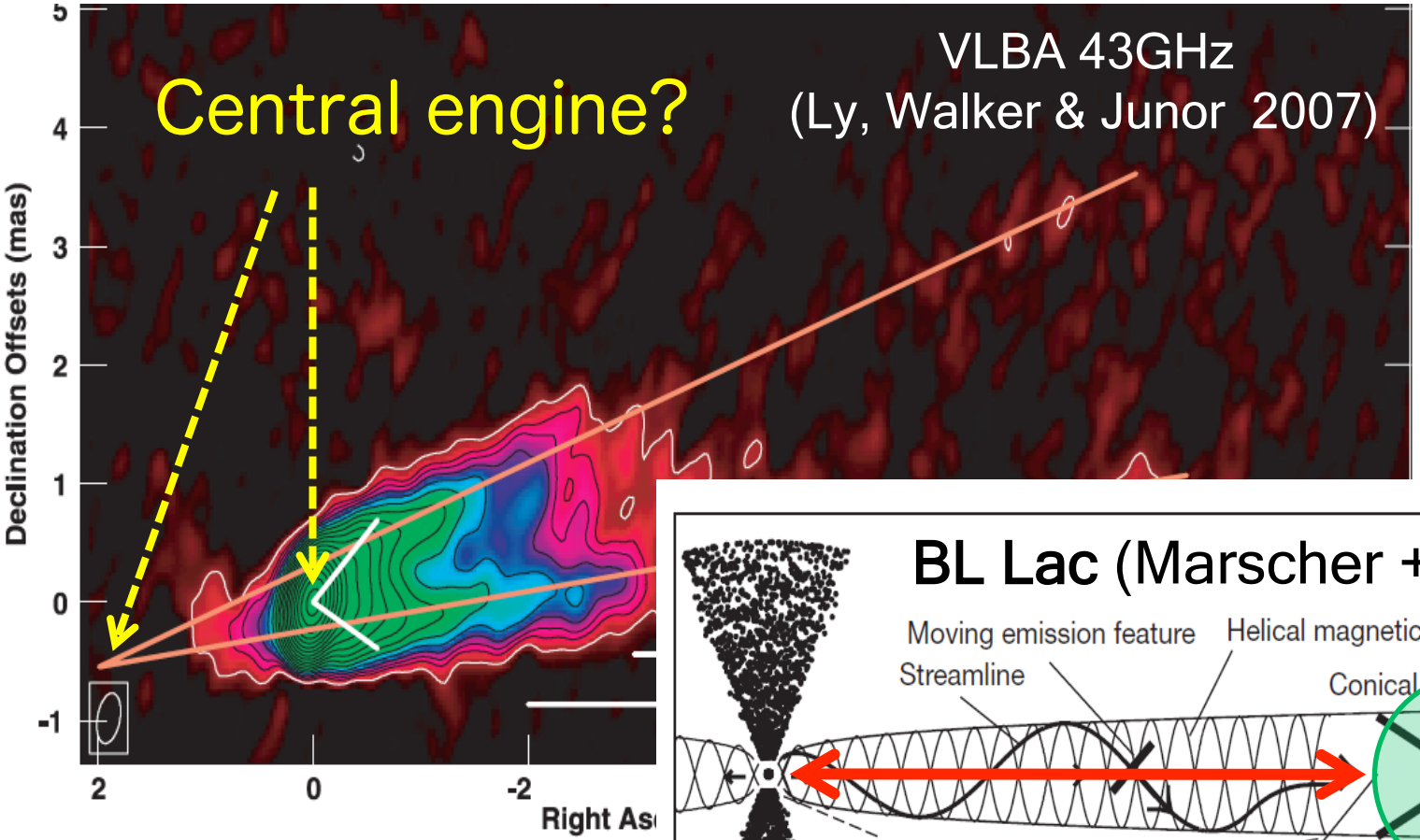


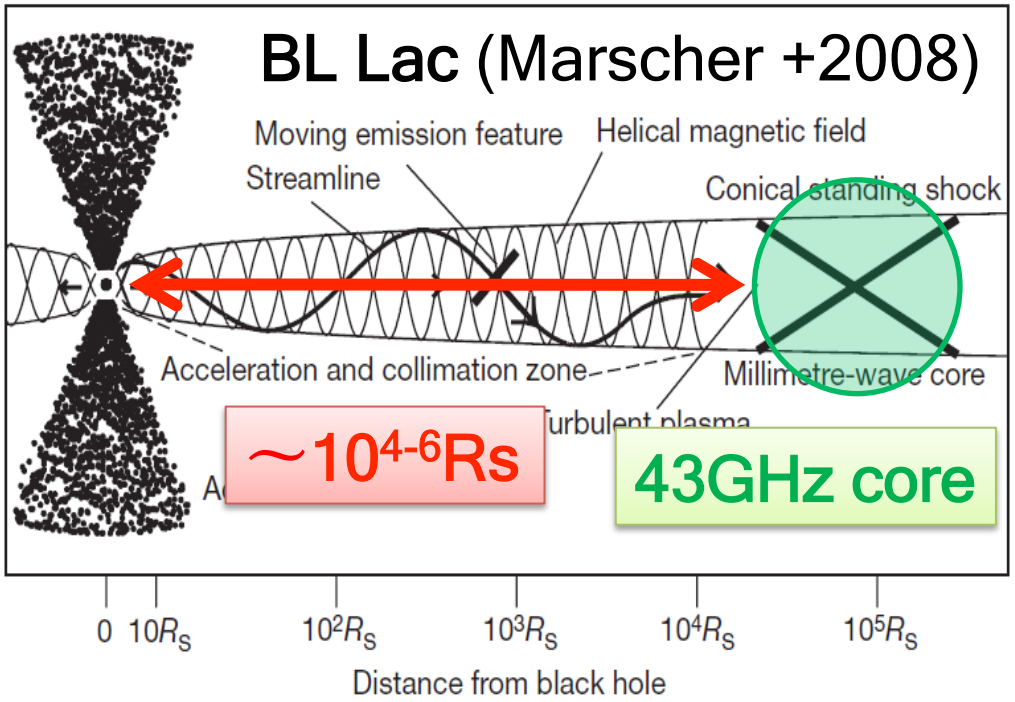
Where is the central engine?



- Radio core
  - a surface of synchrotron-self-absorption or a standing shock feature

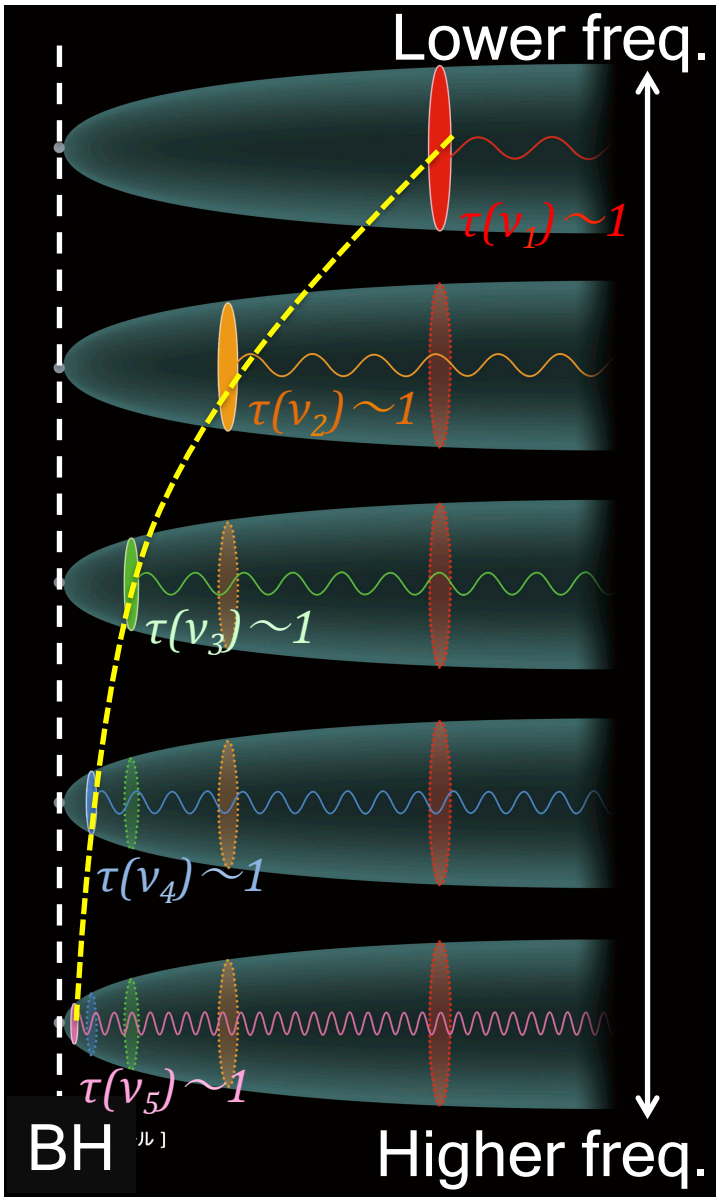
Where is the central engine?





