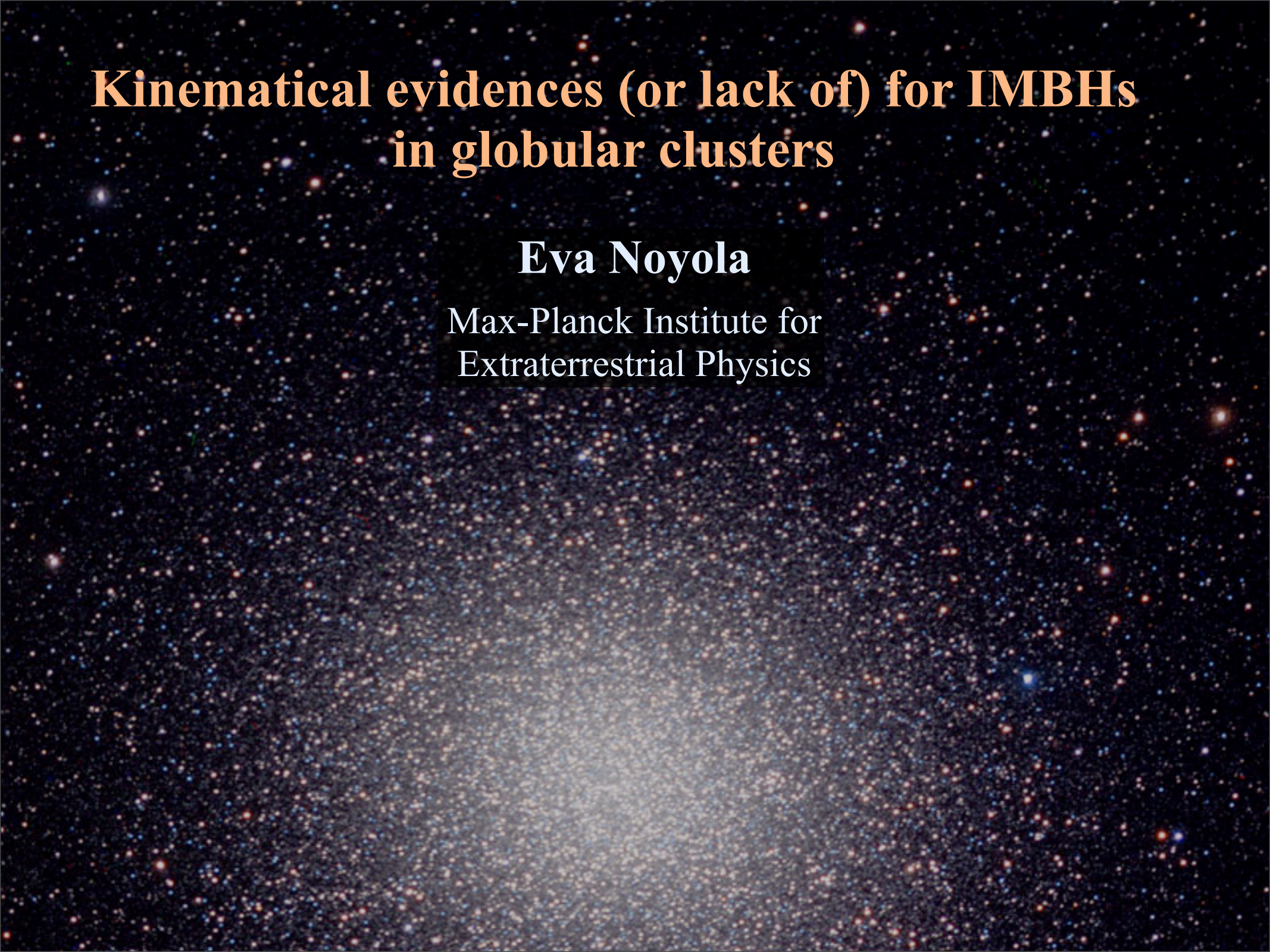

Kinematical evidences (or lack of) for IMBHs in globular clusters

Eva Noyola

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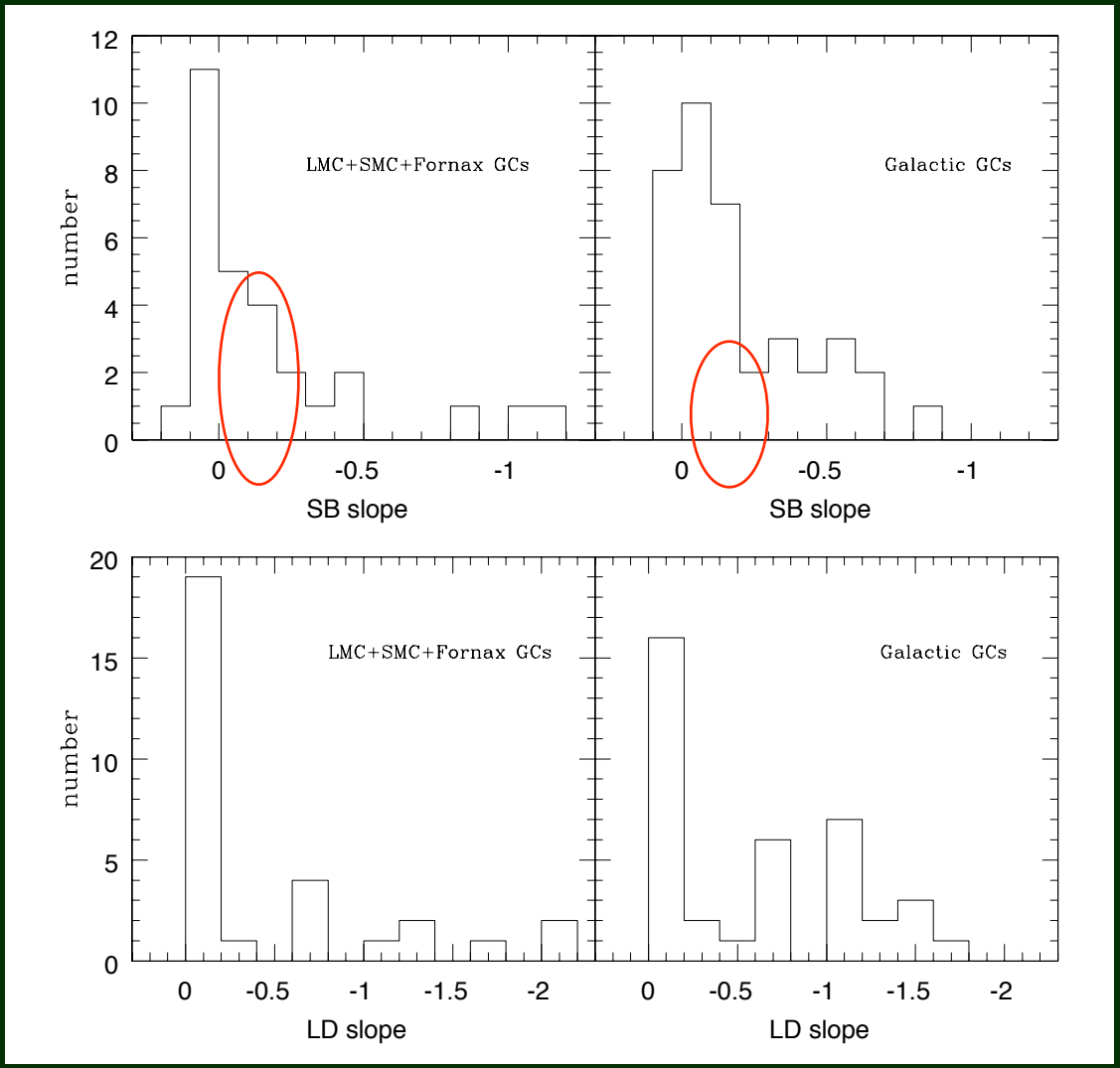
Extraterrestrial Physics

