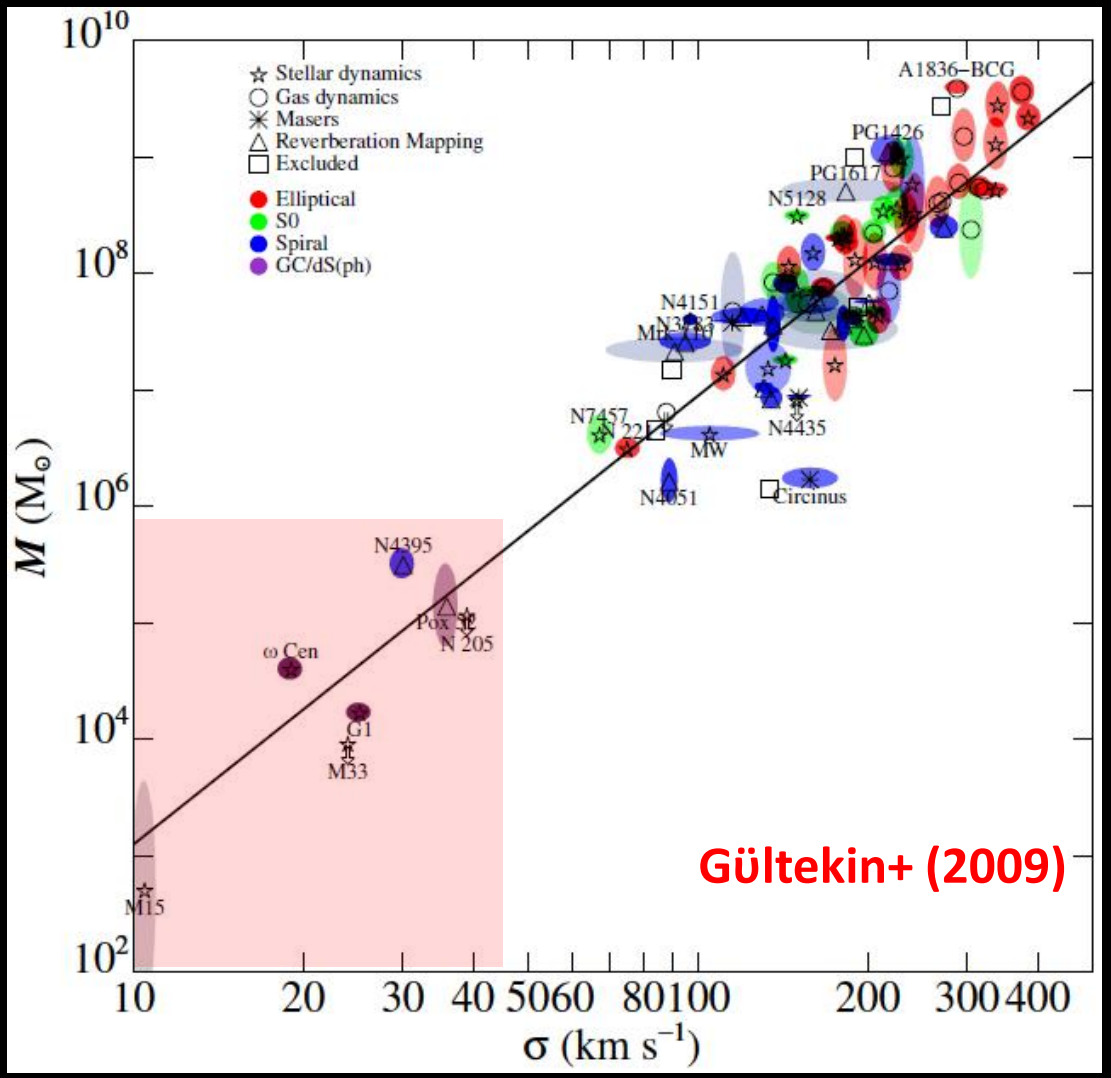
Intermediate Mass Black Holes in ω Centauri

Behrang Jalali,
Holger Baumgardt
Markus Kissler-Patig
Karl Gebhardt
Eva Noyola, Nora Lützgendorf,
and Tim de Zeeuw

Why IMBHs?



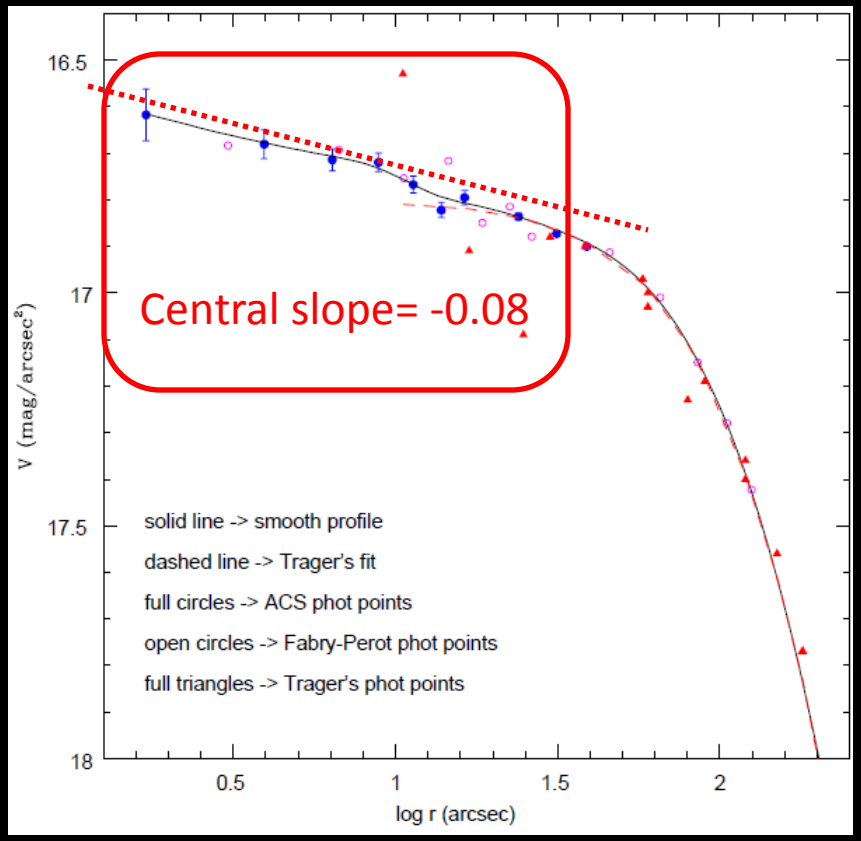
- Important to understand SMBHs growth (seed BHs)
- Could have important consequences for GCs evolution
- Interesting gravitational wave sources

