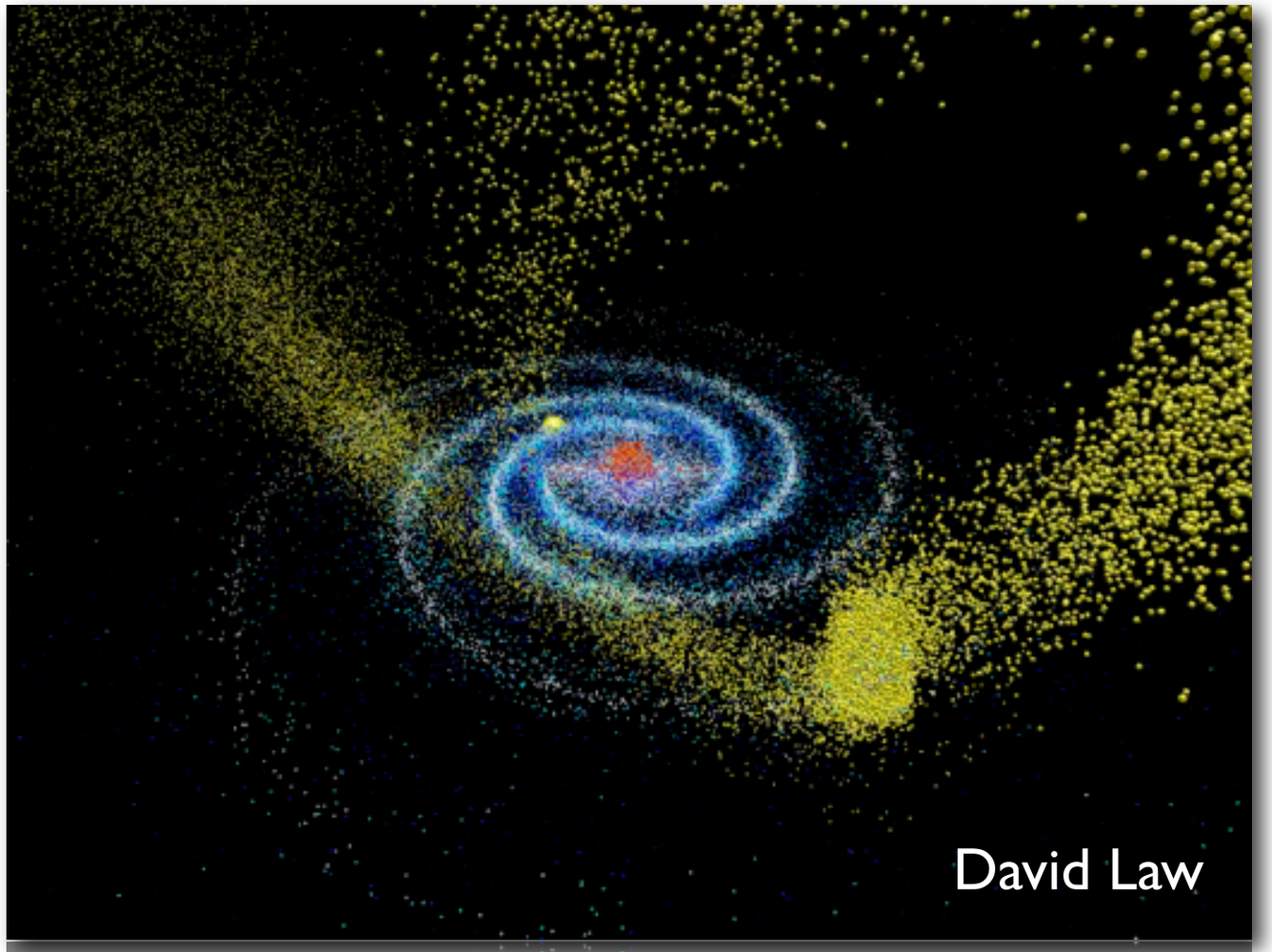
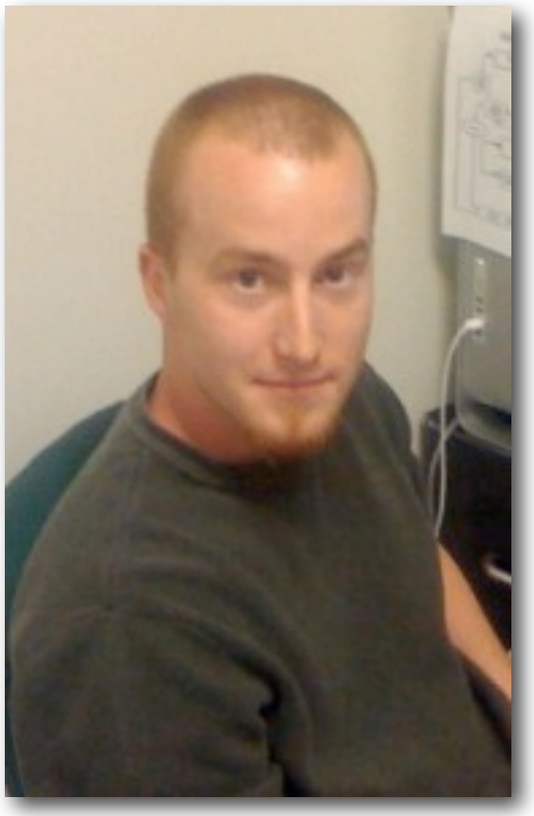
The impact of Sagittarius on the disk of the Milky Way



James Bullock (UC Irvine)

The impact of Sagittarius on the disk of the Milky Way

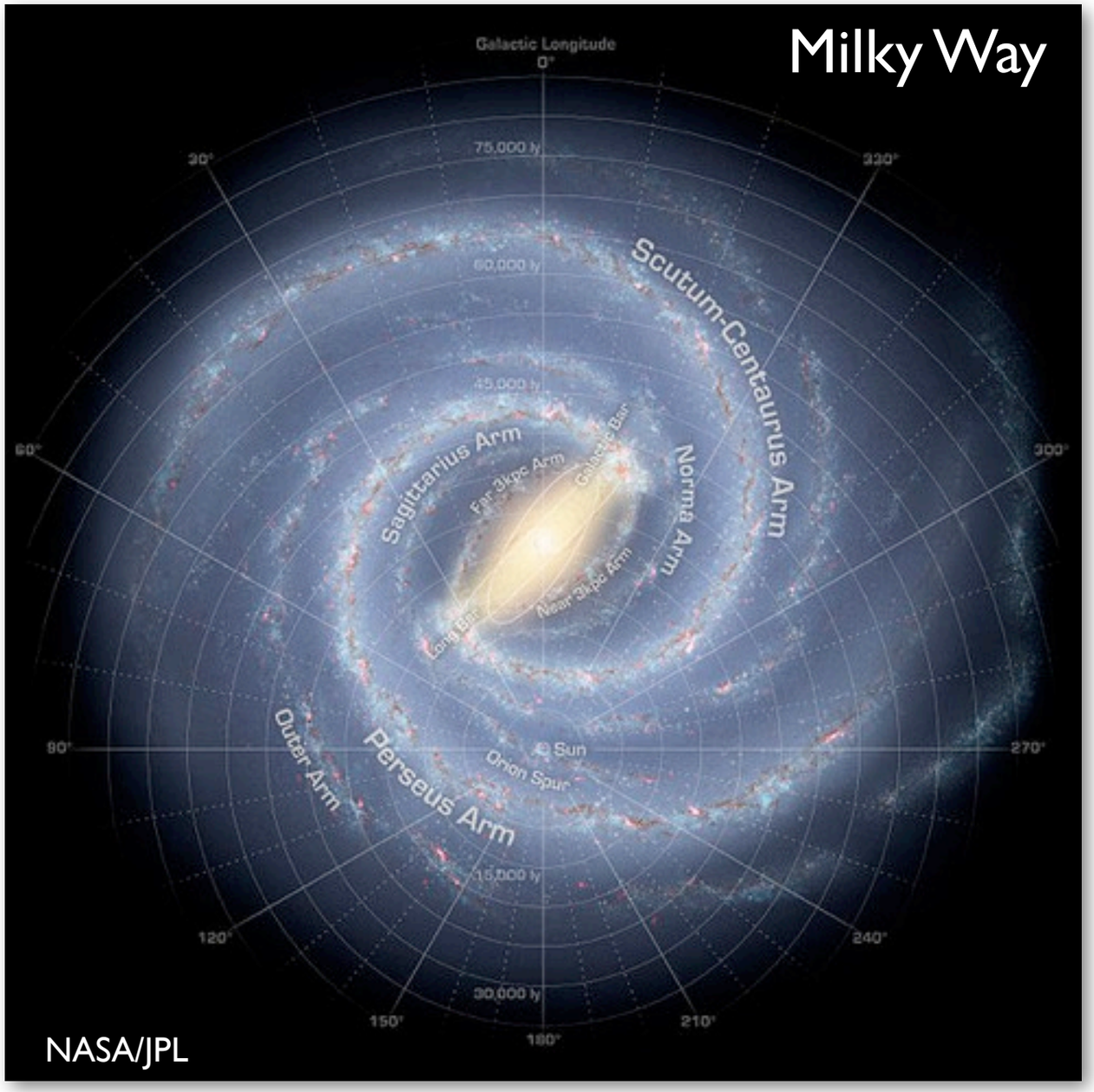


Chris Purcell (Irvine → U Pittsburgh)

Erik Tollerud (Irvine)

Near-Field Cosmology

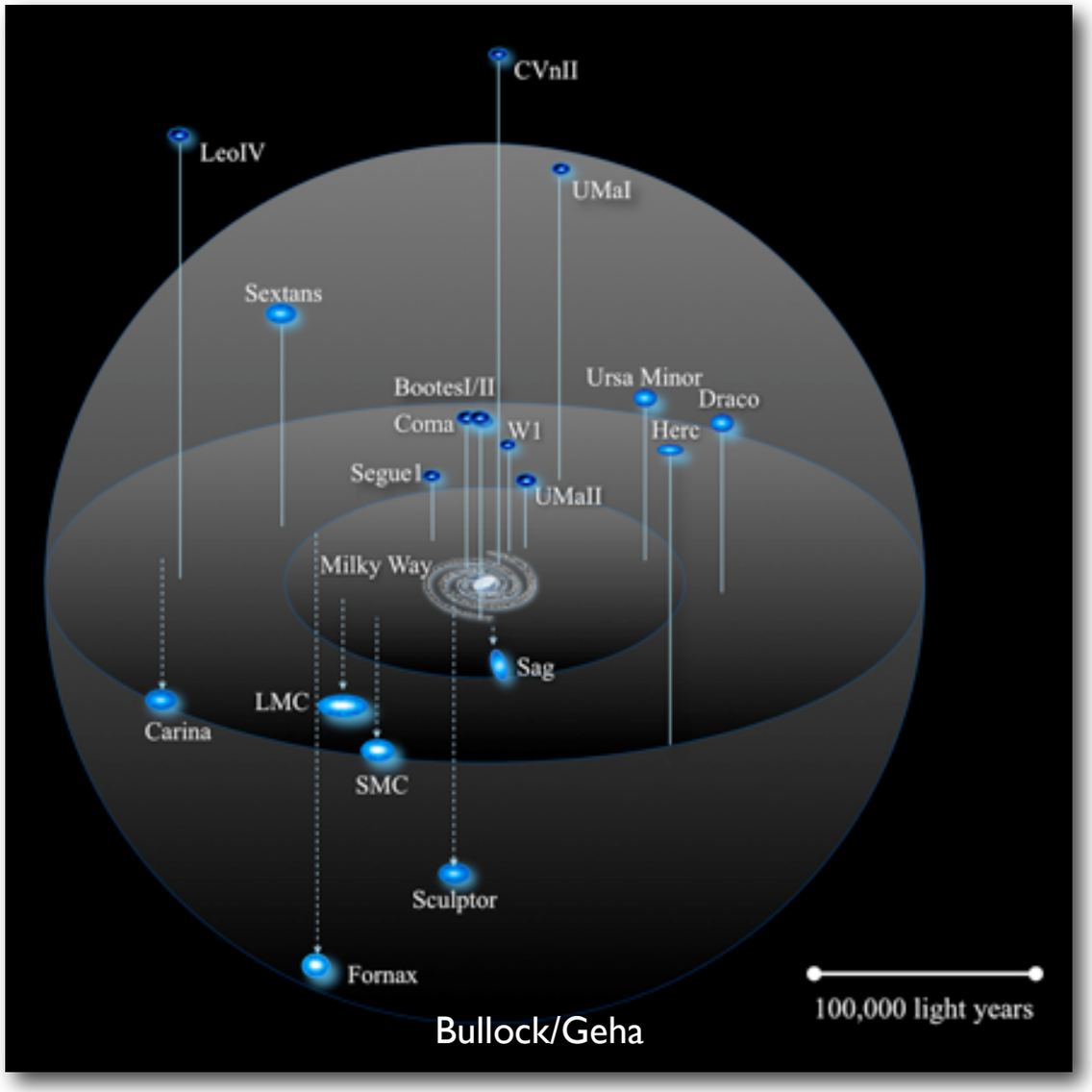
Detailed observations of MW & Local Group to inform general models of galaxy formation.



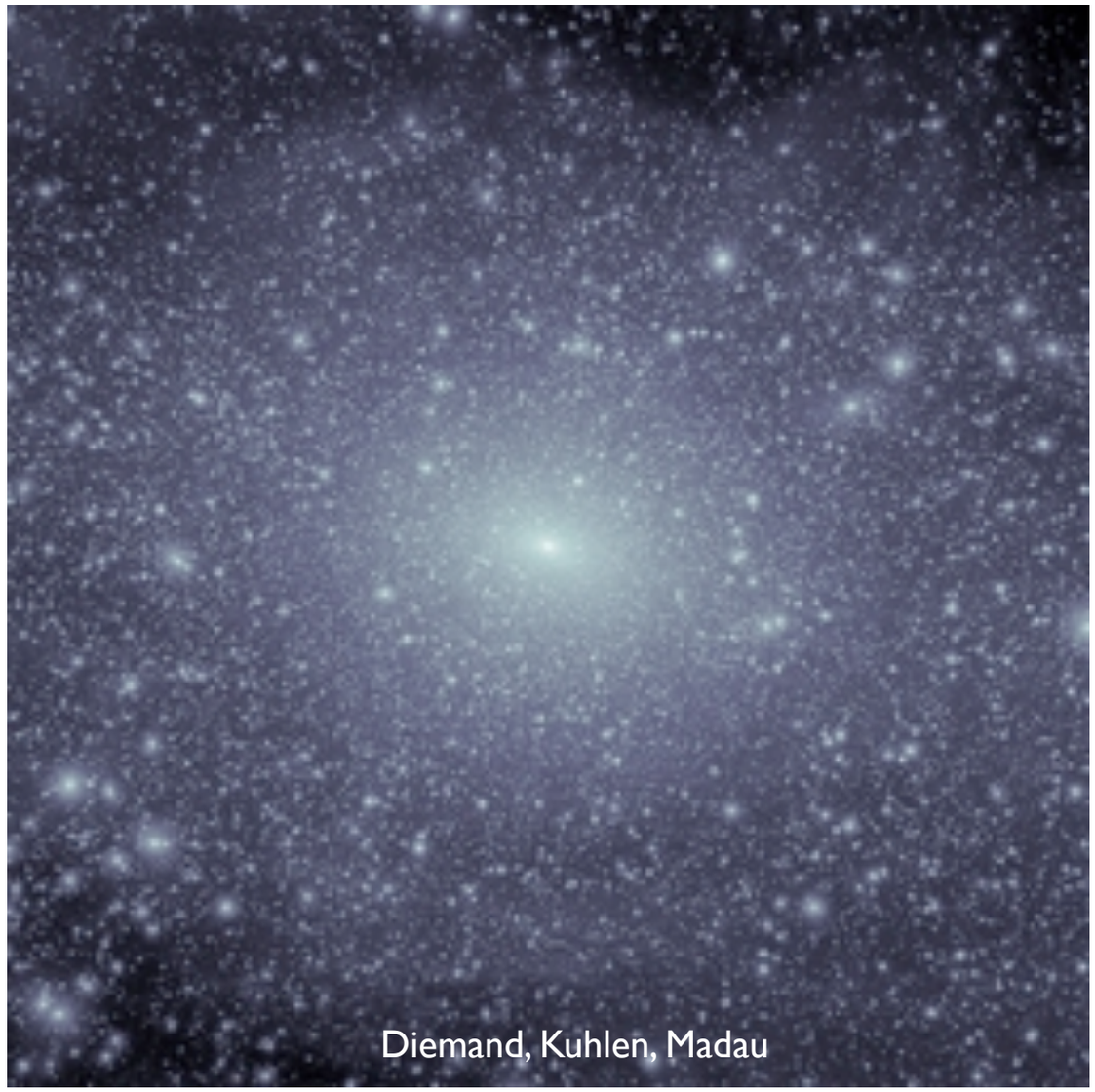
How do we make thin disks like the MW in LCDM?

Bars? Spirality? (Even harder questions)

