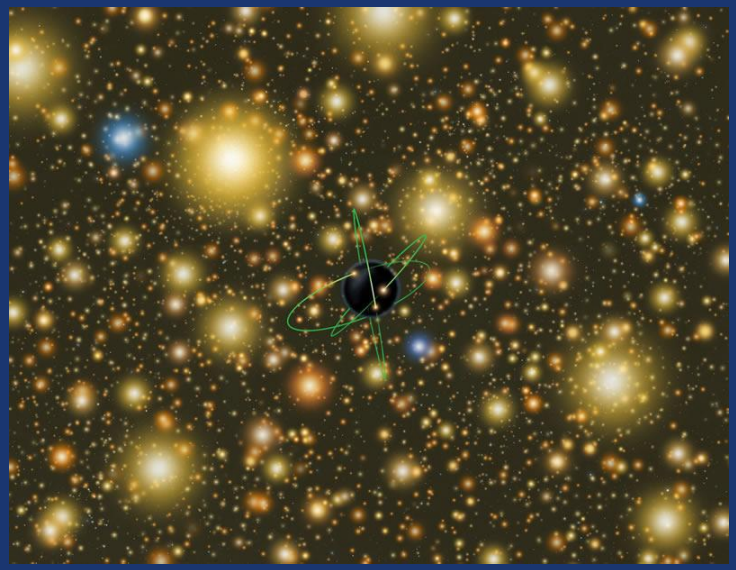
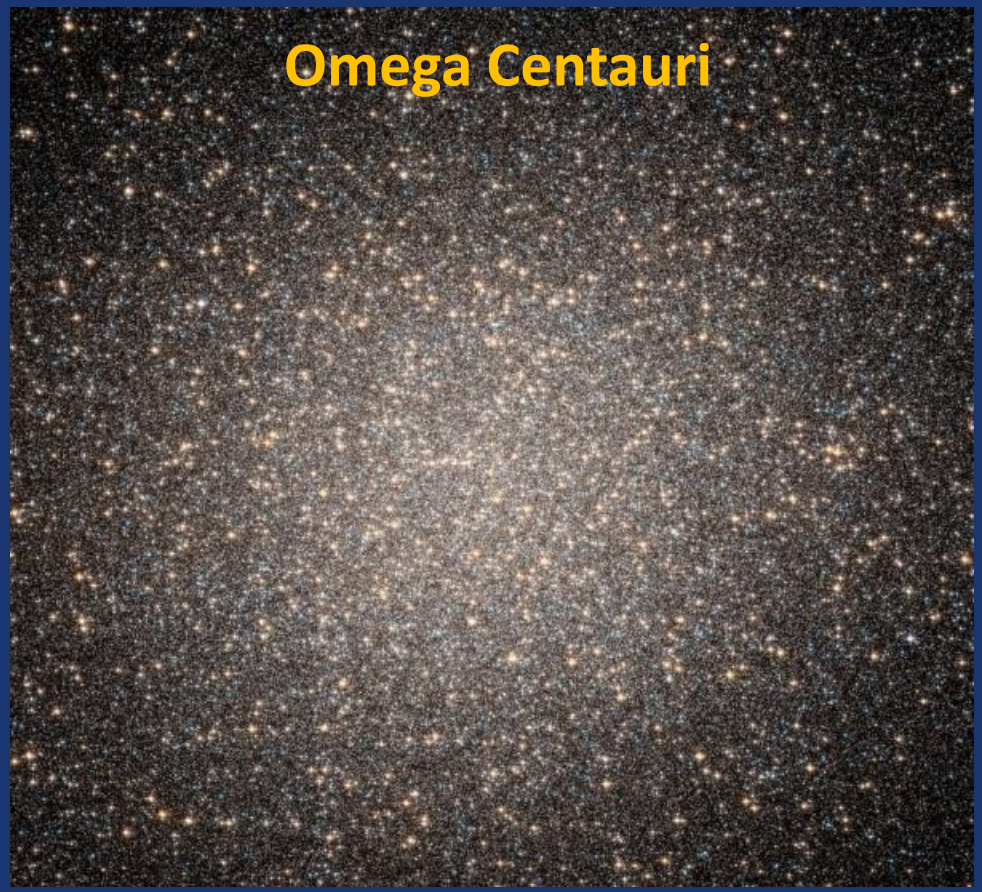
Evidences for an IMBH in Omega Centauri

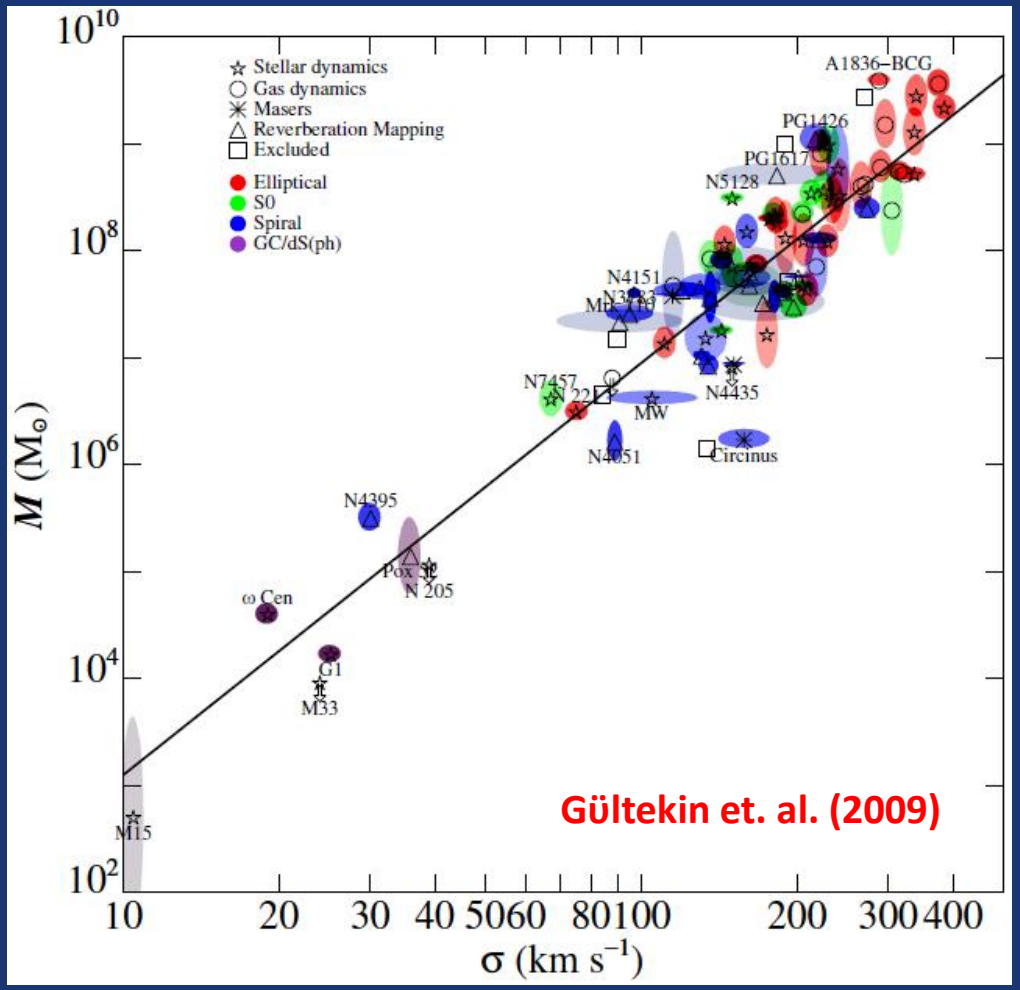


Behrang Jalali (ESO)
Eva Noyola
Karl Gebhardt
Holger Baumgardt
Markus Kissler-Patig
Nora Lützgendorf
Tim de Zeeuw



