



The Sedate Supermassive Binary Black Hole System: 0402+379

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Supermassive Binary Black Hole

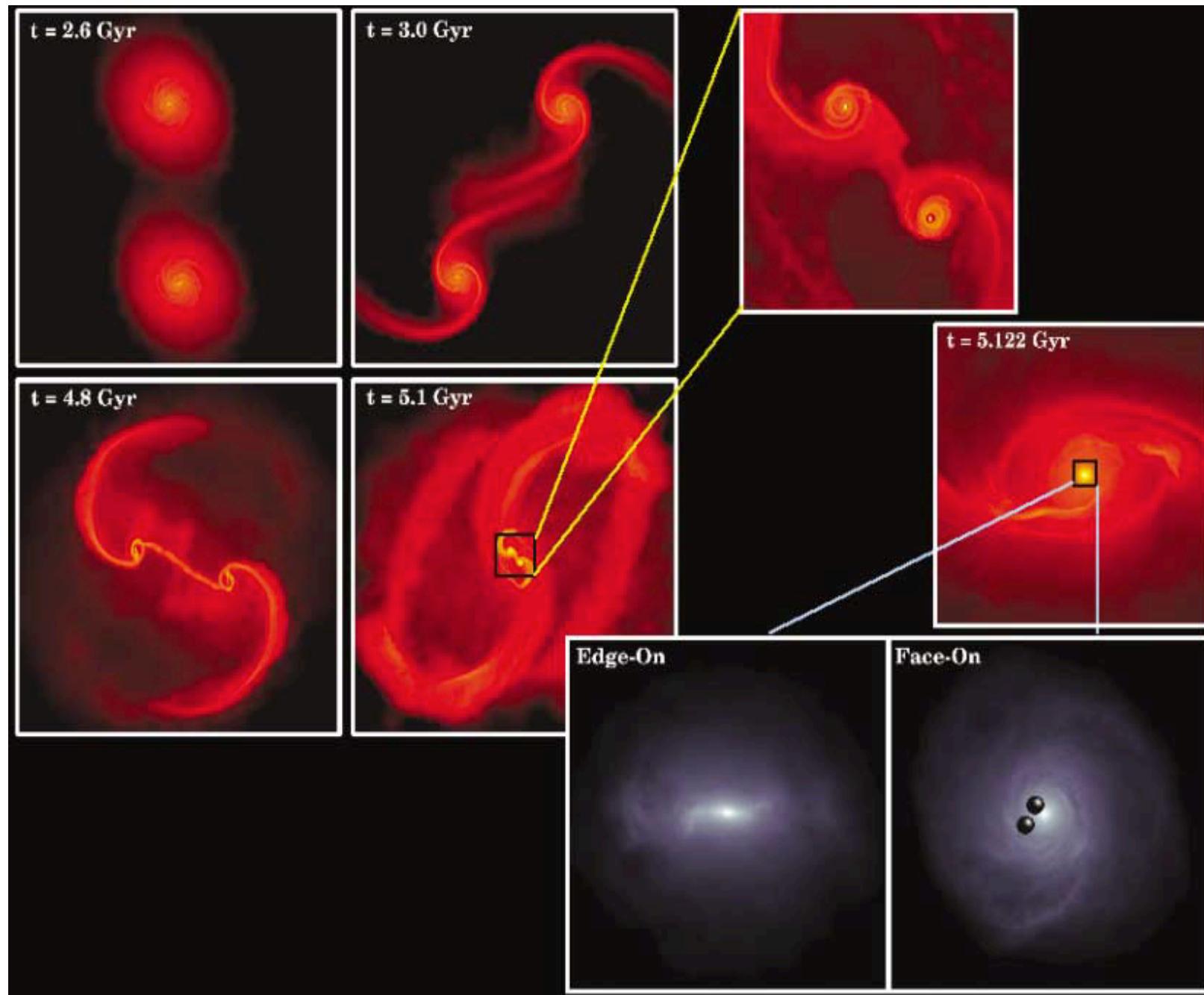
- Supermassive black hole at the center of a galaxy
- When two or more galaxies collide --- Binary Supermassive Black hole!
- Galaxy Merger: Major and Minor



NGC 4676 (Credit: Hubble space Telescope)

Stages of Formation & Evolution

- Binary formation (~ 100 pc, fastest)
- Hardening- scattering with stars (Slowest, 10-1 pc, Last-parsec problem \sim few Gyr)
- Gravitational Wave inspiral (~ 0.1 pc)

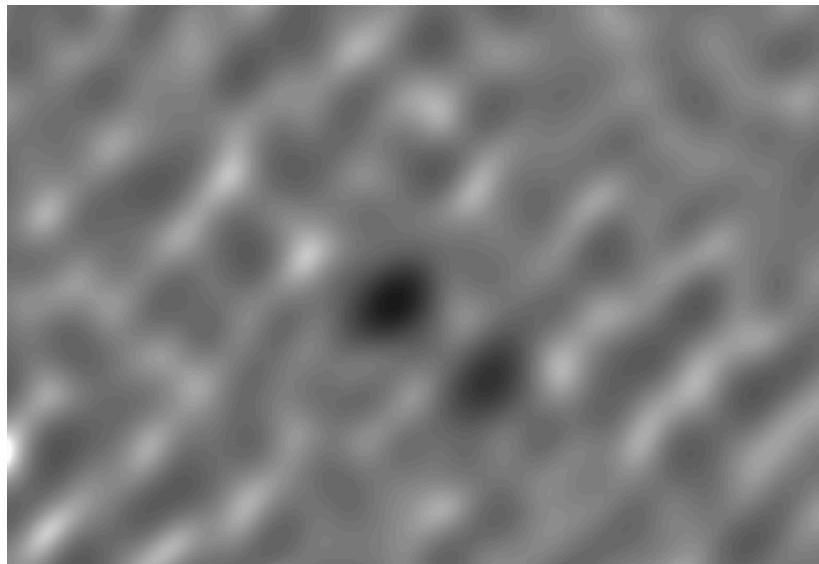


Credit: Mayer et al. (2007)

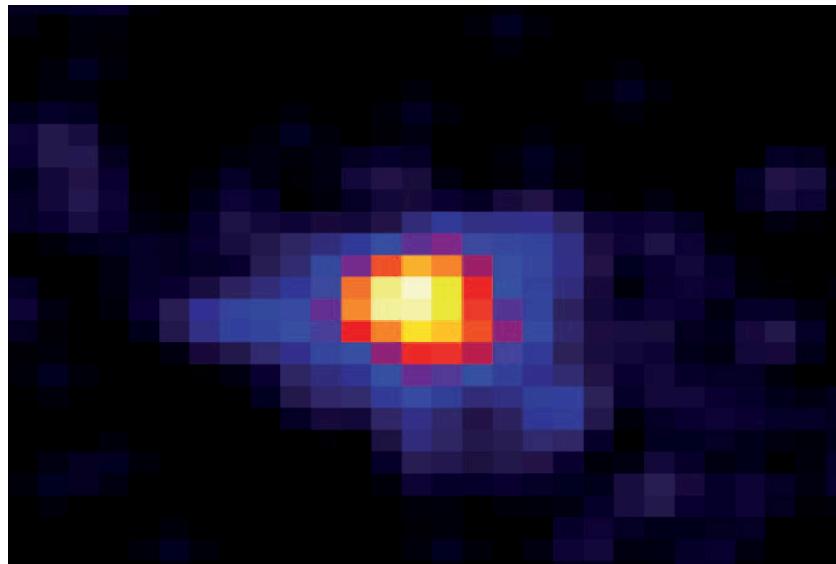
Scientific Importance

- Progenitors of Supermassive black holes
- Galaxy formation and evolution
- Gravitational waves
- Very few systems have been detected

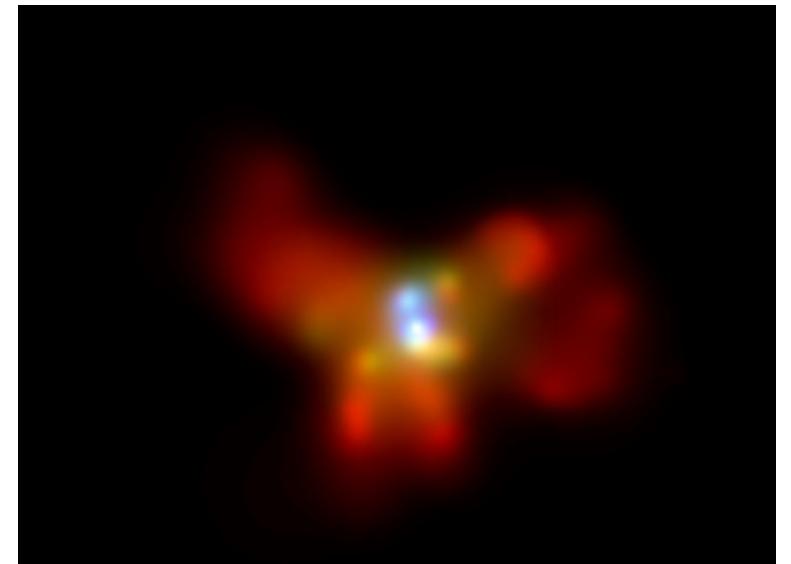
Double AGN Nuclei Candidates



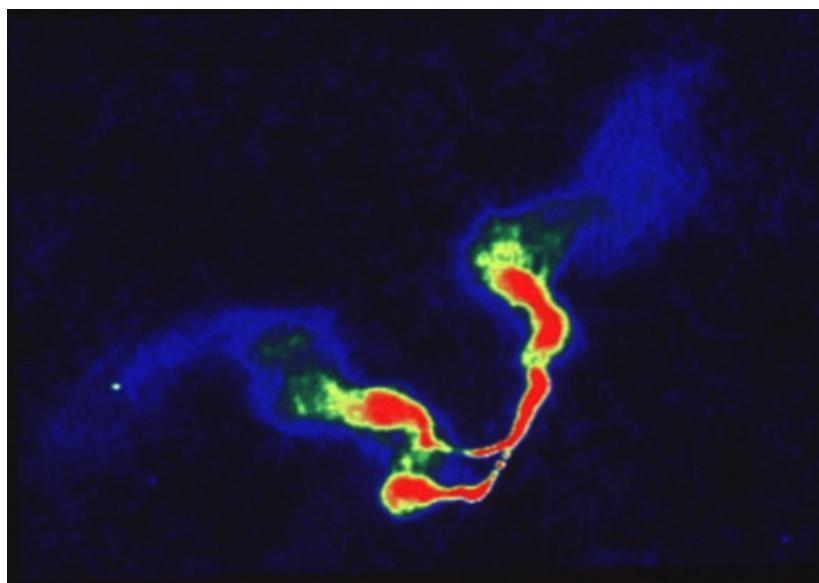
RBS 797 ~77 pc (Gitti et al)