- Radio core
  - a surface of sync
    standing shock fe

Core shift measurements with multi-frequency VLBI astrometry

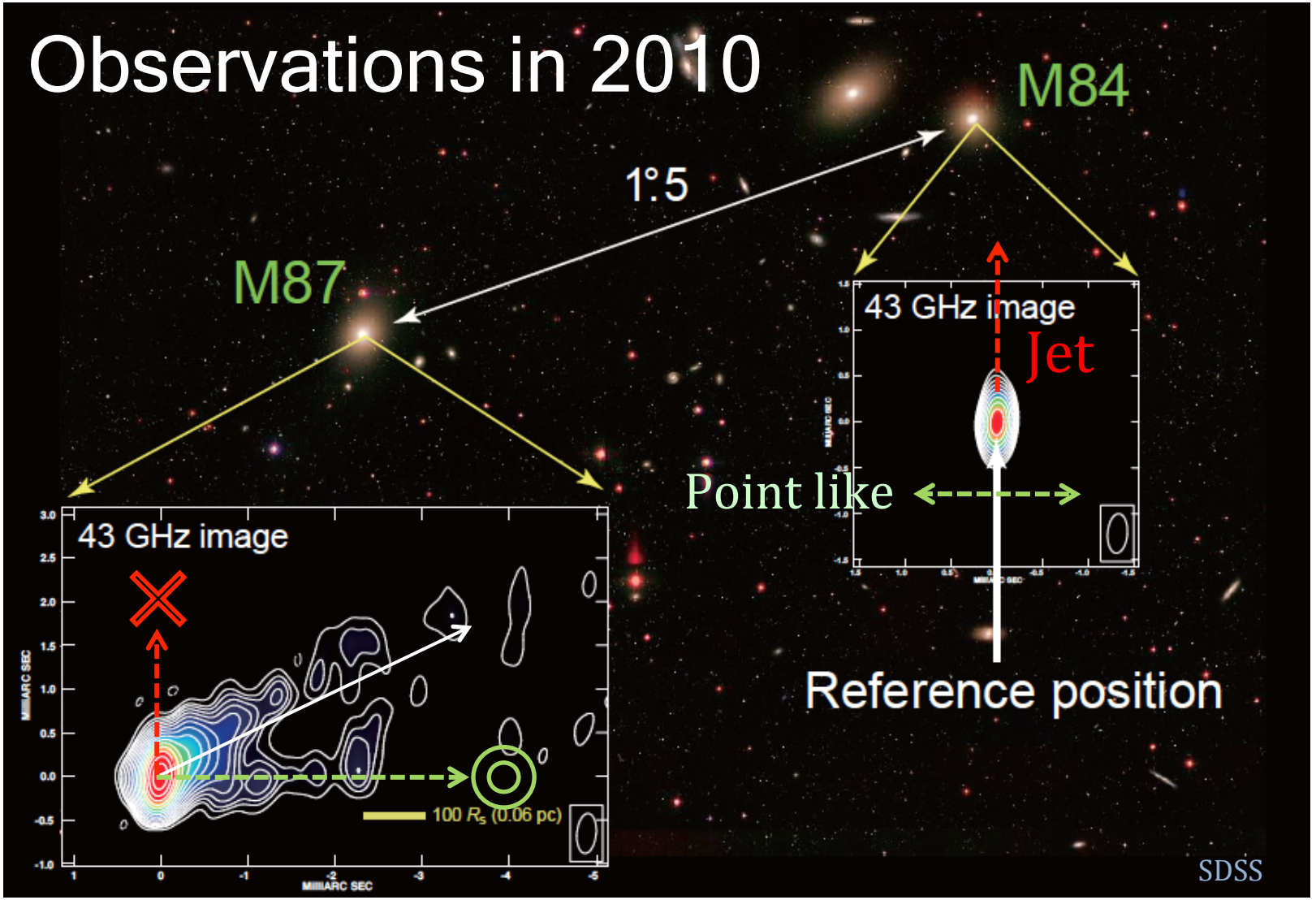


- **Core shift** (O'sullivan&Gabuzda08, Lobanov98)
  - Core position moves toward the central engine at higher frequencies
  - Convergence point

$$r_{core}(\tau_{\nu,ssa}=1)\propto\nu^{-\alpha}$$

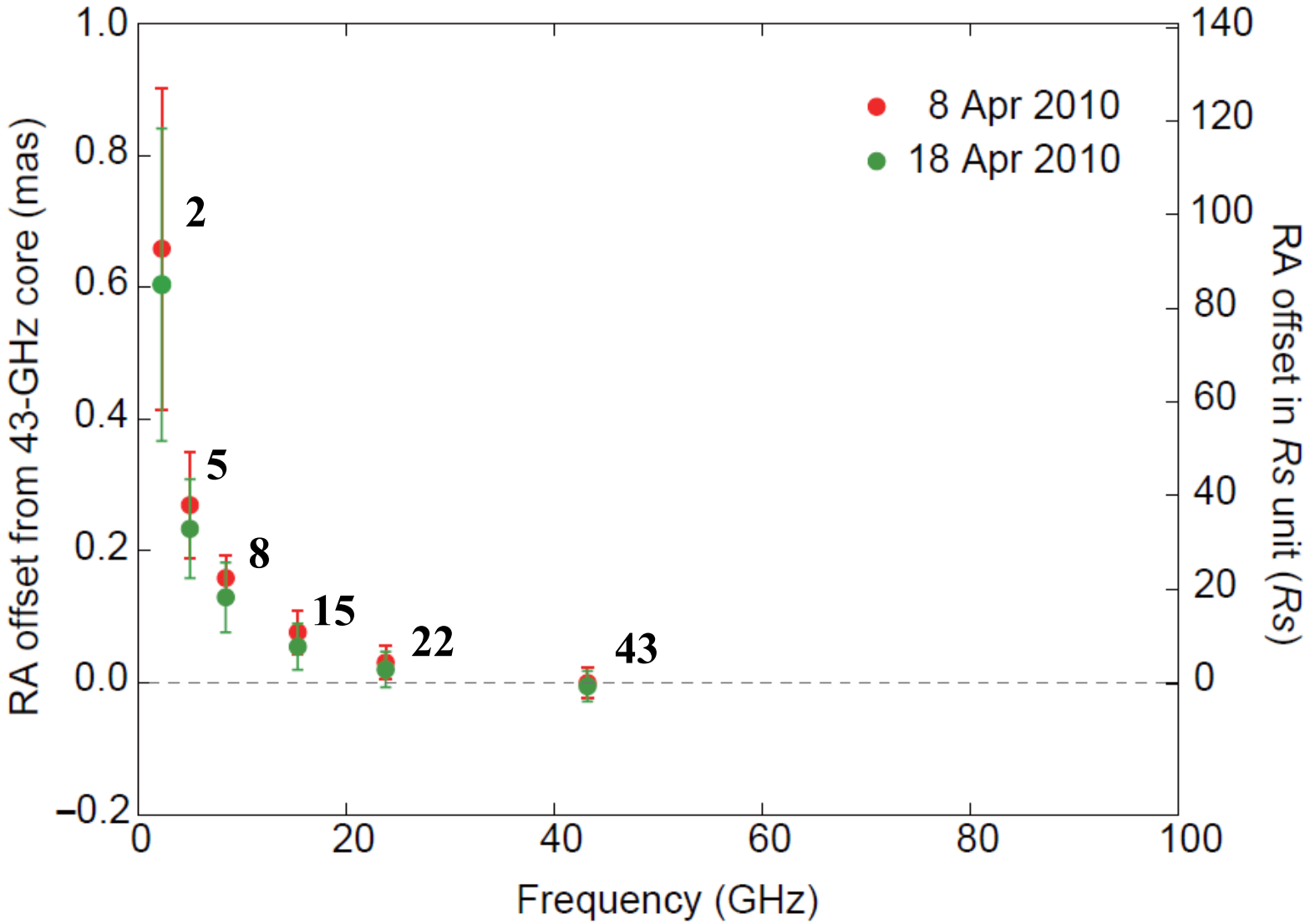
(Blandford&Konigl 1979, Konigl 1981)

