The Galactic Centre Environment

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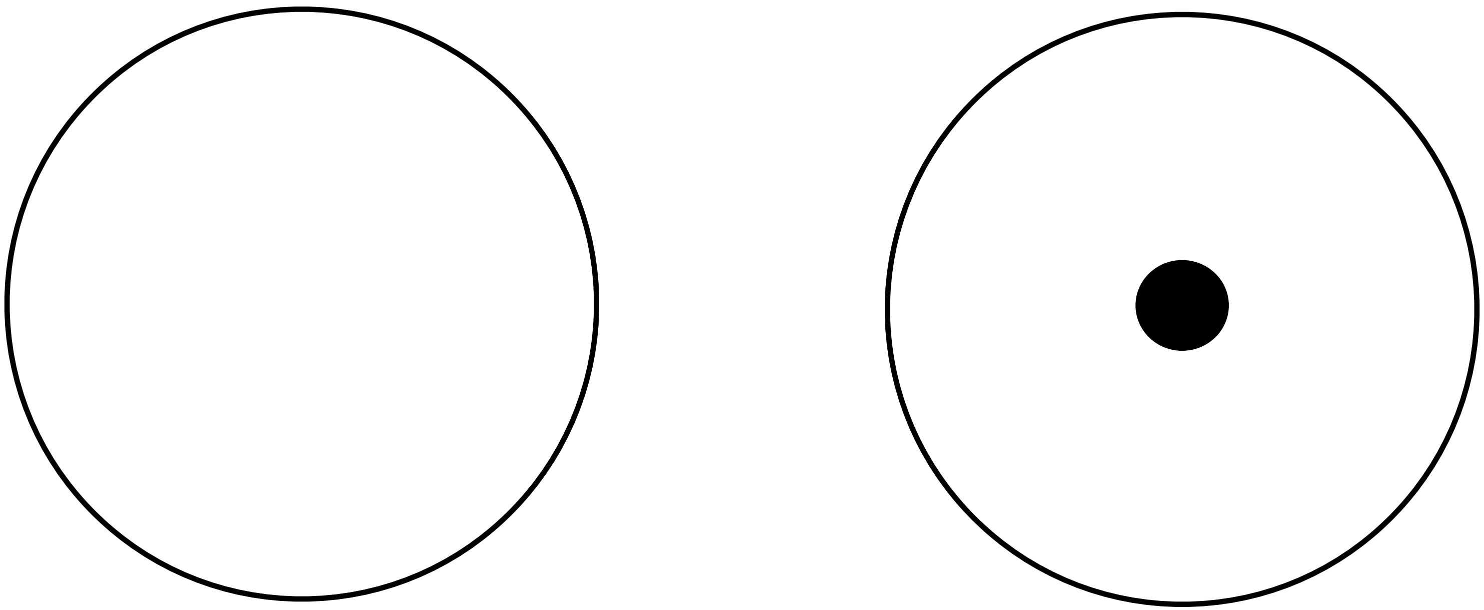
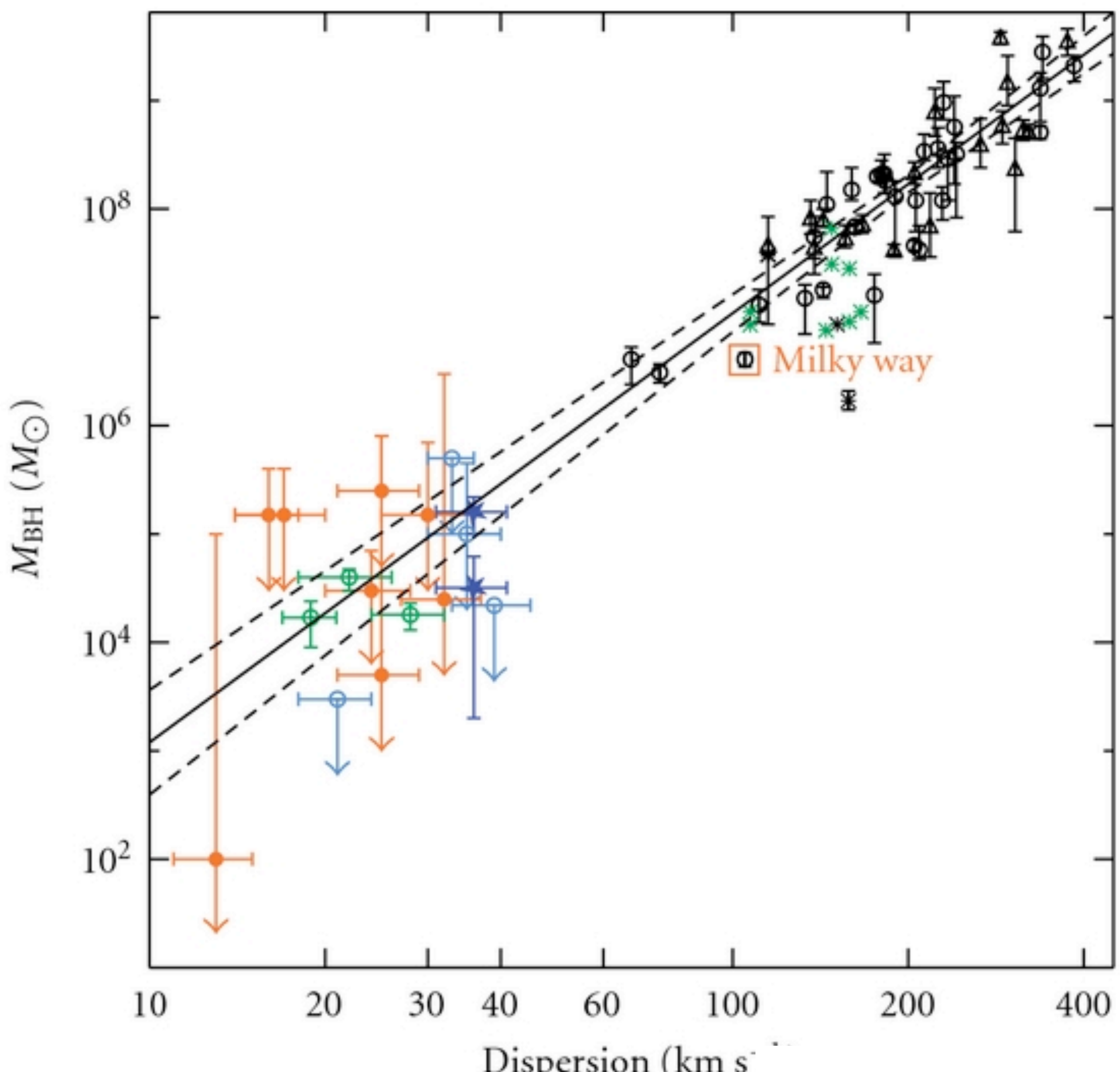
Two types of stellar clusters



No BH

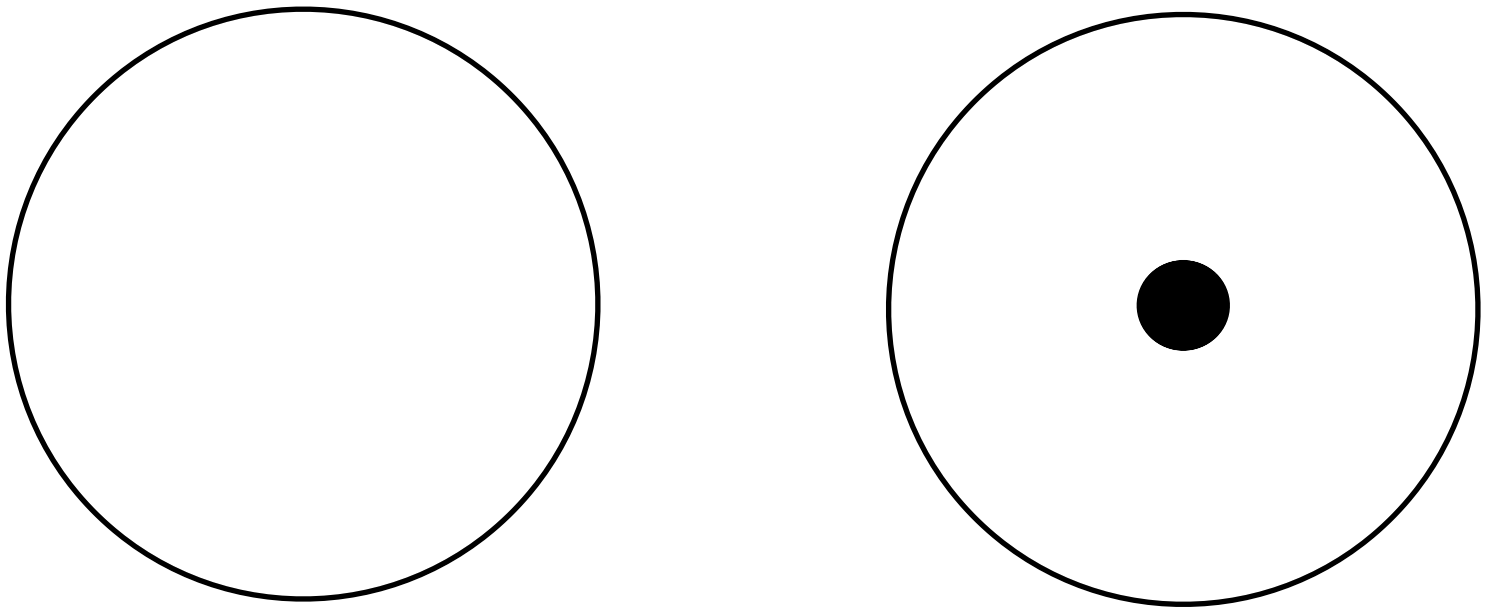
Contains BH

Nuclear Stellar Clusters



(Neumayer & Walcher 2012)

