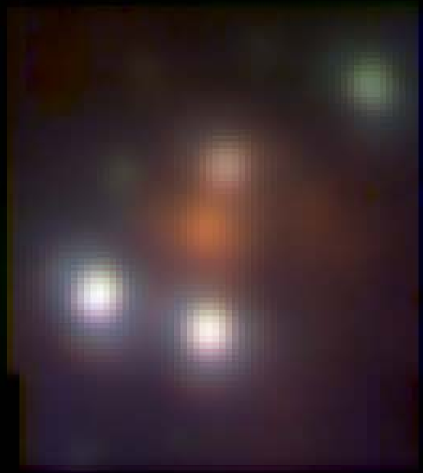
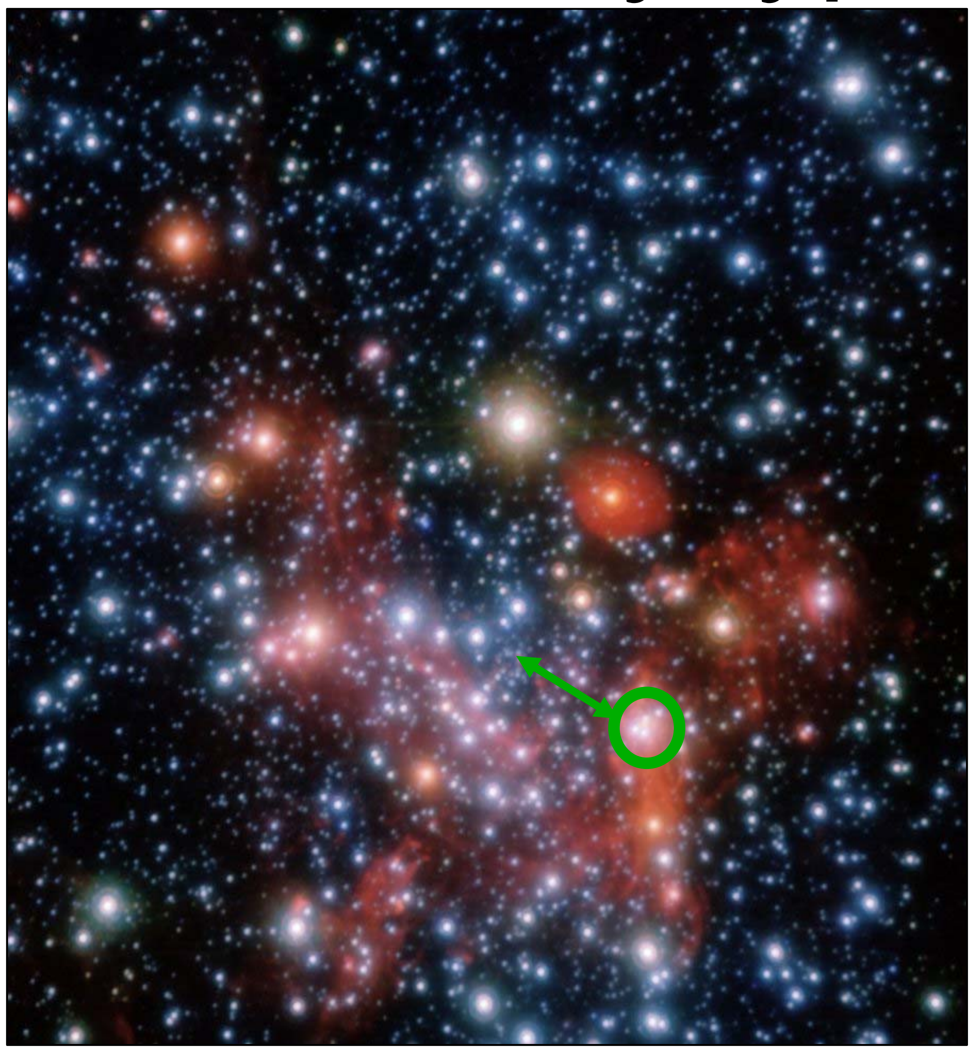
The smallest and the biggest star cluster



T.K. Fritz, S. Gillessen, K. Dodds-Eden, F. Martins, H. Bartko, R. Genzel, T. Paumard, T. Ott, O. Pfuhl, S. Trippe, F. Eisenhauer, D. Gratadour, O. Gerhard, S. Chatzopoulos

GC-IRS13E- A puzzling association of three early type stars

25"~1pc



IRS13E

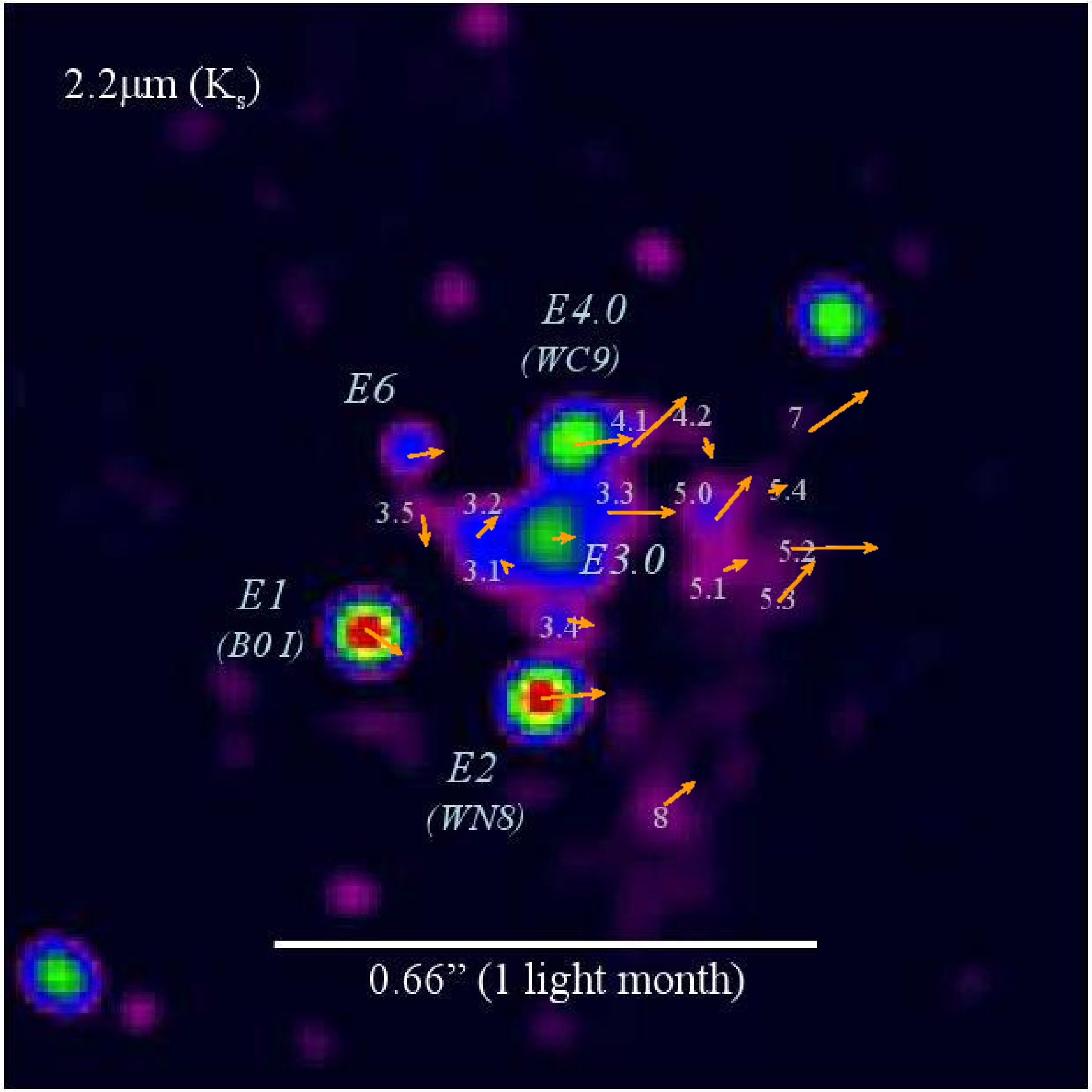
3.5"~0.13 pc
to Sgr A*

T.K. Fritz, S. Gillessen, K. Dodds-Eden, F. Martins, H. Bartko, R. Genzel, T. Paumard, T. Ott, O. Pfuhl, S. Trippe, F. Eisenhauer, D. Gratadour

ApJ 2010, 721, 395

A cluster of 19 stars?

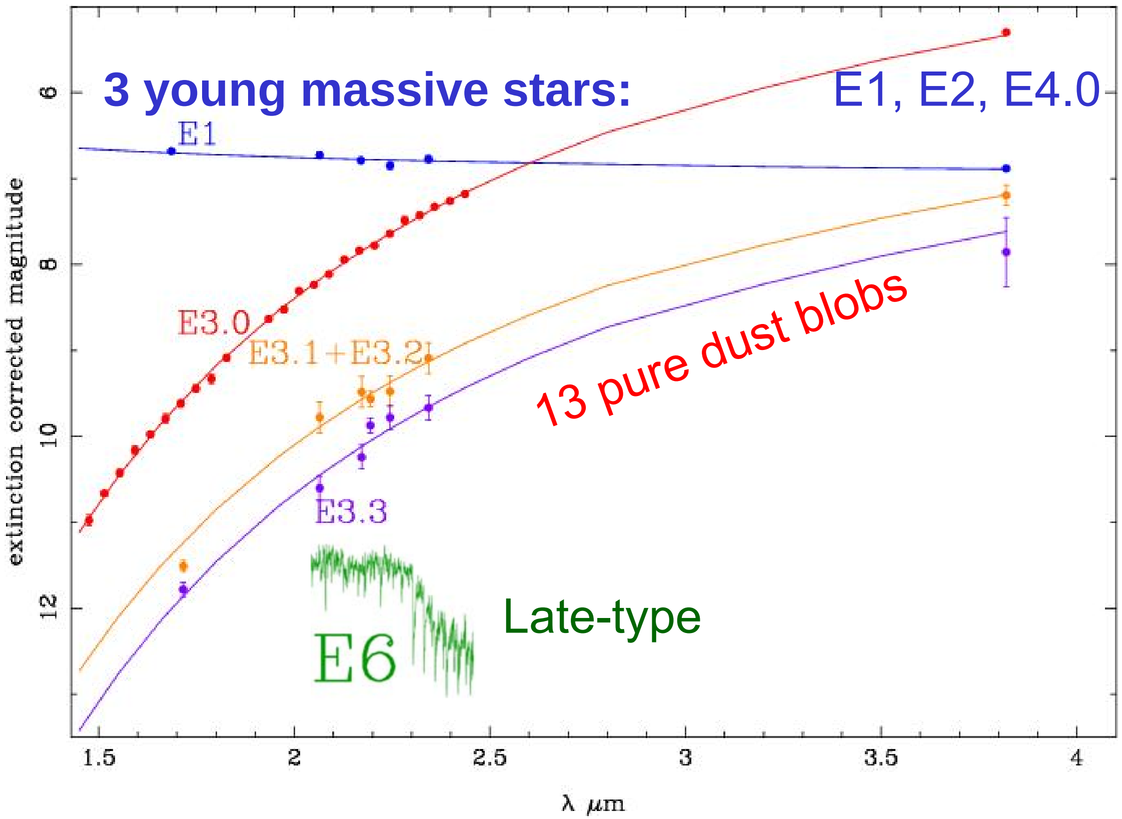
Deconvolved Ks-band NACO/VLT image

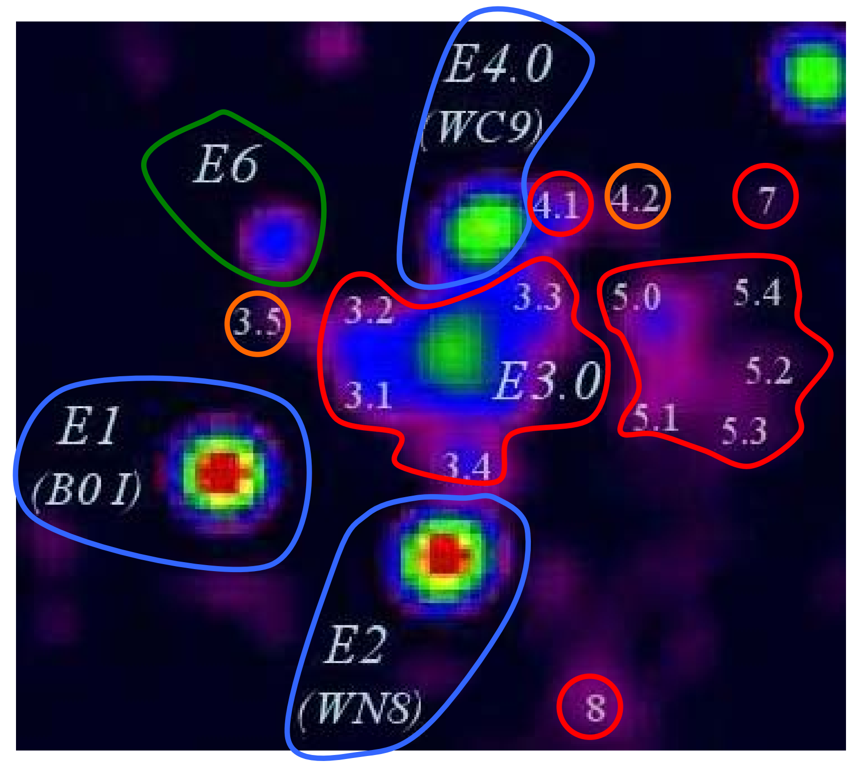


Looks like Cluster (Maillard04 Paumard06)

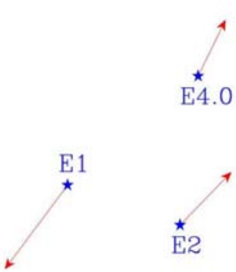
19 sources with proper motions (2002 to 2009)

SED-fitting: Most objects are dust blobs





2 faint stars are expected from background

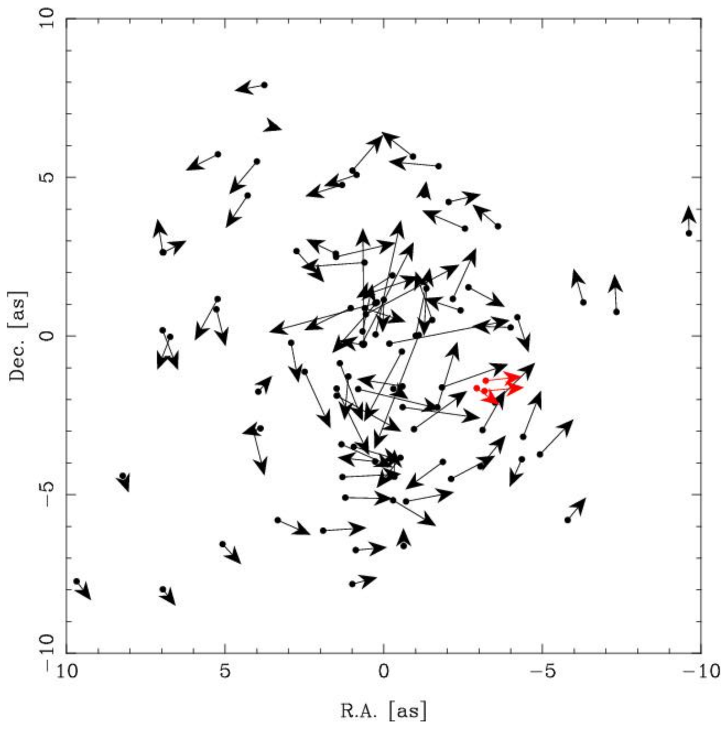


3 young massive stars remain

What is the nature of the association of three young stars?