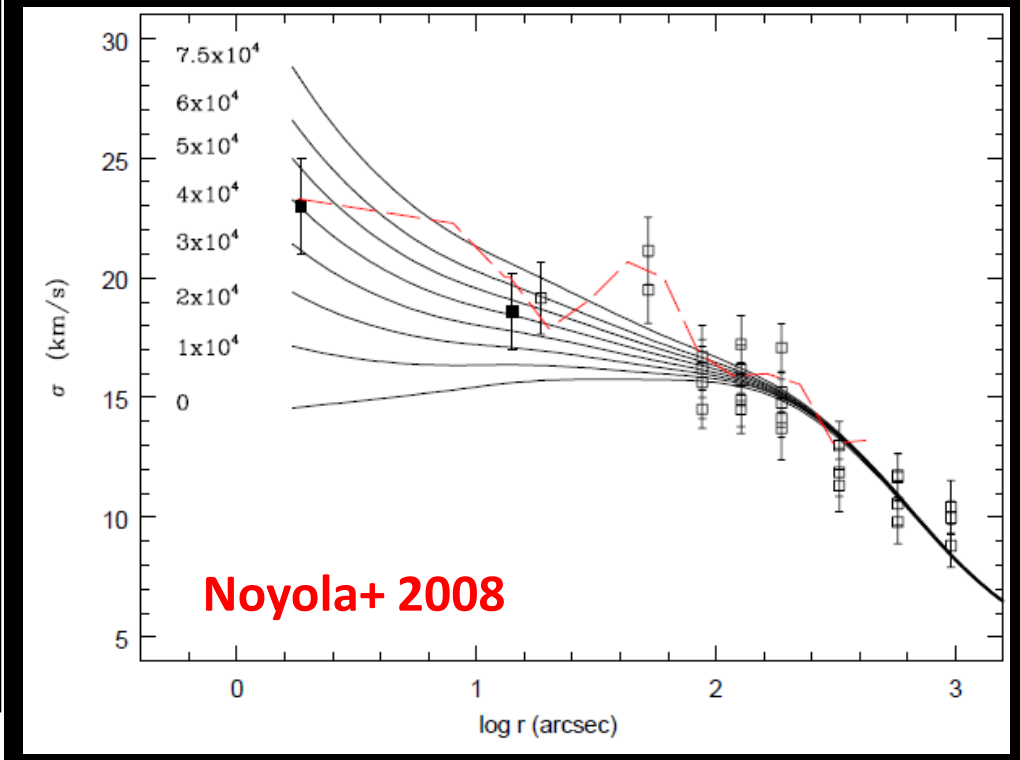
- ω Cen. is the most massive Milky Way star cluster
- Multiple Stellar Populations on Main Seq. and Red Giant stars
- Might be a stripped core of an accreted galaxy!

- ω Cen. is the most massive Milky Way star cluster
- Multiple Stellar Populations on Main Seq. and Red Giant stars
- Might be a stripped core of an accreted galaxy!

- Detailed dynamical model at large radii, using proper motion and radial velocity (Van de Ven+ 2006)

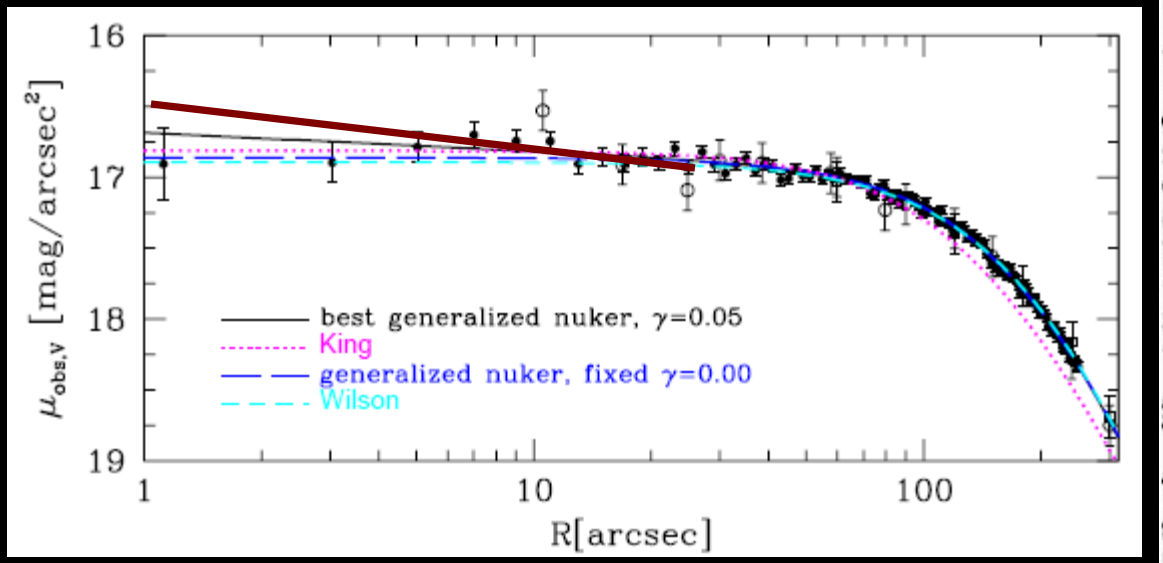
- Distance = 4.8 ± 0.3 kpc,
- $M/L = (2.5 \pm 0.1)\ M_{\odot}/L_{\odot}$, $M = (2.5 \pm 0.3) \times 10^6\ M_{\odot}$
- Inner rotating disk (1'-3') ~ 4% mass

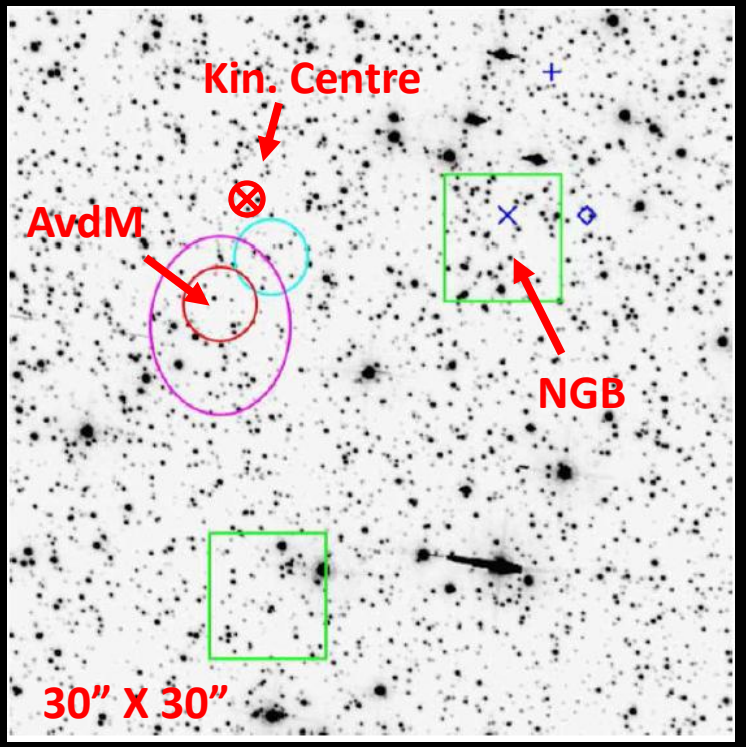




- Central shallow cusp in SB, central rise in σ_{los}
- Spherical Jeans models infer (4 ± 1) x 10^4 $M_\odot$ IMBH (constant M/L)