Two types of stellar clusters



No BH | Contains BH

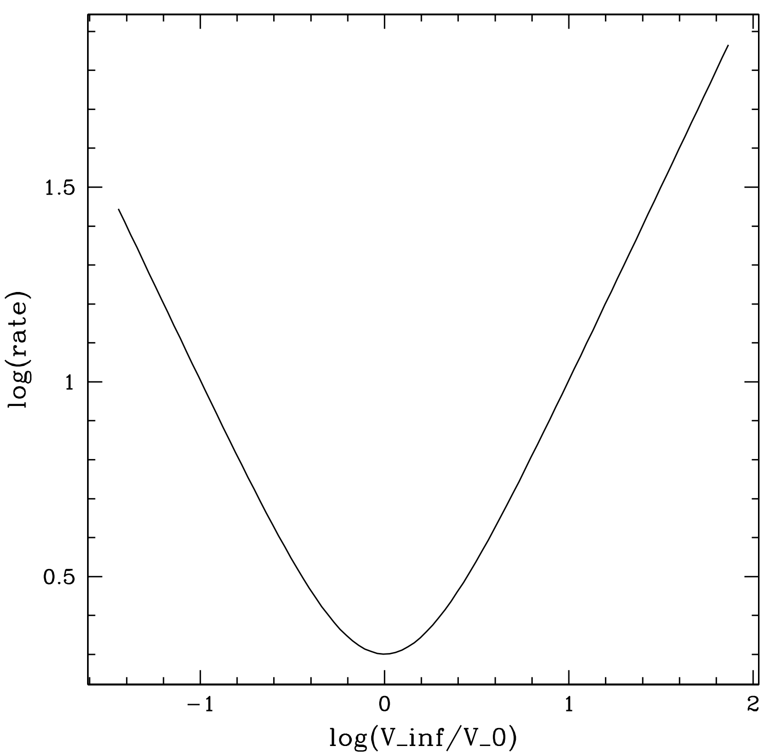
GCs | *odots*

Stellar collision timescale

Cross section is given by

$$\sigma = \pi R_{min}^2 \left(1 + \frac{2G(M_1 + M_2)}{R_{min} V_\infty^2}\right)$$

Encounter rate is given by $\Gamma = n\sigma V_\infty$



Note: Galactic centre collision rate is close to a minimum owing to the mass of the SMBH, as:

$$\sqrt{\frac{GM_{bh}}{0.1\mathrm{pc}}} \simeq \sqrt{\frac{G\mathrm{M}_\odot}{\mathrm{R}_\odot}}$$

KEY IDEA #1

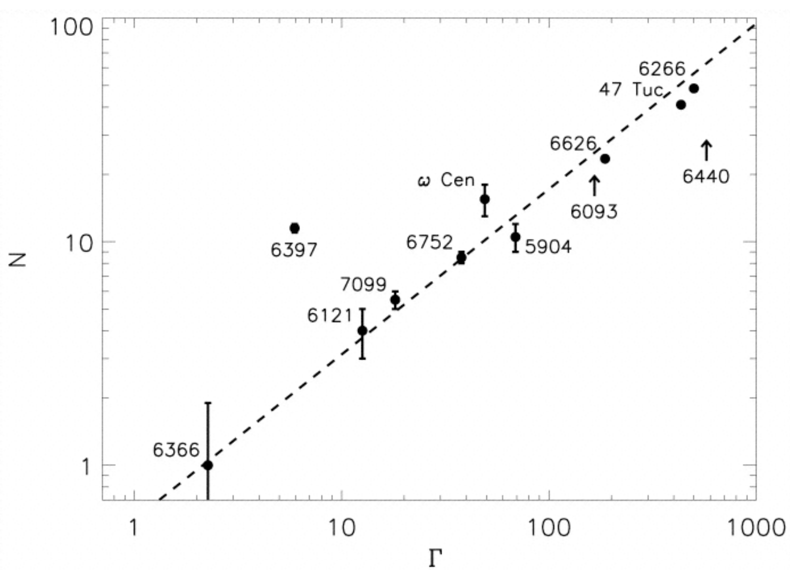
Stellar collision rates are a function of the mass of the supermassive black hole.

Binary-single encounters

- Hard-soft boundary

$$d_{\rm hs} \simeq 6{\rm AU}\left(\frac{V_\infty}{10{\rm km/s}}\right)^{-2}$$

- Soft binaries get broken up
- Hard binaries get harder
- Clean exchanges: lowest-mass star ejected



(In *GCs*: Pooley et al. 2003)

But encounters generally break up binaries for larger Vs.

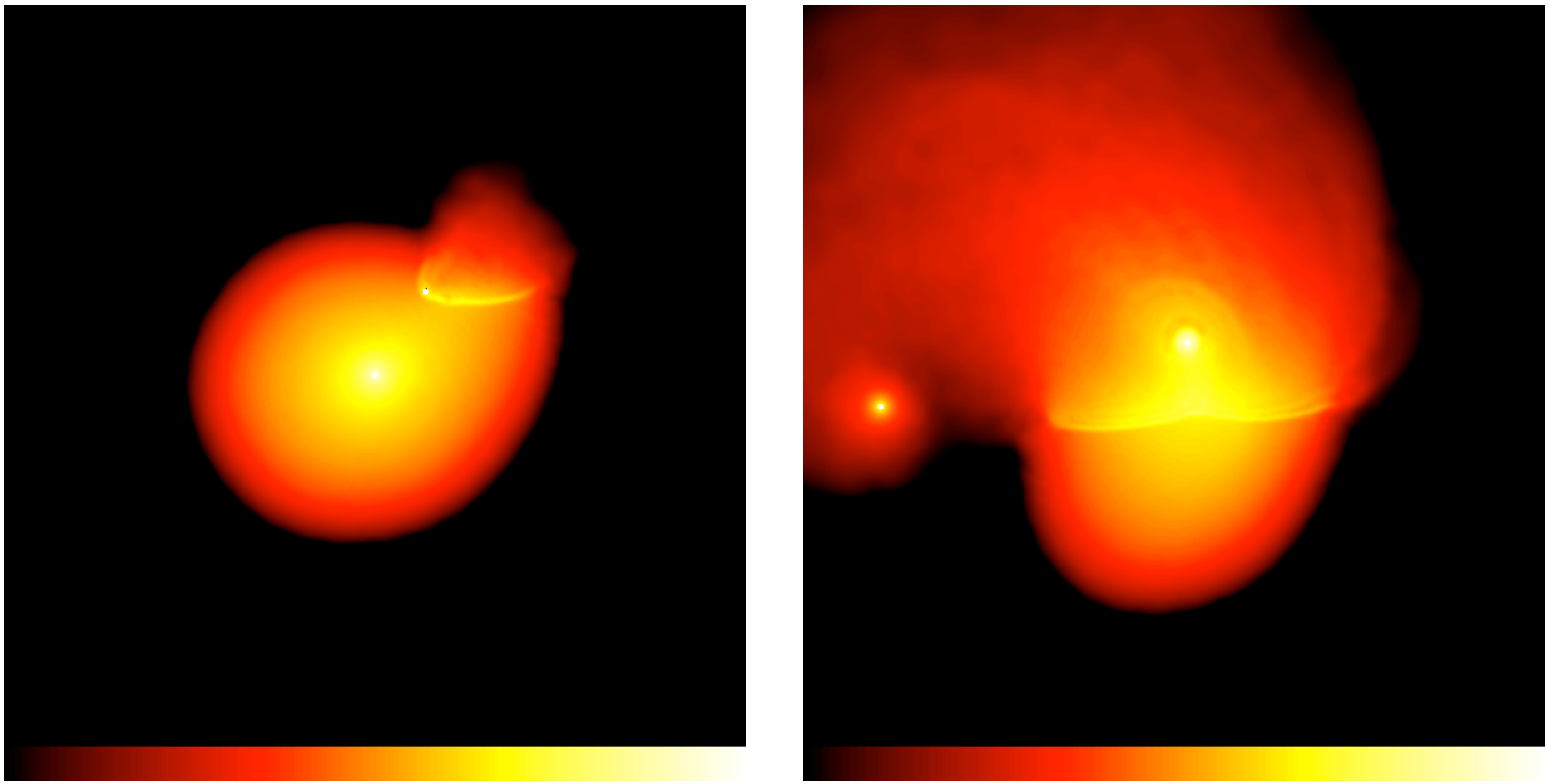
KEY IDEA #2

Encounters tend to break up binaries rather than make interesting objects in *odot* systems *as hard becomes soft.*

RG-BH collisions

Stopping power ~escape speed of RG (Bailey & Davies 1999).

