DYNAMICAL EVOLUTION OF NGC 3603

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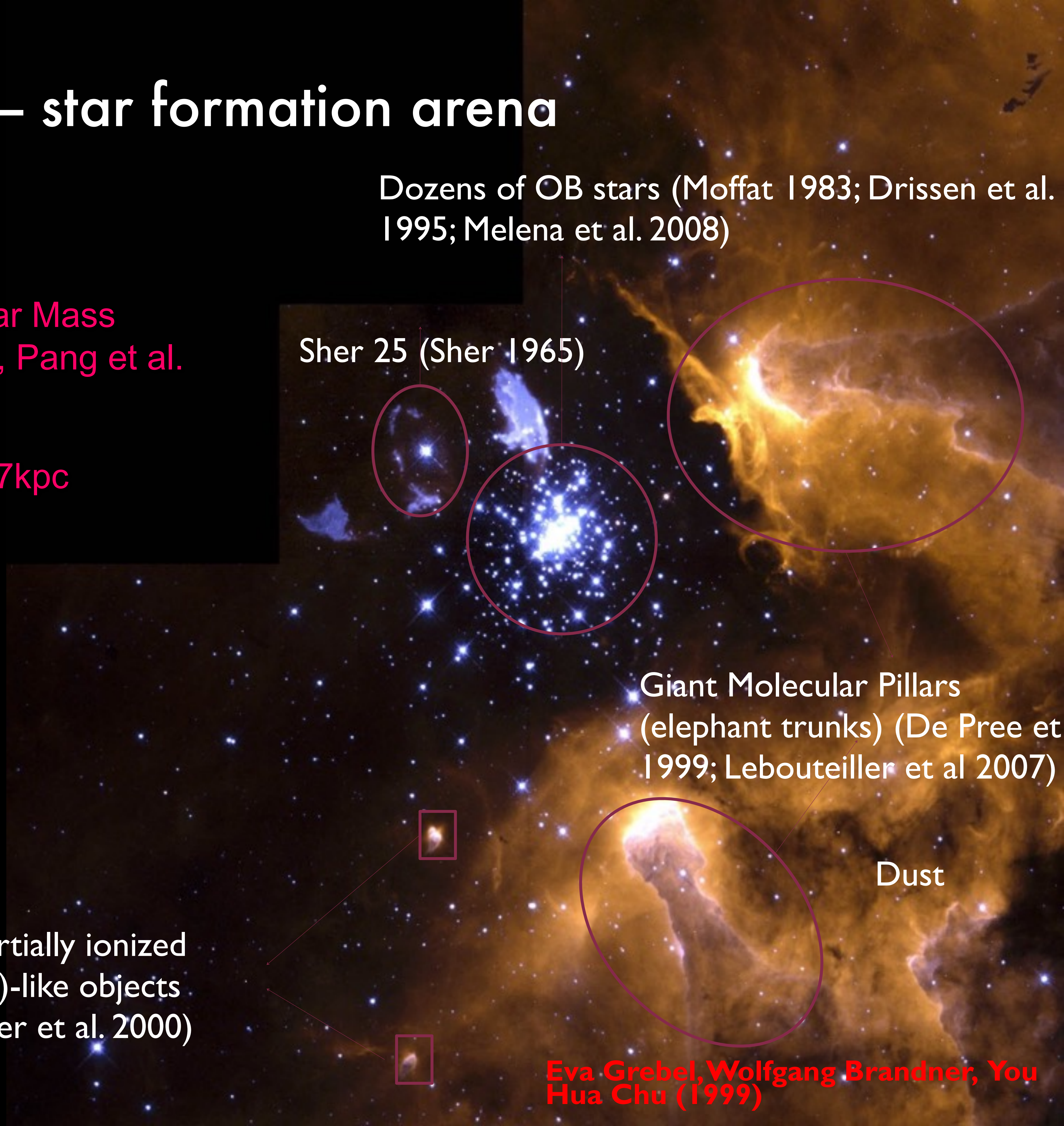
NGC 3603 – star formation arena

- Mass: 1.0 -1.9·10^4 Solar Mass (Harayama et al. 2008, Pang et al. 2013)
- Location: Carina arm, 7kpc



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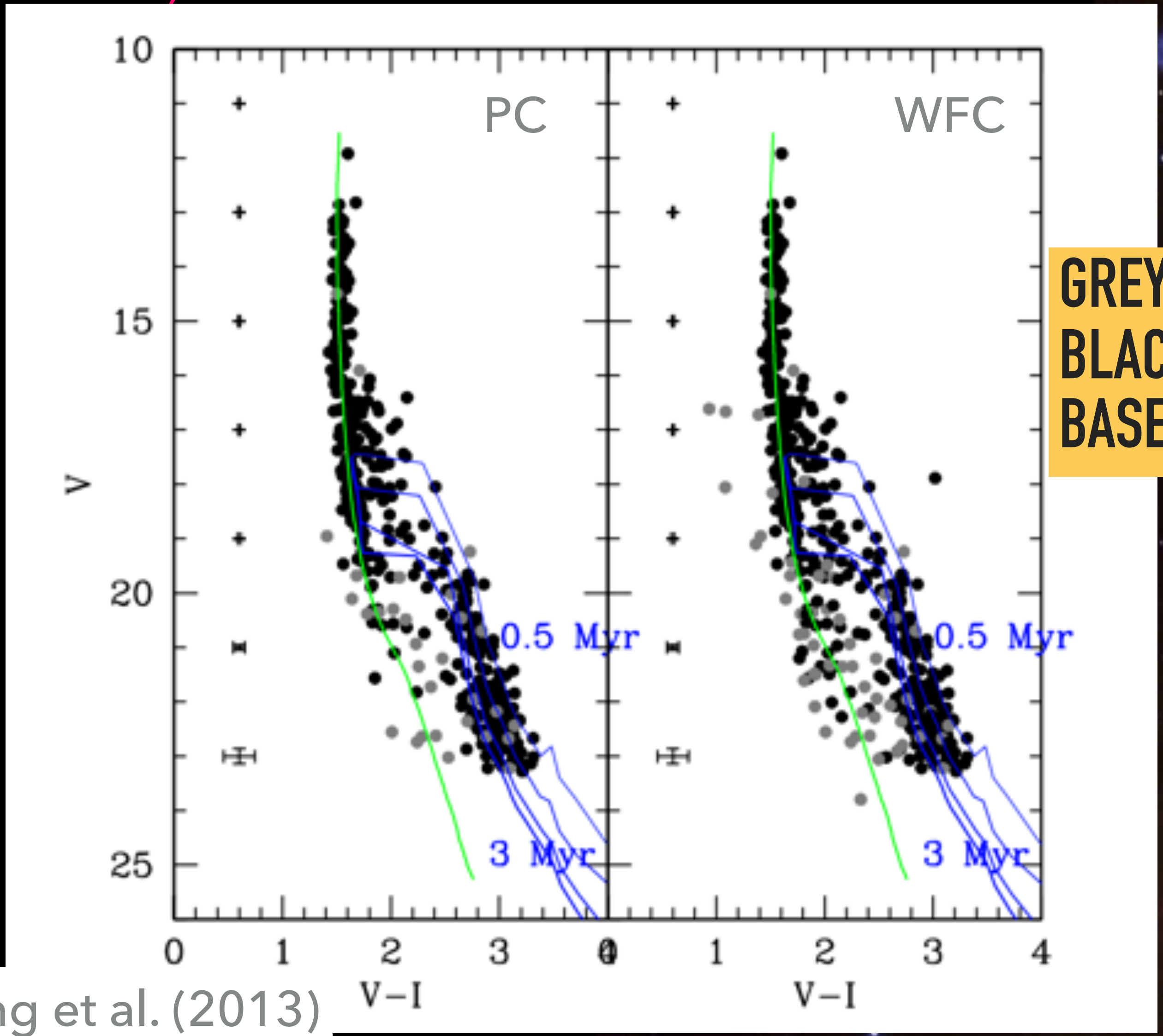


Pang et al. (2013)

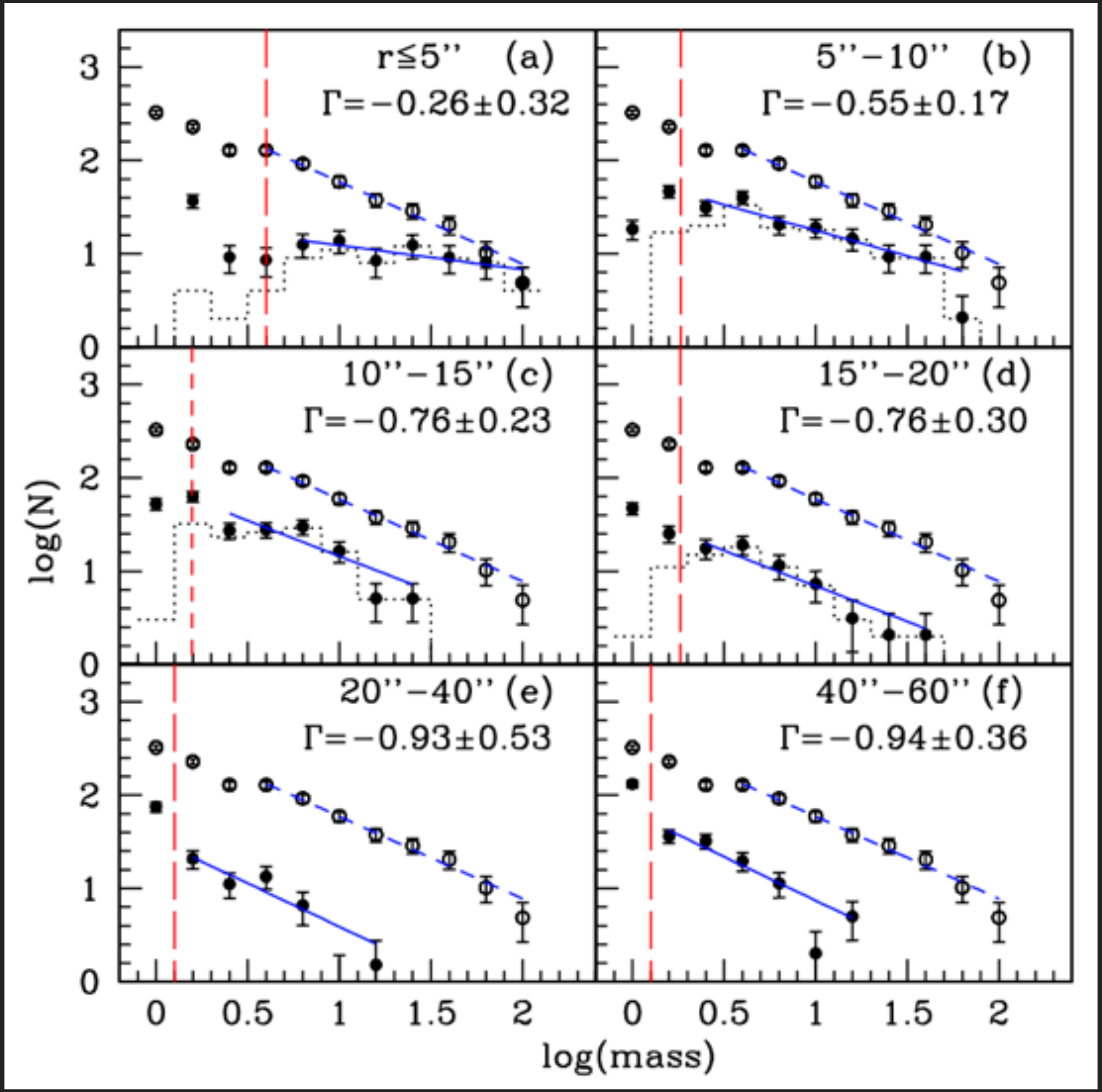
GREY DOTS: NON-MEMBER
BLACK DOTS: MEMBER STARS (RELATIVE PROPER MOTIONS BASED ON HST/WFPC2)