History and motivation

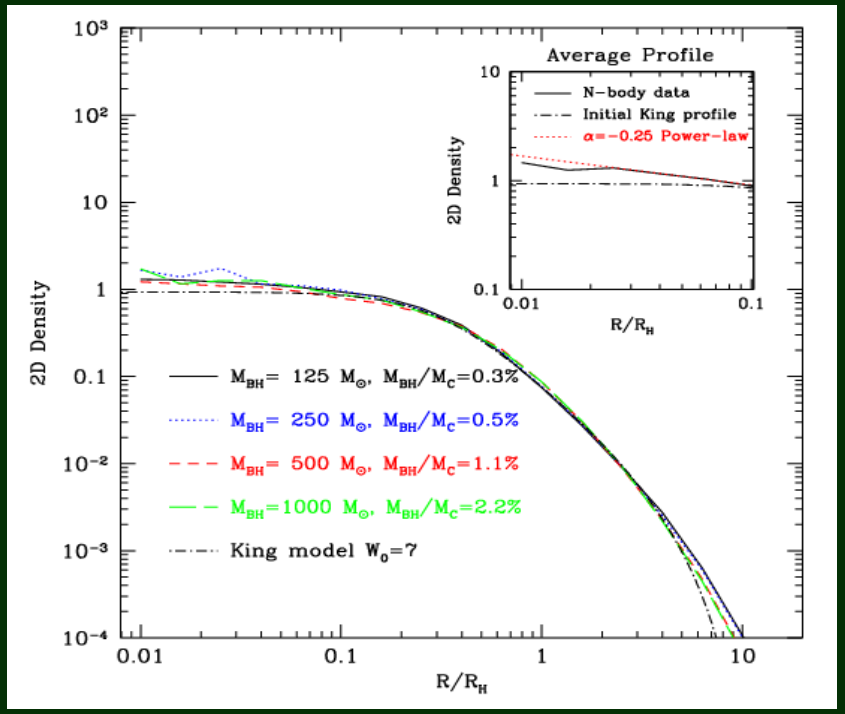
- X-ray sources (Silk & Arons, 1975)
- Analytical models from Bahcall & Wolf (1976)
- Small sphere of influence, only resolved until recently
- Seeds necessary to form SMBHs
- Possible extension of MBH-sigma relation
- Possible sources for gravitational wave detectors

SB slopes distributions

~20% of HST-based SB profiles have central slopes matching N-body models with central BHs



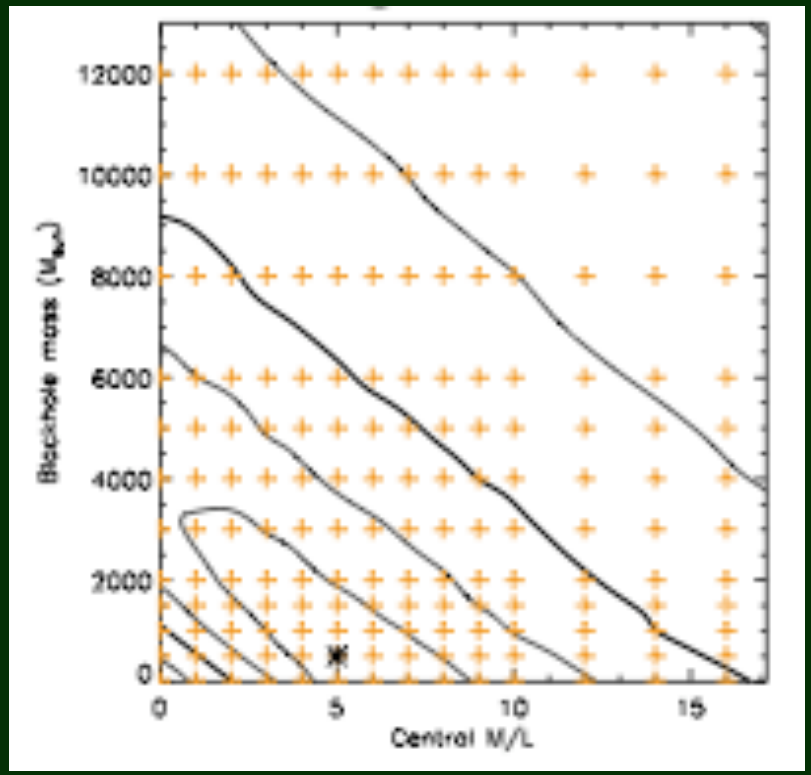
Noyola & Gebhardt, 2006, 2007

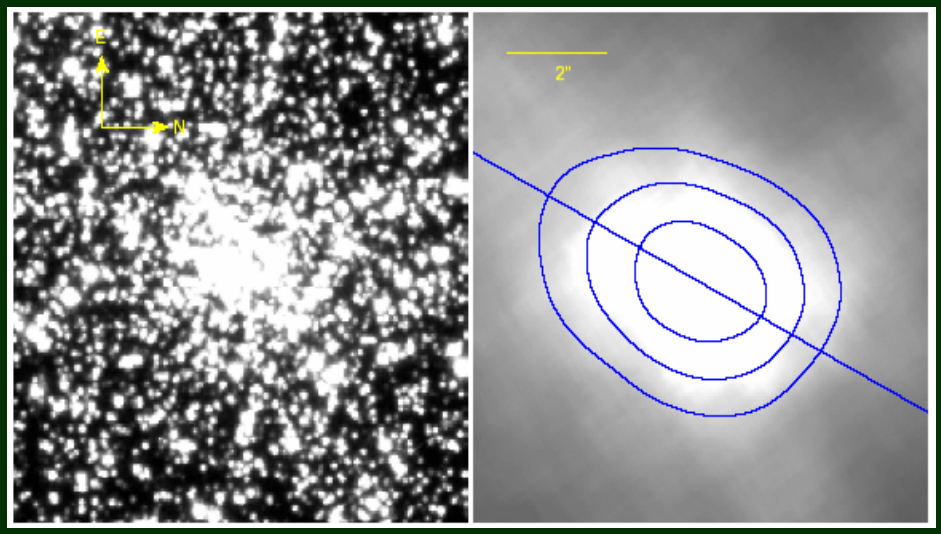


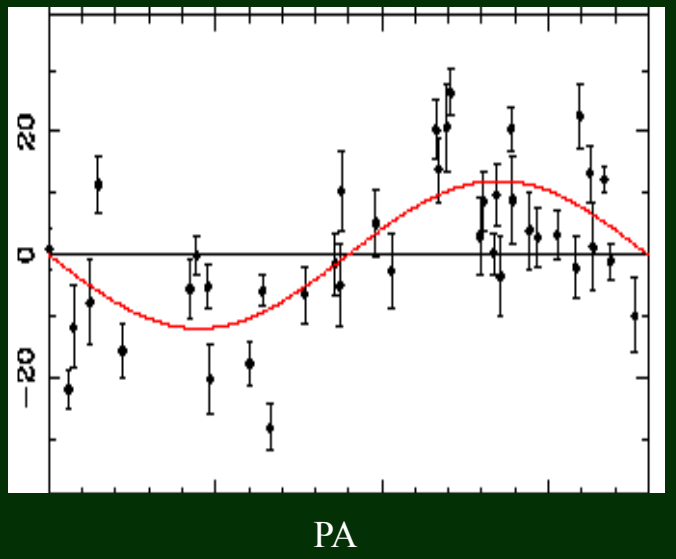
Baumgardt et al (2005)

N-body simulations of star clusters containing central black holes predict a central shallow cusp of slope ~-0.2 in surface density.

M15



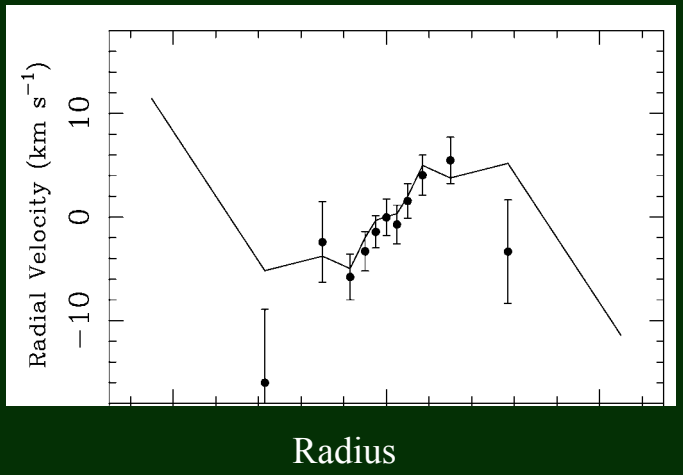


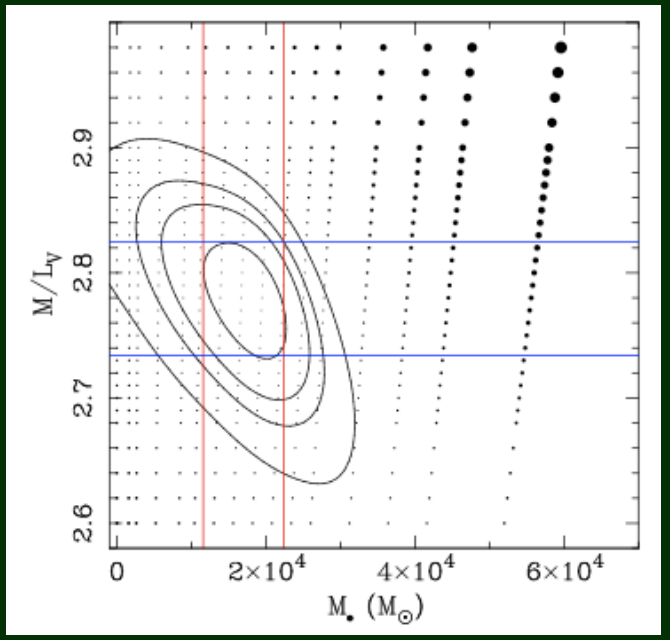


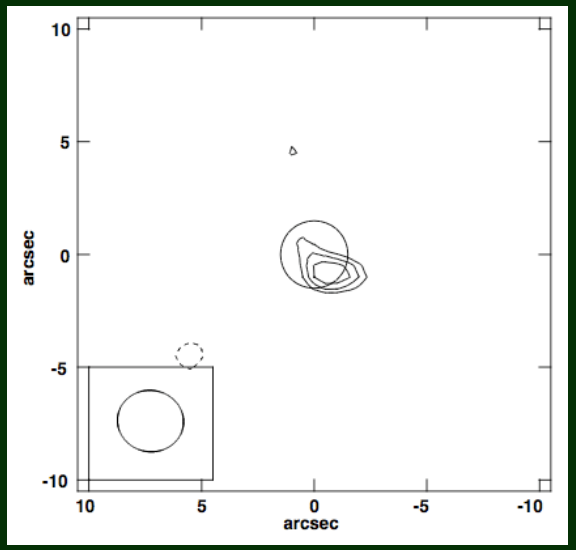
- Evidence for central black hole is inconclusive
- 3400 M⊙ inside 0.05 pc
- Possible central rotation
- SB fits models for post core-collapse bounce