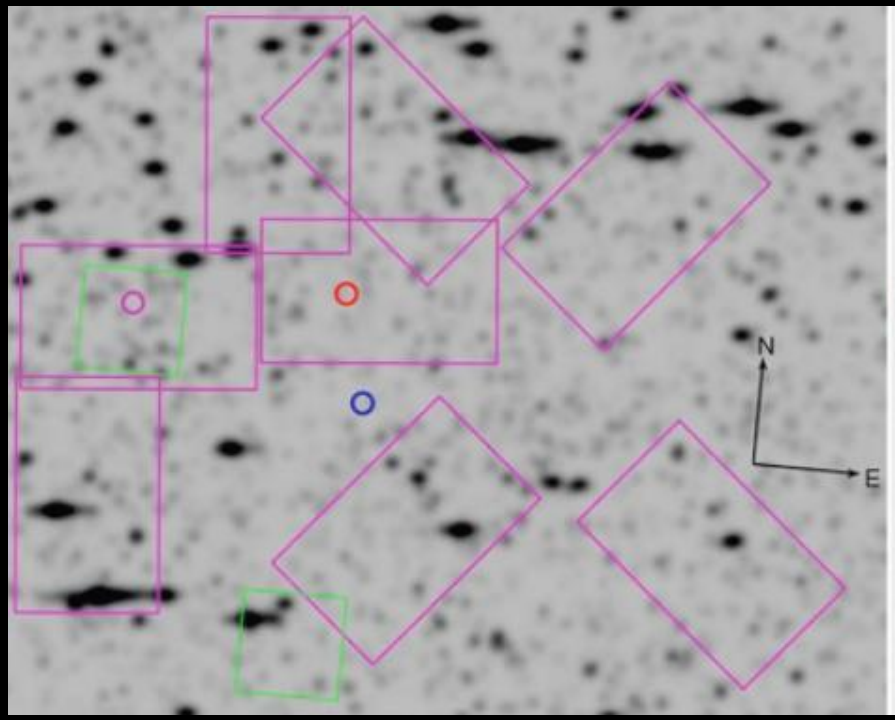
HST: A&vdM and vdM&A (2010)

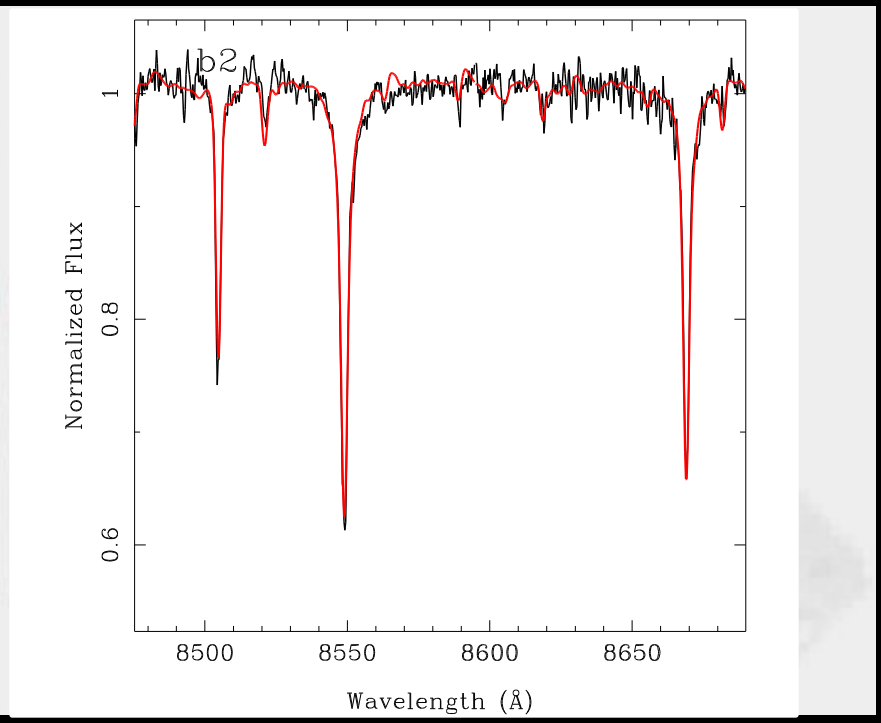




- Large proper motion data-set (> 50,000 stars)
- Star counts & PM kin. center 12" away from previous centers
- Rotation might be removed due to the local PM measurement
- No central rise in the velocity dispersion
- BH mass < 1.2 X 10^4 $M_\odot$

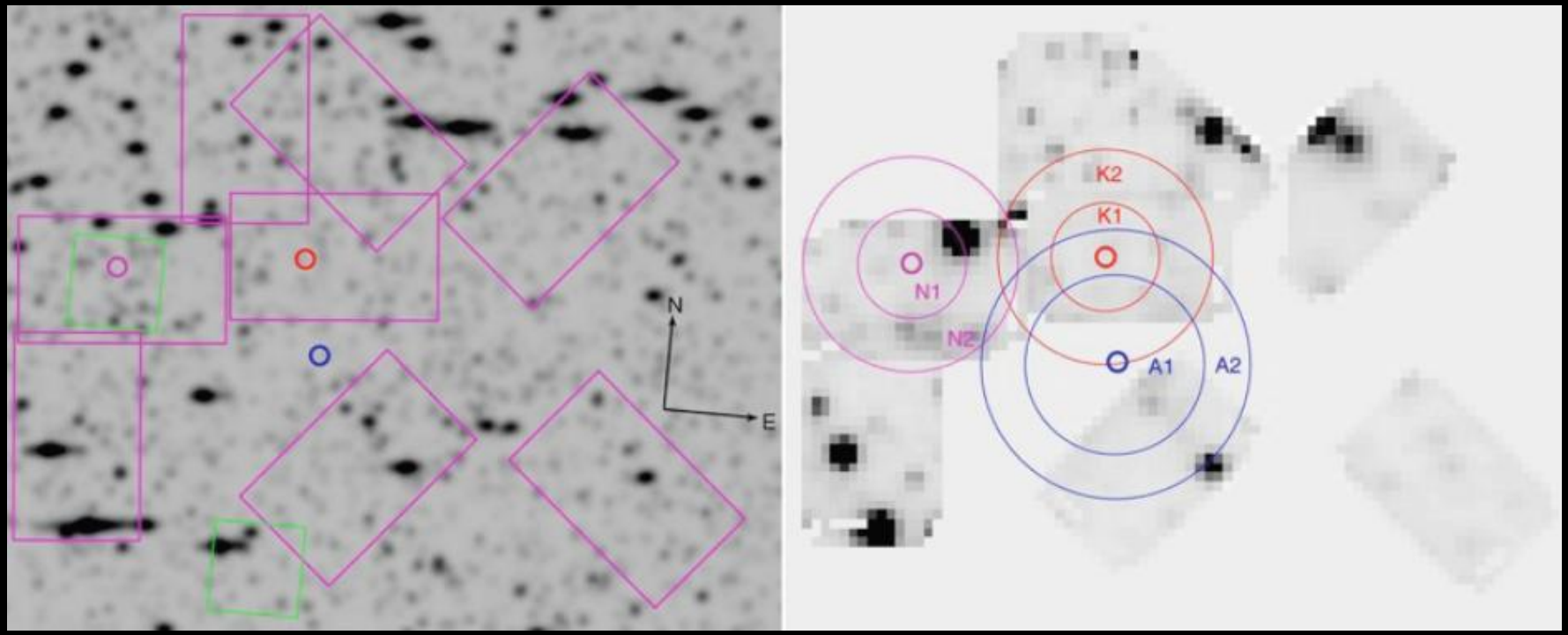
VLT-FLAMES (Noyola+ 2010)