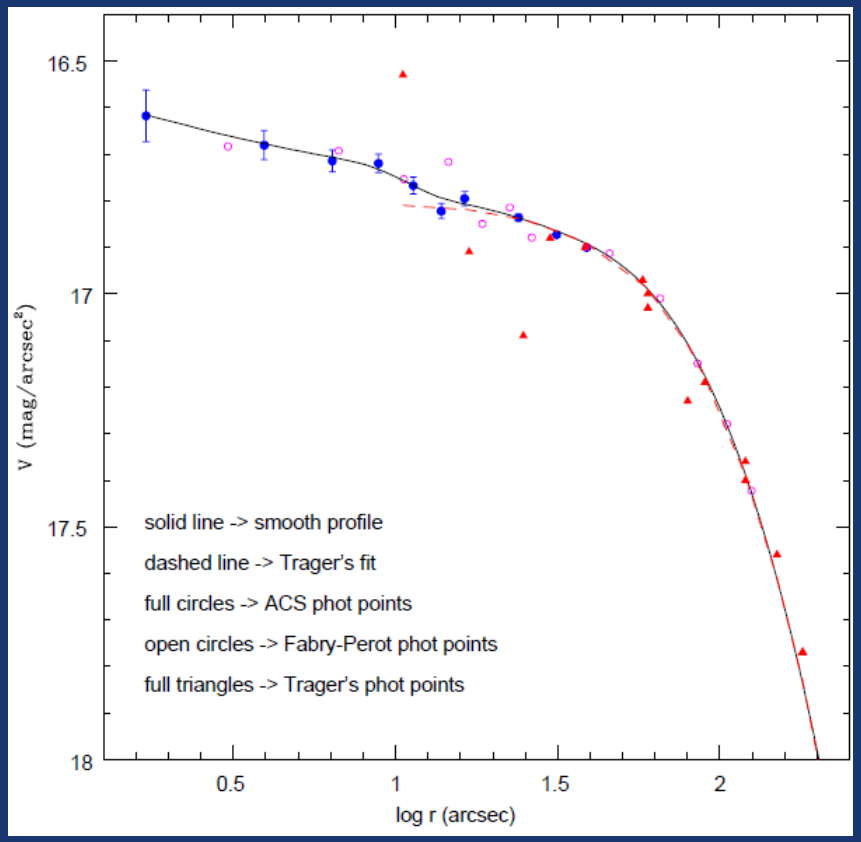
- ✓ Among most massive Galactic GCs ~ 2.5 x 10^6 $M_\odot$
- ✓ Highest central velocity dispersion ~ 22 Km/s
- ✓ Shallow cusp in surface brightness
- ✓ Multiple stellar populations
- ✓ The stripped core of an accreted dwarf galaxy?

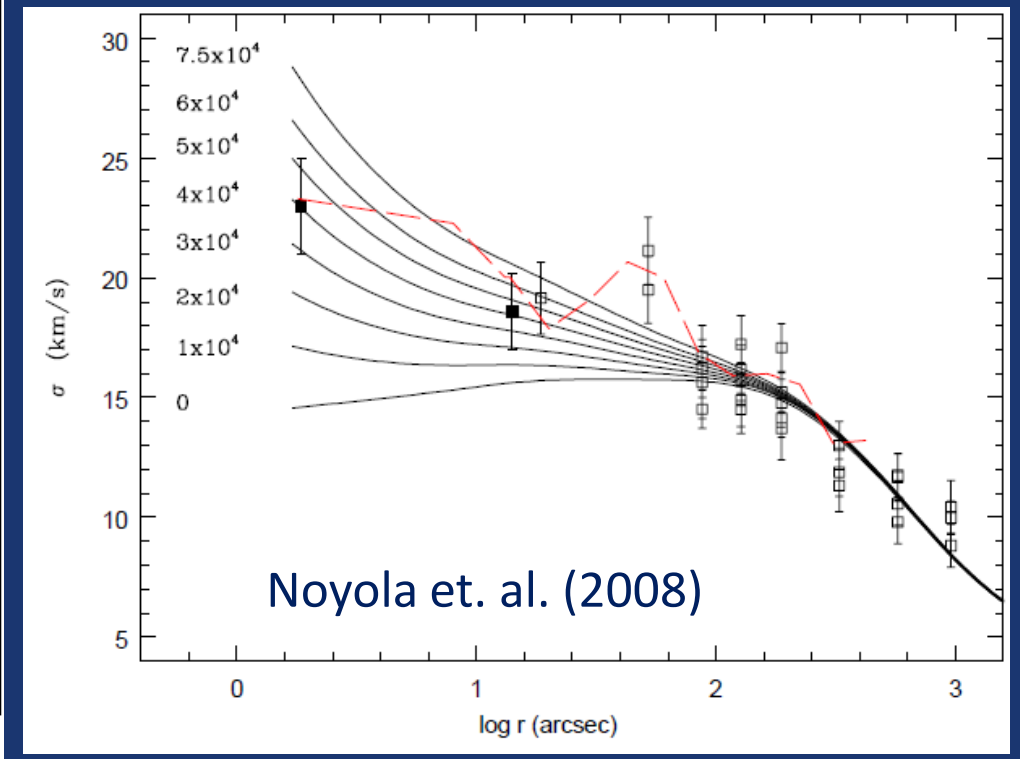
Motivation for IMBHs



- ✓ Important to understand SMBHs growth (seed BHs)
- ✓ Could have very important consequences for GCs evolution
- ✓ Interesting gravitational waves sources

