Supermassive Black Hole Formation and Growth involving Nuclear Stellar Clusters

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Two questions:

1) How can SMBHs form and grow so quickly at high redshift?

2) How can some galactic nuclei avoid forming supermassive black holes?

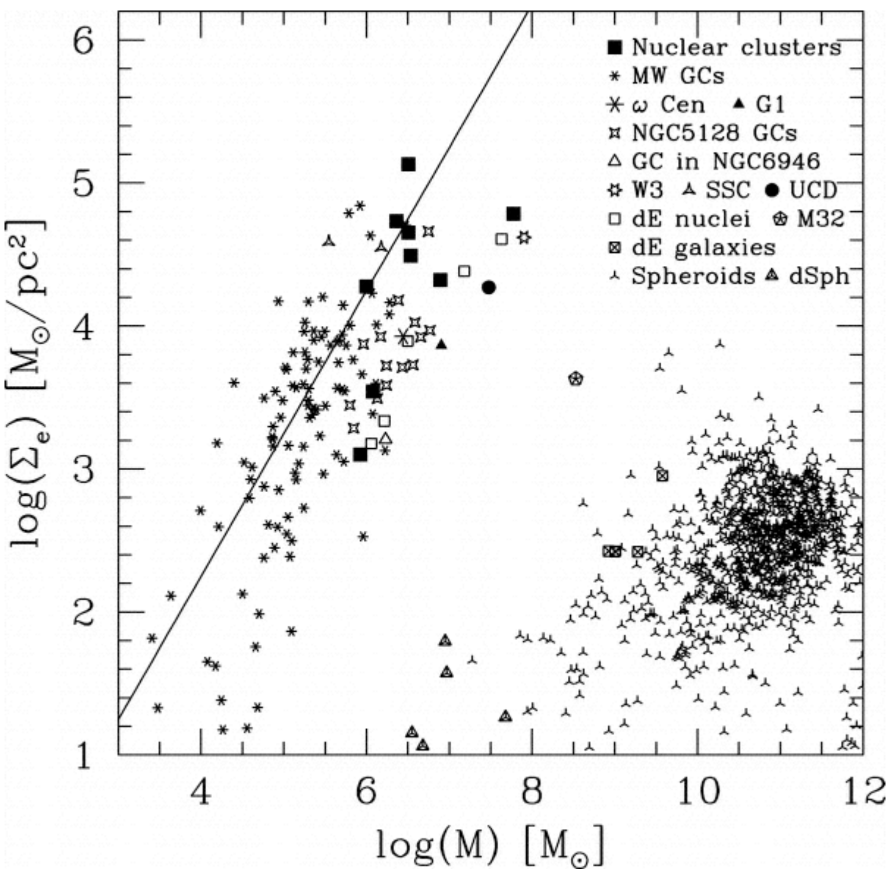
M33

Why no SMBH, even today?

(but there is a nuclear stellar cluster)