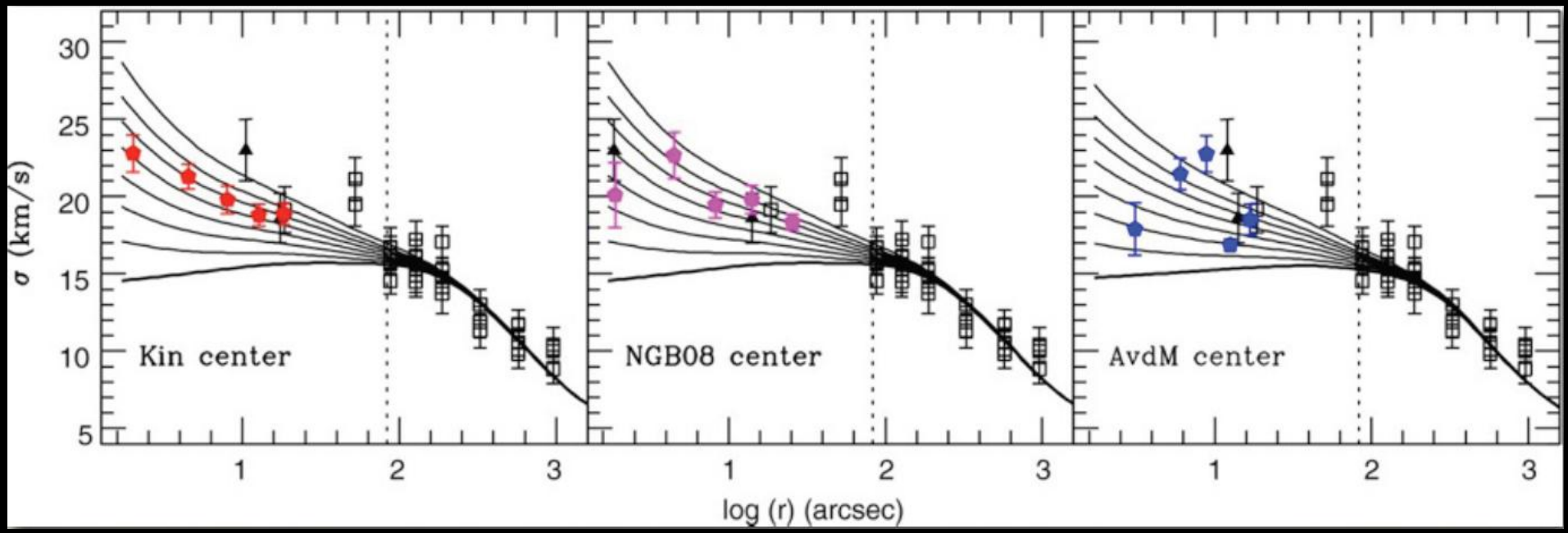
- Almost 5000 spectra @ R=10,000
- Each IFU is 12” X 7” => the core is huge, 100”!

VLT-FLAMES (Noyola+ 2010)



- Bin radially in order to overcome on shot noise
- Extract velocity profile from combined spectrum

Noyola+ 2010



- Spherical isotropic Jeans models consistent with $(5 \pm 1) \times 10^4$ $M_\odot$ BH
- Orbit-based models are being analyzed (Jalali+ 2011, in preparation)

Our recipe for N-body simulations:

Spherical isotropic King model in virial equilibrium

Kroupa IMF: 0.1-100$M_\odot$ + 10% NS retention, no Galactic field + stellar evolution & two-body relaxation