Previous Works

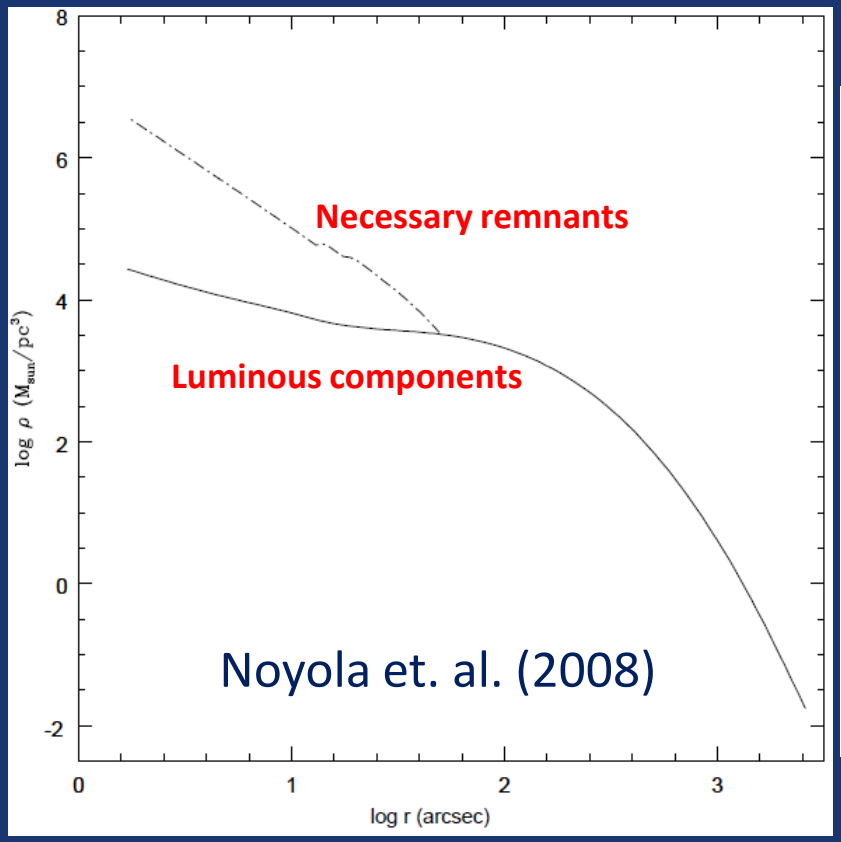


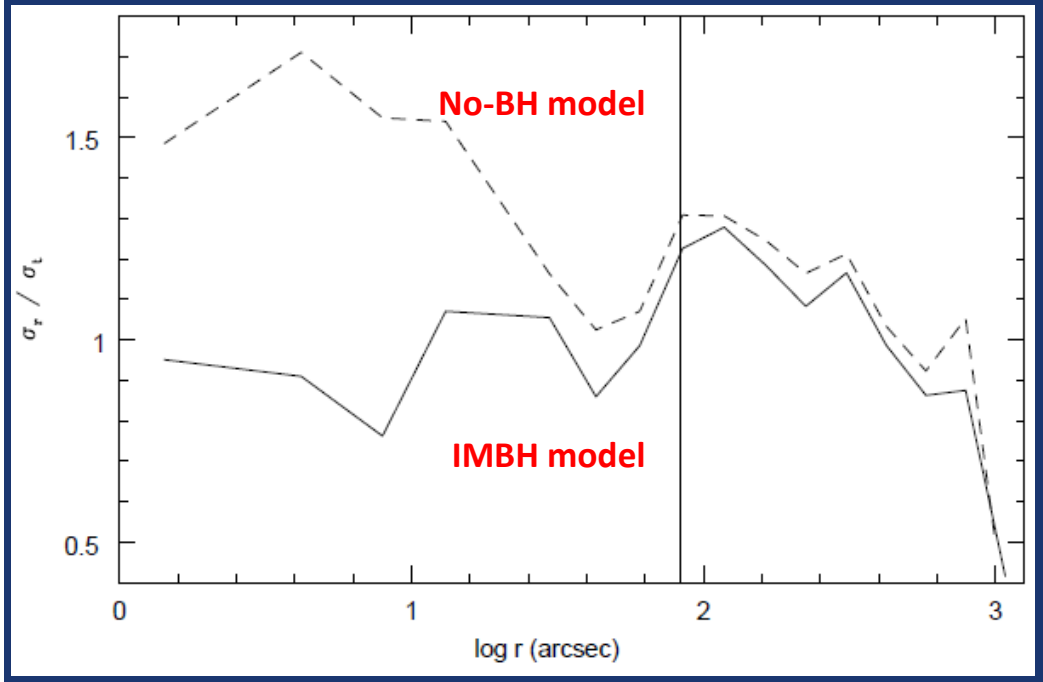


- ✓ Central shallow cusp in SB
- ✓ Spherical Jeans models infer 4 (±1) x 10^4 $M_\odot$ with constant M/L

  (detailed dynamical models at large radii, van de Ven et. al. 2006)

Main alternatives are ruled out



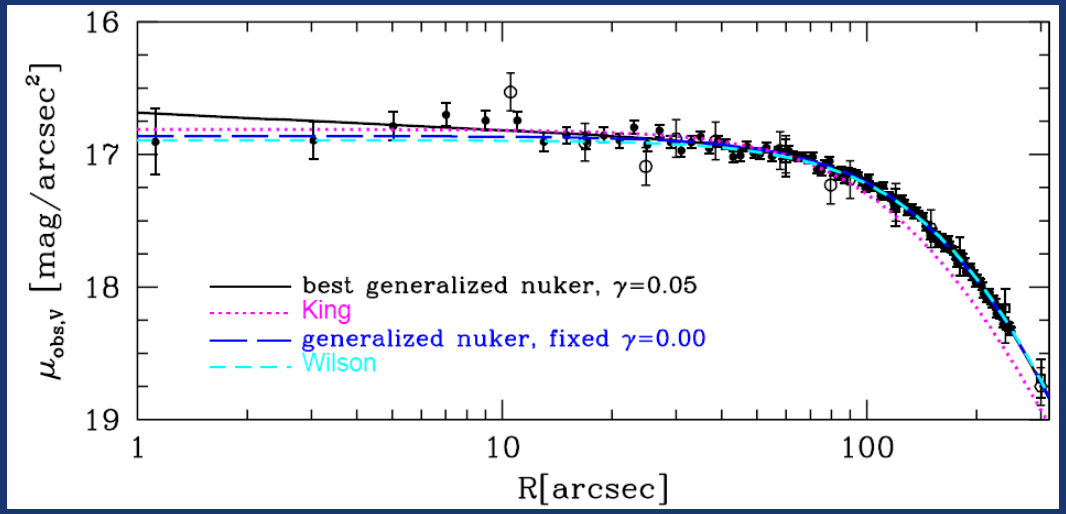


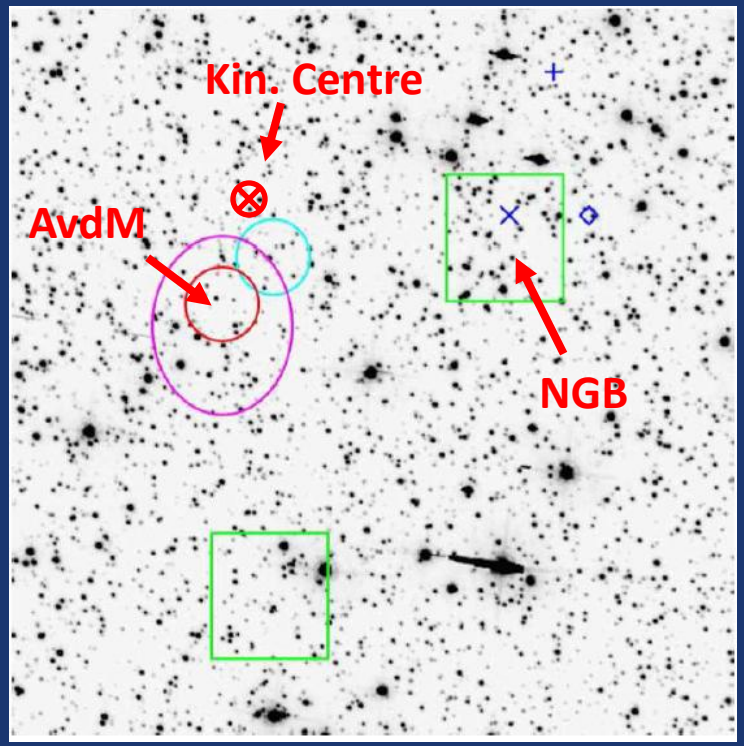
- ✓ Such a concentrated cluster of NS & WD would evaporate on a short timescale
- ✓ Unstable in short timescale
- ✓ van de Ven (2006) inferred isotropy at large radii

Multi-epoch HST data

- Large PM data set (about 50,000 stars)
- Centre 12” away from Noyola centre
- SB profile has only, at most, a weak cusp
- No central rise in velocity dispersion
- Rotation is removed due to the local PM measurement
- With a 3-sigma upper limit of 1.8 x 10^4 M⊙

Jay Anderson & Roeland van der Marel (2010)

