The Formation history of the Nuclear Star Cluster and of the Nuclear Stellar Disc

Rainer Schödel - IAA(CSIC)

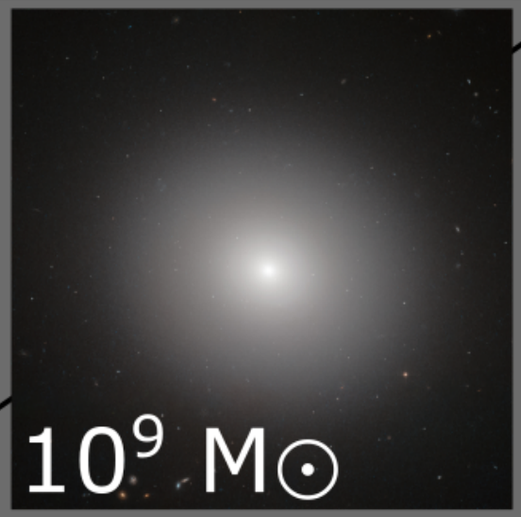
CPB 2022, Brno, 1 Jun 2022

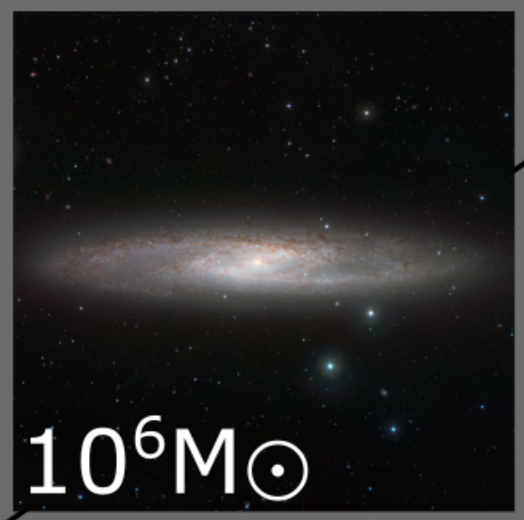
Instituto de Astrofísica de Andalucía, IAA-CSIC

EXCELENCIA SEVERO OCHOA

1. Galactic nuclei

Bulge mass



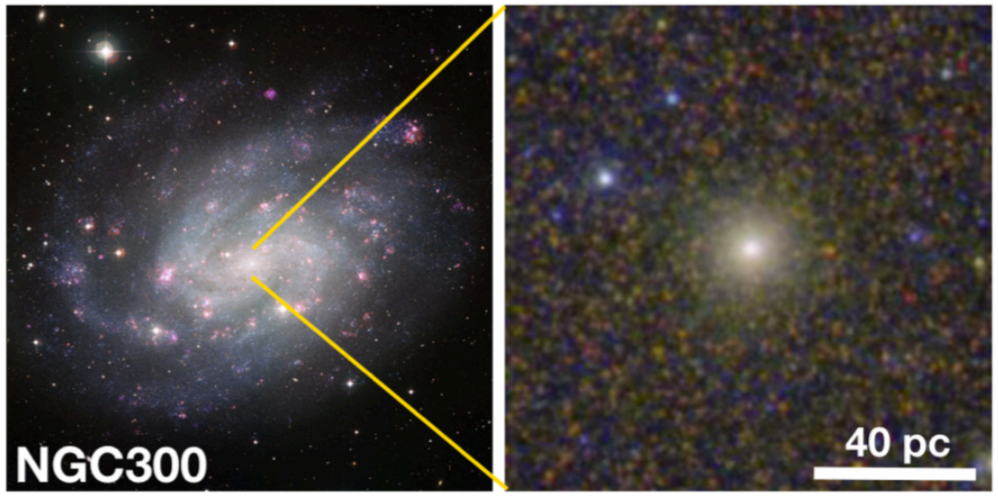


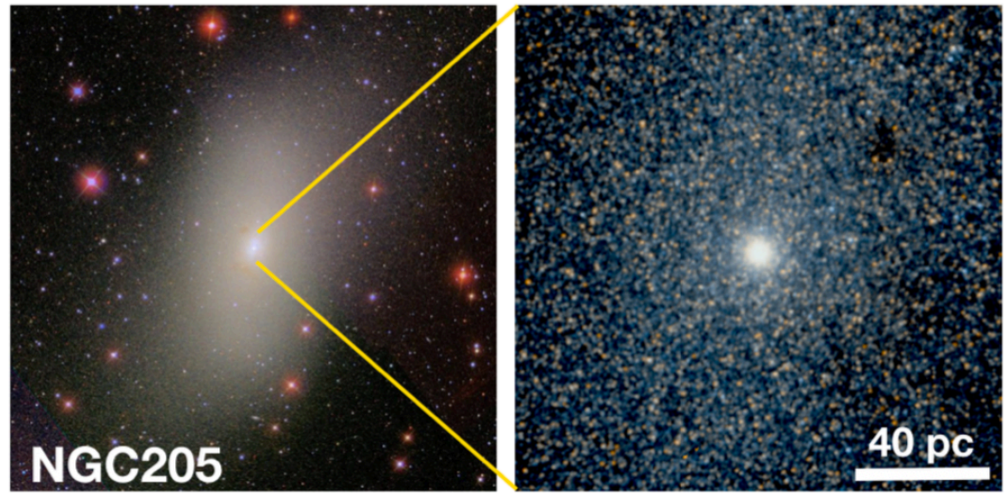
Black hole mass

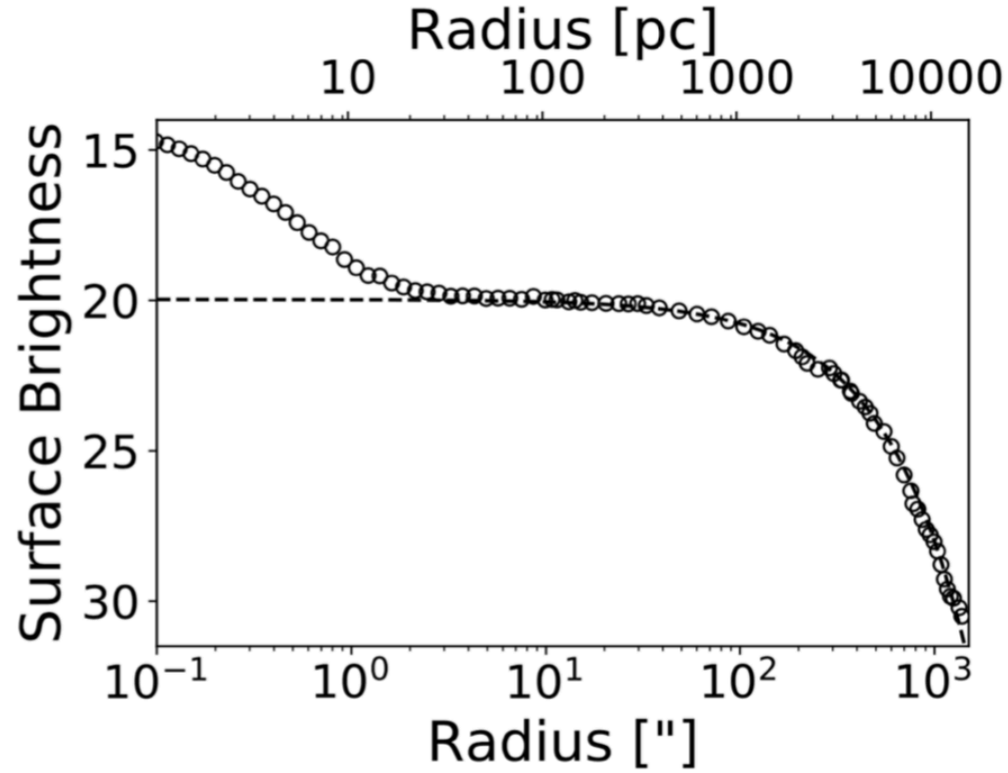
Gültekin et al. (2009), Haering & Rix (2004), Tremaine et al. (2002), Ferrarese & Merritt (2000), Magorrian et al. (1998) …

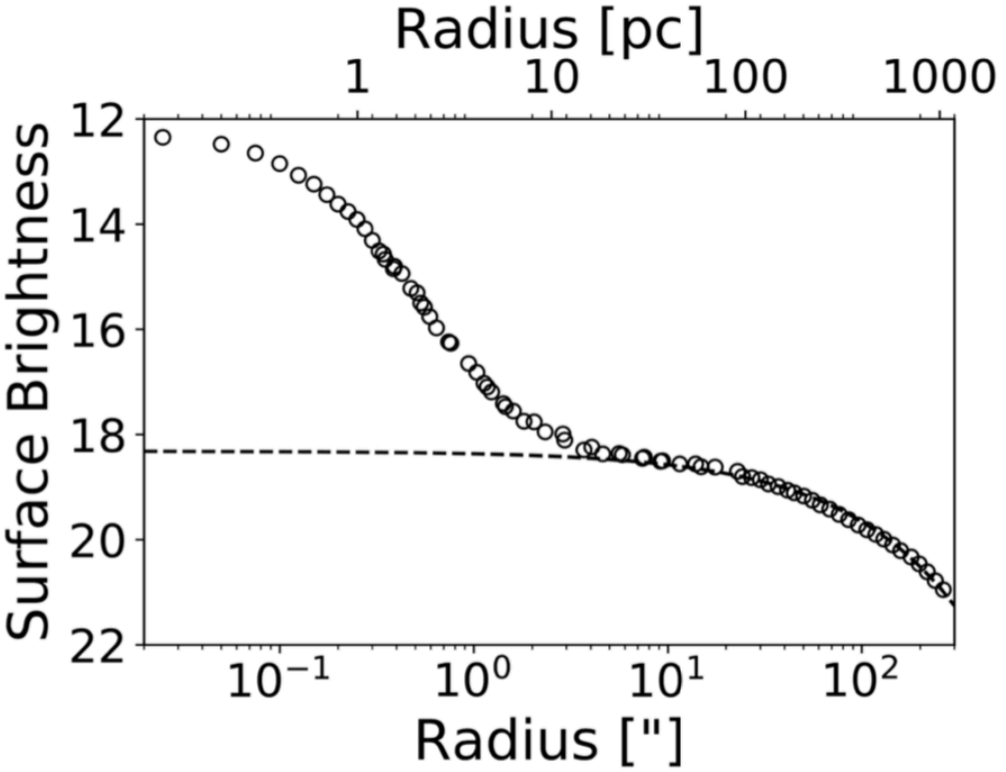
Nuclear star clusters

Figure: Neumayer, Seth & Böker (2020)