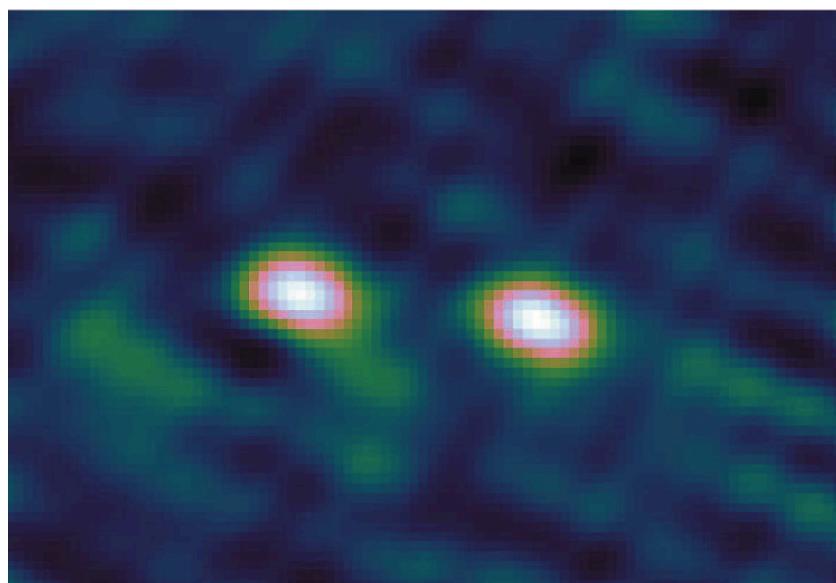
NGC 3393 ~150 pc (Fabbiano et al)



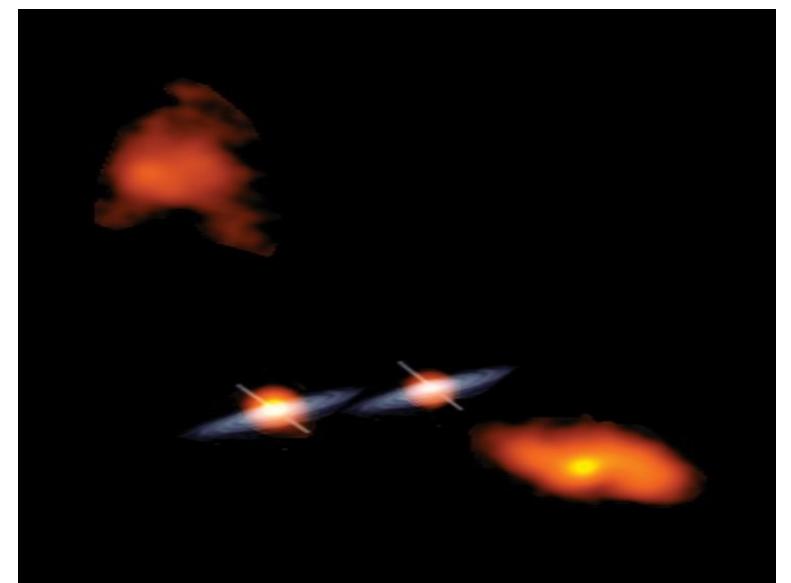
NGC 6240 ~1 Kpc (Chandra)



3C 75 ~8 Kpc (credit: NRAO/AUI and F.N. Owen et al)

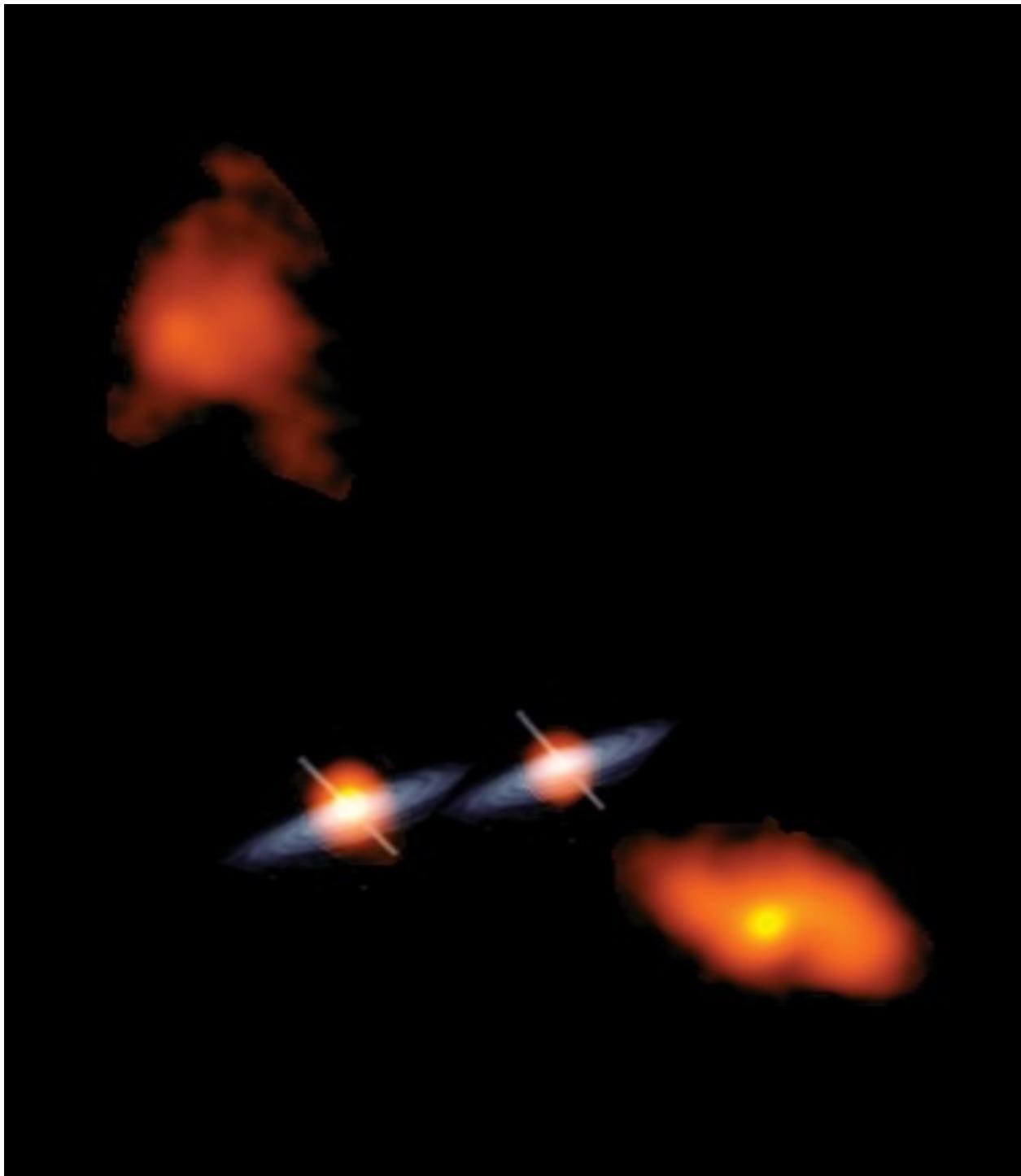


J1502+1115 ~150 pc (Deane et al)

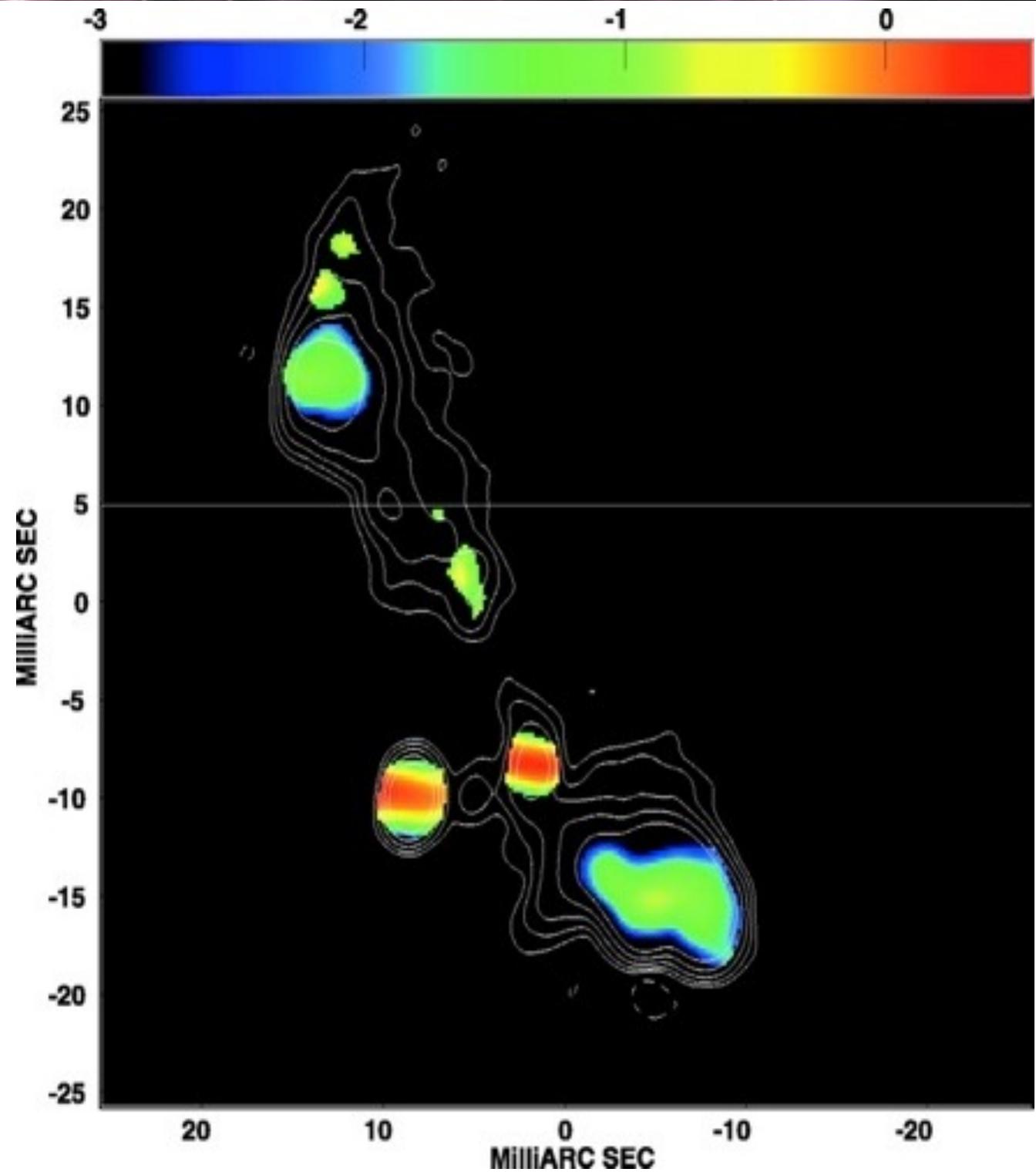


0402+379 ~ 7 pc (Credit: NRAO and Greg Taylor, UNM)