NGC 3603 – star formation arena

- Location: Carina arm, 7kpc
- Mass: 1.0 -1.9·10^4 Solar Mass (Harayama et al. 2008, Pang et al. 2013)
- Age: ~1 Myr (Sung & Bessel 2004); age spread up to 3 Myr among PMS (Pang et al. 2013)

MASS SEGREGATION

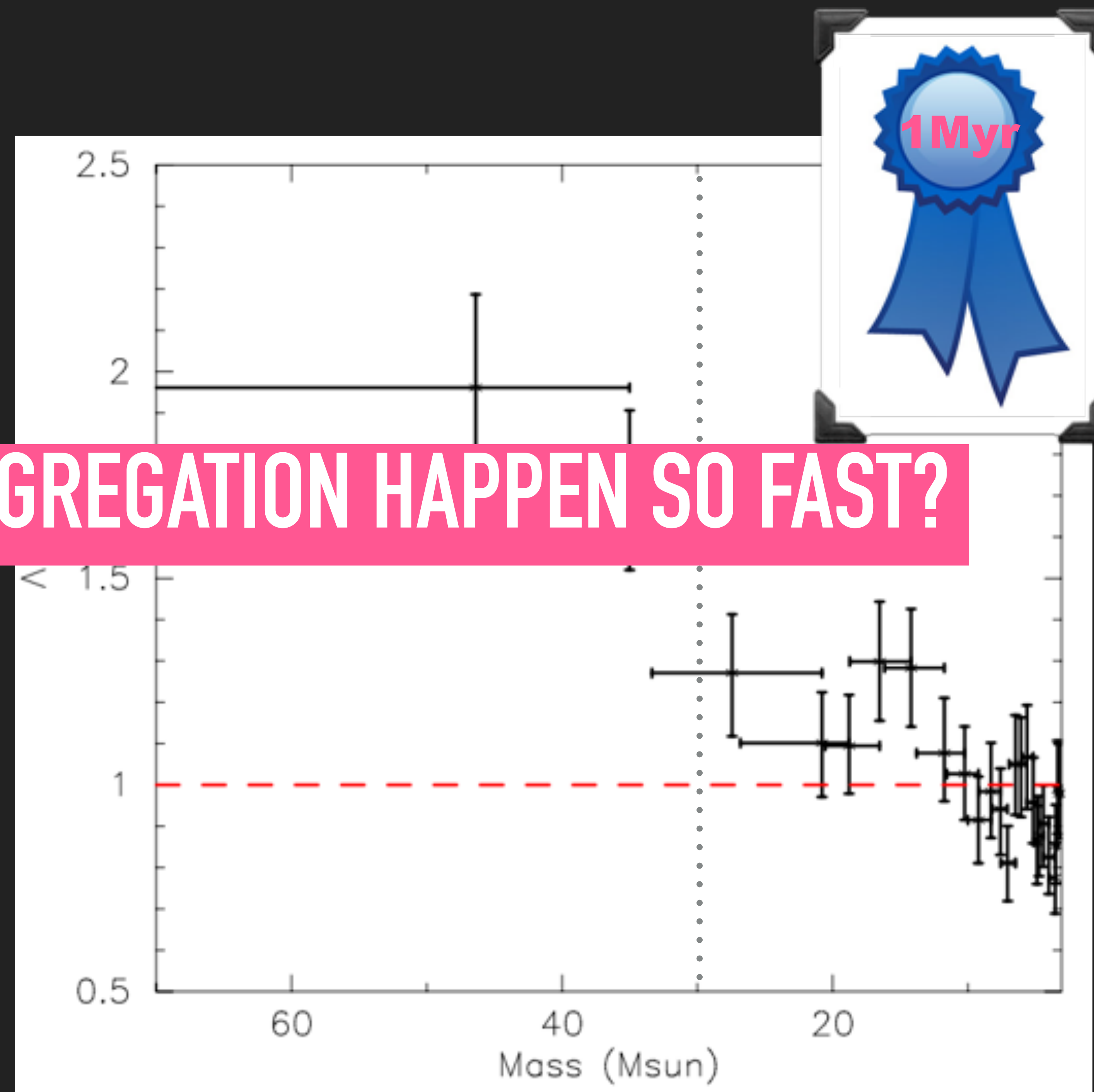
- Slope of mass function gets steeper in the outer annulus –> mass segregation.



Pang et al. (2013)

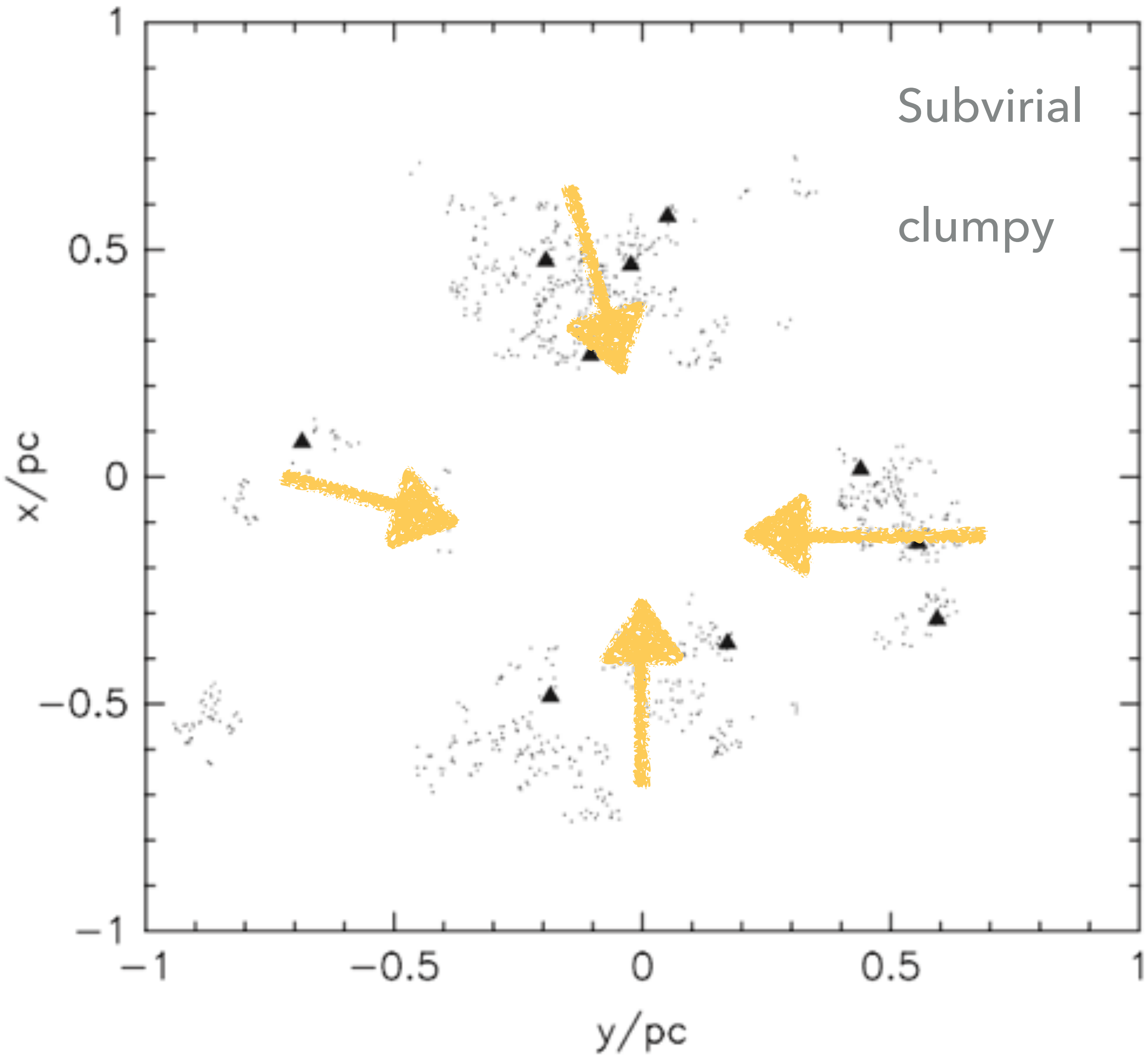
MASS SEGREGATION

- Minimum spanning tree method to quantify the mass segregation
- HOW CAN DYNAMICAL SEGREGATION HAPPEN SO FAST?
- significant segregation down to 30 solar masses.