van den Bosch et al., 2006; McNamara et al., 2003; Gerssen et al., 2002

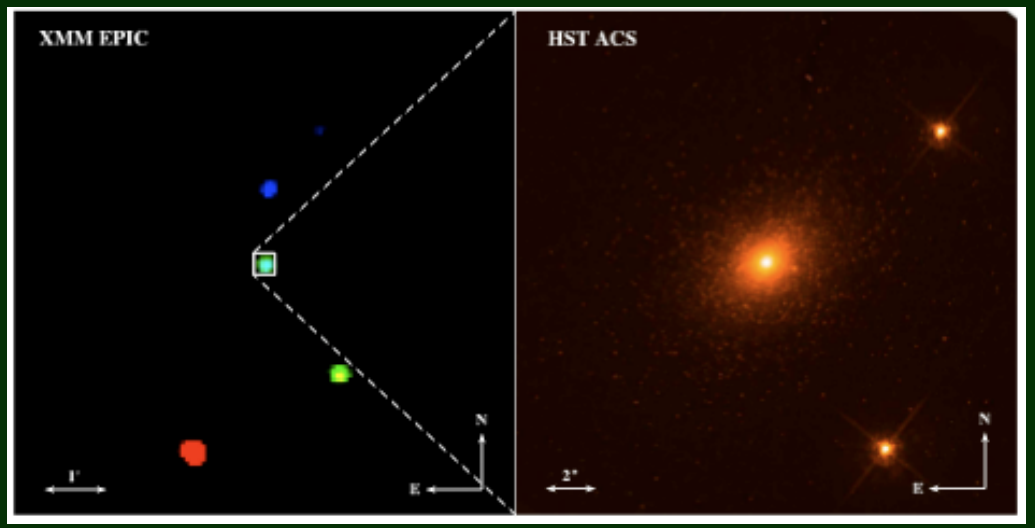
G1





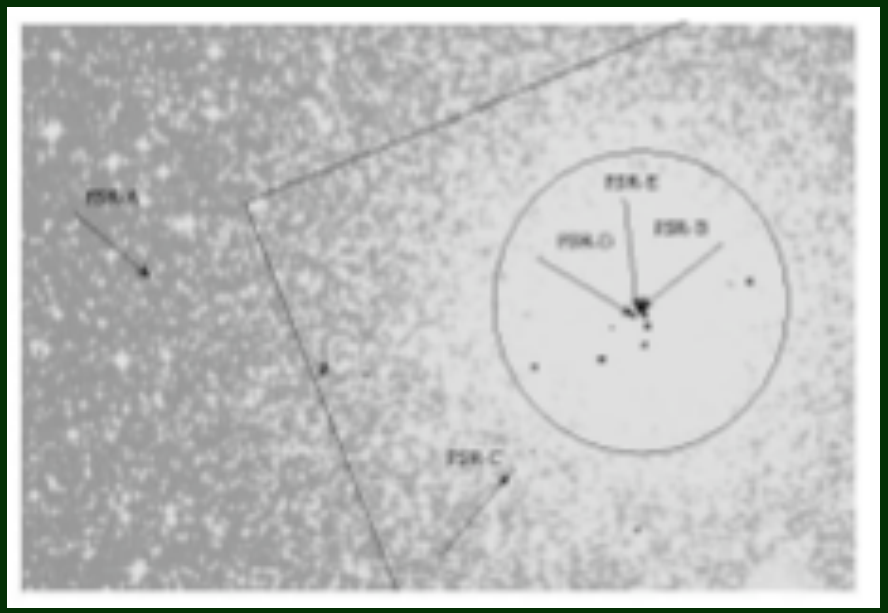


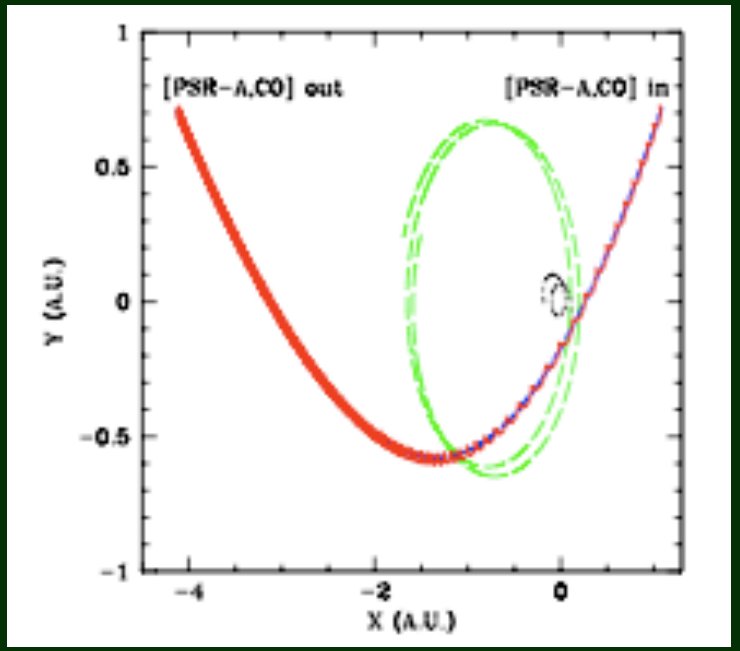
- 20,000 M⊙ central black hole from orbit-based models
- Alternative model fits kinematics. Requires two merging clusters
- Central rotation detected
- Flat central core in SB
- Central X-ray and radio emission detected



Gebhardt et al., 2005; Baumgardt et al., 2003 Pooley & Rappaport, 2006; Ulvestad et al., 2007