0402+379



Credit: NRAO and Greg Taylor, UNM

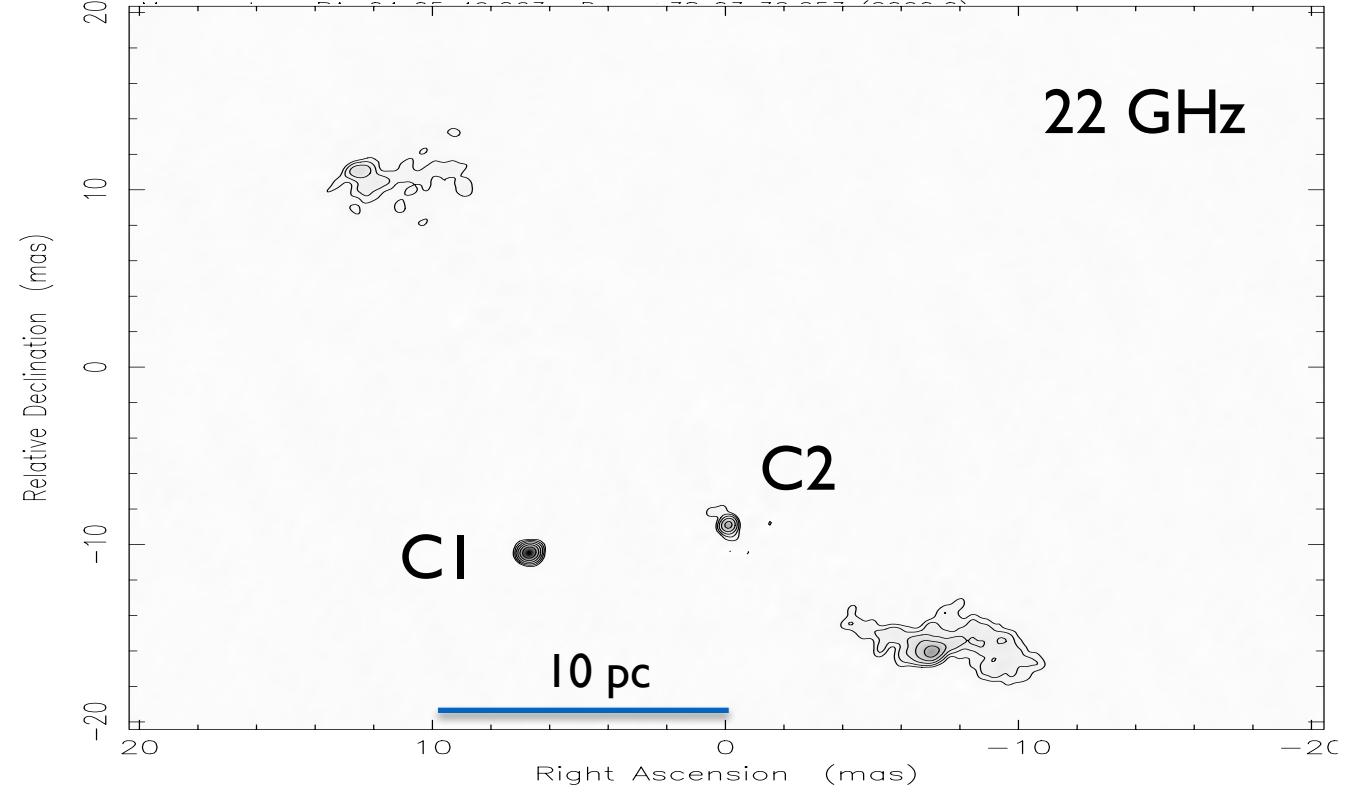
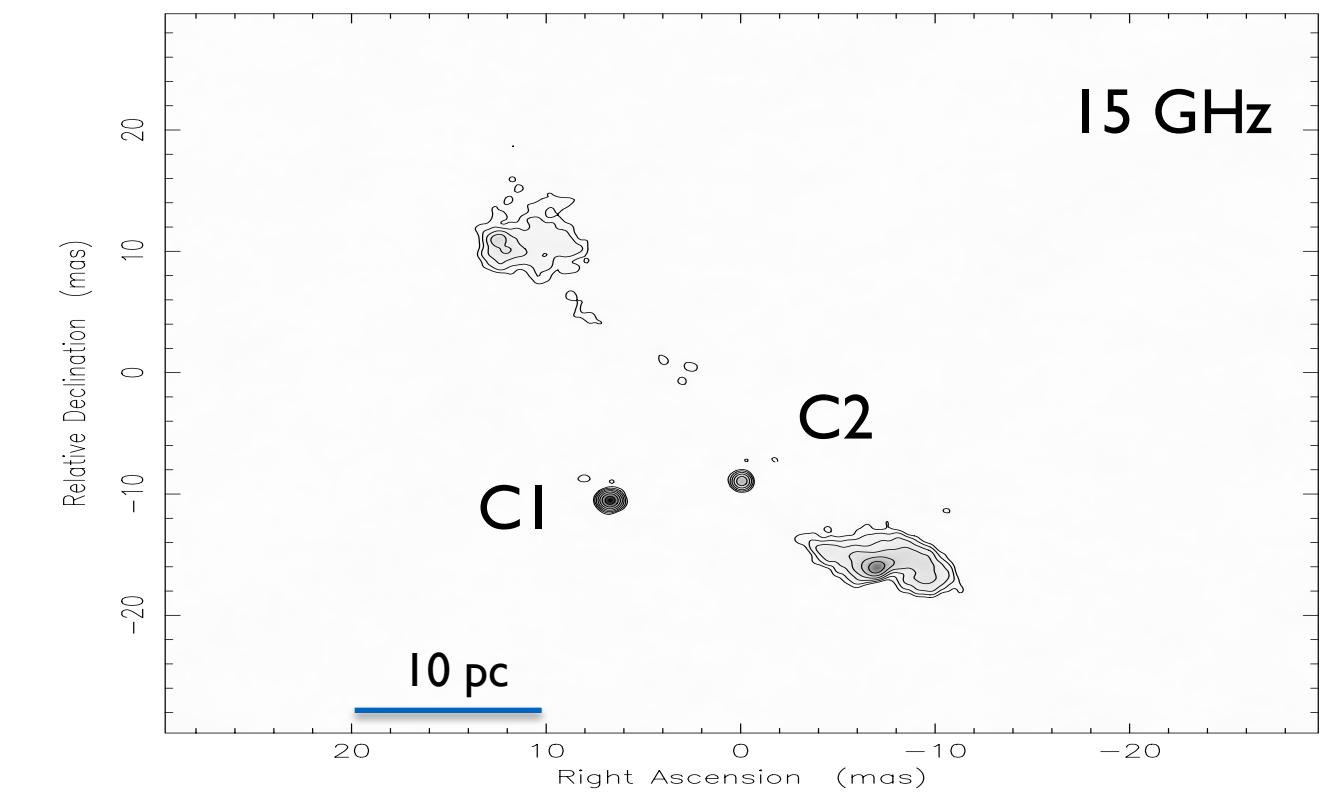
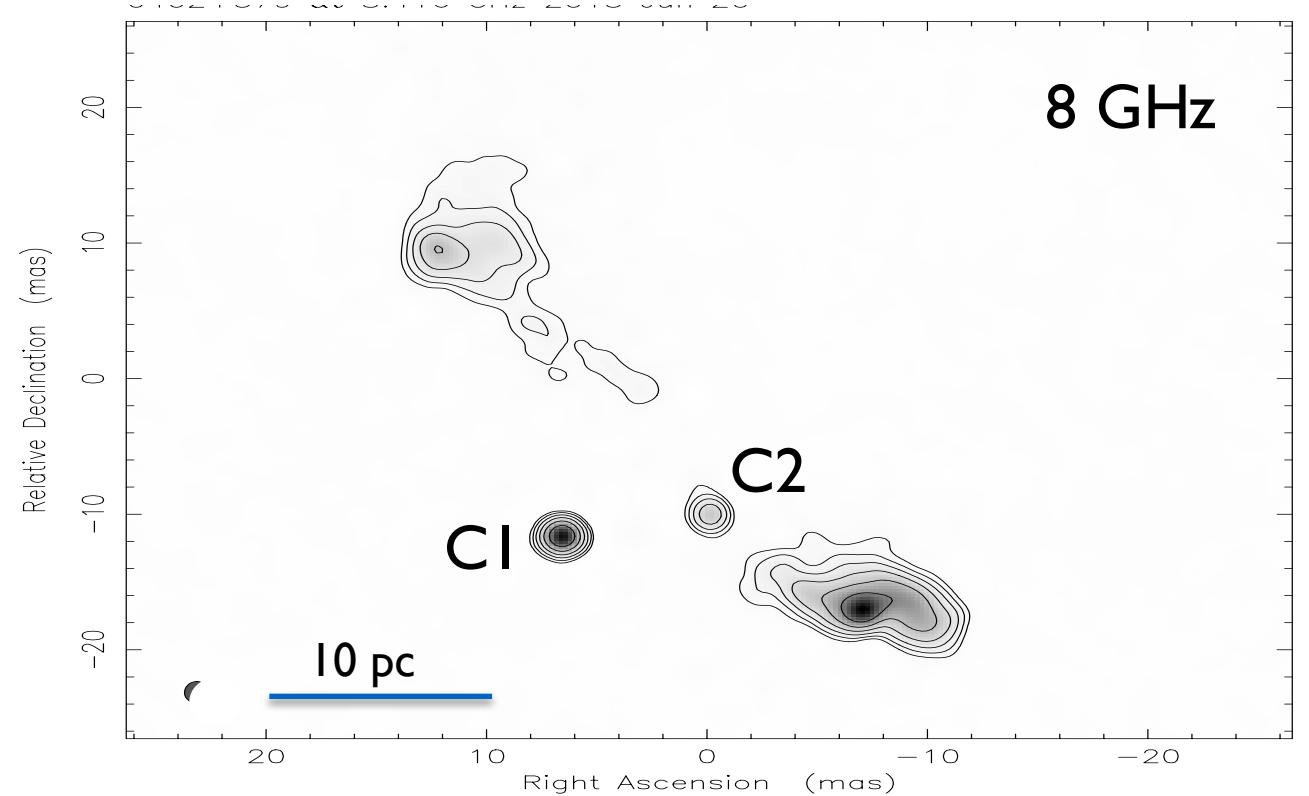
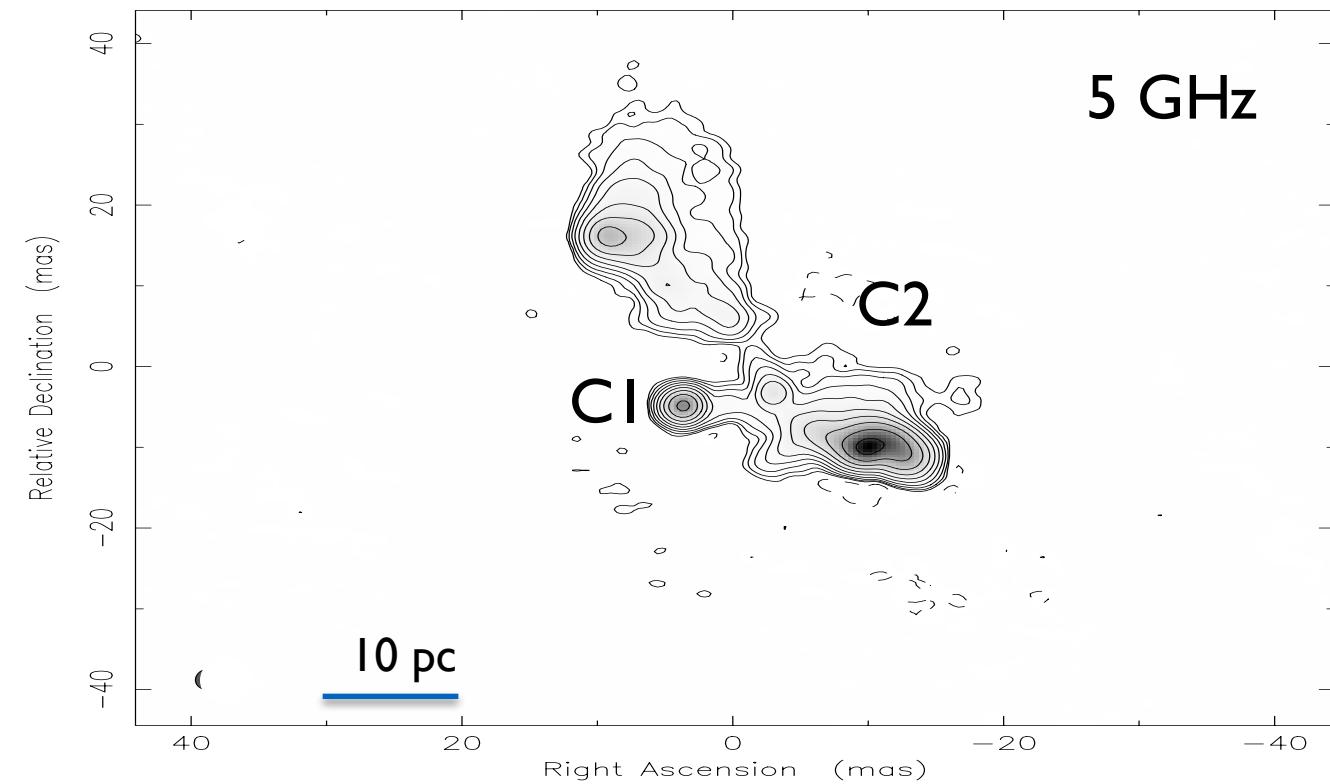