Missing Satellites Problem

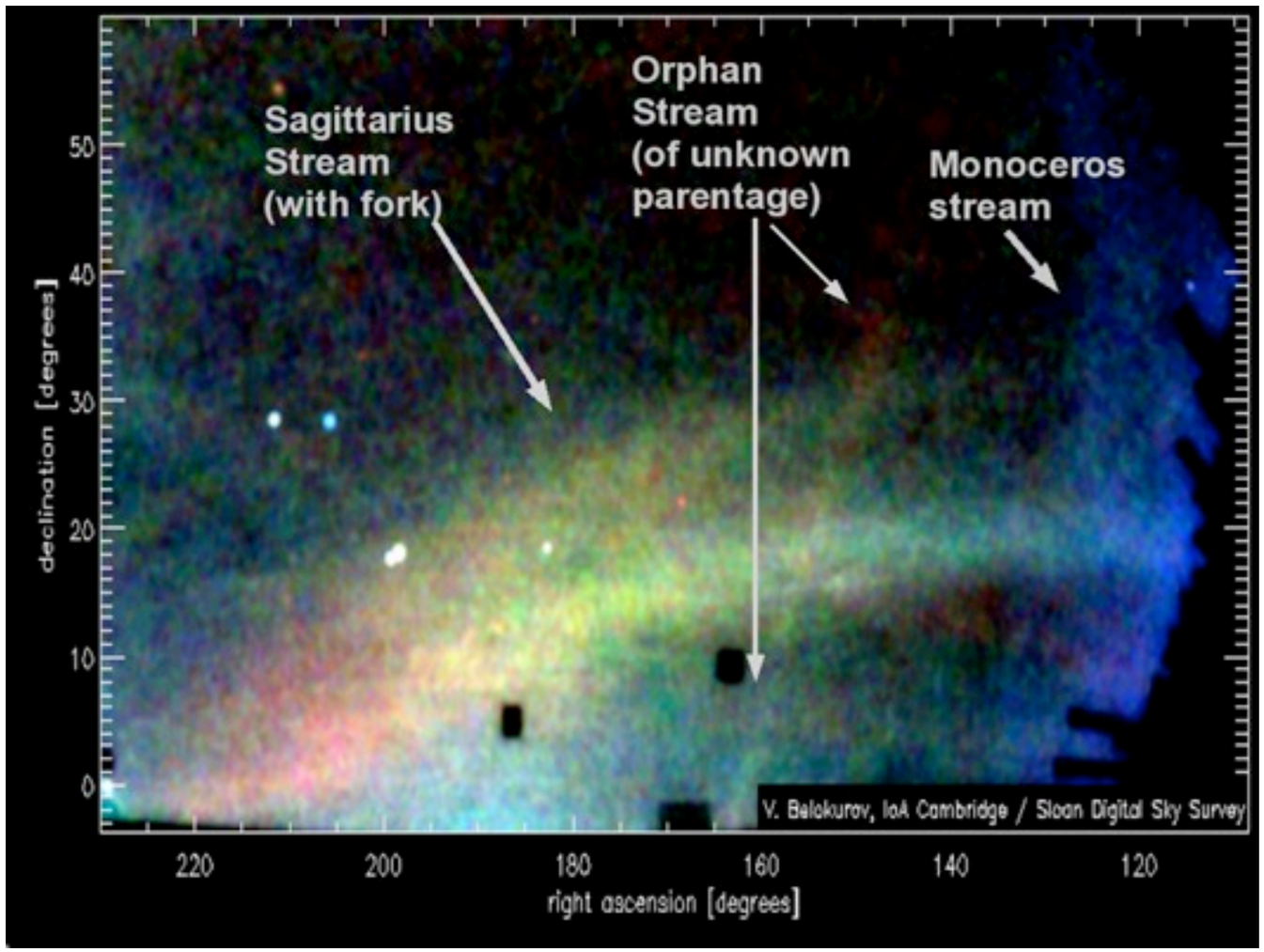


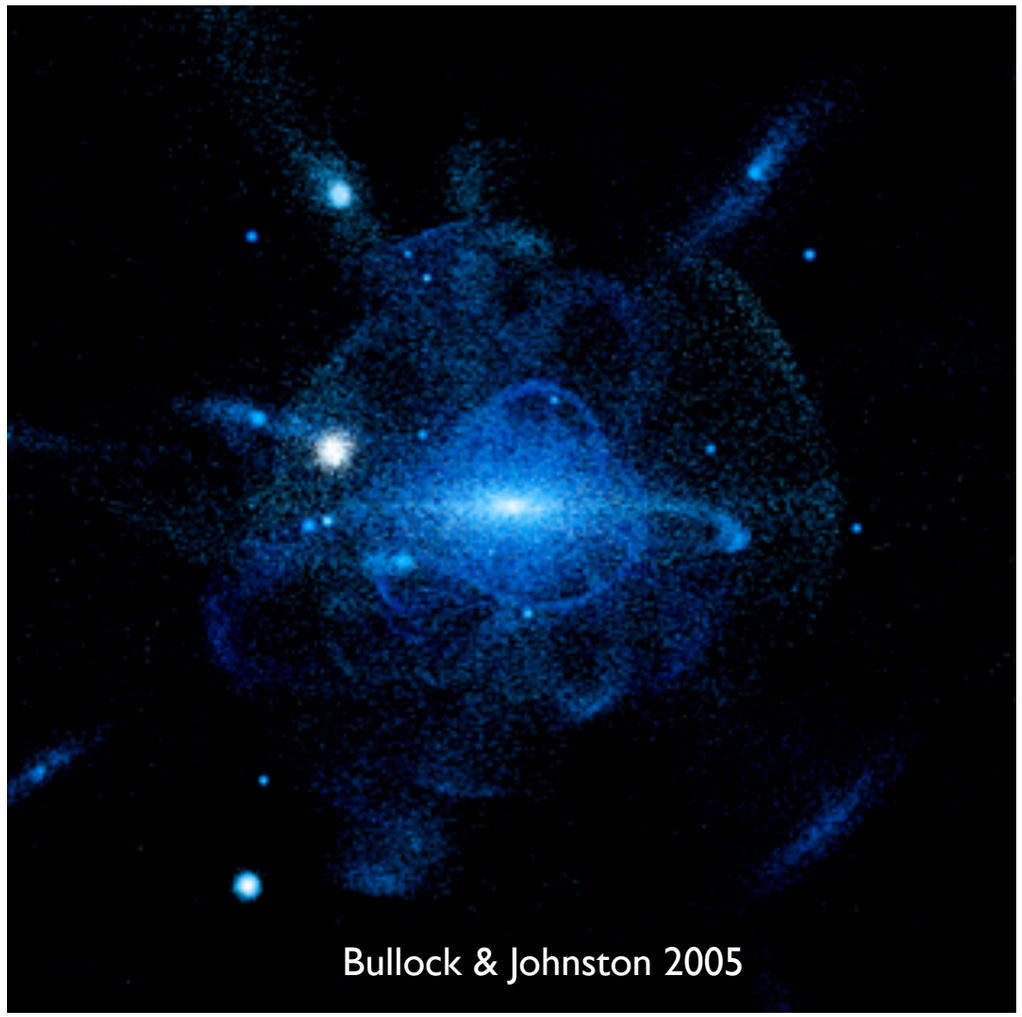
Bullock/Geha


Diemand, Kuhlen, Madau

Halo Streams & Substructure

Milky Way looks hierarchical

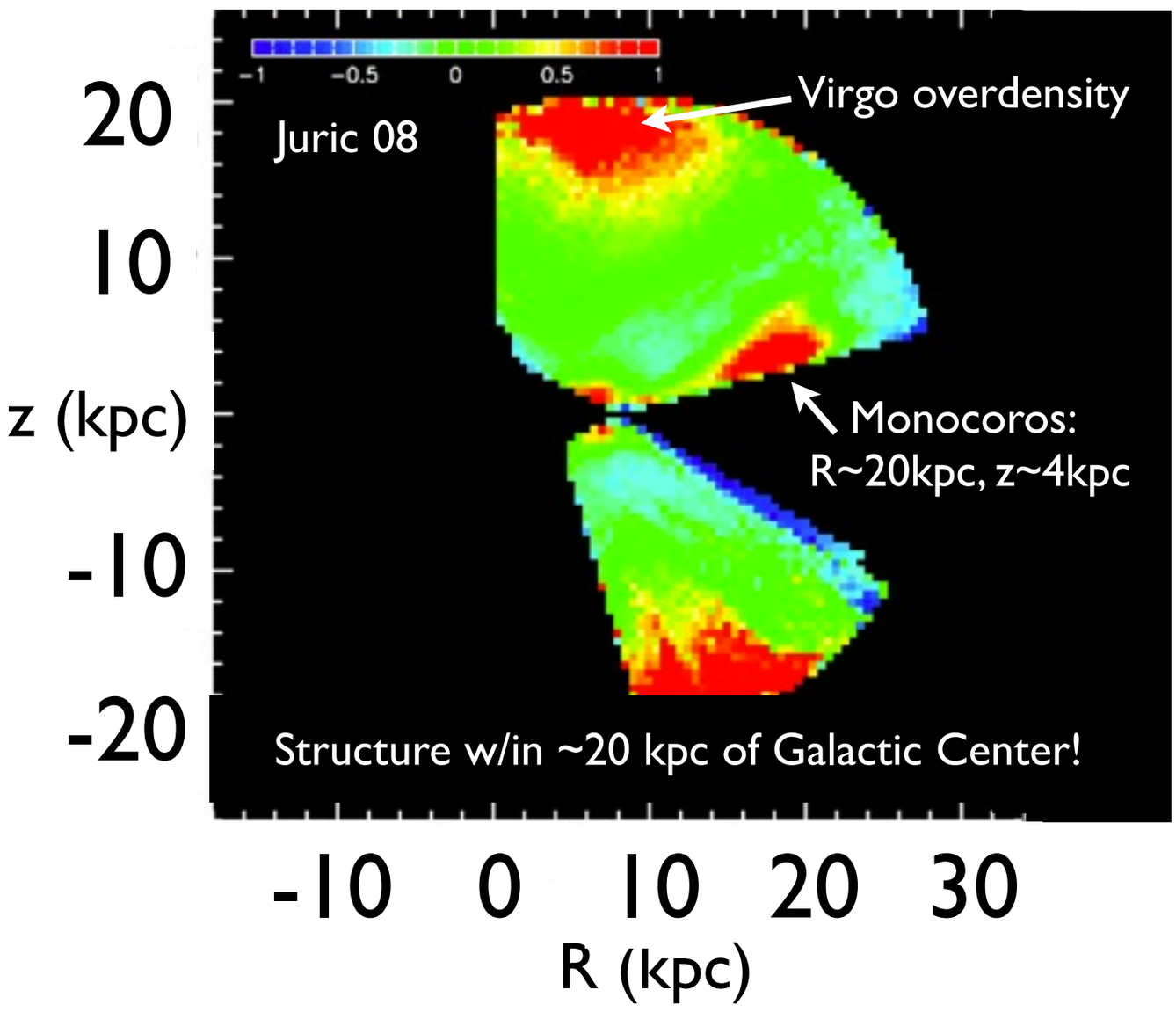




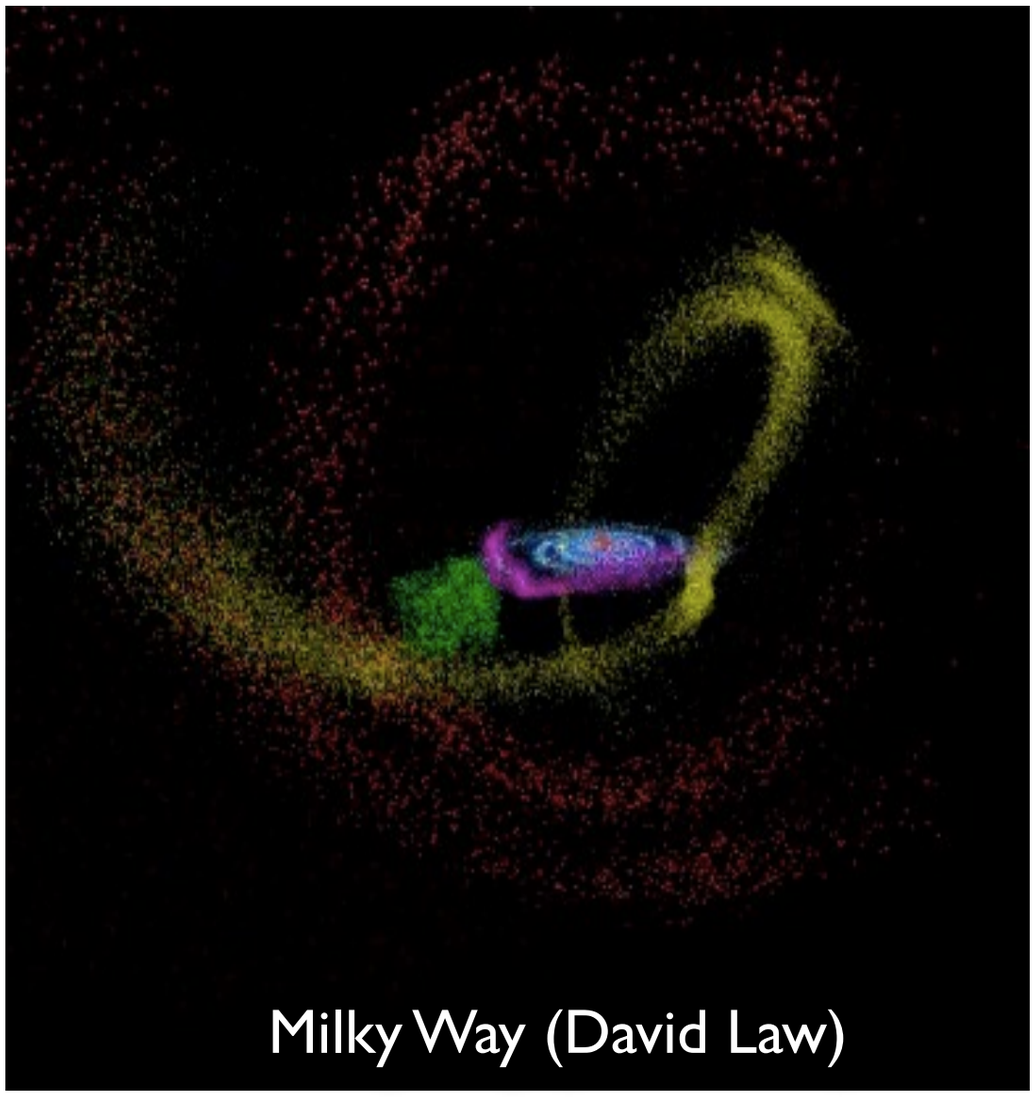
Bullock & Johnston 2005

Halo Streams & Substructure

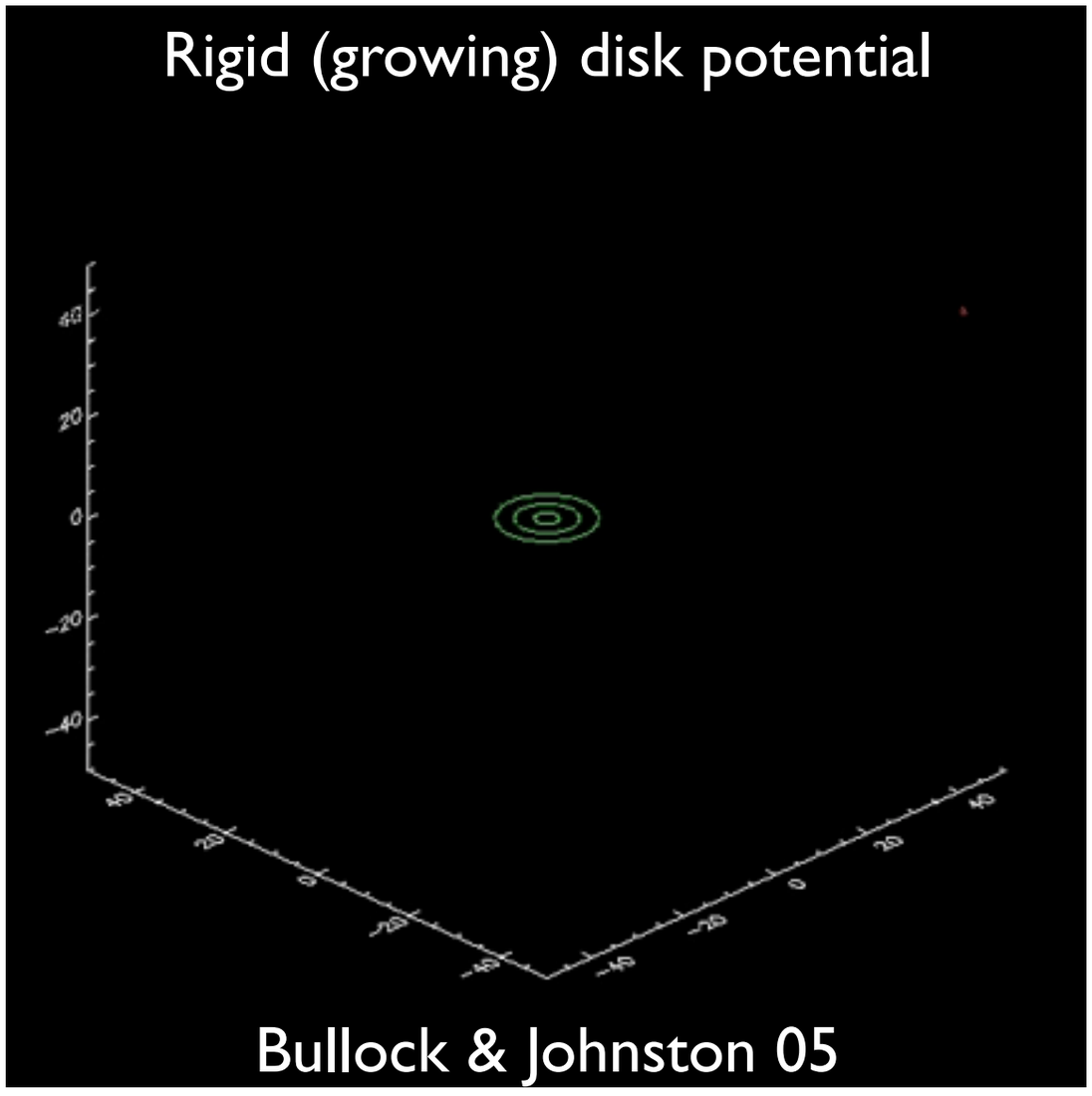
Substructure within ~20 kpc of Galactic Center!



Ghosts of past mergers...

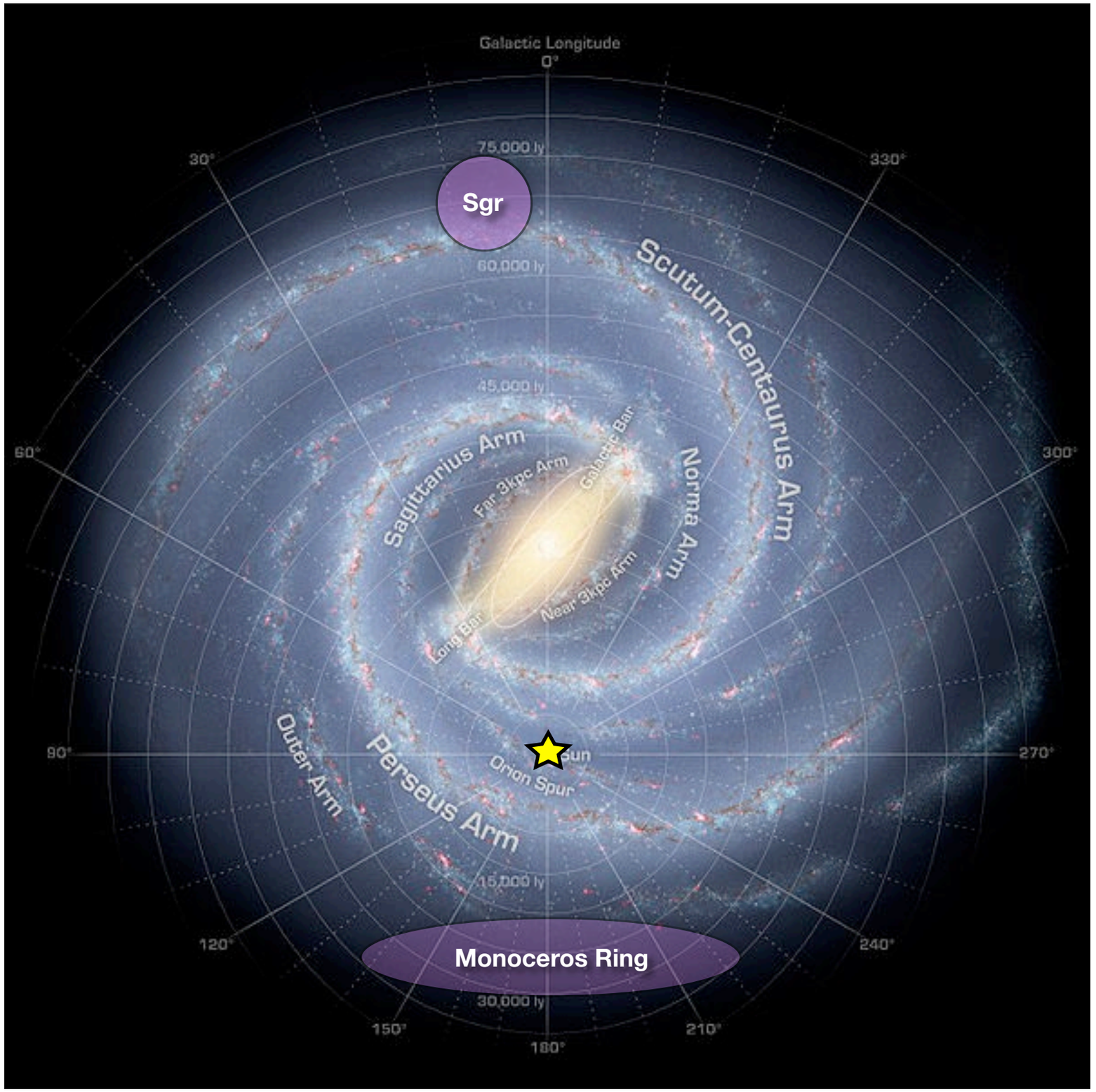


Milky Way (David Law)