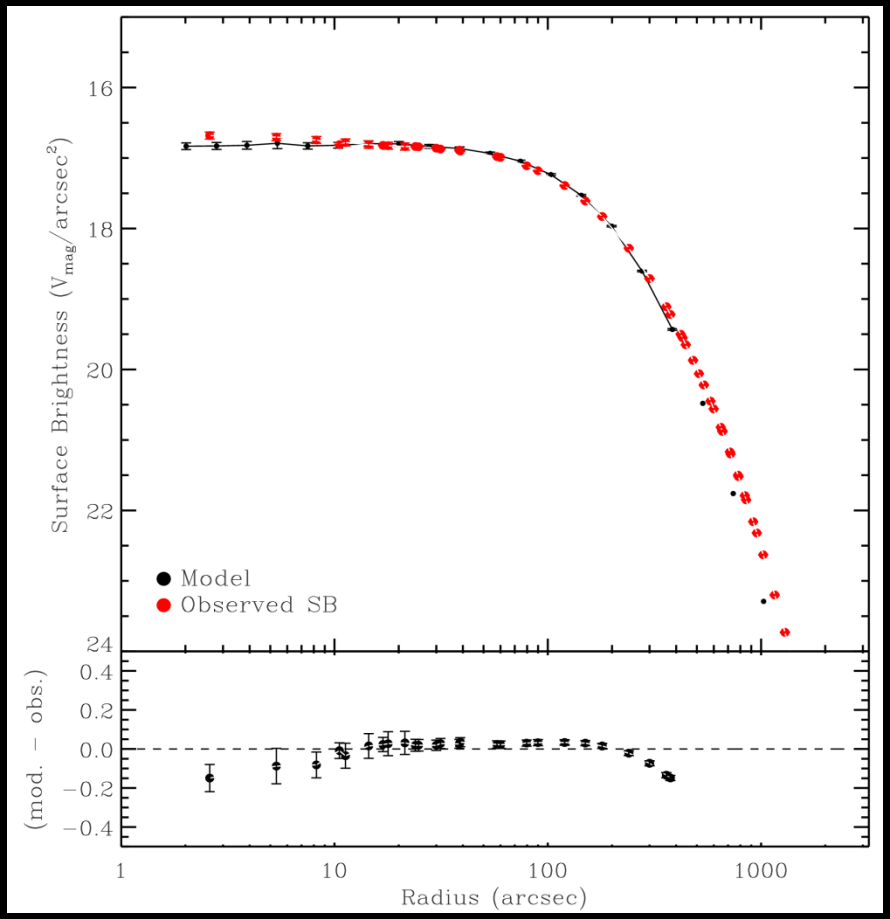
+

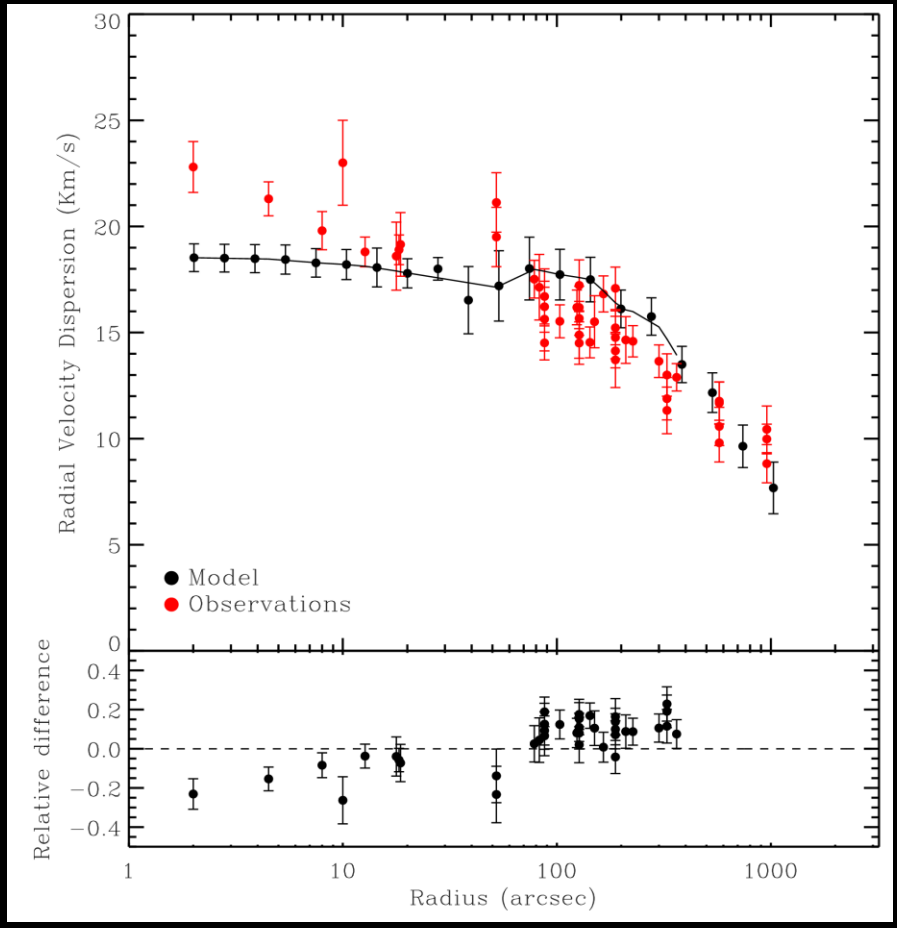
Special thanks to GPUs

12 Gyr of evolution with NBODY6 (Aarseth)

5×10^4 stars, scaling with constant relaxation time

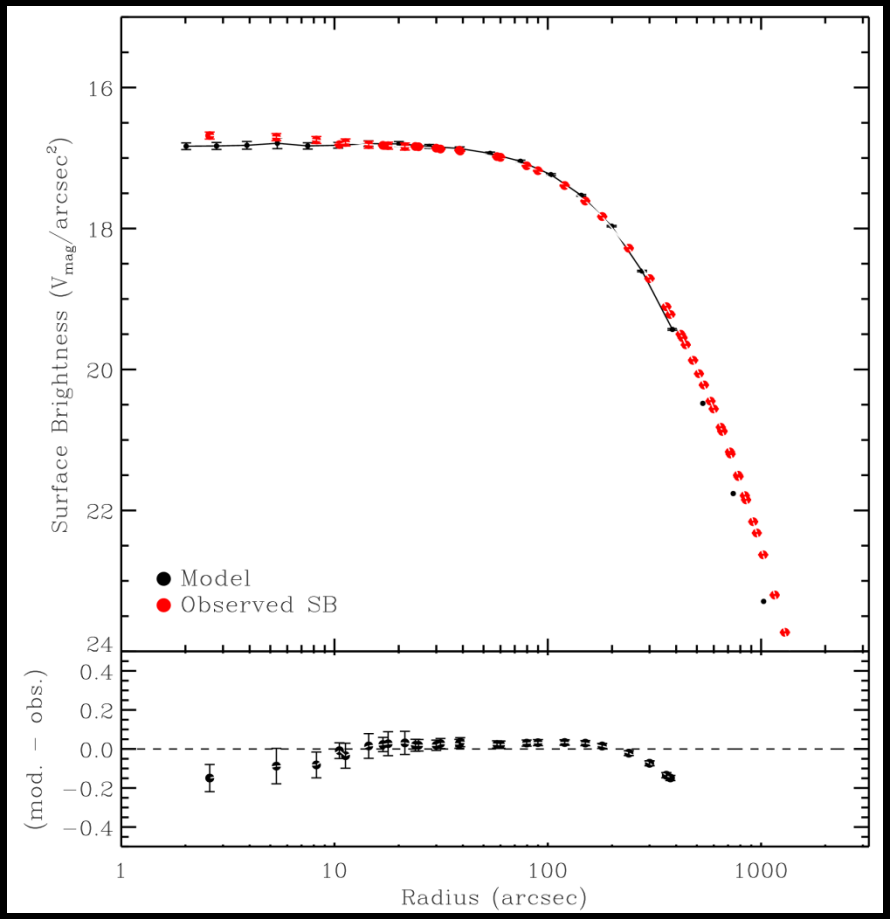
Varying "c", "r_h" and "IMBH mass" to find the initial condition