RG-BH collision with v_∞=800kms^{-1},R_{min}=10$R_\odot$, 1$M_\odot$ giant, 10$M_\odot$ BH



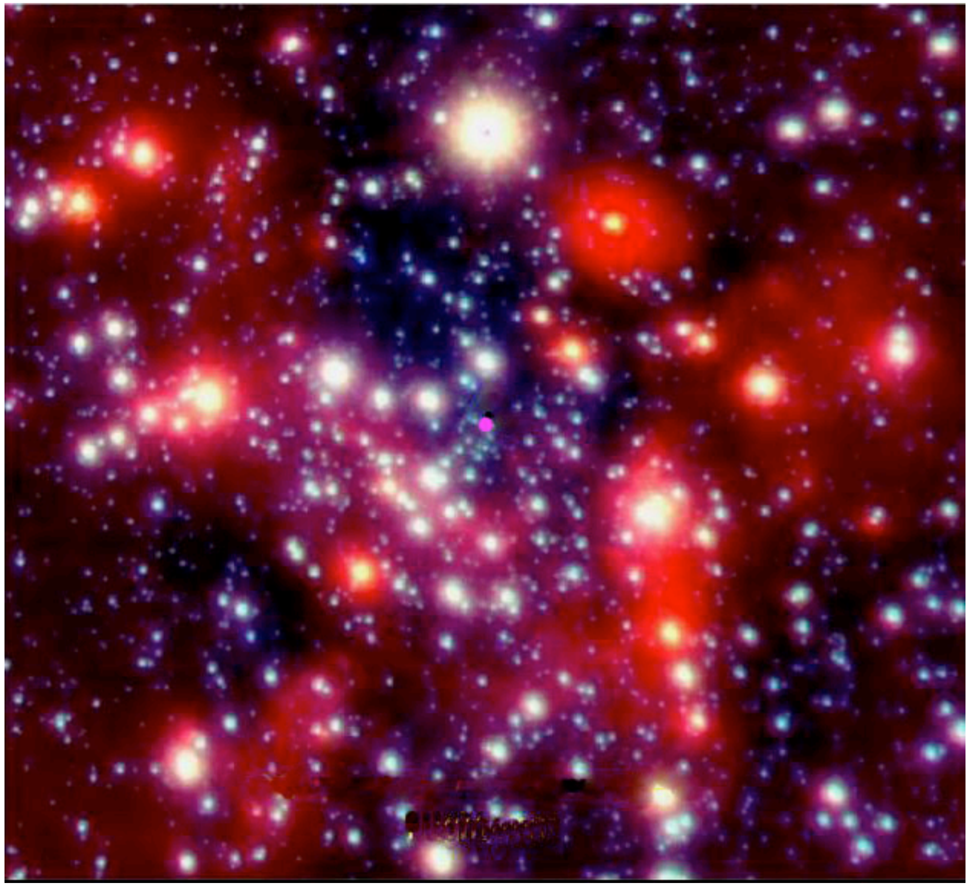
(Dale et al. 2009)

However: RG-MS/NS/WD leave a RG (because 1=2)

KEY IDEA #3

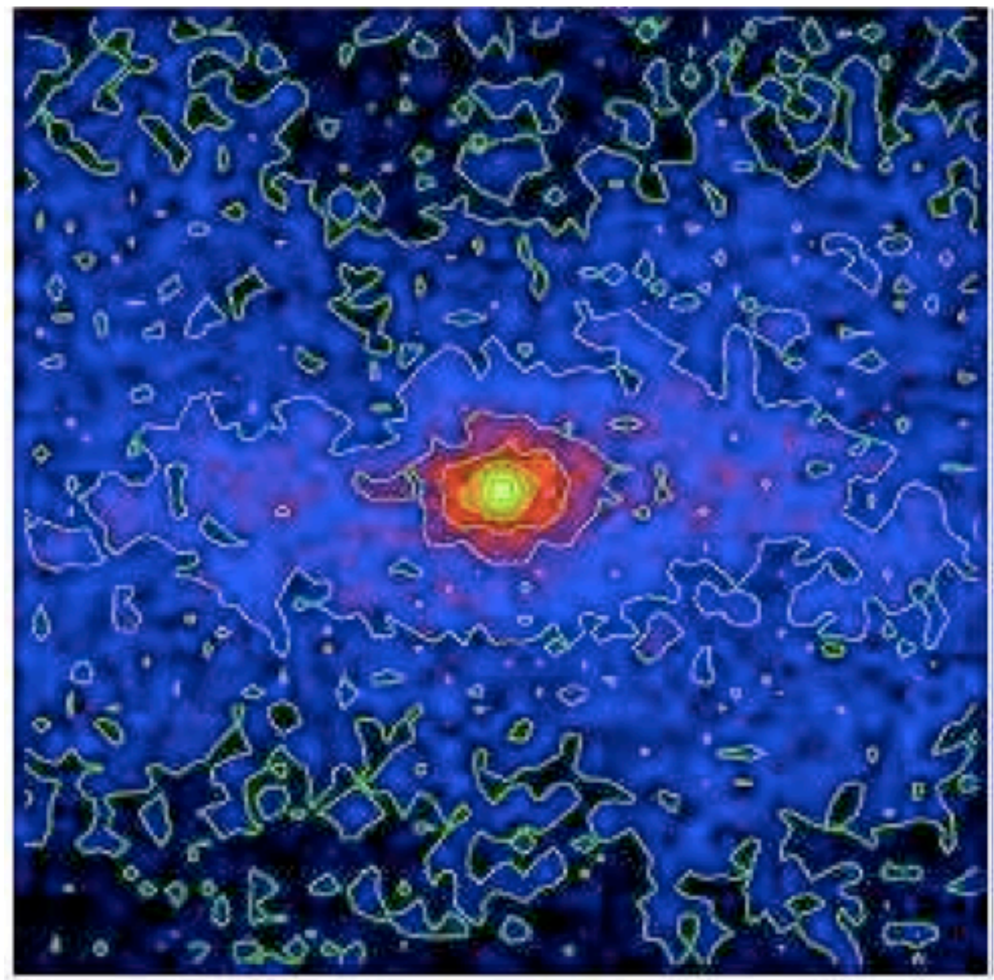
Encounters with RGs may not produce common envelope systems in *odot* systems *so RGs may be harder to destroy.*