NGC 6752

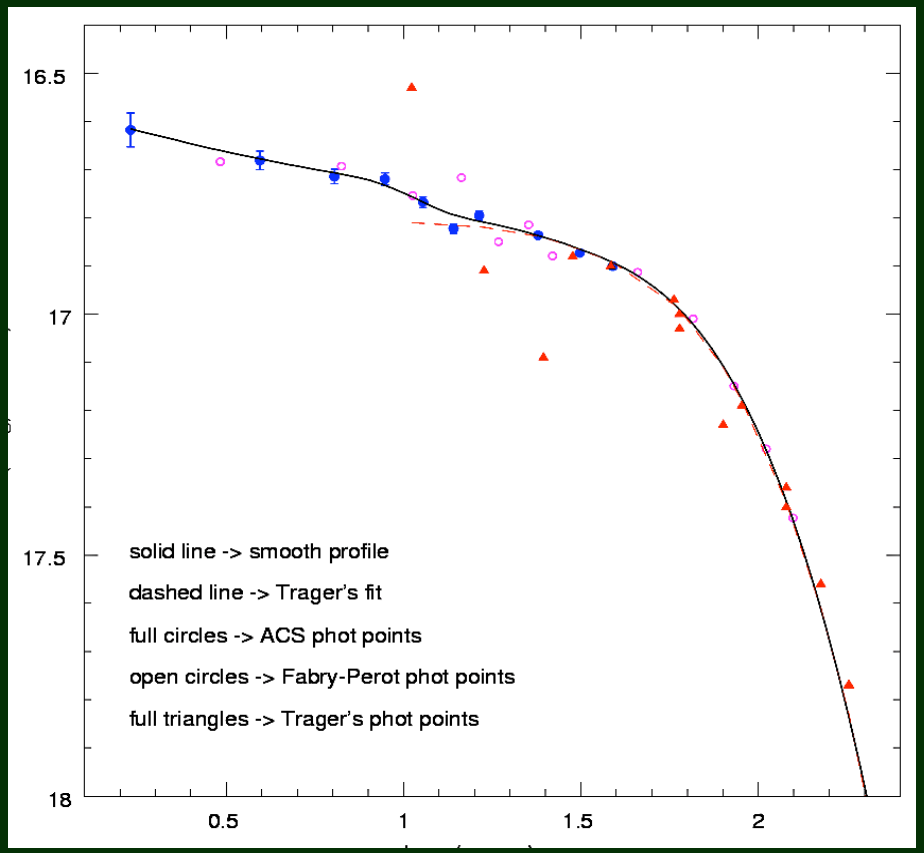


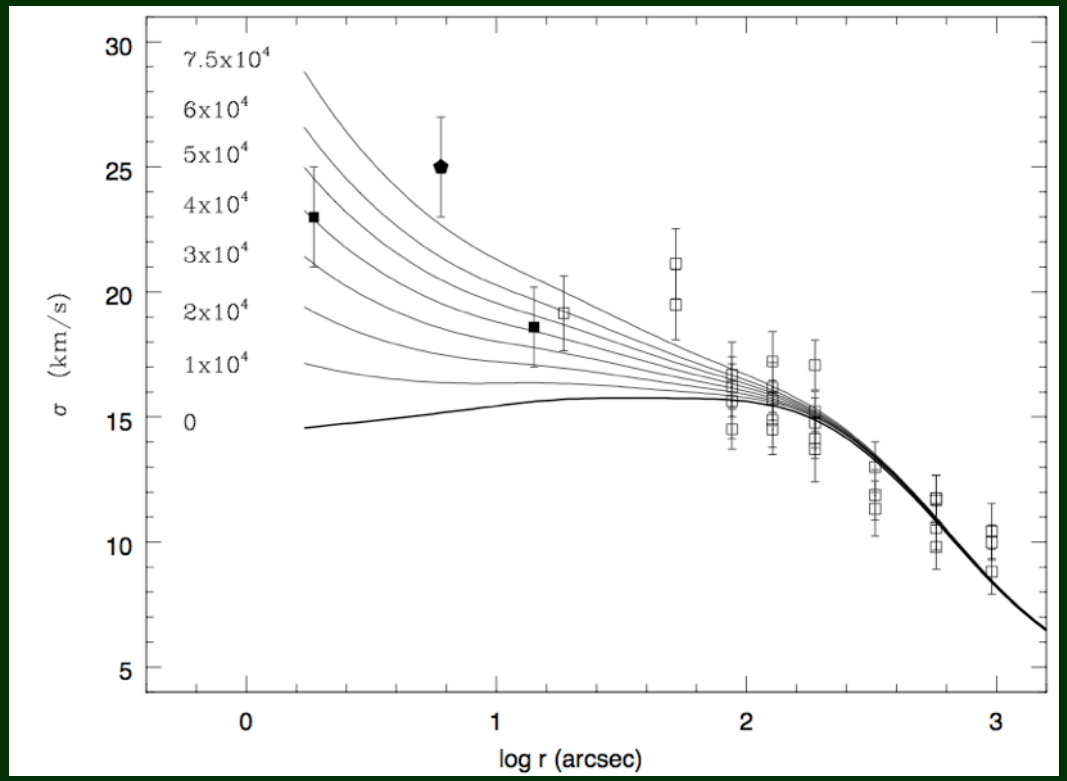


- Unusual millisecond pulsar population
- Measured central M/L implies 1000-2000 M⊙ inside 0.08 pc
- Configuration could come from single or double black hole of 200-500 M⊙

D'Amico et al., 2002; Colpi et al., 2003;

Omega Centauri



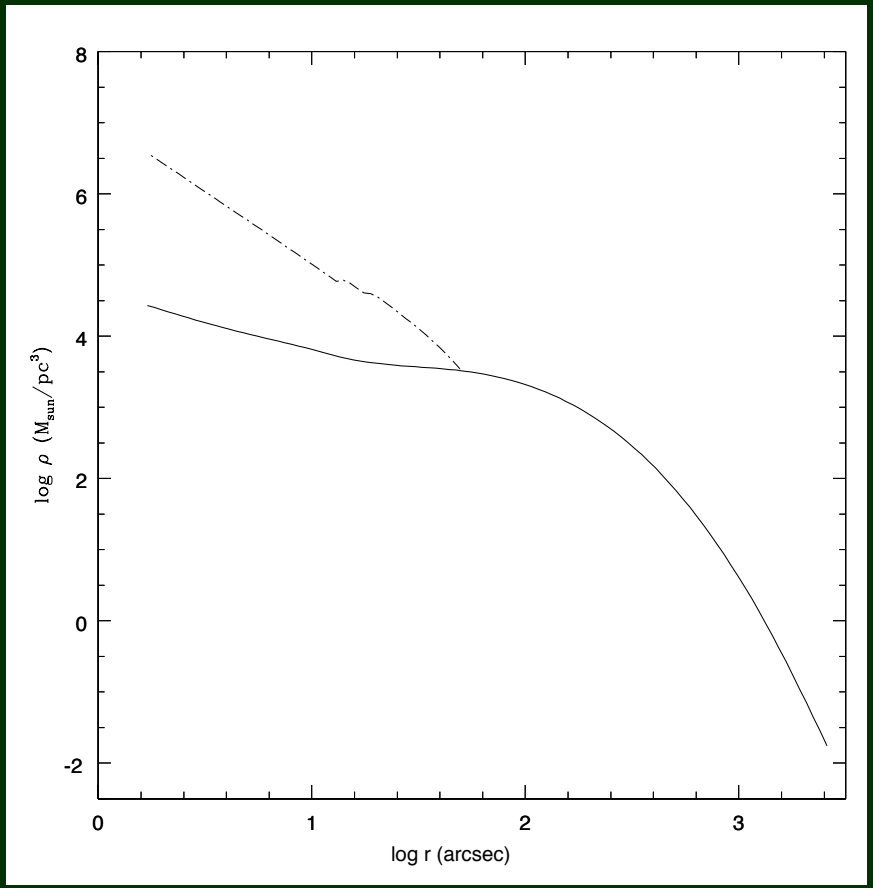


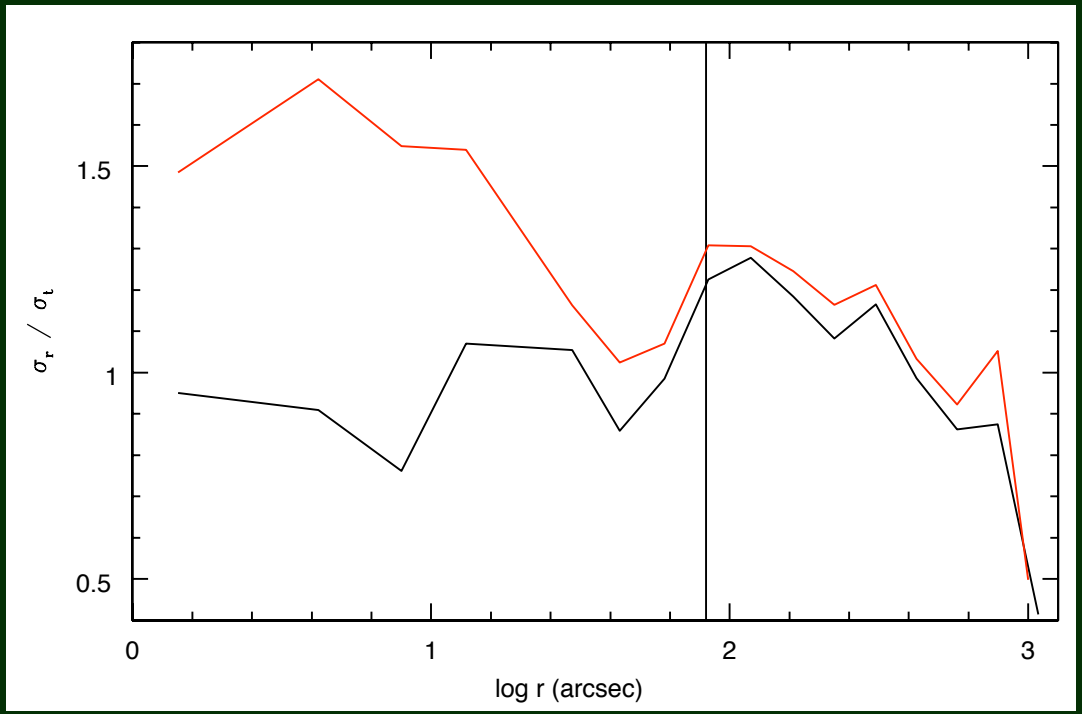
- Presents a shallow central cusp with -0.08 logarithmic slope

- Spherical models consistent with a black hole of $4 \pm 1 \times 10^4$ $M_\odot$