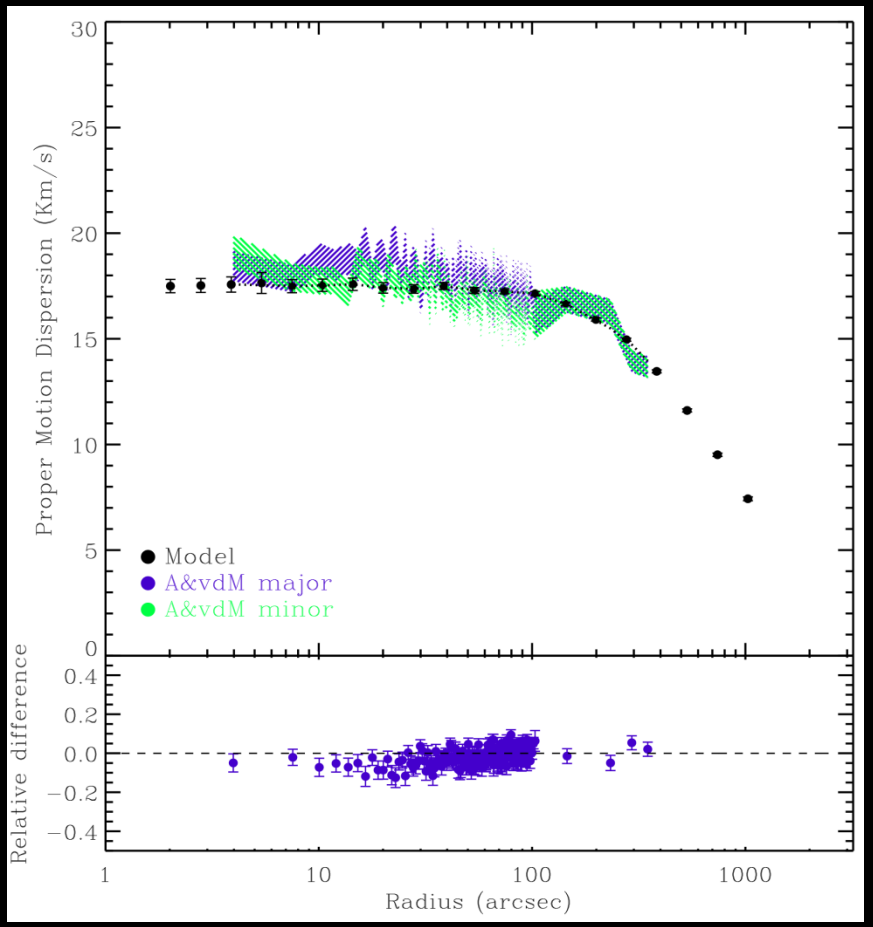




Best-fit no-IMBH model: initial log(c)= 0.9, r_h= 12.8 pc

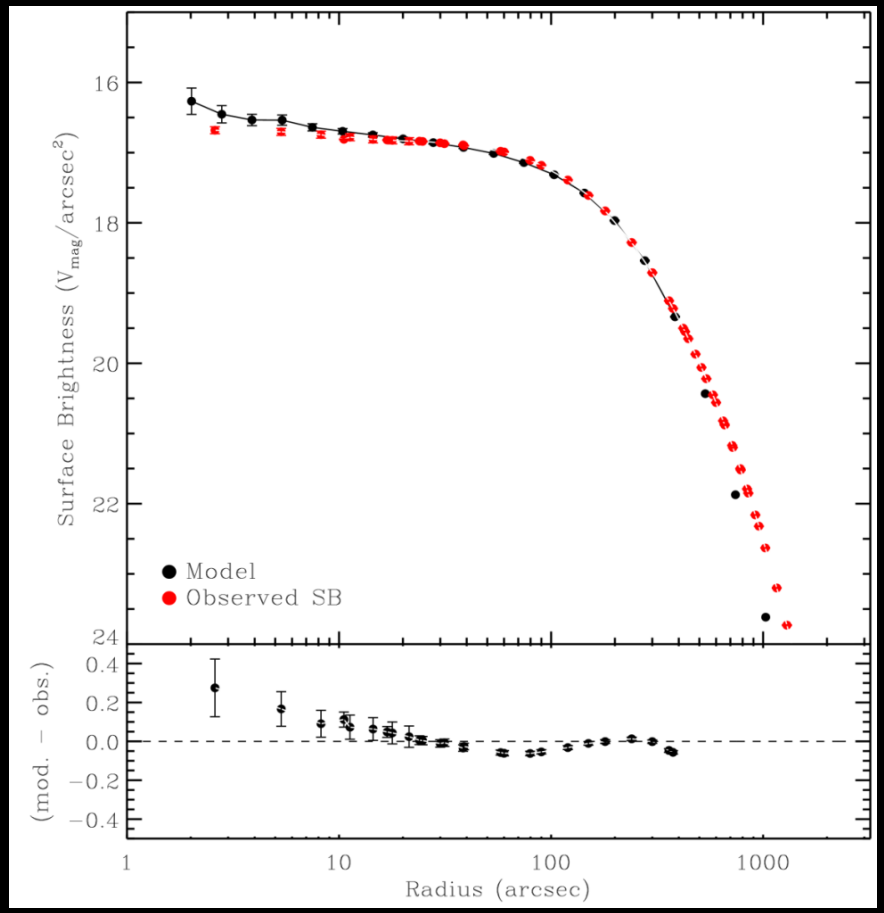
(Jalali+ 2011, submitted)