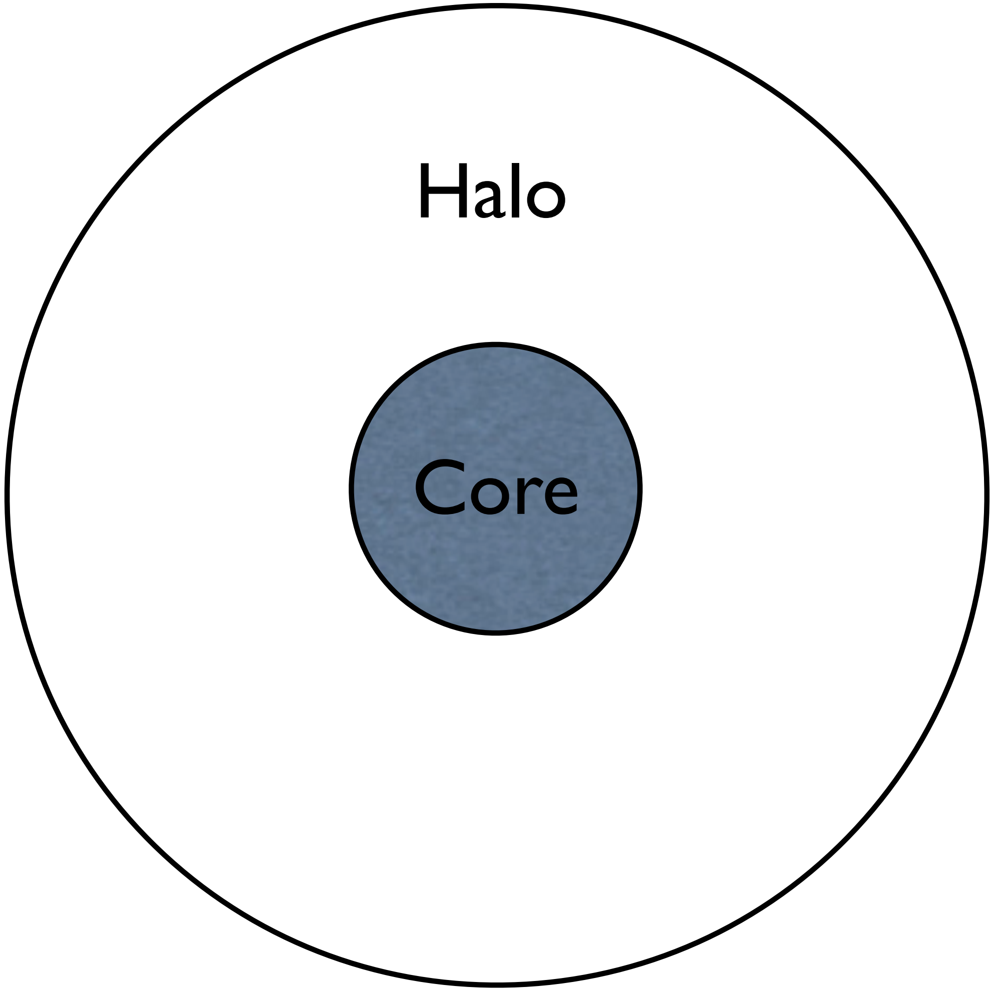
Nuclear stellar clusters:

Found in a large fraction of galactic nuclei.
Typically 10-100 times more massive than globular clusters, and slightly larger.



(eg Carollo et al 1997, 1998; Böker et al 2002; Walcher et al 2005; Côté et al 2006)

A Model Nuclear Stellar Cluster



Key ideas:

Scattering between stars transports energy within a cluster (two-body relaxation).

Self-gravitating systems have a negative heat capacity.

A competition between two processes:

Energy loss via two-body scattering from cluster core leading to core collapse.

Heating via binary-single encounters which could prevent or delay core collapse.

If binaries are tight enough they will spiral together and merge before they can heat the cluster.

Key idea for M33-likes:

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

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

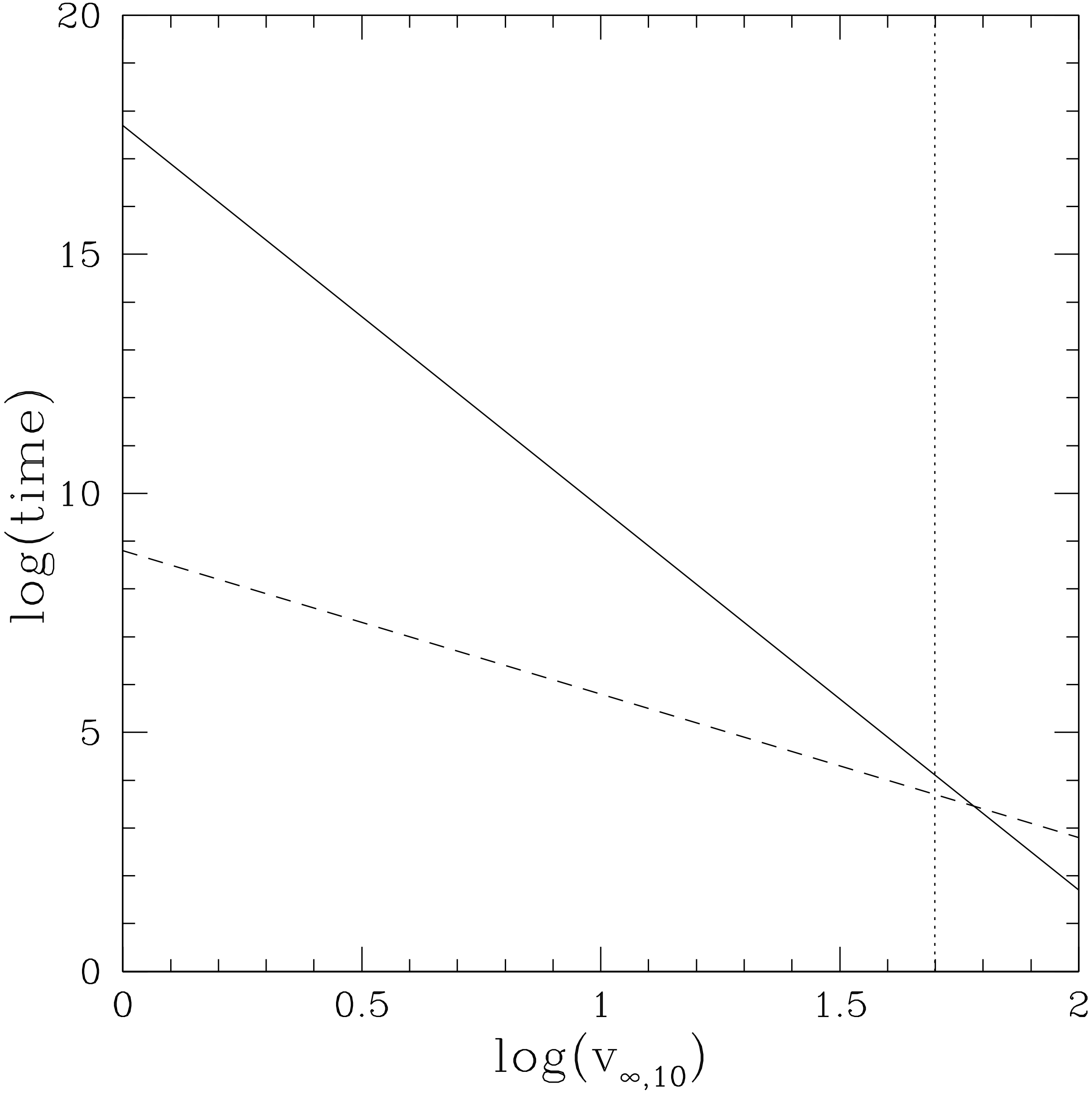
(Miller & Davies 2012)

Key ideas for SMBH formation:

Addition of gas into nuclear stellar cluster leads to significant contraction in core and increase in cluster velocity dispersion (eg Mayer et al 2010).

Binaries can no longer support cluster which undergoes core collapse.

binary-single encounter and GR inspiral timescales



(Davies, Miller & Bellovary 2011)

Bottom line for SMBH formation:

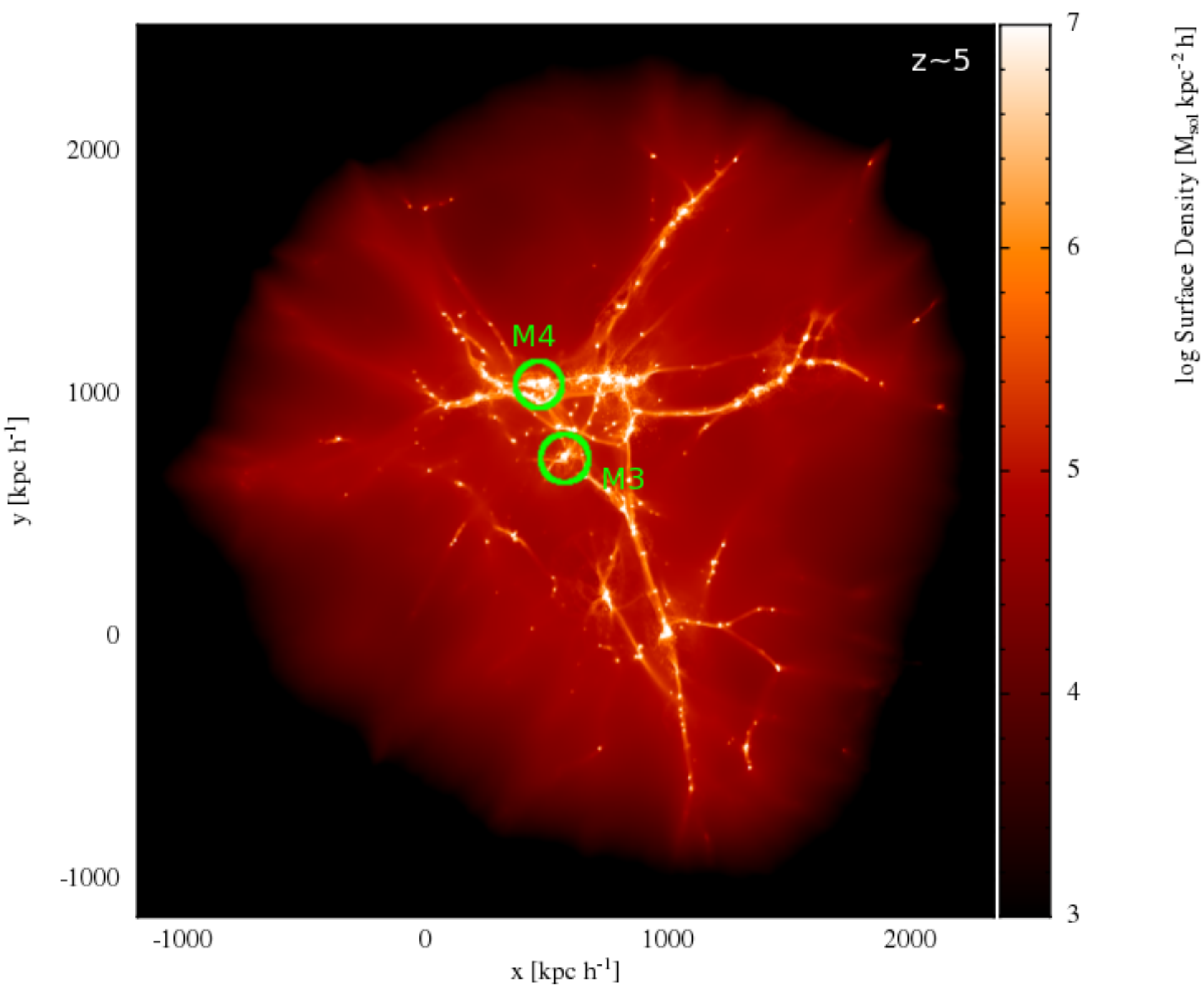
Tight binaries merge but are retained (due to high velocity dispersion) to go on to merge with other objects thus building up a seed SMBH.

SMBH will reach a mass of around 10^5 solar masses from stellar-mass BHs, NSs, and WDs within cluster.

Eddington-limited growth onto moderately spinning black hole would see growth to $\sim 10^9$ solar masses by $z \sim 7$.