Noyola, Gebhardt & Bergmann., 2008

Alternatives to a BH



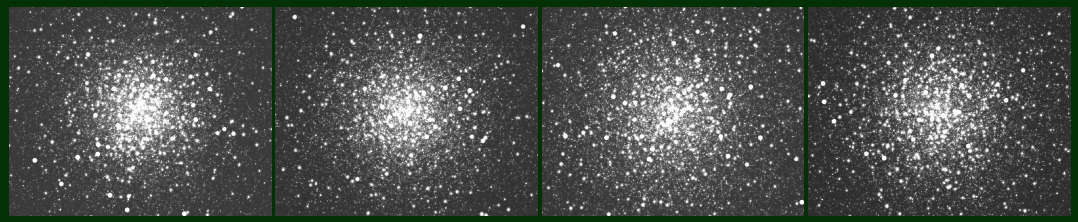


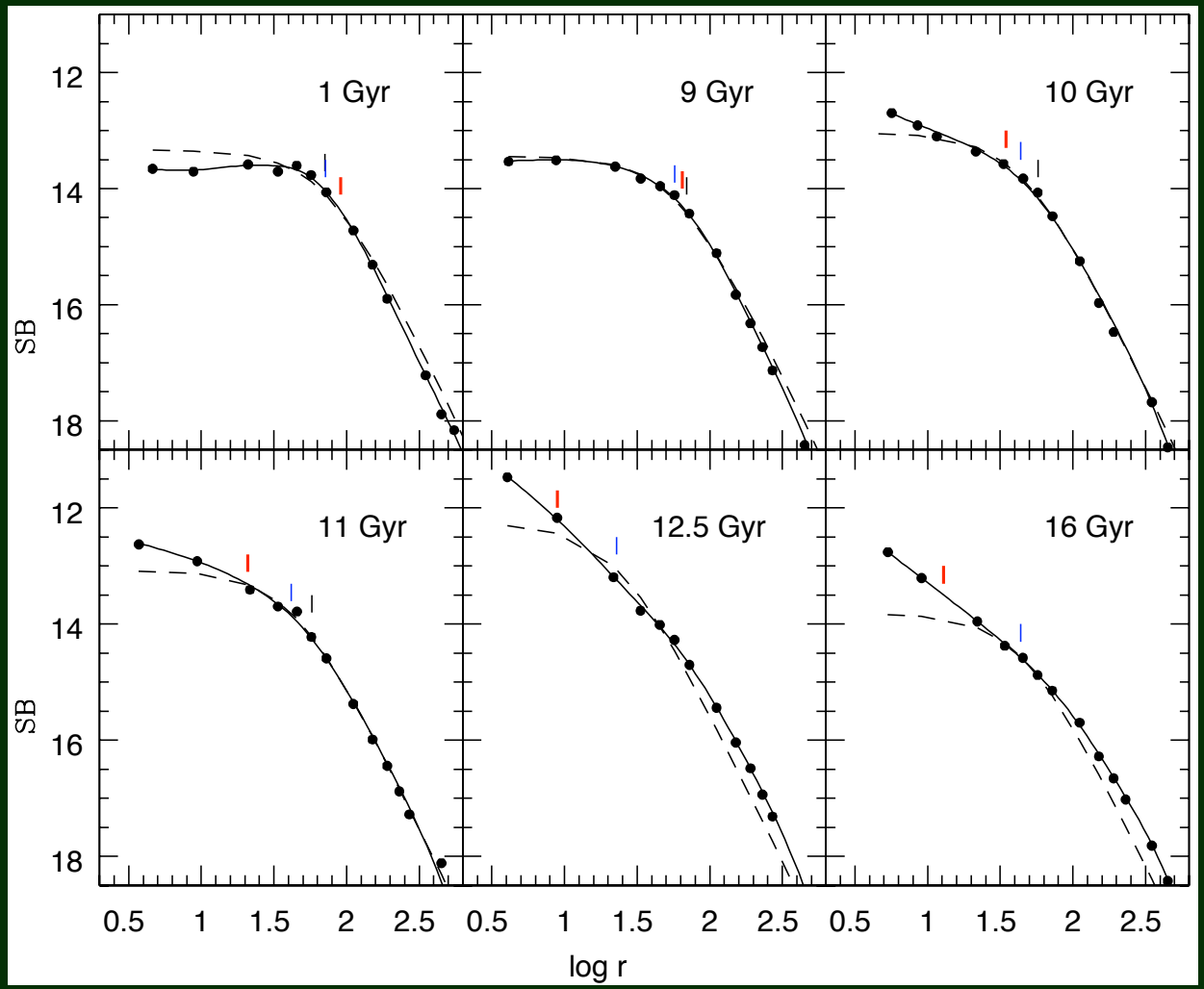
- If kinematics are due to dark remnants, then they have a very concentrated configuration, with a logarithmic slope of -2.0

- Large central radial anisotropy required to match kinematics if no central black hole is present

Both alternative models appear to be unstable in timescales shorter than the age of the cluster

Turning N-body models into realistic images

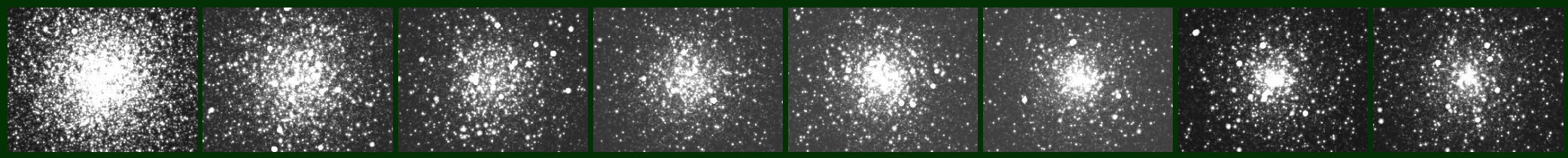




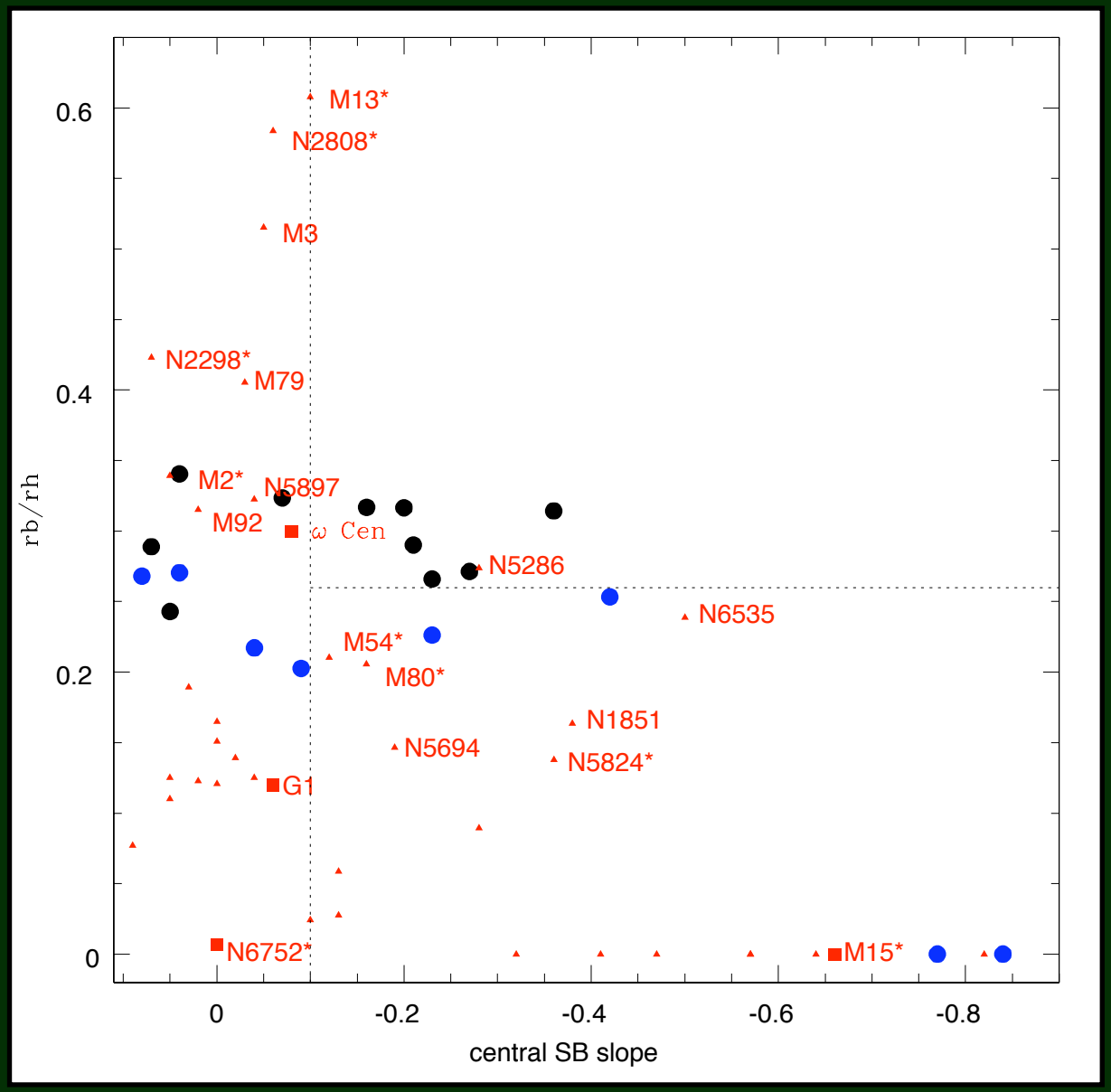
Noyola & Baumgardt, 2009, in prep

- r_c measured as FWHM of profile
- r_c measured from a single mass King model fit
- r_b measured as turnover radius