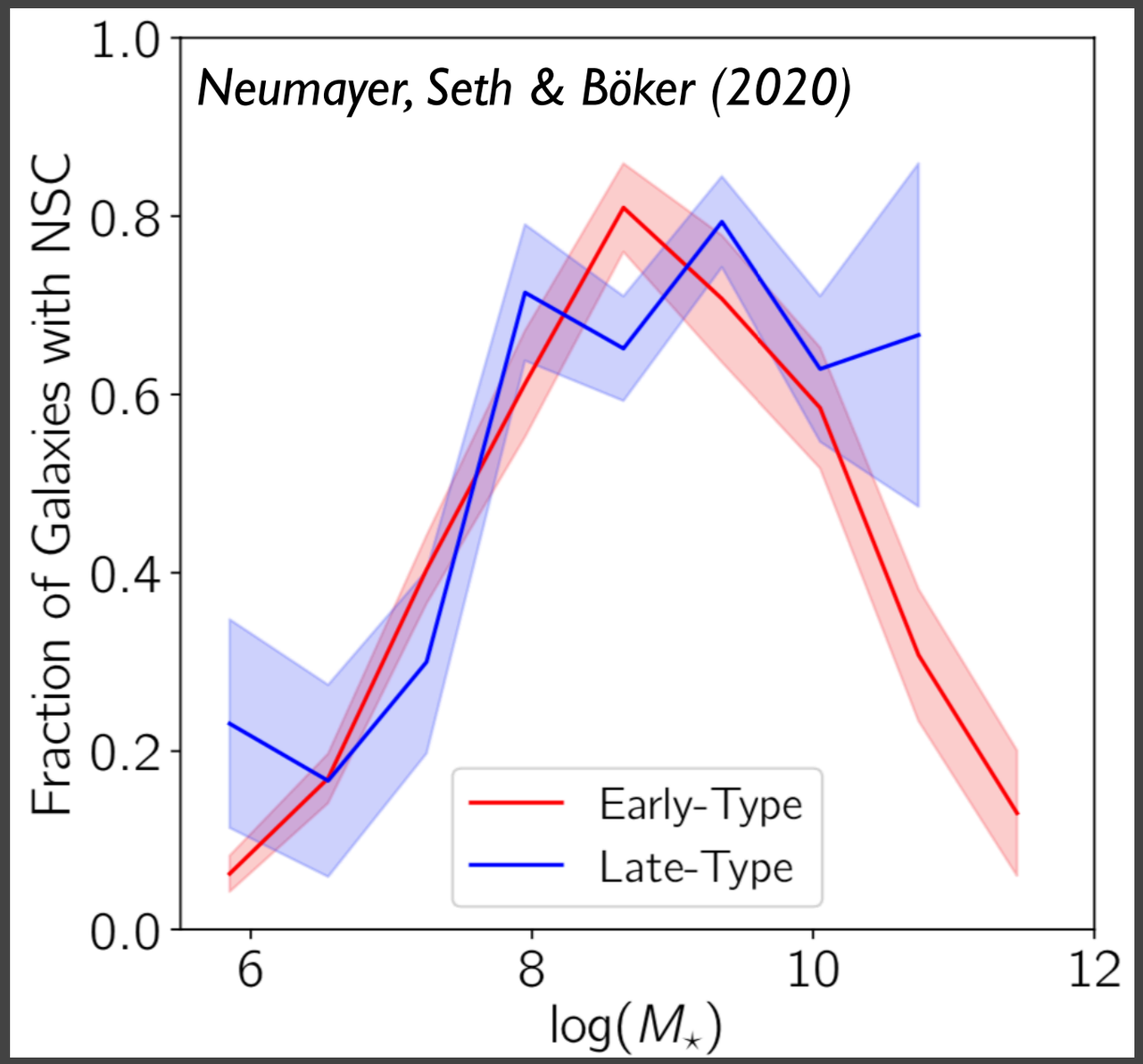






Reviews by T. Böker (2008), Neumayer (2017), Neumayer, Seth & Böker (2020)

Nuclear star clusters



- More frequent than SMBHs
- R_{eff} = 2-5 pc
- Mass 10^6 - 10^7 $M_\odot$
- Complex populations
- Coexistence with SMBHs
- Scaling relationships with host galaxies

T. Böker (2008), Neumayer (2017), Neumayer, Seth & Böker (2020)

NSCs: Why are they interesting?

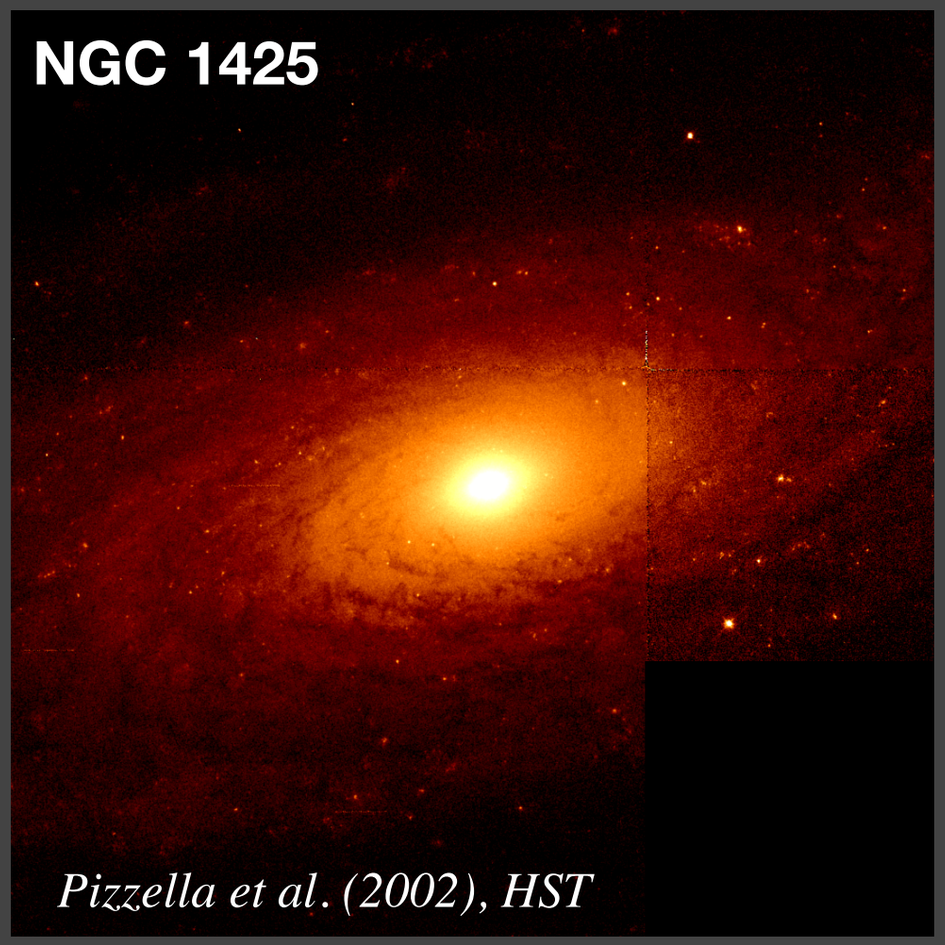
1) Galaxy evolution

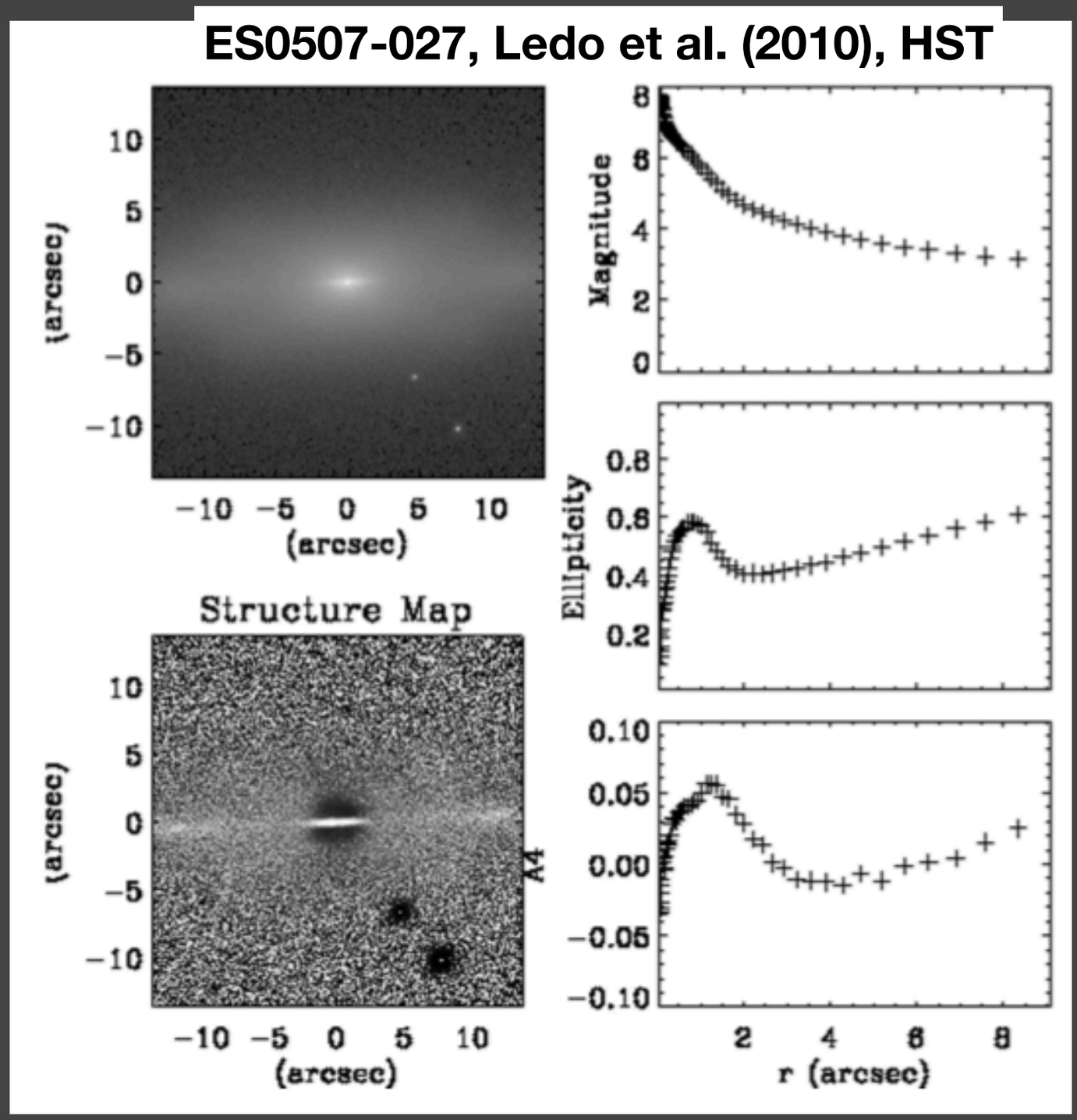
- They are everywhere.
- Scaling relationships: connected to galaxy evolution
- Formation sites of MBH seeds?