Chance association (Schödel05,Trippe08):

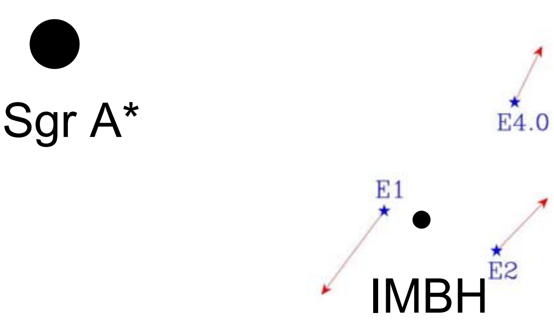
How likely is IRS13E as chance association in phase space given the **early-type stars outside** (Bartko09) of IRS13E?



Cluster with intermediate mass black hole (Maillard04):

IMBH (M~20000 solar masses) necessary for binding the stars.

How likely is an IMBH given the **acceleration limits** of the stars and **the radio motion** of Sgr~A* (Reid04)?



Probability~0.2%

Uncertainty a factor 2

Probability~0.8%

Uncertainty: a factor 2

IRS13E conclusions

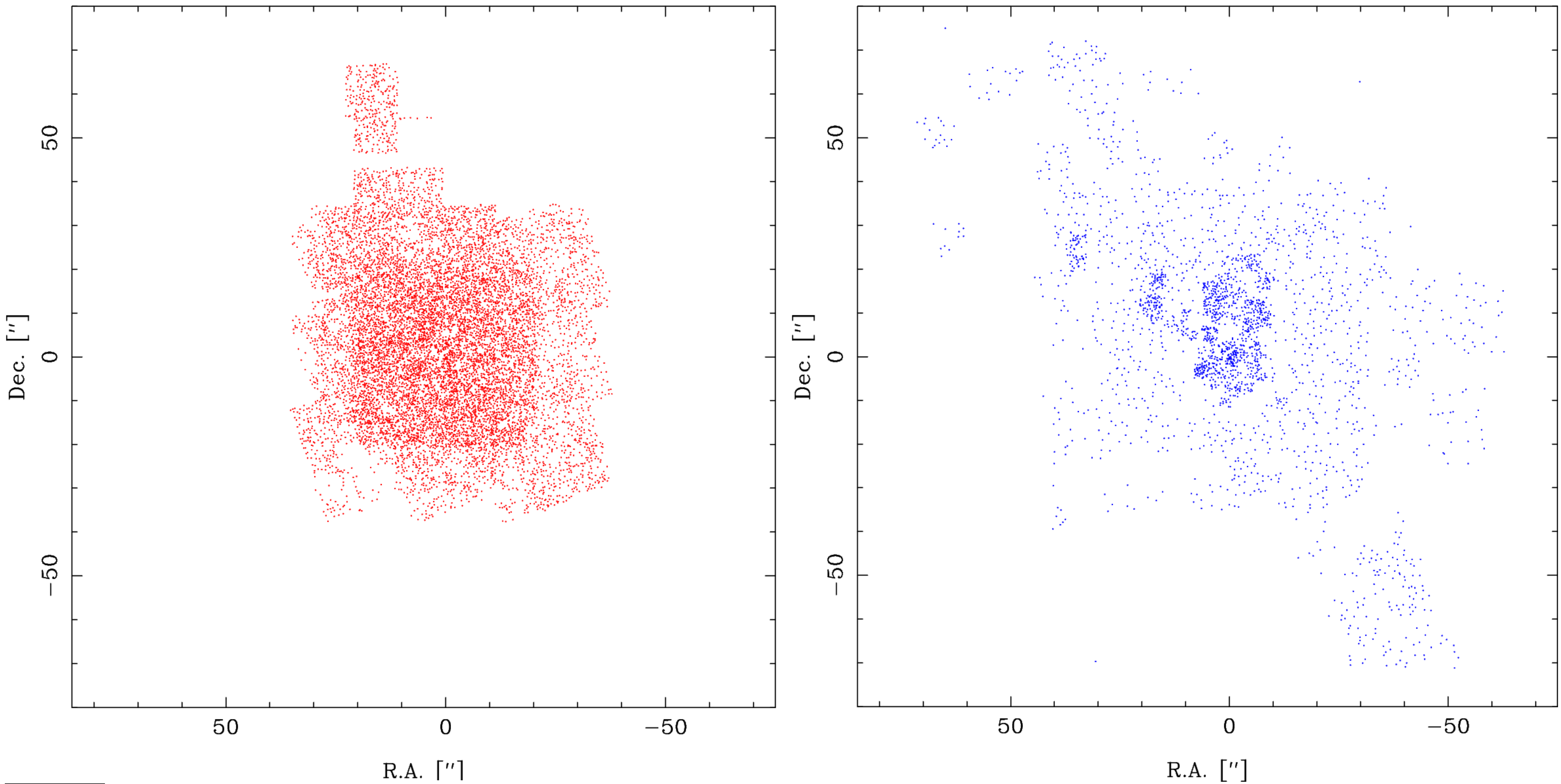
- IRS13E consists of 19 objects but only 3 young stars.
- This association has a probability of about 0.2 % as chance association
- An IMBH inside has a probability of only about 0.8%
- Too few early-type stars around for inspiraling cluster with IMBH
- No bright X-ray source in IRS13E, although there is gas and dust (see also Schödel05)
- More likely no IMBH

ApJ, 2010, 721, 395

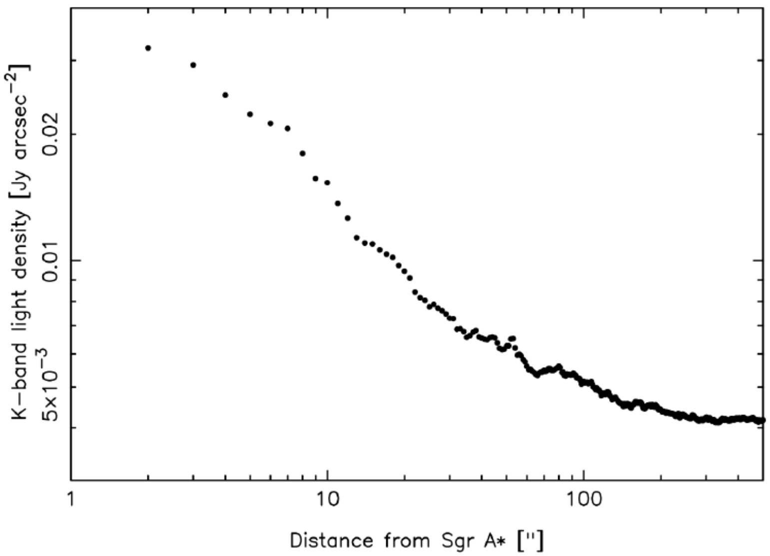
The nuclear star cluster of the Milky Way

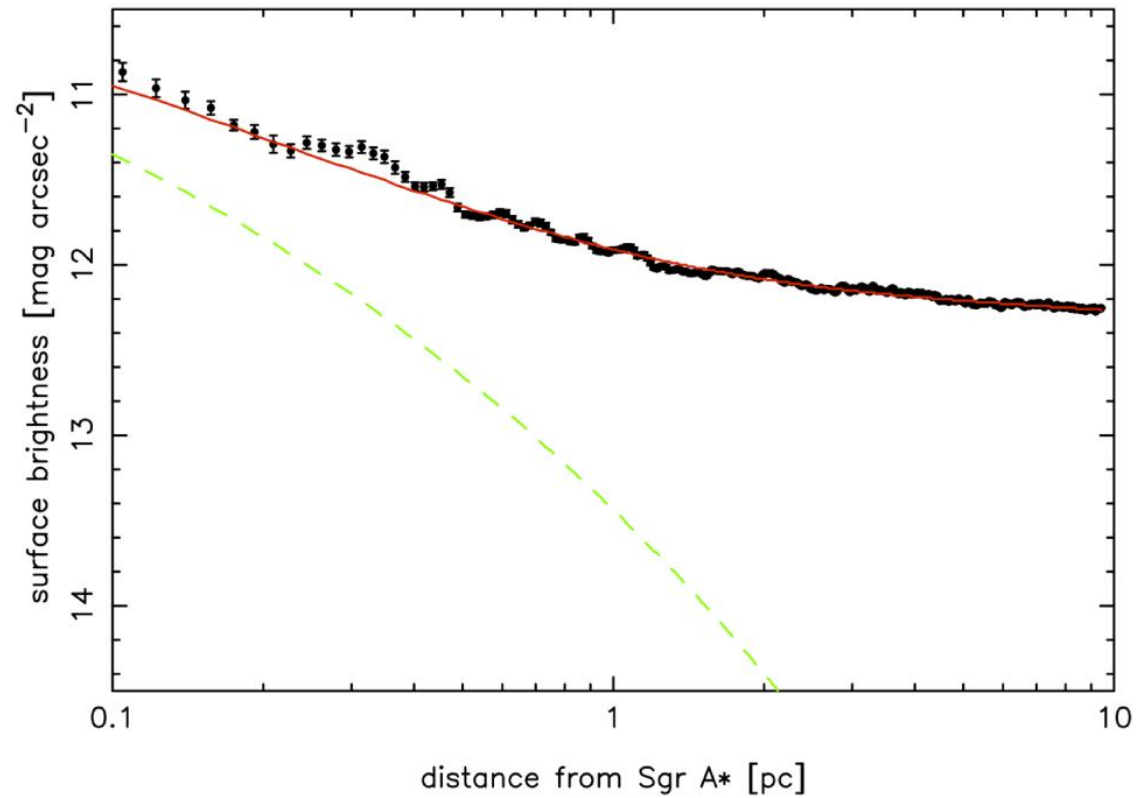
- The closest nuclear cluster
- Not only its central parsec but a larger scale for comparison with other nuclear clusters
- Its main component the probable relaxed old stars (at least > 20 Myrs, mostly >5 Gyrs, Pfuhl11)
- Their light and mass distribution
- What is its origin? Local formation or immigration of globular clusters
- Important works for comparison in case of mass distribution and dynamics properties: Trippe et al. 2008, A&A, 492, 419 (Trippe08) and Schödel, Merritt &Eckart, 2009, A&A, 469, 125 (SME09)