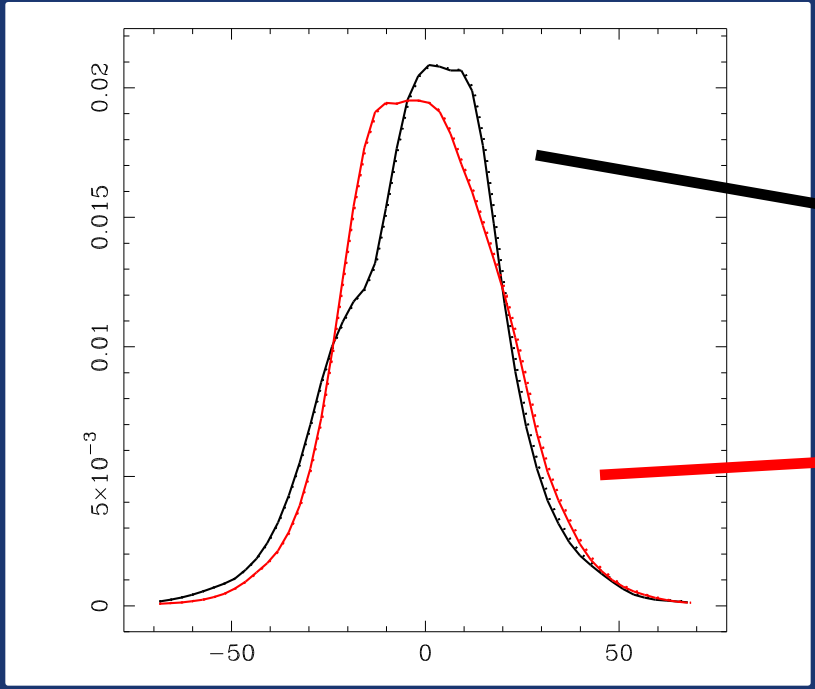




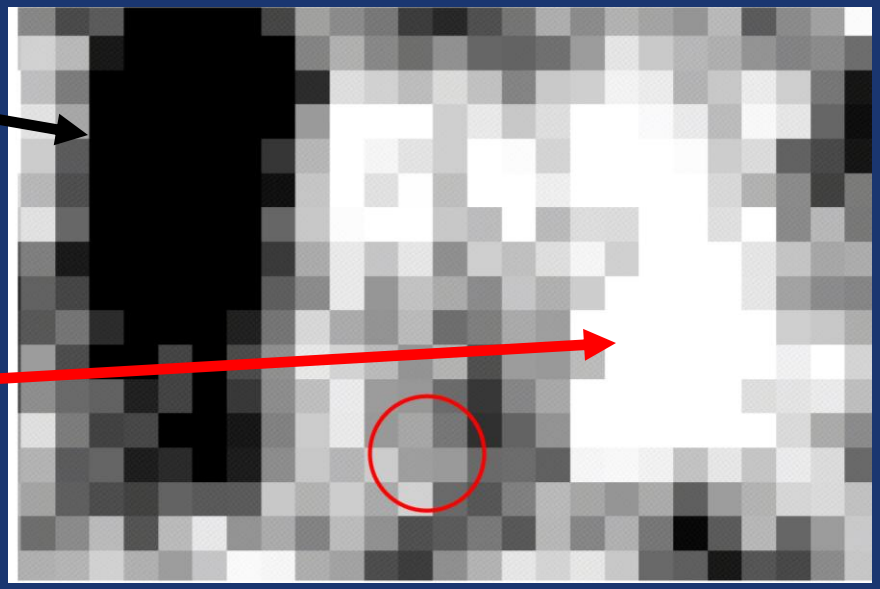
Kinematics with VLT-FLAMES

Kinematic Centre and Rotation

- ✓ Peak of proper motion dispersion in minor axis
- ✓ Symmetry point of h3 map in proper motion major axis
- ✓ Radial velocity rotation about this centre
- ✓ Radial velocity dispersion peak