Credit: Manness et al (2004)

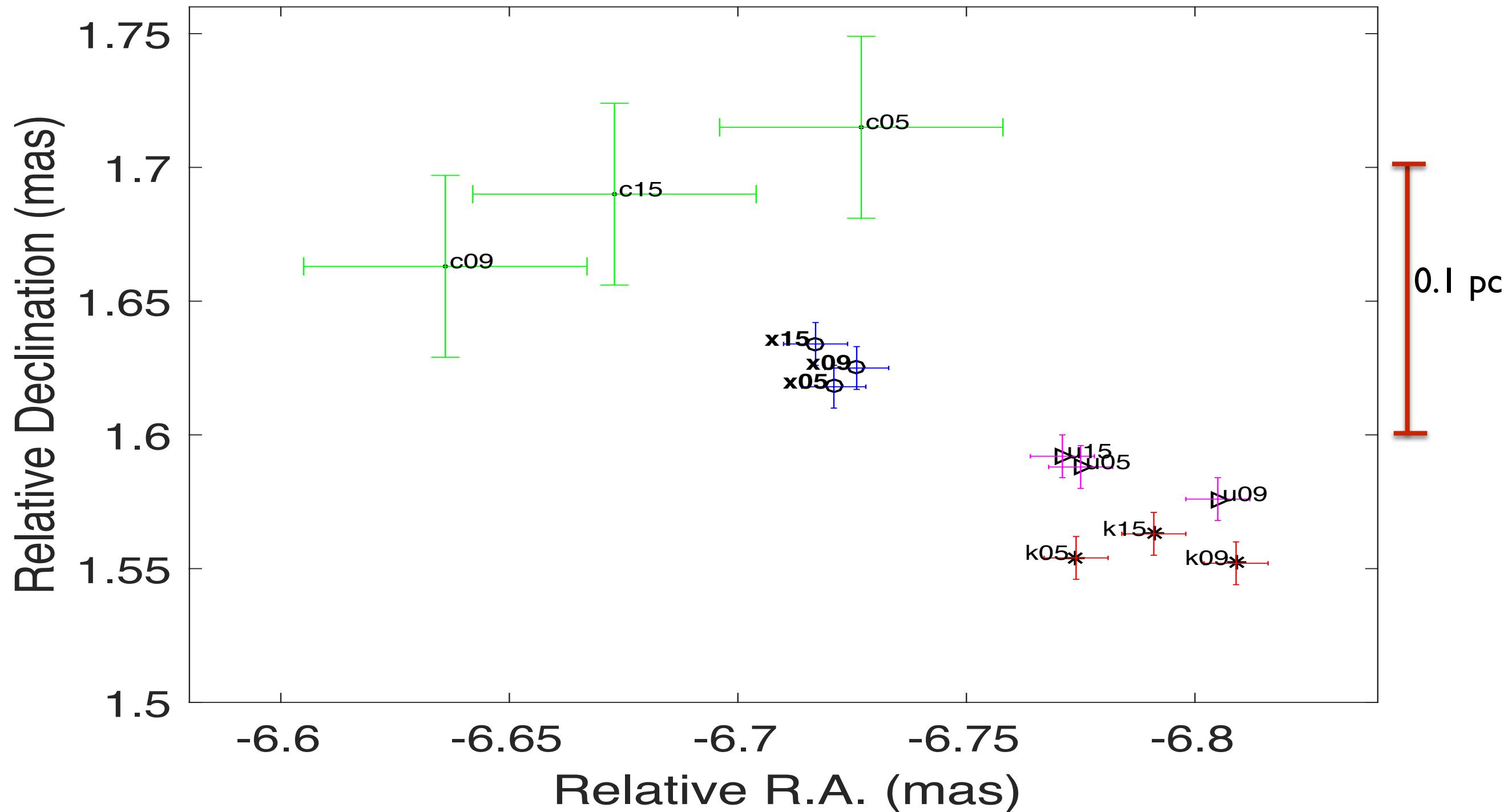
0402+379

- First observed in 1995 (Xu et al.)
- Compact Symmetric Objects (CSO) in 2003 (Pollack et al. (2003))
- In 2004, was classified unusual CSO (Mannes et al (2004))
- In 2006, it was concluded to be a supermassive black hole (Rodriguez et al. (2006))