Data: 10000 proper motions
2500 radial velocities



How big is the nuclear cluster? New works: small

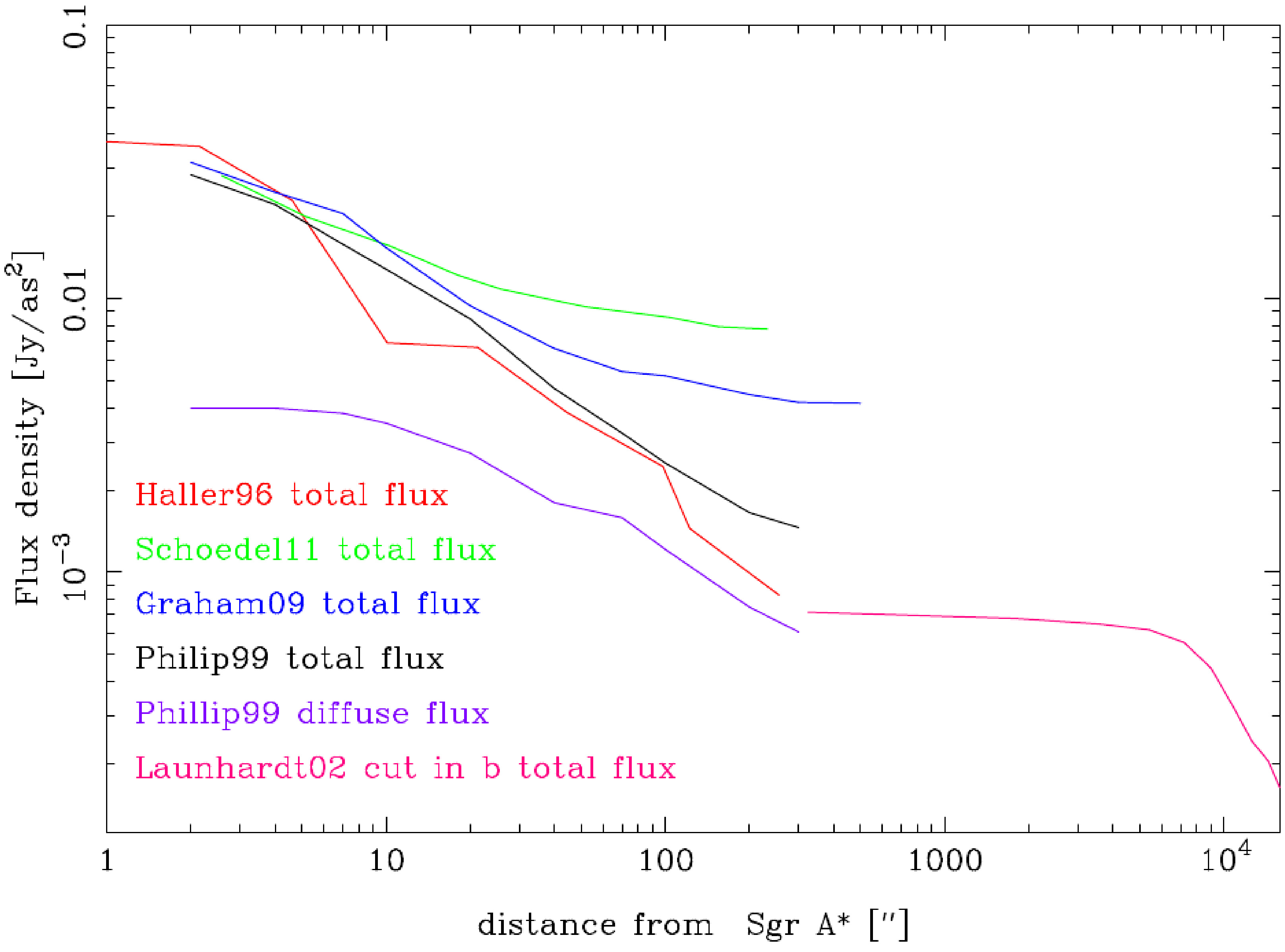




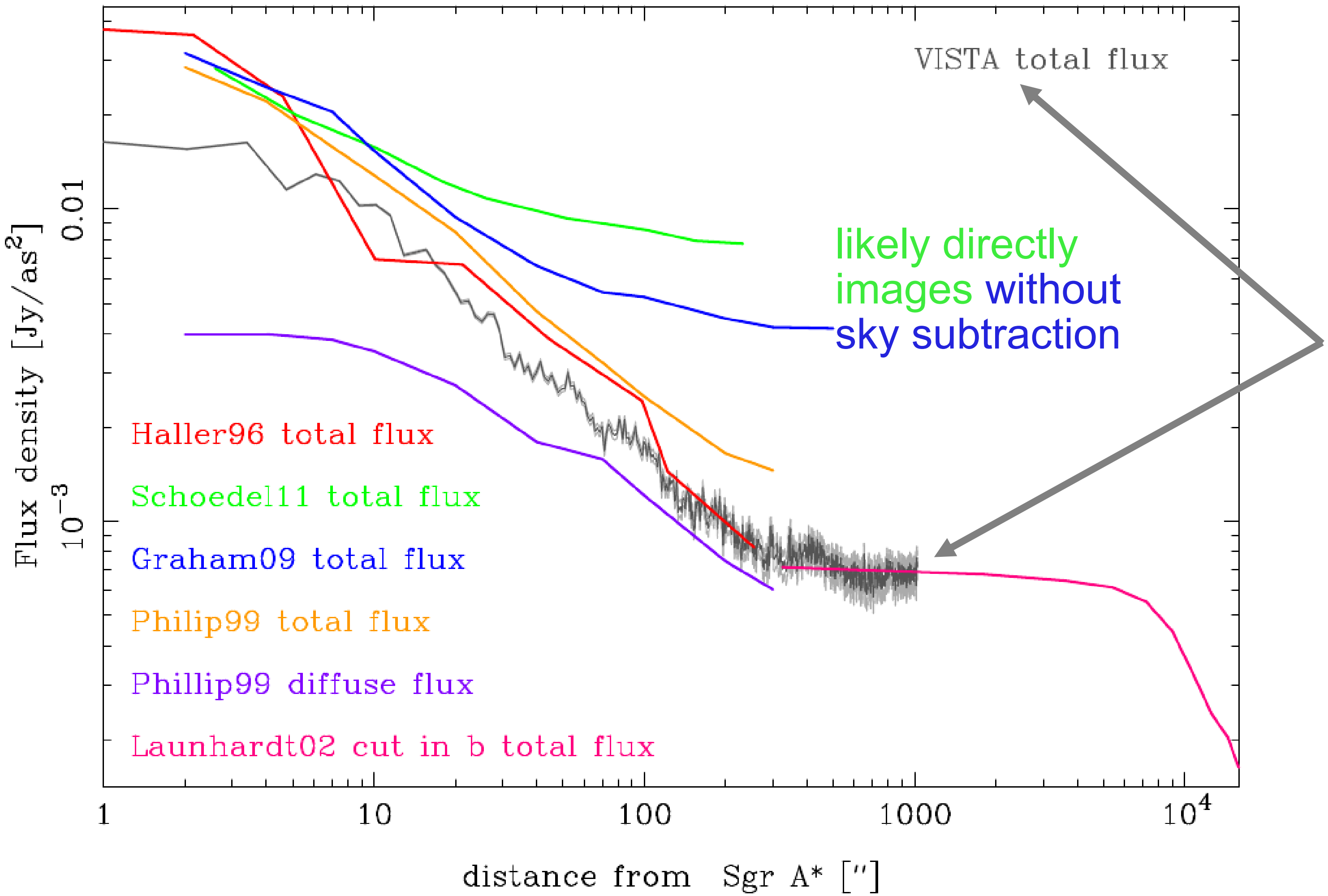
Schödel et al. 2008, JphCS
Graham & Spitler 2009, MNRAS

Schödel, 2011, ASPC

Old works: big



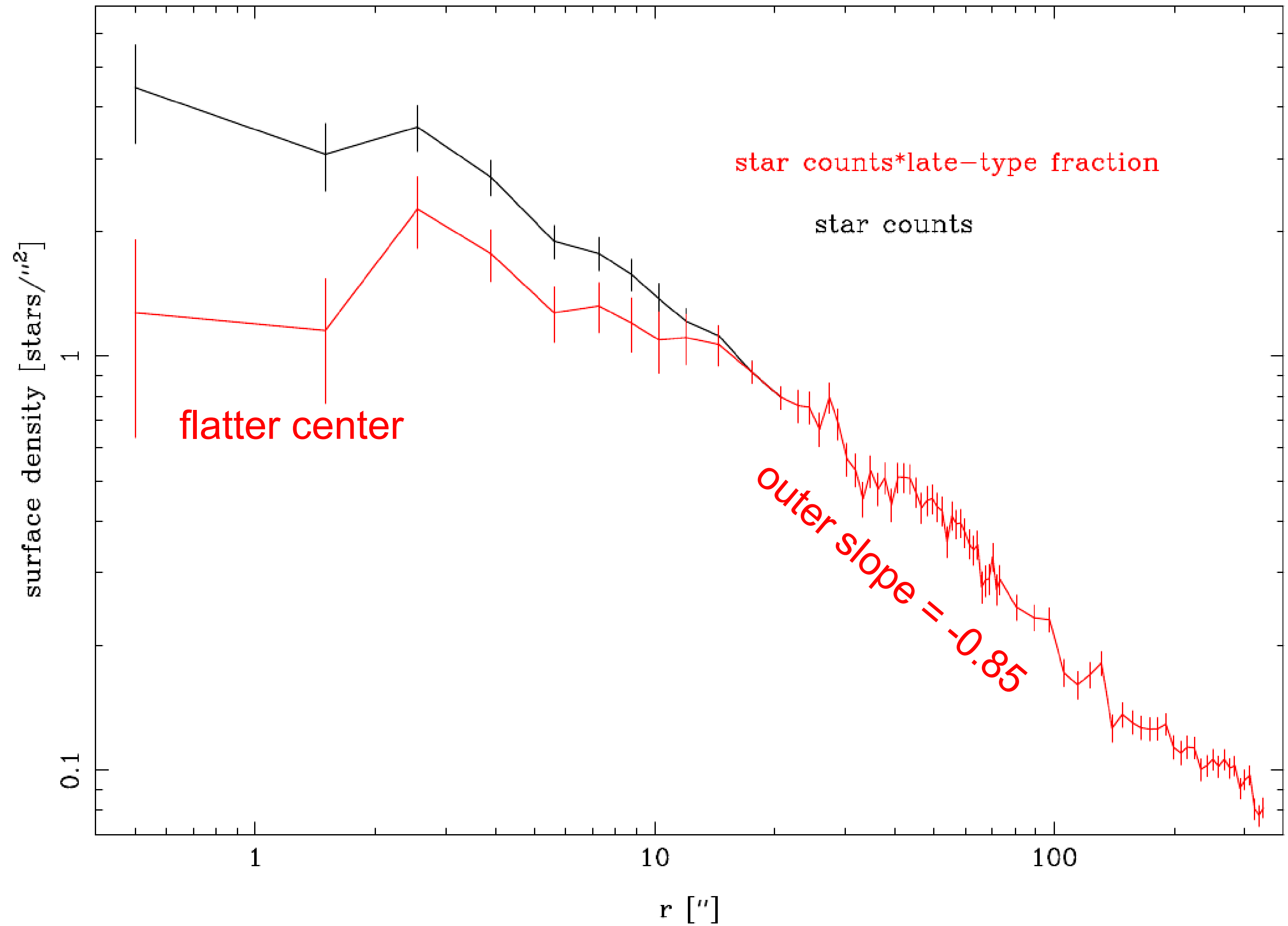
New VISTA data



VISTA image,
Originally an image w/o sky subtracted.

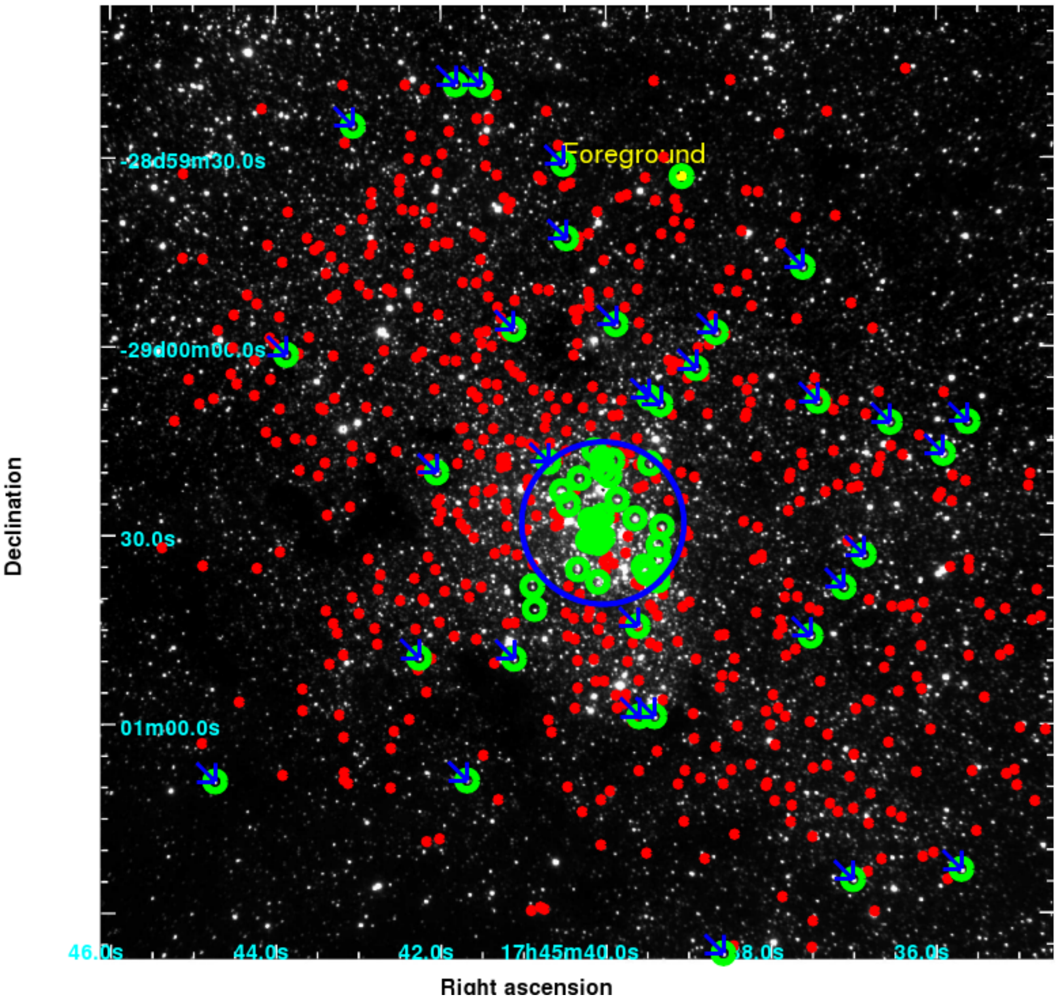
I subtracted the counts towards dark clouds

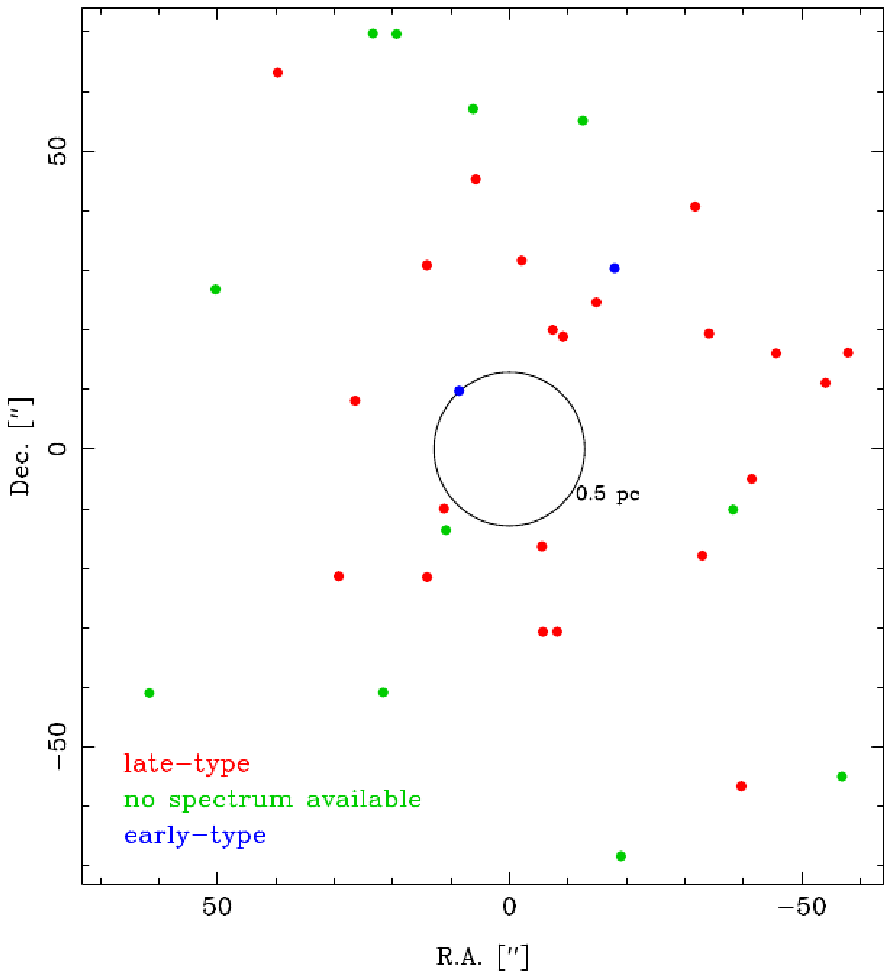
Data: radial surface density



completeness and extinction variation (H+Ks-band) corrected star counts,
3 different images: VISTA (big, worst resolution), ISAAC, NACO (small, best resolution)
In the center exclusion of not old stars important (Bucholz09,Do09,Bartko10)

Early-type stars further out irrelevant





spectral identifications

Narrow band imaging m_{Ks}~10-12:
early-type candidates late-type
Nishiyama & Schödel 2012, arXiv1210.6125