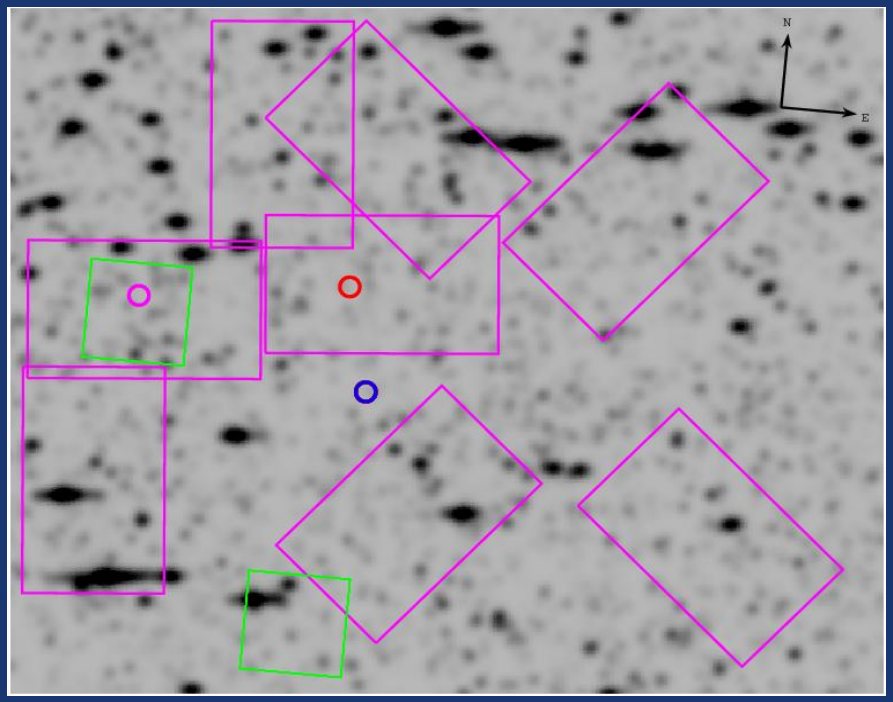
Major axis pm h3 map

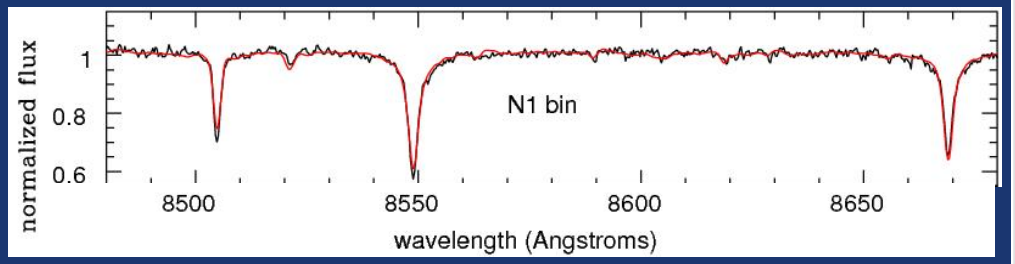


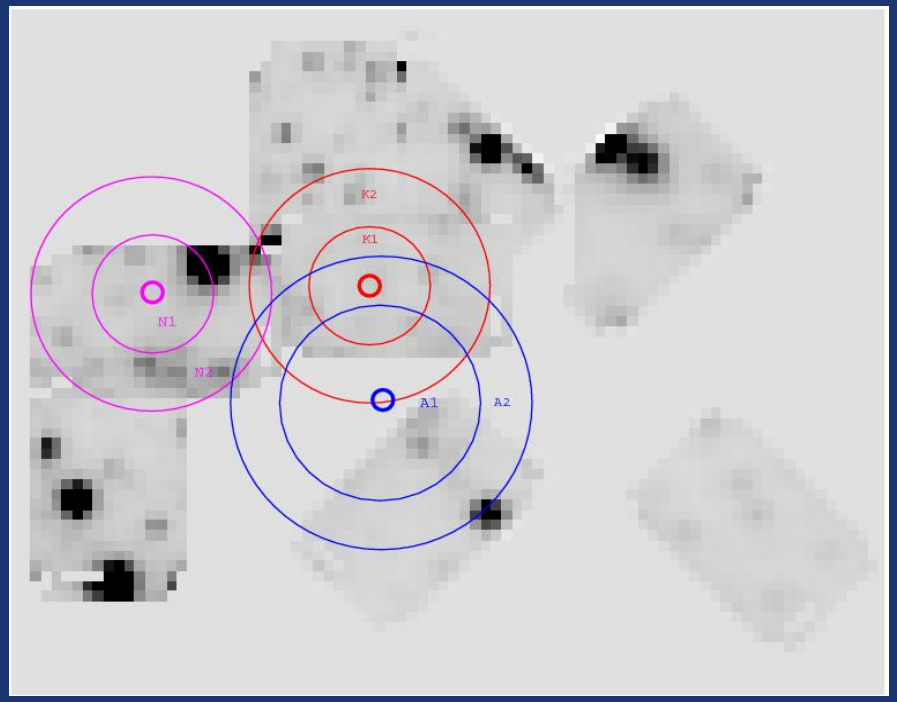
VLT-FLAMES data

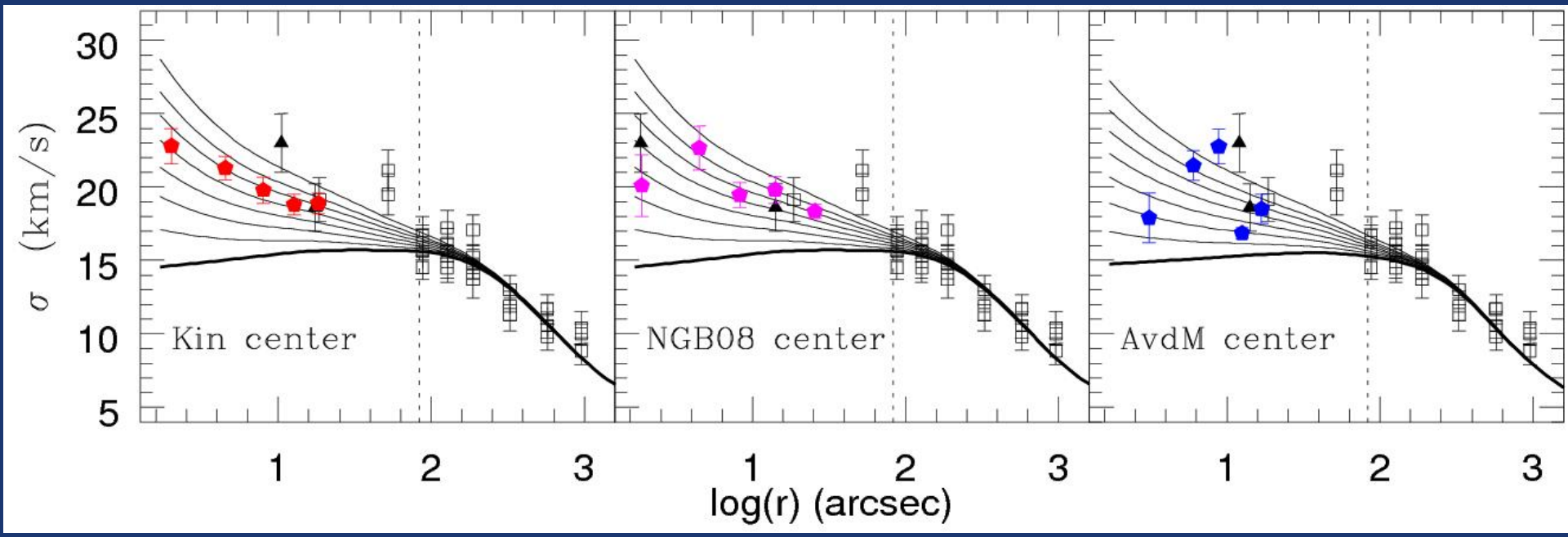
Noyola et. al. 2010 ApJL accepted

- ✓ Ca-triplet , R=10400, FoV 11.5” x 7.3“
- ✓ IFU radial velocity of about 5000 spectra
- ✓ Local estimates suffer from large shot noise (individual bright stars)
- ✓ Bin radially to overcome shot noise (Kin. Centre neighborhood is clean)
- ✓ Extract velocity profile from combined spectrum





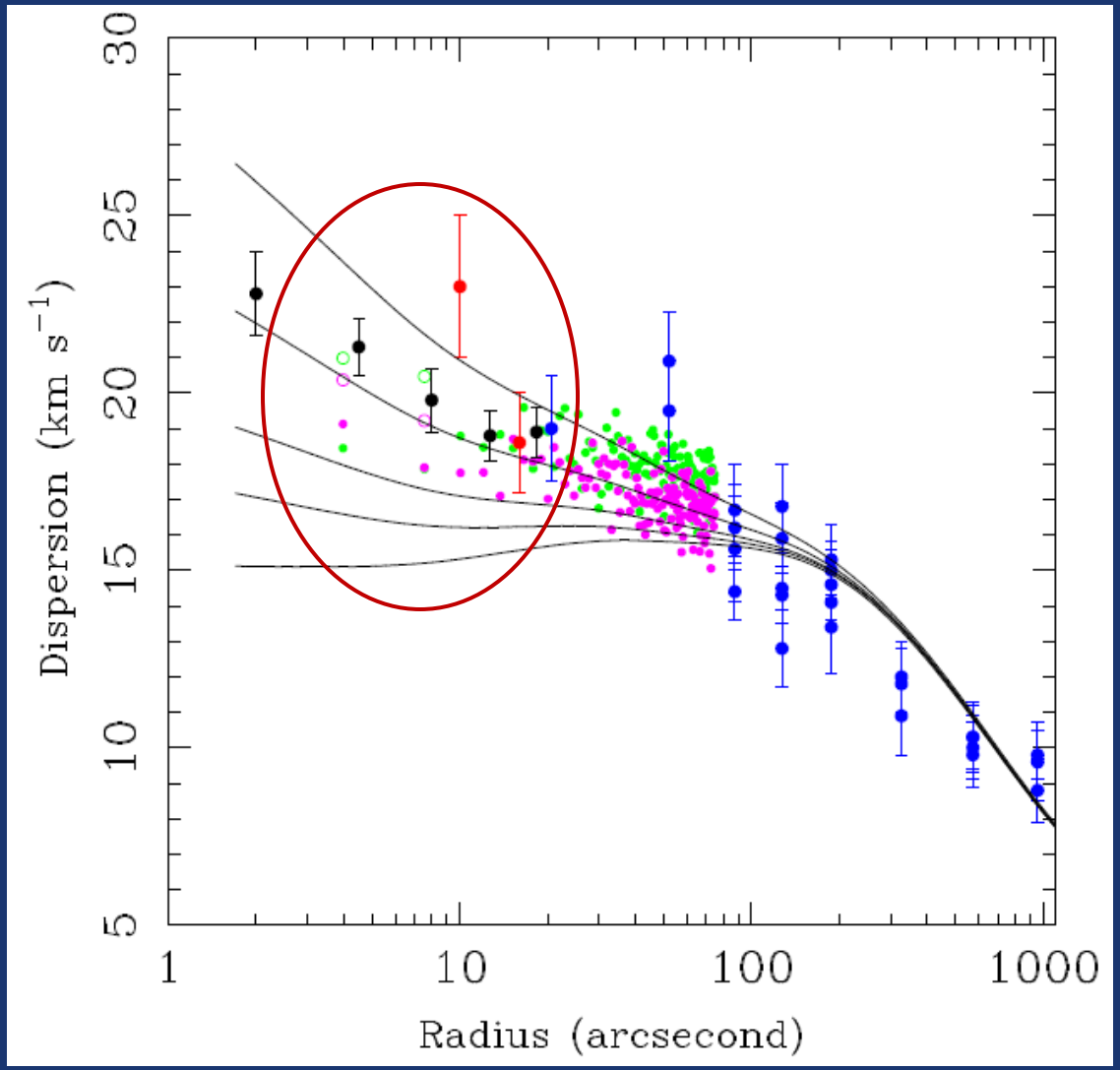




Noyola et. al. (2010)

- ✓ Central kinematic rise is confirmed ~ 22Km/s
- ✓ Jeans isotropic models consistent with 5×10^4 $M_\odot$ IMBH
- ✓ Orbit-based models with both PM & RV is being analyzed

(Jalali, Gebhardt, Kissler-Patig et. al. 2010 in preparation)