- **VLBI astrometry**
  - Tens of micro-arcsec position accuracy

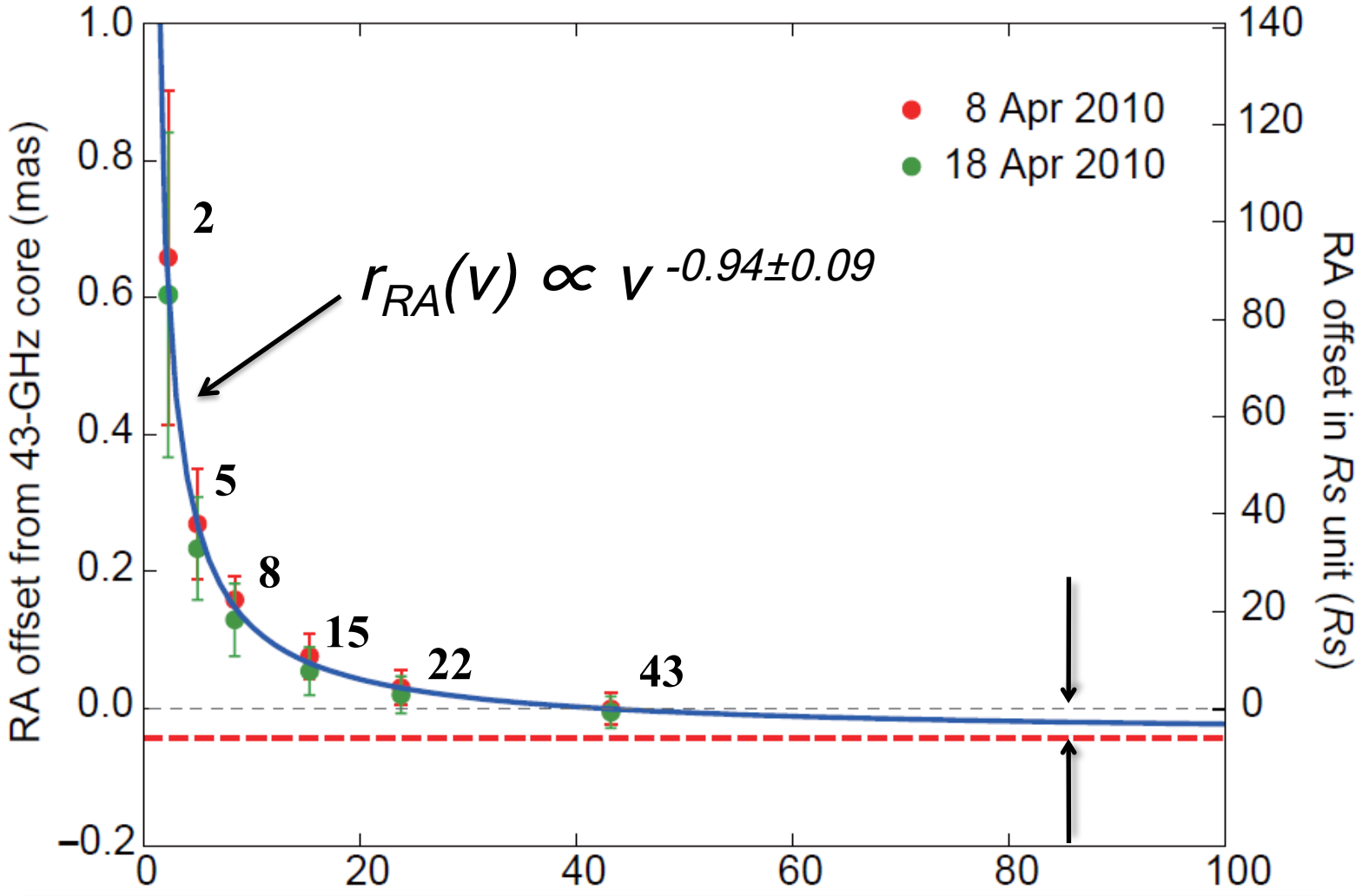


- VLBA（2010/Apr/8,18）@ 2, 5, 8, 15, 22, 43GHz
- Phase-referencing relative to M84 (1.5° from M87)
  - Core shift measurements in RA direction

Measured core shifts of M87 (in RA)

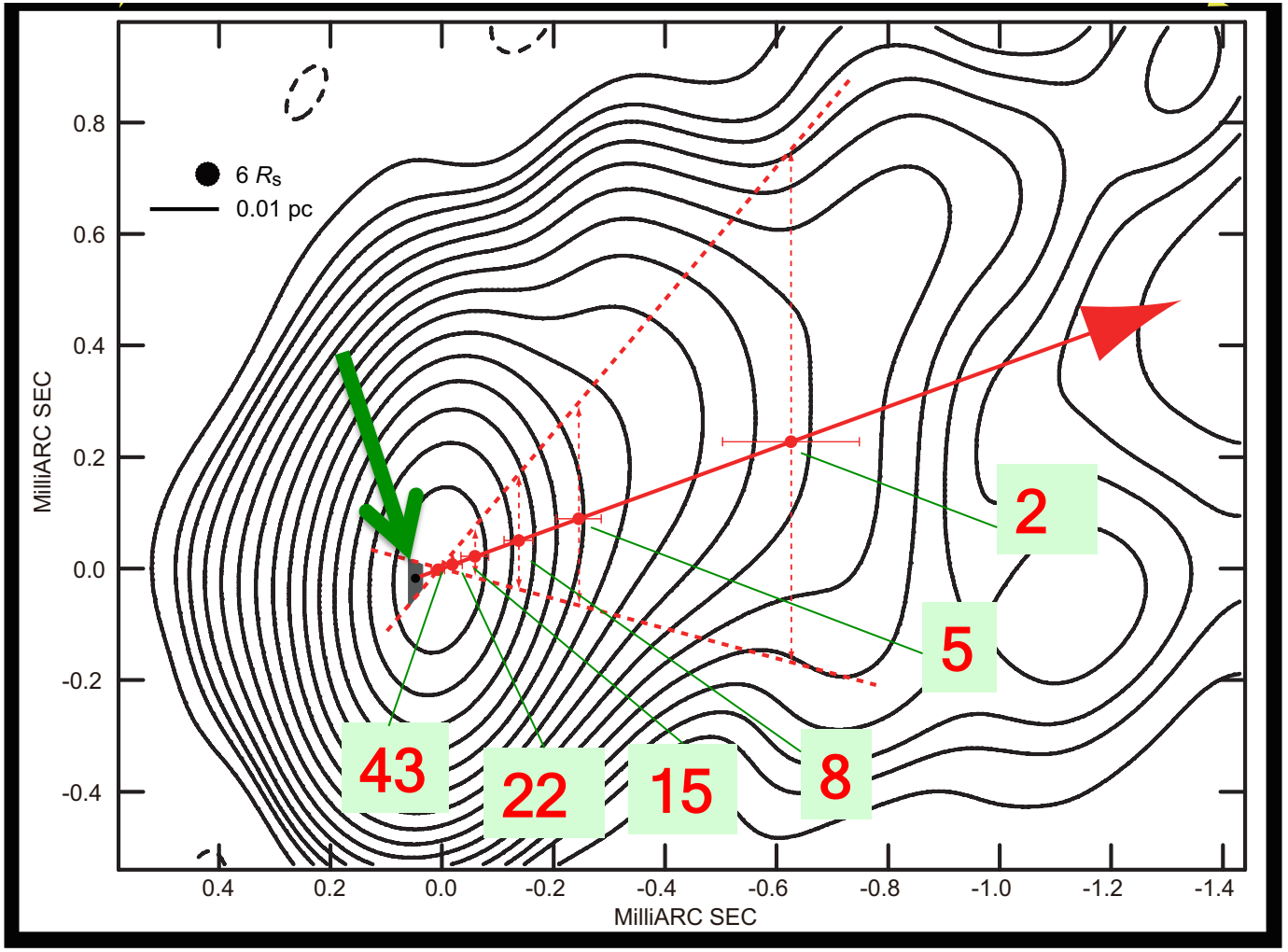


Measured core shifts of M87 (in RA)