The Galactic Centre

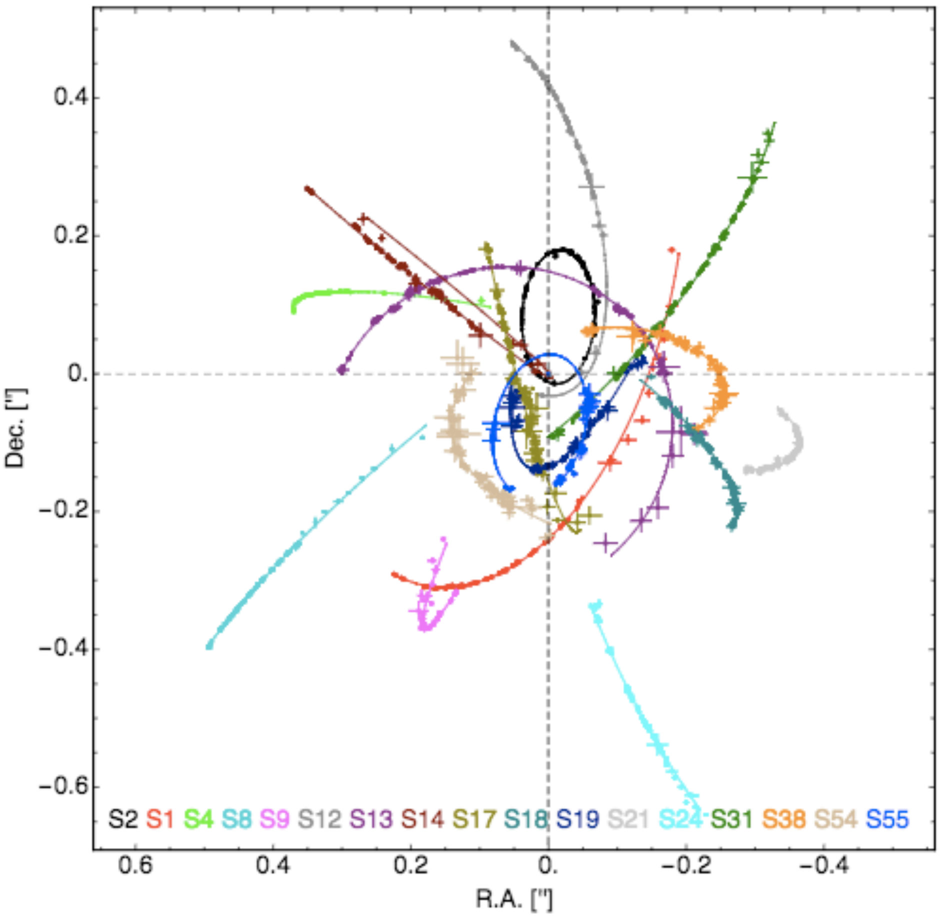


(Genzel et al. 2003)

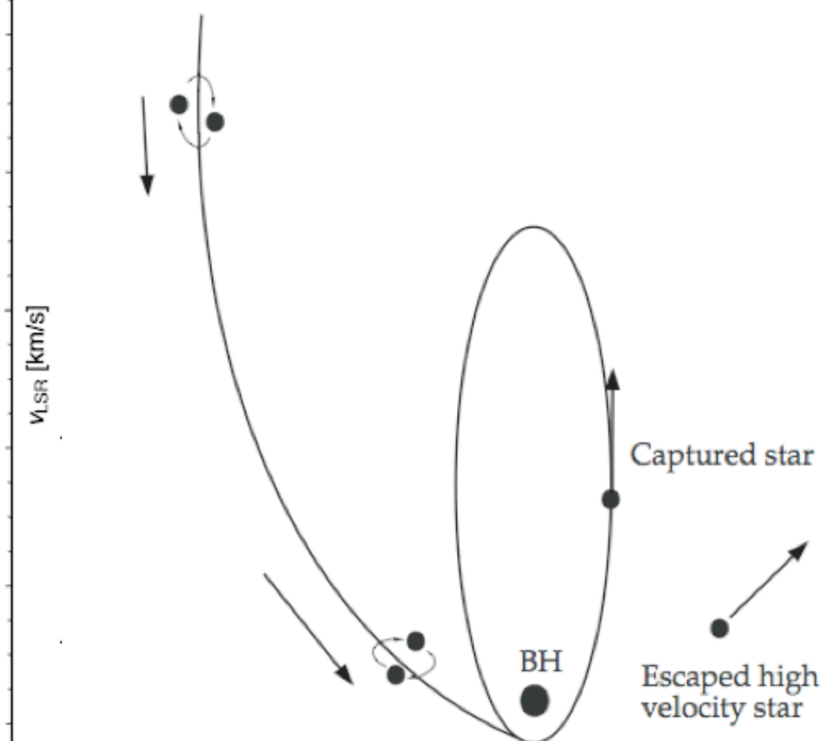
(Fritz et al. 2014)



S-Stars very close to the SMBH



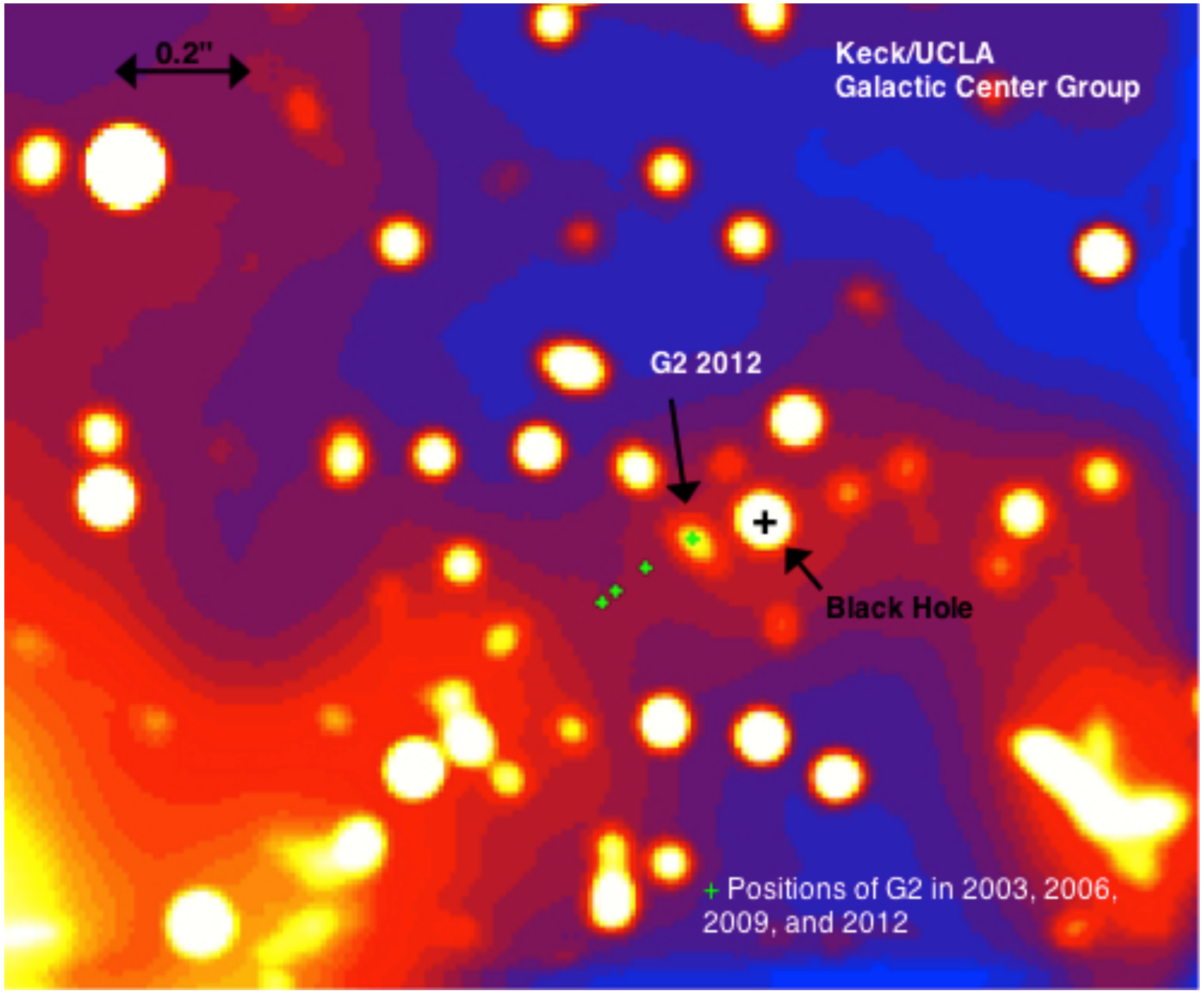
(Gillessen et al. 2009, 2016)



(Hills1988)

See talk by Maryam Habibi

G2, G1 et al. in the Galactic Centre



Produced in RG-X collisions?