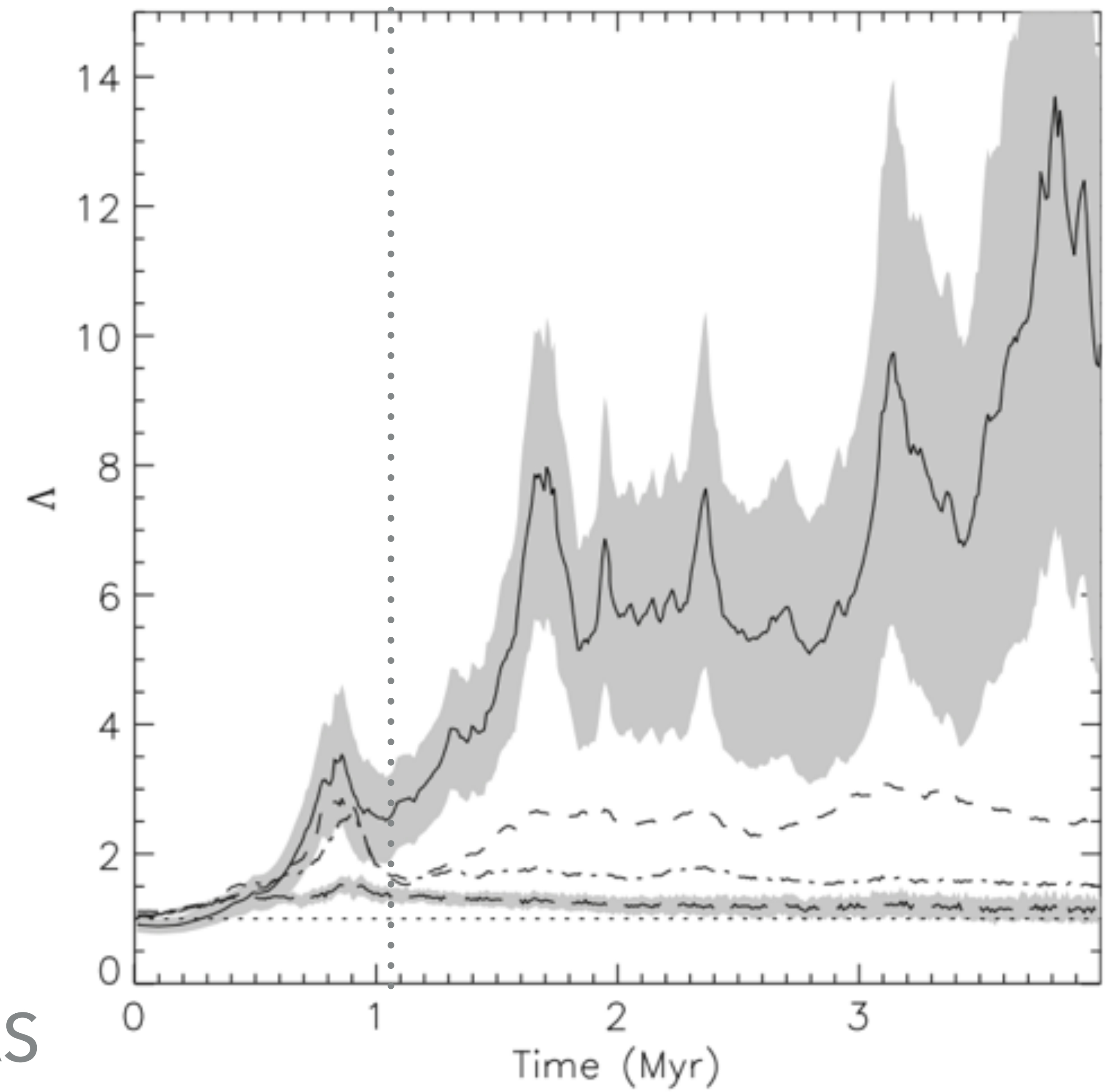
Pang et al. (2013)

DYNAMICAL MASS SEGREGATION WITHIN 1 MYR



(a) 0 Myr

NO GAS



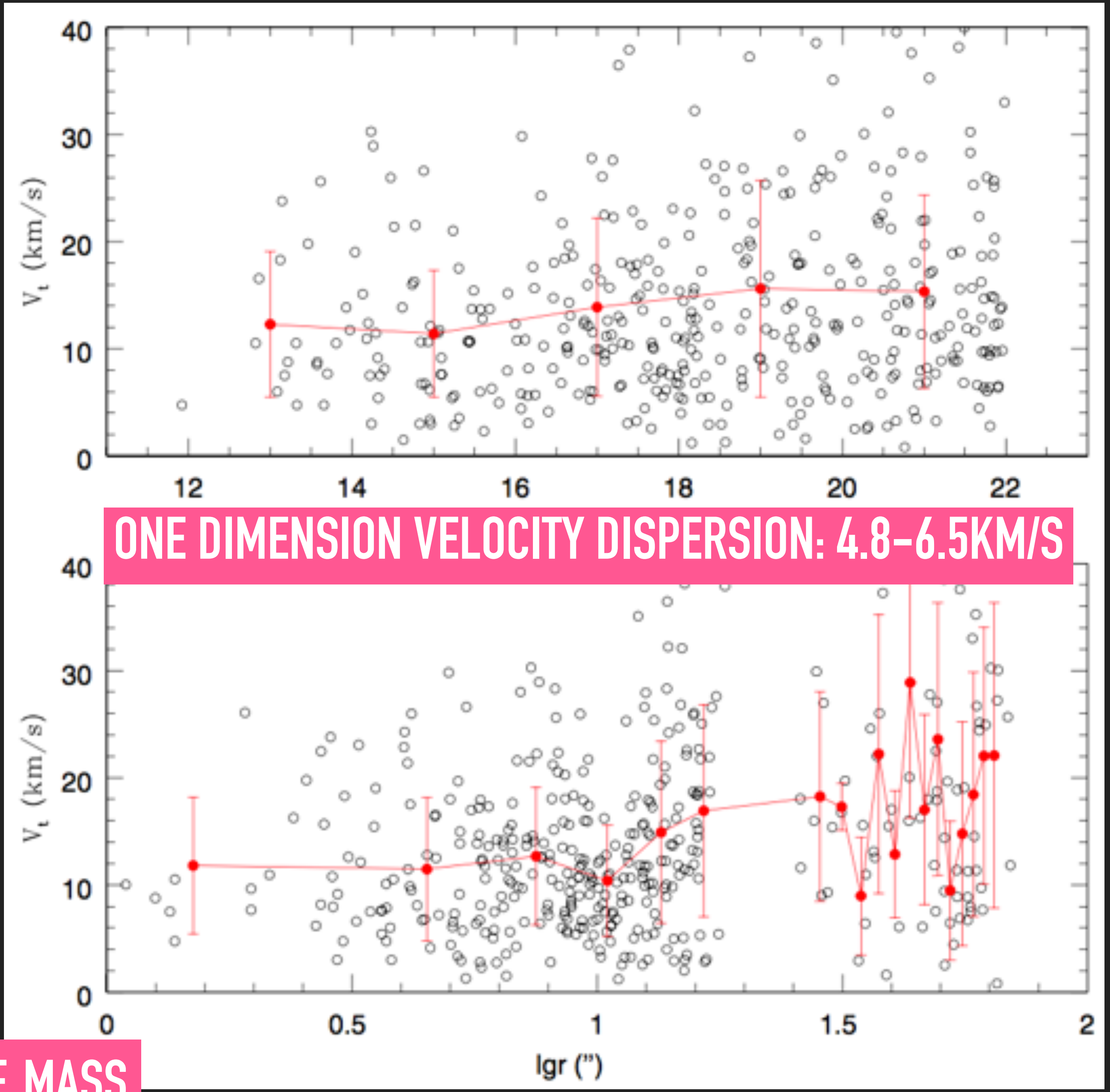
Allison et al. (2009)

KINEMATIC SIGNATURE

- The tangential velocity dispersion for stars >30 M⊙ is 6.8 ± 0.8 km s^{-1} . It does not change much for stars of 10 M⊙ (5.9±0.6kms^{-1})
- The tangential velocity dispersion increases to9.0±0.9kms^{-1} for stars of ~2.5 M⊙ .

$$t_{\rm seg}(M) \sim \frac{\langle m \rangle}{M} t_{\rm relax} = \frac{\langle m \rangle}{M} \frac{N}{8 \ln N} t_{\rm cross}.$$