Methods

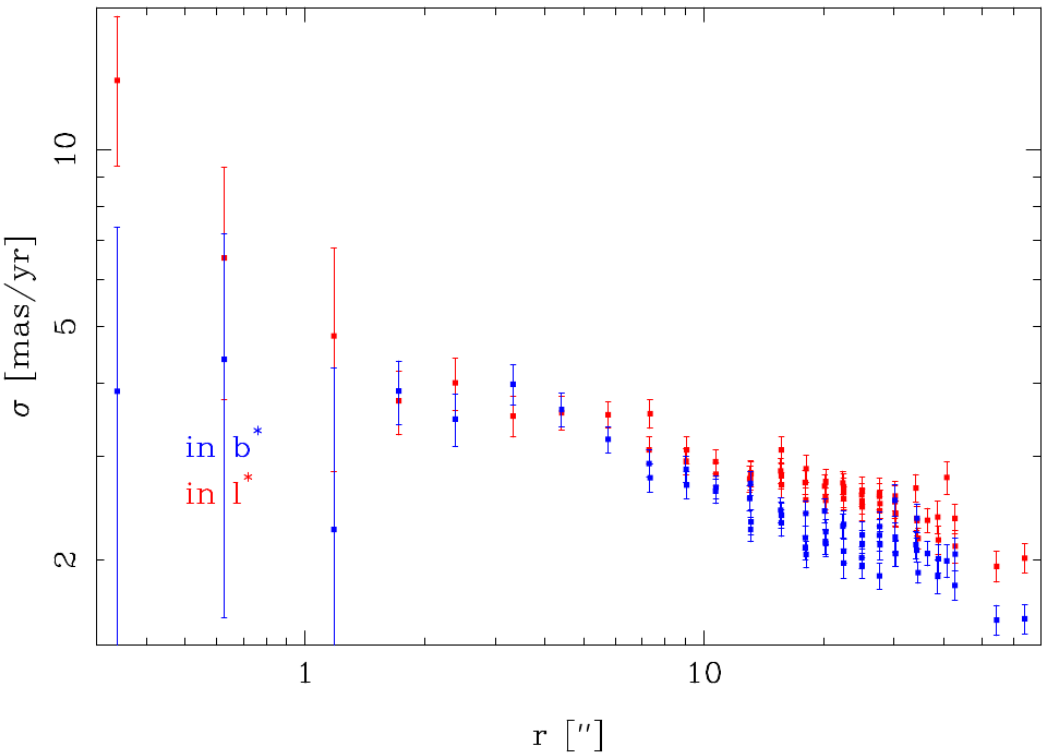
- N-body code NMAGIC for fitting particle models (Chatzopoulos, Gerhard et al. in preparation)
- Jeans modelling, currently mostly isotropic modelling w/o rotation (relative simple to setup self-consistently, not describing the data)

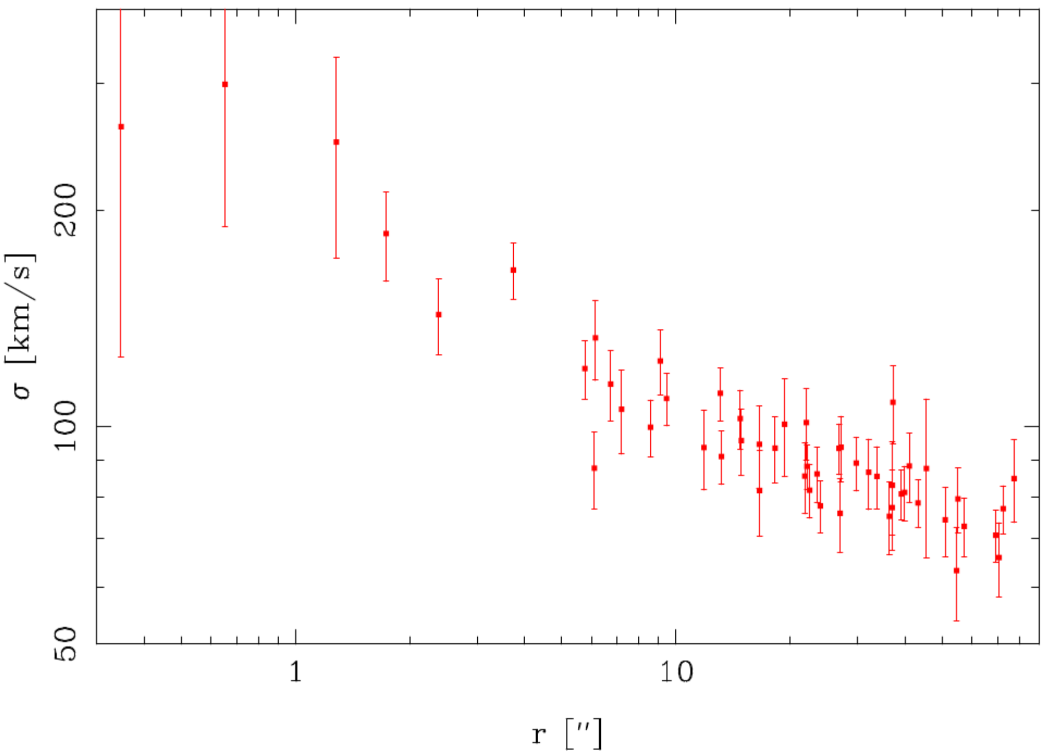
Dispersions data

proper motion

radial velocities

for combination a distance necessary or obtained as fit result.
mostly R_0=8.2 kpc





Isotropic Jeans modeling

Direct fitting of projected properties like SME09

To fit projected tracer profile

$$\Sigma(r) = 2\int_R^\infty n(R) R dR / \sqrt{R^2 - r^2}$$

And projected dispersion profile

$$\sigma^2(r)/G = \frac{\int_r^\infty dr\, R^{-2}(R^2 - r^2)^{1/2} n(R) M(R)}{\int_r^\infty dr\, R(R^2 - r^2)^{-1/2} n(R)}$$

Deprojection of observed radial tracer profile

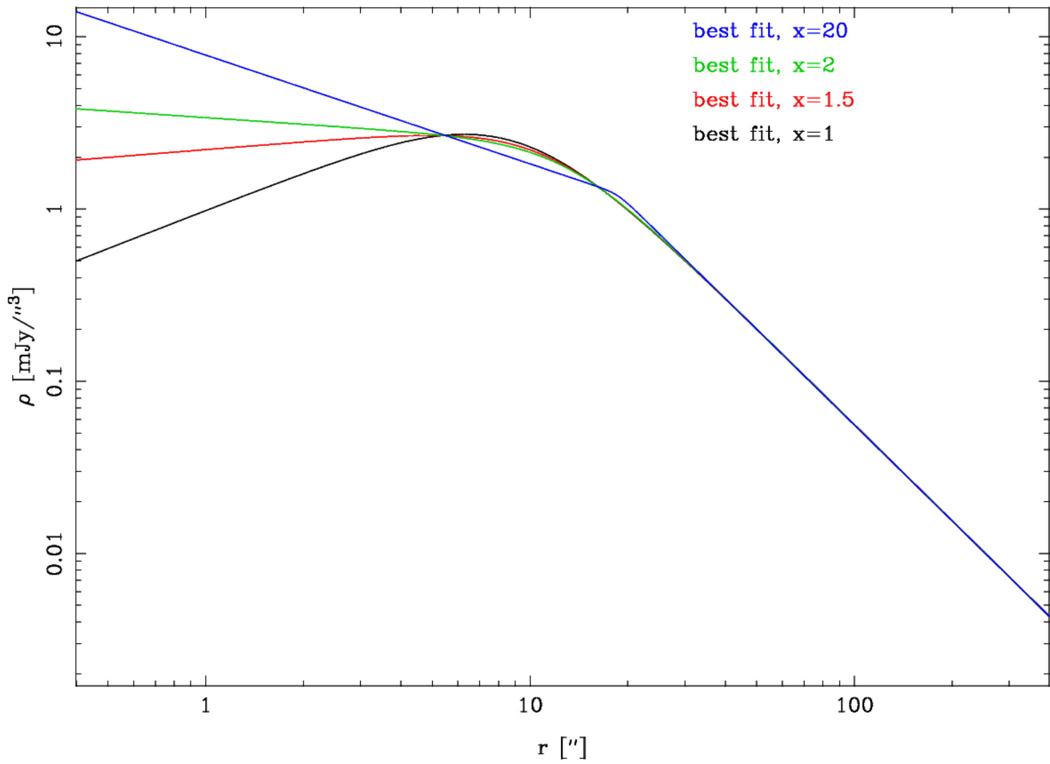
$$n(R) = \Sigma_b/(((R/R_b)^{\delta})^x + ((R/R_b)^{\alpha})^x)^{1/x}$$

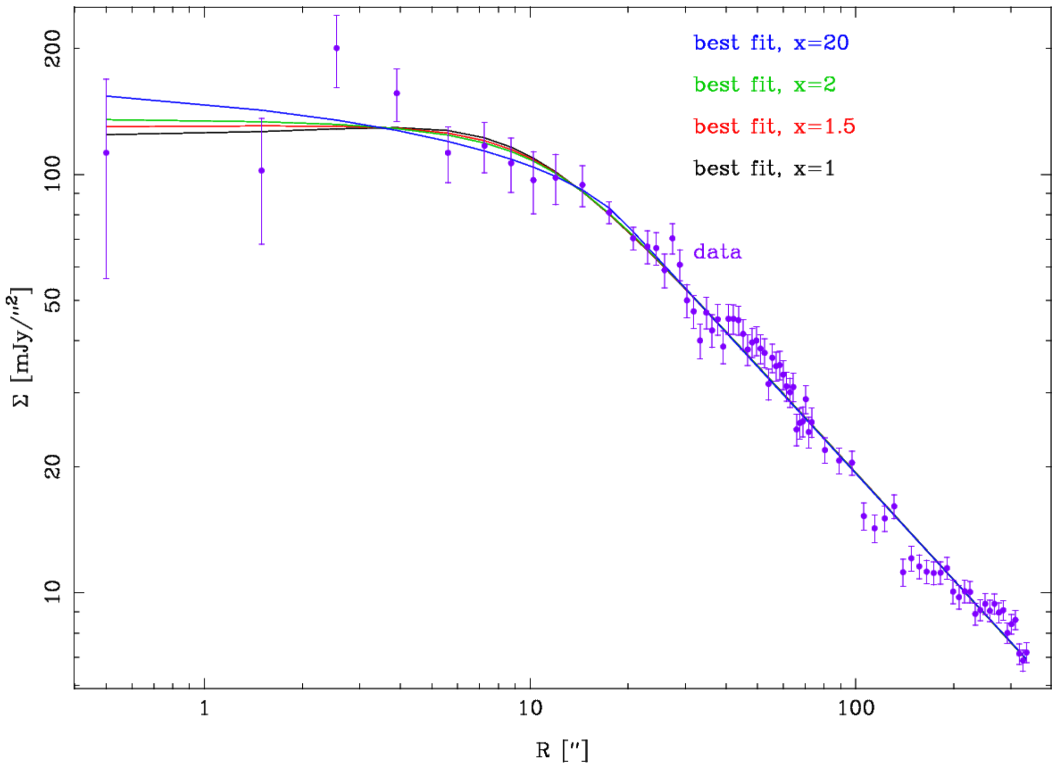
transits from inner power law slope δ to the outer slope α.
parameter x: smoothness of the transition at the break radius r_b
x=1:smooth transition (Genzel96, Trippe08)
x=20: broken power law (Do09)

$$n(R) = \Sigma_b(R/R_b)^{-\delta}(1 + R/R_b)^{-\alpha+\delta}$$

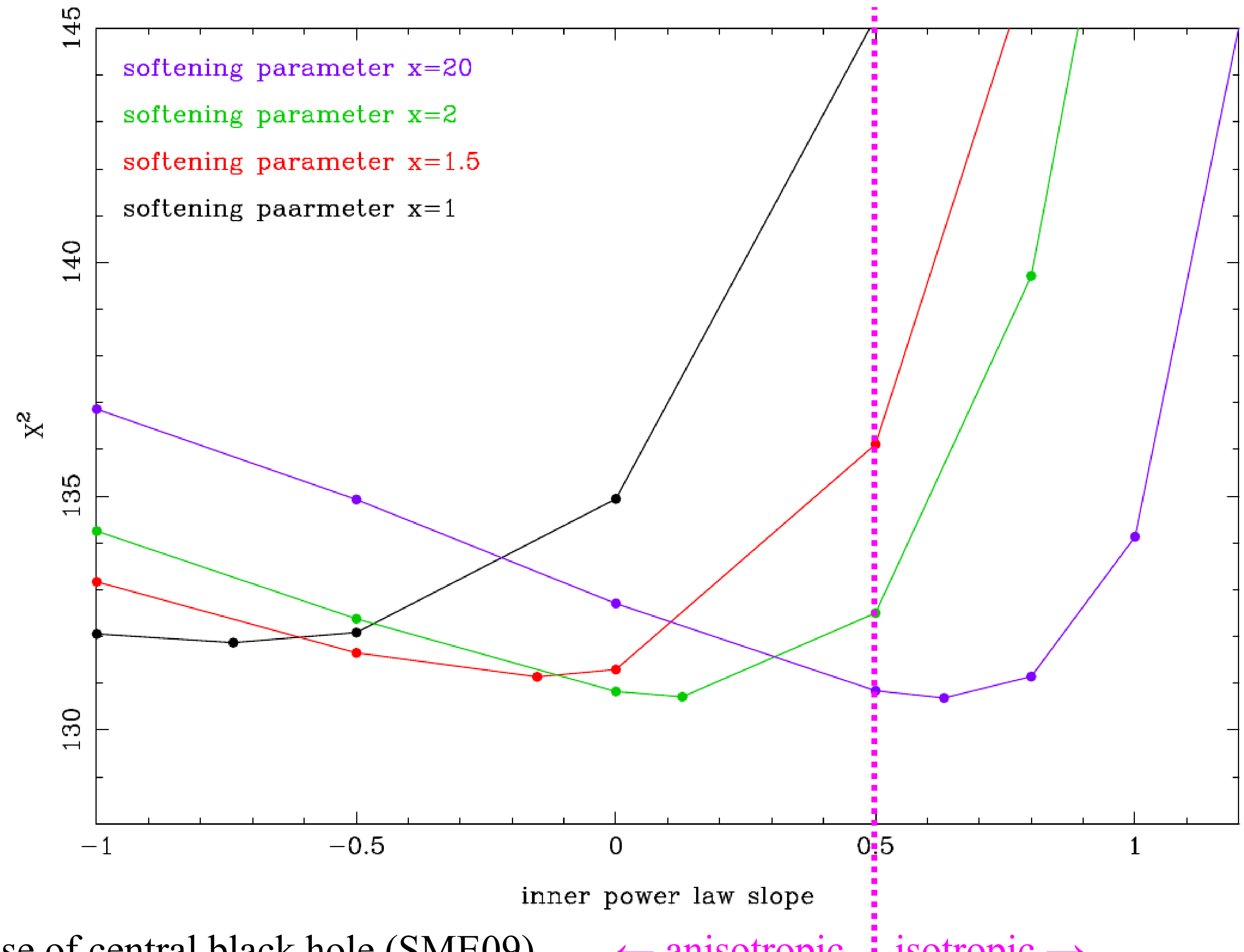
Parametrization of SME09. Their parameters: R_b=20 δ=0.5 α=1.8