(Gillessen et al. 2012)

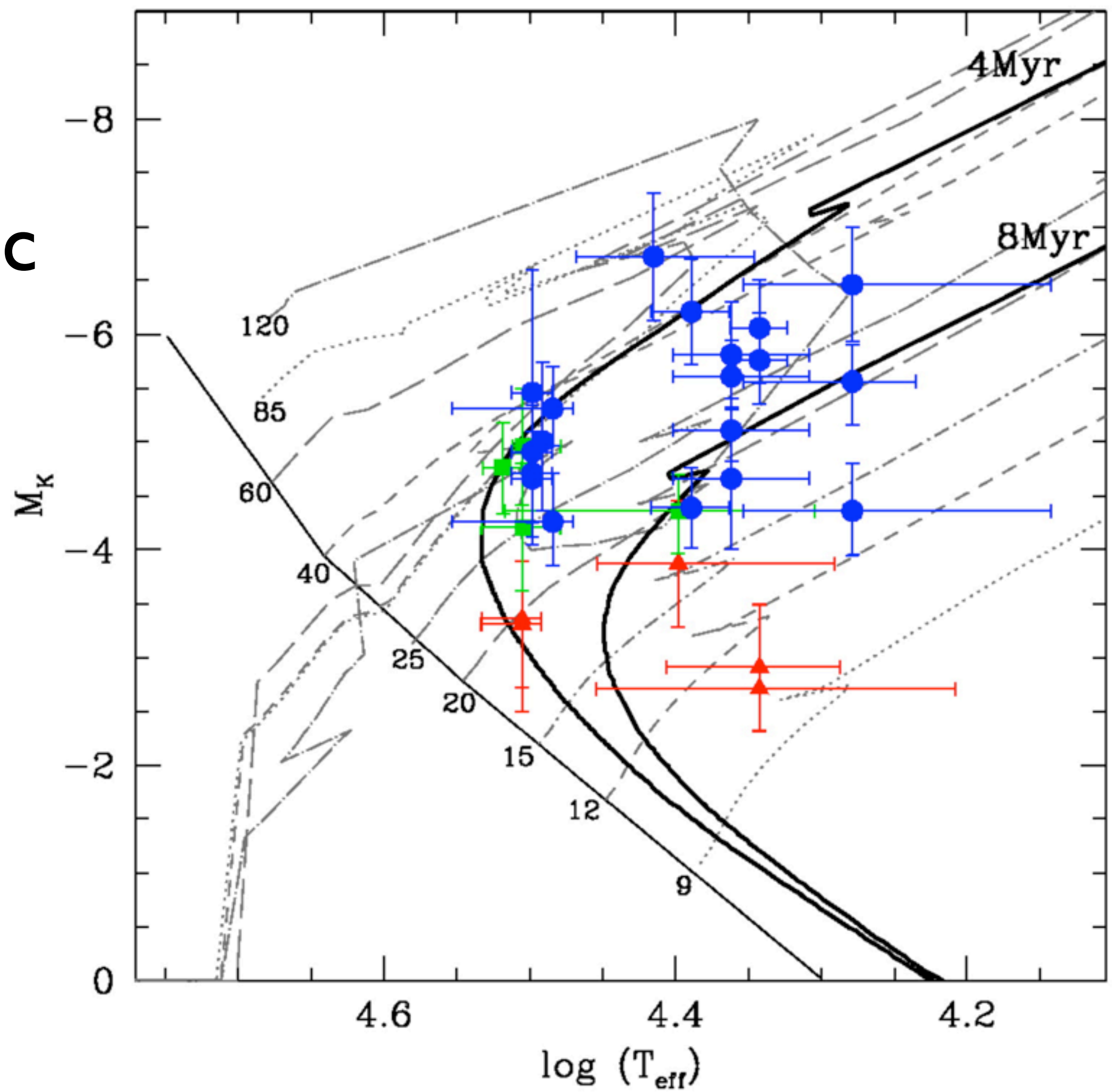
See talk by Philipp Plewa

KEY IDEA #4

The Galactic centre contains stars very close to the SMBH (S stars) and a population of enigmatic gas clouds (G1, G2 et al.). Both tell us something about processes within the Galactic Centre.

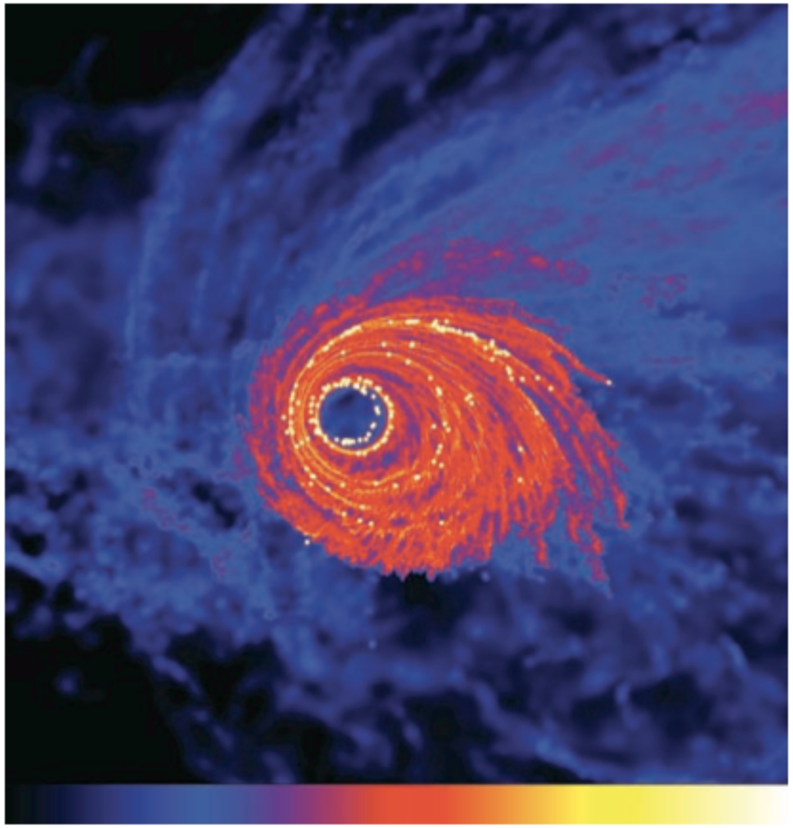
The Galactic Center Contains Very Young Stars

A flatter IMF has been suggested for the young stellar disc (Bartko et al. 2010; Lu et al. 2013)



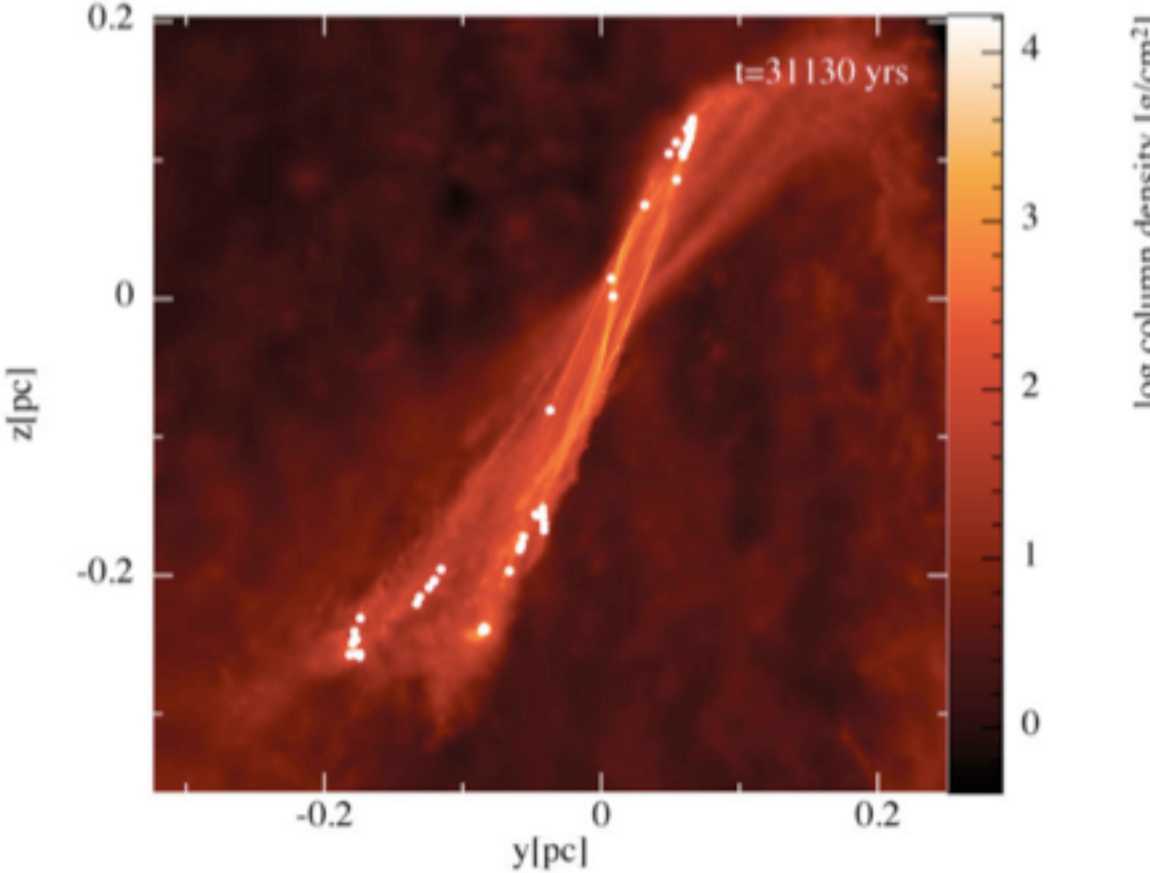
(Paumard et al. 2006)