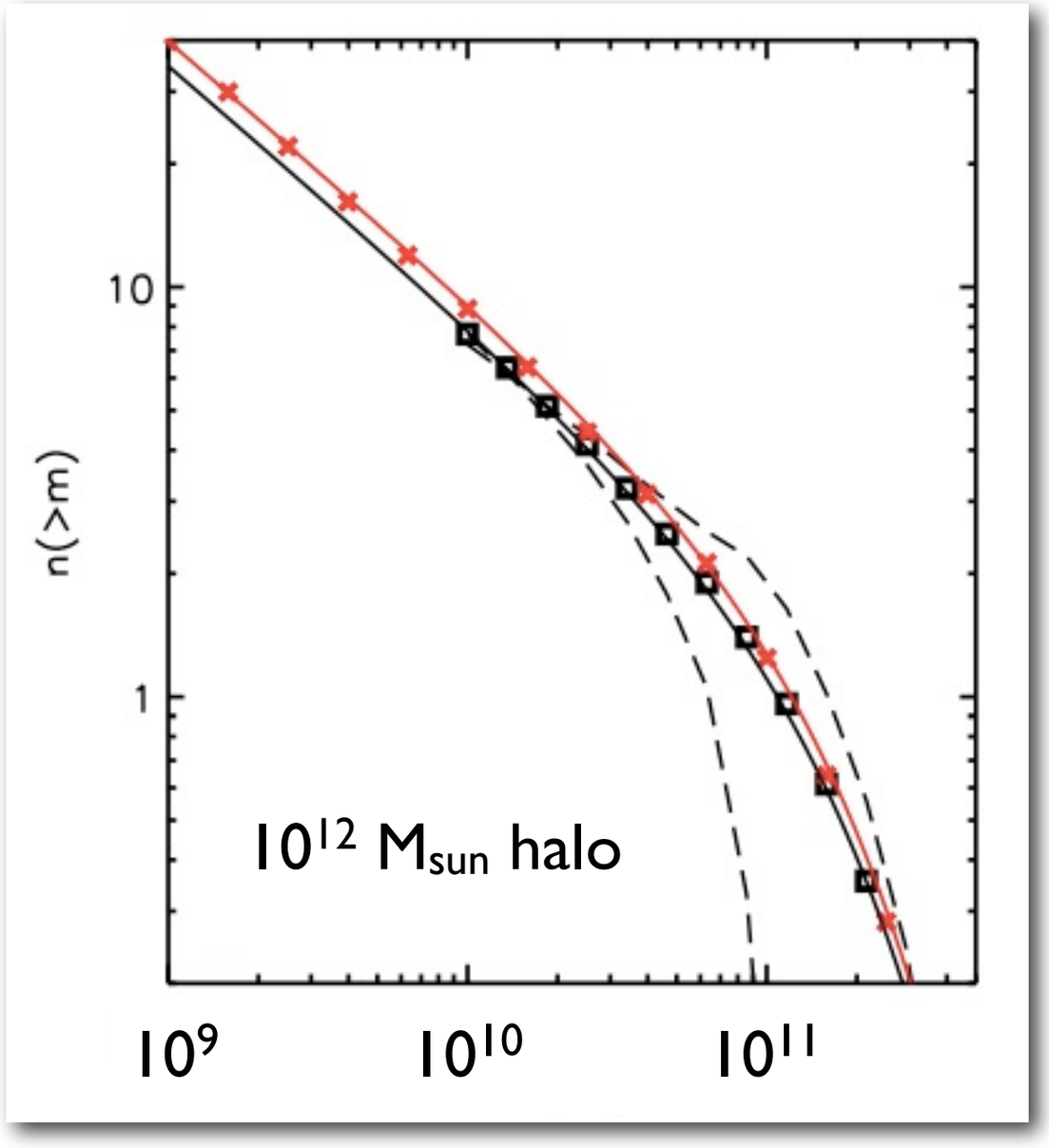
Bullock & Johnston 05

What do all of these mergers do to the disk?



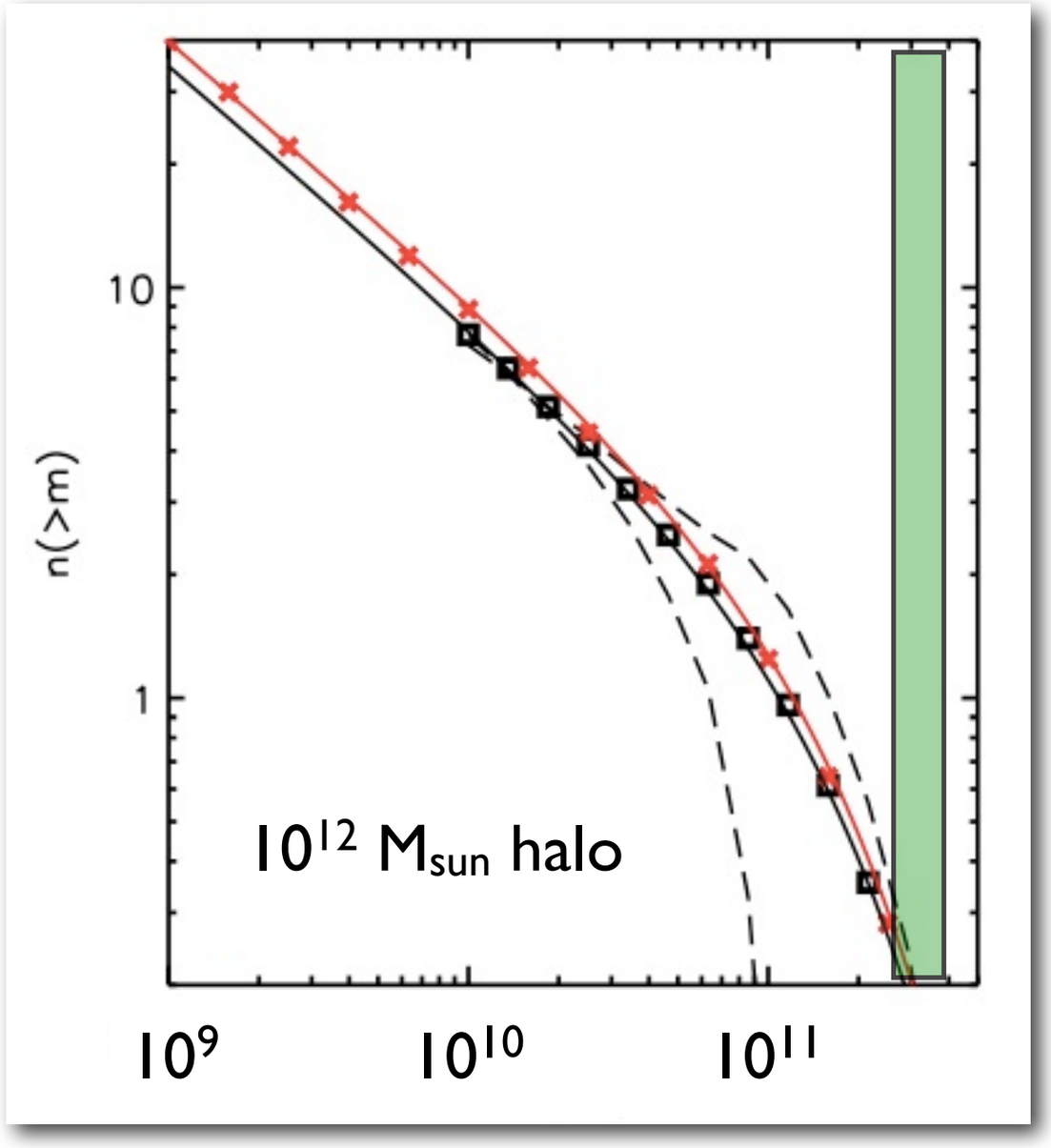
Cosmological Context

Stewart et al. 08



Cosmological Context

Stewart et al. 08

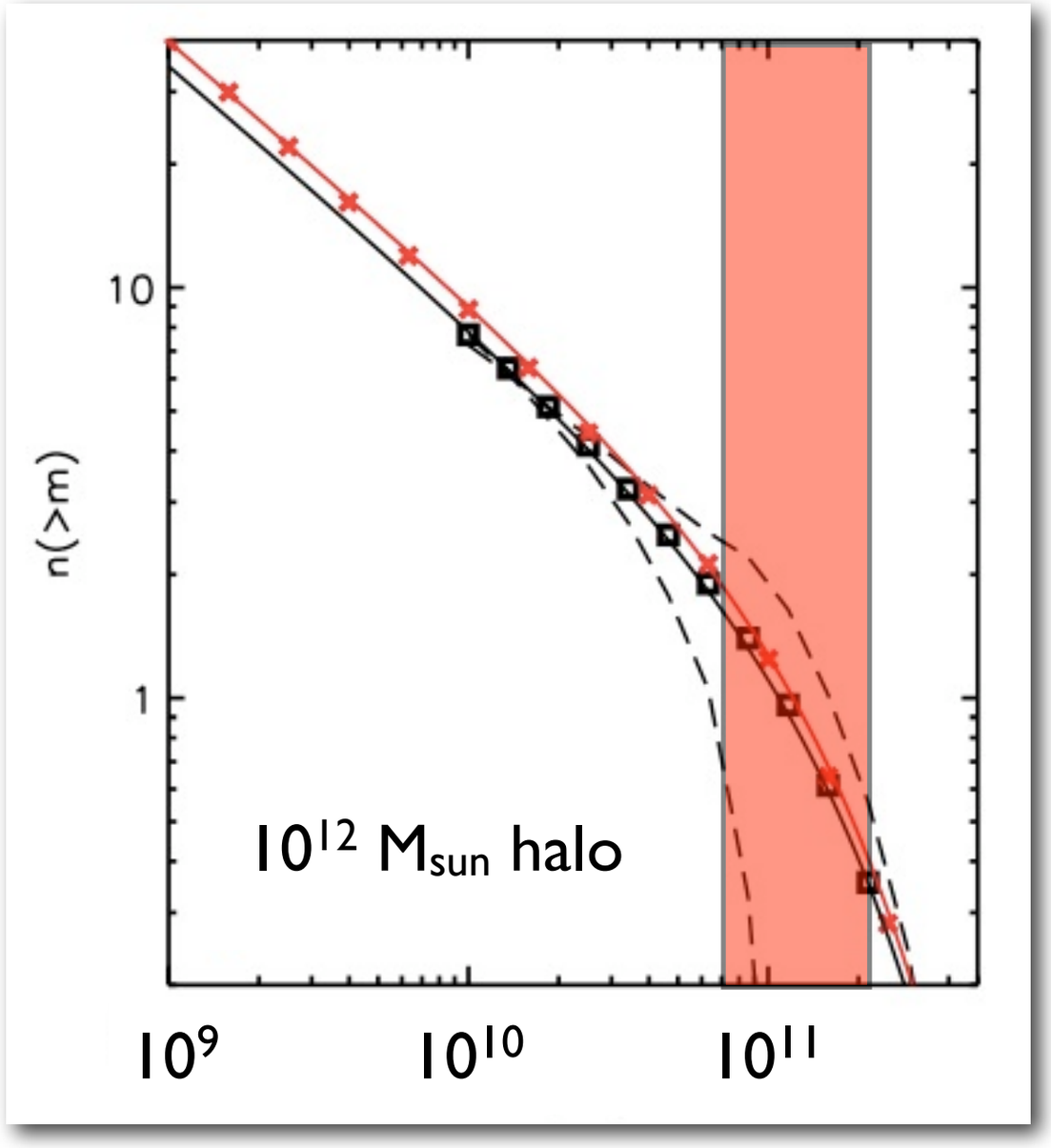


>2.10^{11} M_{sun} mergers

- HAVE NOT happened

Cosmological Context

Stewart et al. 08



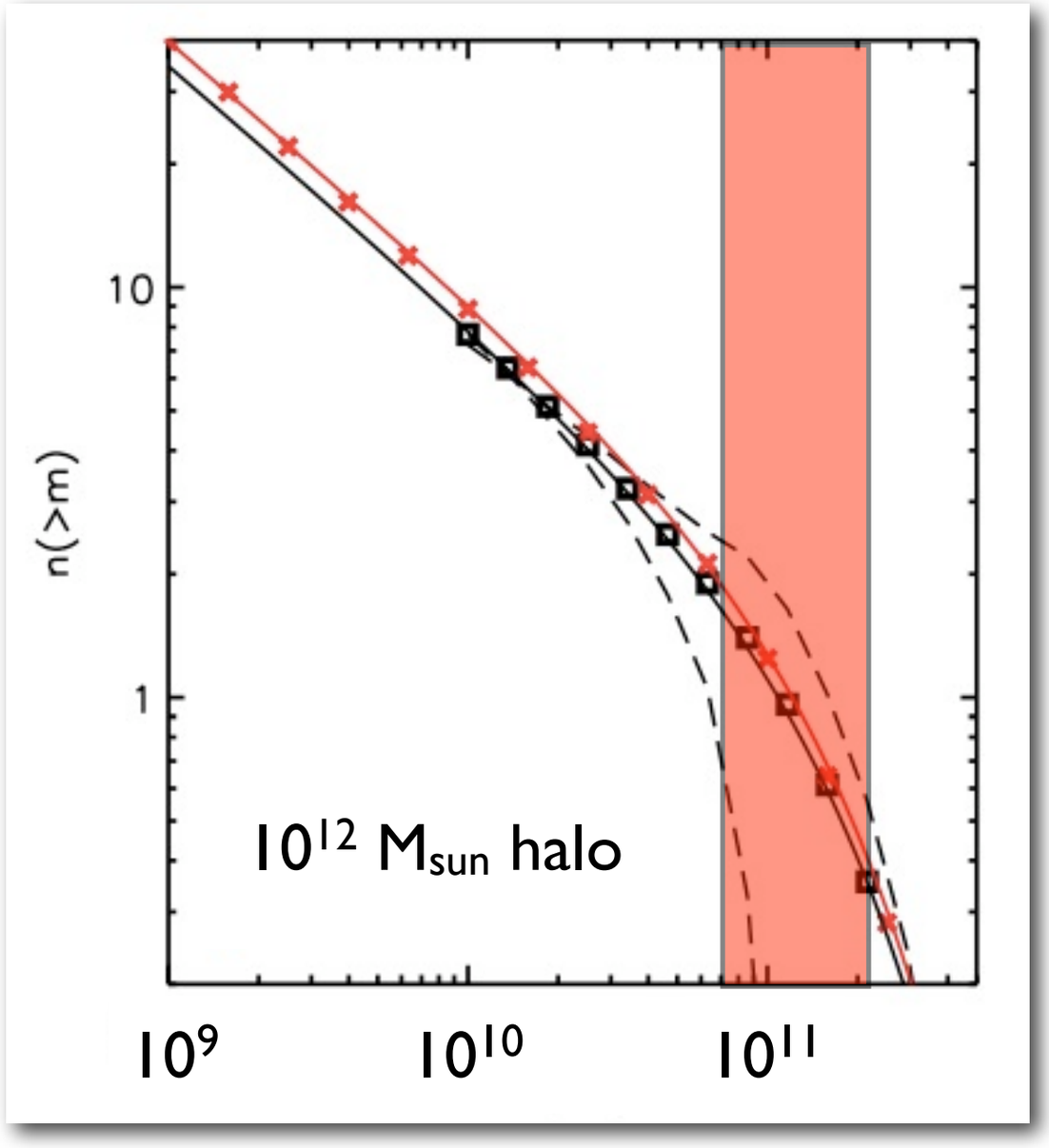
10^{11} M_{sun} mergers

~70% of the time

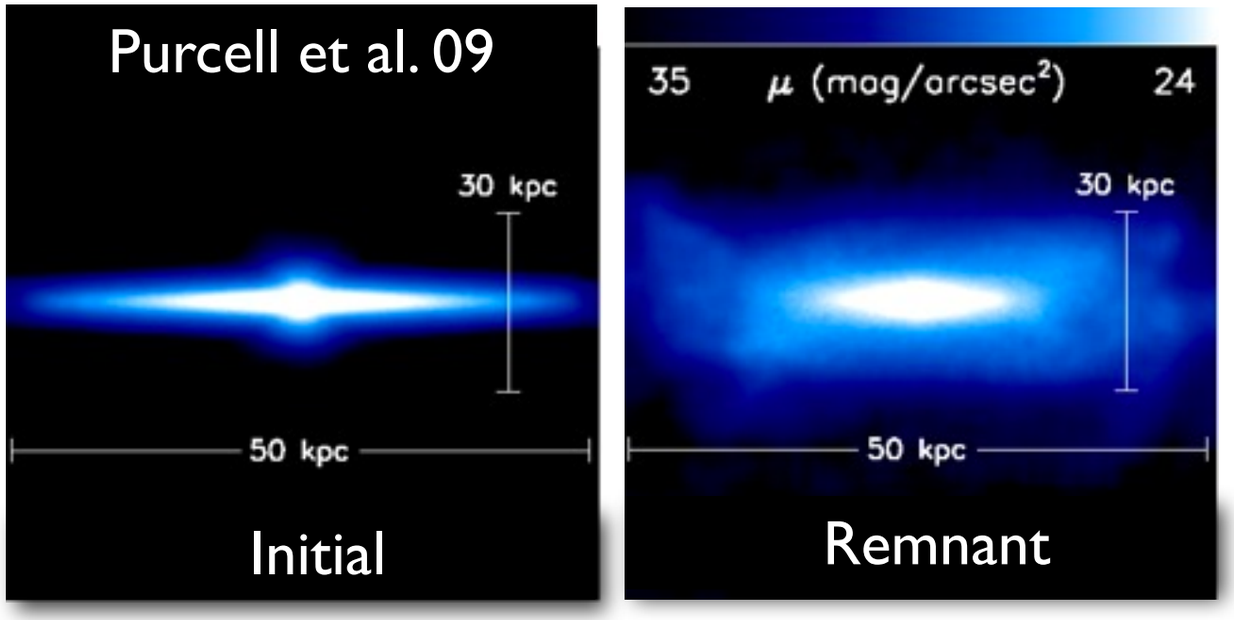
~1 over last 10 Gyr

Cosmological Context

Stewart et al. 08



10^{11} M_{sun} mergers

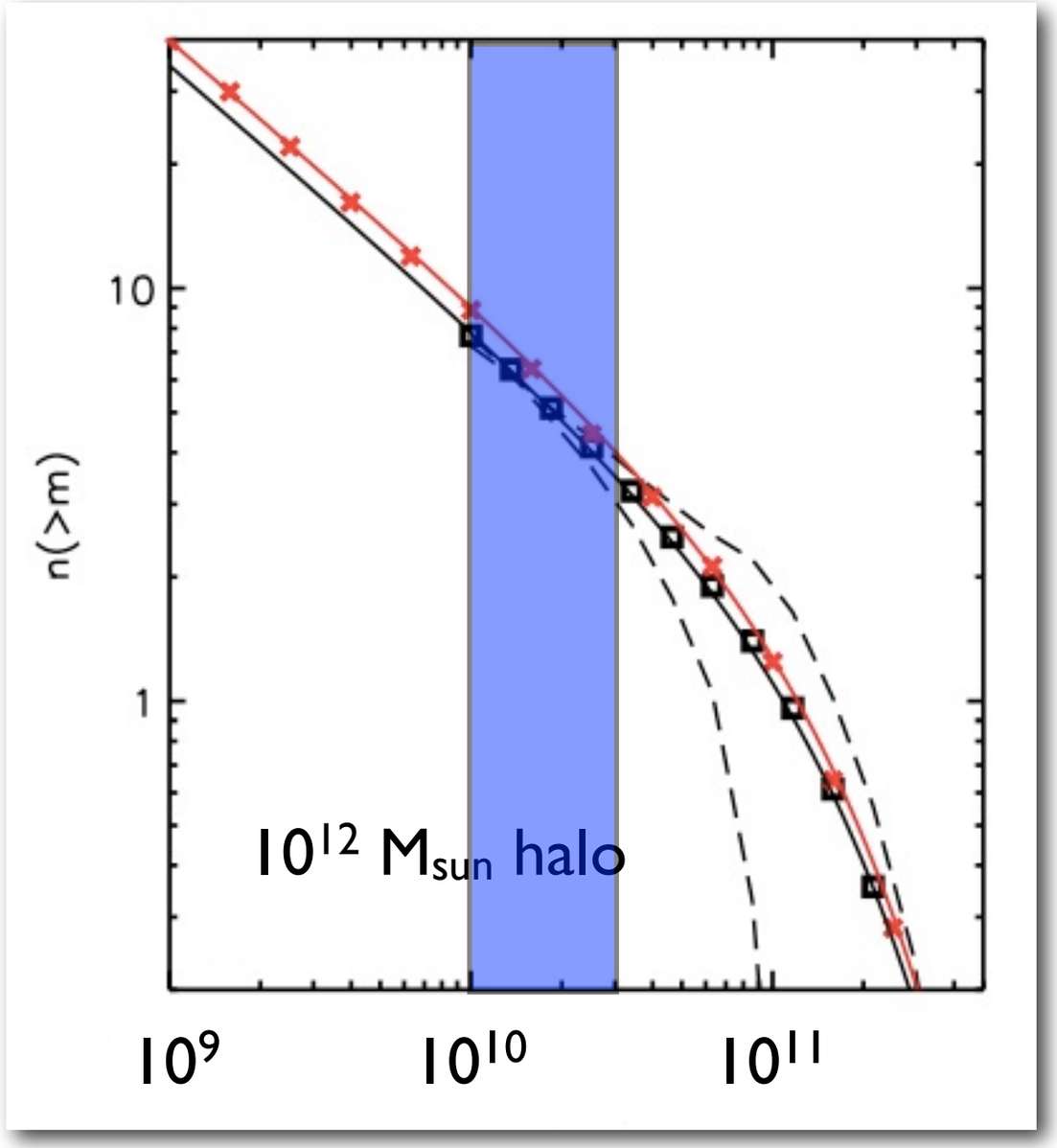


- Heat disks, don't destroy them

- Milky Way is probably too cold to have had one. MW uncommonly quiescent. (Purcell, JSB, Kazantzidis 09).