Deprojection of radial profile



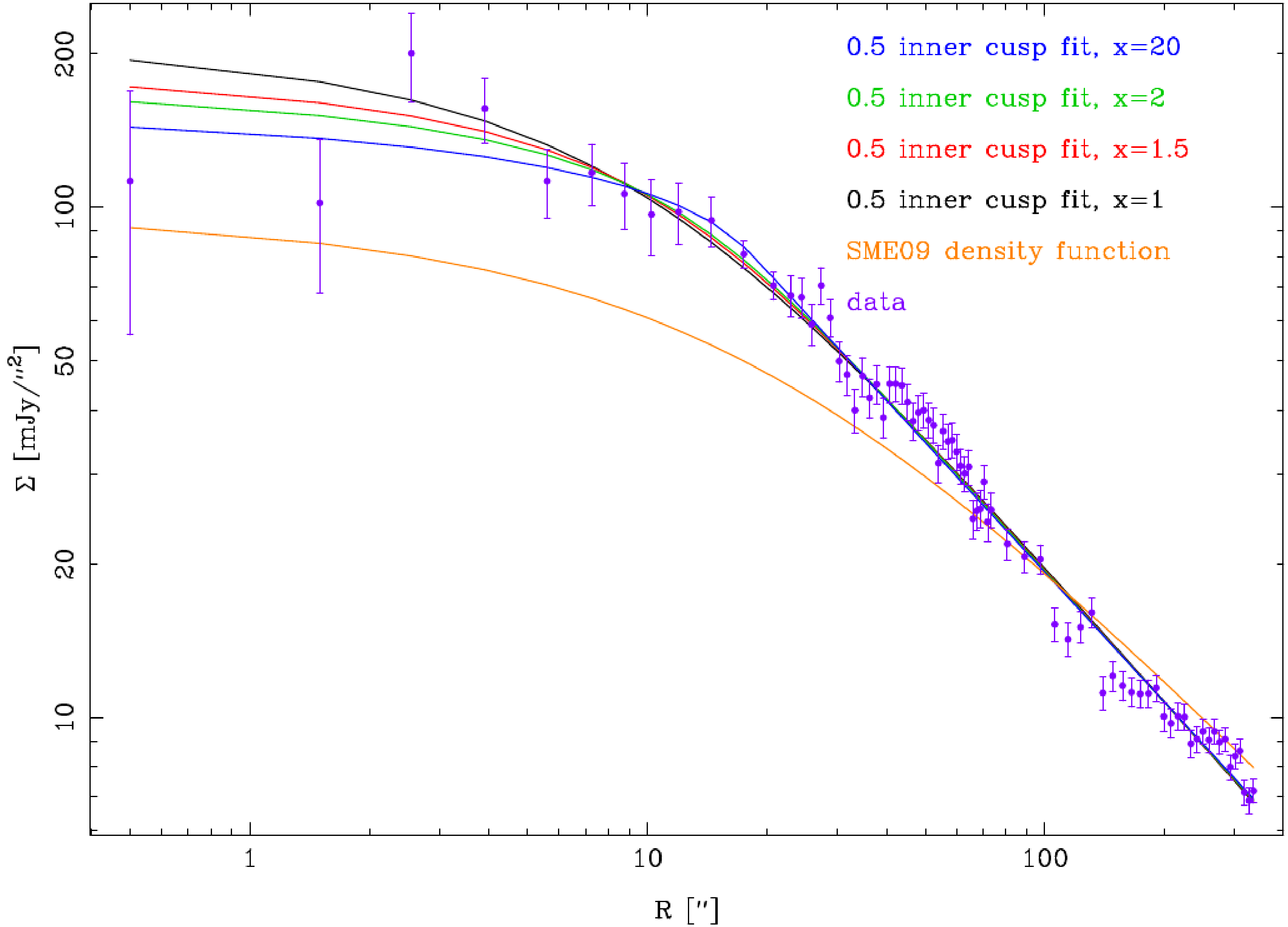


The inner slope is uncertain



In case of central black hole (SME09) ← anisotropic isotropic →

The SME09 profile seems to have a too big core



SME09 profile X^2=534

δ=0.5,x=1: X^2=145

Mass parametrization similar to SME09

- 3 parameters
- Central point mass (SMBH)
- Extended mass, the nuclear cluster:

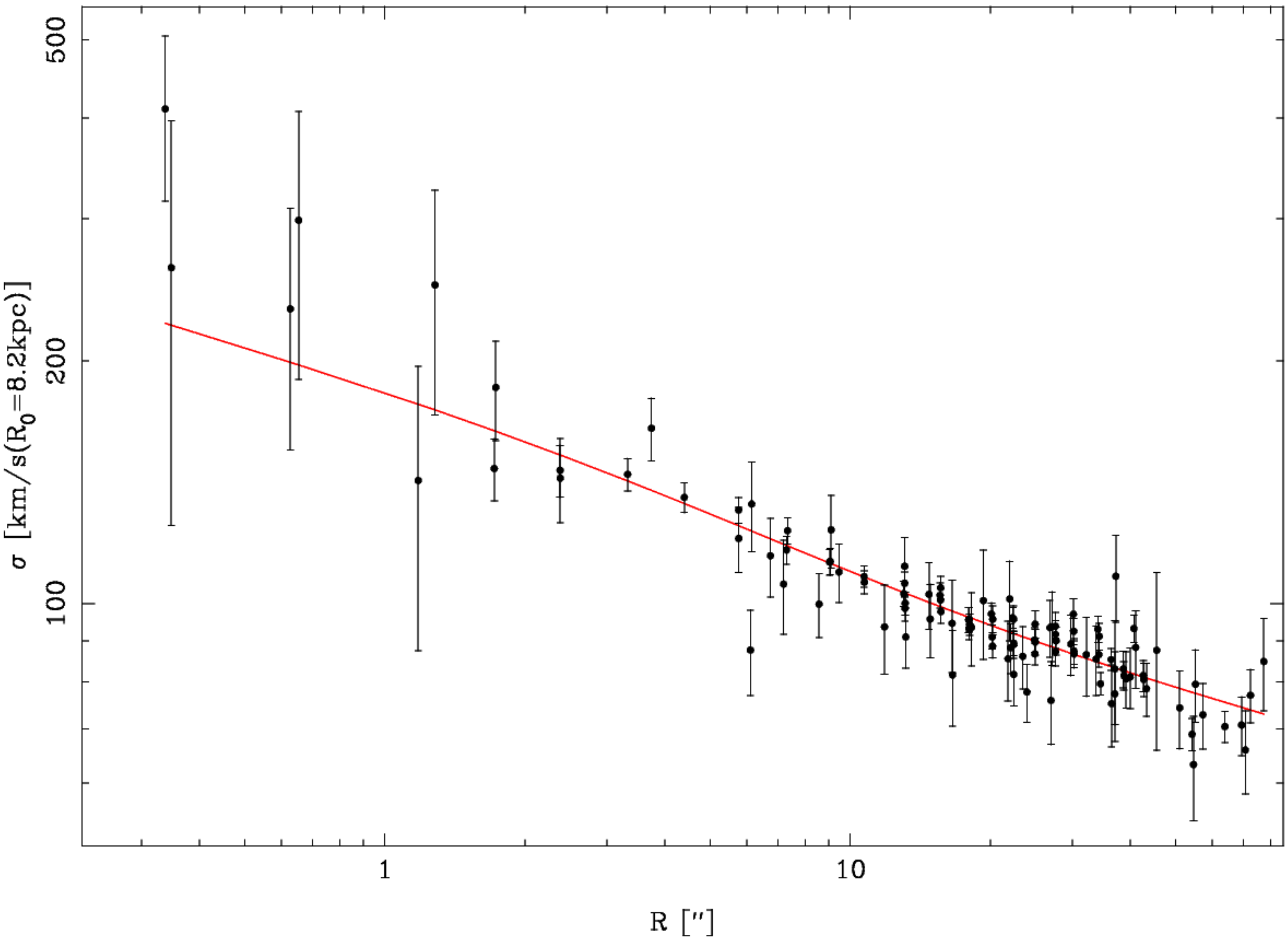
$m(R)=m(R_X)*(R/R_X)^{\gamma}$

R_X ~ R where extended Mass is most certain

Nearly identical to SME09,

only difference: extended mass distribution, transits from an inner free to an outer fixed power law

Too small SMBH mass in free fit

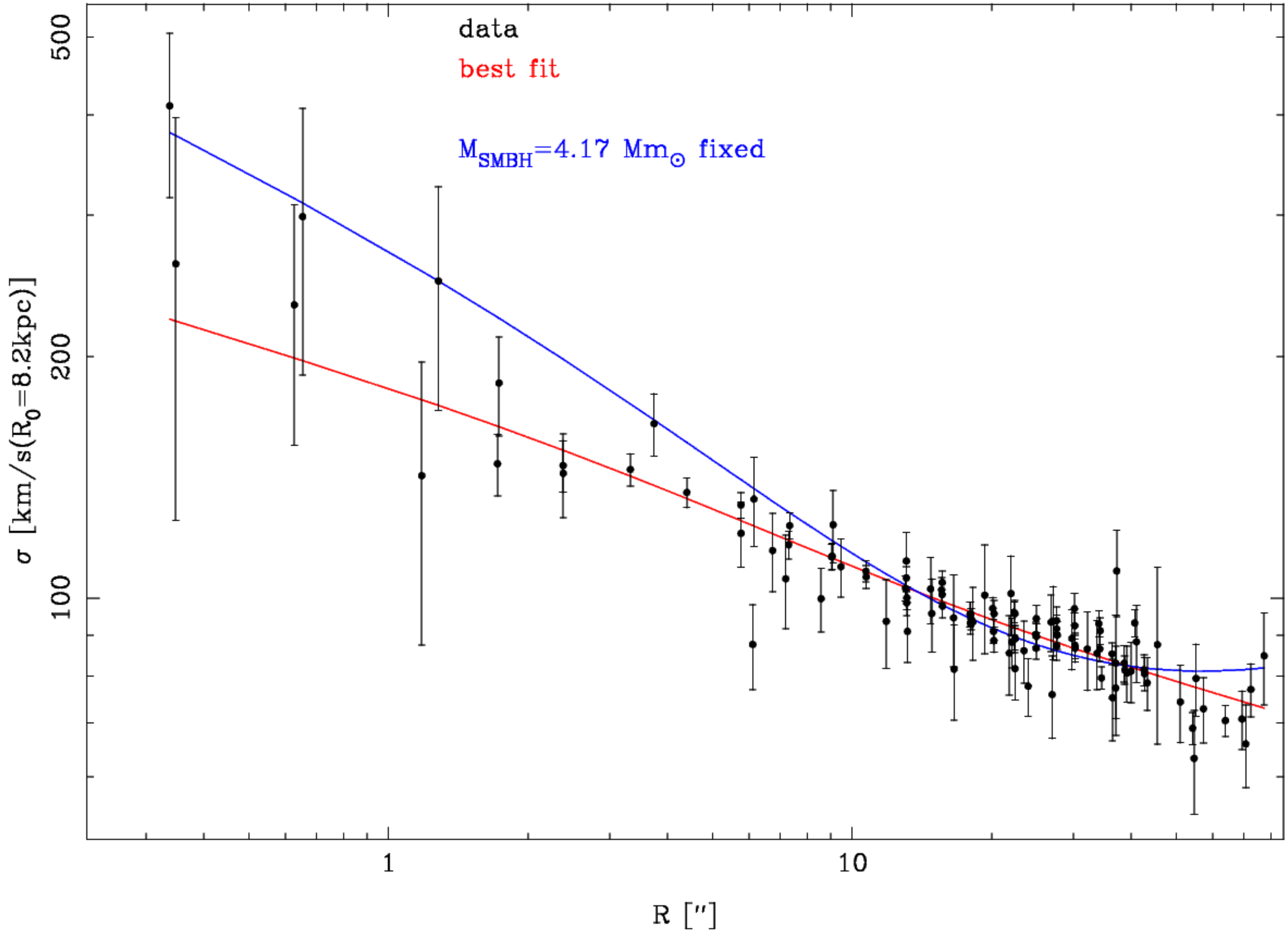


Good fit: X^2/d.o.f.=1.206

M_{SMBH}=(0.63±0.45)*10^6 solar mass not (4.17±0.06)*10^6 (Ghez08,Gillessen09)

Extended mass slope γ=0.696 ±0.059 from the light follows 1.15

Much worse fit with right SMBH mass



X^2: 129.12→ 300.95 discrepancy mainly, within 10"

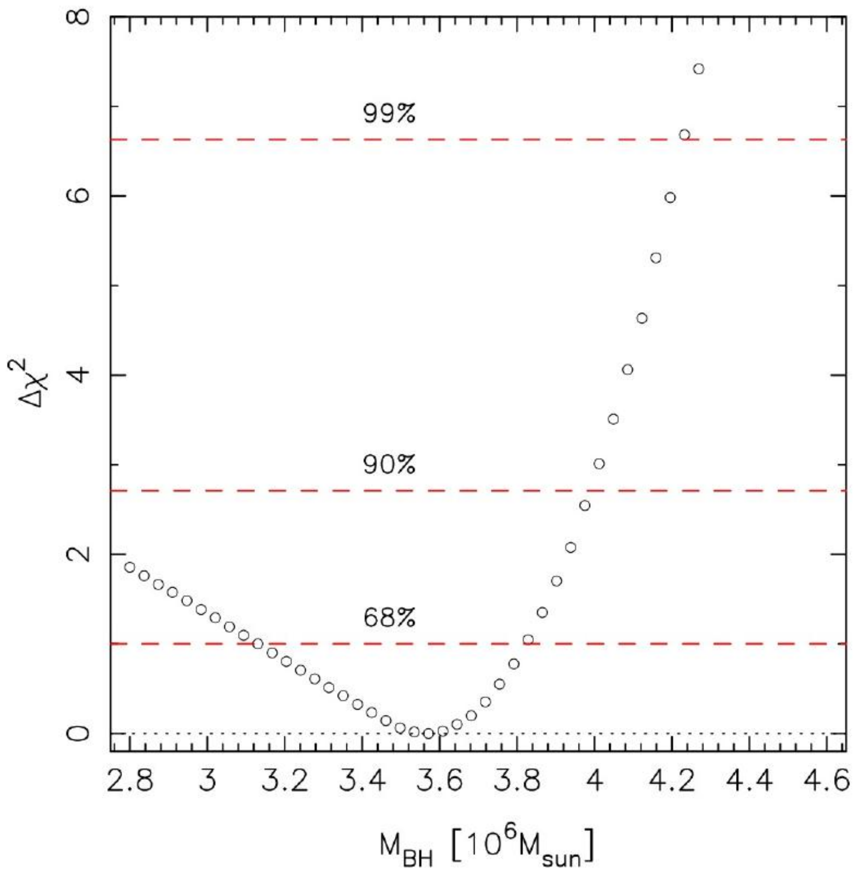
Too small SMBH mass obtained by many from old stars dynamic, e. g.