2) Astrophysics of extreme environments

3) Source regions of gravitational waves

Nuclear stellar discs





NSDs: Why are they interesting?

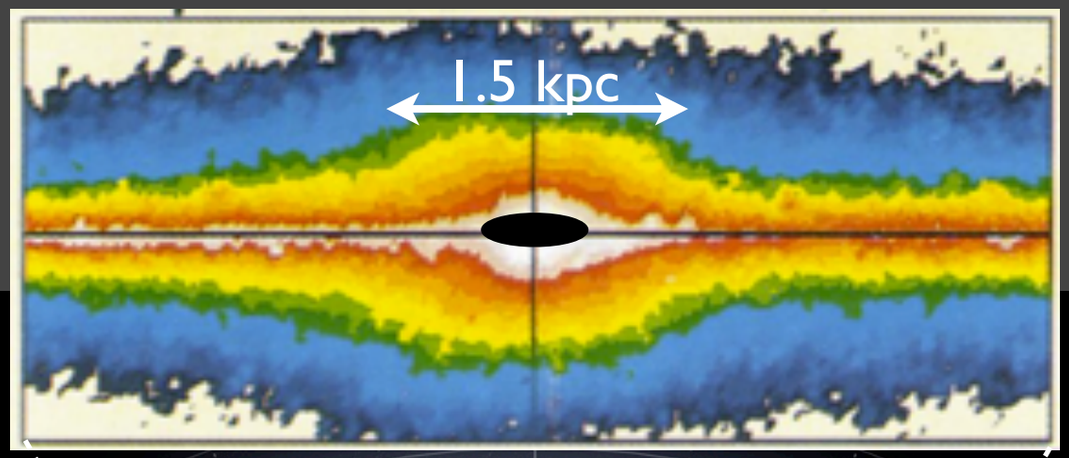
1) Tracers of galactic history:

- Common in barred spirals *(Gadotti et al. 2020)*
- Destroyed by major mergers, created by gas inflow

2) Astrophysics of extreme environments

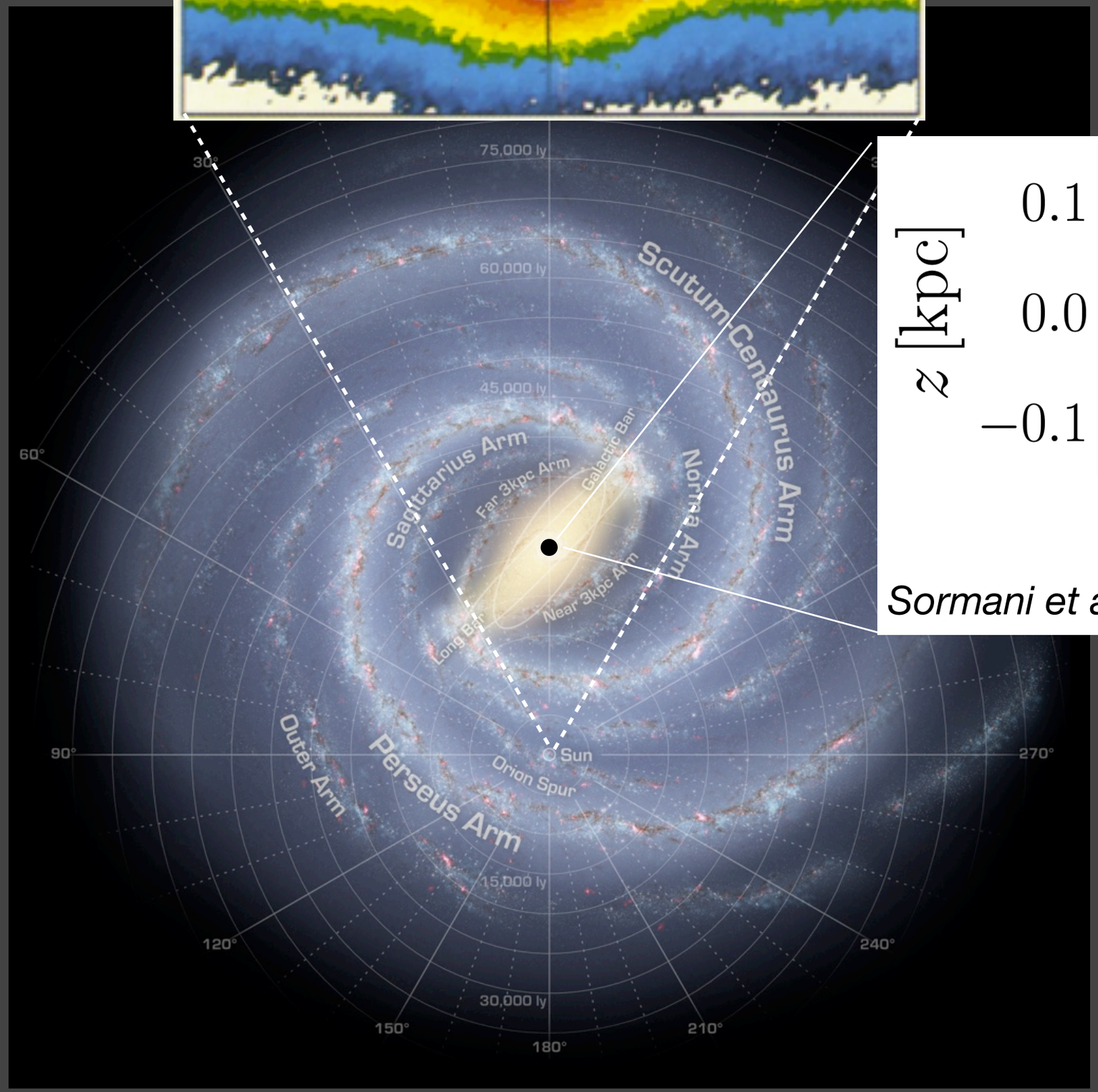
- Habitats of NSCs and large numbers of SBHs?
- Habitats of very massive star clusters
- Extreme environments: Universality of IMF, outflows

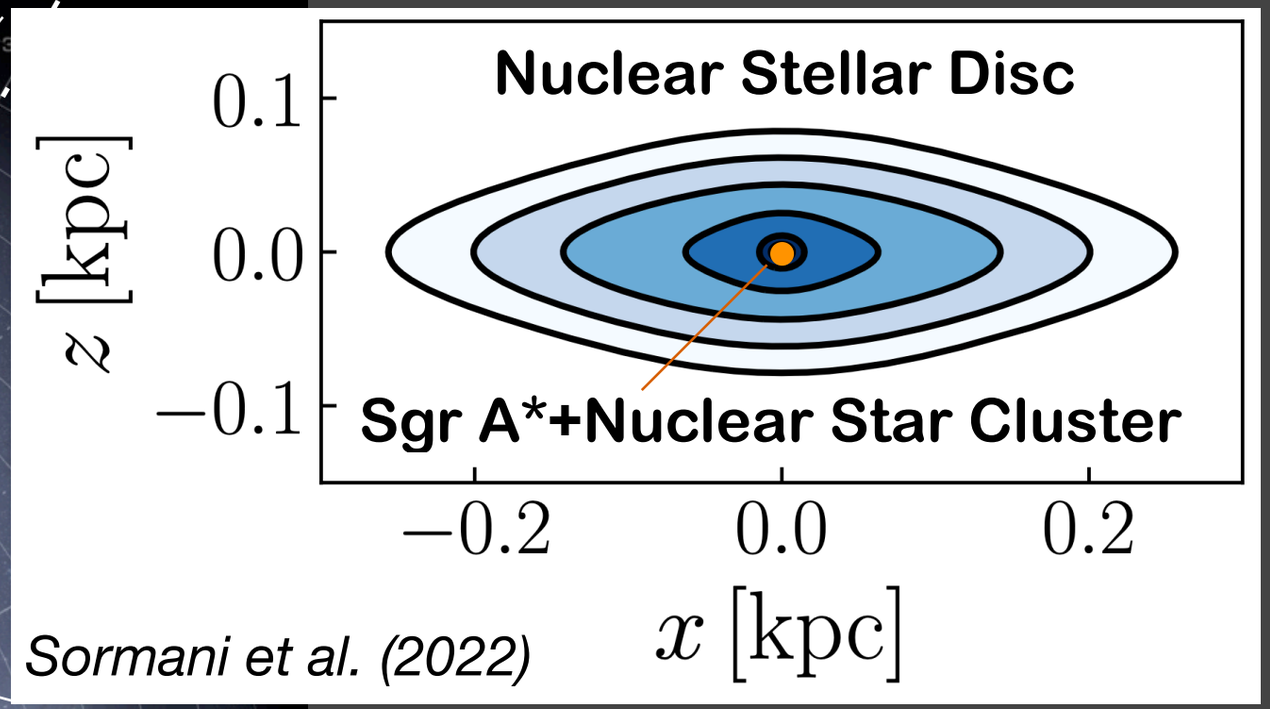
2. Overview of the Galactic Centre



4.9 μm COBE/DIRBE

(Weiland et al., 1994)