- ✓ If there is a rotation, then PM dispersion is actually compatible with RV

NBODY simulations

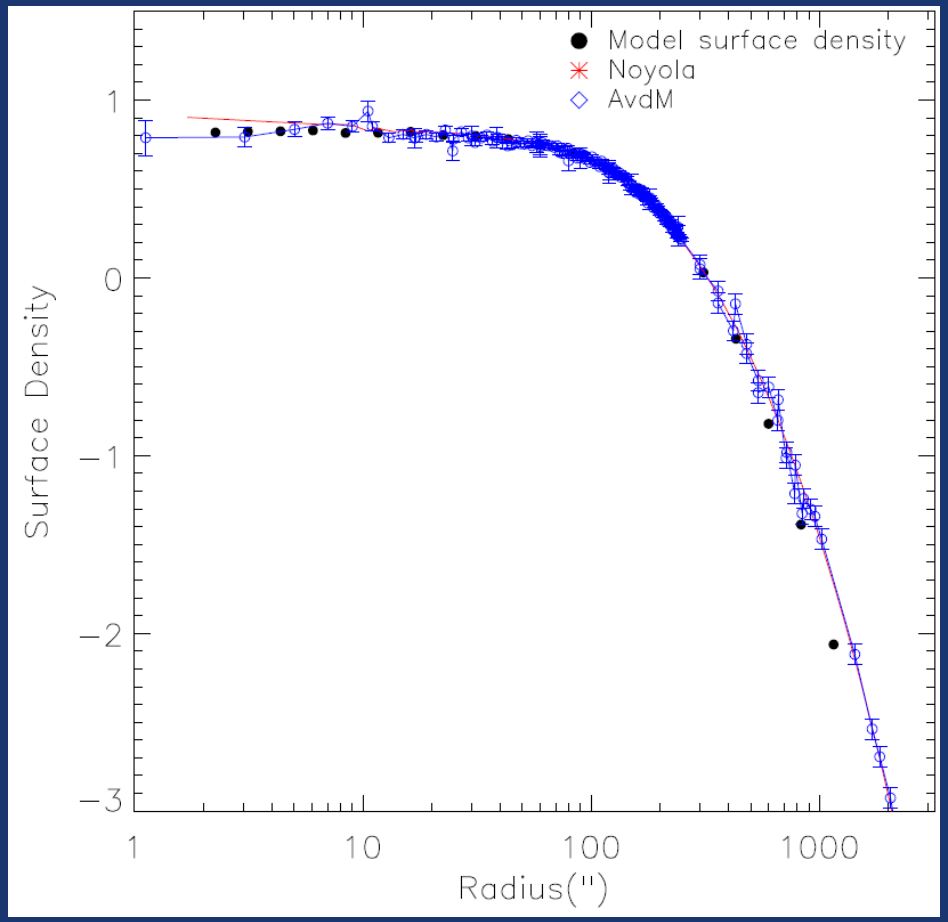
NBODY simulations

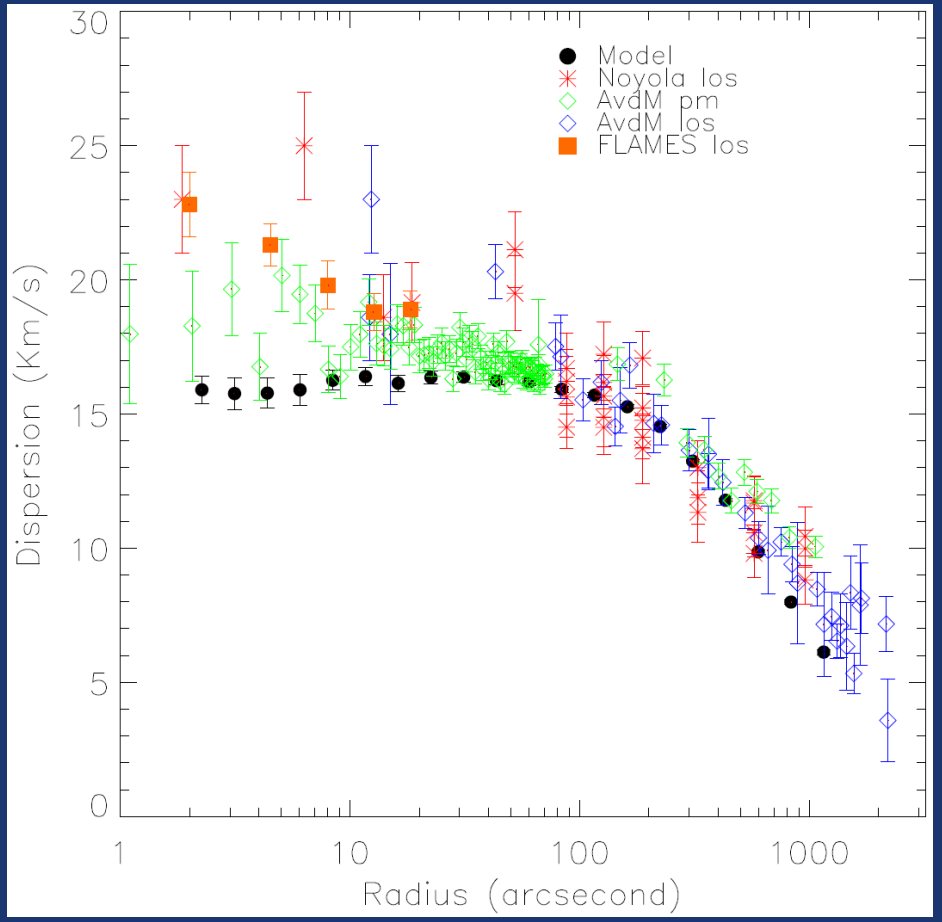
- ✓ Need to see if we have a better fit to observations with IMBH-models
- ✓ Need to test the stability of alternatives

- Direct NBODY simulations with “NBODY4” on GRAPEs at ESO
- 50,000 stars for 12 Gyr evolution, King model, Kroupa IMF
- 10% NS retention, No tidal field

(Jalali, Baumgardt, Kissler-Patig et. al. 2010 in preparation)