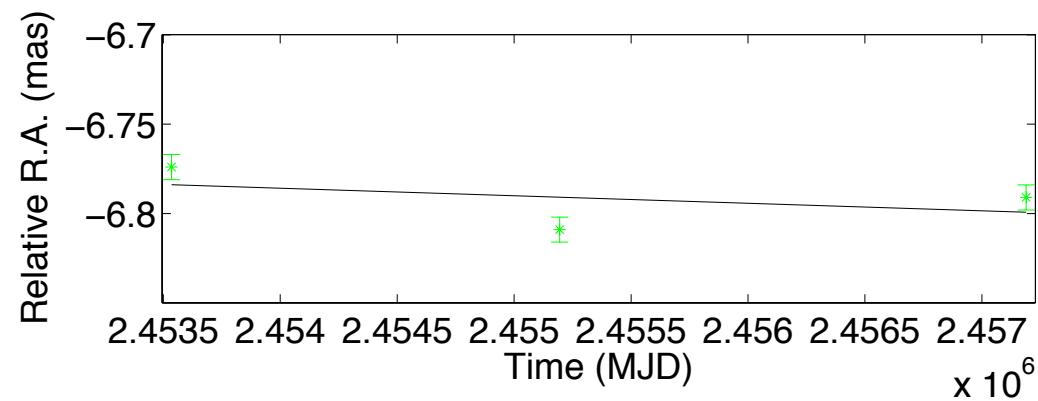
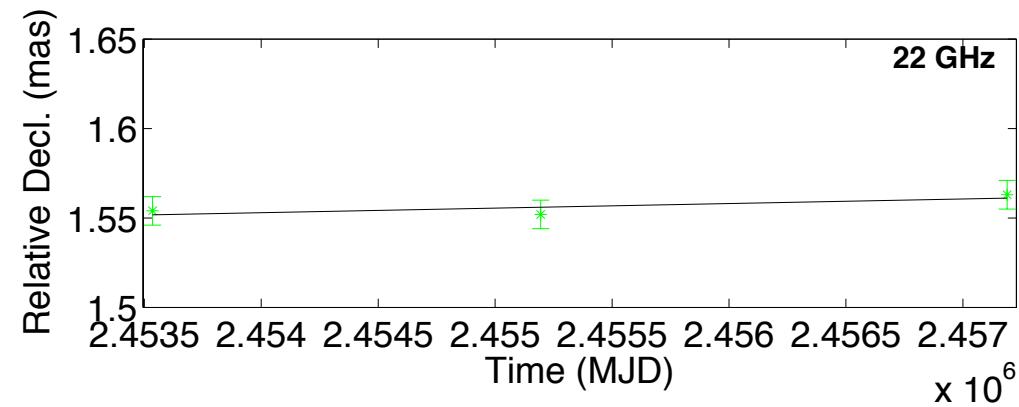
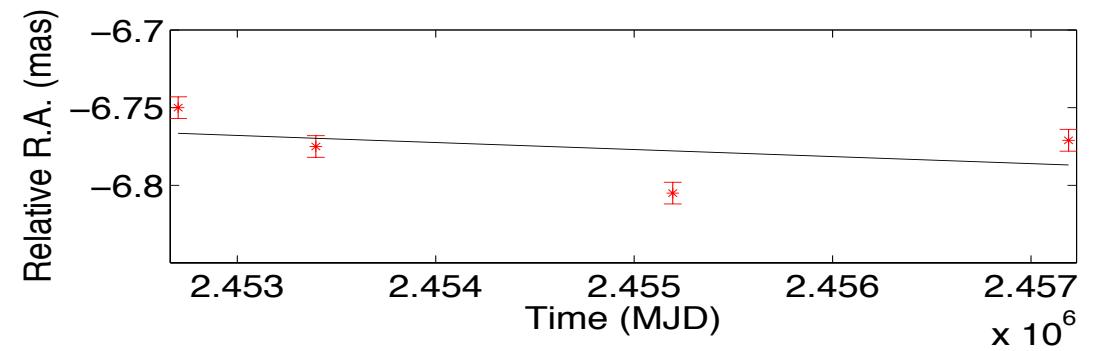
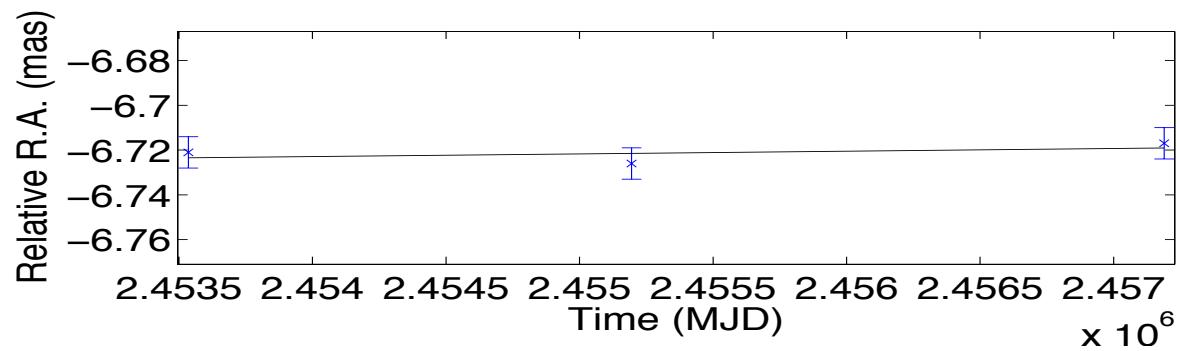
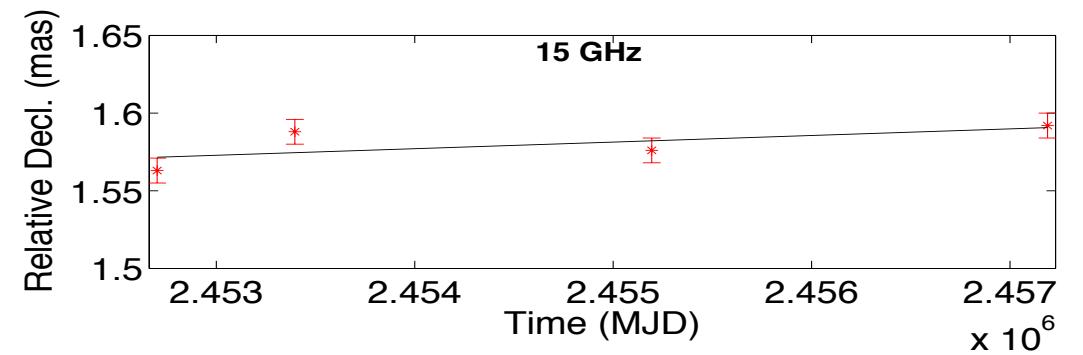
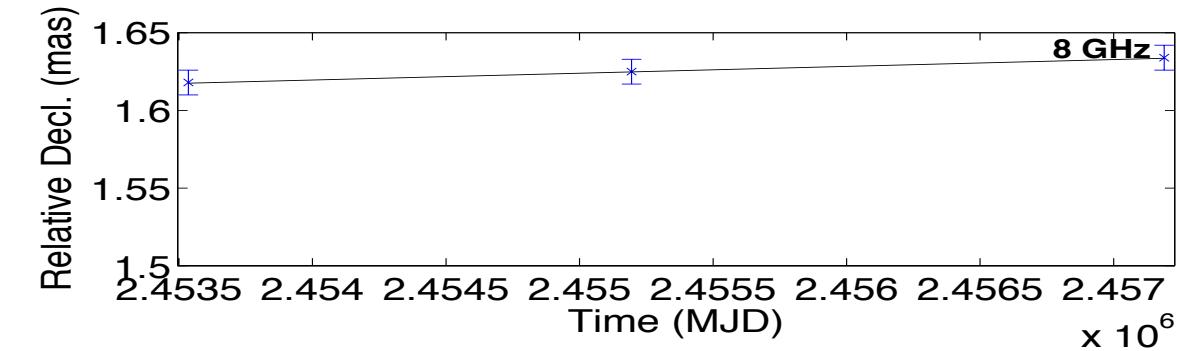
Recent Observations