Shredding GMCs to make a stellar disc



(e.g. Bonnell & Rice 2008)

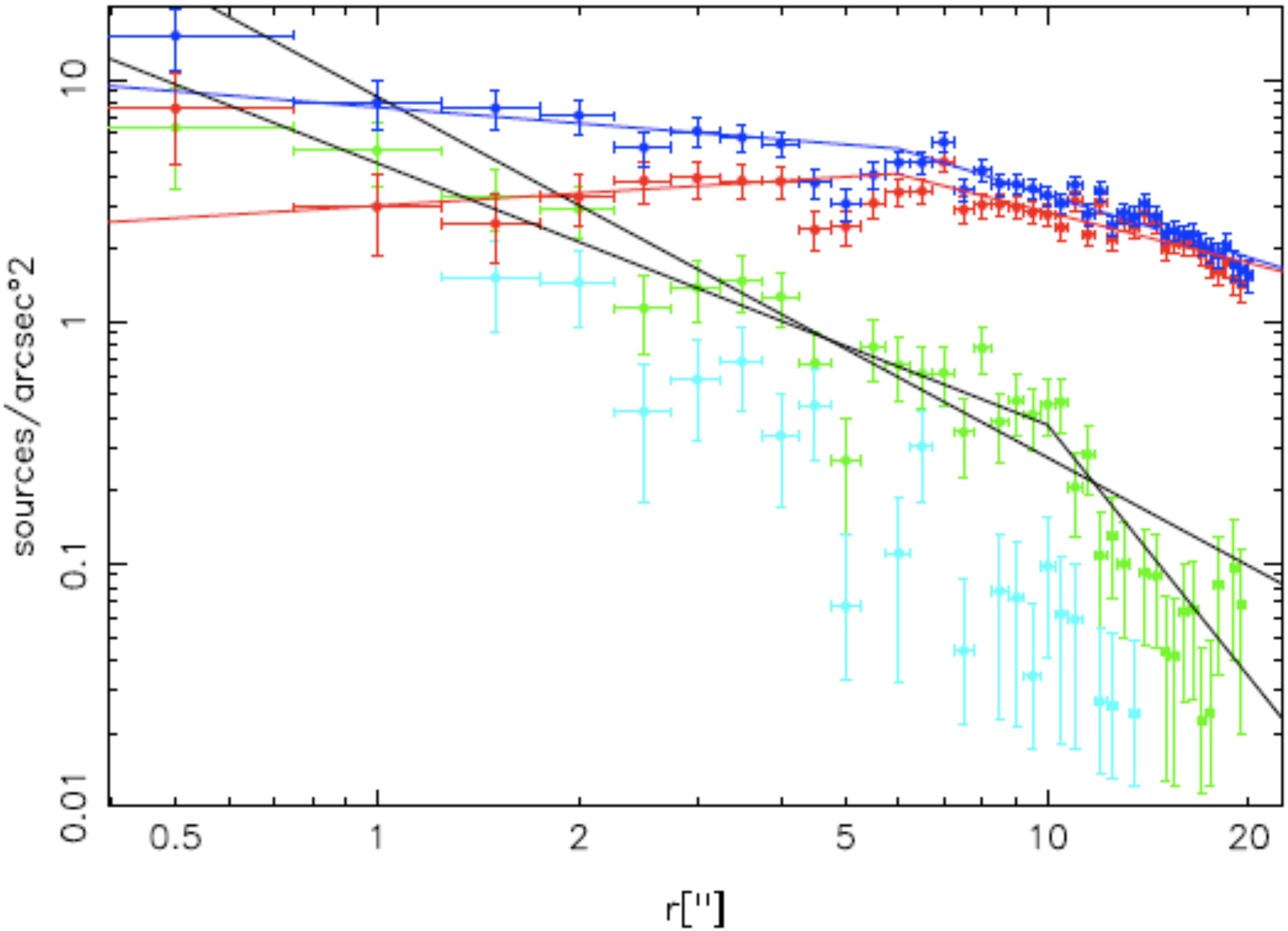
(Lucas et al. 2013)



KEY IDEA #5

A stack of discs over 10 Gyr could add up to a large fraction of the central cluster.

Observations: missing red giants



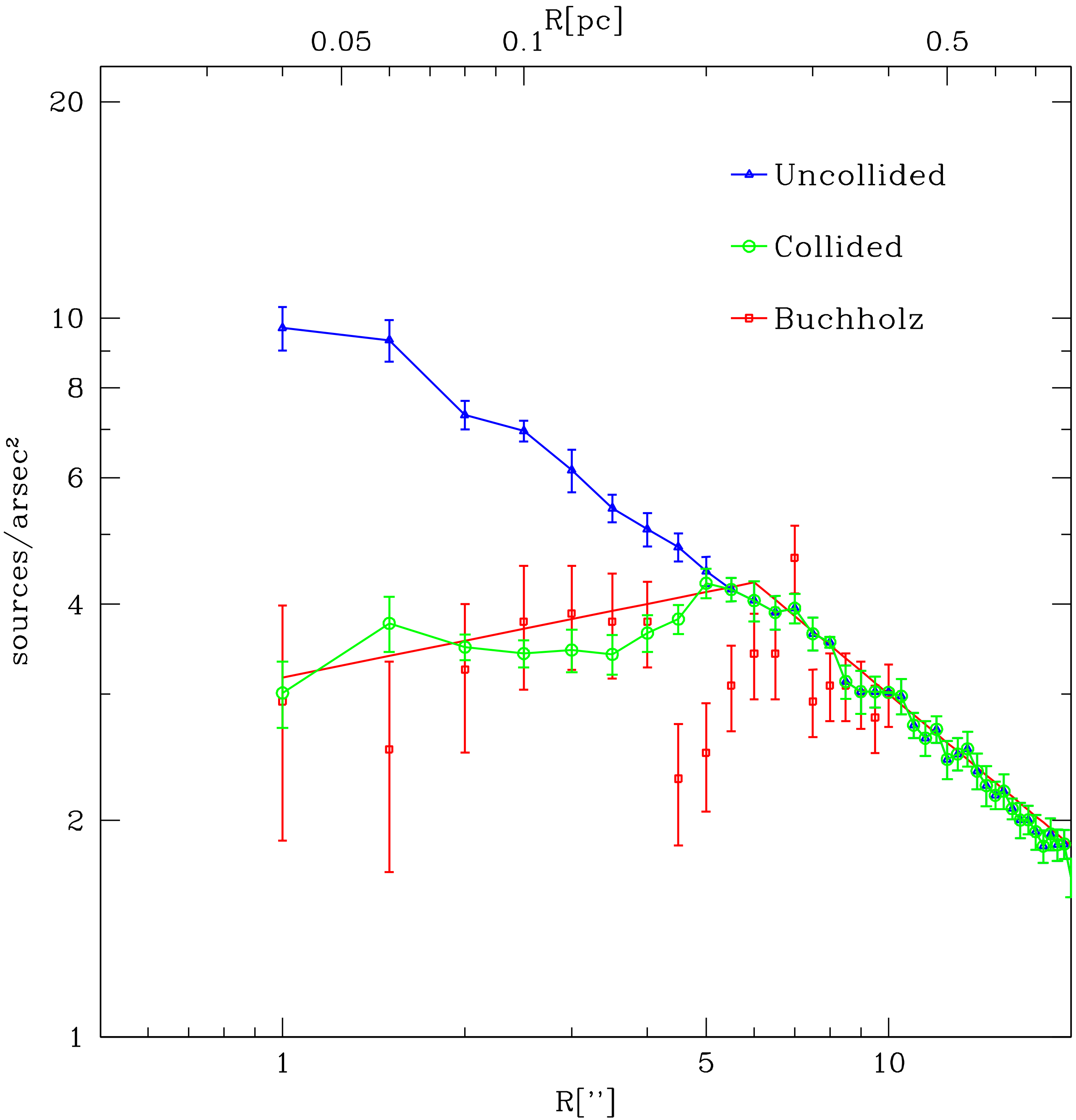
(Buchholz et al. 2009)

Buchholz et al observations are a surprise

We would expect to see a *cusp* of late-type stars as predicted by Bahcall & Wolf (1976) as the SMBH dominates within about 1pc. Instead the distribution is flat within 5 arcsec (0.2pc).