Cosmological Context

Stewart et al. 08

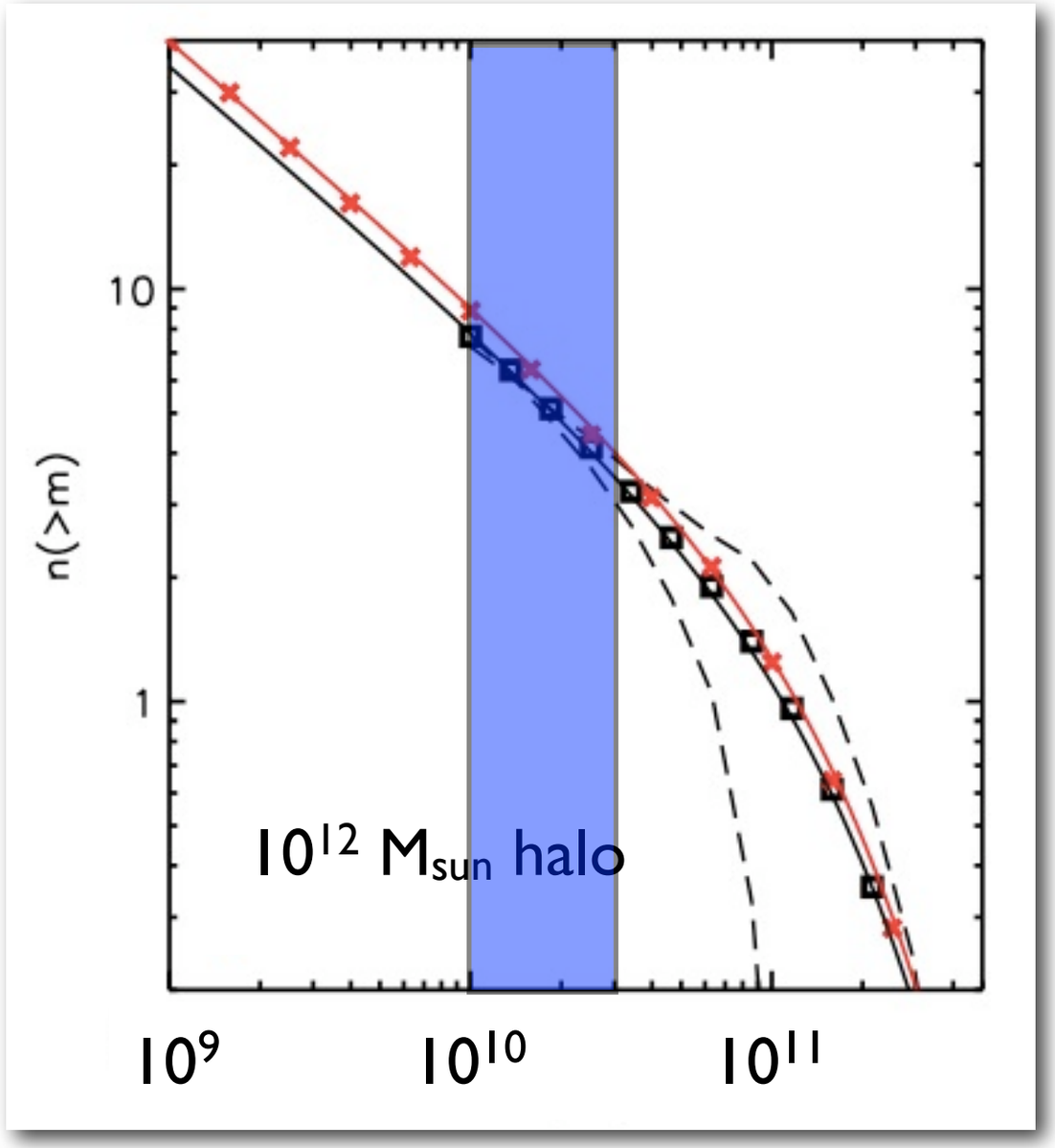


~10^{10} M_{sun} mergers

- ALWAYS happen
- Typically ~6 in last 10 Gry

Cosmological Context

Stewart et al. 08



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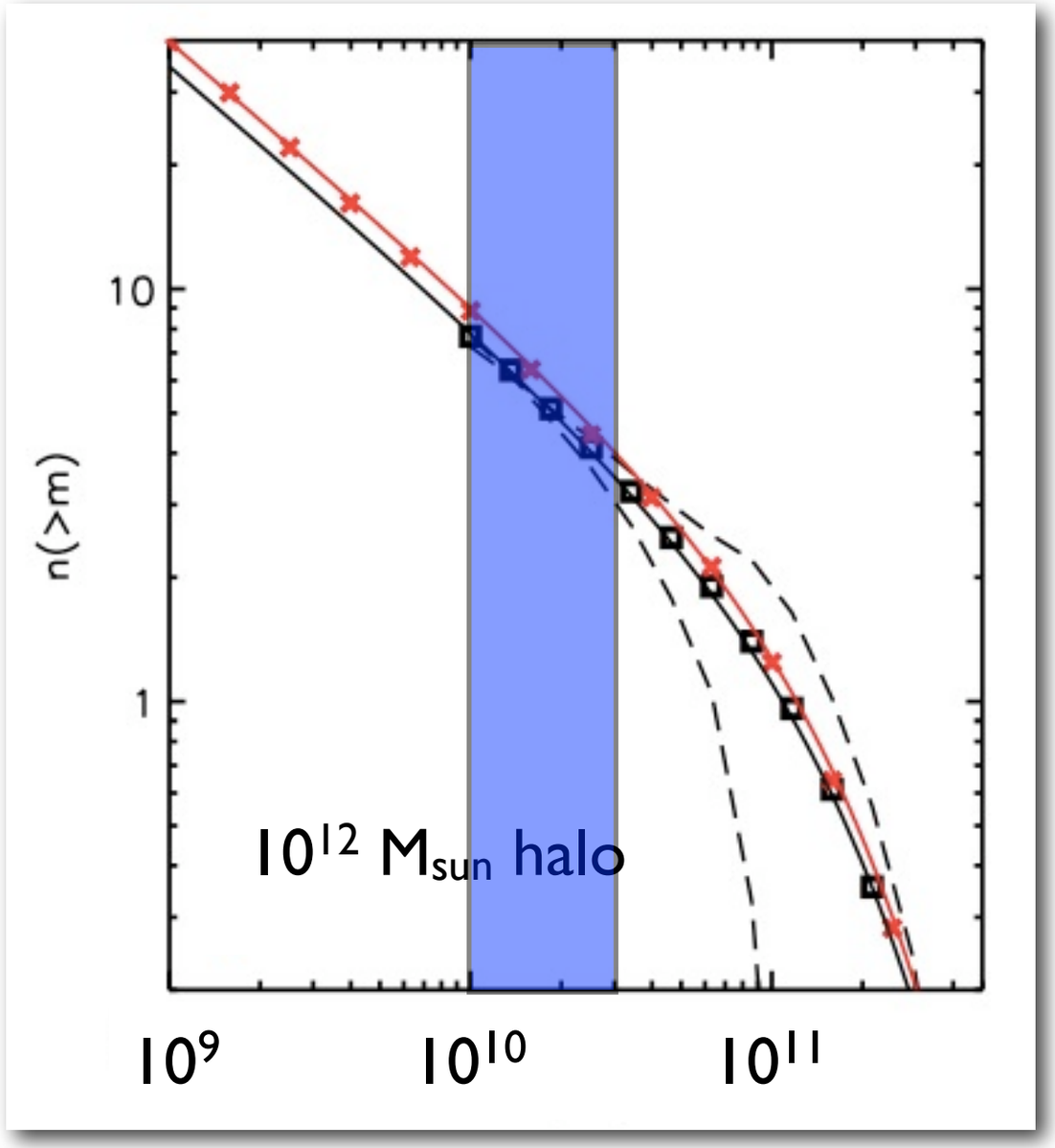
Cosmological Context

Stewart et al. 08



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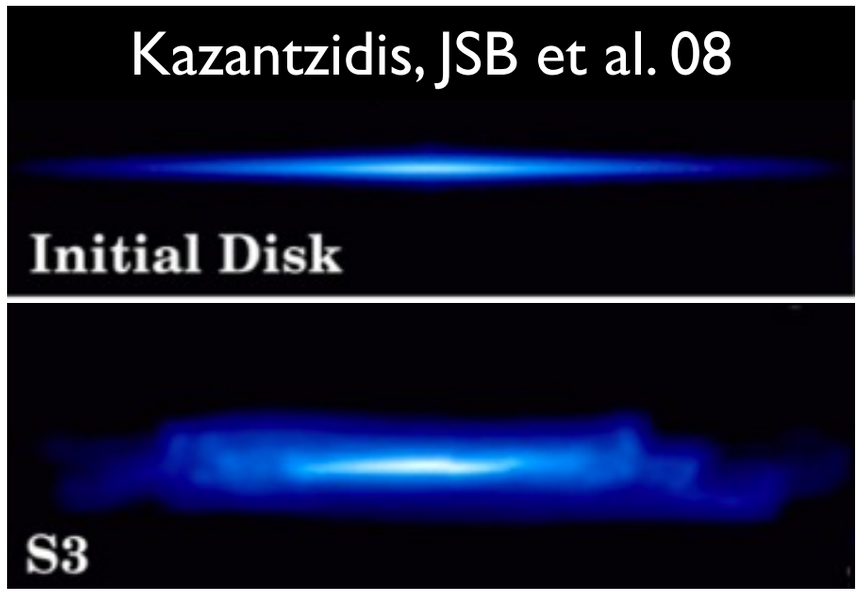
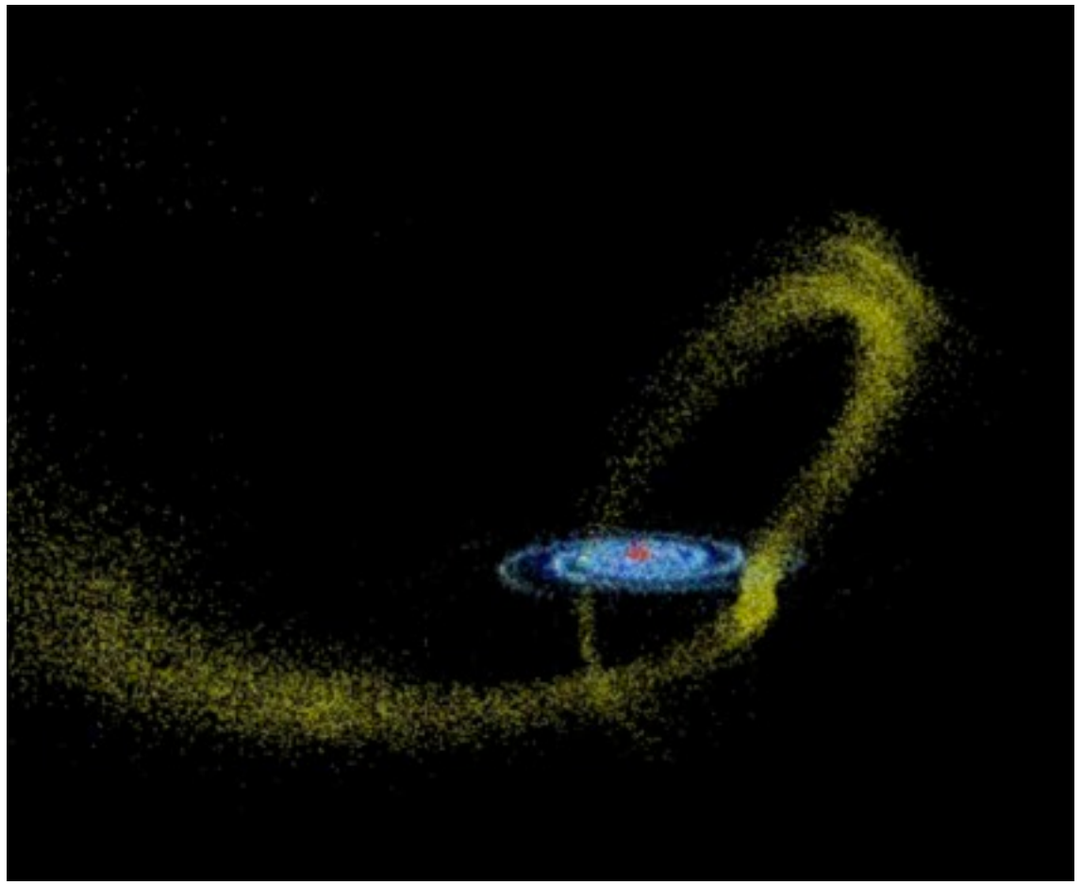


- Create interesting disk structures
- Rings, spirals, flares
- Detailed predictions depend on orbits, masses, timing, etc.

Sgr Dwarf Progenitor?

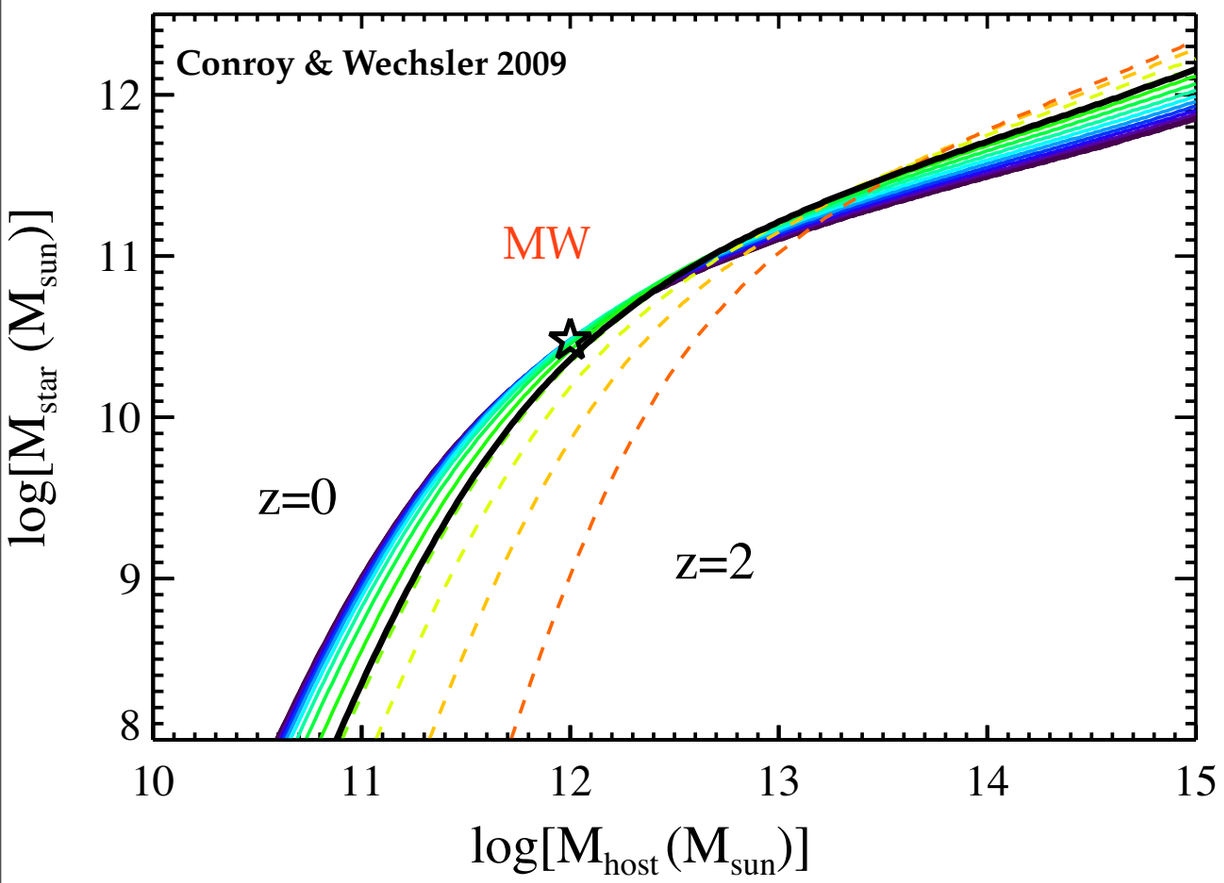


Nierderste-Ostholt et al. 2010:
(~70% of light in stream)

$$L^{\rm Sgr}_{\rm total} \simeq 10^8 L_\odot$$

$$\Rightarrow \quad M_* \simeq 2 \times 10^8 M_\odot$$

Sgr Dwarf Progenitor?