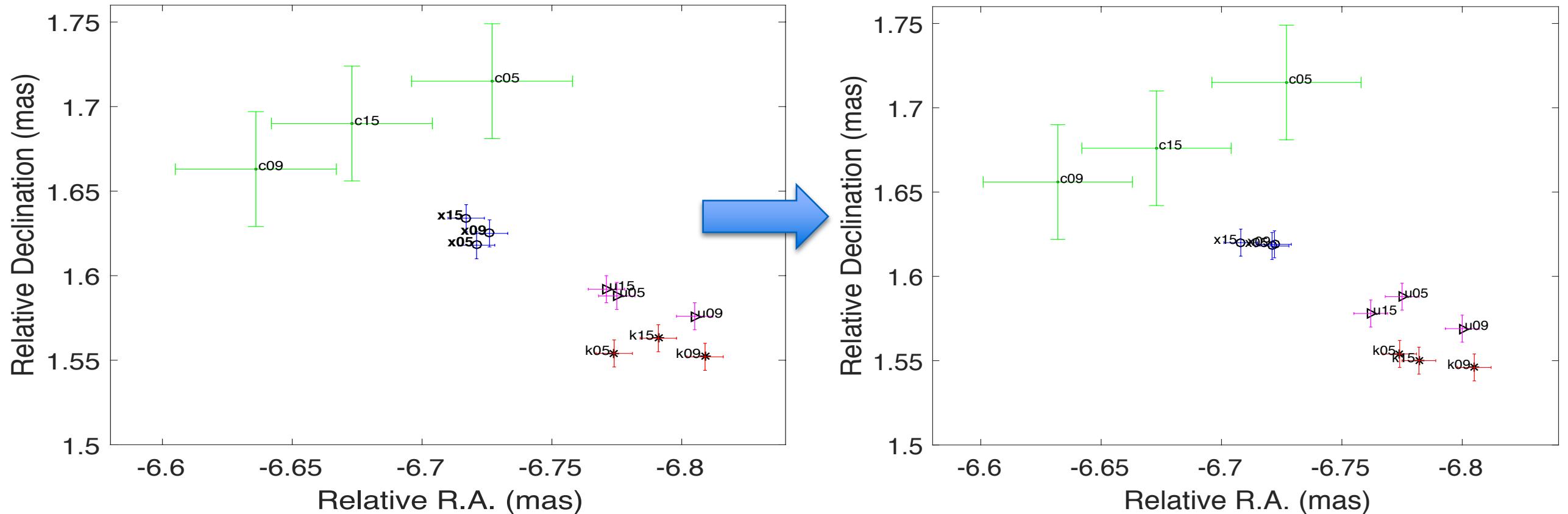
Measurements



Relative Motion

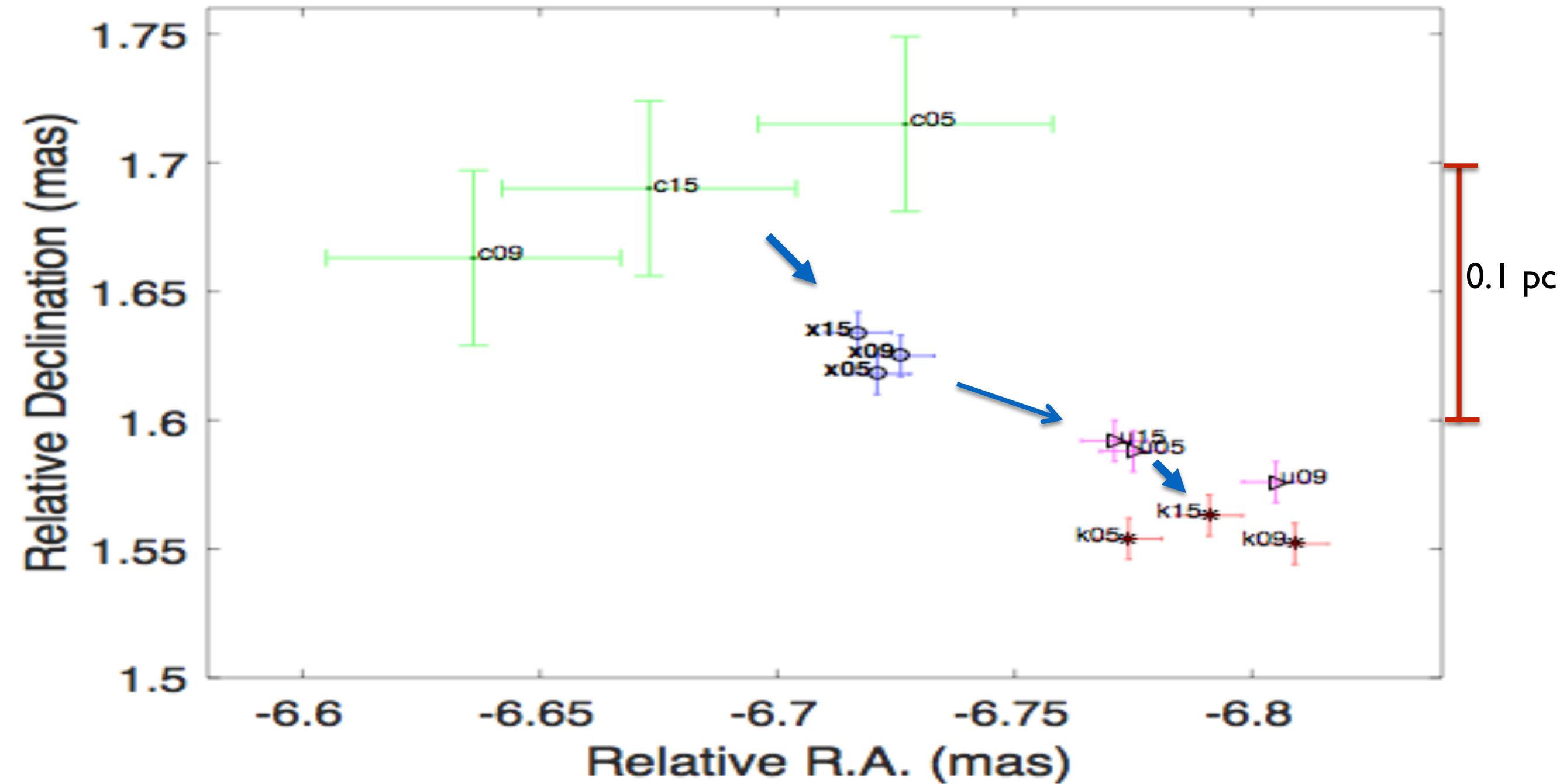


Fitting Results



- Velocity along RA : $(0.0032 \pm 0.0031)c$
- Velocity along Declination : $(0.0046 \pm 0.0036)c$
- Net Velocity : $(0.0066 \pm 0.0034)c$
- Velocity Direction: $(-30.0^\circ \pm 29.7^\circ)$

Core-Shift Effect

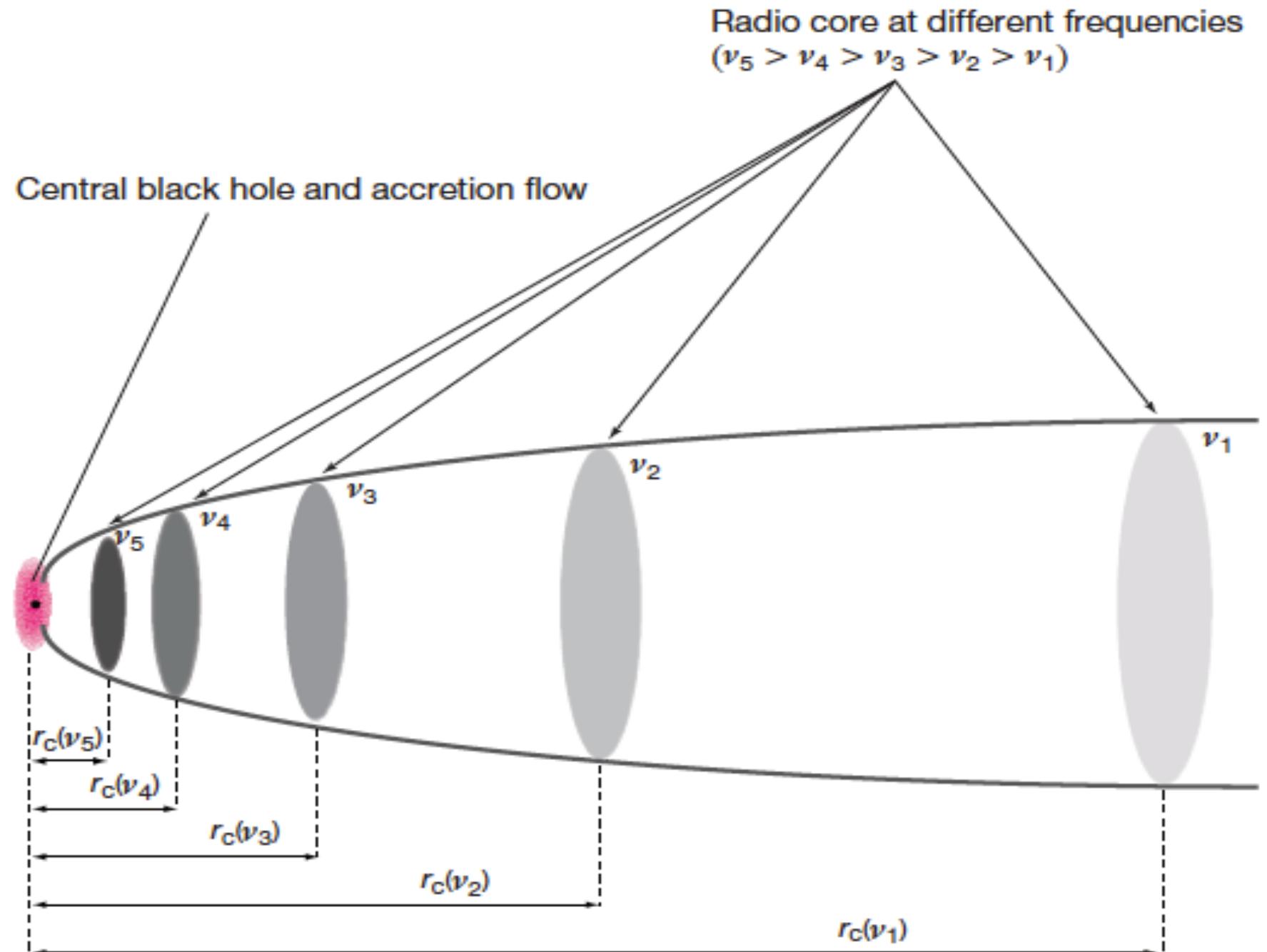


Core-Shift Effect

- Frequency dependent effect.

$$r \propto (\nu)^{-1/k}$$

- k tells about the absorption mechanism



Core-Shift Fitting

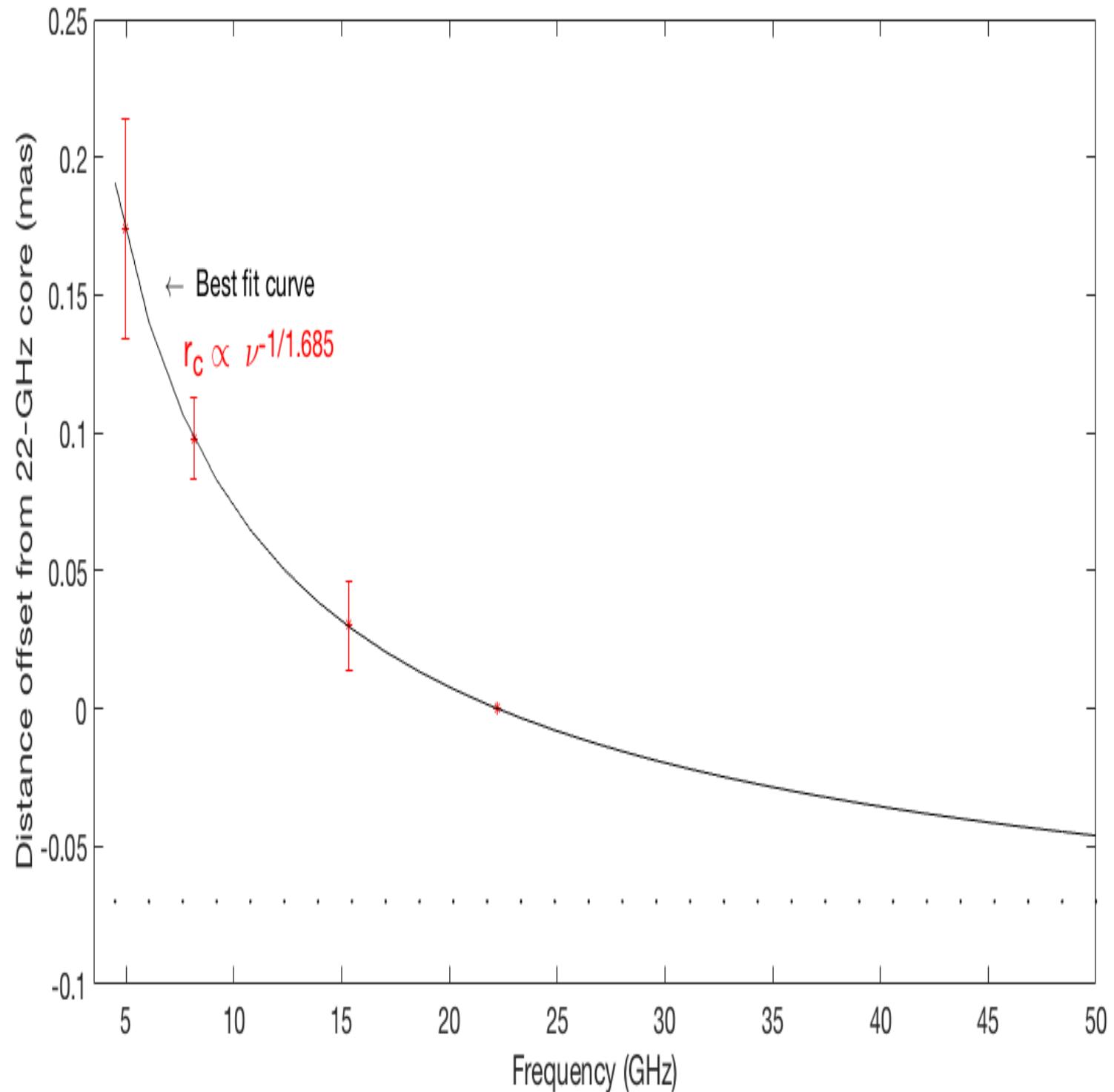
Fitting Function:

$$r_c = a((\nu)^{-1/k} - (22.22)^{-1/k})$$

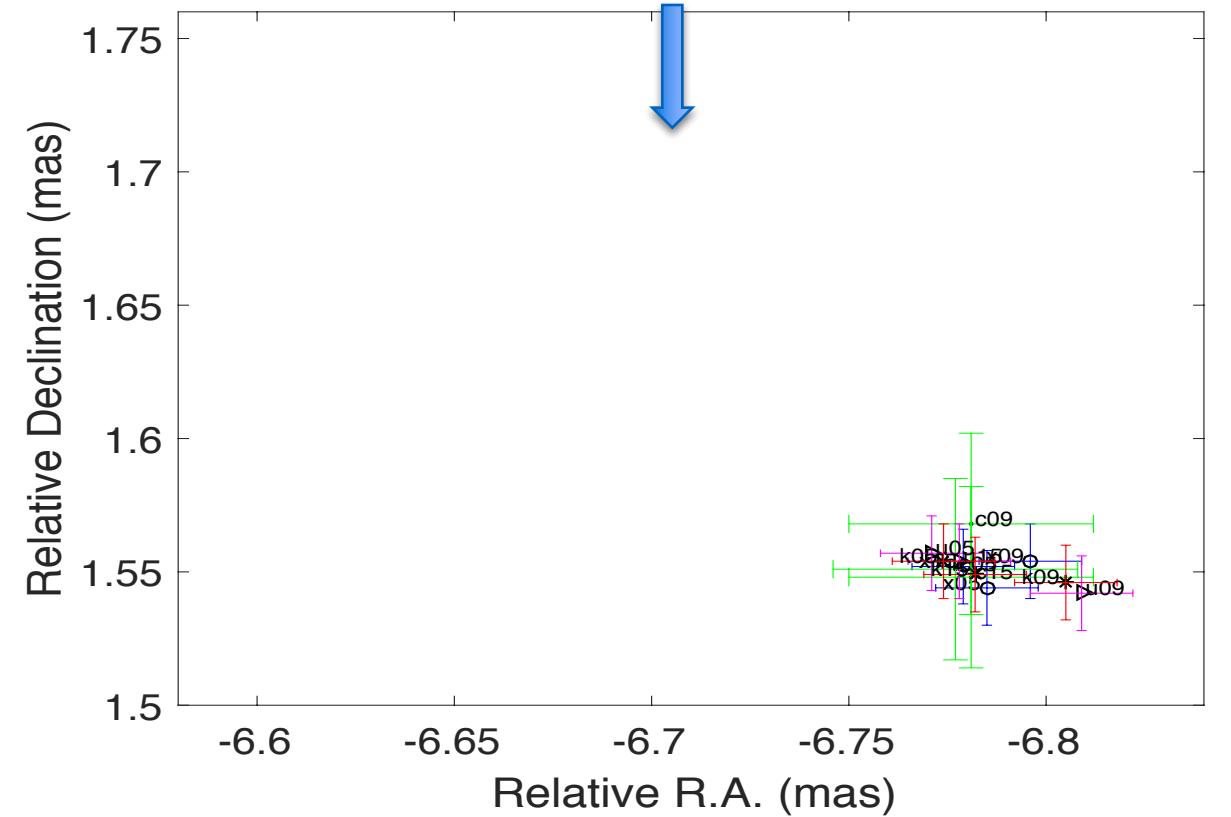
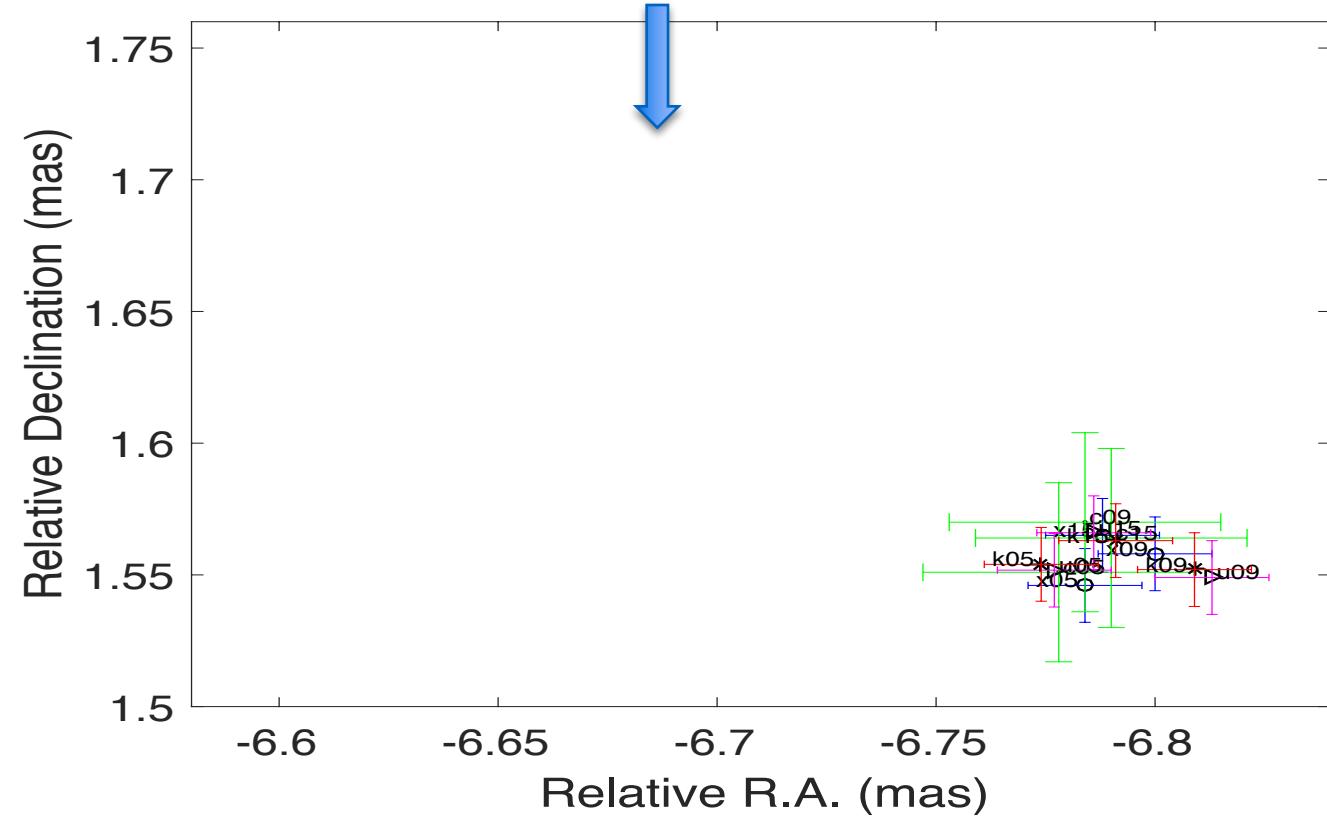
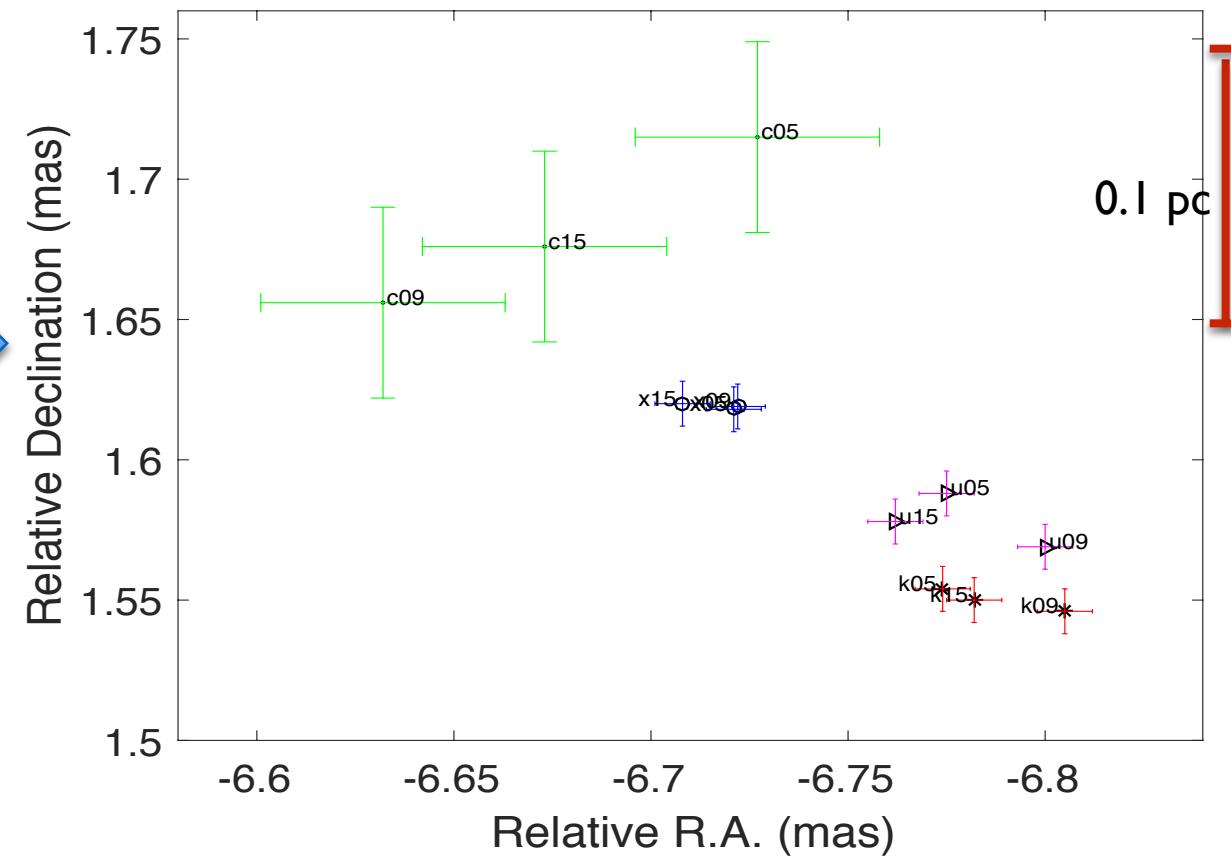
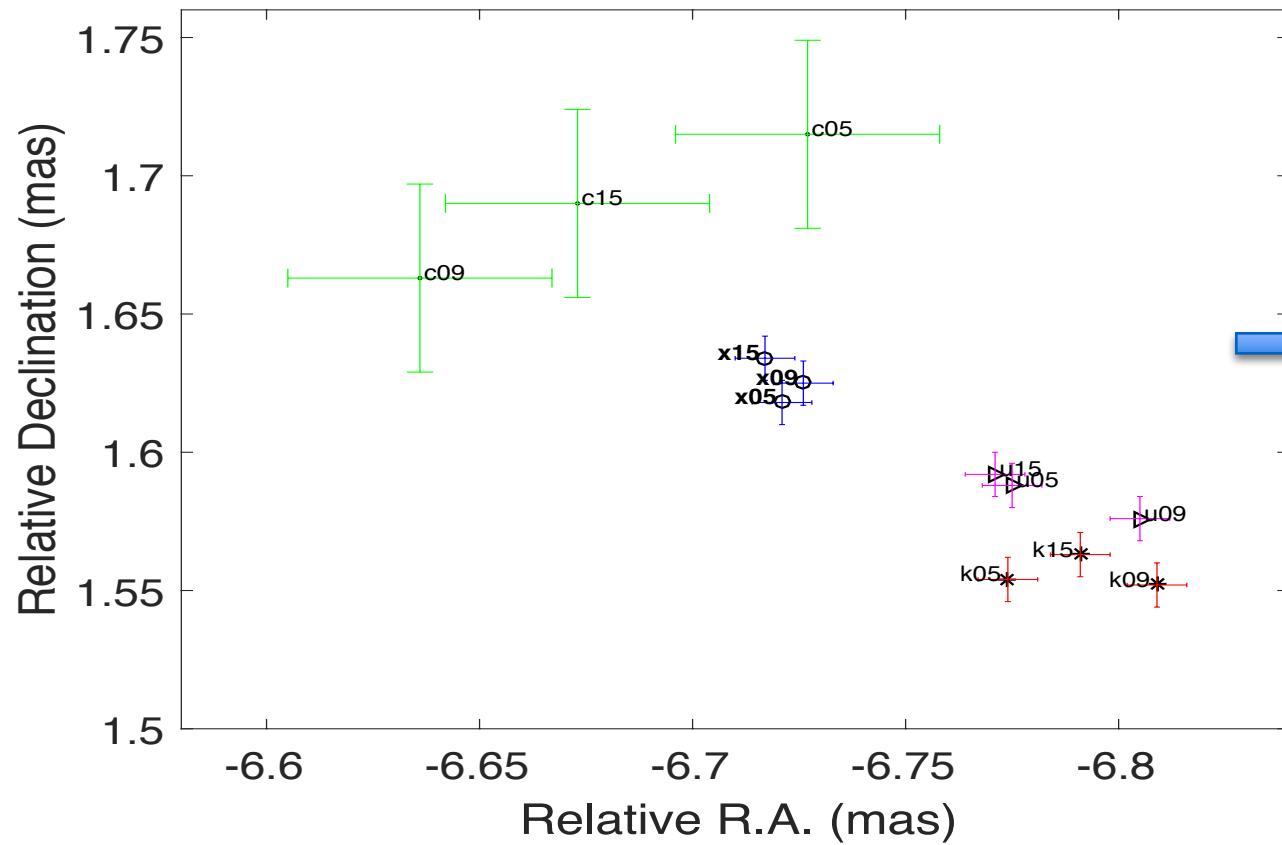
$$a = 0.760 \pm 0.083$$