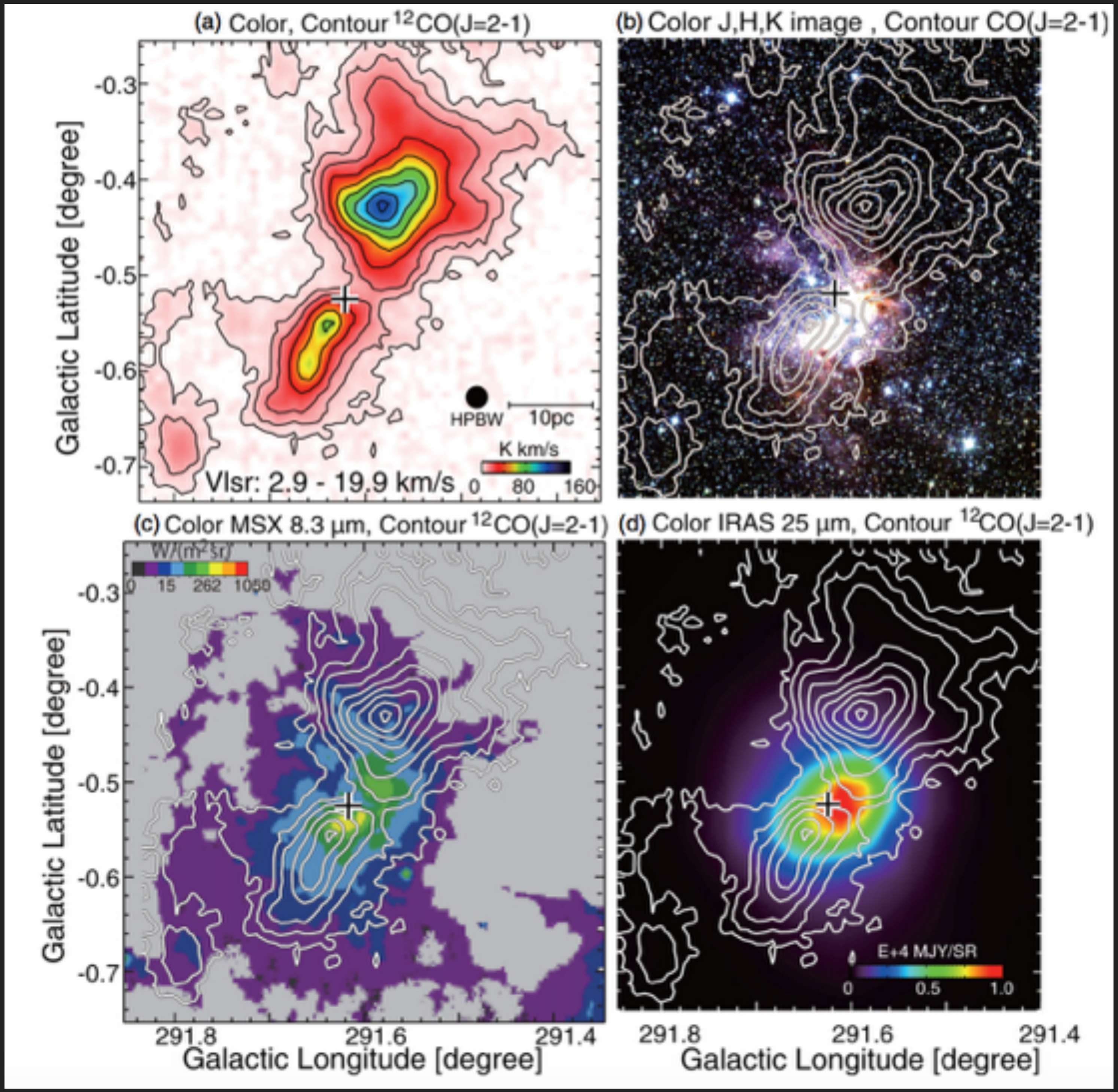
N = 10^4, ⟨M⟩ = 0.4 M⊙, KROUPA'S (2002) IMF, MASS SEGREGATE TO 30 M⊙ AT ONE CROSSING TIME



Pang et al. (2013)

FORMATION SCENARIO - COLLISION MODEL

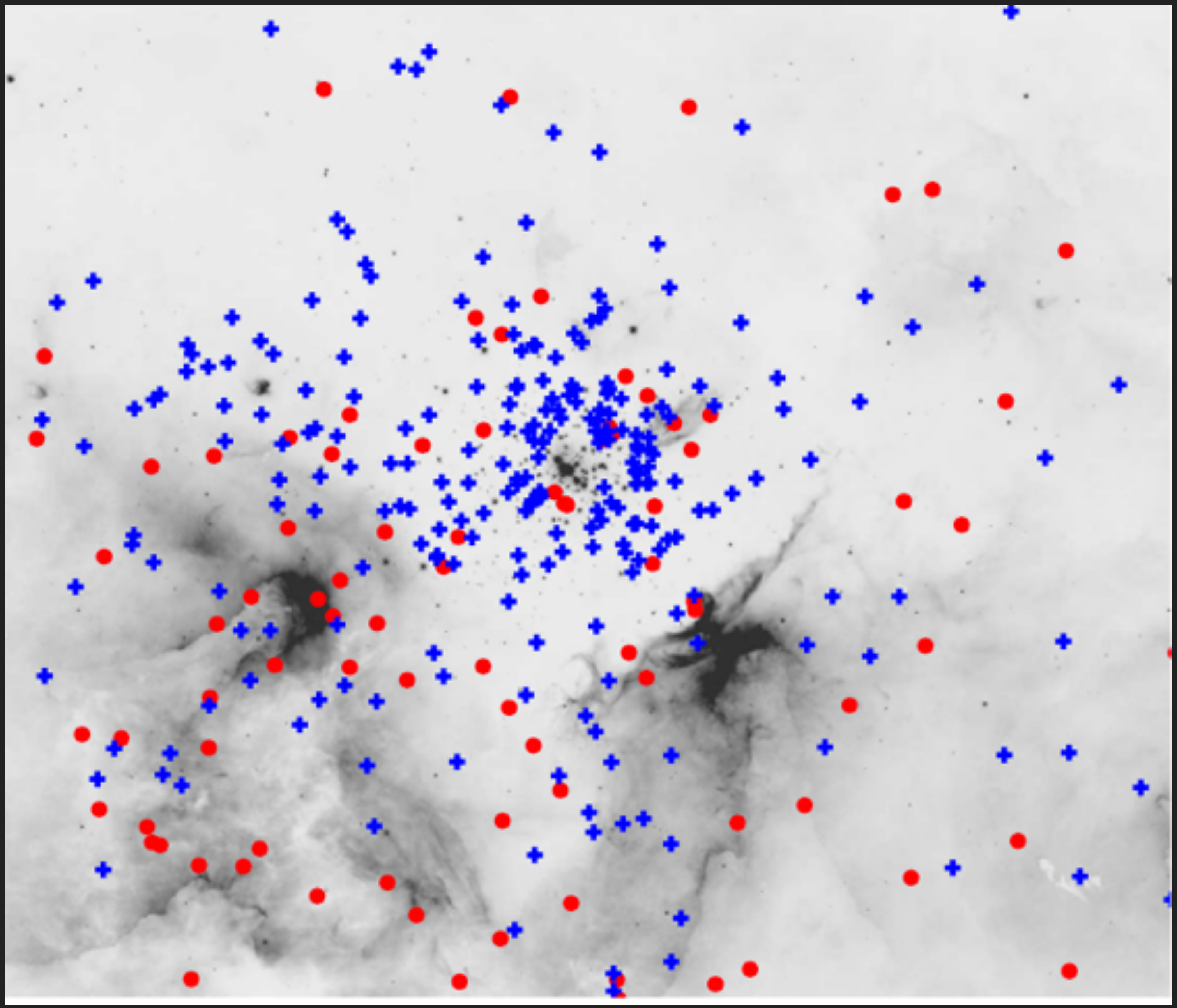
- Two molecular clouds at 13 km/s and 28 km/s are associated with NGC 3603
- The mass of the clouds is too small to gravitationally bind them, given their relative motion of ~20 km/s.
- The two clouds with stars formed before collided with each other 1 Myr ago to trigger the formation of the super star cluster.



Fukui et al. (2014)

FORMATION SCENARIO - COLLISION MODEL

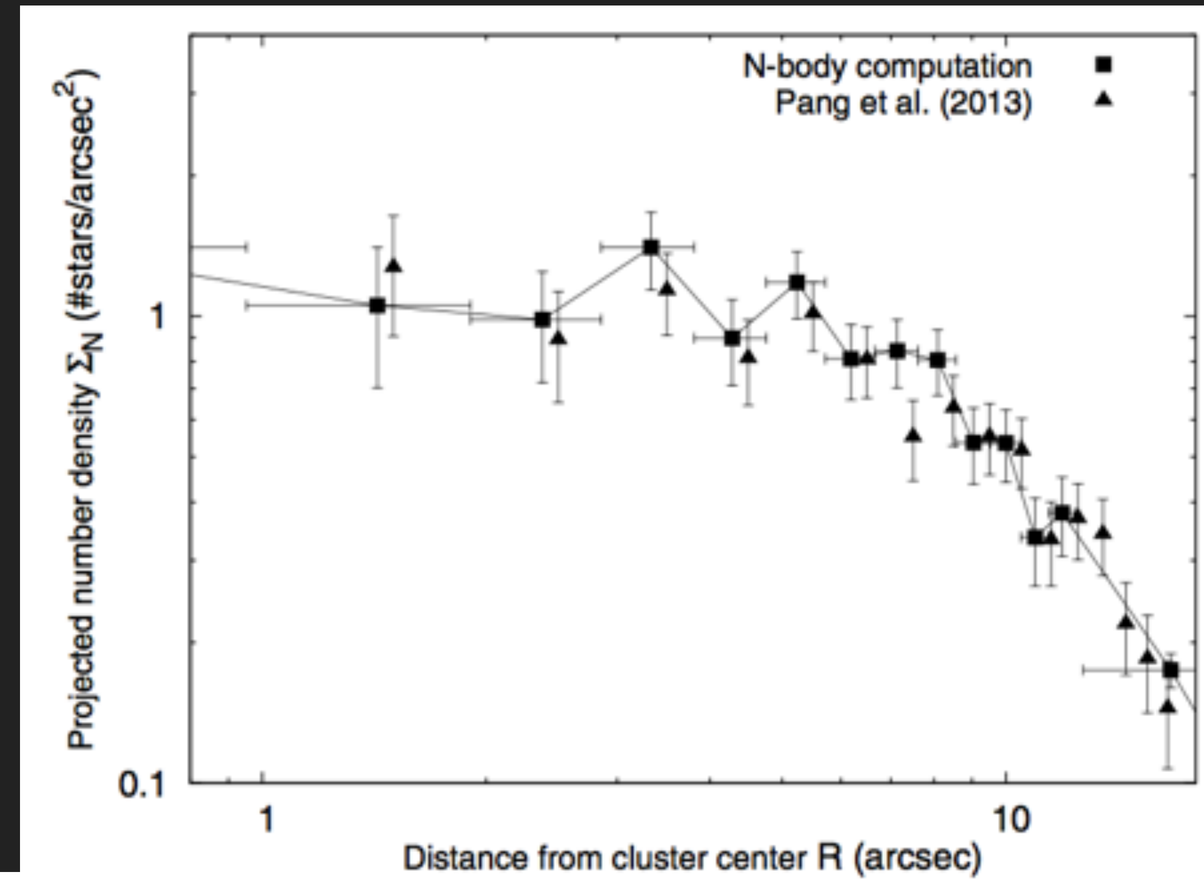
- Young PMS stars (<10 Myr) : blue crosses
- Old PMS stars (>10 Myr) : red dots