- McGinn89: ~2.5*10^6 solar masses
- Haller96: ~2.5*10^6 solar masses
- Genzel96: ~2.8*10^6 solar masses
- Trippe08: ~1.2*10^6 solar masses

But

- McGinn89: ~2.5*10^6 solar masses
- Haller96: ~2.5*10^6 solar masses
- Genzel96: ~2.8*10^6 solar masses
- Trippe08: ~1.2*10^6 solar masses
- SME09: 3.6*10^6 solar masses

consistent with orbit mass

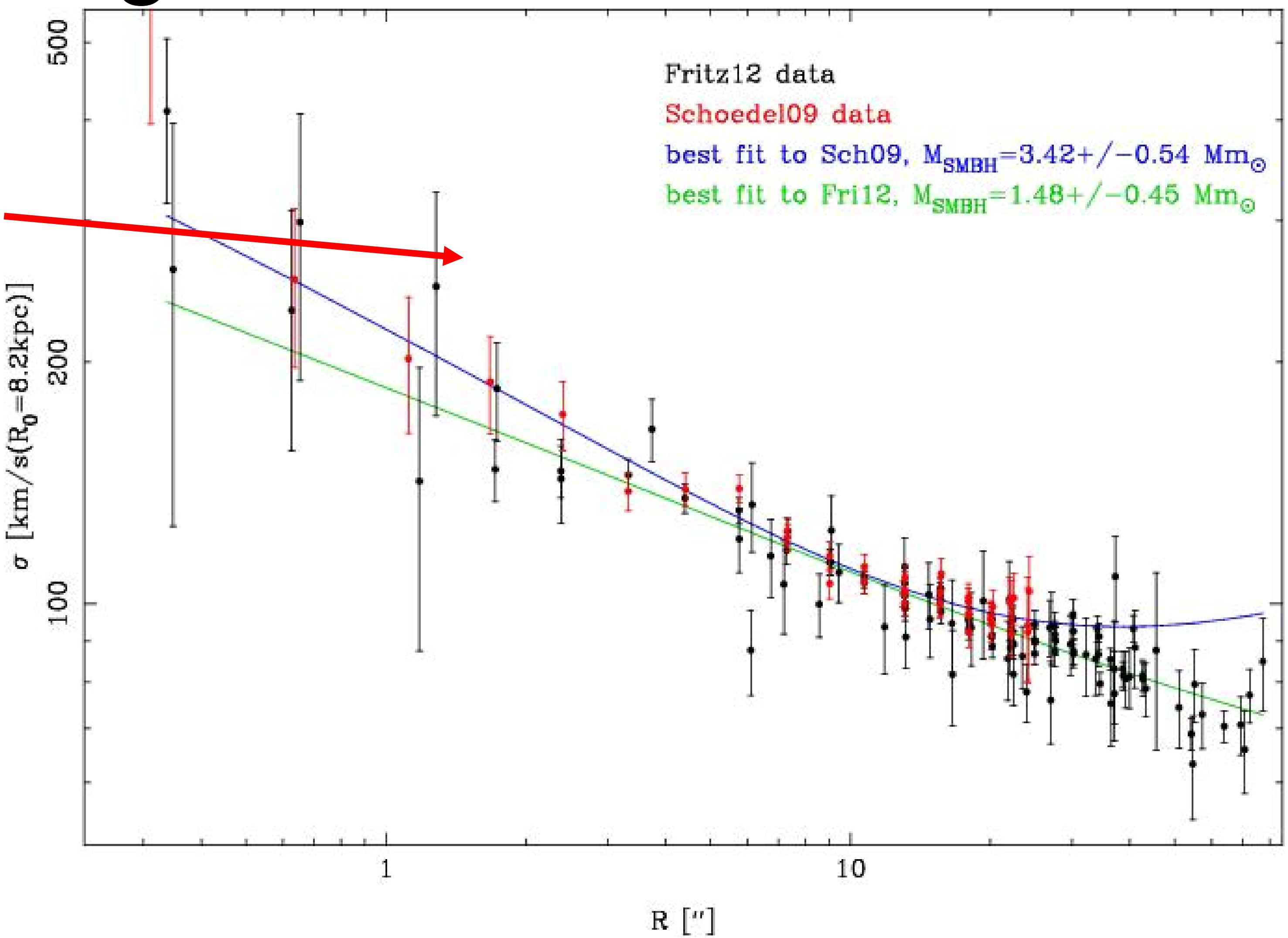


SME09 use nearly the same method as I

Why different mass?

Using the SME09 data for fitting

Higher central dispersion in the SME09 data

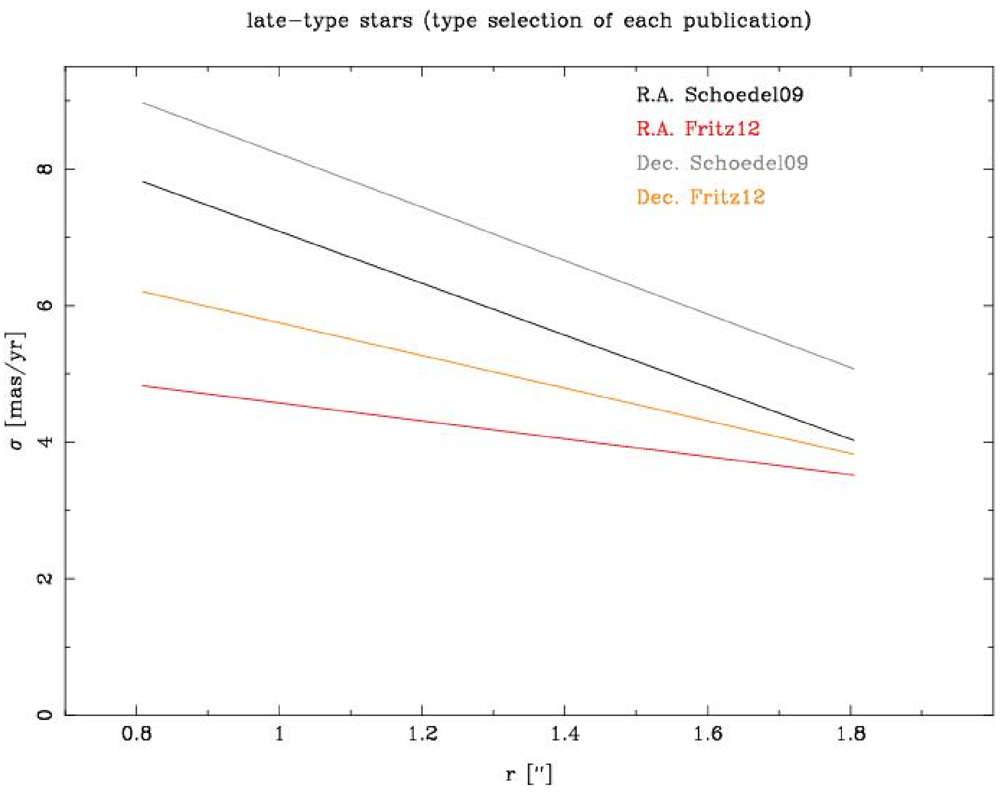


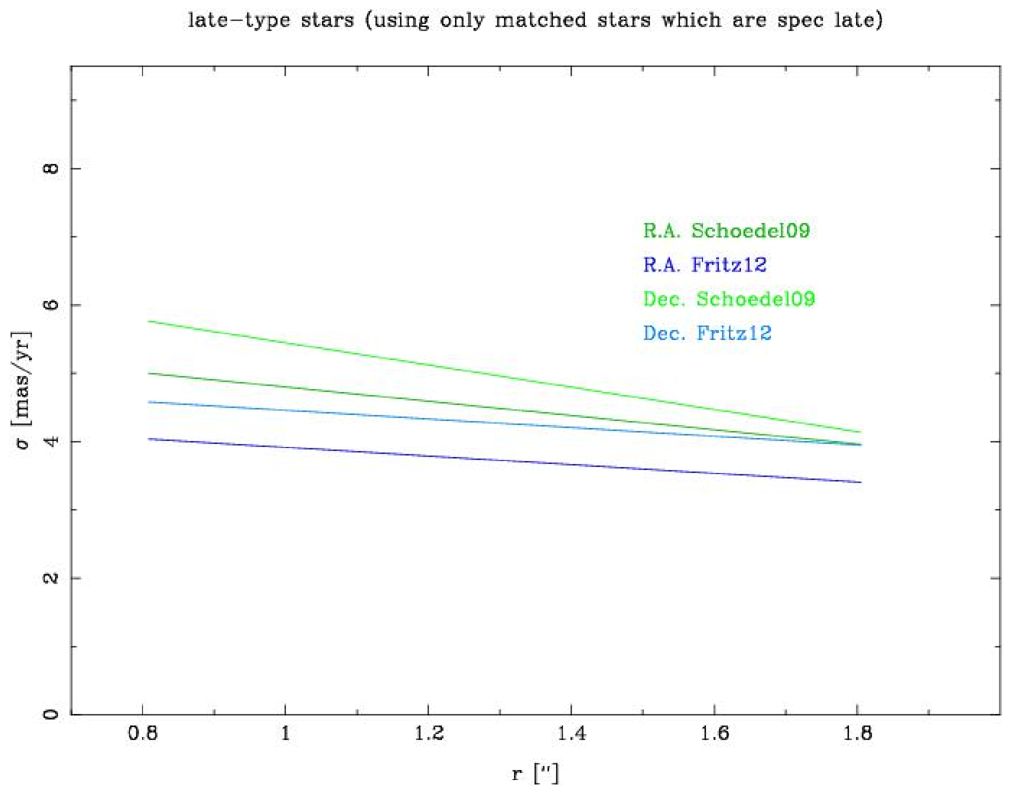
Consistent with their value in their paper

Uses the SME09 tracer profile

SMBH Mass from orbits: (4.17± 0.06) 10^6 m_{solar} (Gillessen09, for R_0=8.2 kpc)

What is the reason of the higher dispersion in the SME09 data?

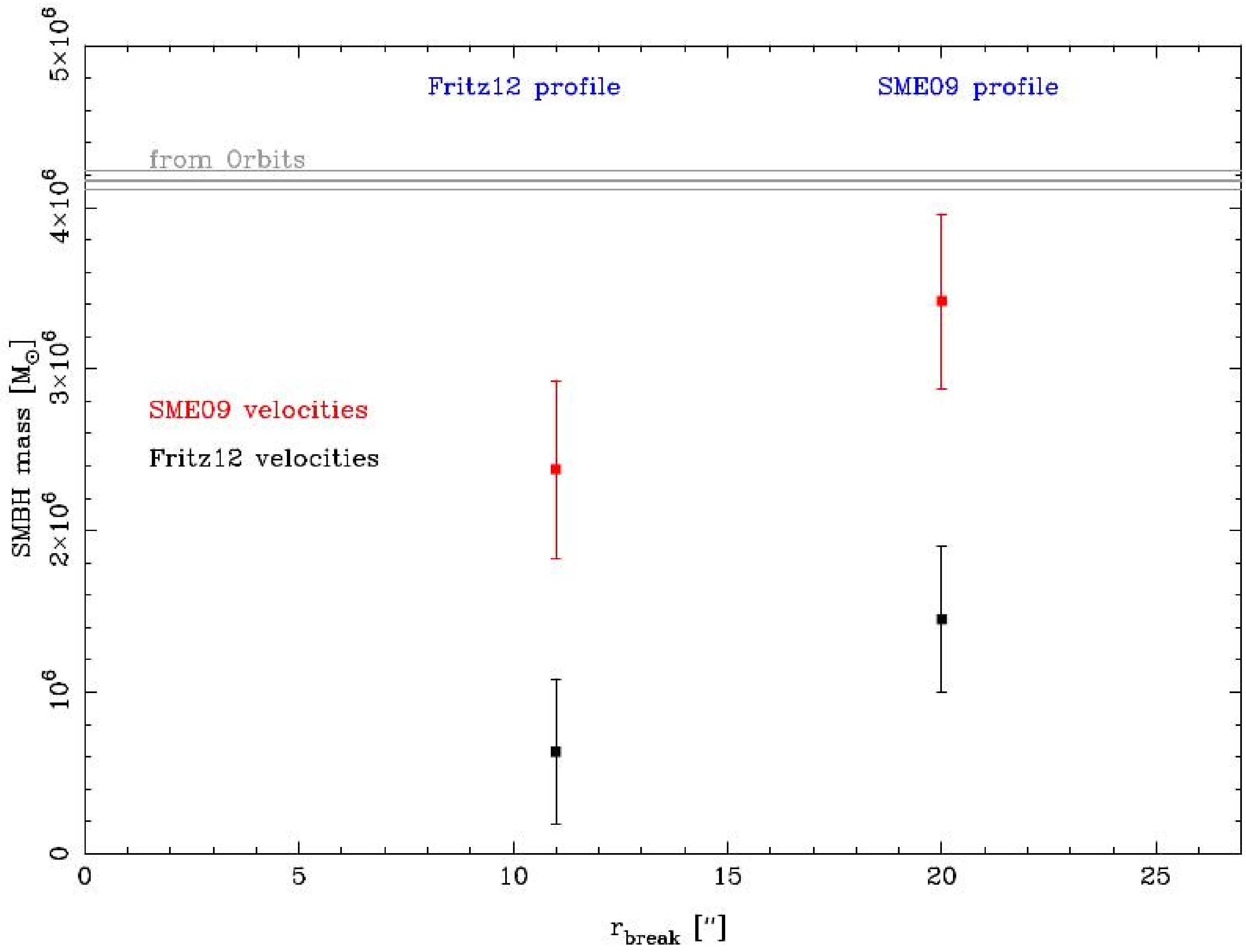




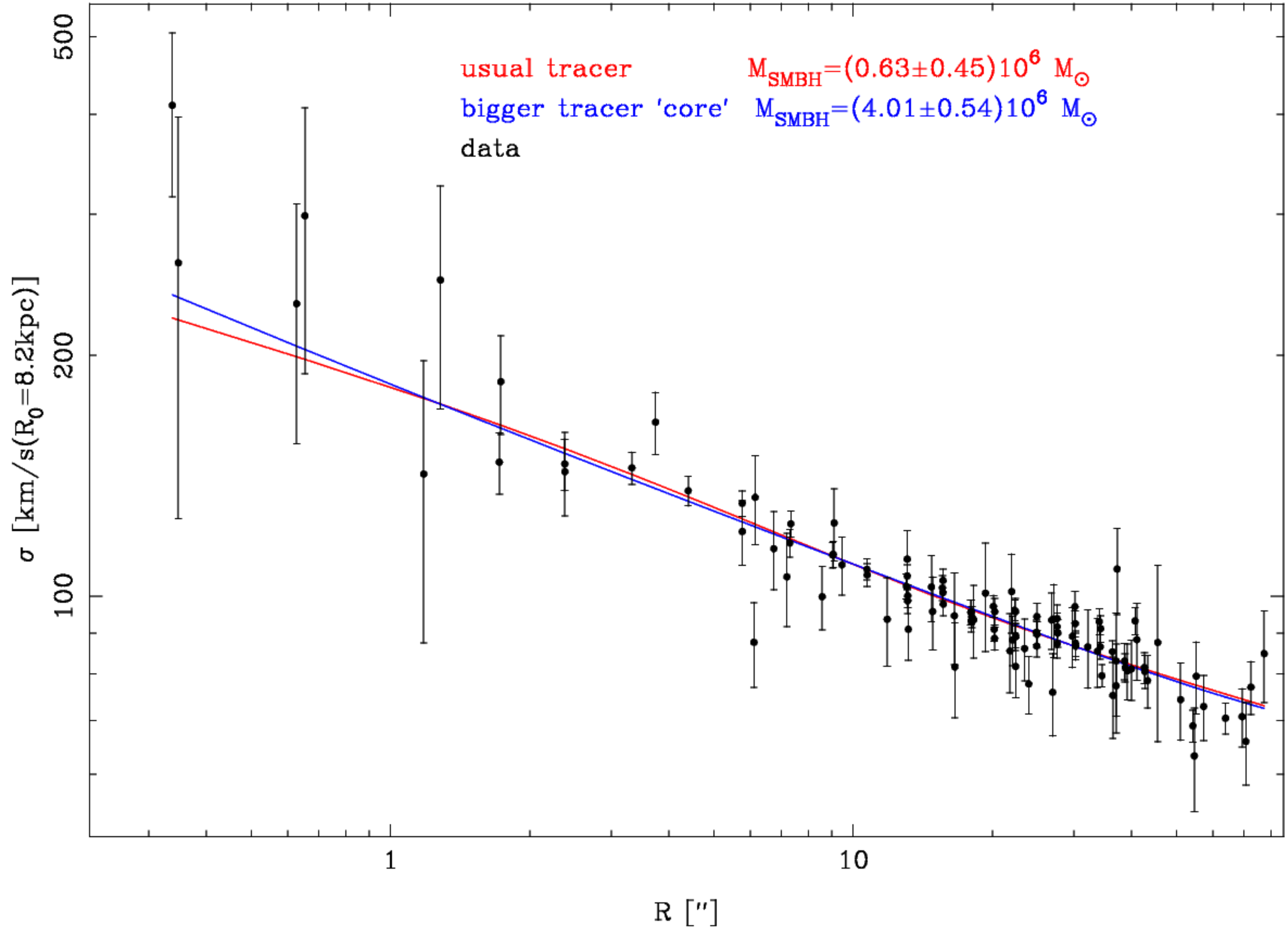
Main reason type selection:
myself: only spectral late-type stars.
SME09: photometric selection, some of their late-type stars are spectral early-type stars.
Early-type stars are more concentrated and move thus faster.