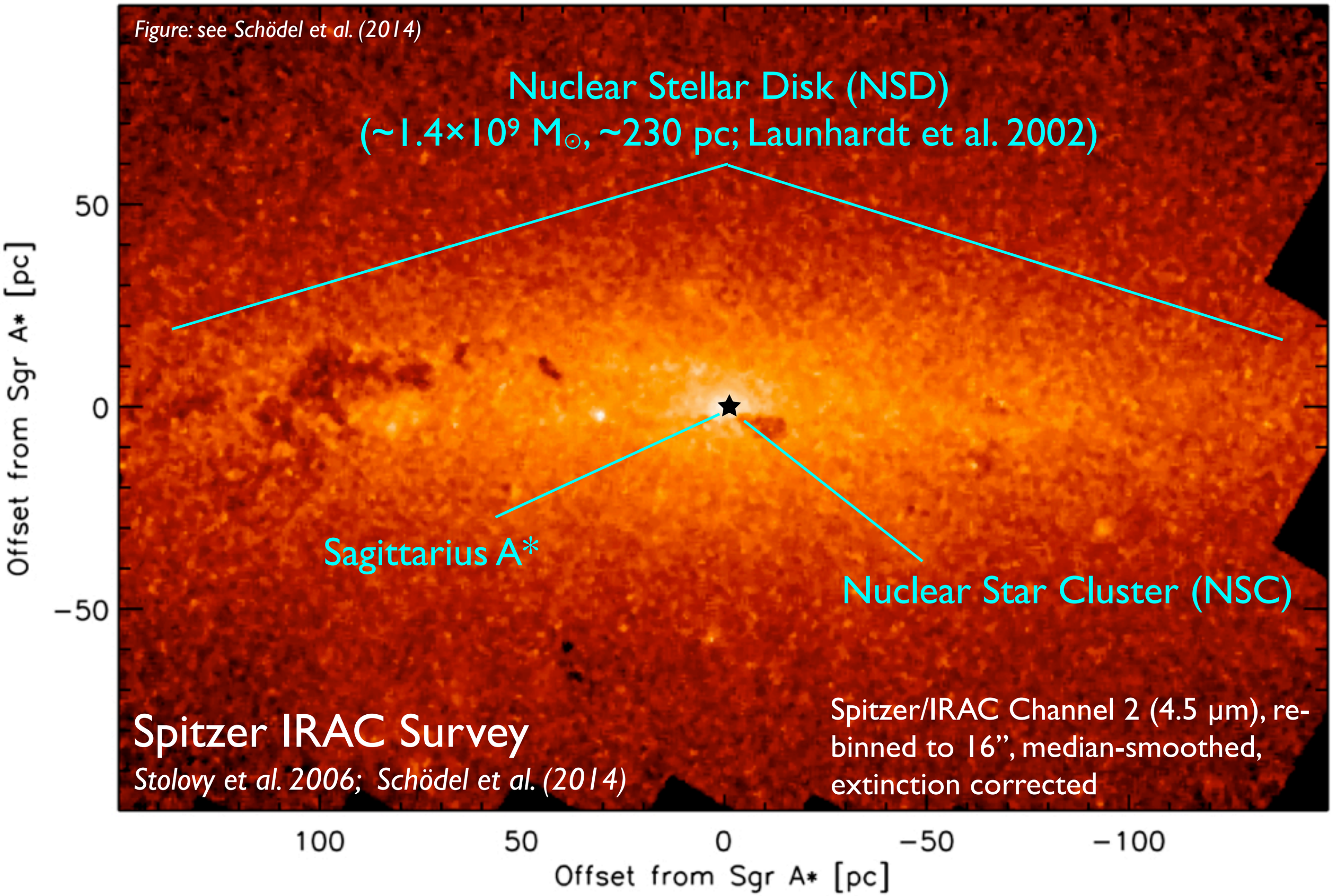


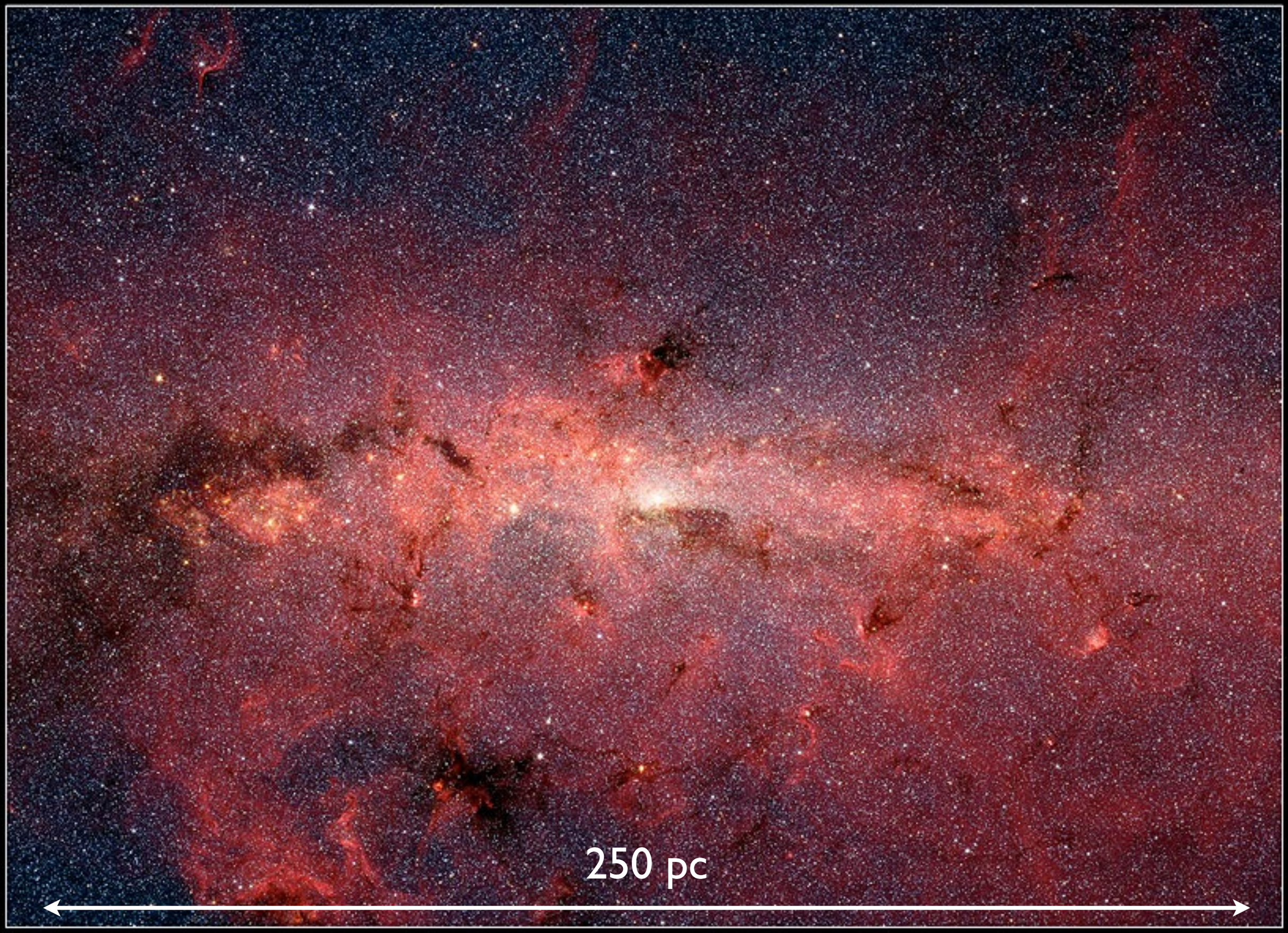


Sormani et al. (2022)

Churchwell et al. (2009, PASP): The Spitzer/GLIMPSE Surveys: A New View of the Milky Way

Overview of the GC





The Center of the Milky Way Galaxy

Spitzer Space Telescope • IRAC

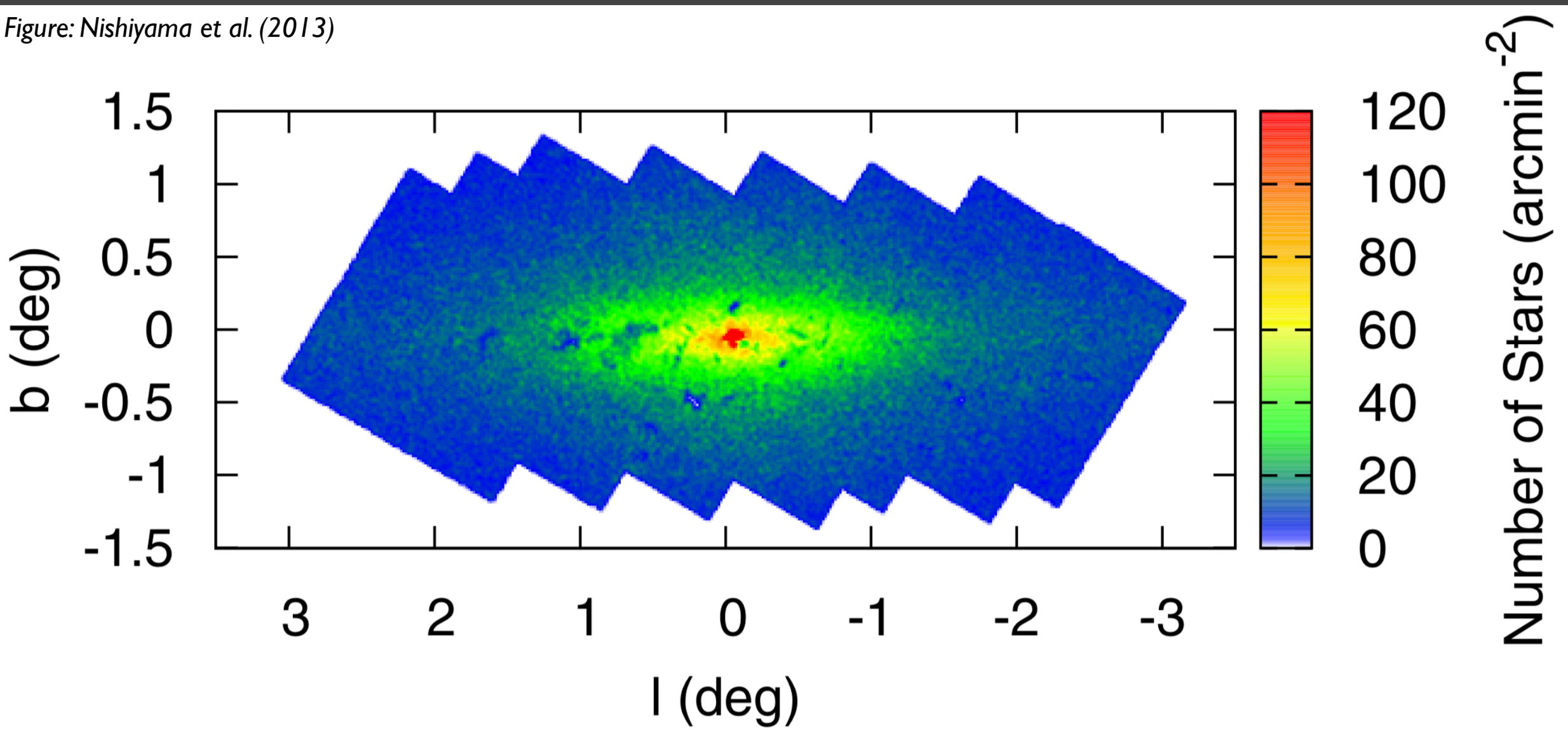
NASA / JPL-Caltech / S. Stolovy (Spitzer Science Center/Caltech)