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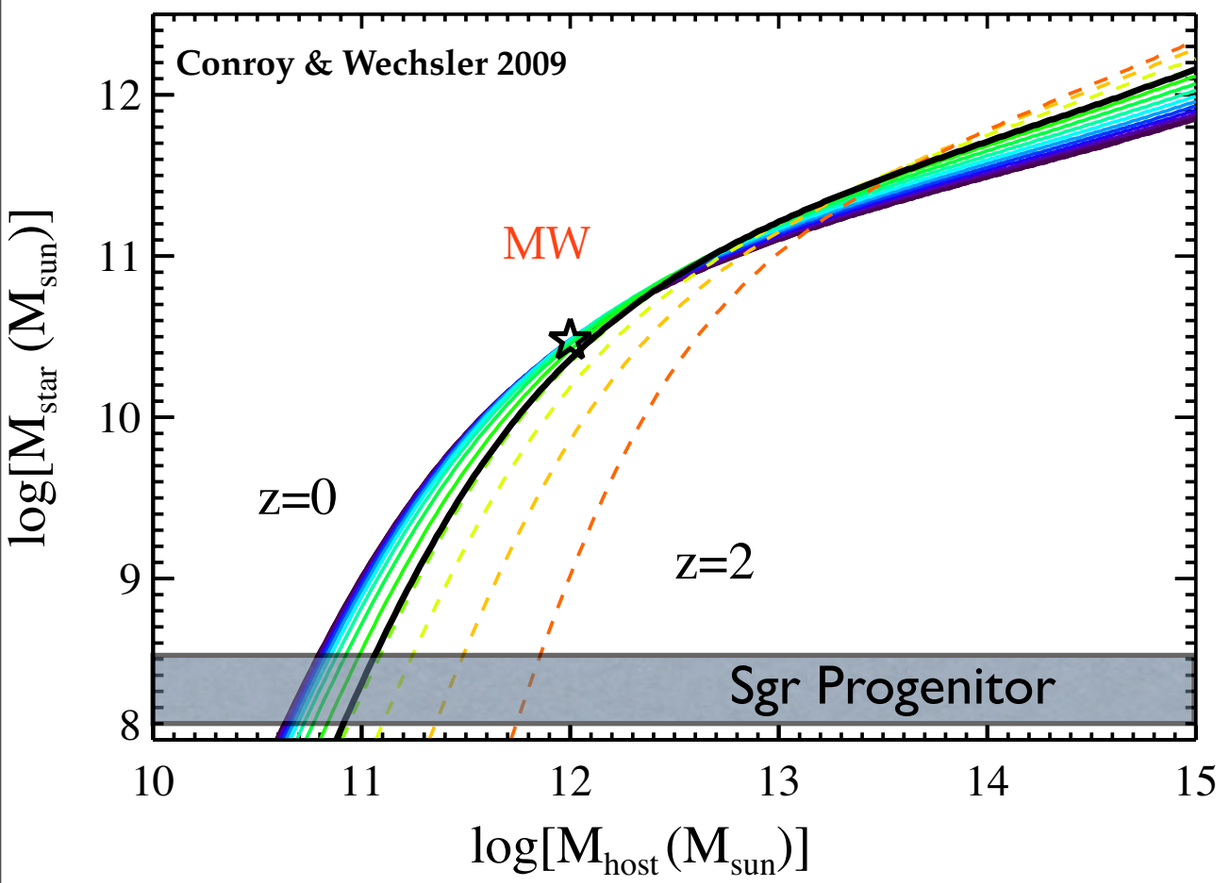

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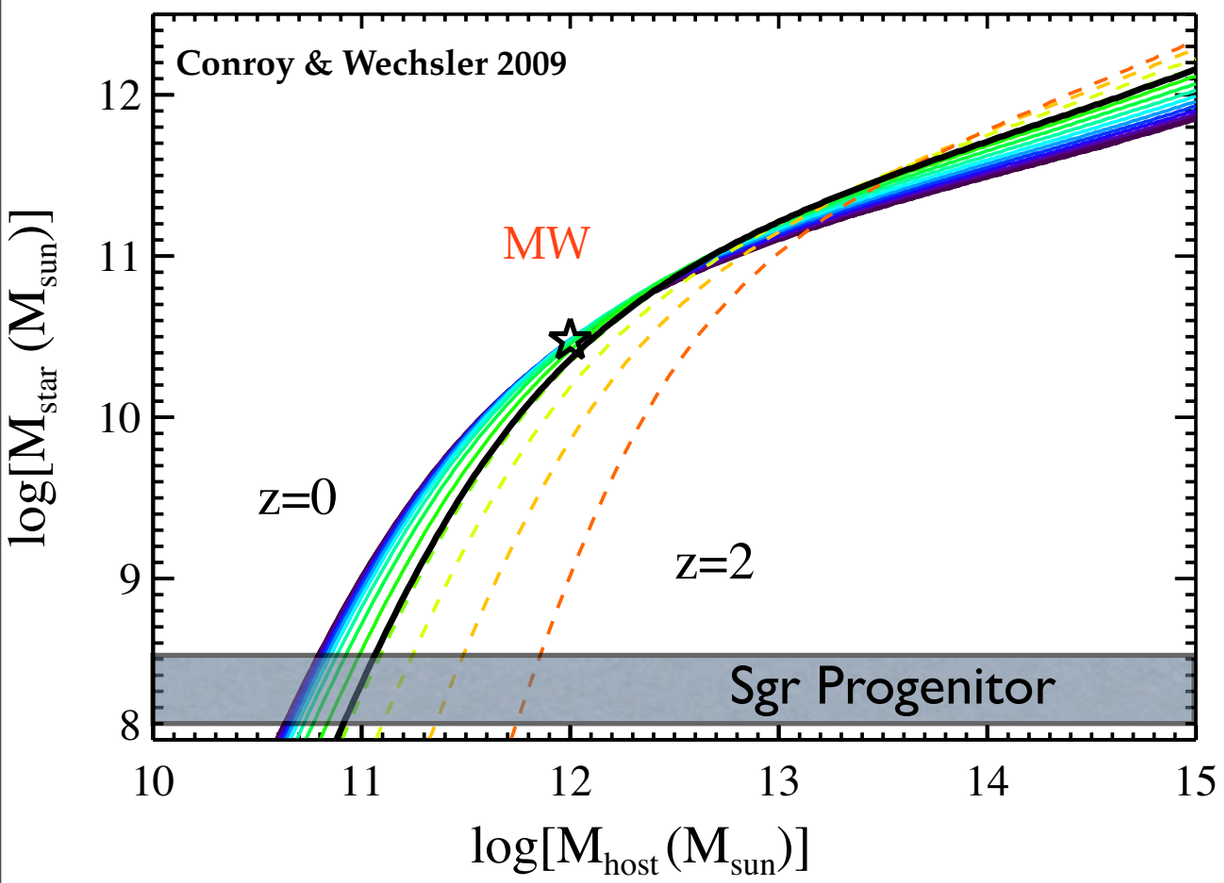

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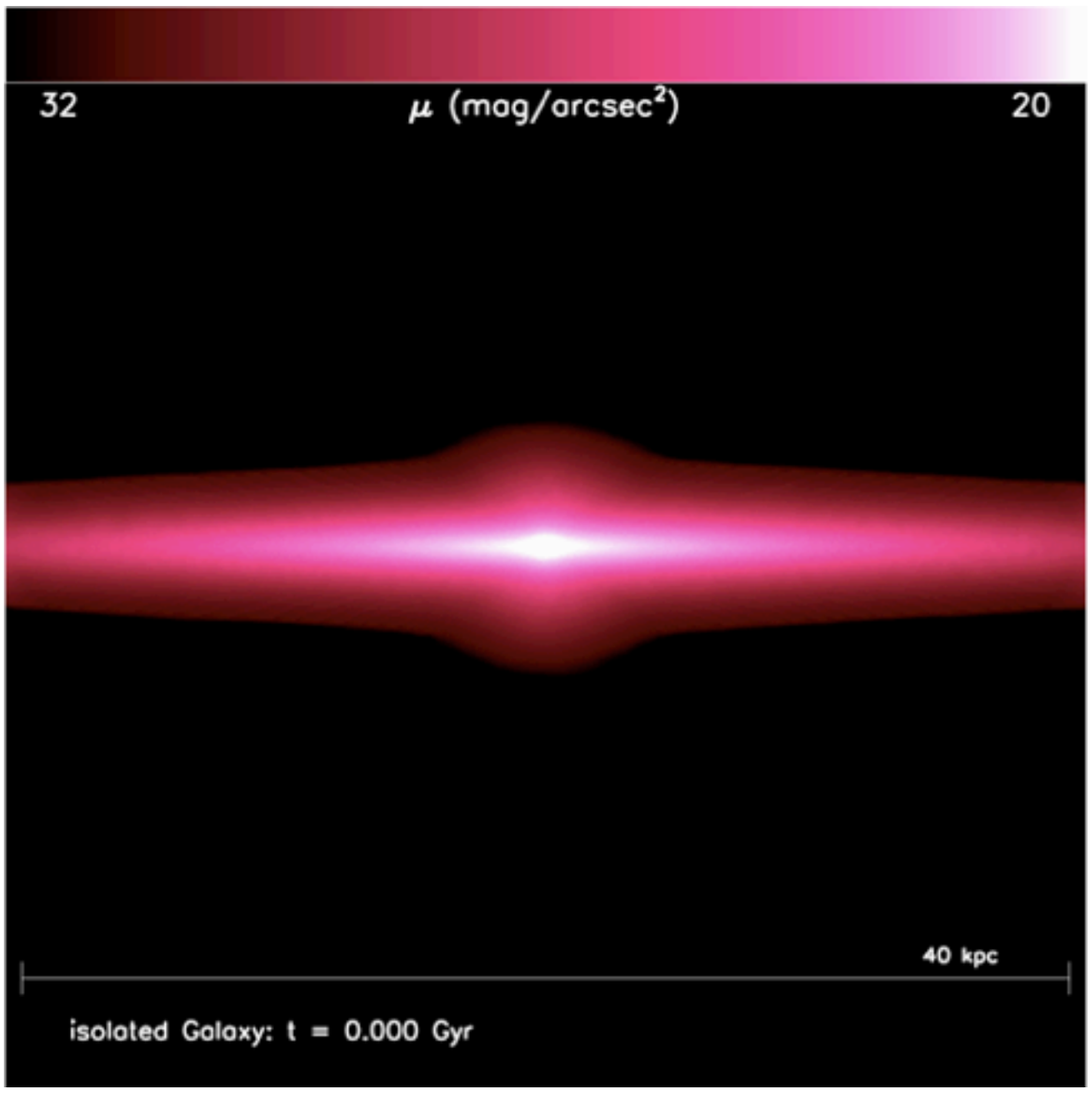
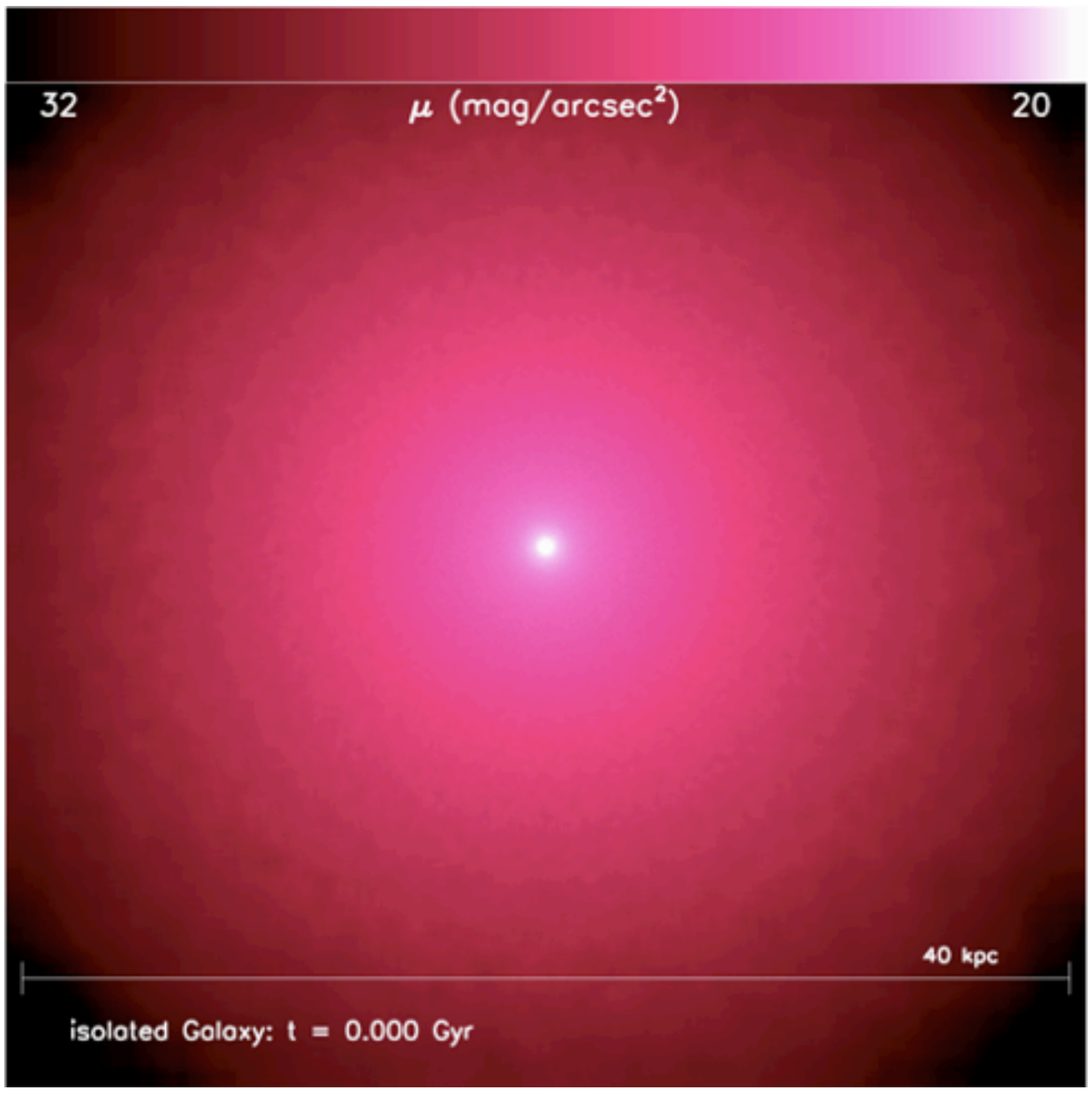
$$\Rightarrow \quad M_{\rm vir} \gtrsim 3 \times 10^{10} M_\odot$$