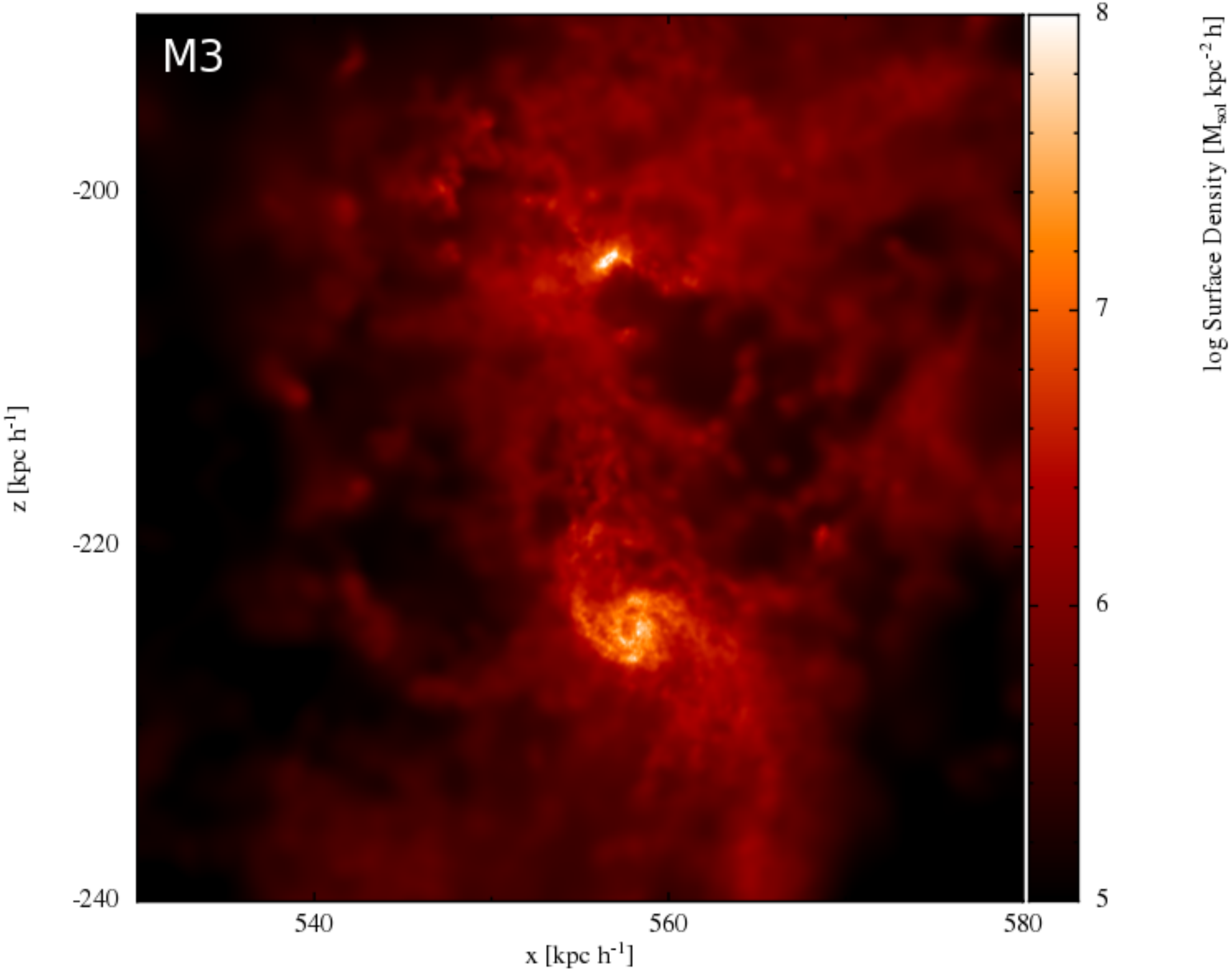
(Davies, Miller & Bellovary 2011)