ssc2006-02a

2. Nuclear Stellar Disc

Morphology

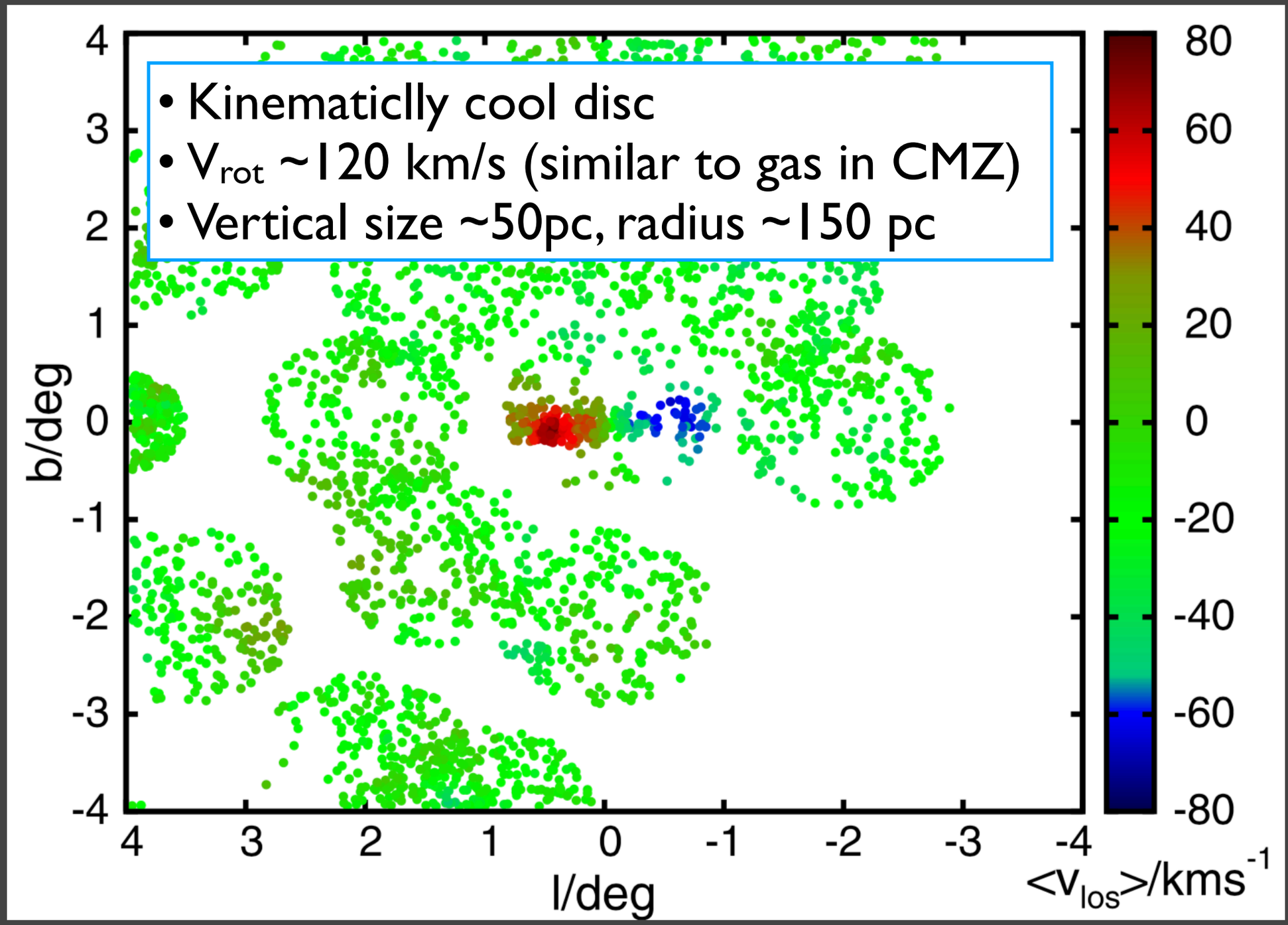
Figure: Nishiyama et al. (2013)



- Half light radius ~150 pc
- Mass ~ 1 × 10^9 $M_\odot$
- Strongly flattened along GP

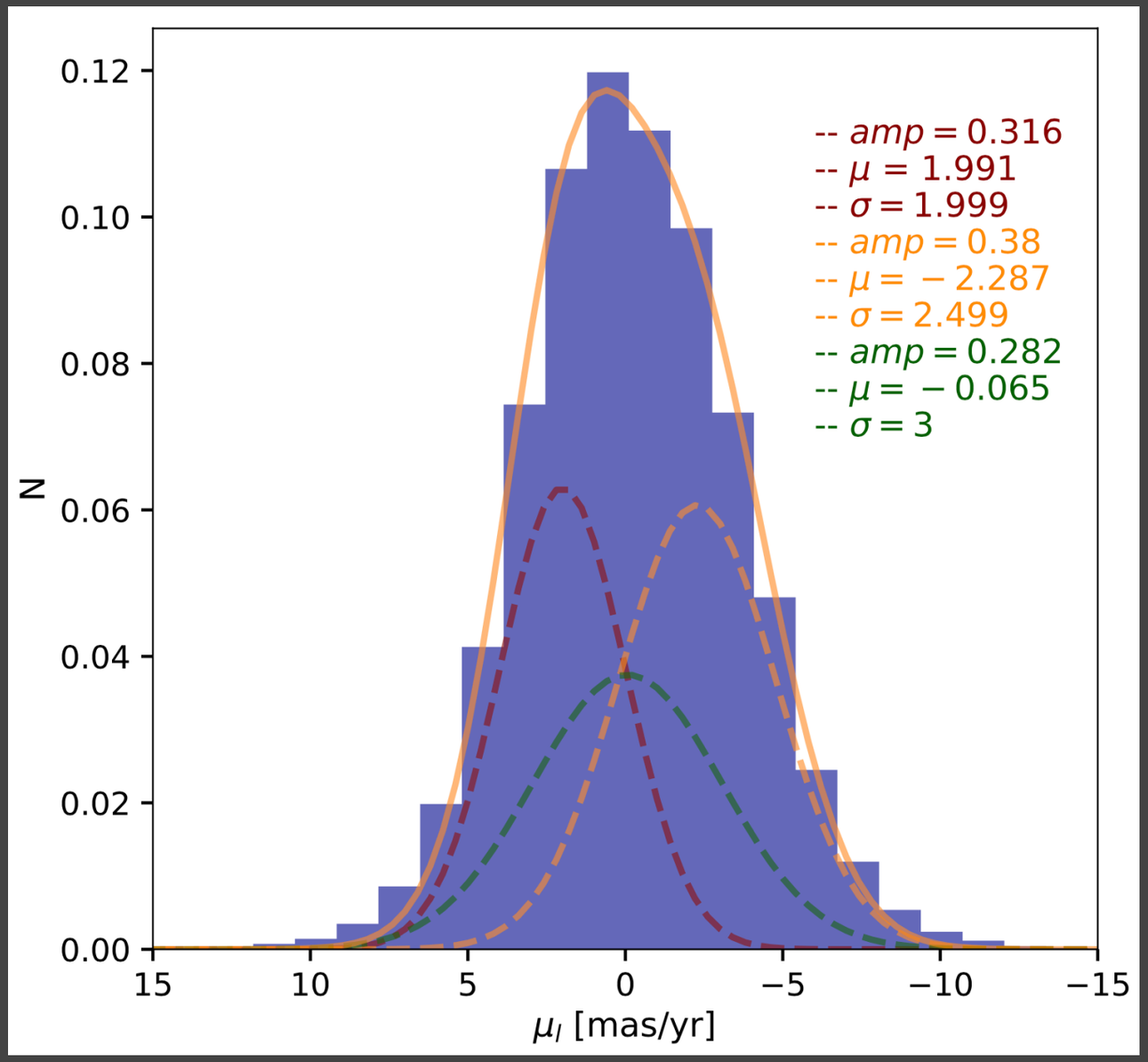
Launhardt et al. (2002); Nishiyama et al. 2013; Schödel, et al. 2014; Gallego-Cano et al. (2020)