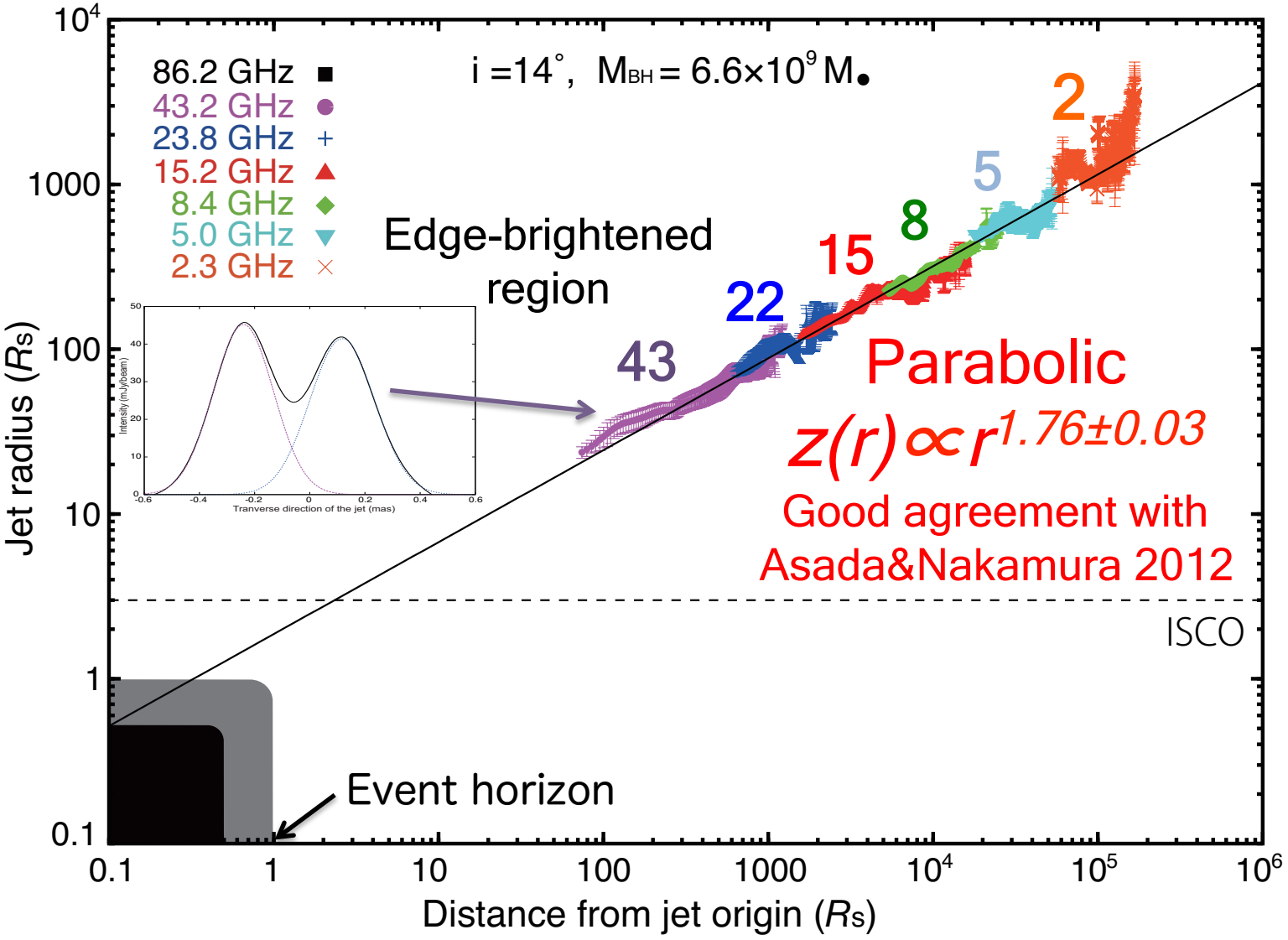
Core shift convergence: (41±12)μas upstream of the 43-GHz radio core

Location of the central engine (Hada+2011)



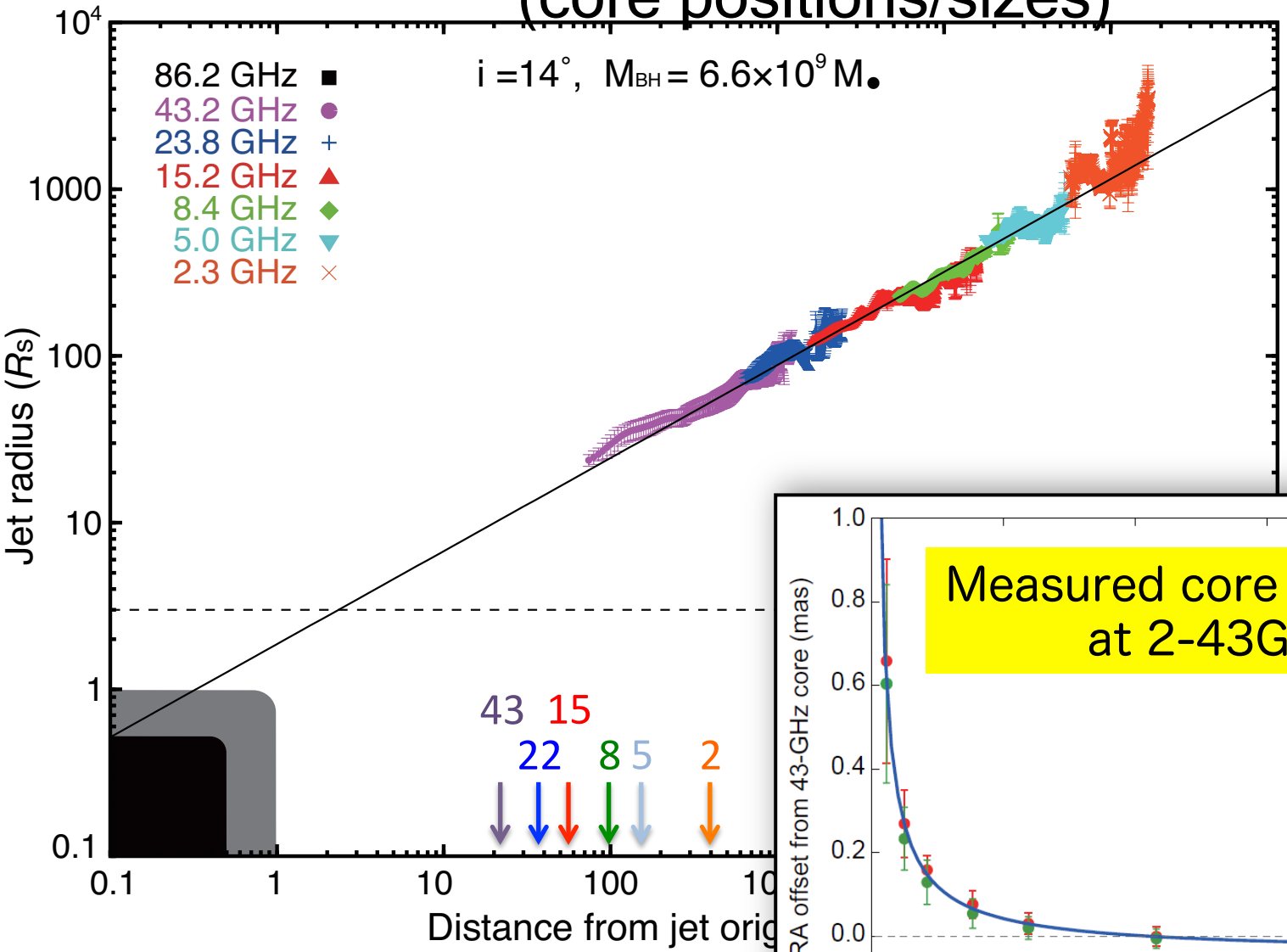
- BH-43GHz core distance: ~20Rs (viewing angle i~20°)
- 86 ,230 and 345GHz VLBI → even closer to the BH !!