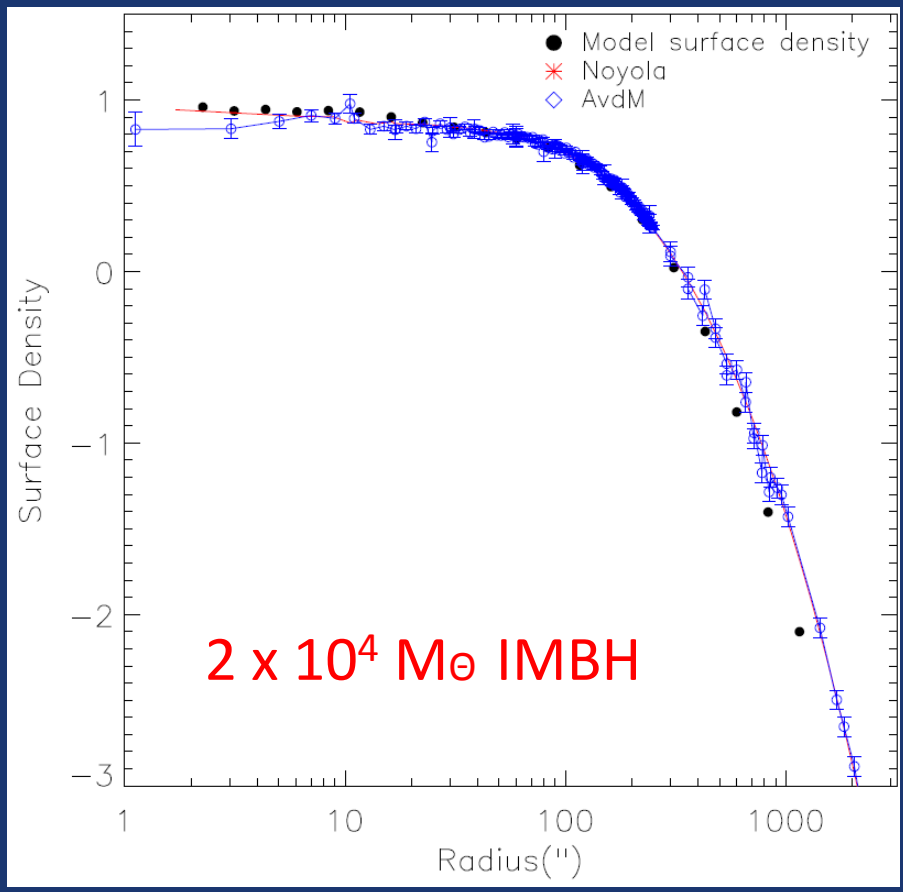
Models without IMBH

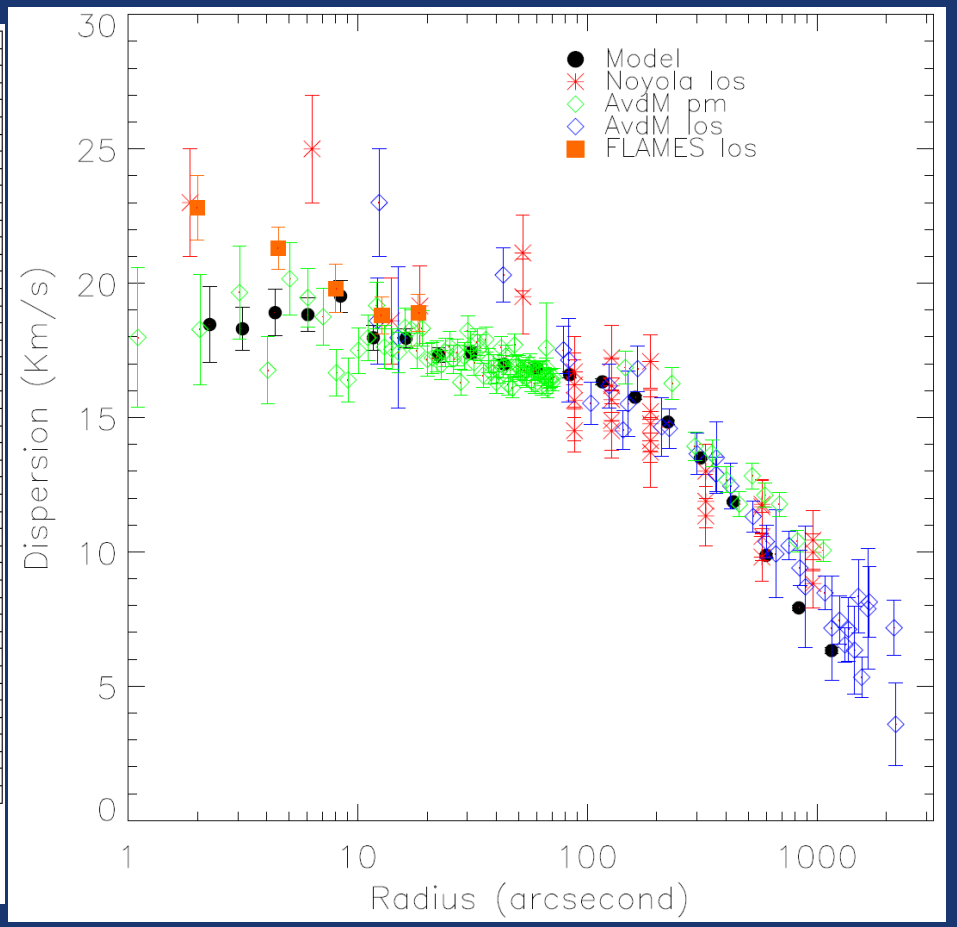




- does NOT match the observed central 10” kinematics

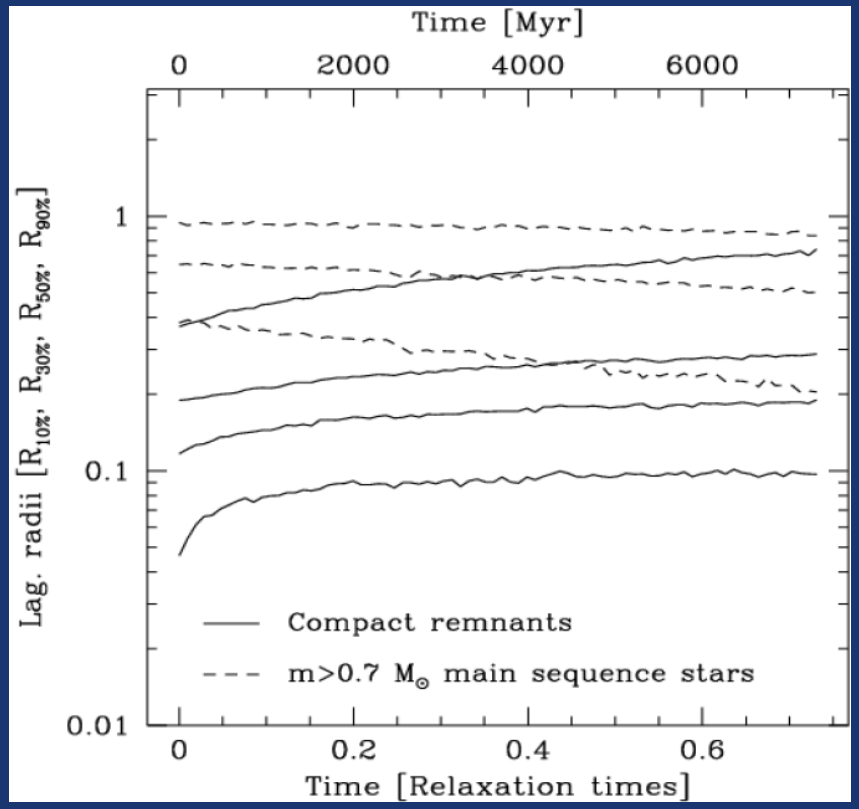
Models with IMBH

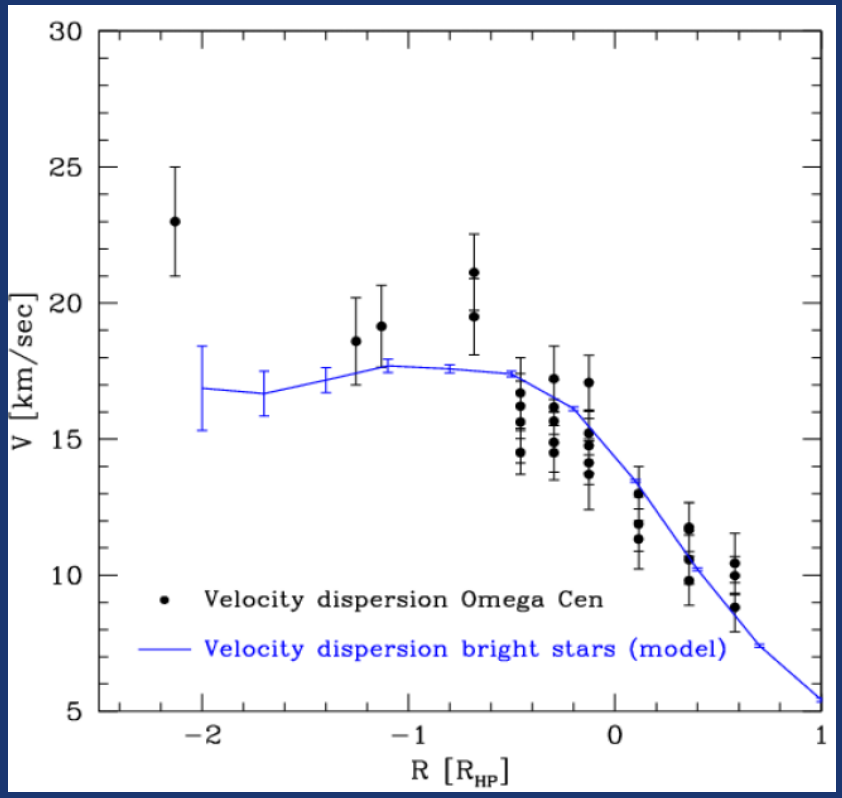




- We are currently analyzing different IMBH masses
- DOES match with Noyola SB shallow cusp & also has better central match with observed kinematics

Alternative: Mass segregation





- ✓ Compact remnants are put on orbits with the lowest energies (method of Baumgardt 2008)
- ✓ The observational data can't be matched after a few Gyr

Conclusions

- ✓ *We use new "kinematic" centre*
- ✓ *We confirmed central velocity rise ~ 22 Km/s*
- ✓ *Without an IMBH one can NOT explain the central kinematics; consistent w/ $5x10^4$ $M_\odot$ IMBH*
- ✓ *Orbit-based models using proper motion & radial velocity are in preparation …*

(Jalali, Gebhardt, Kissler-Patig et. al. 2010 in prep.)

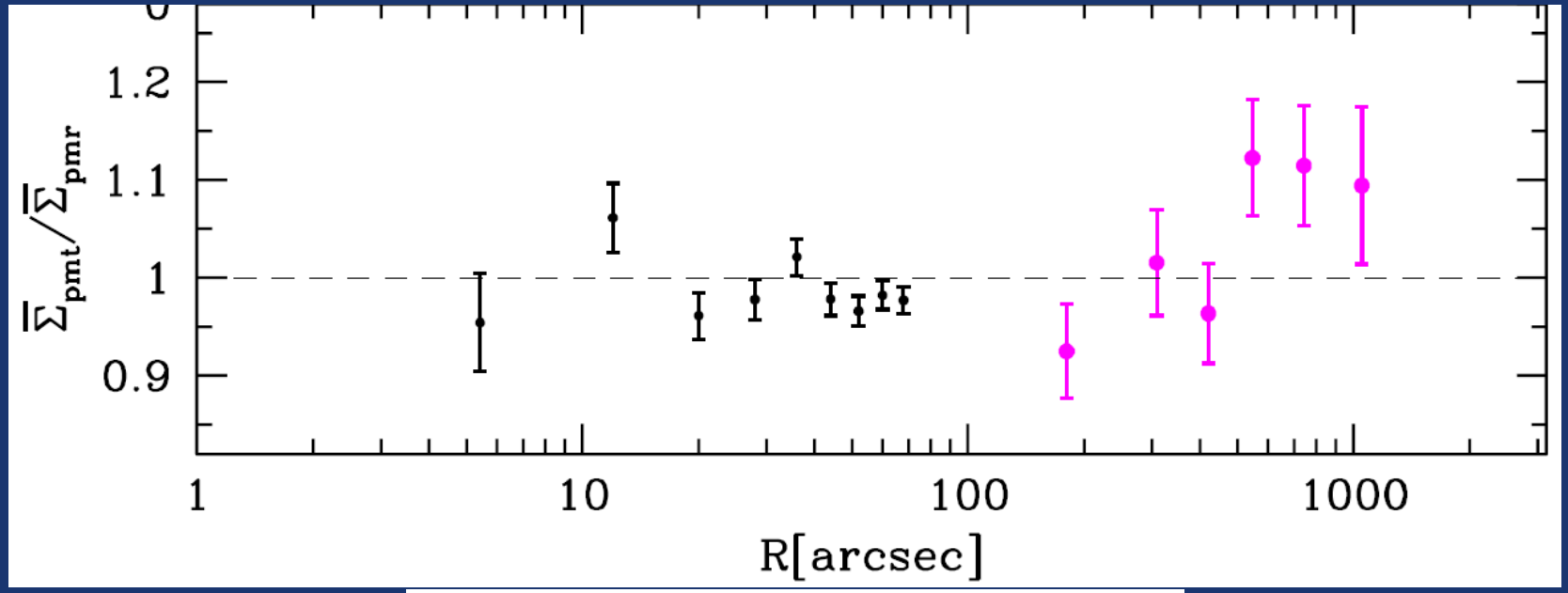
(Jalali, Baumgardt, Kissler-Patig et.al. 2010 in prep.)