Minor reason:
I have smaller dispersions for the same stars. My measurements uses a longer time line and more than 10 times more images.
Possible in SME09 underestimated velocity errors enlarge the dispersion.

Impact of tracer profile choice

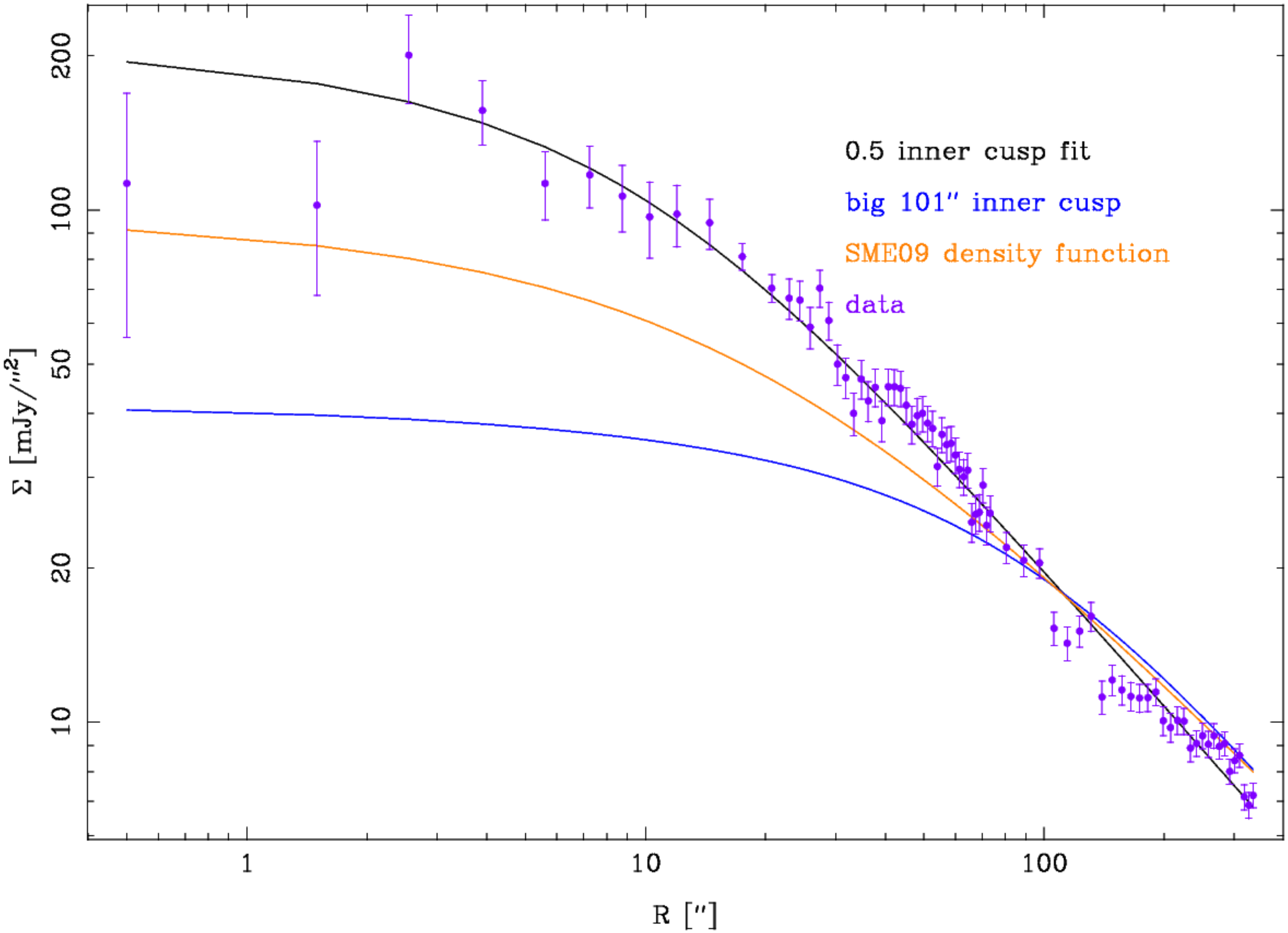


Bigger tracer core gets the right mass



r_{break}: 11" →101" !!!

Profile which fits mass does not fit light



fit to SMBH mass X^2=1115

fit to light X^2=145 !!!

Flatter inner slope probable not the solution

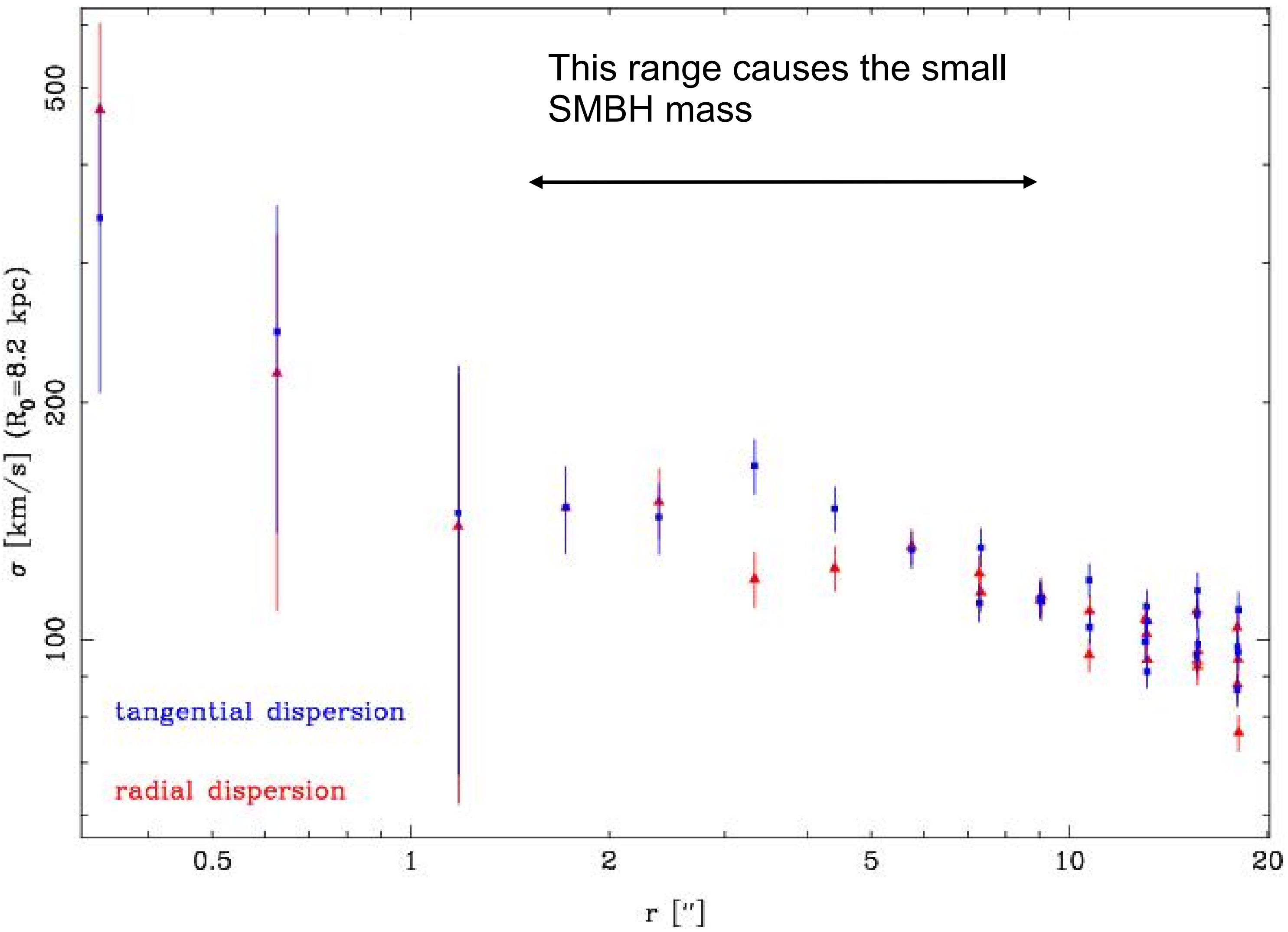
Many (e.g. Genzel10): the flatter inner tracer slope leads to SMBH mass underestimation and a bigger error

But why should there be a bias?

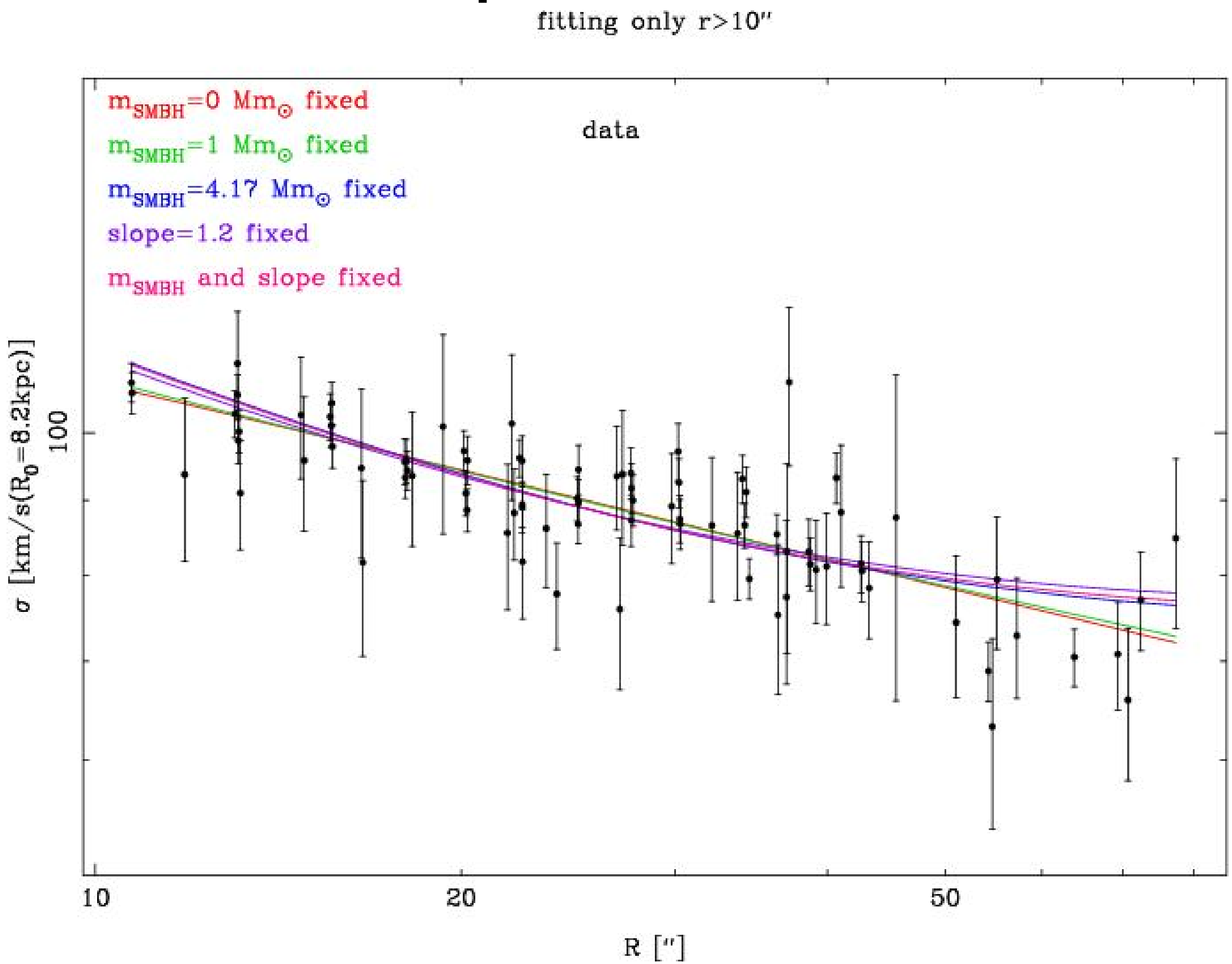
The possible tracer profile obtain similar masses.