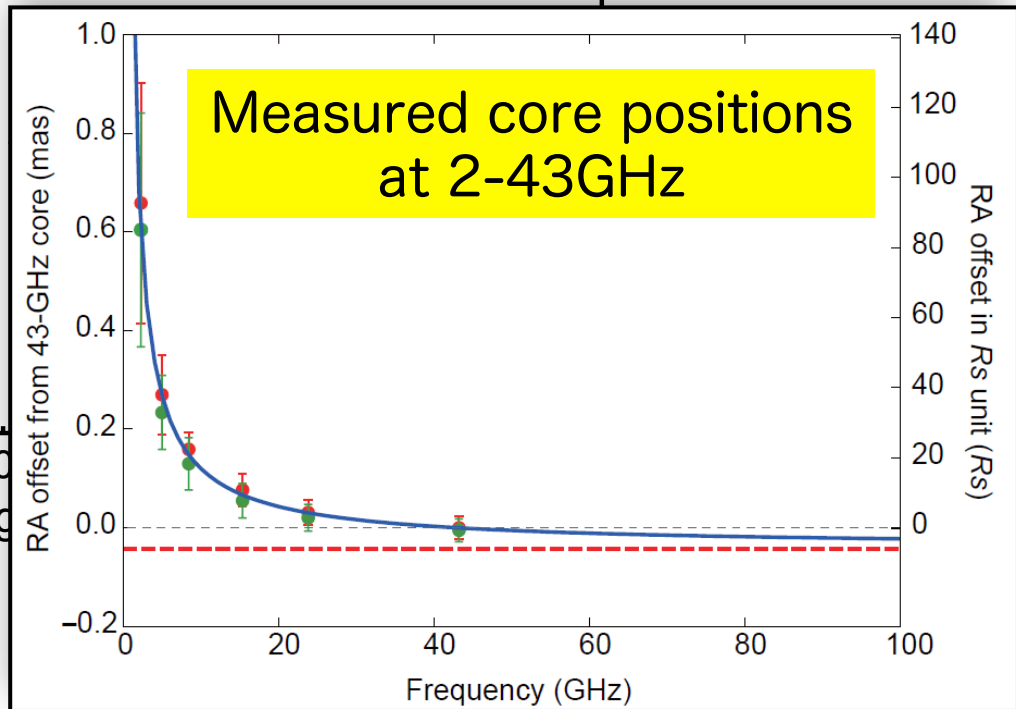
Jet width profile from 10^5 to 10^2 R_s



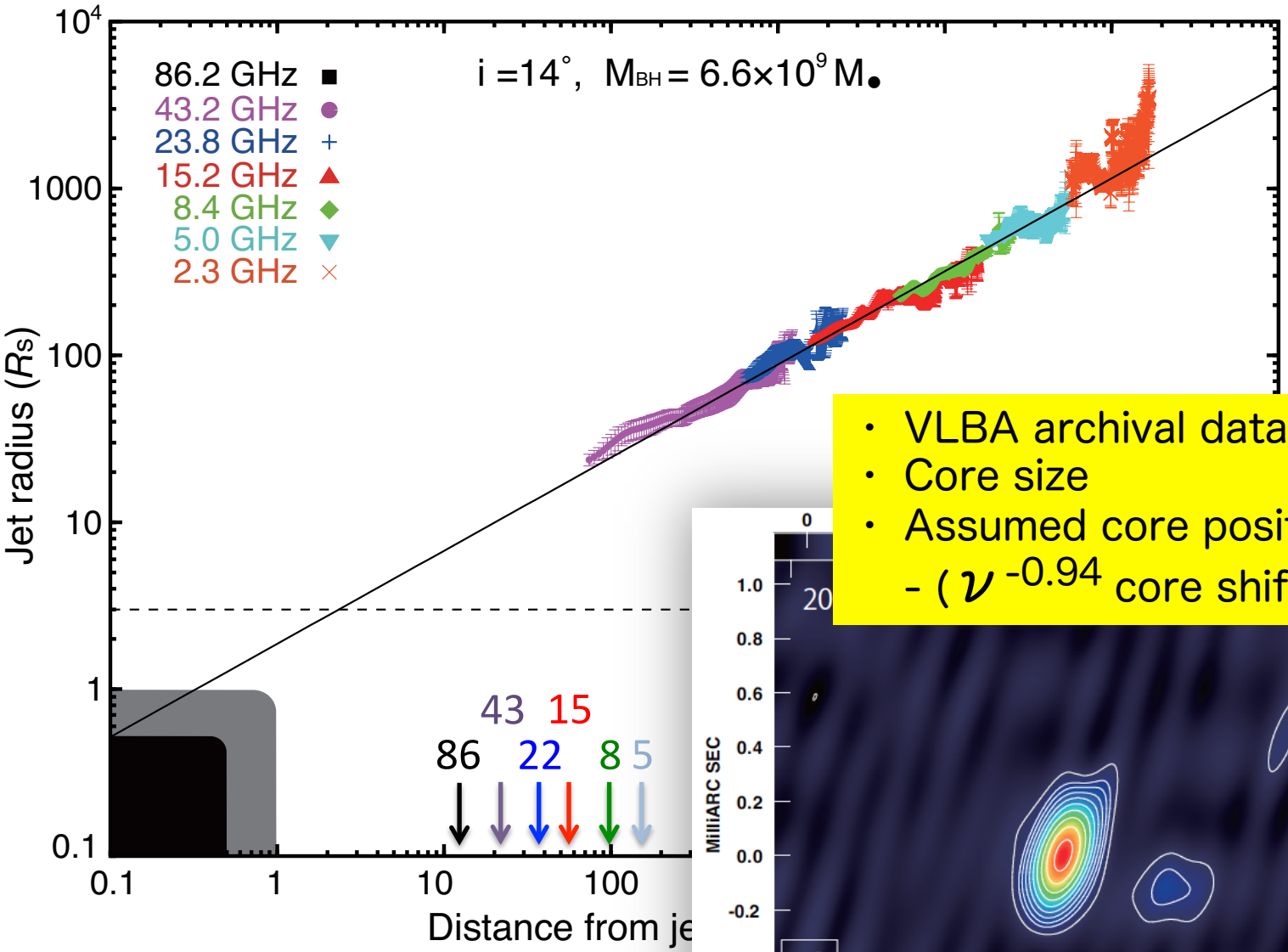
Inclusion of astrometry results

(core positions/sizes)