Something has happened to either remove the RGs (we don't see) in the middle or to dynamically heat the stellar cluster (e.g. Antonino et al. 2012).

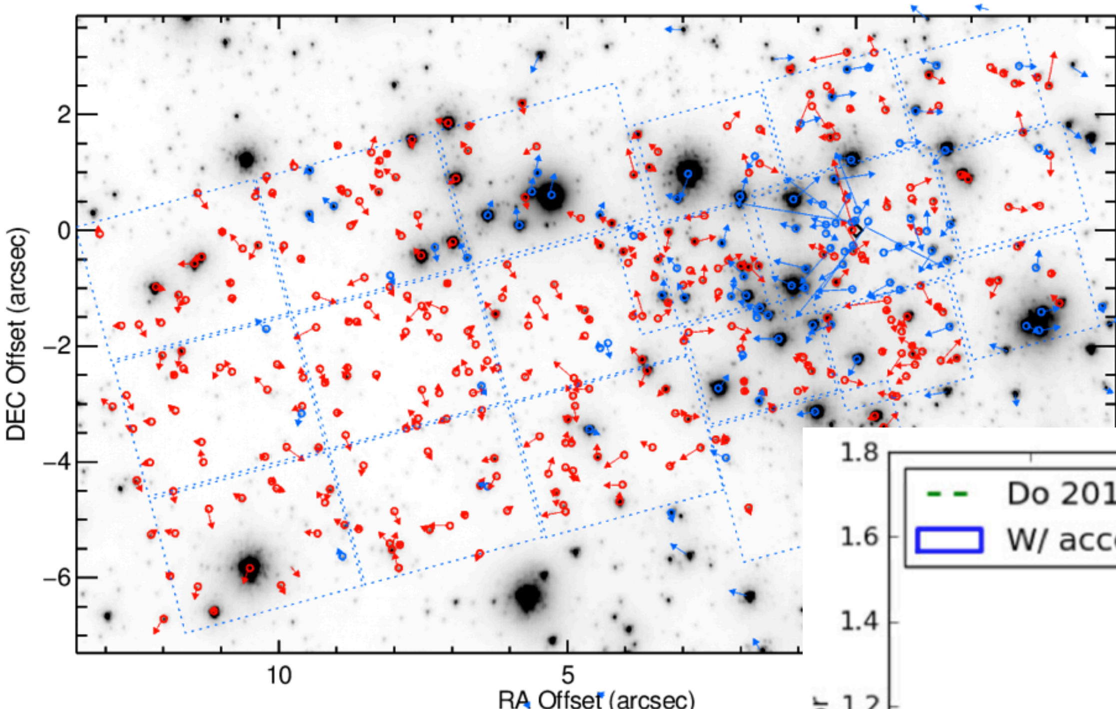
Observations are consistent with RG destruction



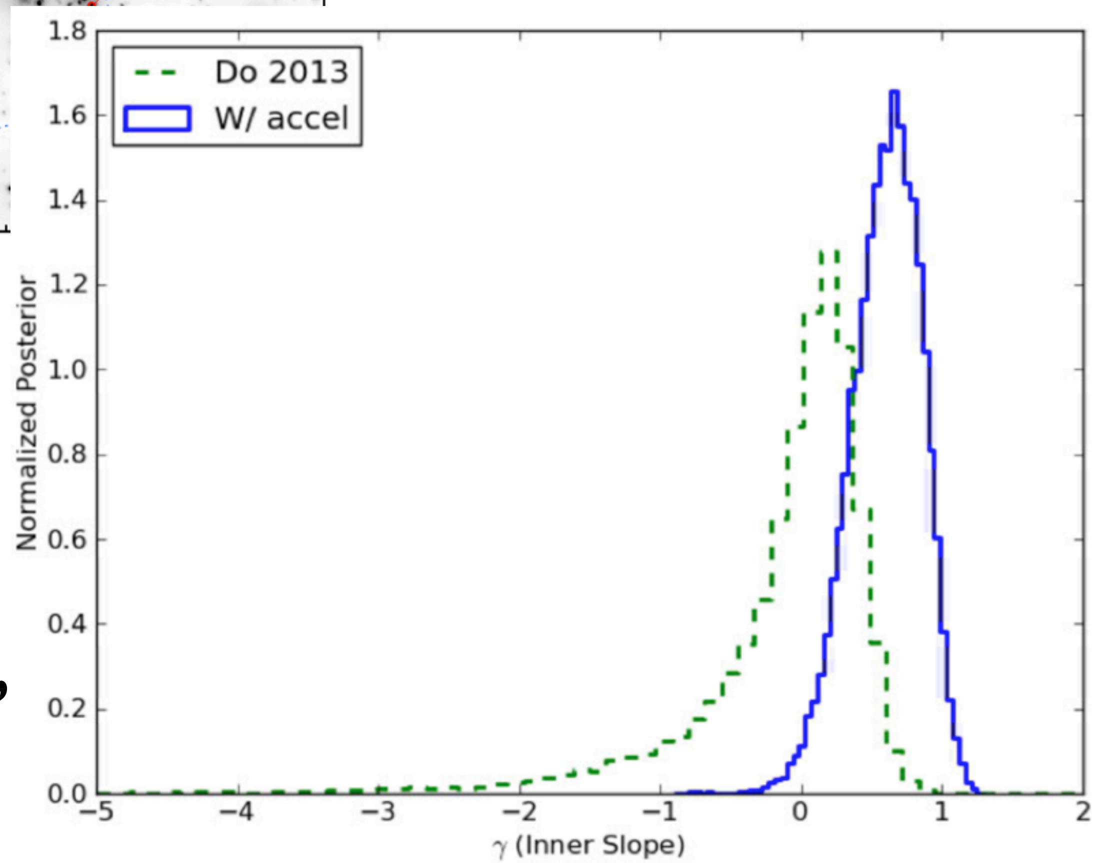
r_kill = 0.2pc

But density could have a cored profile.

Measuring RG proper motions

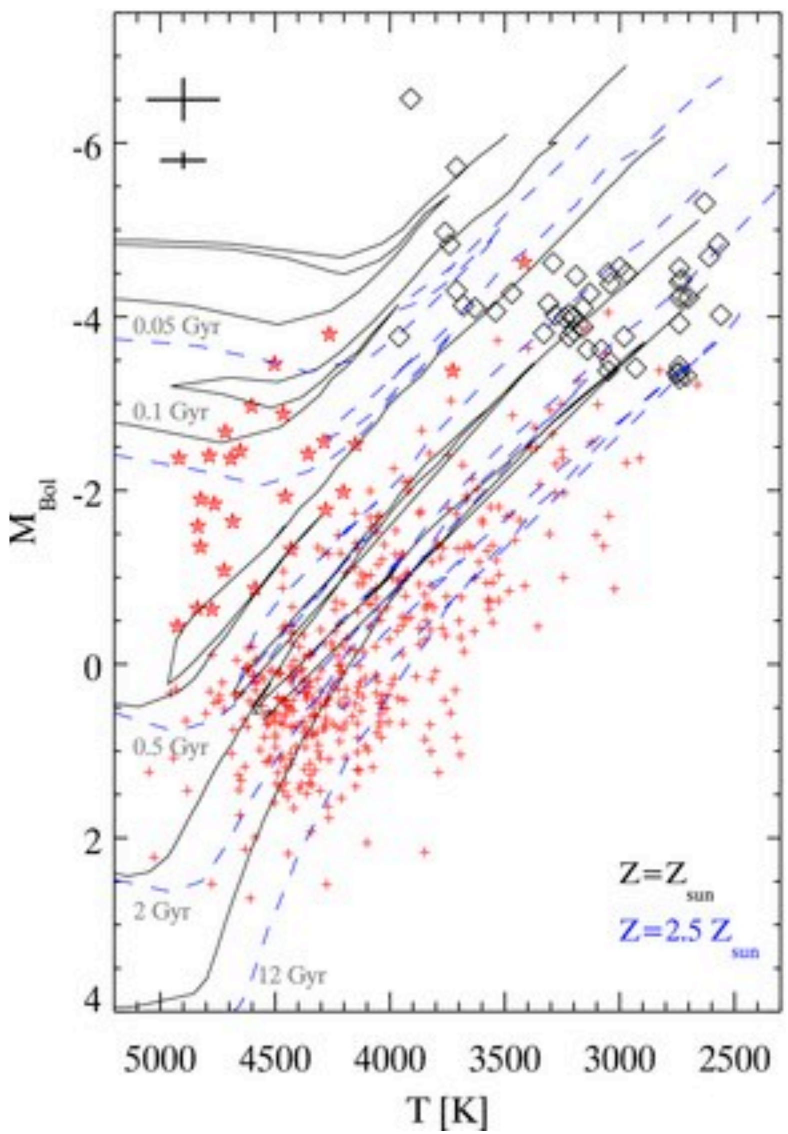


(Do et al. 2013)