The error due to the tracer profile is small, because: the core is small compared to the sphere of influence

Anisotropy is not the obvious solution

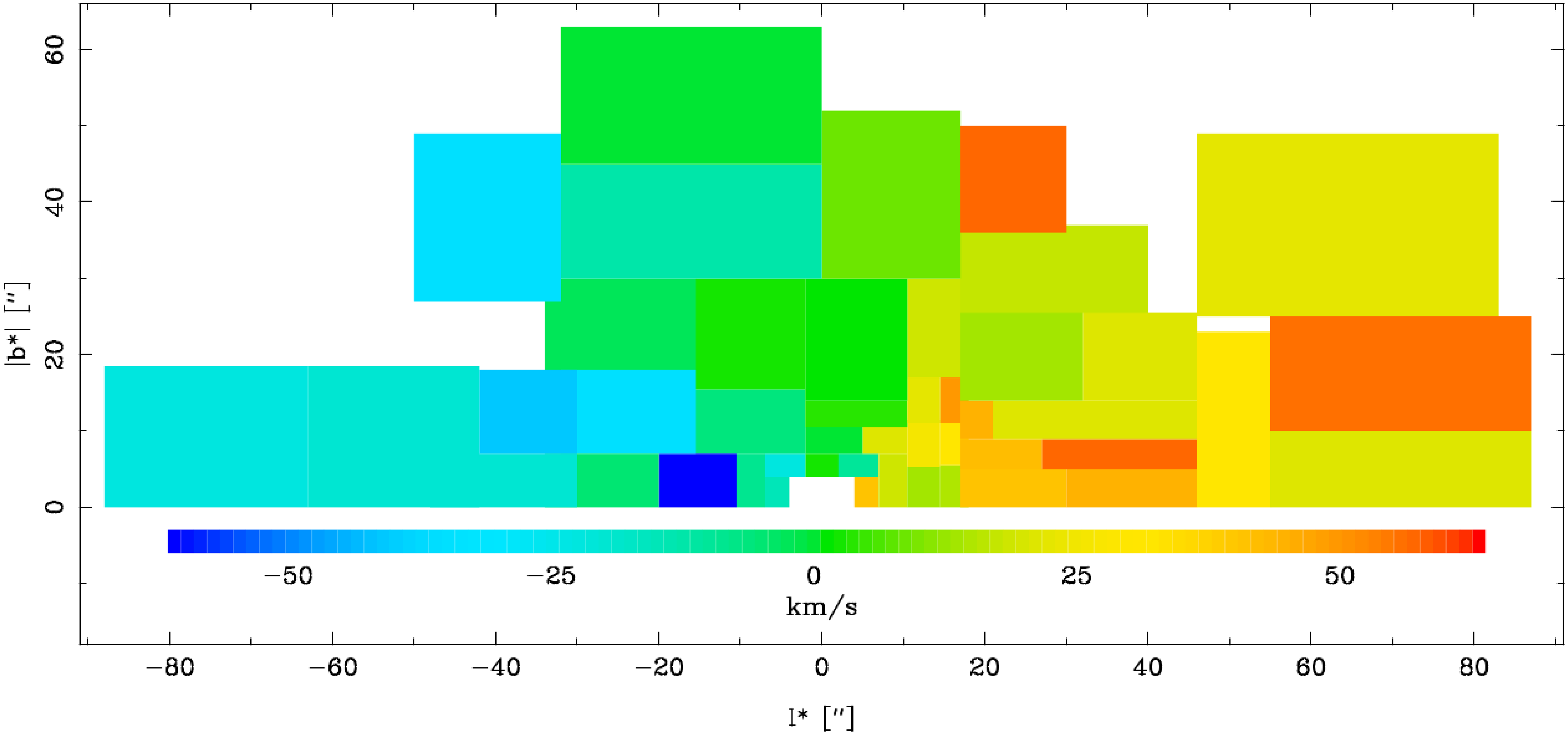


Current ‘solution’ for the SMBH mass problem

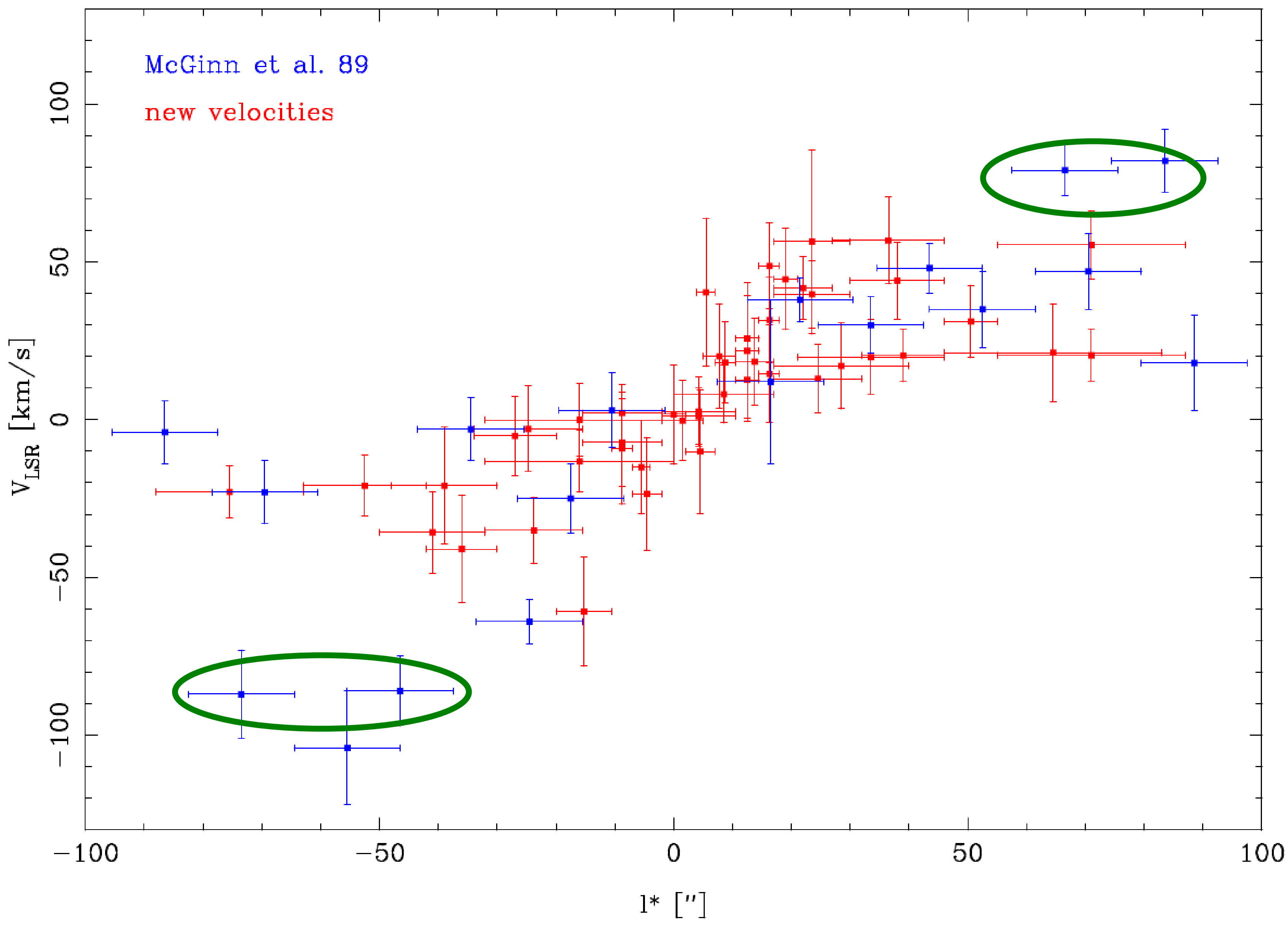


Smaller difference: M=0: X^2/d.o.f.=1.157, M=4:X^2/d.o.f.=1.3861
For M=4: γ= 1.178+/-0.056 consistent with the light slope of 1.150

Data: mean radial velocities

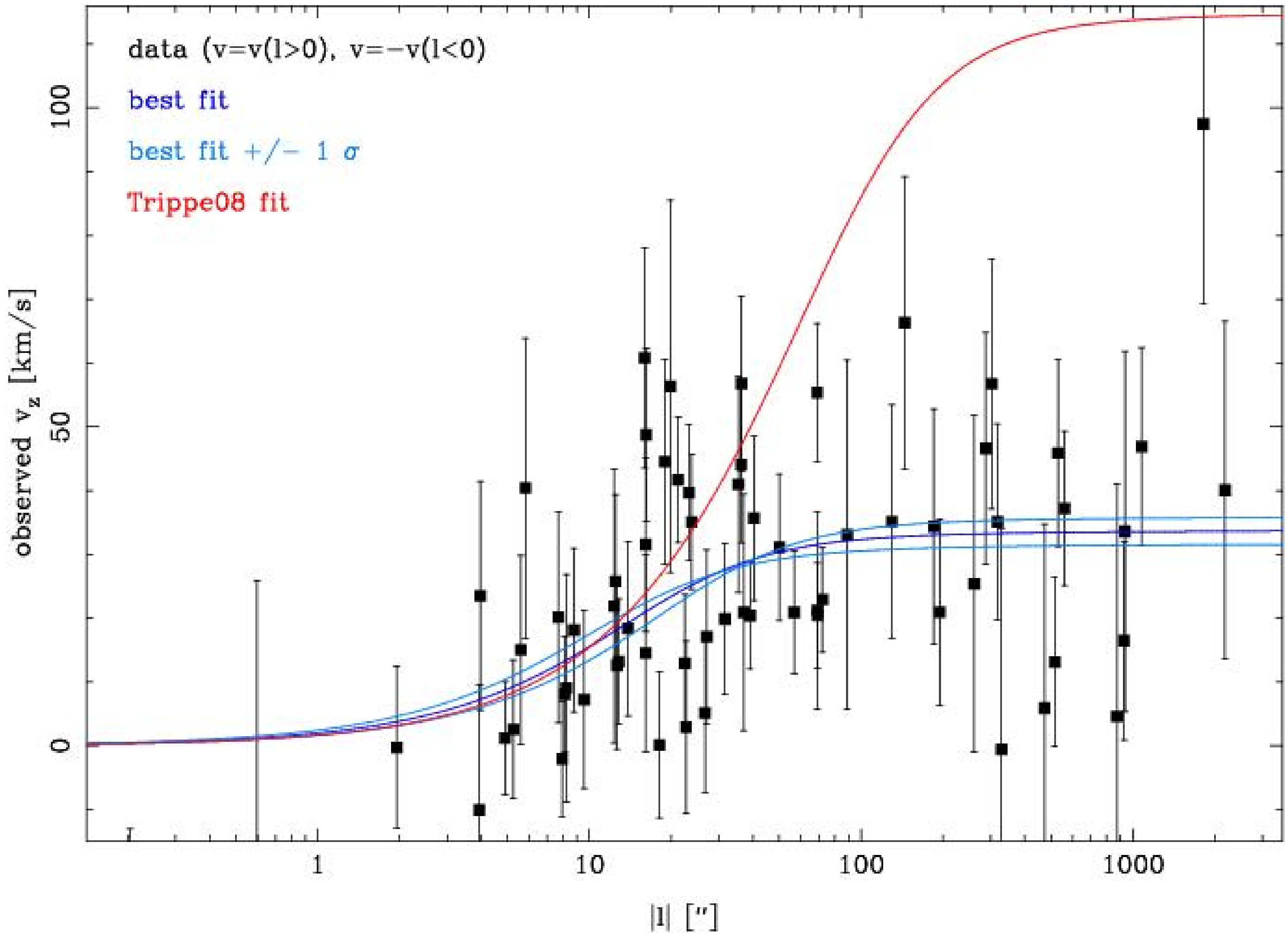


Comparison with the literature



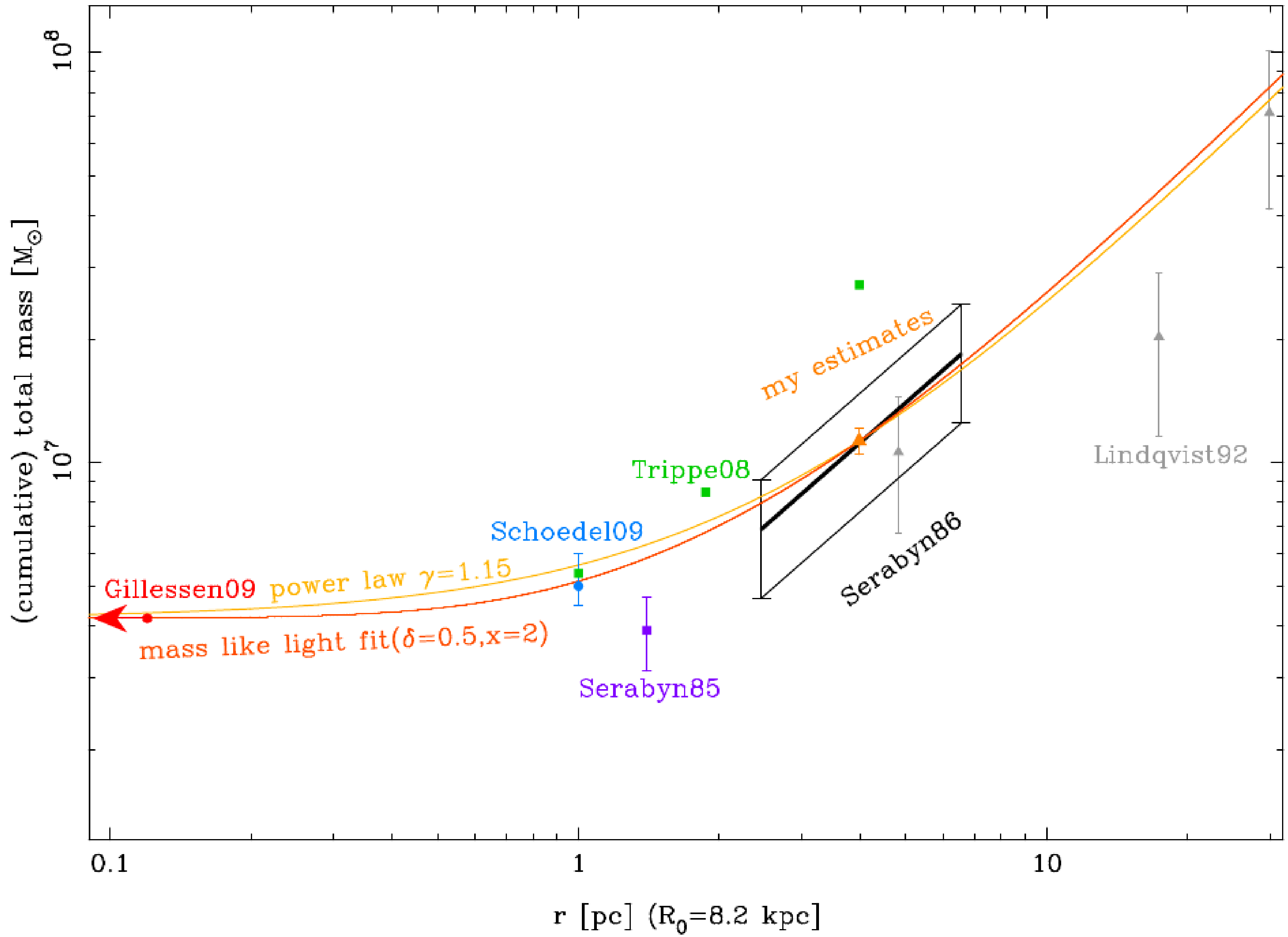
Used by Tripple08

Tripp08 overestimated rotation



Maser velocities from
Lindqvist92, Deguchi04

Preliminary: from Jeans modelling with rotation



Nuclear cluster conclusions

- The nuclear cluster is big in the light, no bulge visible inside 300''
- The black hole mass is severely underestimated, no obvious solution
- Less rotation than assumed by Trippe08
- Mass within 100'' about 7 million solar masses
- M/L_K=0.6 consistent with (Kroupa)Chabrier IMF
- Does this fit globular cluster migration to the center?