$$M^{\rm Sgr}_{\rm total} \simeq M^{\rm MW}_{\rm disk}$$

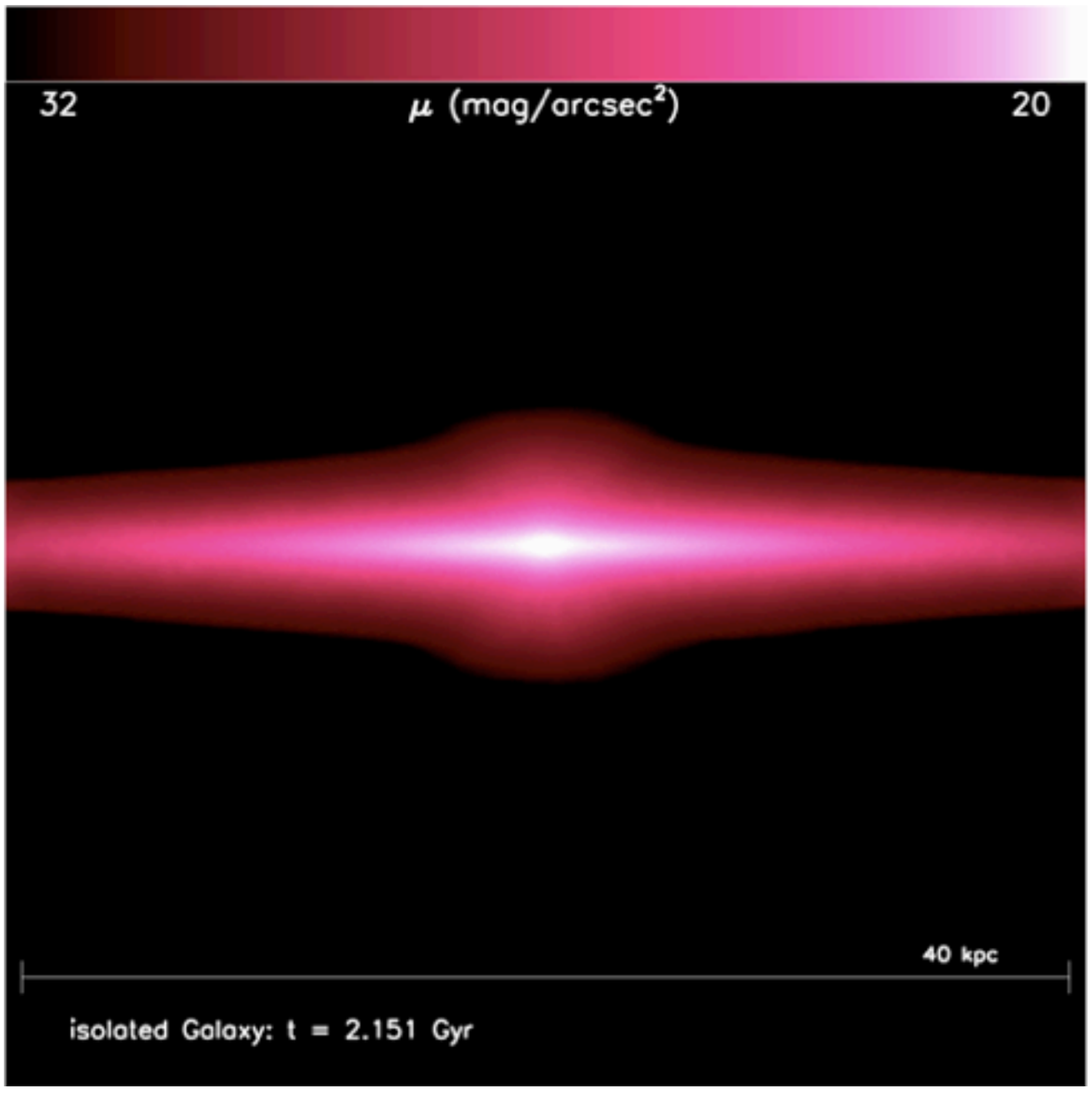
30 million particle disk + live halo

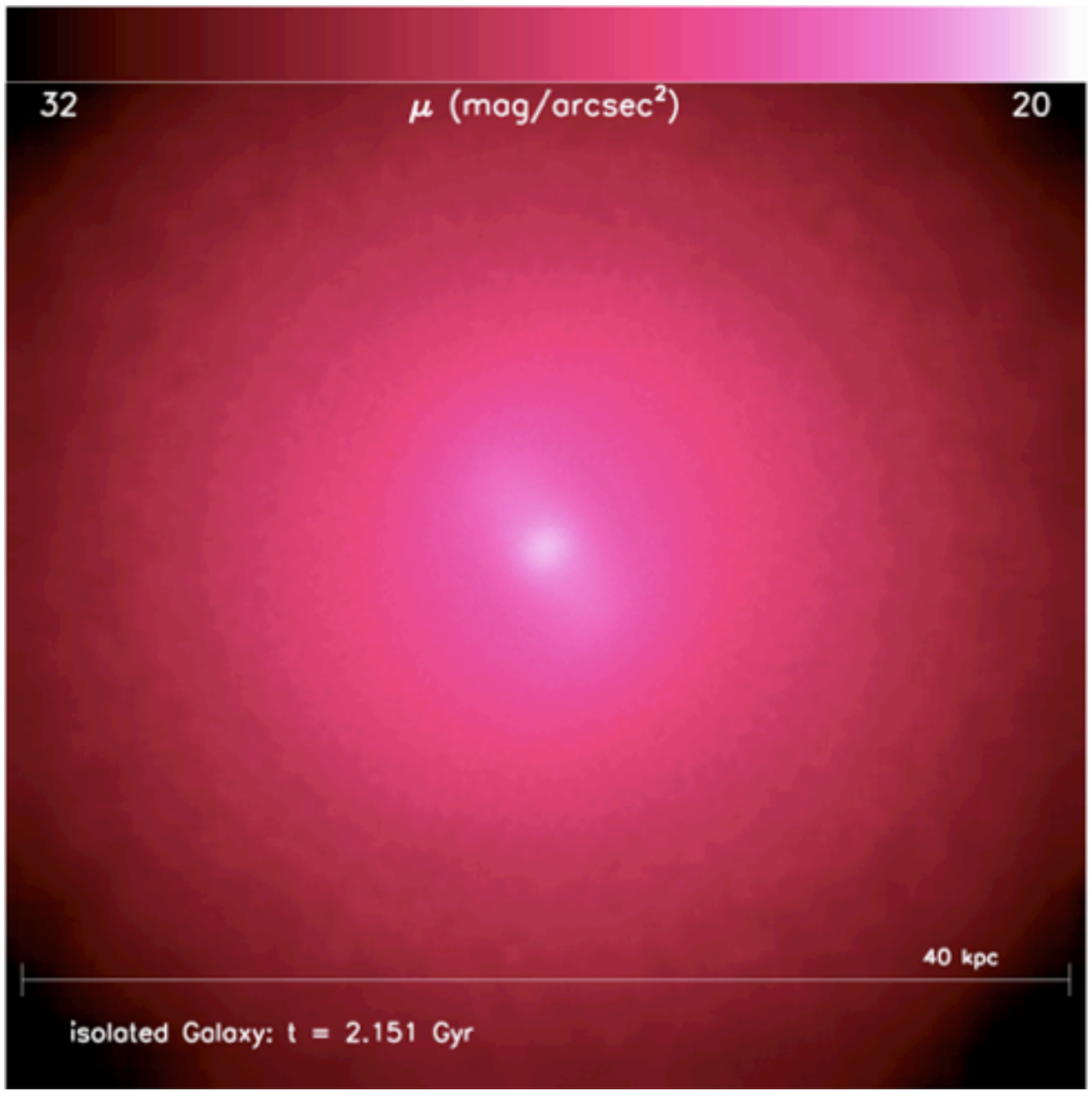




Purcell, JSB, Tollerud 2010

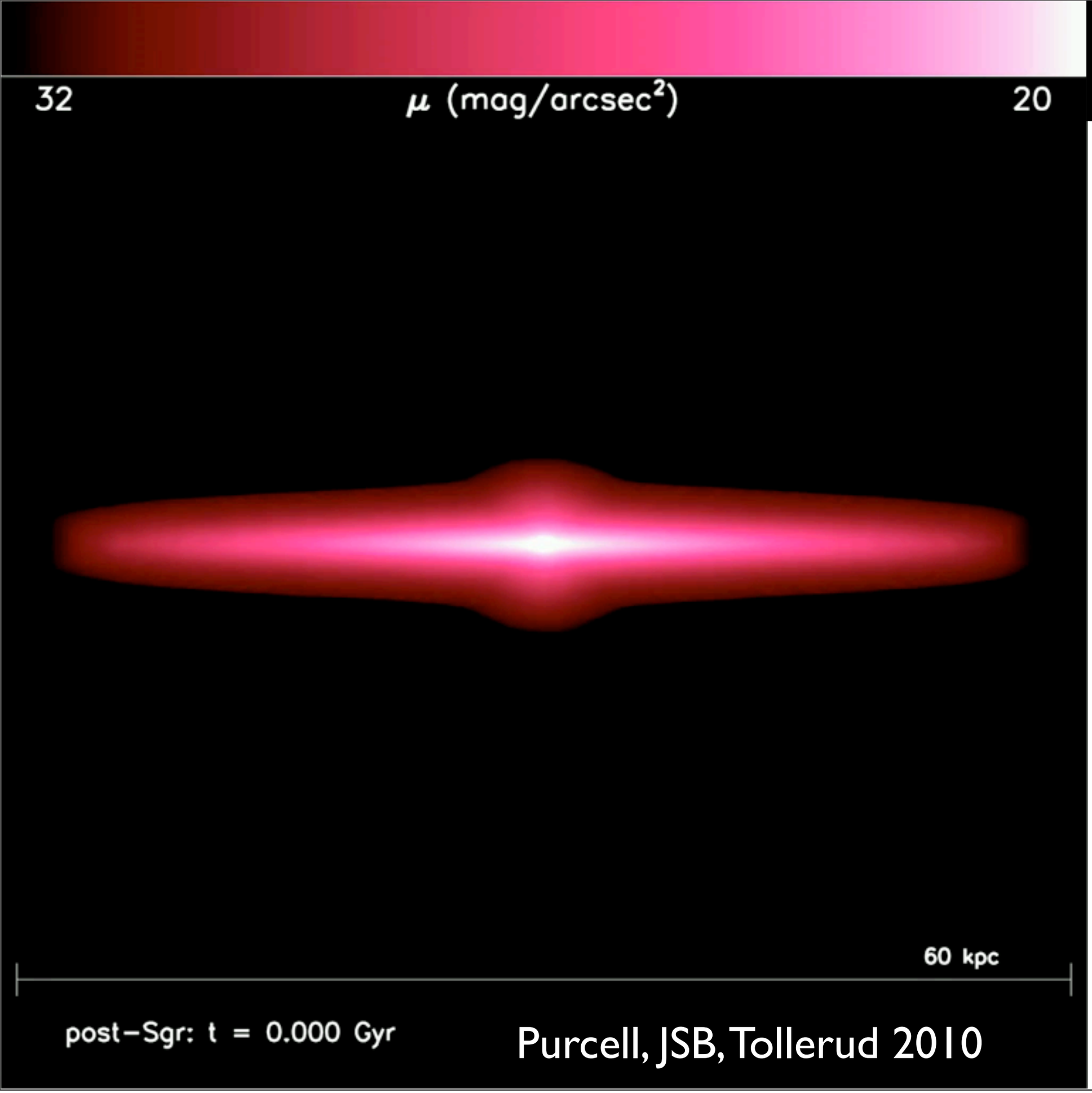
Stable to secular instabilities





Purcell, JSB, Tollerud 2010

‘Light’ Sgr Model
M_v = 1.5e10 M_{sun}



Purcell, JSB, Tollerud 2010

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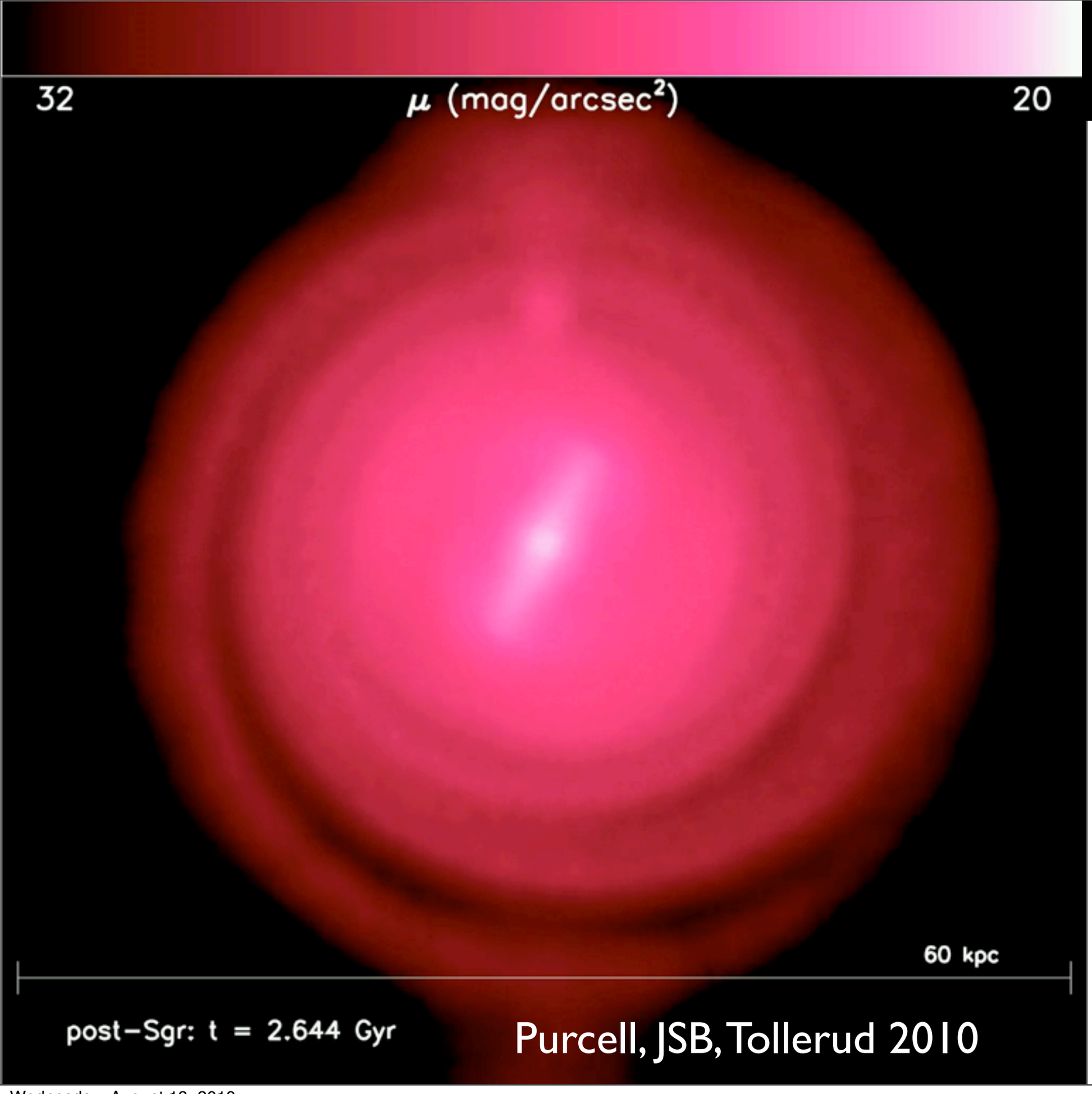
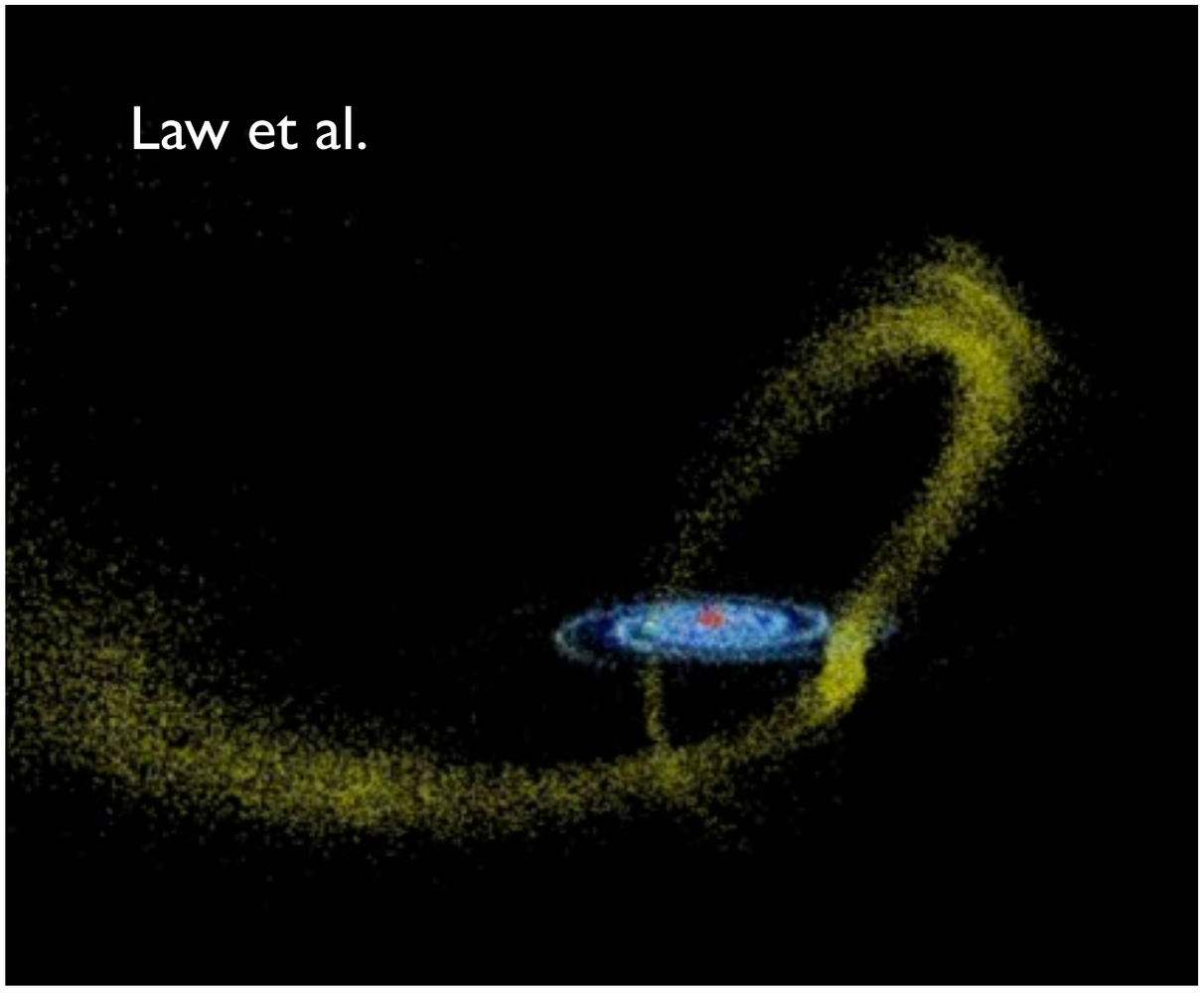
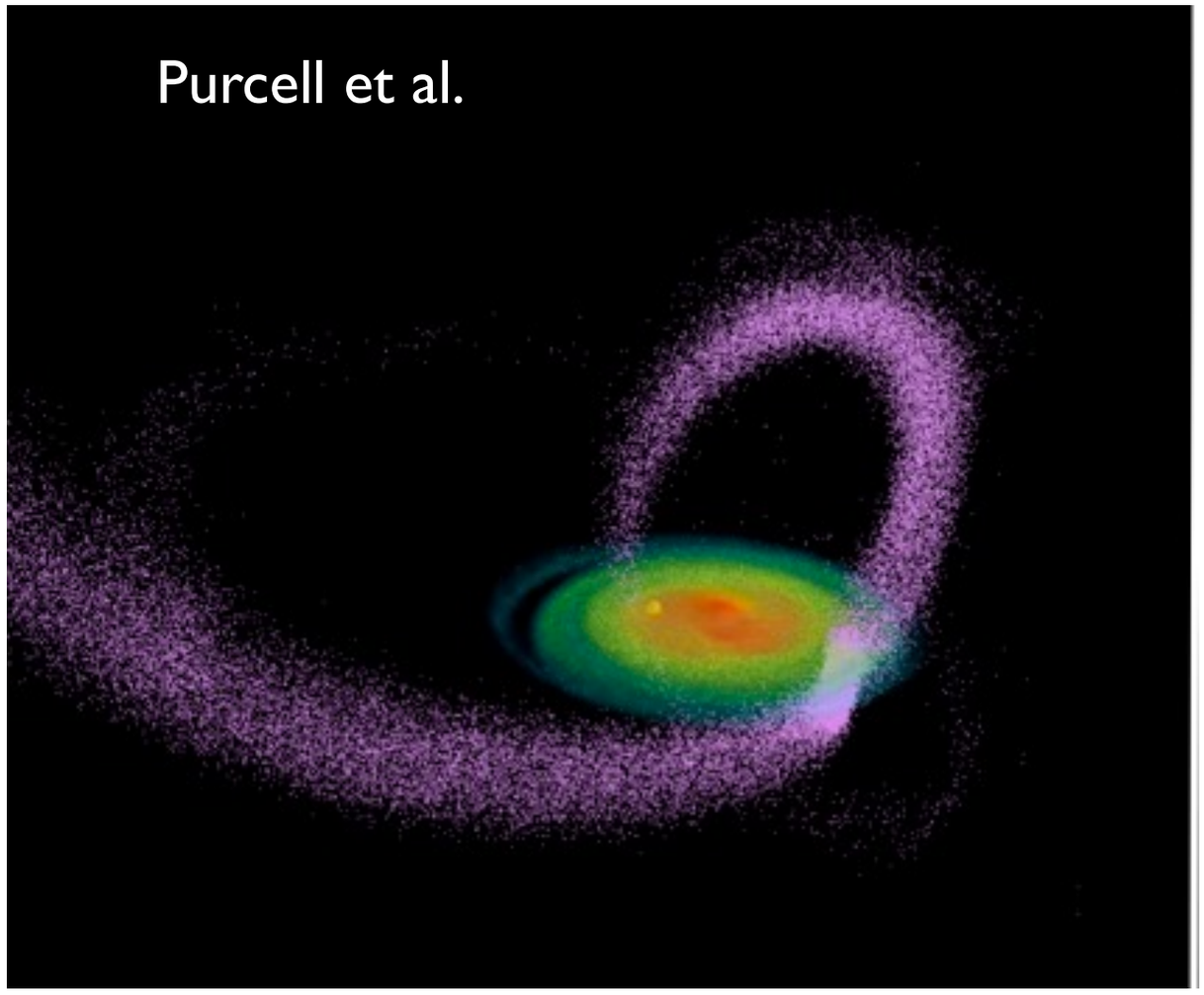


Purcell, JSB, Tollerud 2010

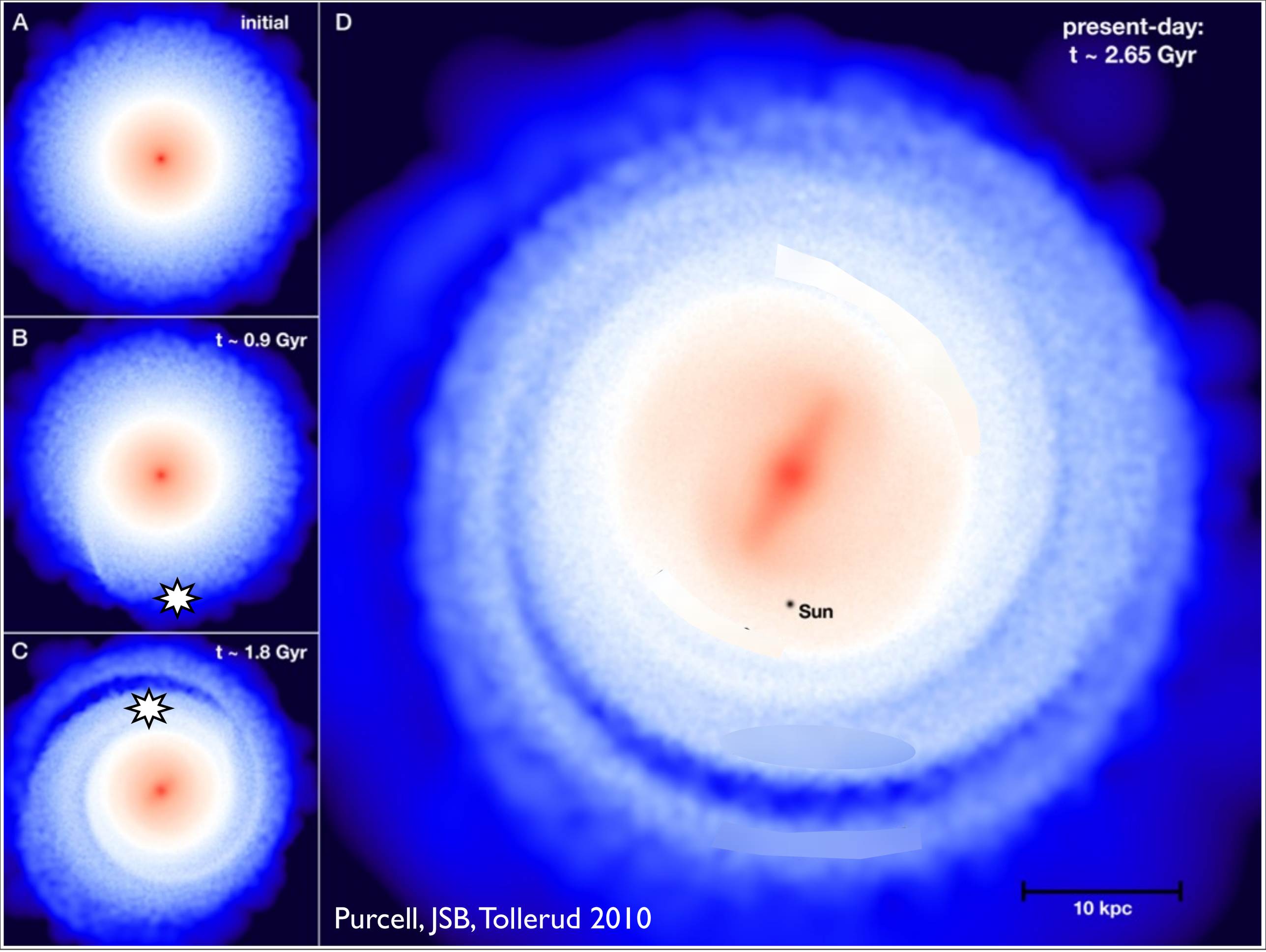
The impact of Sagittarius on the disk of the Milky Way