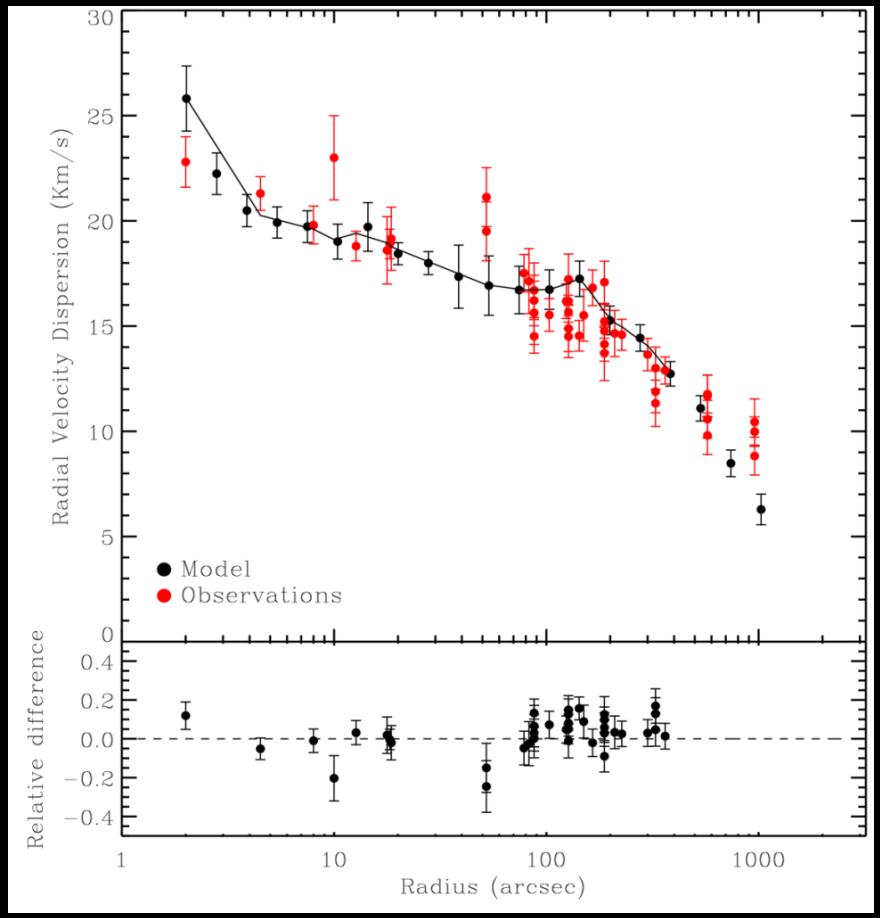




Best-fit no-IMBH model: initial log(c)= 0.9, r_h= 12.8 pc

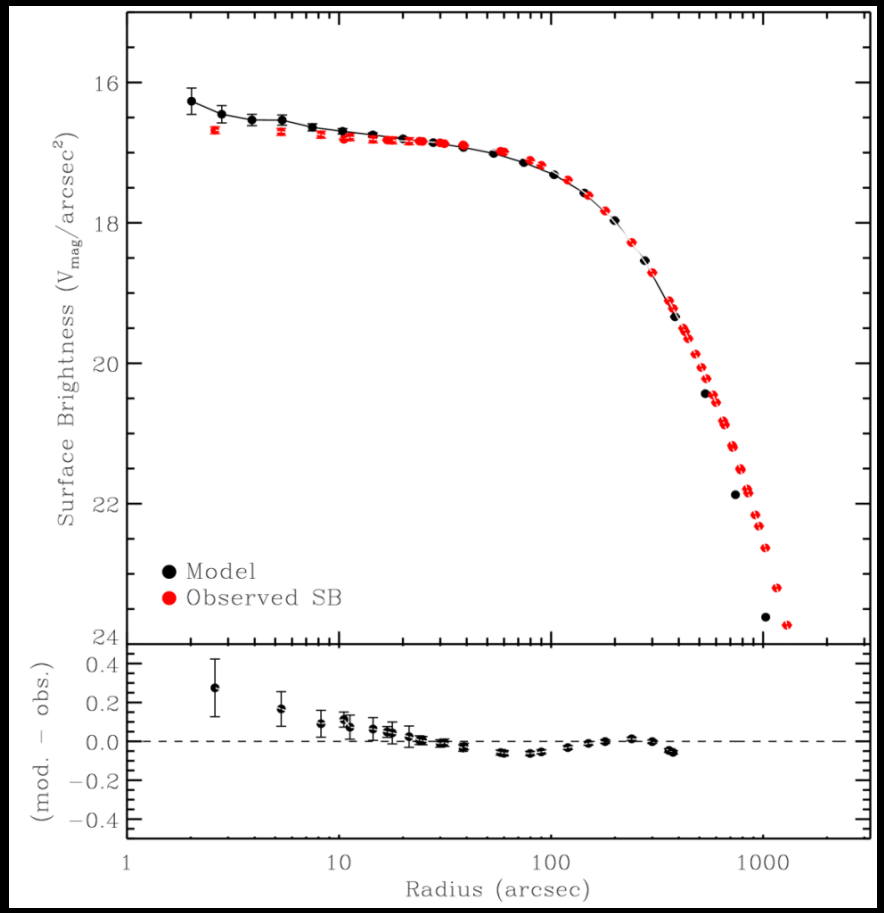
(Jalali+ 2011, submitted)