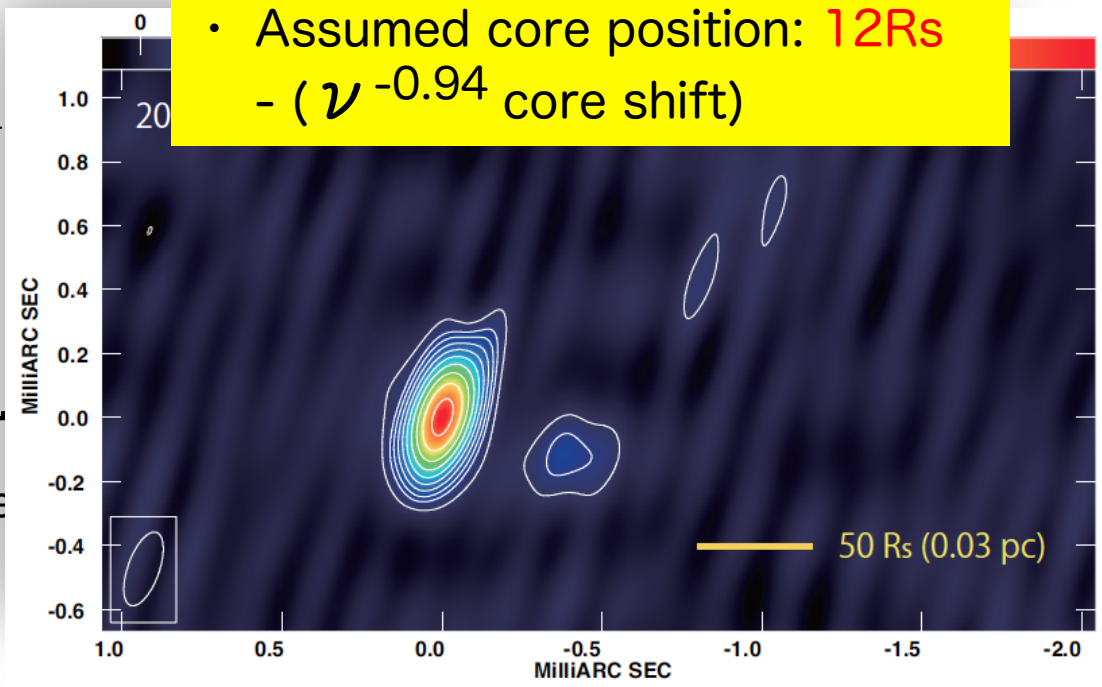




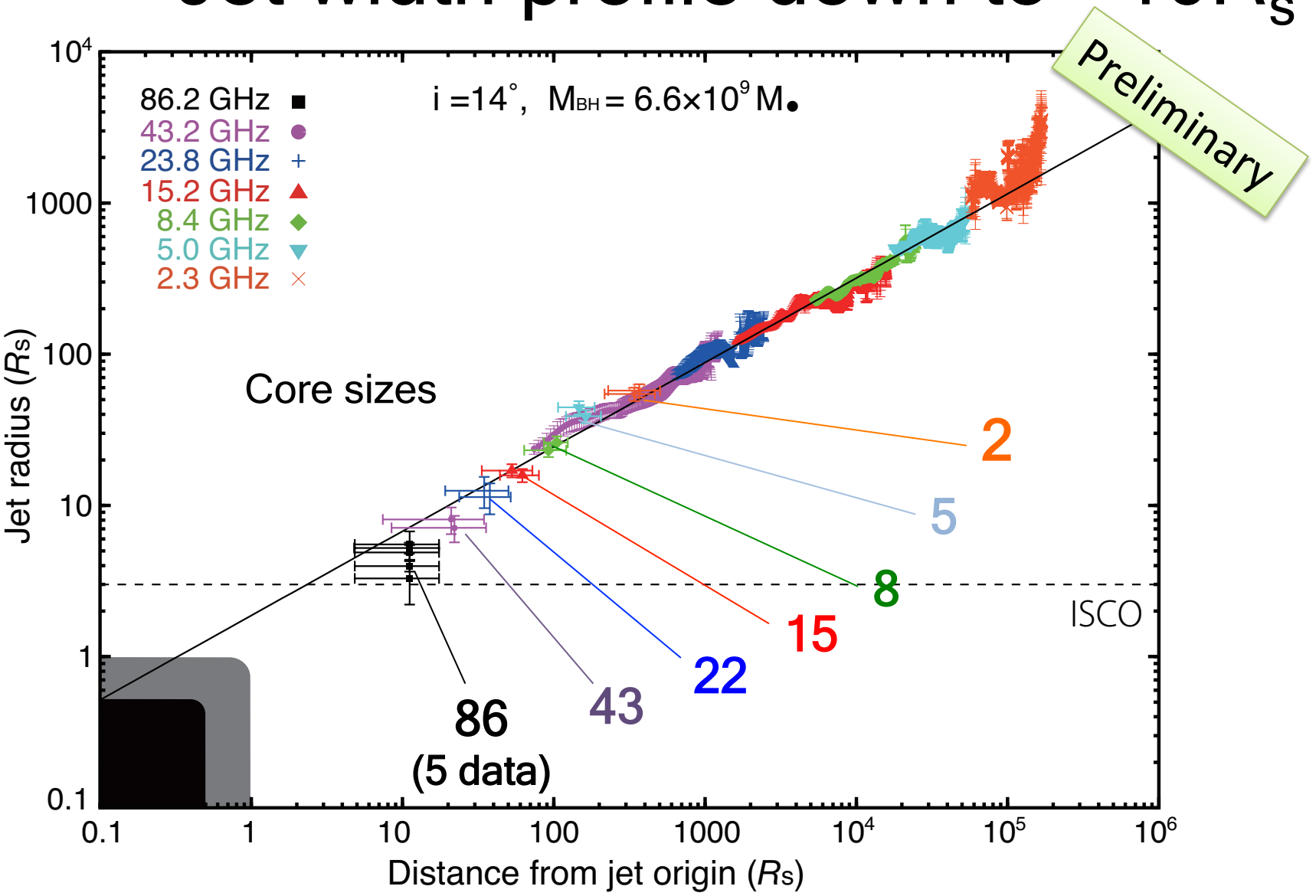
Inclusion of 86GHz data



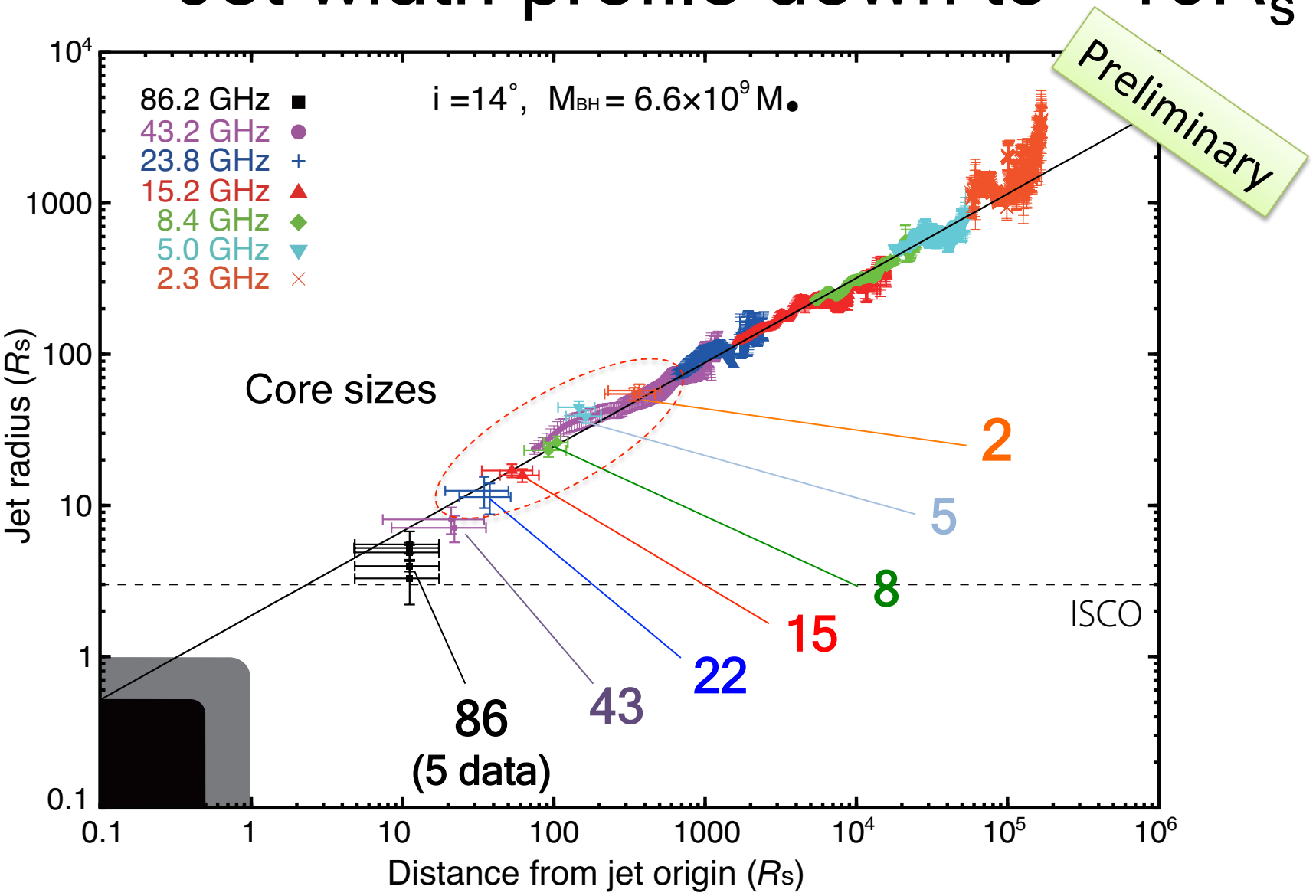
- VLBA archival data
- Core size
- Assumed core position: 12Rs
  - ($\nu^{-0.94}$ core shift)