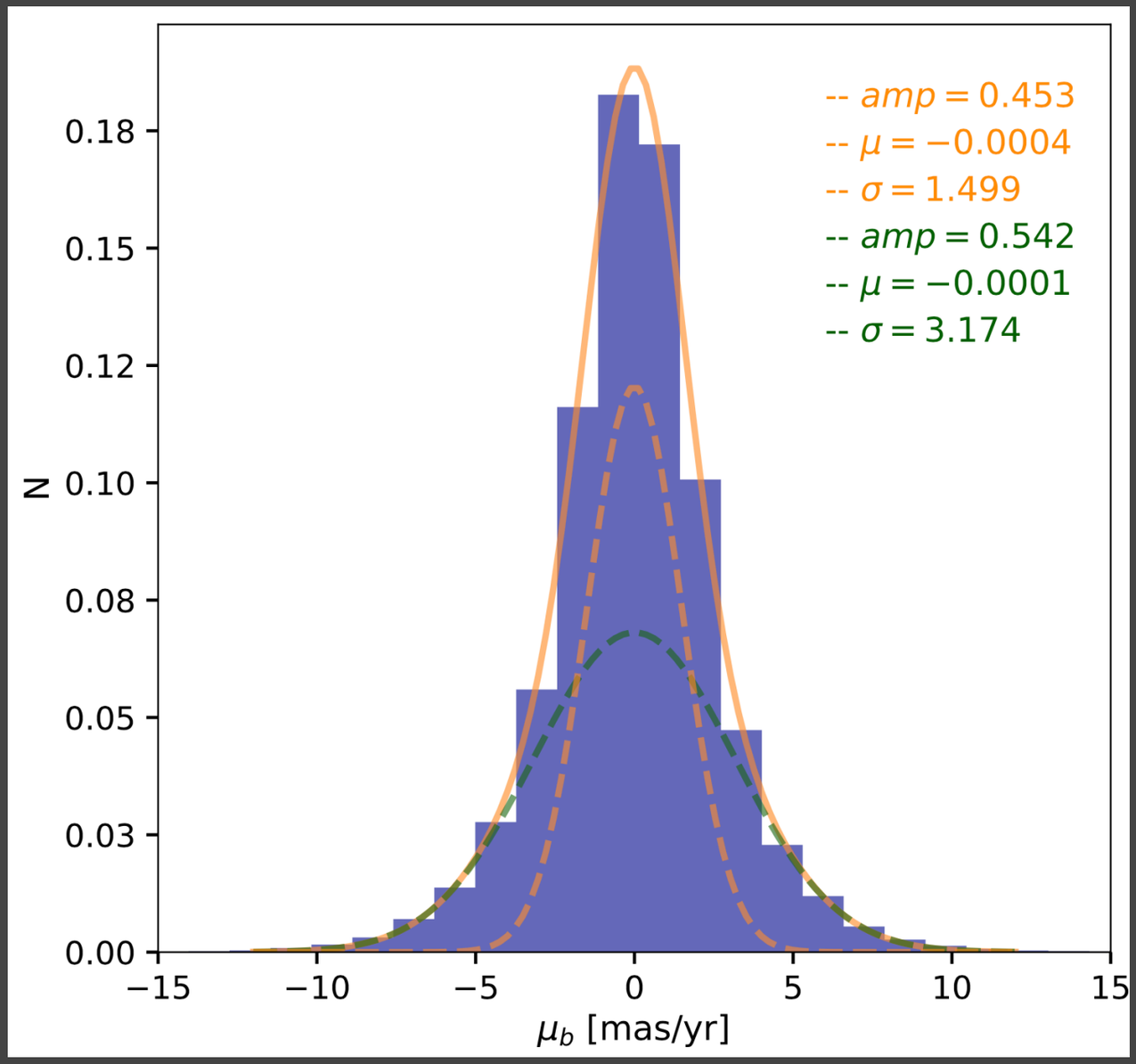
Kinematics



Schönrich, Aumer & Sale (2015)

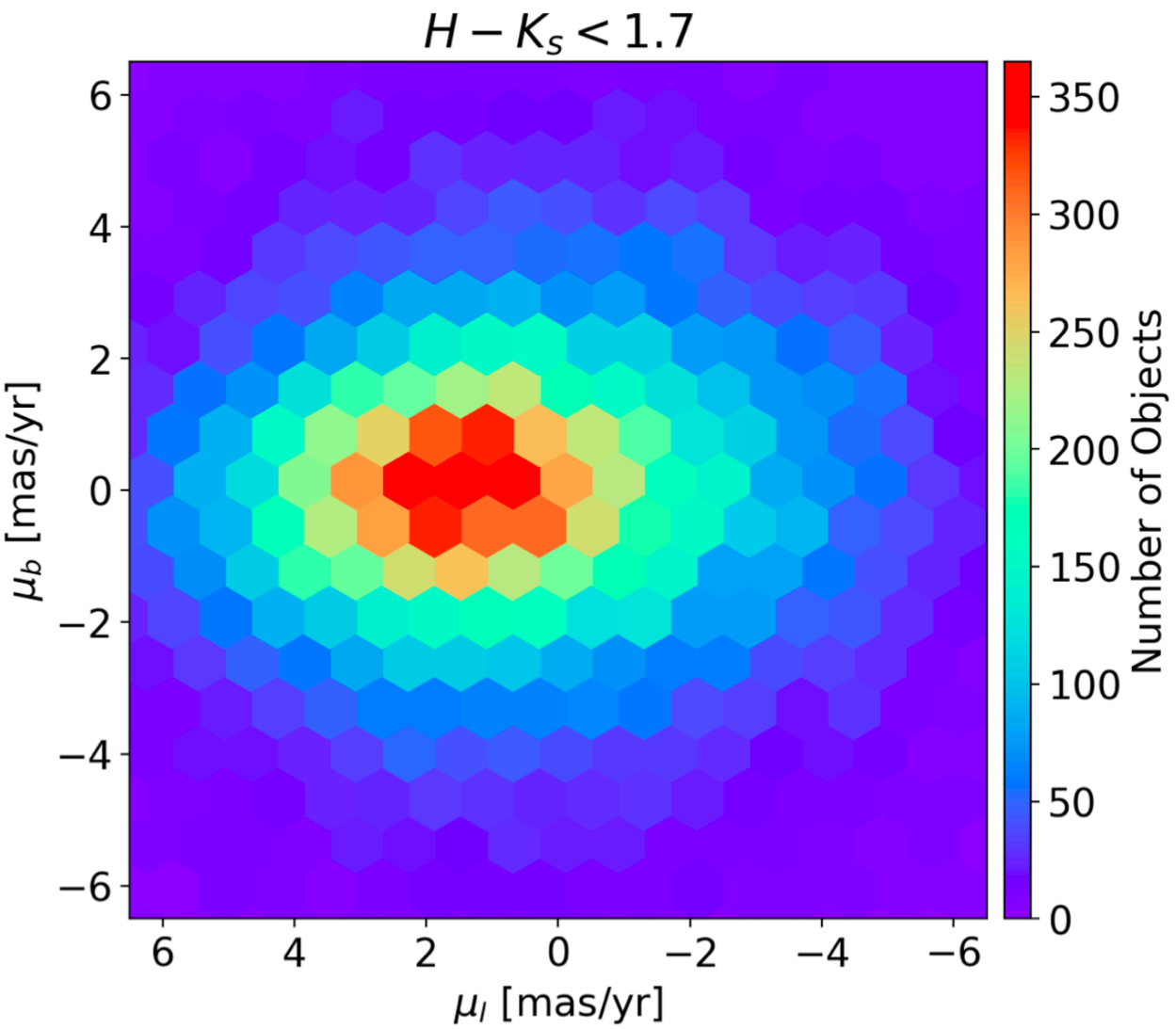
Kinematics

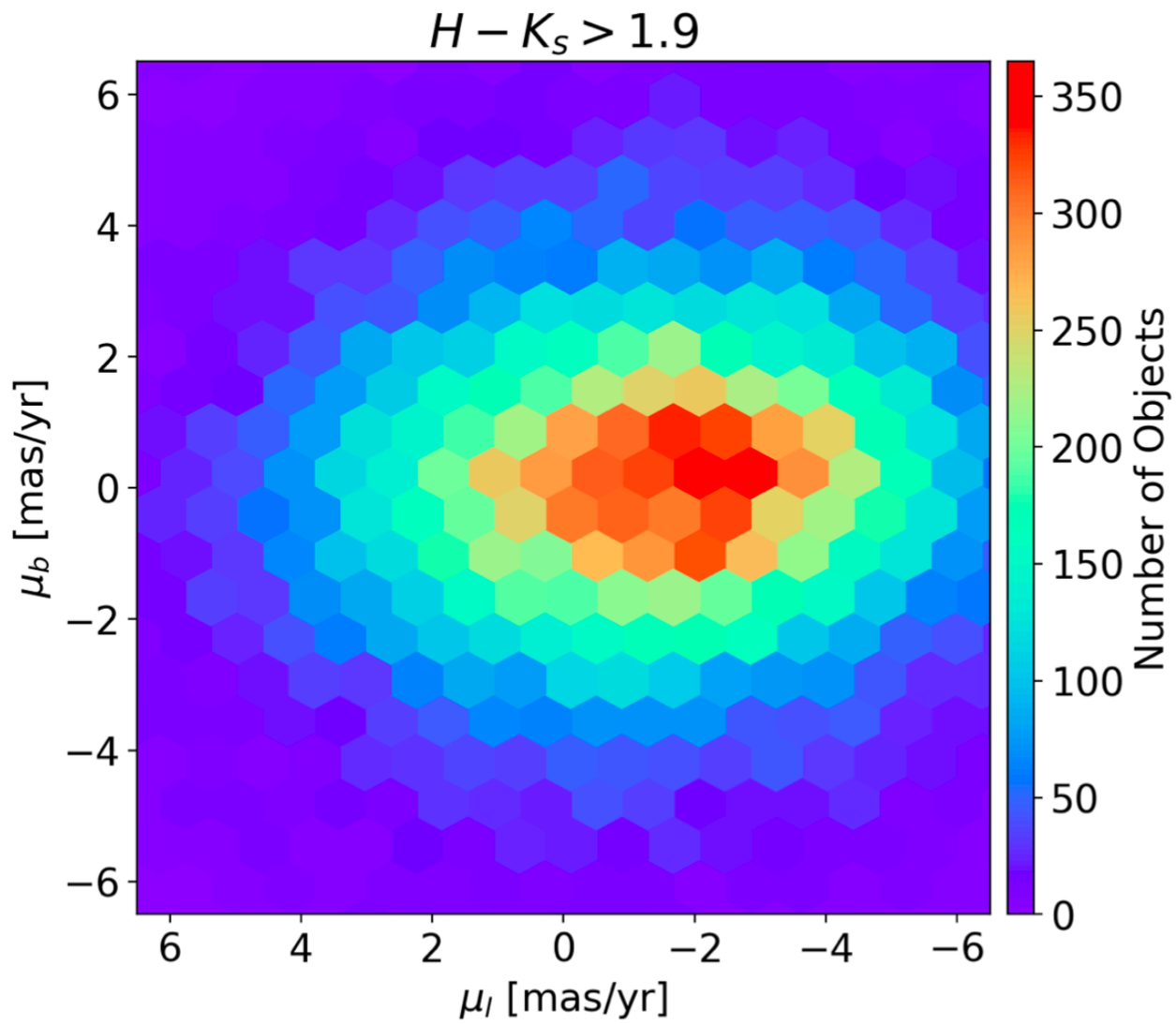




Shahzamanian et al. (2022)