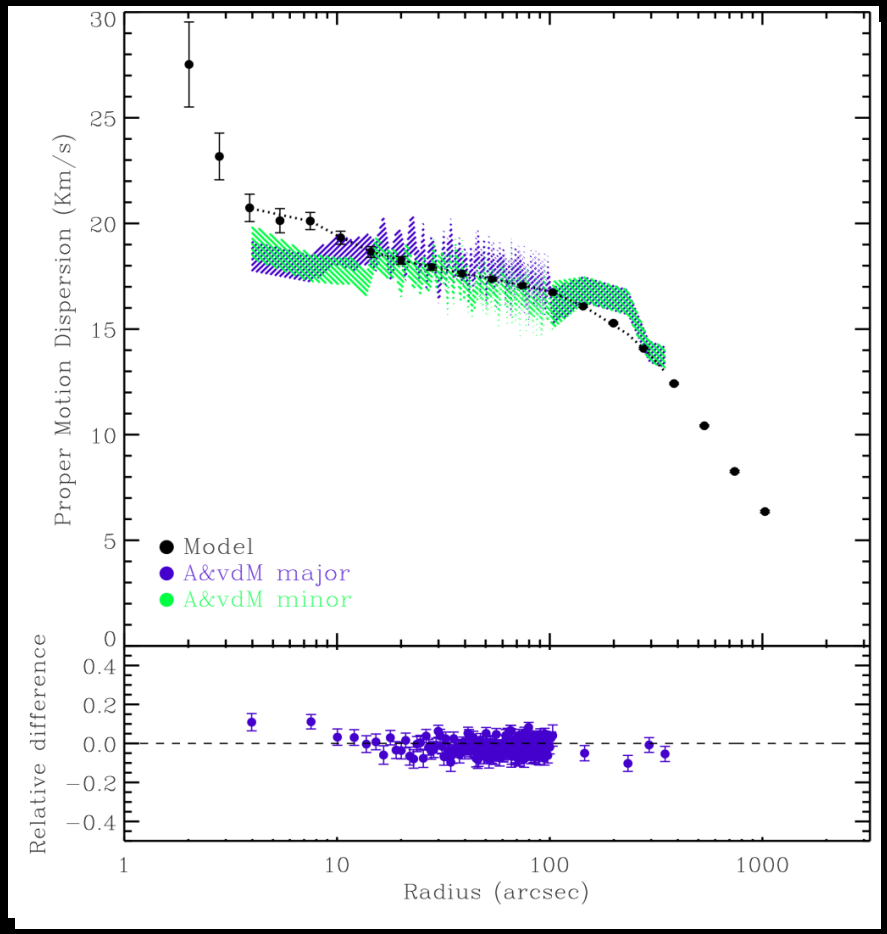




Best-fit model for IMBH2%: initial log(c)= 0.5, r_h = 12.8 pc

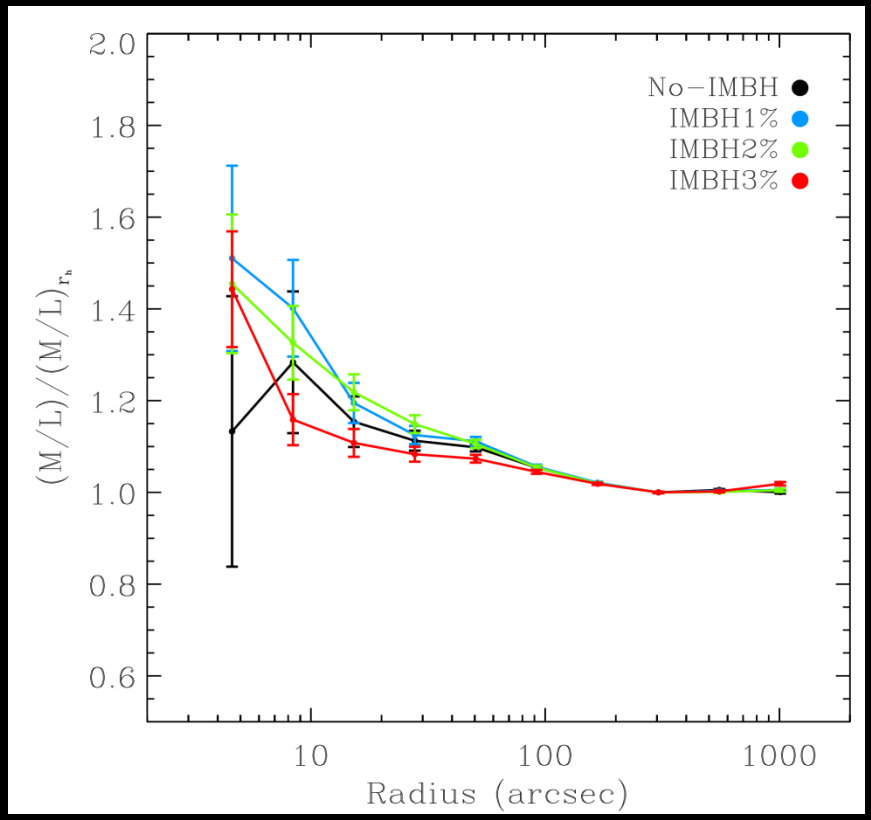
(Jalali+ 2011, submitted)





Best-fit model for IMBH2%: initial log(c)= 0.5, r_h = 12.8 pc

(Jalali+ 2011, submitted)



- M_{cl} ~ 2.5 X 10^6 $M_\odot$ for the best-fit model, in agreement with vdV+ 2006
- No significant difference between different models with and without an IMBH

Conclusions and Perspective:

- A cluster containing 2% IMBH mass (i.e. 5 X 10^4 $M_\odot$) :
  - reproduces the observed SB and l.o.s dispersion with respect to kin. center, (proper motion dispersion?)
  - nicely agrees with Noyola+ 2010 results
  - shows constant M/L ratio over all radii (agree with vdV+ 2006)

- N-body Advantages:
  - Evolutionary path of the cluster,
  - Stability of dark remnants concentration and radial anisotropy,
  - "measuring" M/L as a function of radius

- A bit difficult for interpretation:
  - Hypothesis comparison (time consuming) not differential one such as in orbit-based approach

- Future: Set a tighter constraint on IMBHs with **GRAVITY** (2014) ?

Conclusions and Perspective:

- A
  - re
  - ni
  - sh

pect to kin.

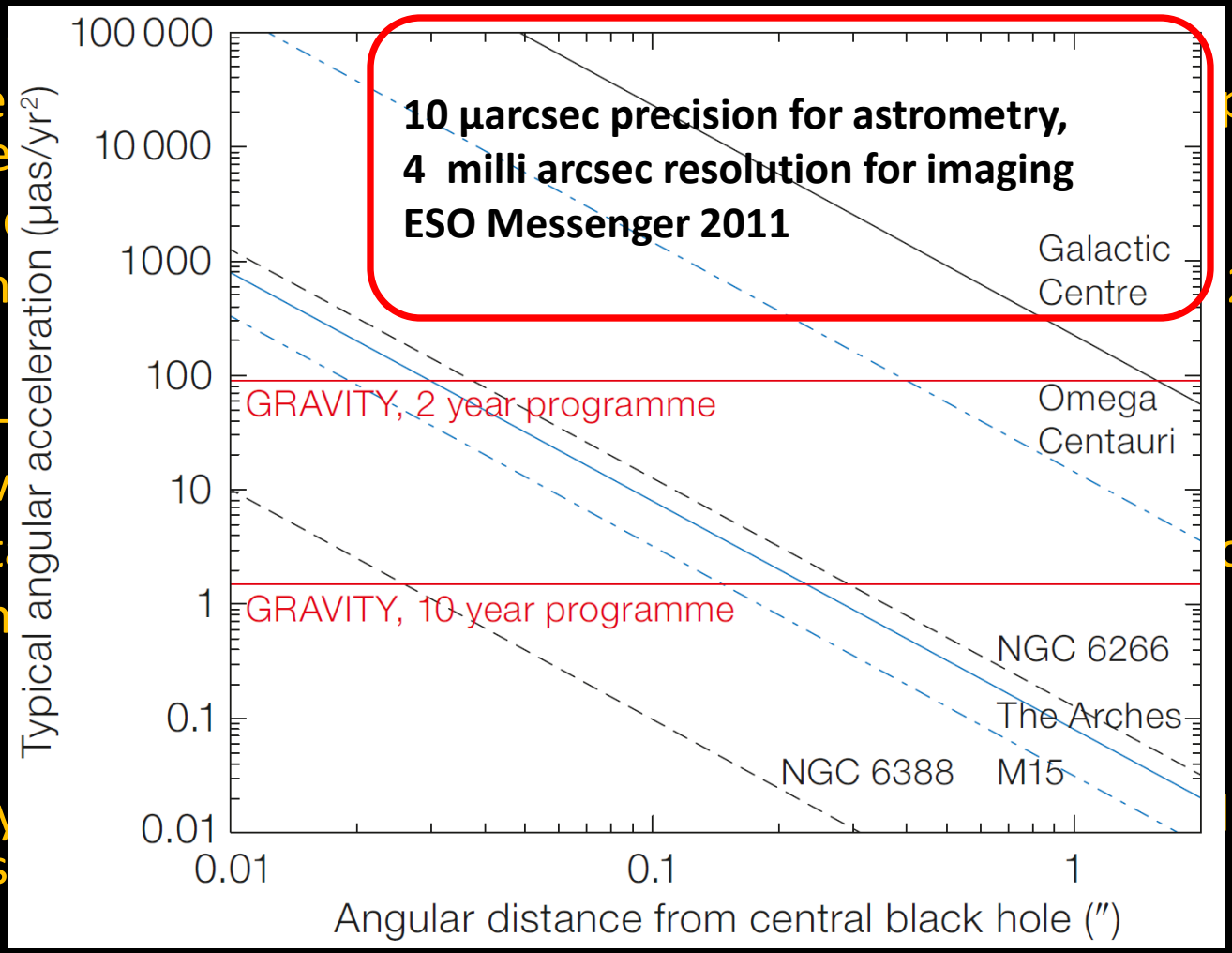
2006)

- N-
  - Ev
  - St

otropy,

  - "n
- A
  - Hy

one such as



- Future: Set a tighter constraint on IMBHs with **GRAVITY** (2014) ?