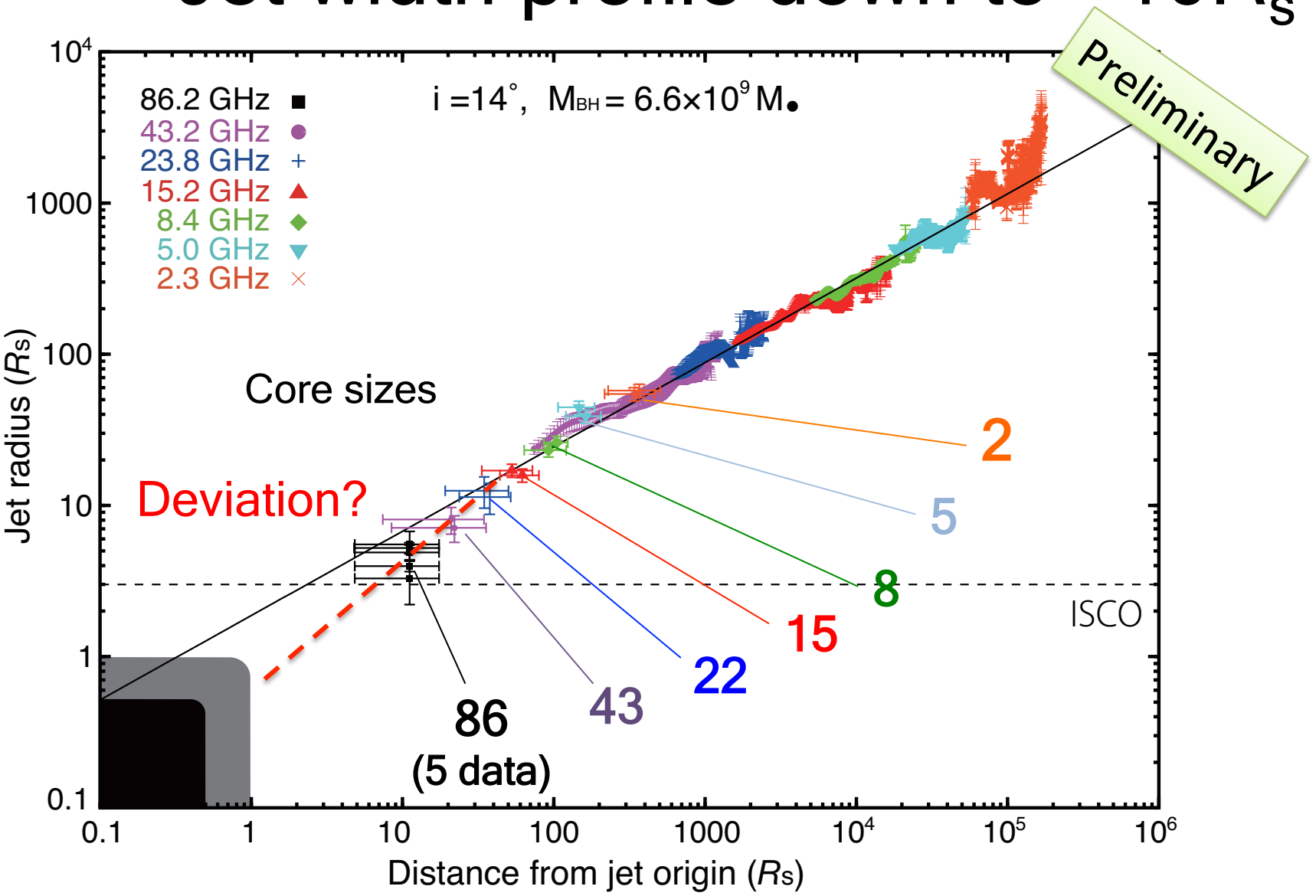
Jet width profile down to ~10R_s



Jet width profile down to ~10R_s



Jet width profile down to ~10R_s



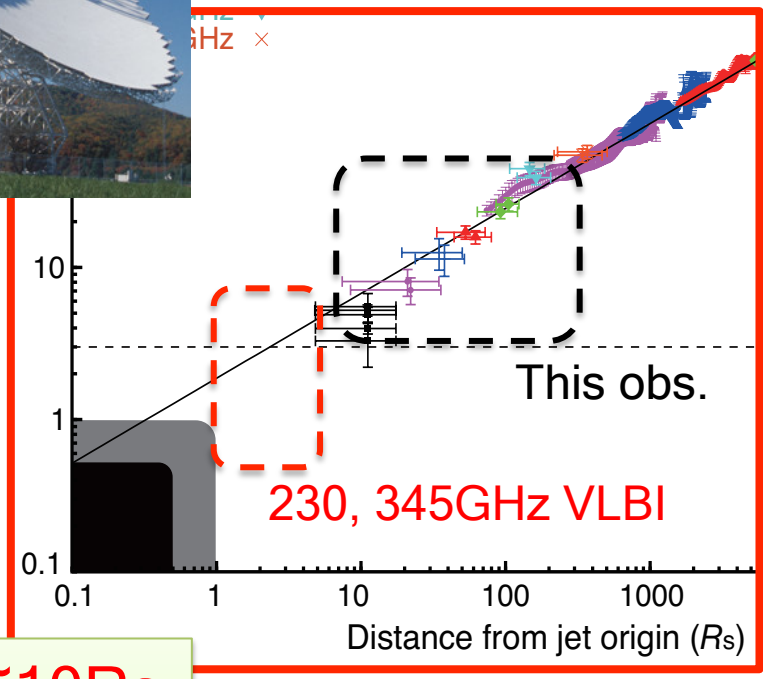
New observations approved

- VLBA+GBT@86GHz

  ✚

- VLBA astrometry
  - 43, 22,15, 8, 5, 2,1GHz
- Quasi-simultaneous (<1 week)
- 2Gbps recording
- Full polarization mode

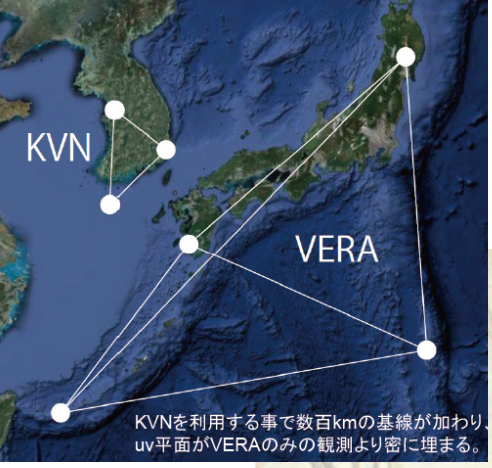
GBT

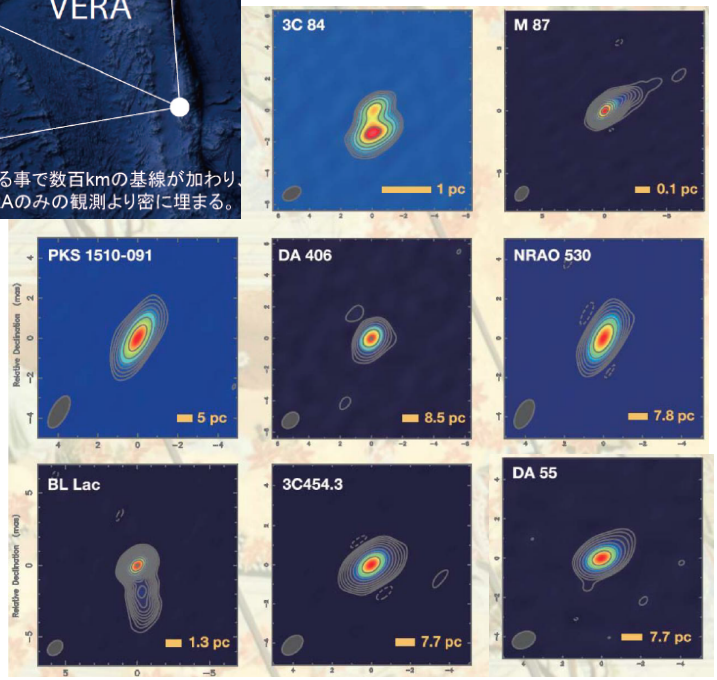


- Exact collimation profile down to ~10Rs
- Polarization properties in this region
- Connection with submm VLBI