- r_c from FWHM only makes sense for flat central profiles
- r_b cannot be reliably measured for very steep central profiles



BH diagnostics



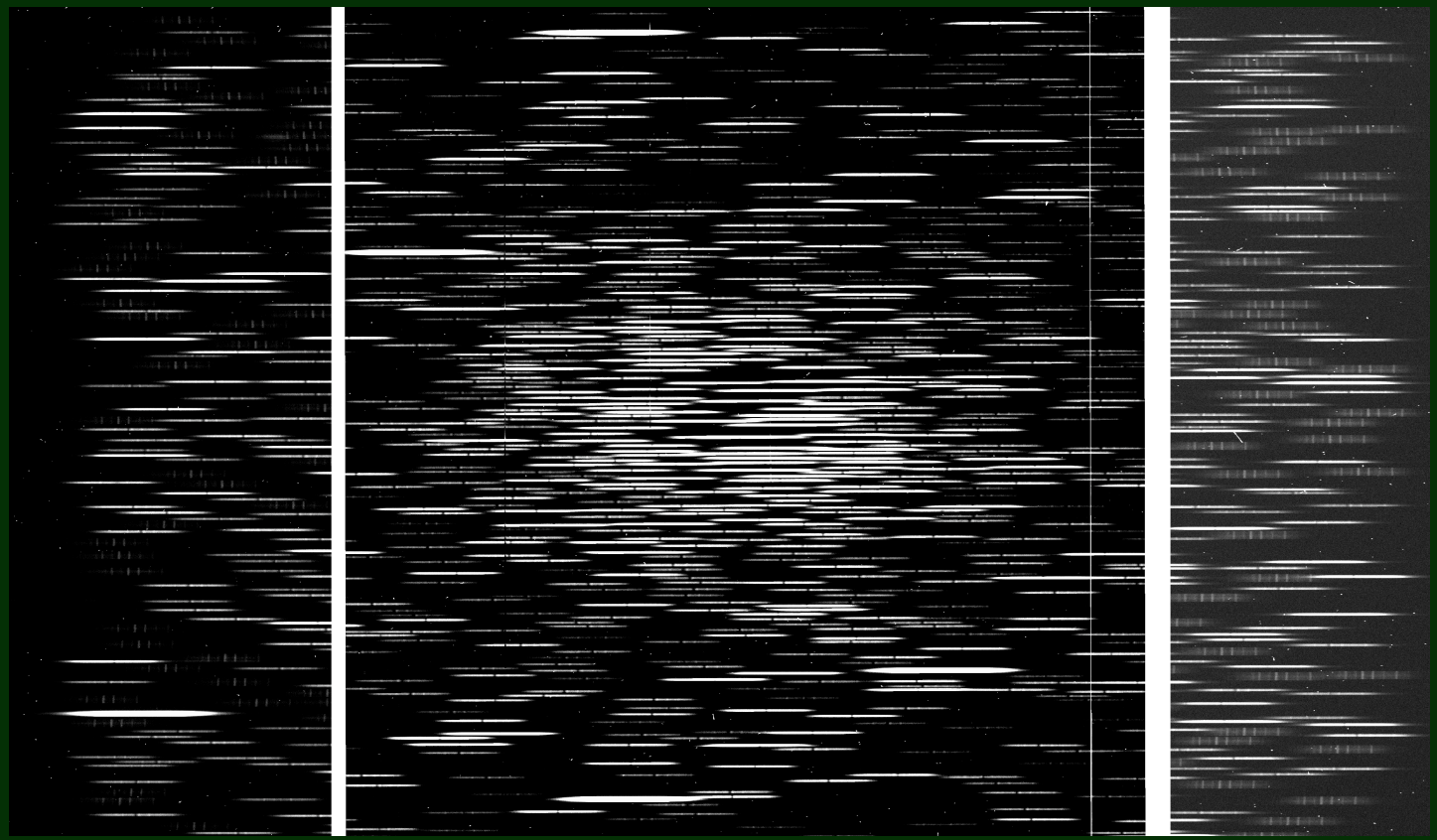
models with central BH

models without central BH

- Very concentrated clusters (such as M15) appear not to have central BHs
- Crucial to check cases with flat central slopes and large cores

GNIRS and GMOS data for M54

GMOS

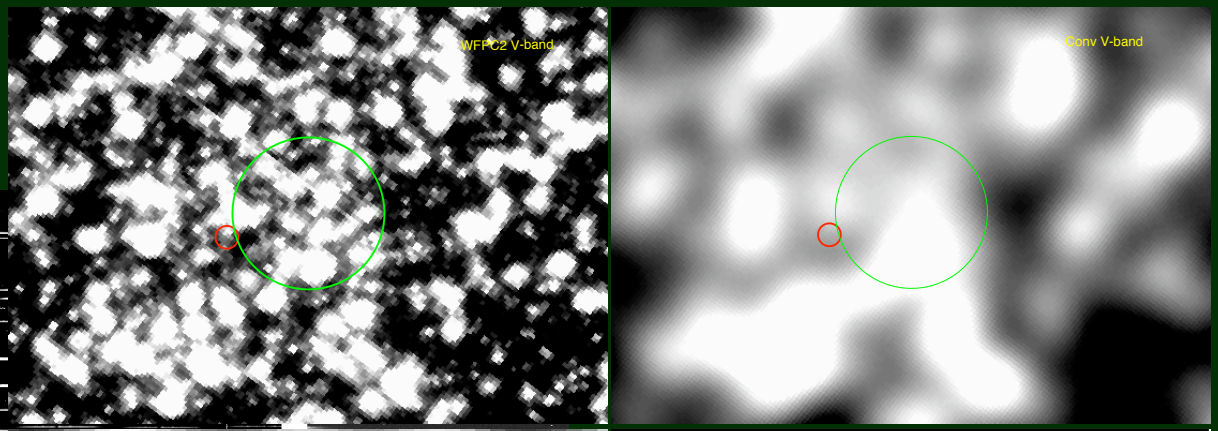


H-alpha filter; ~700 velocities

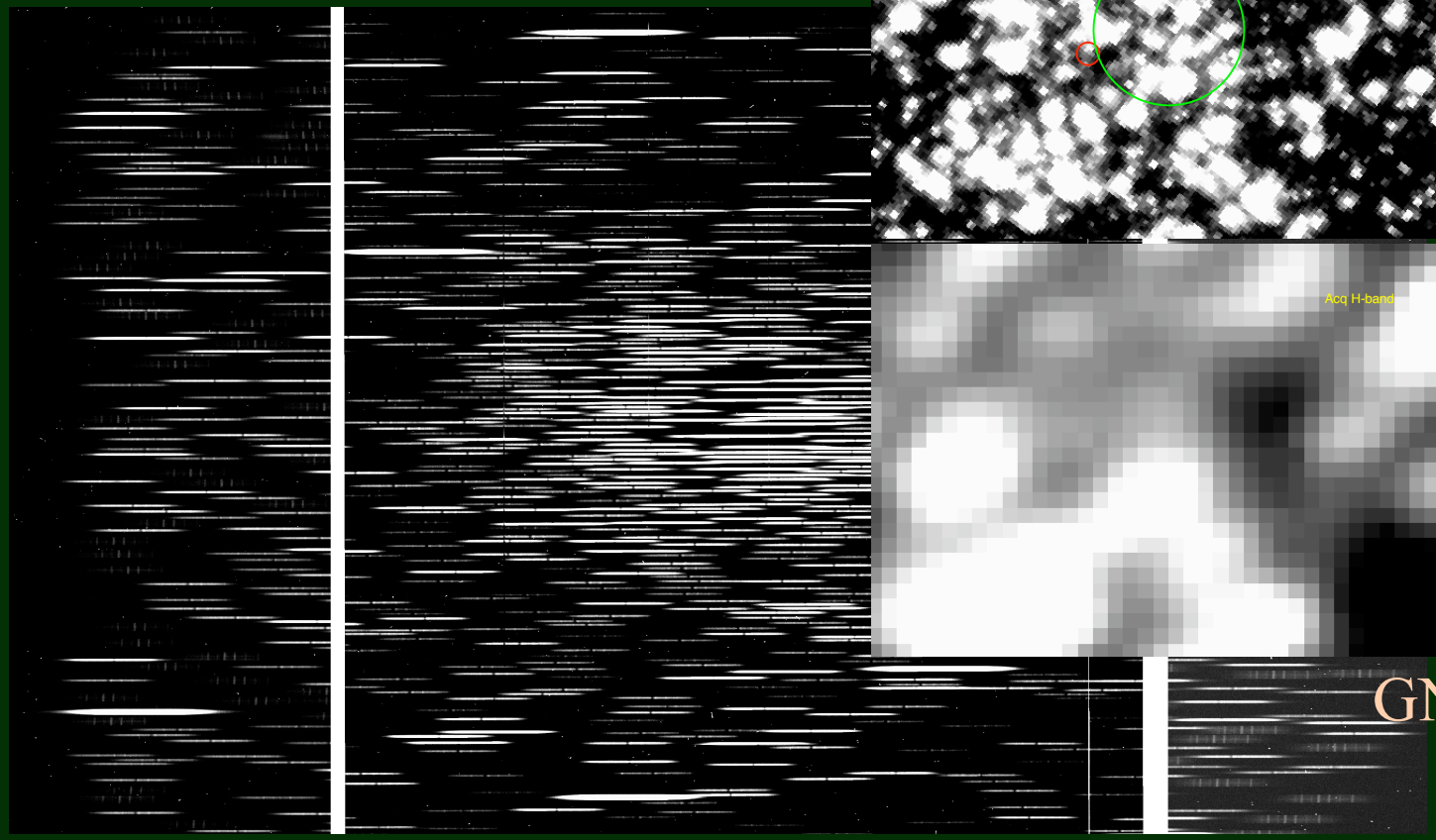
Noyola, Gebhardt & Bergmann., 2009, in prep