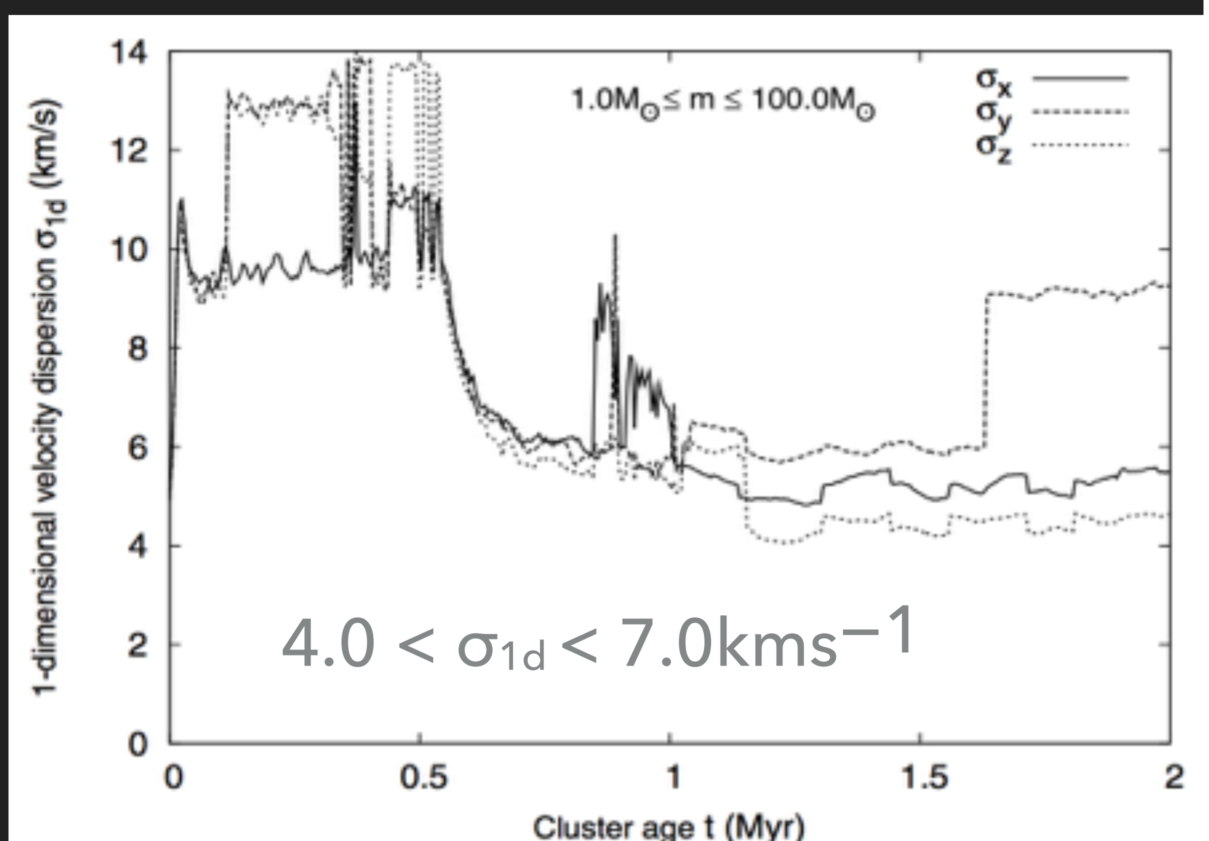


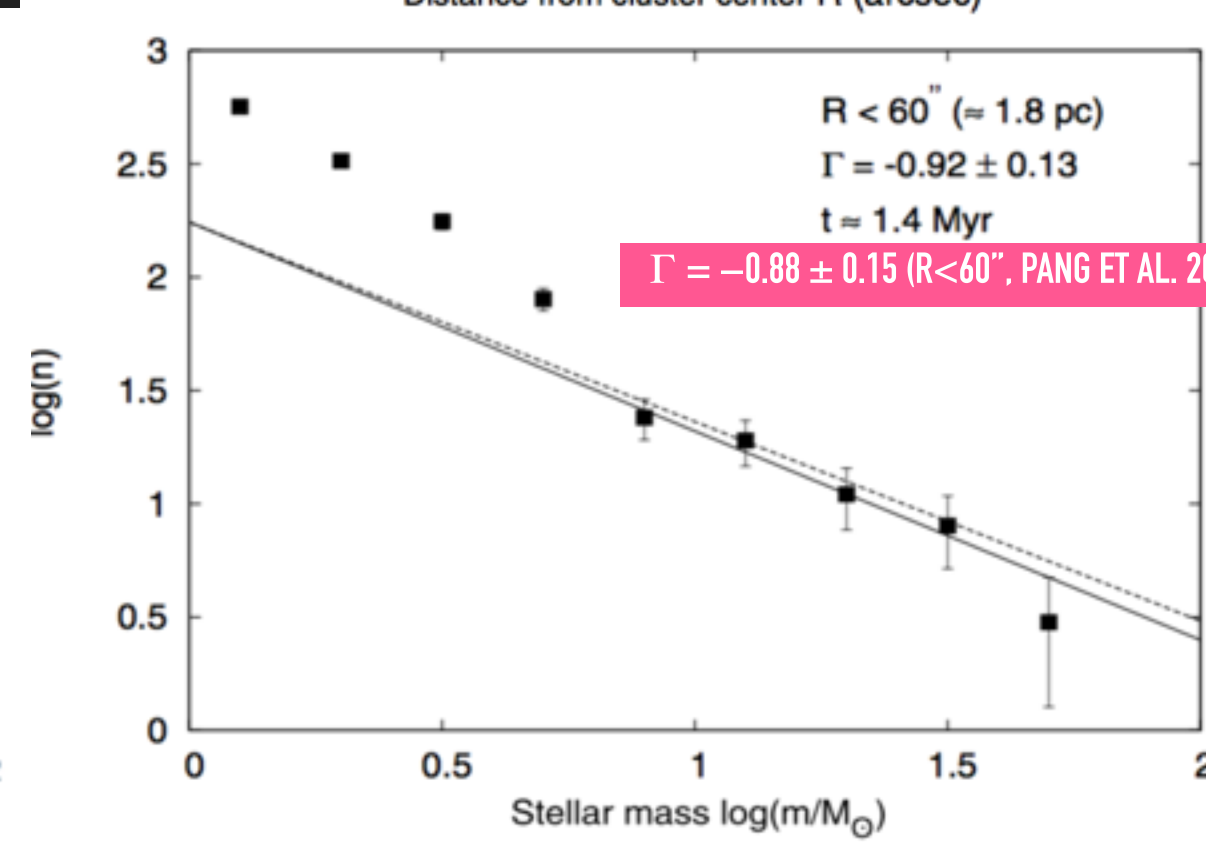
Beccari et al. (2010)

FORMATION SCENARIO – MONOLITHIC MODEL

- Formation of star clusters through single-starburst events (in-situ) followed by significant residual gas expulsion (<0.6 Myr).



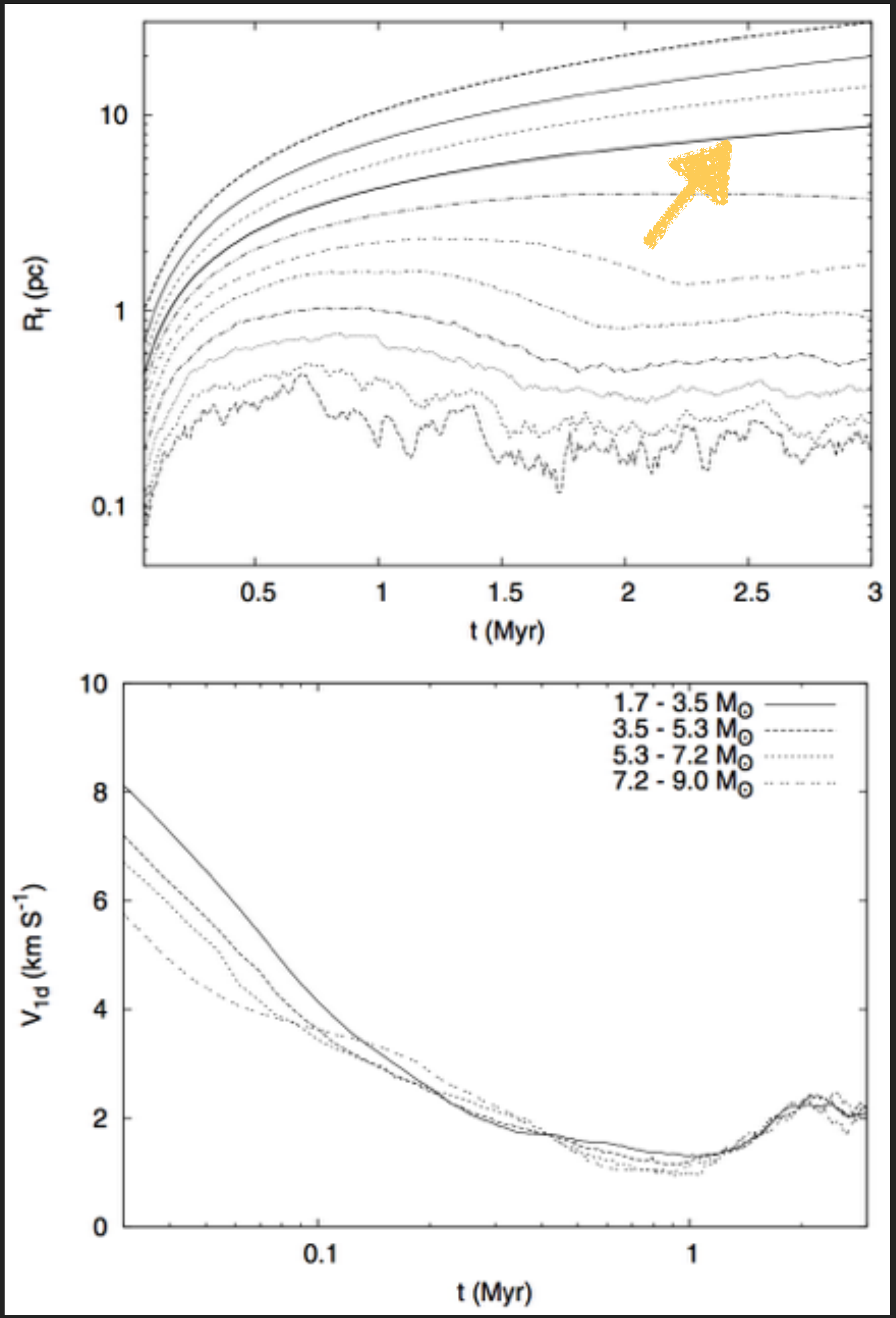




Banerjee et al. (2014)