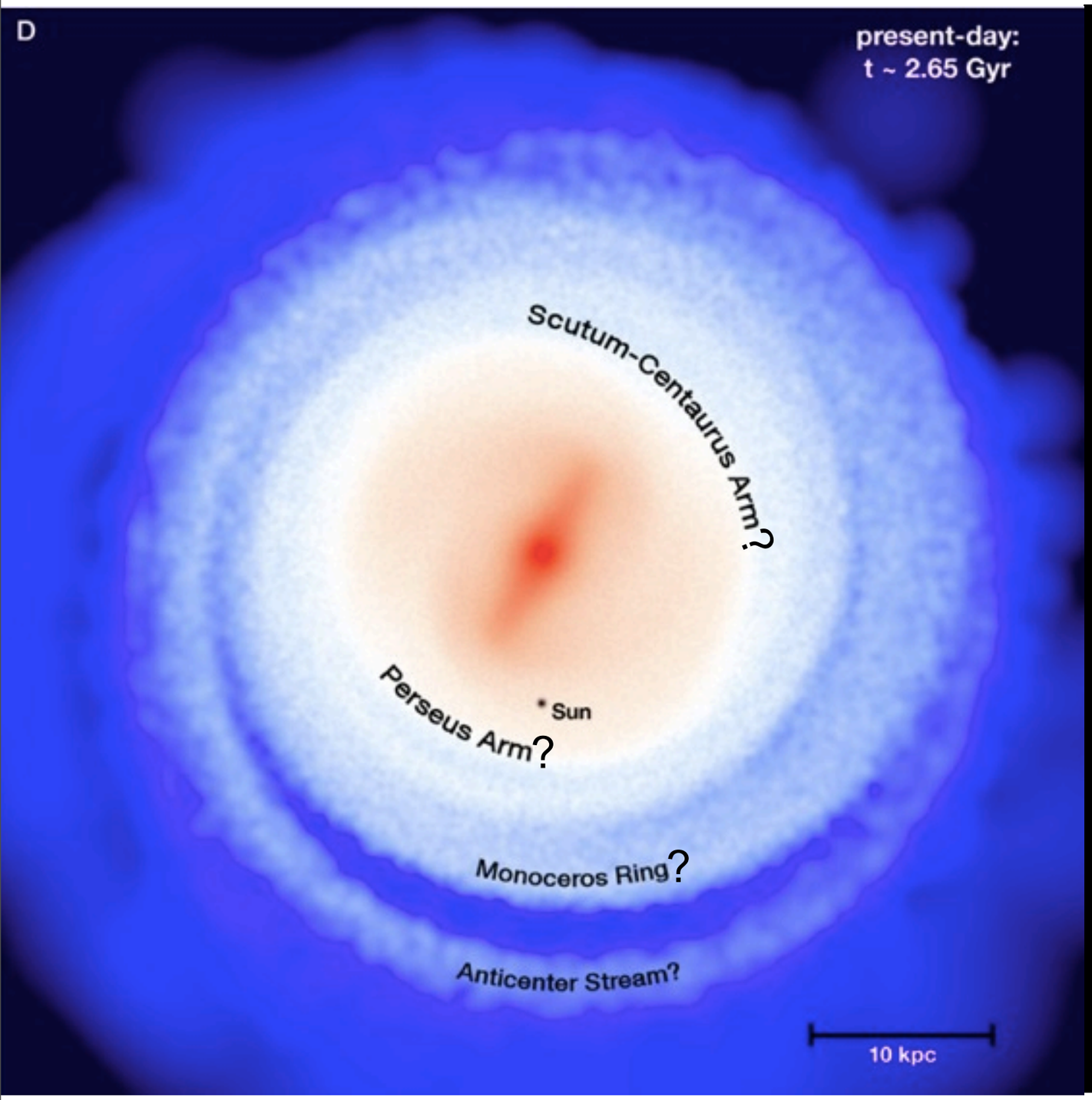
Rigid halo, rigid disk,
no dark matter in Sgr

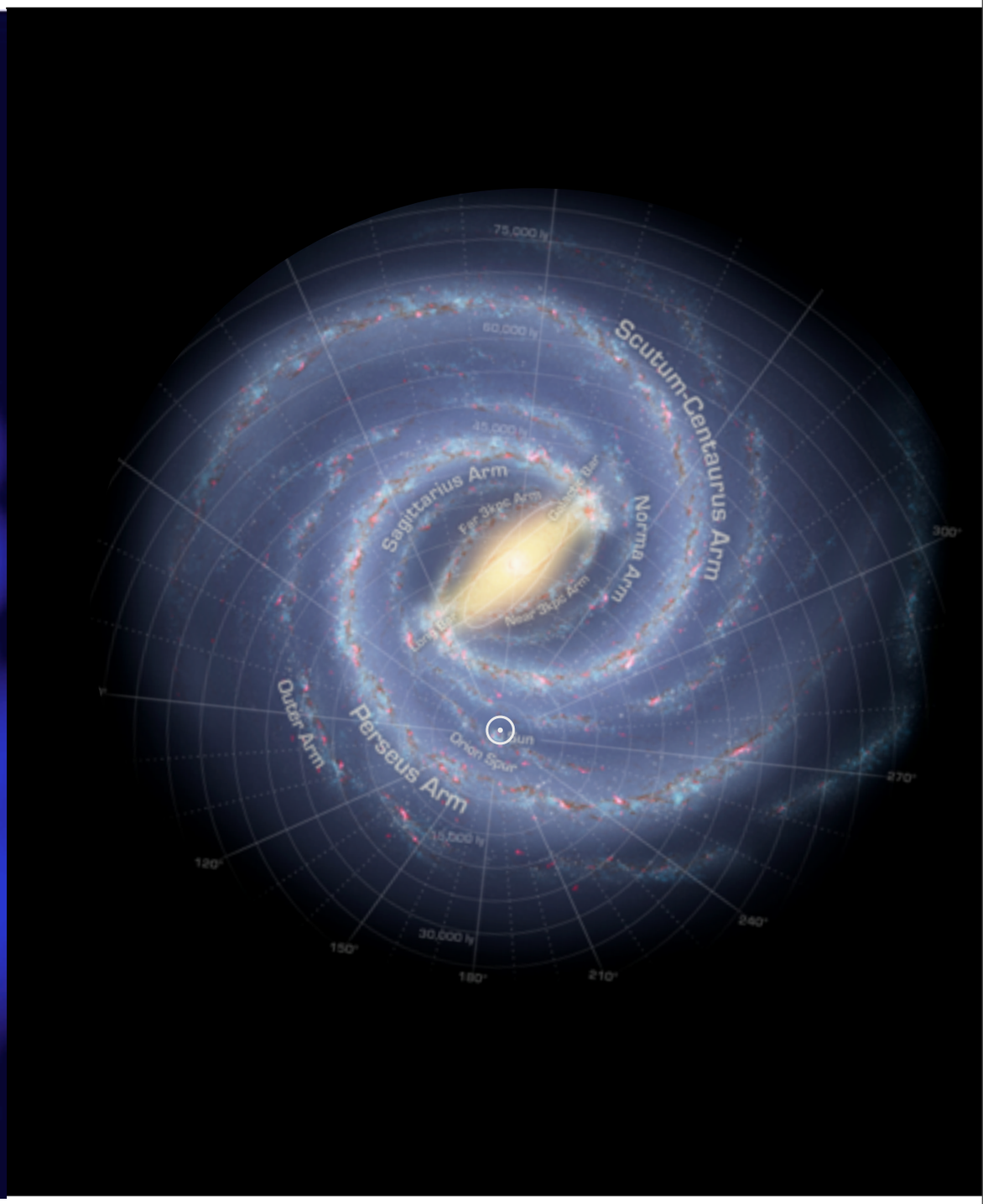


Fully self-consistent


A
initial
B
t ~ 0.9 Gyr
C
t ~ 1.8 Gyr
D
present-day:
t ~ 2.65 Gyr
Sun
10 kpc
Purcell, JSB, Tollerud 2010

Intermediate-scale spiral structure, similar to MW





Purcell, JSB, Tollerud 2010

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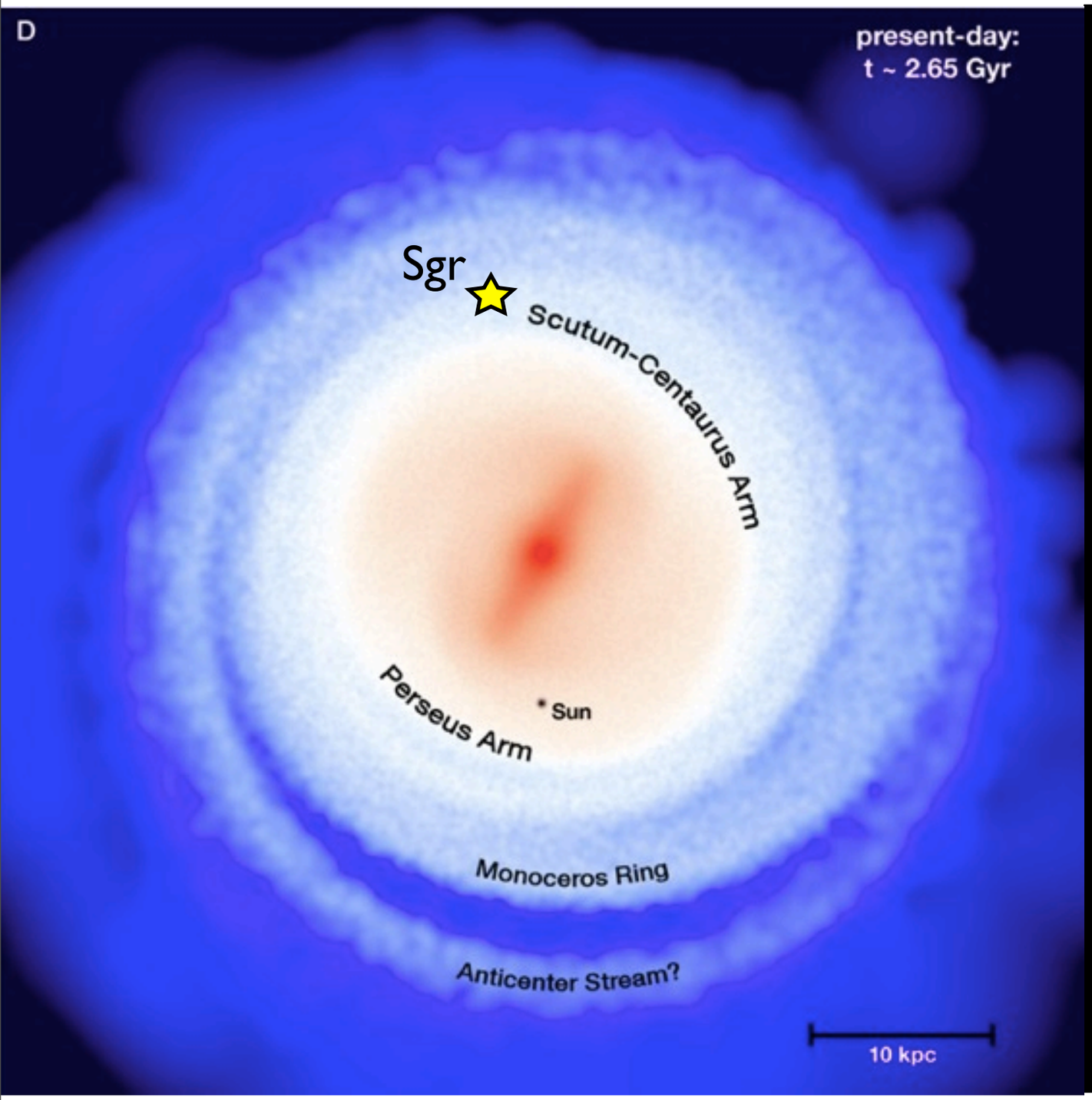

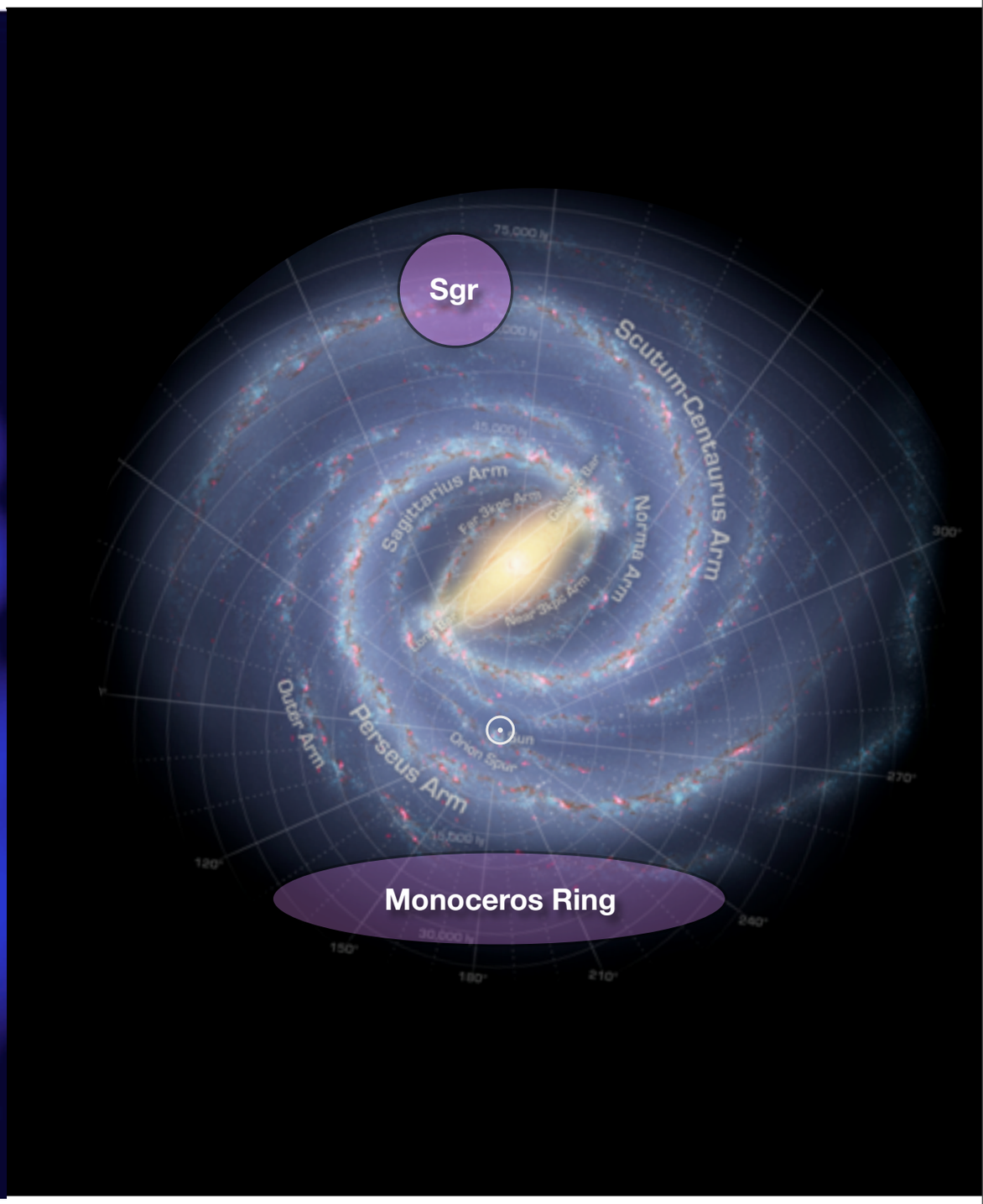

Purcell, JSB, Tollerud 2010

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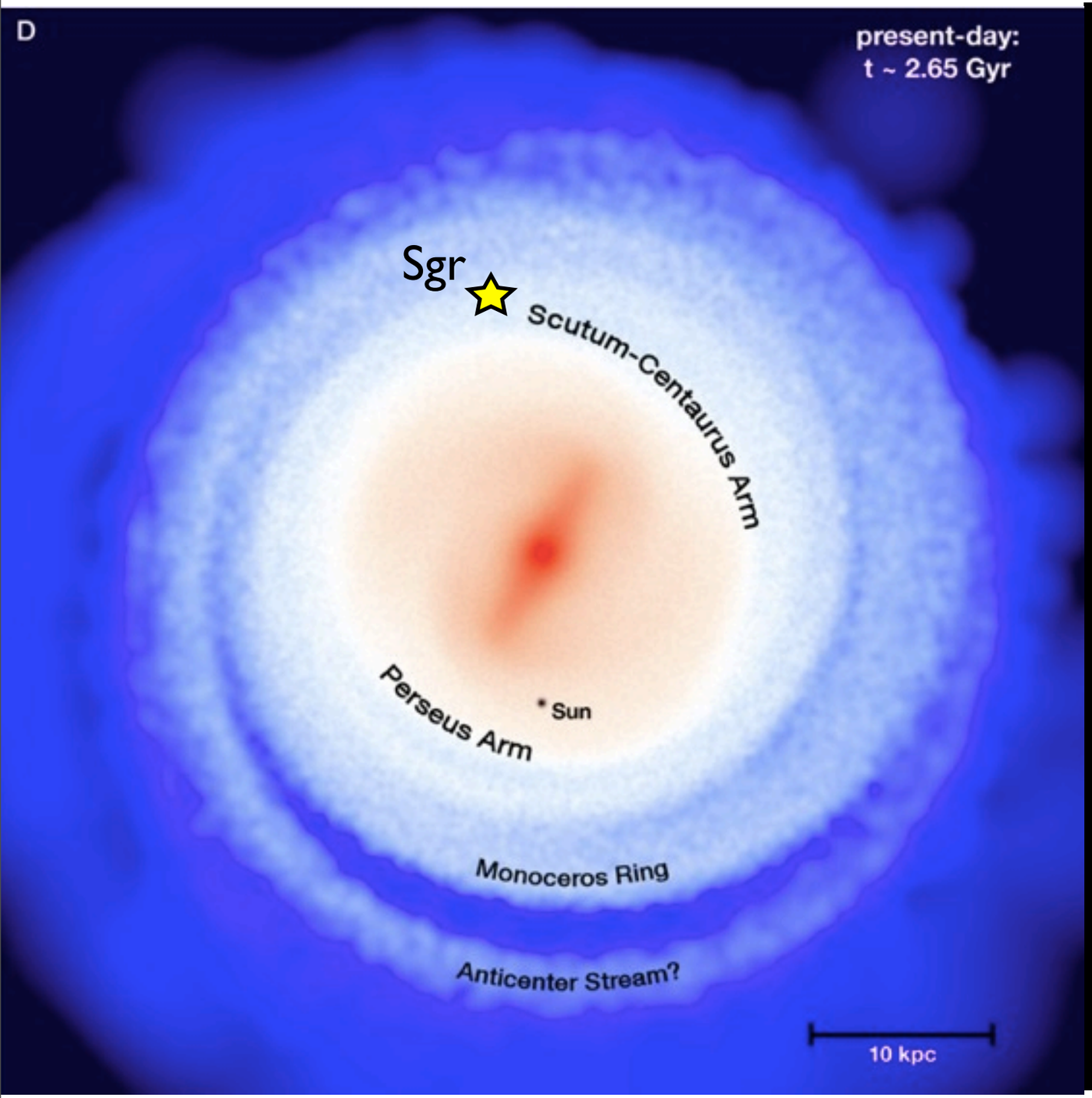