Extra Slides

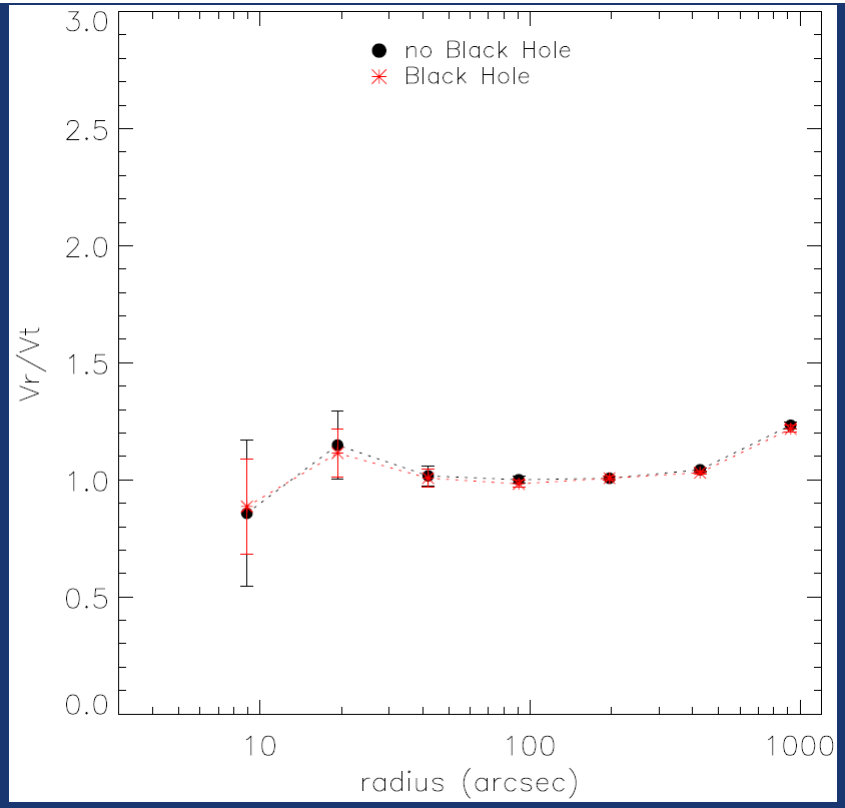
- ✓ Using AvdM color-magnitude diagram
- ✓ Shot noise is about 1% in the 4 outer radial bins, for velocity dispersion is corresponding to 0.2 Km/s (> 500 stars contributing for 50% of light)
- ✓ Shot noise in the central bin: (~ 200 stars contributing for 50% of light)

	Shot Noise	Velocity Dispersion
Kin. Centre	2.7%	0.5 Km/s
Noyola Centre	9%	1.8 Km/s
AvdM centre	7%	1.4 Km/s

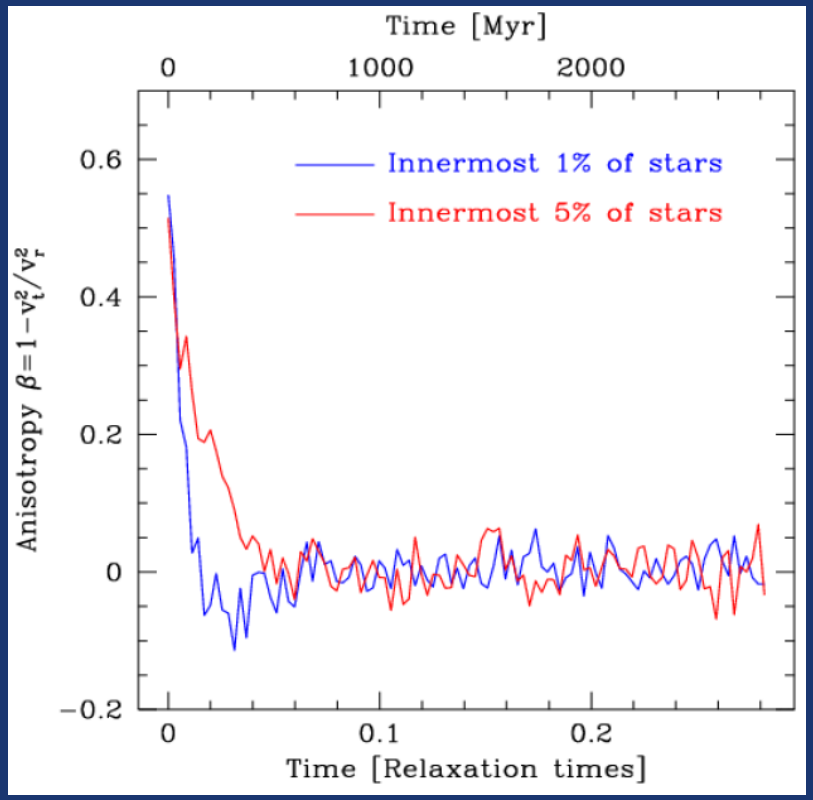
✓ **Shot noise does NOT have a strong effect and is under control**

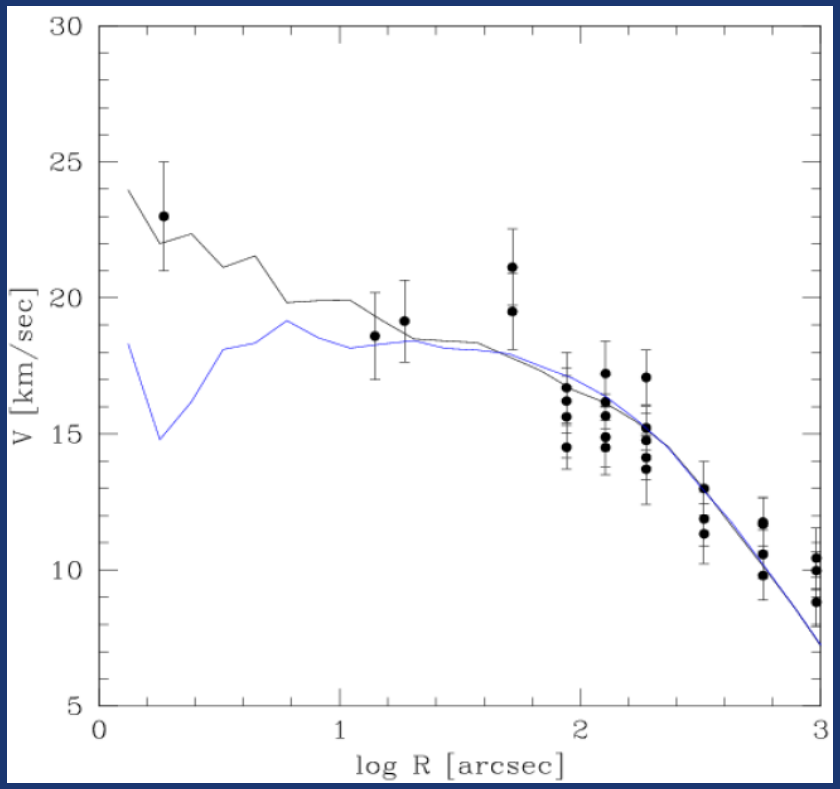


isotropic profile



Alternative (2): Anisotropy





- ✓ Radially anisotropic models, stars on the 10% lowest-energy orbits move on orbits with β = 0.5
- ✓ Due to relaxation, the velocity profile gets isotropic within a Gyr, i.e. only a fraction of the lifetime of Ocen.