DYNAMICAL STATE OF NGC 3603

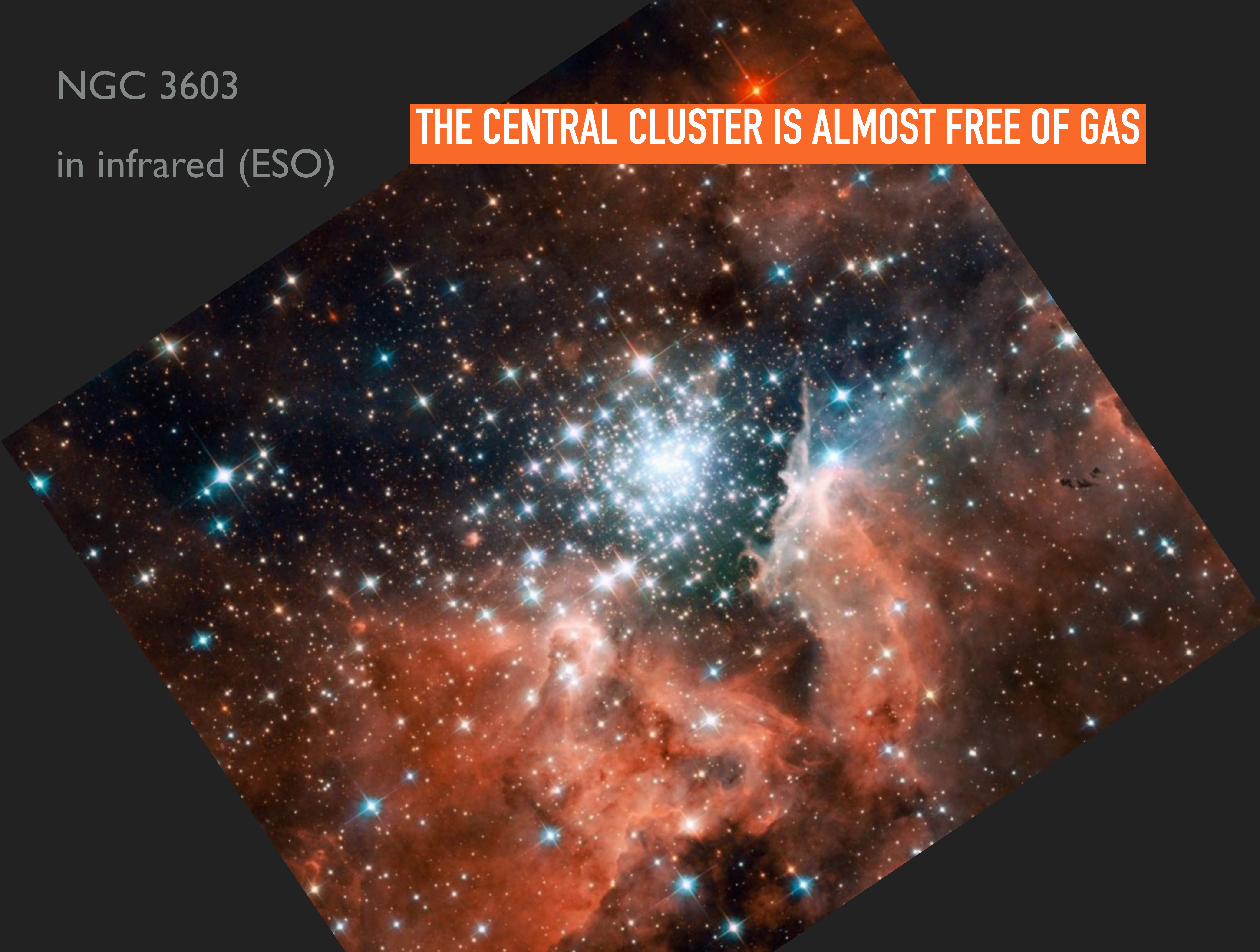
- Virialization?
  - $M_{dyn} \sim 1.9 \pm 0.6 \times 10^4\ M_\odot$ (Pang et al. 2013)
  - $M_{phot} = 1\text{–}1.6 \times 10^4\ M_\odot$ (Harayama et al. 2008)
- Sub-virial?
- Super-virial?
  - Banerjee & Kroupa (2013): virialization timescale > 2 Myr; the observed one dimension velocity dispersion V_{1d} (4.5-6.5km/s; Rochau et al. 2010, Pang et al. 2013) is larger than V_{1d} computed from simulation at 1 Myr.



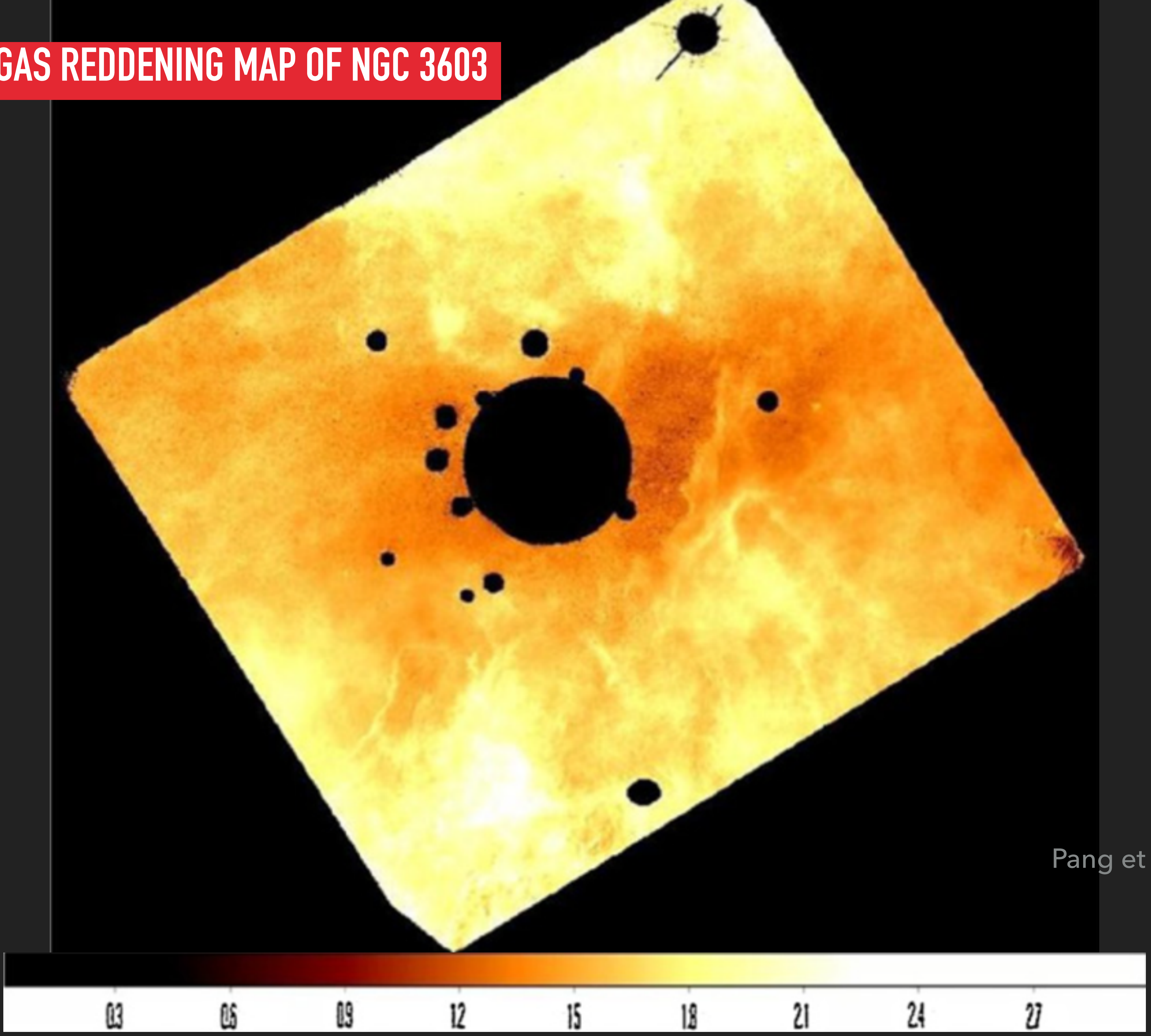
Banerjee & Kroupa (2013)

NGC 3603

in infrared (ESO)