The Next Step



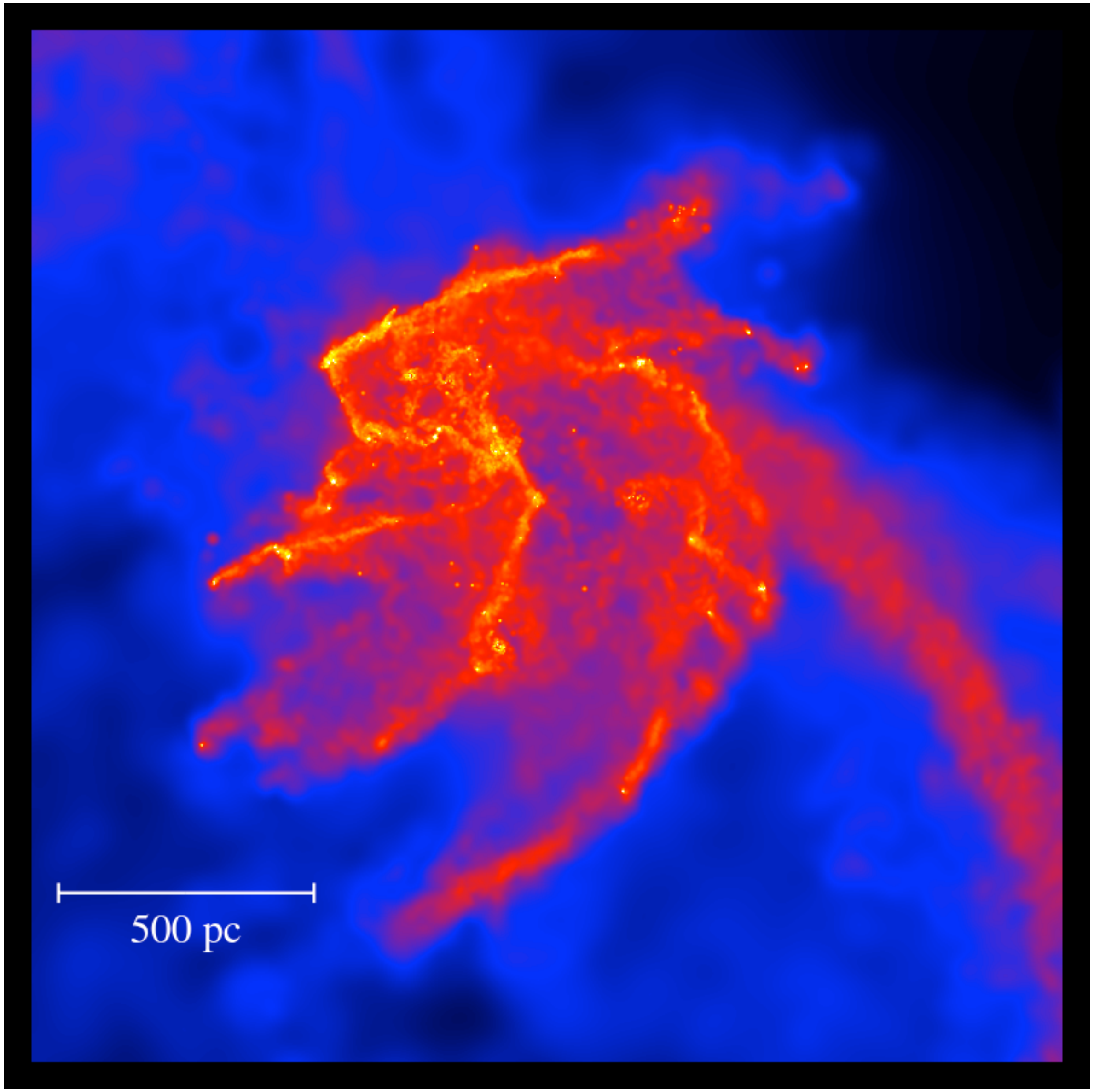
(Fiacconi & Mayer, priv. comm.)

The Next Step



(Fiacconi & Mayer, priv. comm.)

The Next Step



(Fiacconi & Mayer, priv. comm.)

Summary:

Gas inflow into nuclear star clusters may accelerate SMBH formation at high redshift.

SMBH formation may be inevitable in nuclear stellar clusters having sufficiently high velocity dispersion.

M33-like nuclear stellar clusters have low velocity dispersions and so might avoid SMBH formation.