$$k = 1.685 \pm 0.382$$

Core shift angle $\sim 46^\circ$



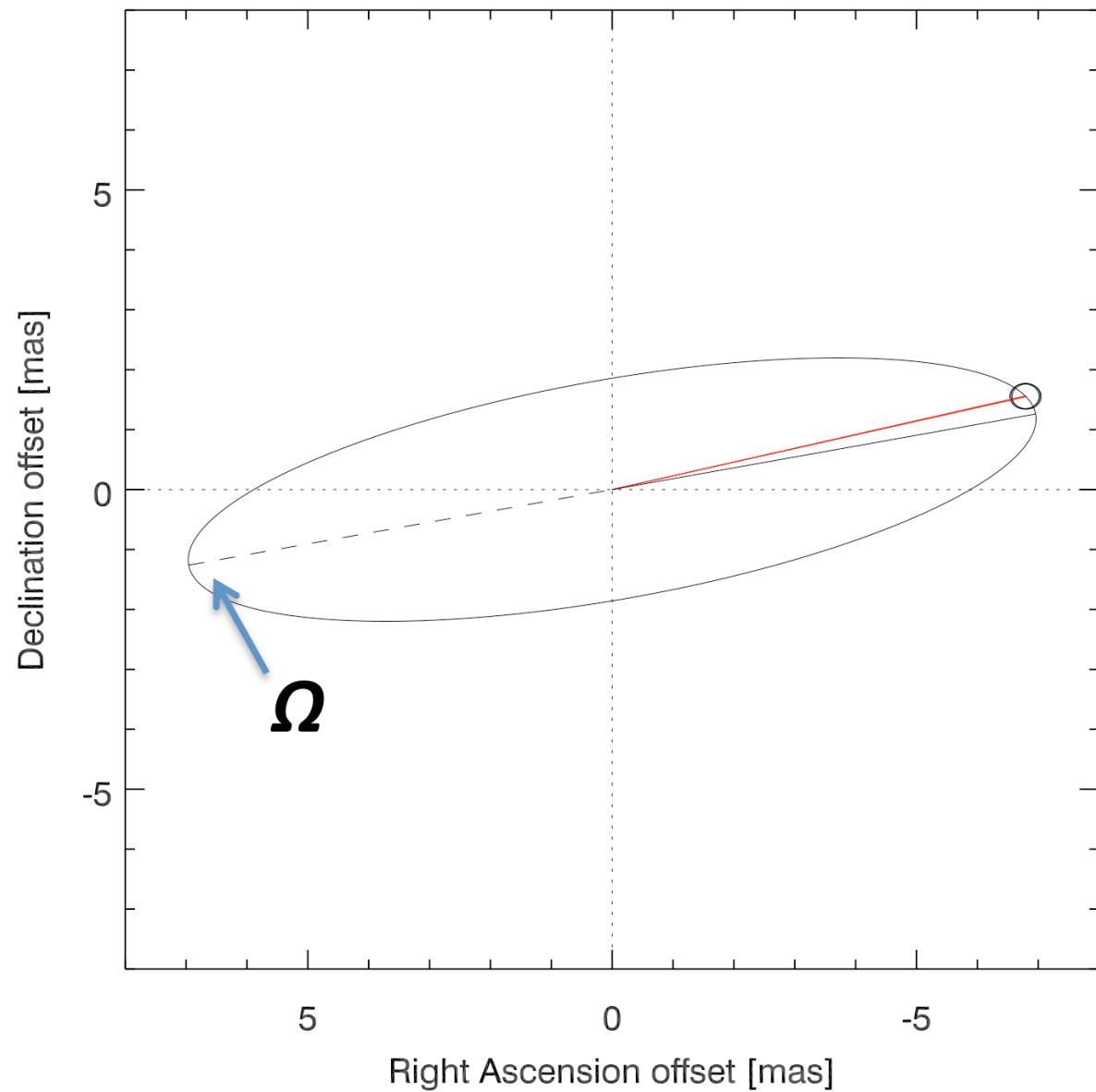
Correction



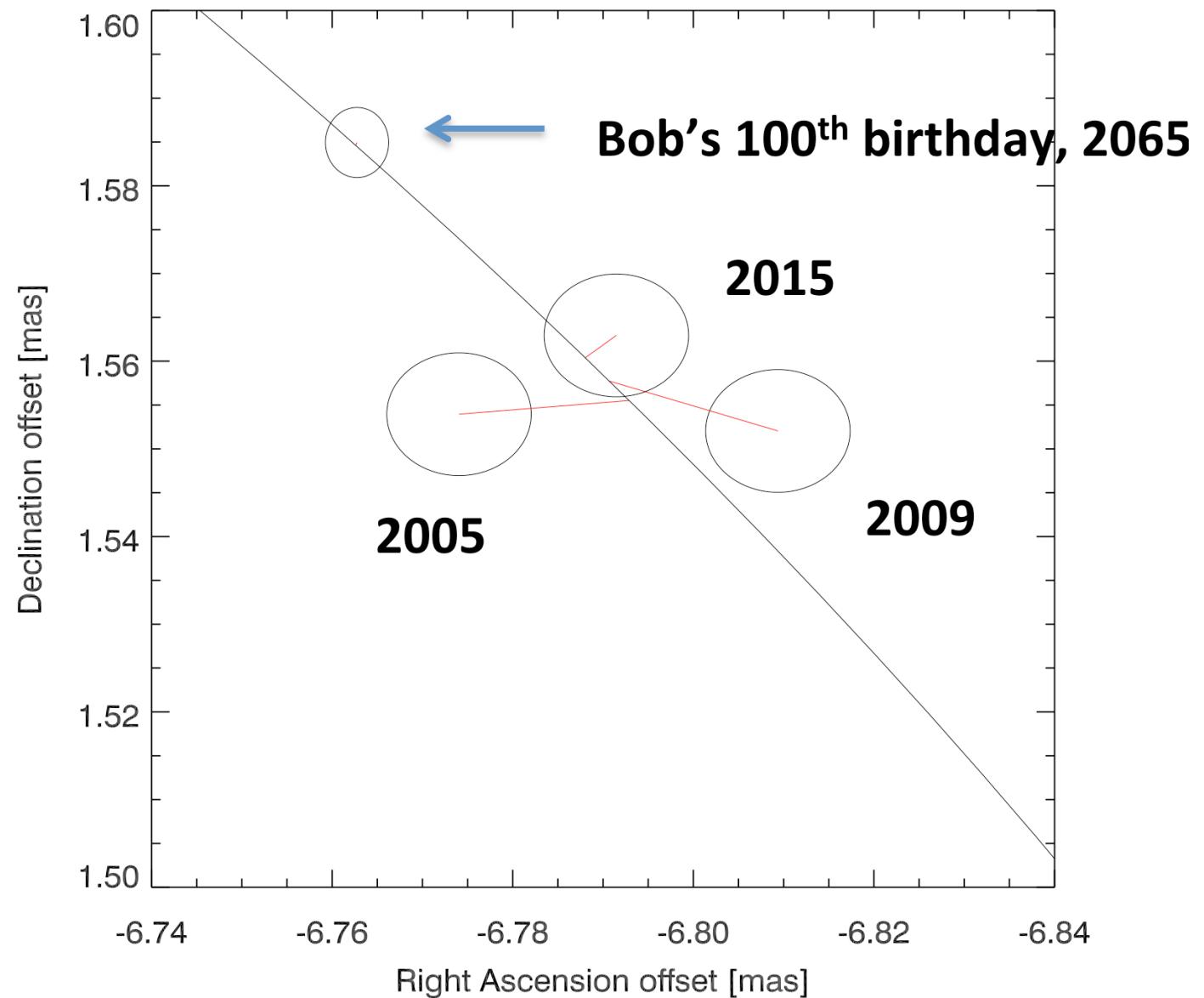
Orbital Fitting Parameters

- Circular Orbit
- Inclination angle $\sim 75^\circ$ (Rodriguez et al (2009))
- a (mas) = 7.1 pc
- Ω (deg) = 100.4°
- $P = 2 * 10^4$ years

Orbital Fitting



Circular orbit at an inclination



Close-up view

Conclusions

- Combined mass of the system $\sim 6 \times 10^9 M_{\odot}$
- Observe for ~ 20 years more to constrain the orbit
- Conduct more surveys - cD galaxies, nearby galaxy groups