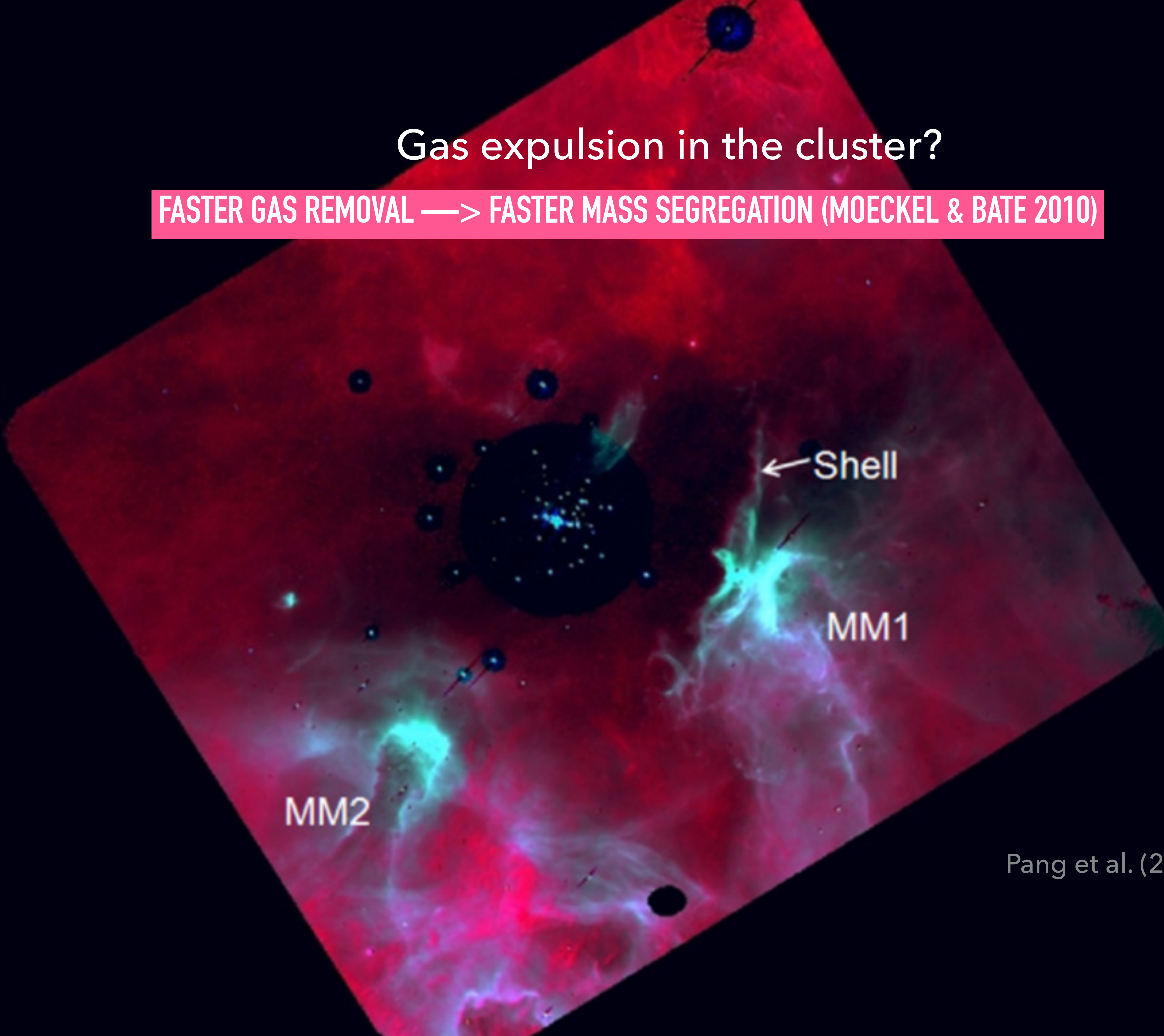
GAS REDDENING MAP OF NGC 3603



Pang et al. (2011)

Gas expulsion in the cluster?

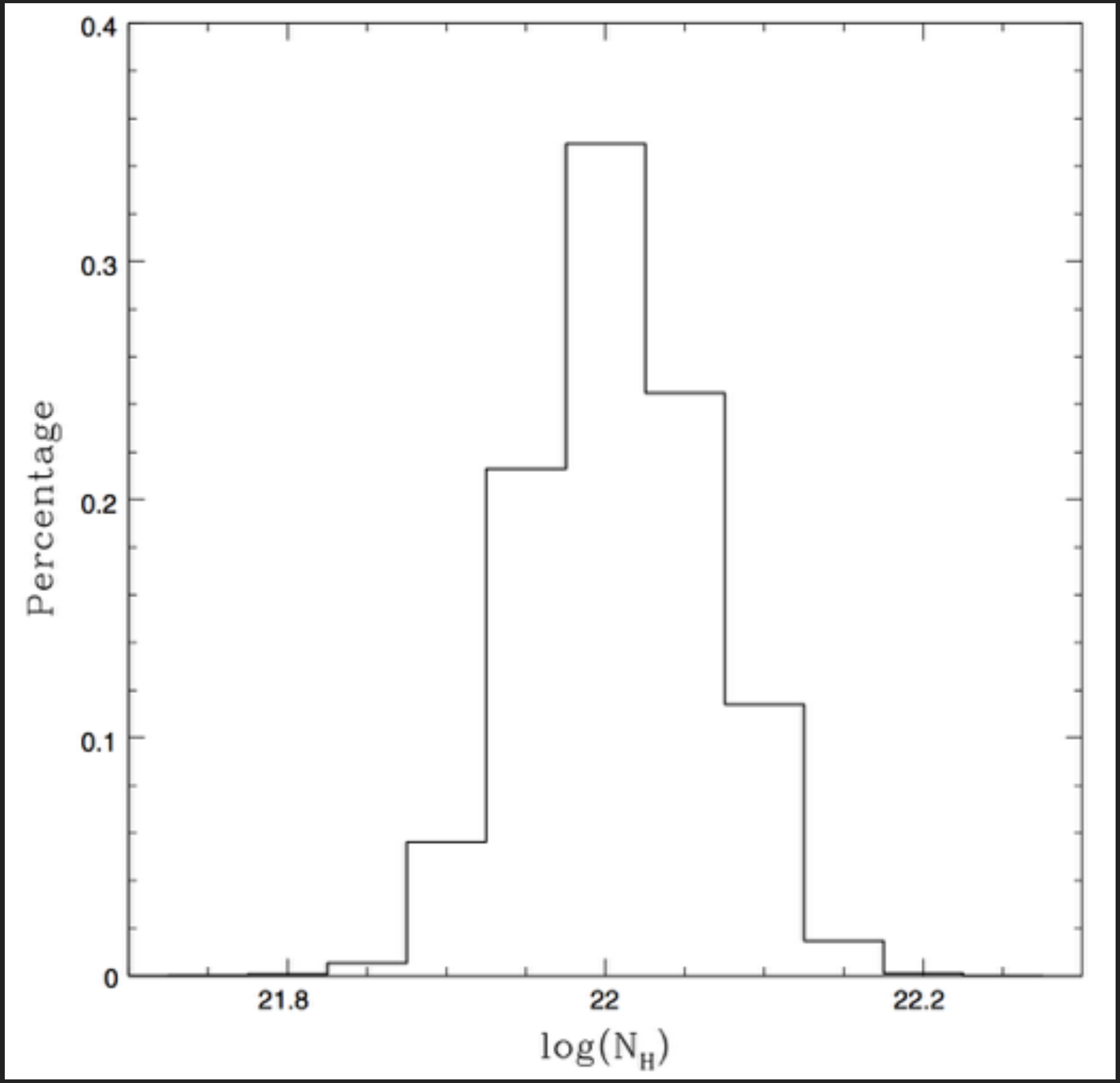
FASTER GAS REMOVAL —> FASTER MASS SEGREGATION (MOECKEL & BATE 2010)



Pang et al. (2011)

GAS MASS ESTIMATION

- Size of the cloud:
  20 pc * 20 pc
- Column density of molecular hydrogen: ~1*10^23
- Total mass with NGC 3603: 40000 solar masses
- SFE: 25%



Pang et al. (2011)