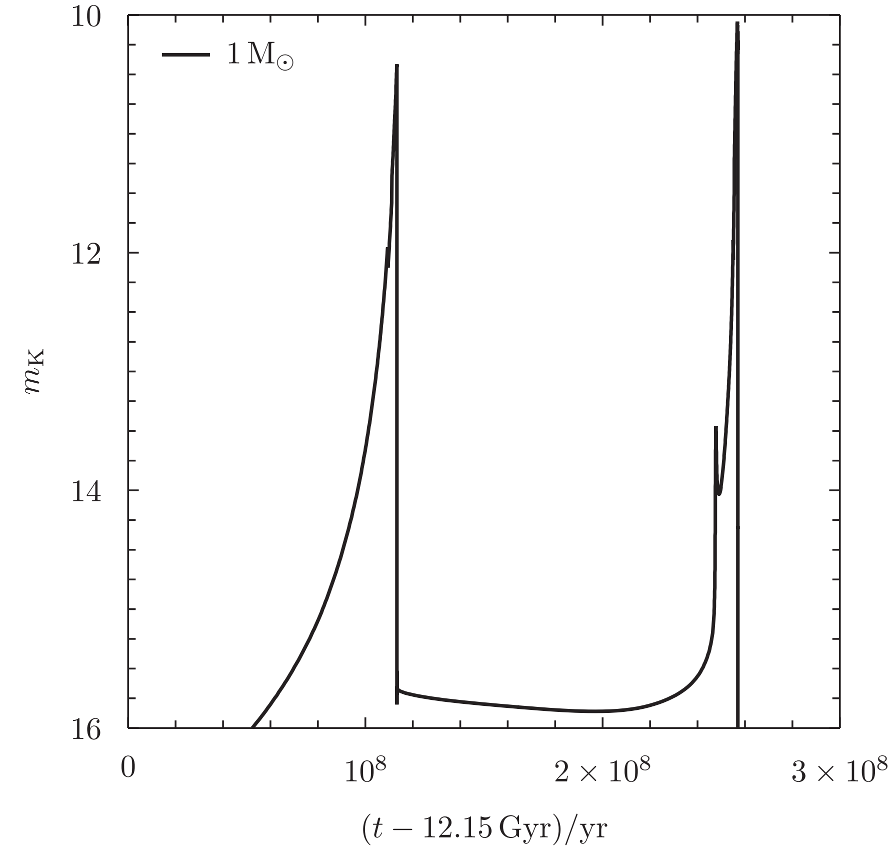


(Chappell et al., in prep.)

Which red-giant stars are missing?



(Pfuhl et al. 2011)



Most red giants are small

Possible ways to remove red-giant population:

1) RG stellar collisions: RG-anything else, RG-BH (clobber giant)
2) MS stellar collisions: MS-MS (change mass distribution), MS-CO
3) Star-disc interactions: strip RG as it ascends giant branch
4) Illumination from active SMBH: illumination affects stellar evolution
5) Encounters between single stars and binaries

Dynamical ways which might remove red-giant population
6) Stellar binaries affected by Kozai effect
7) Make NSC first then form SMBH
8) Age and/or metallicity segregation of infalling clusters
9) Mass segregation: BHs sink, RGs pushed out

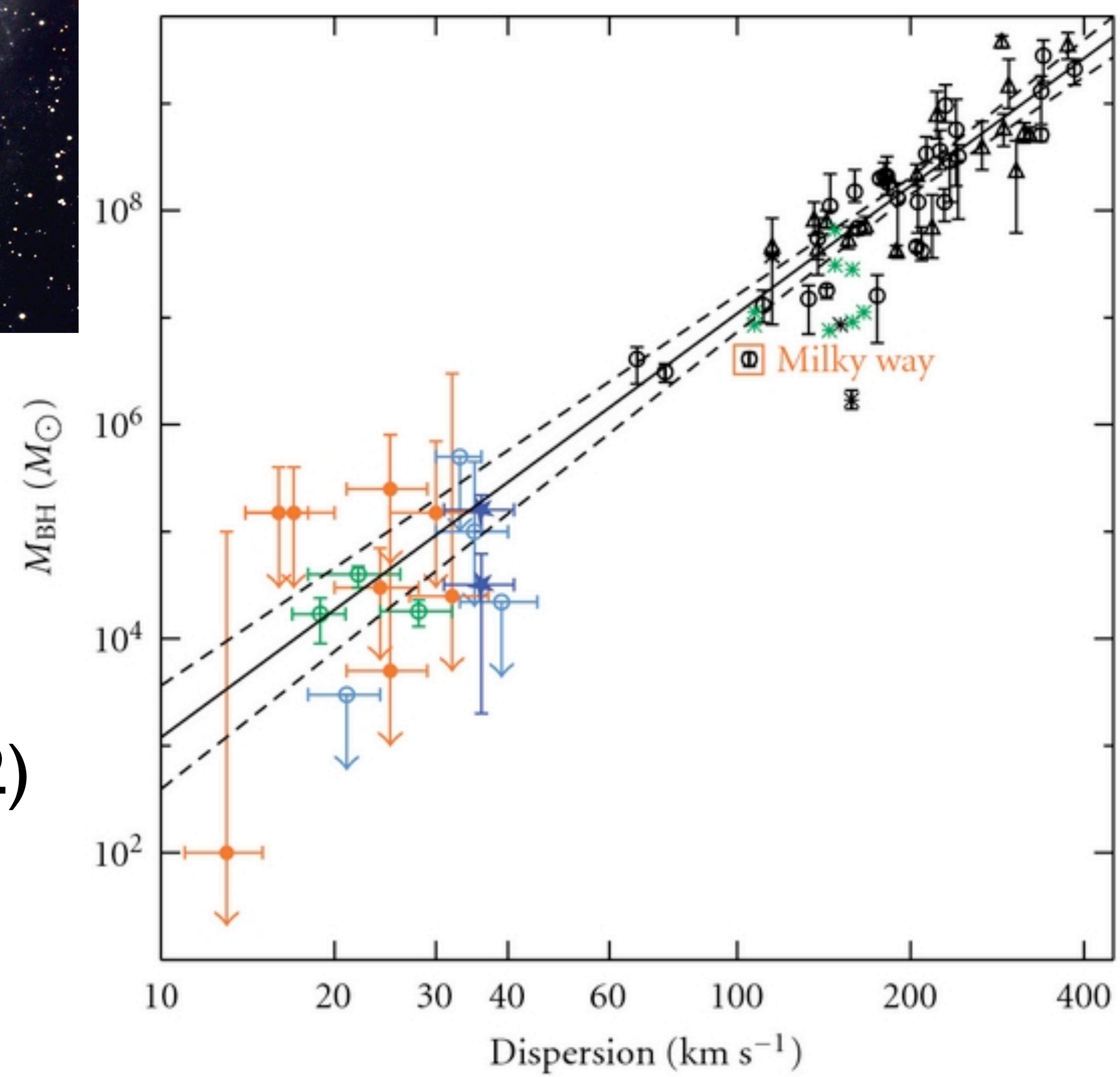
KEY IDEA #6

Explaining the observed distribution (depletion?) of RGs may tell us something about the history of the Galactic Centre. It matters whether any, all, or only the largest RGs are missing.

Nuclear Stellar Clusters

M33 contains no SMBH

(Neumayer & Walcher 2012)



KEY IDEA for M33-likes:

Above a critical velocity dispersion (around 40 km/s), SMBHs may form in relaxed stellar systems.

This is because primordial binaries cannot support the cluster against core collapse.

(Miller & Davies 2012, but note also Breen & Heggie 2013)

...So our Galactic center may have contained only a NSC which then *produced a SMBH* via core collapse meaning the NSC was *denser* in the past.

...Or gas inflow could lead to a contraction of the central regions of the cluster leading to collisions and SMBH formation.

(Davies et al. 2011)

WET vs. DRY growth of NSCs

KEY IDEA #7

Remember M33. It could be that in our galaxy, the SMBH was produced *after* the formation of the NSC. If so, stellar collision rates could have been much higher in the past.

Summary:

1) collision rate = f(black-hole mass)

2) most binaries soft in *odot* systems

3) RG-X $\not\Rightarrow$ CE systems in *odot* systems

4) more on G2 and S stars in following talks

5) local disc-mode of star formation may matter

6) RG depletion = f(collisions & other processes)

7) which came first, BH or NSC?