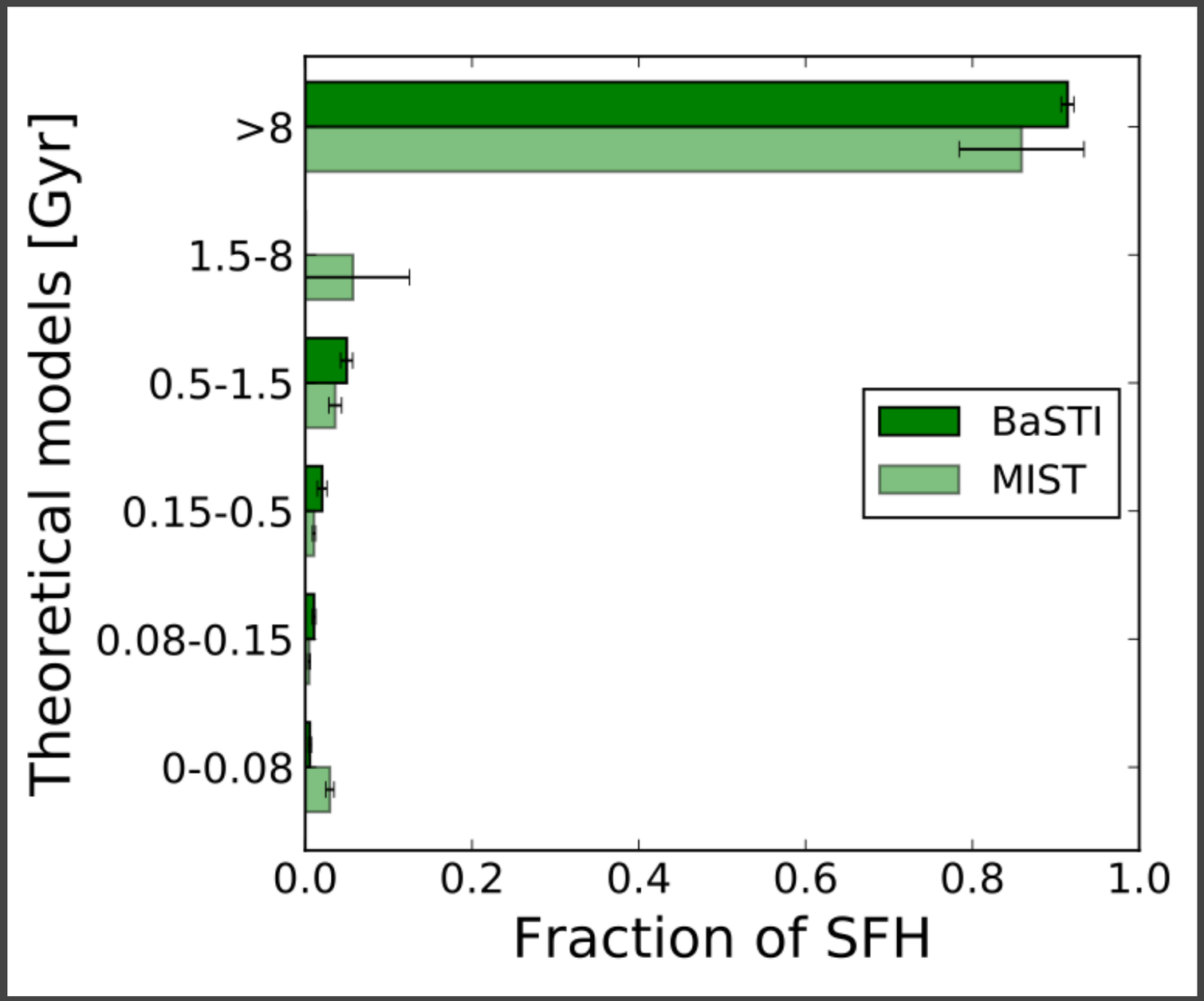
Kinematics





Proper motions show eastwards rotation on front, westwards on back side. *(Shahzamanian et al. 2021)*

Formation History



1) **Not compatible with quasi-continuous SFH** *(Morris & Serabyn 1996, Figer et al. 2004).*

2) Different from SFH of NSC.

3) Starbust event ~1 Gyr ago.

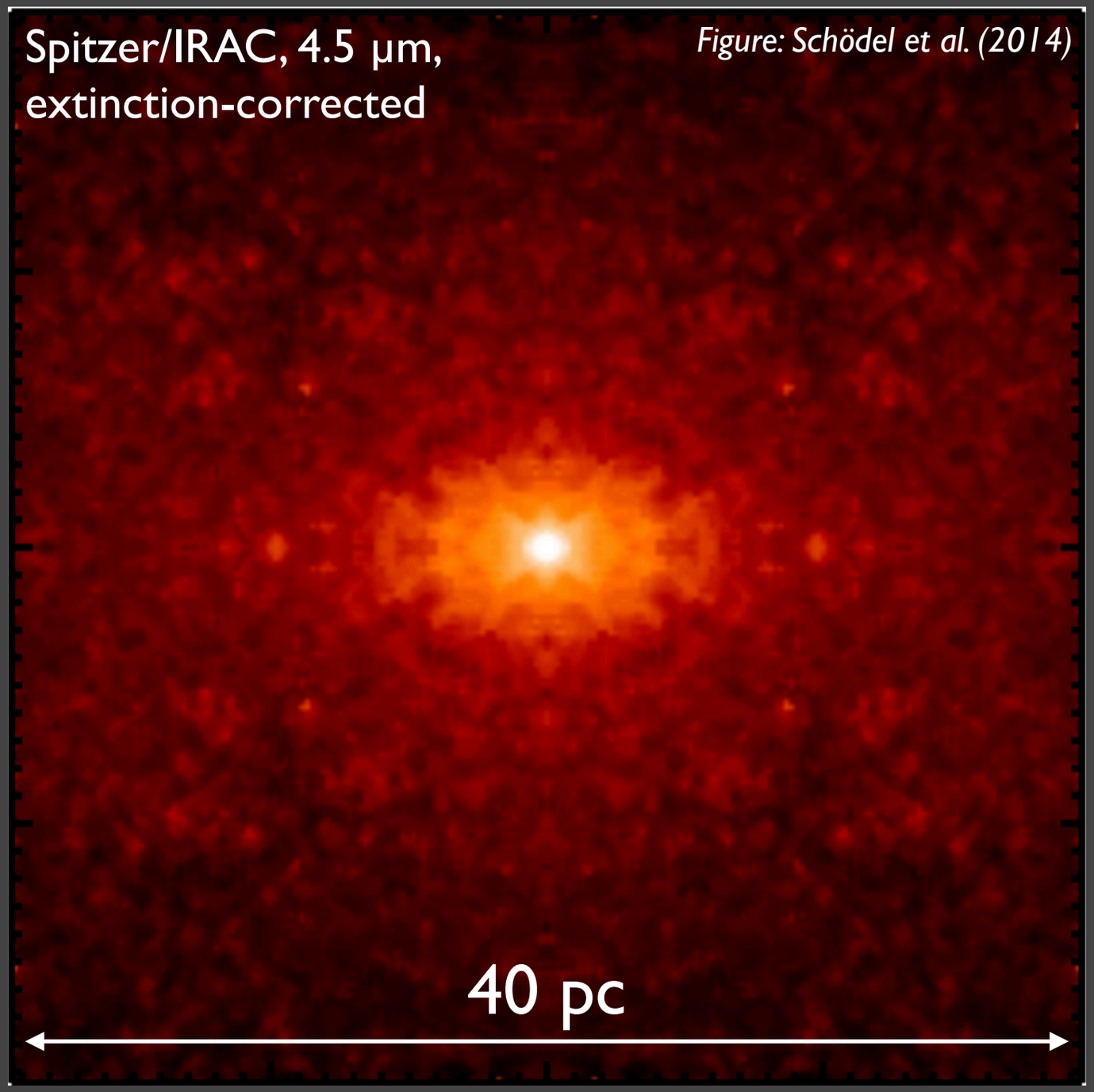
Nogueras-Lara et al. (2019, Nature Astronomy)

The Milky Way 1 Gyr ago?

M82 (NASA/JPL-Caltech/STScI/CXC/UofA/ESA/AURA/JHU)

3. Nuclear Star Cluster

Morphology

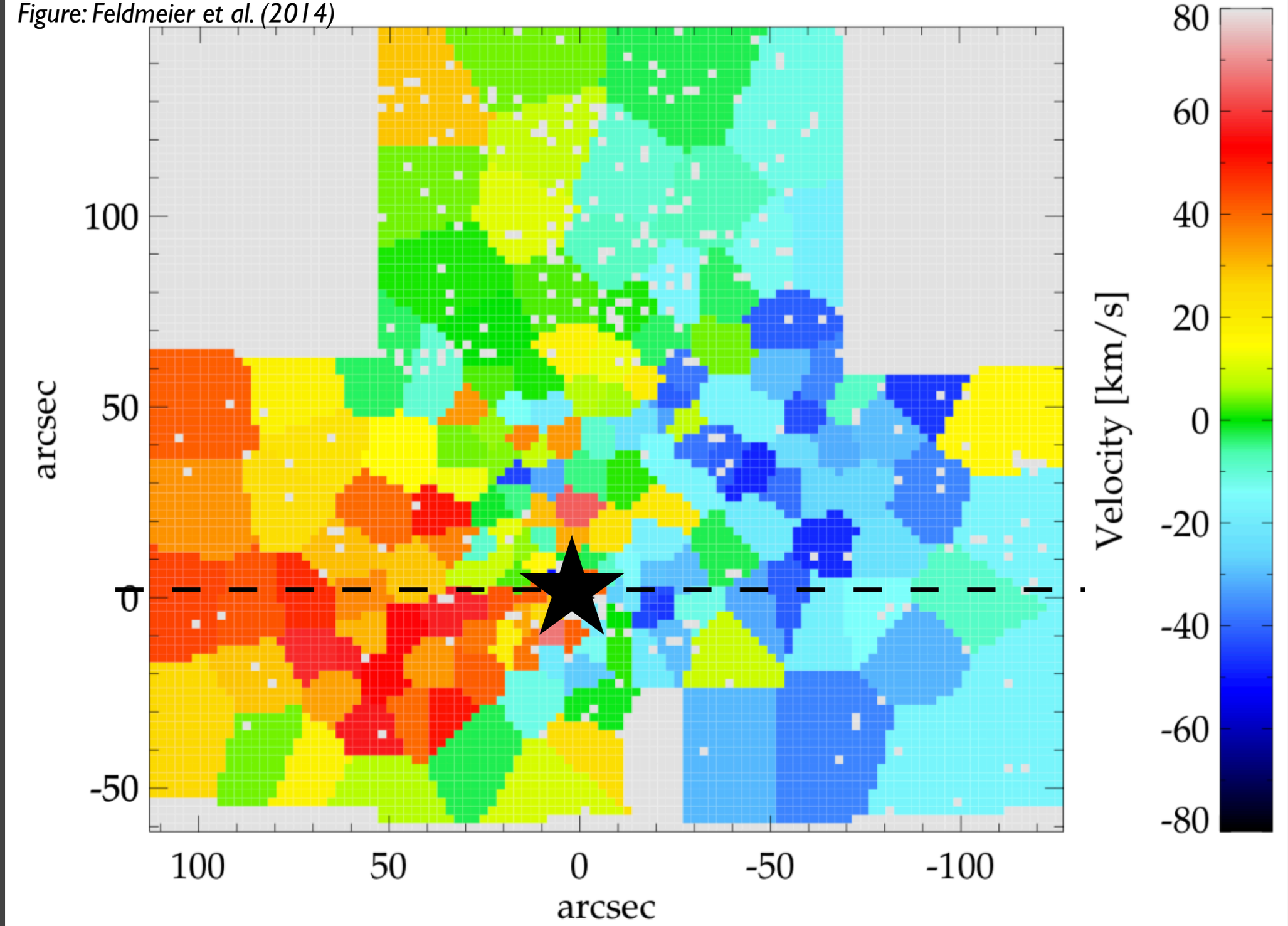


- Centred on Sgr A*
- Flattened along Galactic Plane
- Half light radius = 4.2 ± 0.4 pc
- Mass 2.5 ± 0.4 × 10^7 $M_\odot$