NGC 3603

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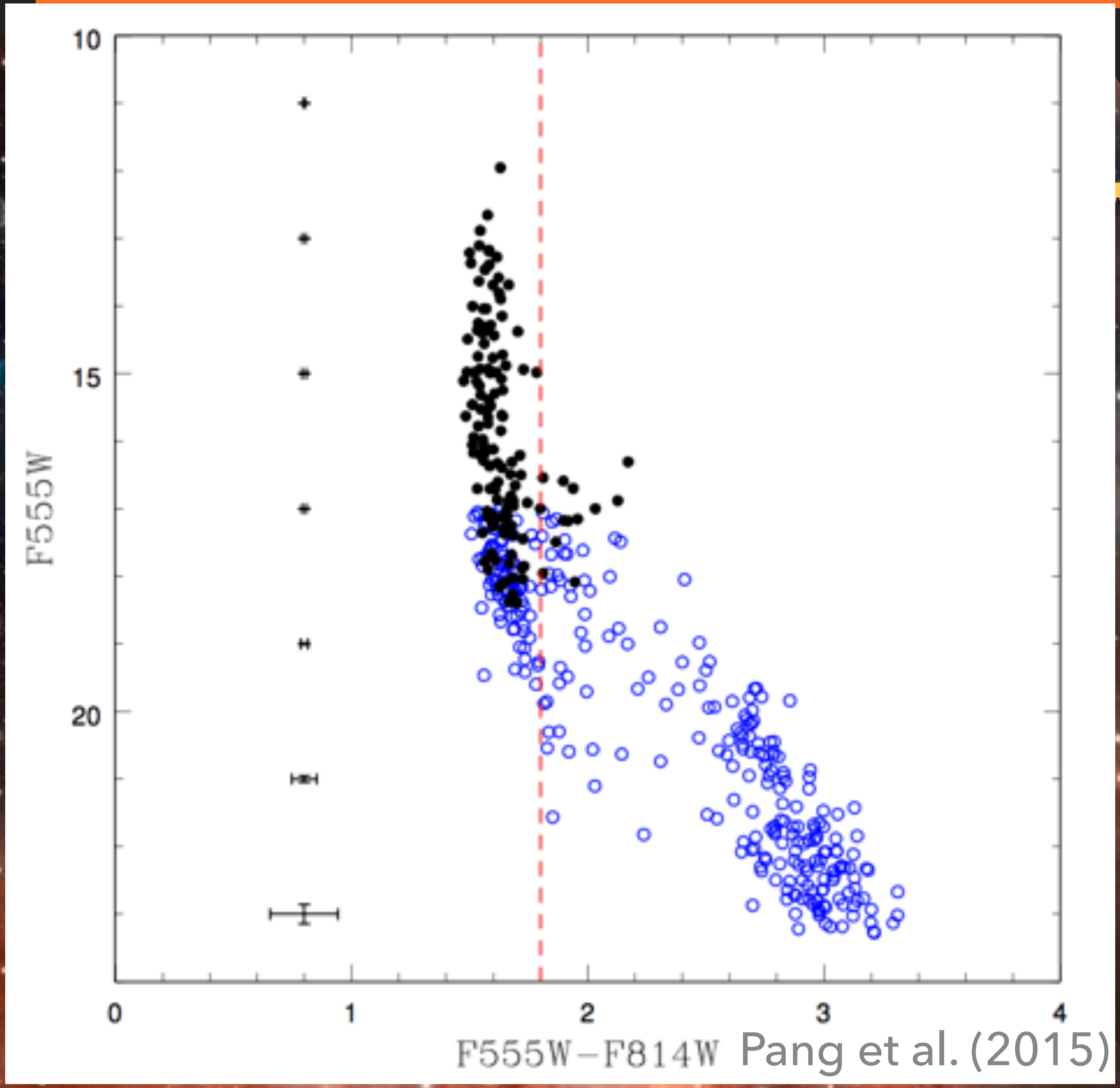
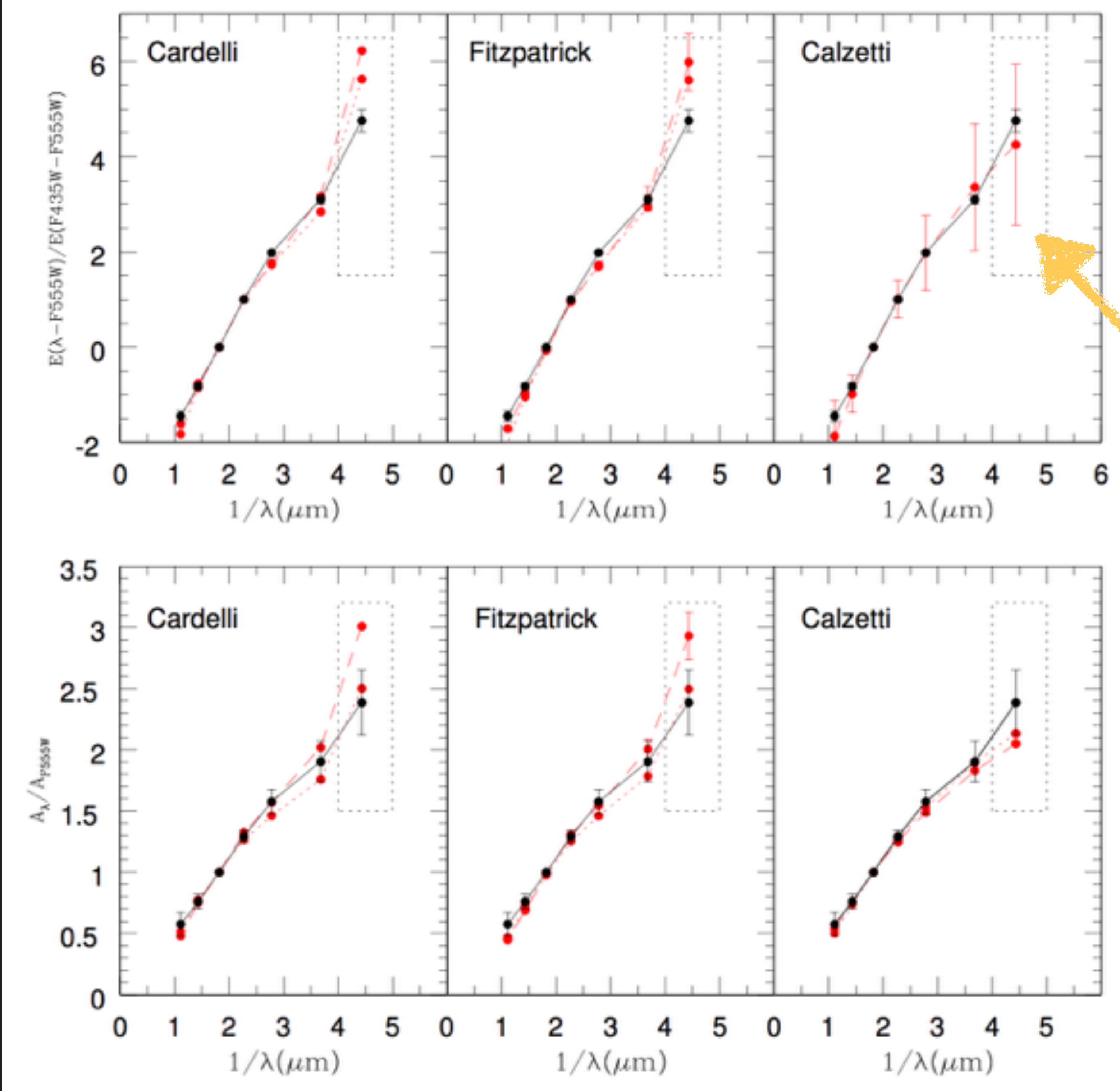
THE CENTRAL CLUSTER IS ALMOST FREE OF GAS

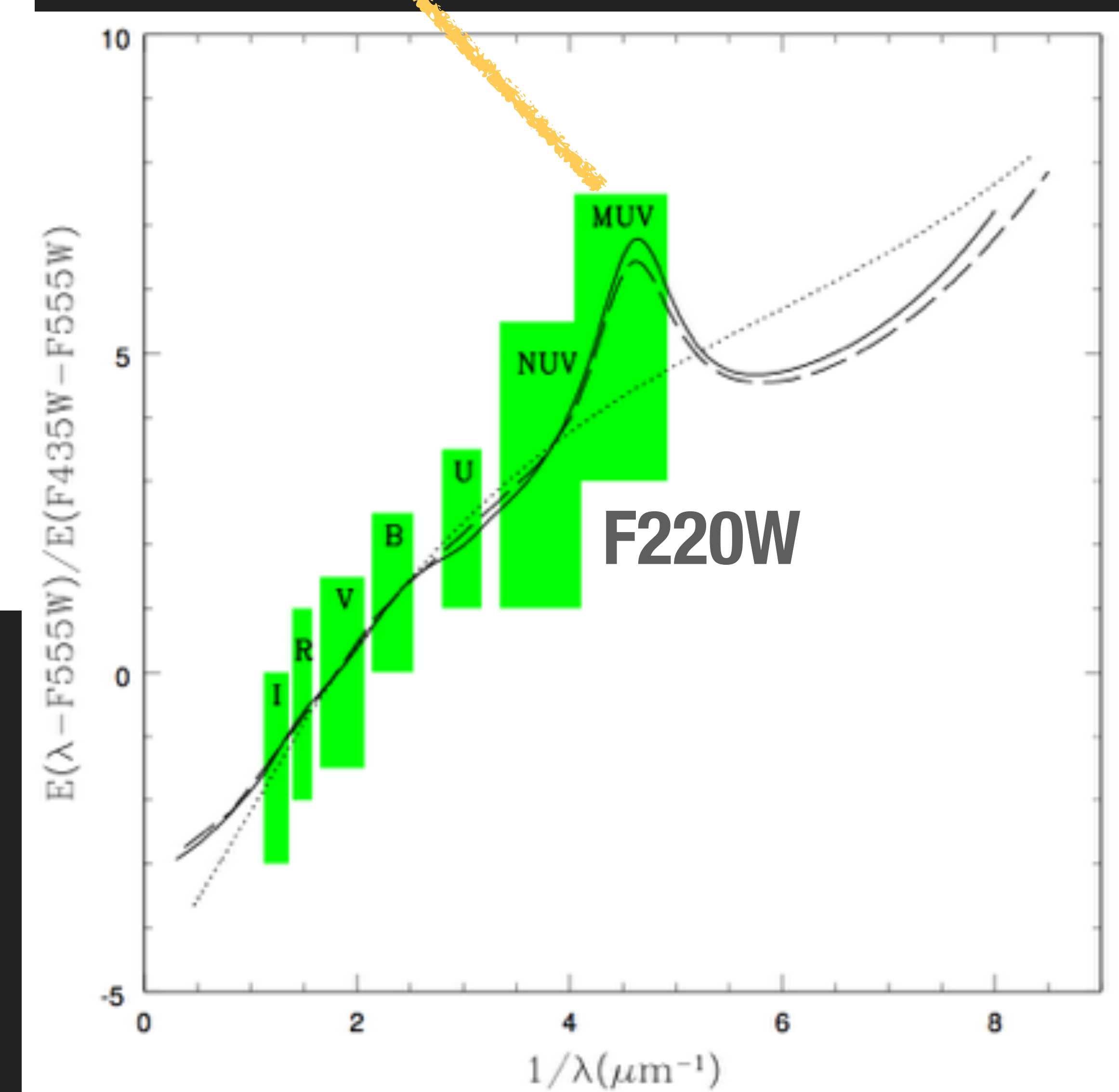


Pang et al. (2015)



$$R_{F555W} = 3.75 \pm 0.87$$

STARBURST-LIKE DUST.
CLUMPINESS OF DUST DISTRIBUTION
LARGER GRAIN SIZE THAN THE AVERAGE DIFFUSE GALACTIC ISM



Pang et al. (2015)

SUMMARY

- Mass segregation down to 30 solar masses, primordial segregation cannot be excluded
- Dynamical segregation is possible while gas is removed quickly
- Debatable dynamical state: supervirial or virial?
- Fast gas expulsion within the centre generates clumpy dust distribution