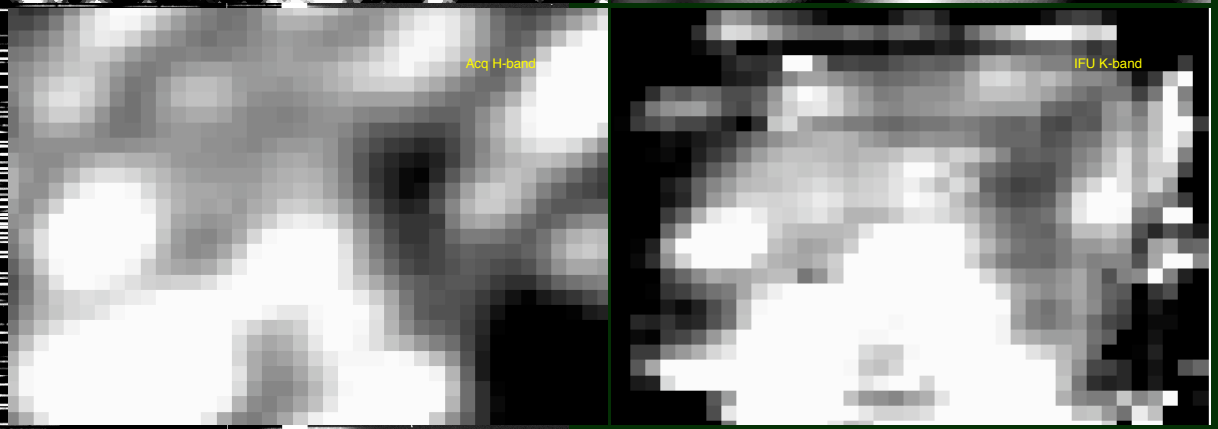
GNIRS and GMOS data for M54

WFPC2 V-band



GMOS



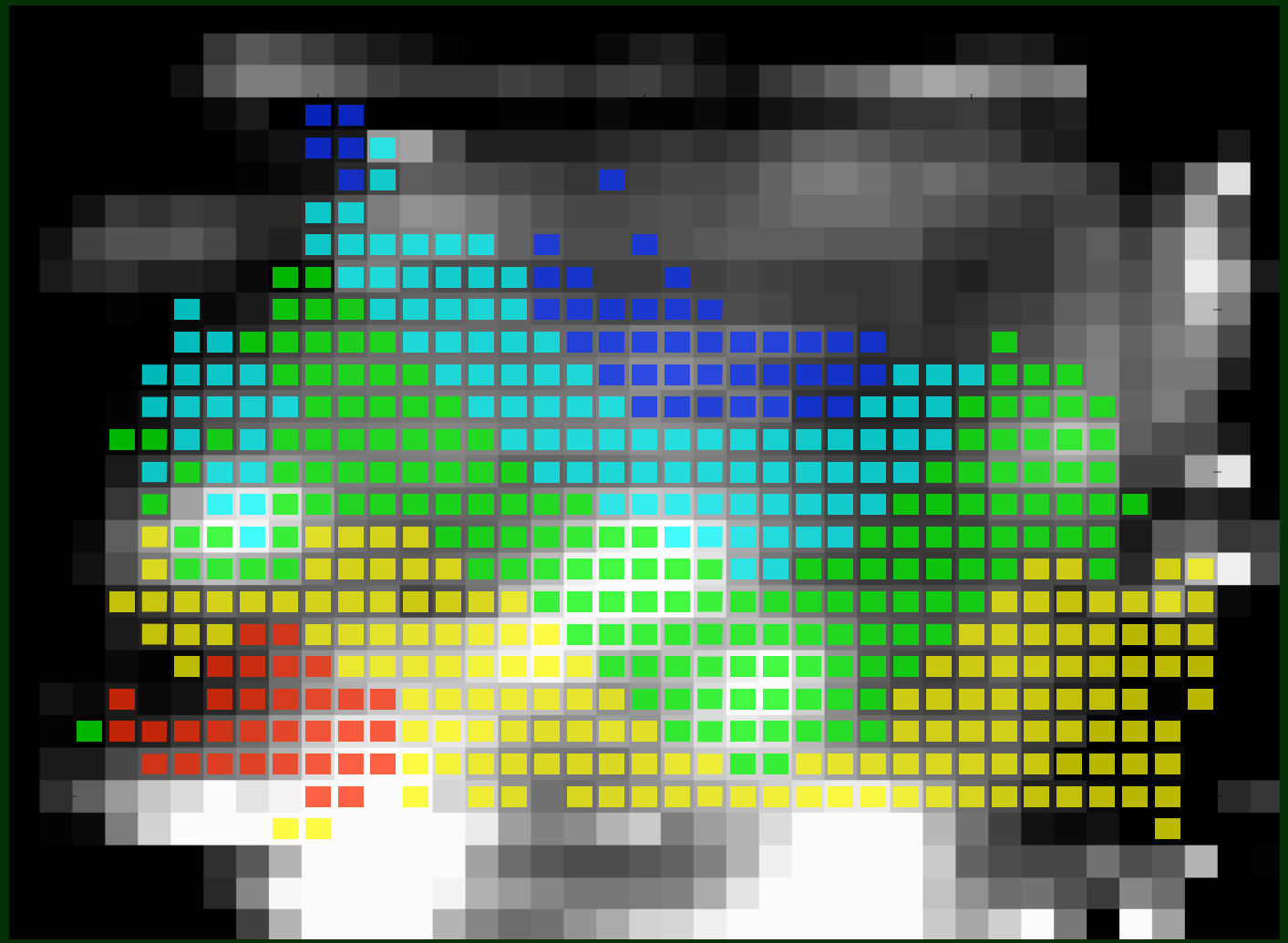


GNIRS

H-alpha filter; ~700 velocities

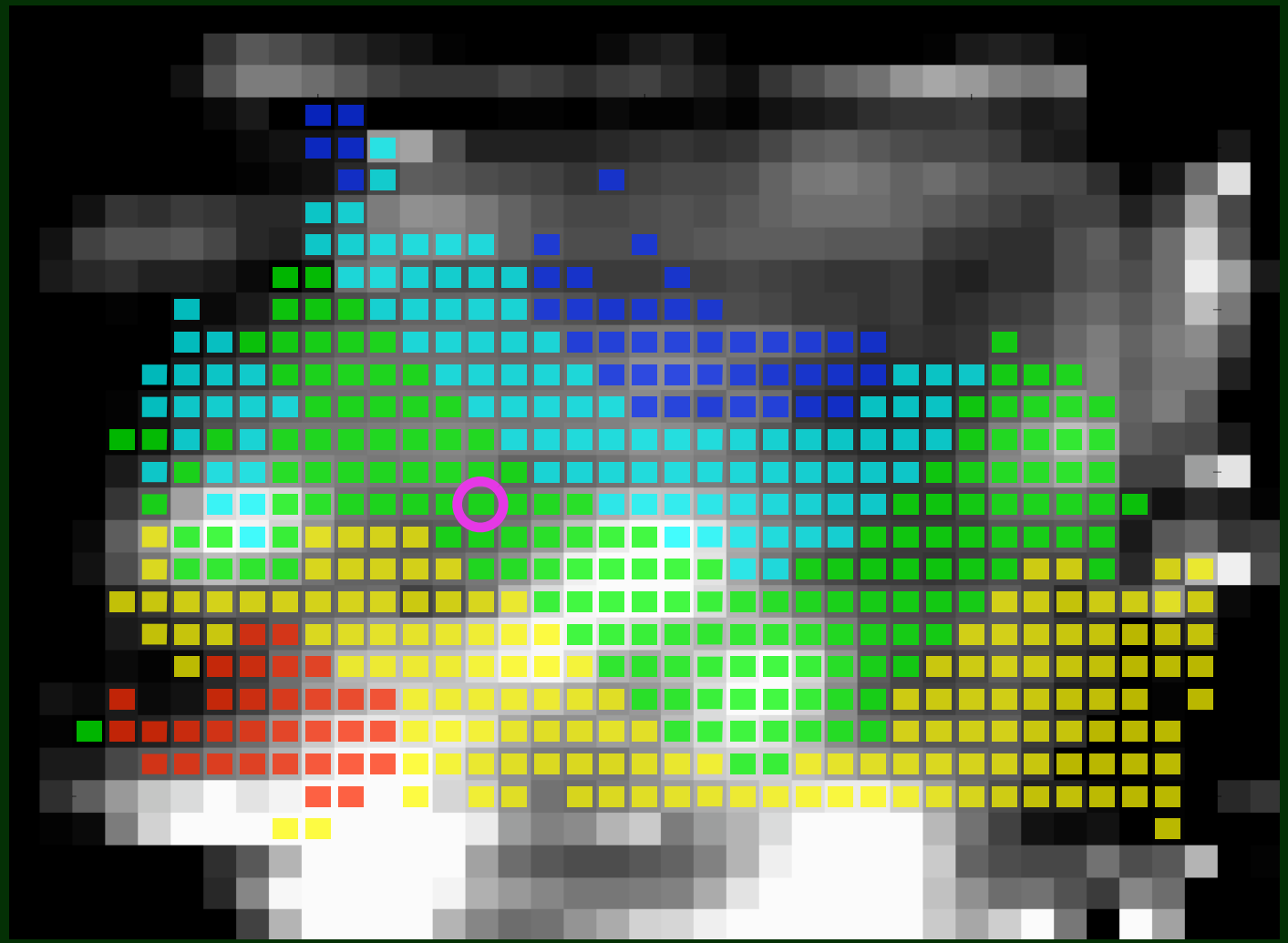
Noyola, Gebhardt & Bergmann., 2009, in prep

Velocity map



- Use CO bandhead to measure kinematics
- Detect rotation pattern with 13 km/s amplitude, σ = 15 km/s

Velocity map



- Use CO bandhead to measure kinematics
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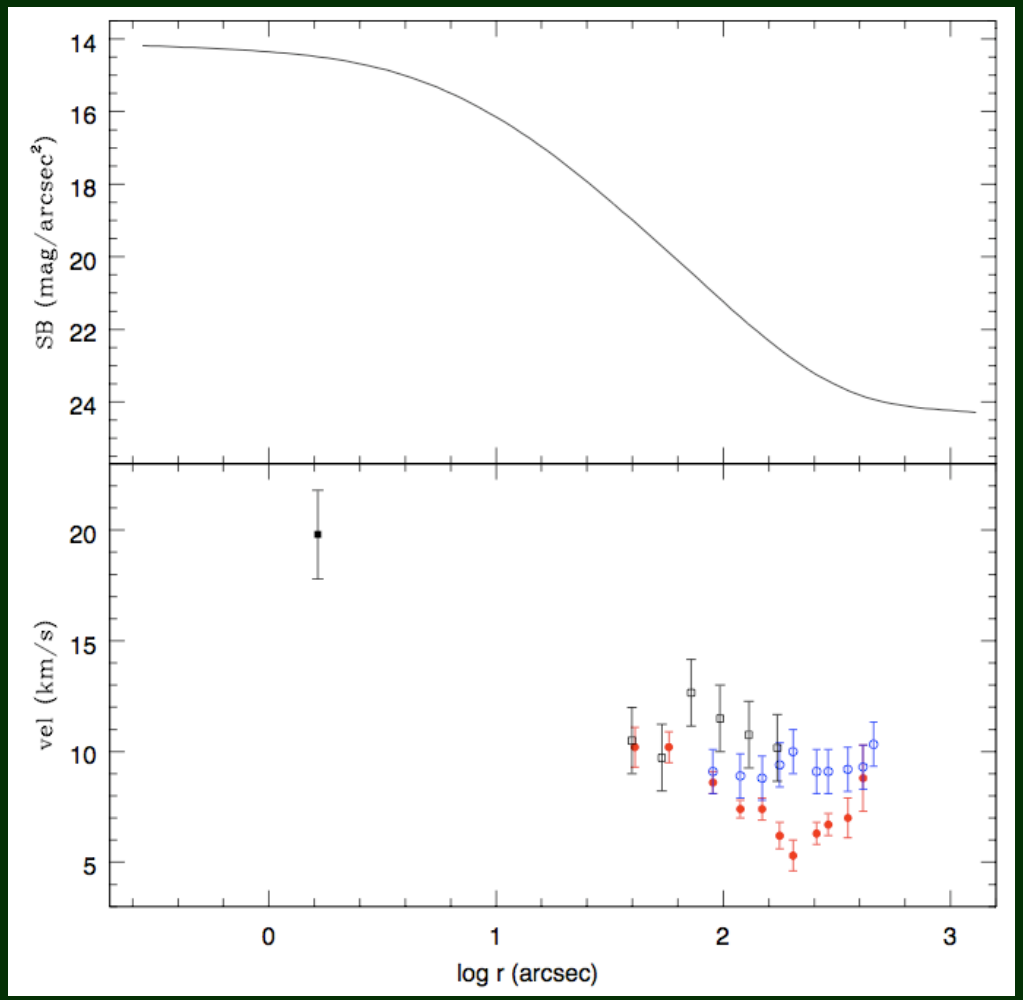