Schödel, et al. 2014; Feldmeier et al. 2014; Fritz et al. 2016; Gallego-Cano et al. (2019)

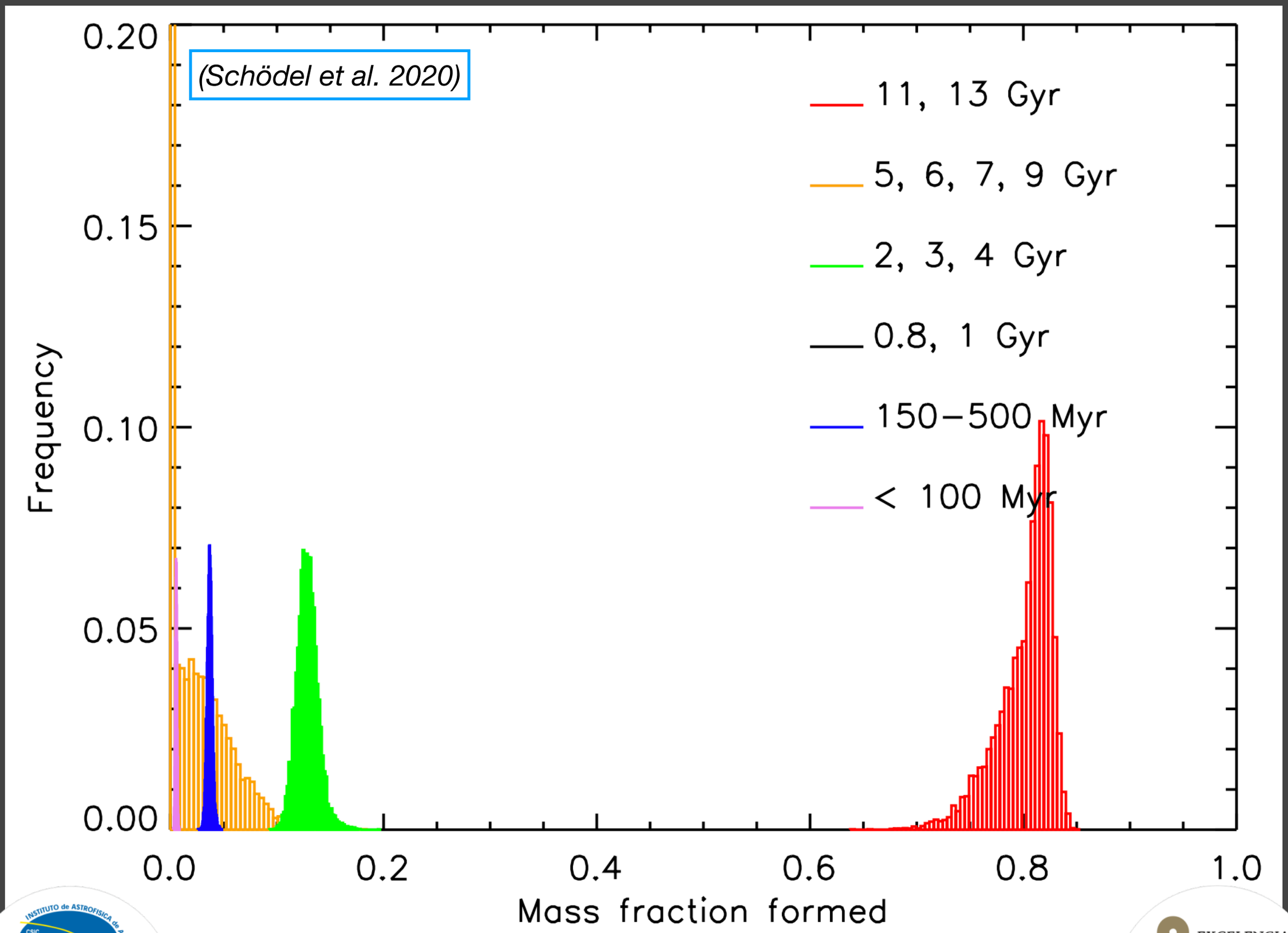
Kinematics

Figure: Feldmeier et al. (2014)



Trippe et al. (2008); Schödel, et al. (2009); Feldmeier et al. (2014)

The NSC is old and metal rich

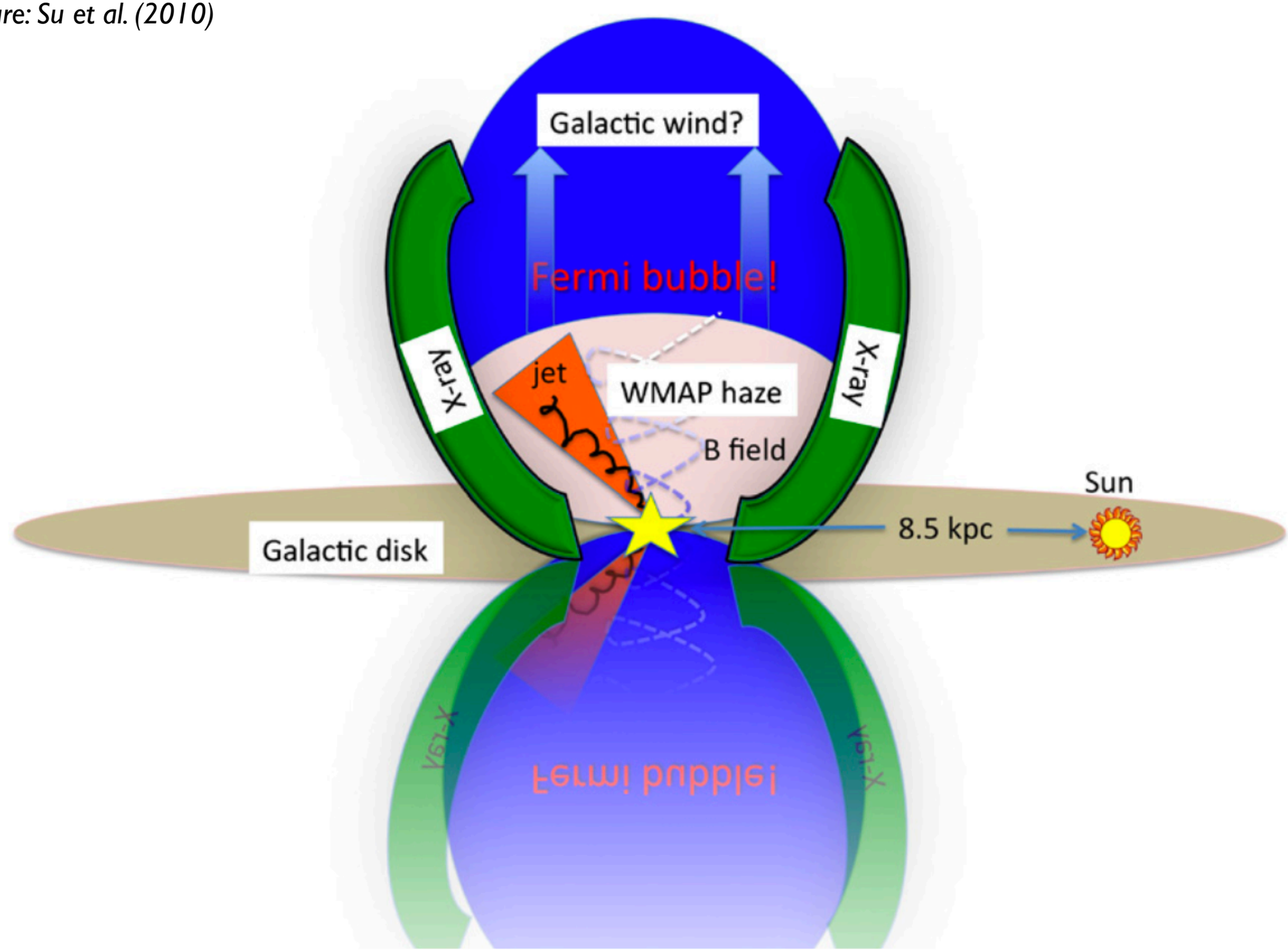


4. The Sgr A*
(dis)connection

Sgr A* - EHT Collaboration

There are strong outflows from the GC

Figure: Su et al. (2010)



Su et al. (2010), Heywood et al. (2019), Ponti et al. (2019), Yang et al. (2022)

Rotation axis of Sgr A*

1. Not aligned with Milky Way disc (thickness few 100 pc)
2. Not aligned with NSD (thickness few 10 pc)
3. Not aligned with NSC (thickness few 1 pc)
4. Axis does not point toward Fermi Bubbles
5. NSC and NSD at least 8-10 Gyr old
6. MW Bar transports ~1 $M_\odot$/yr of gas to GC

➡ Molecular clouds 6-7 orders of magnitude larger than Sgr A*

➡ Did Sgr A* acquire its mass before the NSD/NSC?

➡ Did Sgr A* form inside the NSC (runaway collisions)?

➡ Star formation dominates the energetics of GC (Crocker 2012)

Thank you!

Galactic Center Workshop 2023

24 - 28 April 2023, Granada, Spain