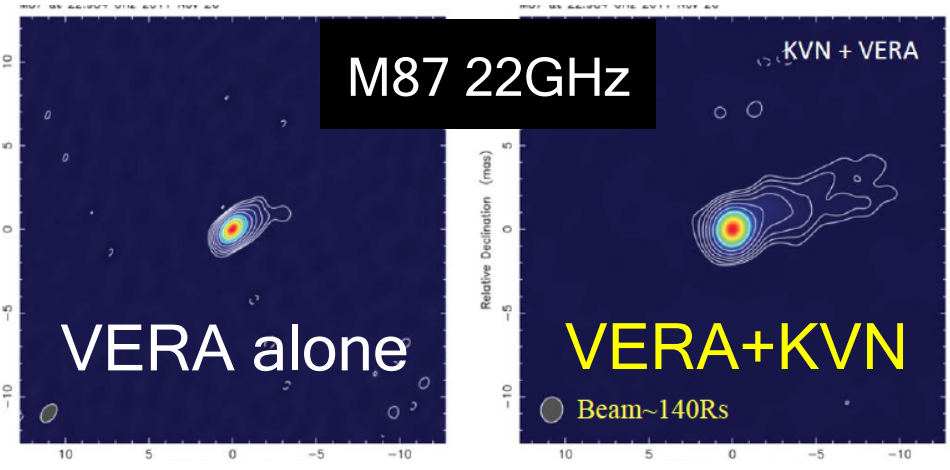
(Bi)weekly monitoring of bright γ-ray blazars/radio galaxies with VERA

Nagai+ in prep





- *GENJI* program (2010/Oct～)
  - 22/43GHz
  - Lightcurves, kinematics
- VERA+KVN test obs. (2011/Nov～)
- Tie-up with (sub)mmVLBI
  - spectra, lightcurves etc..

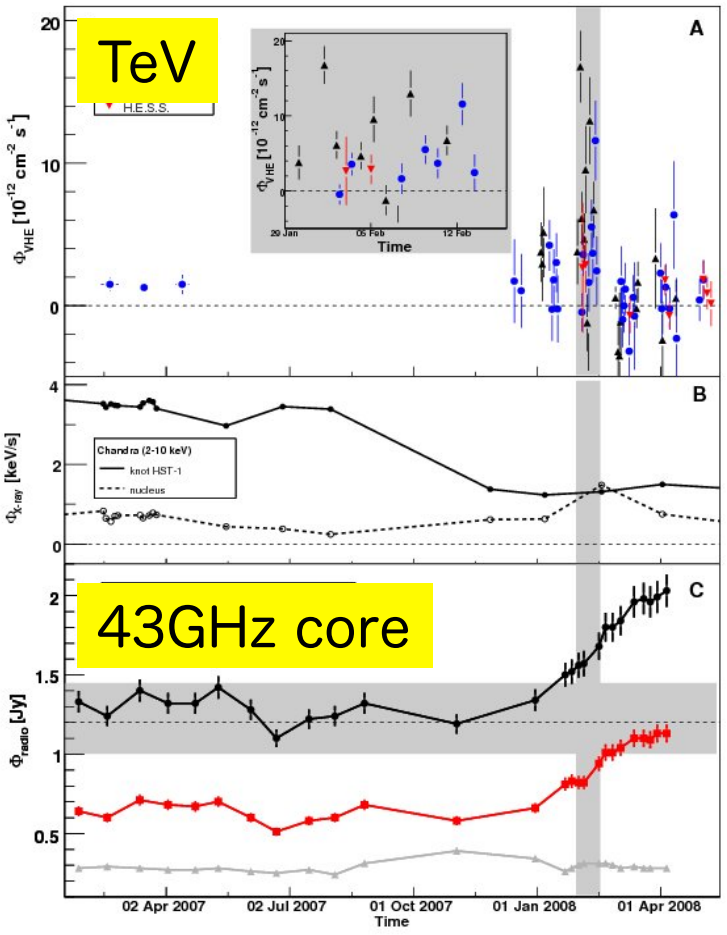


Summary

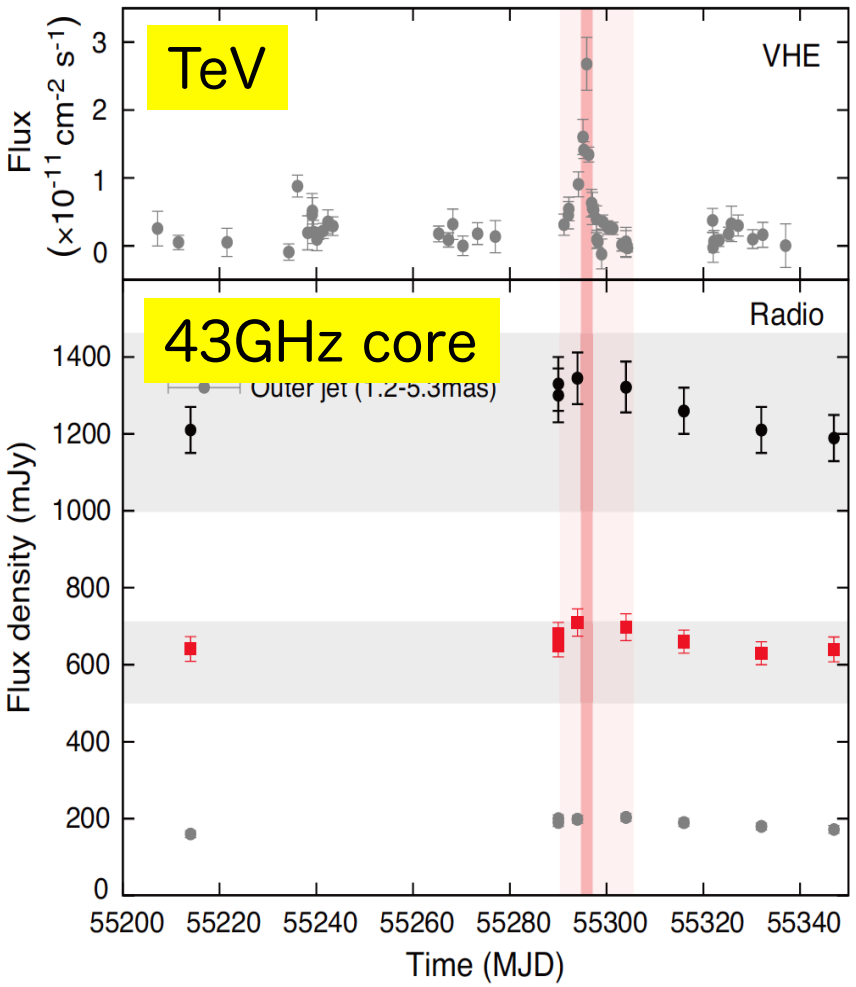
- With multi-frequency astrometry VLBA observations, we have constrained the location of the central engine of M87.
- Preliminary finding: a possible change of the jet collimation profile near the BH.
- To investigate the jet structure near the BH in more detail, we are going to carry out new multi-frequency observations including GBT
- Dense monitoring of γ-ray blazars/radio galaxies with VERA(+KVN): synergy with mm-submmVLBI

TeV γ-ray from the M87 jet base

2008 VHE flare (Acciari+2008)



2010 VHE flare (Hada+ submitted)



- Higher transparency&resolution to the jet base are essential !
  → mm-submmVLBI