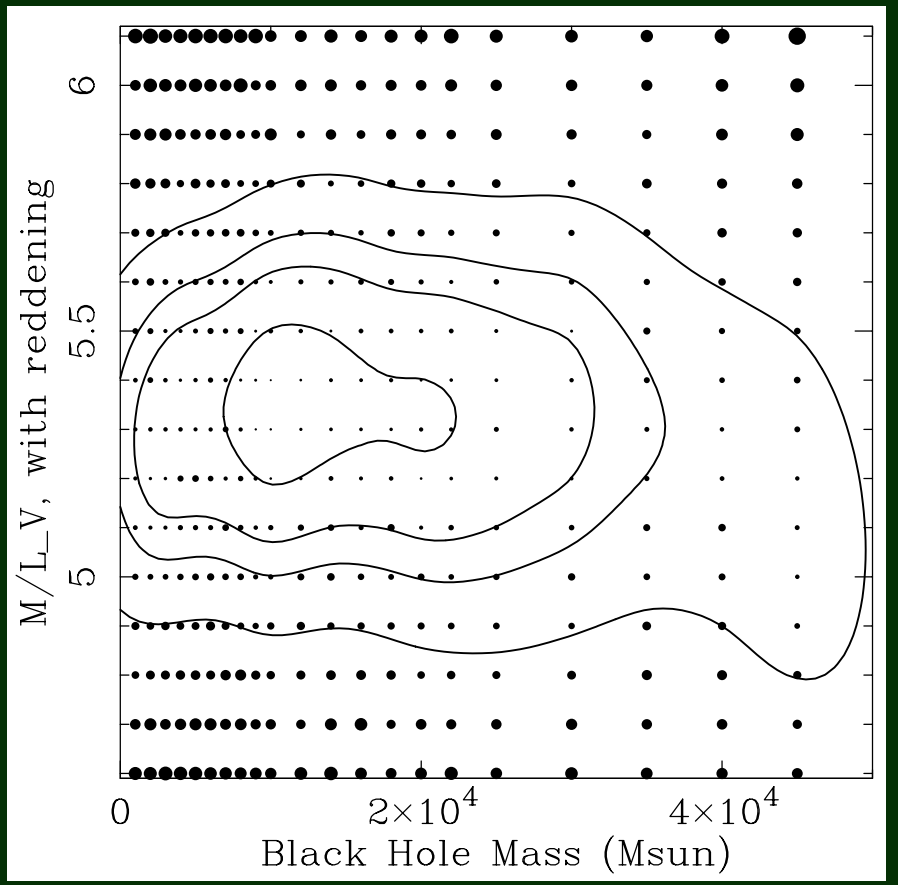
Models





- Density and velocity inputs completed with other data

Bellazzini et al., 2008; Monaco et al., 2005

- Best fit model has BH mass of 10^4 $M_\odot$
- No BH model requires some radial anisotropy

Conclusions

- G1 and omega Cen have good indications of hosting central black holes of ~ 10^4 $M_\odot$
- M15 and other very concentrated clusters are not good candidates for hosting IMBHs
- Best fit model for M54 requires a 10^4 $M_\odot$ central BH
- Stability tests are crucial to evaluate alternative scenarios