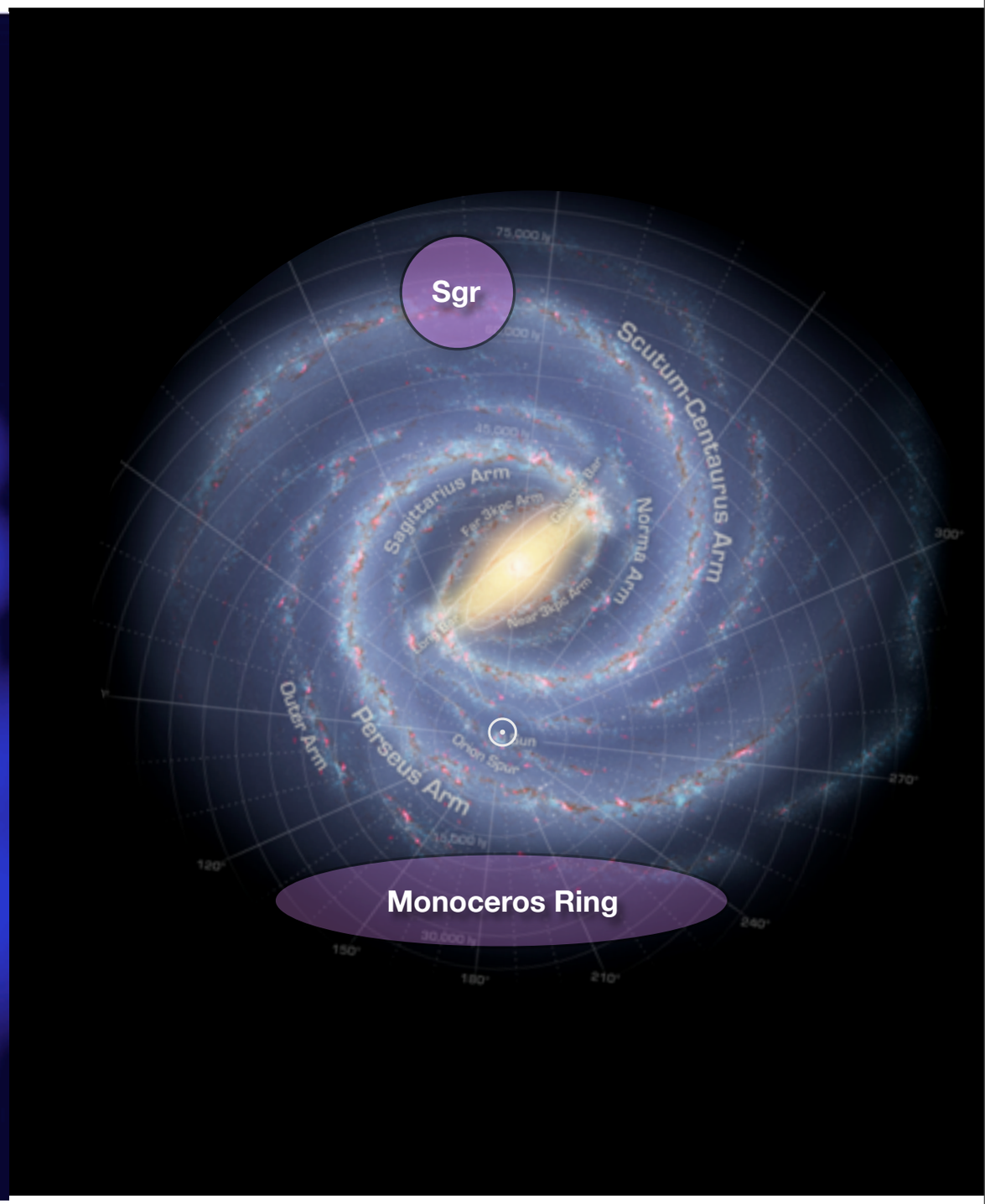

Purcell, JSB, Tollerud 2010

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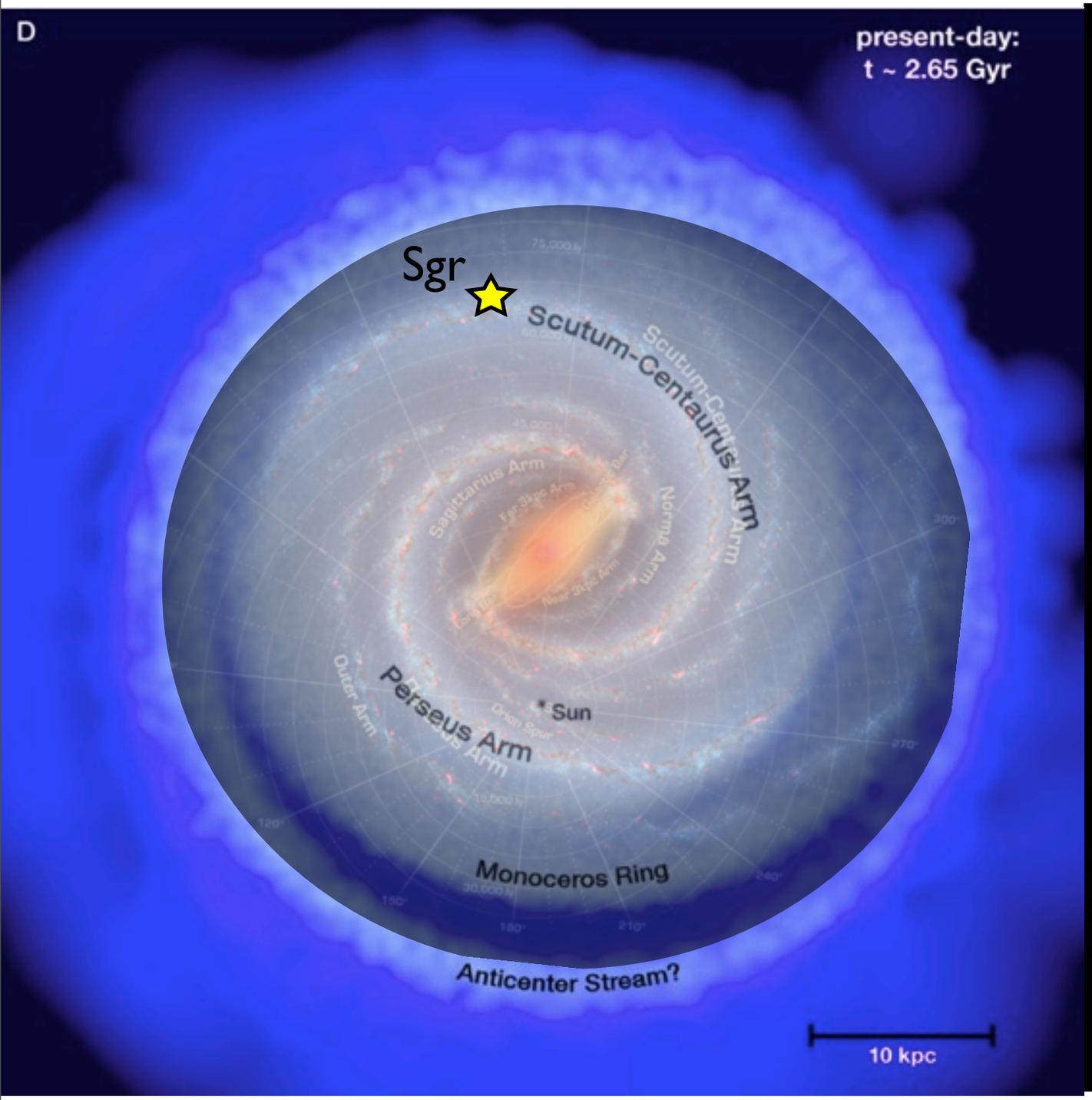
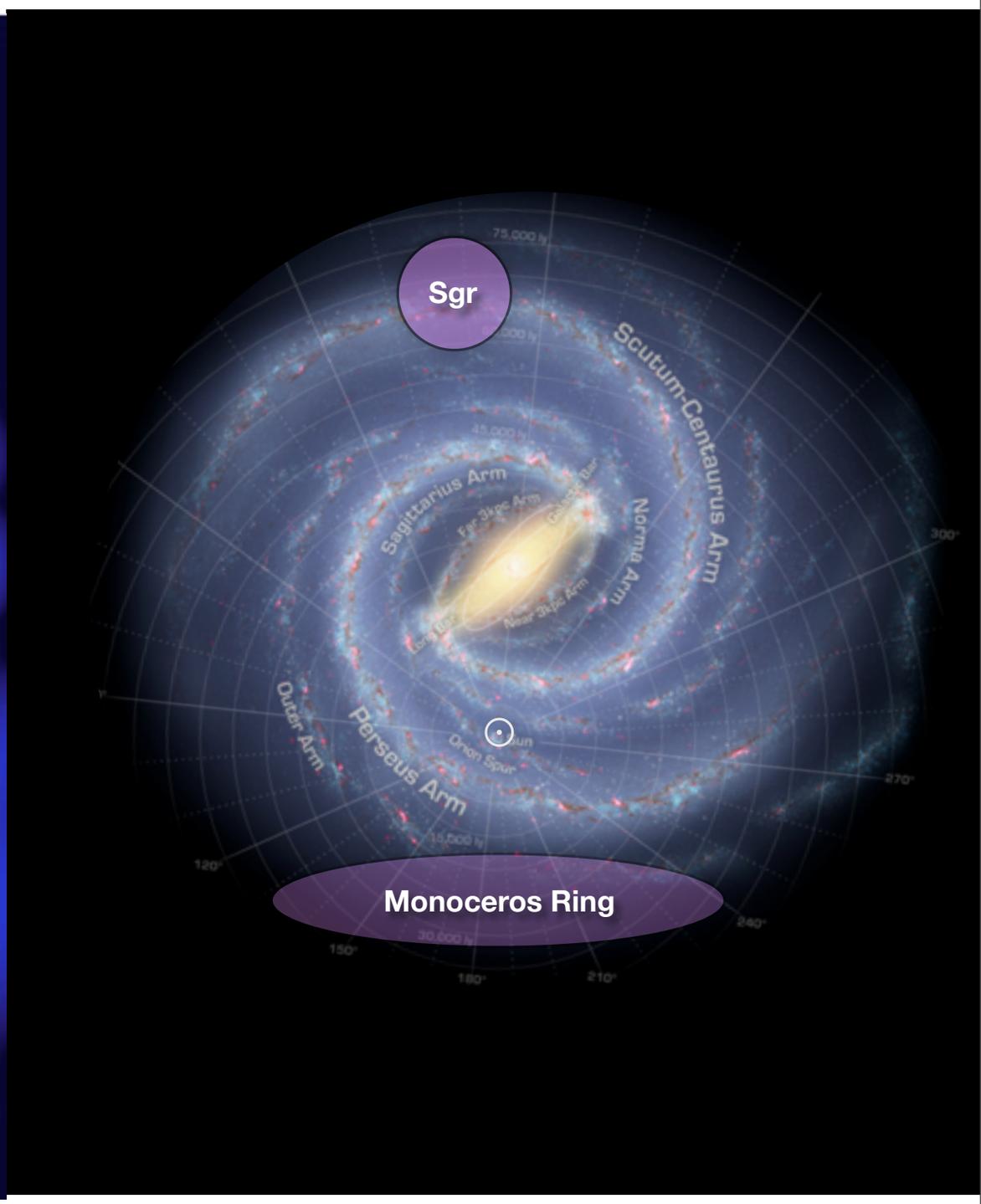
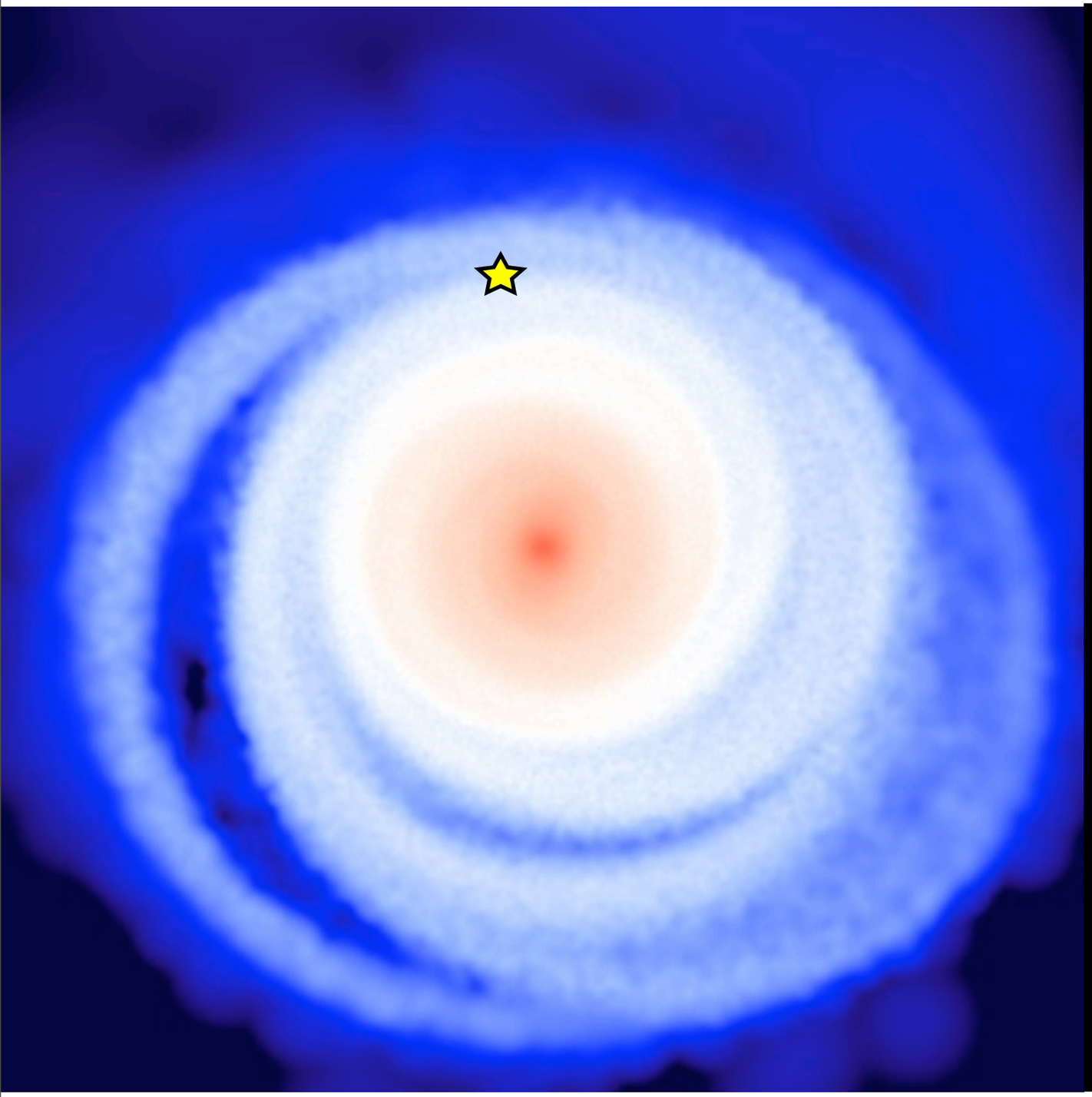
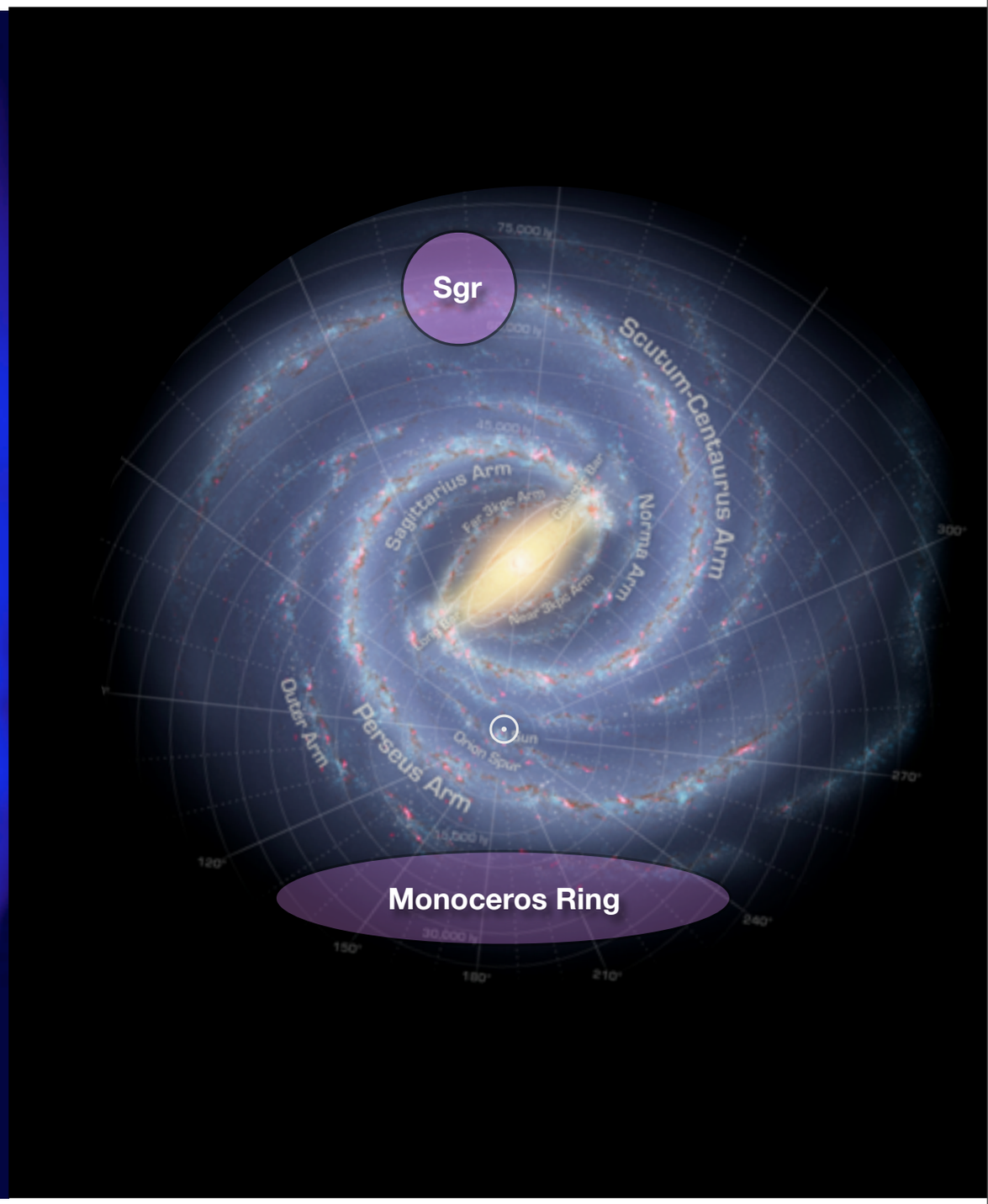




Purcell, JSB, Tollerud 2010

Heavy Sag, M=3.e10M_{sun}

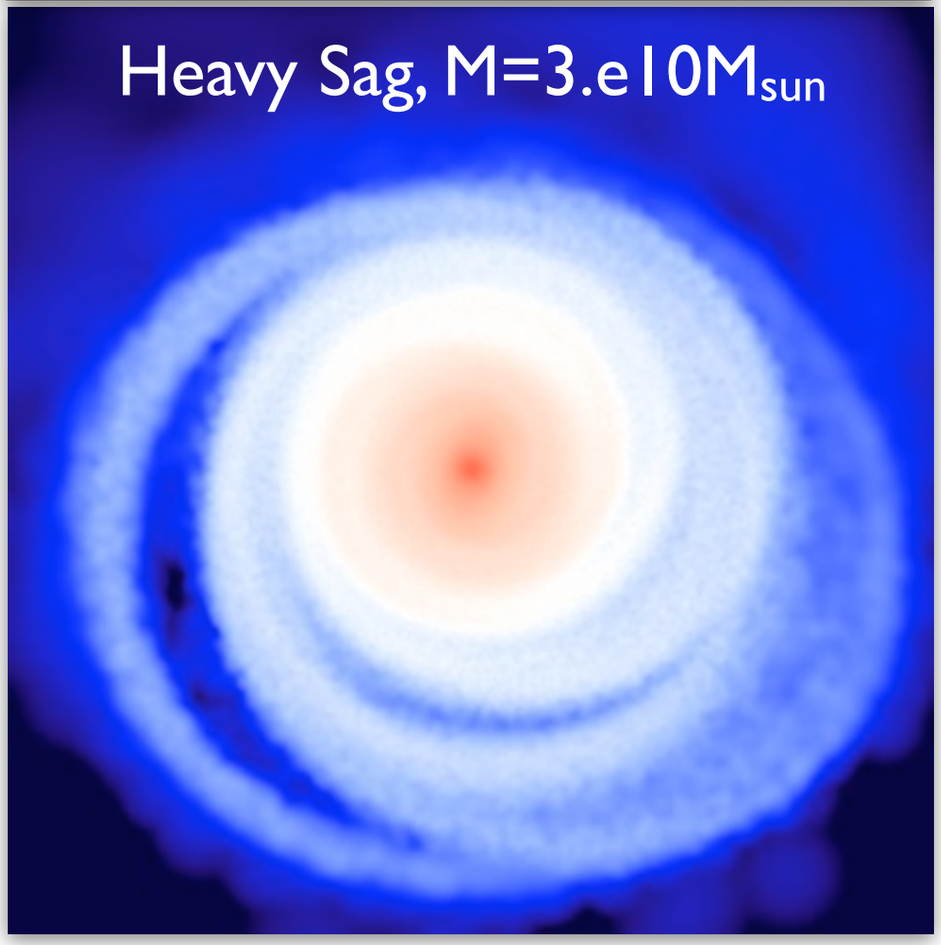




Purcell, JSB, Tollerud 2010

Scale height ~ 400 pc

Velocity Ellipsoid ~ (35, 32, 20) km/s

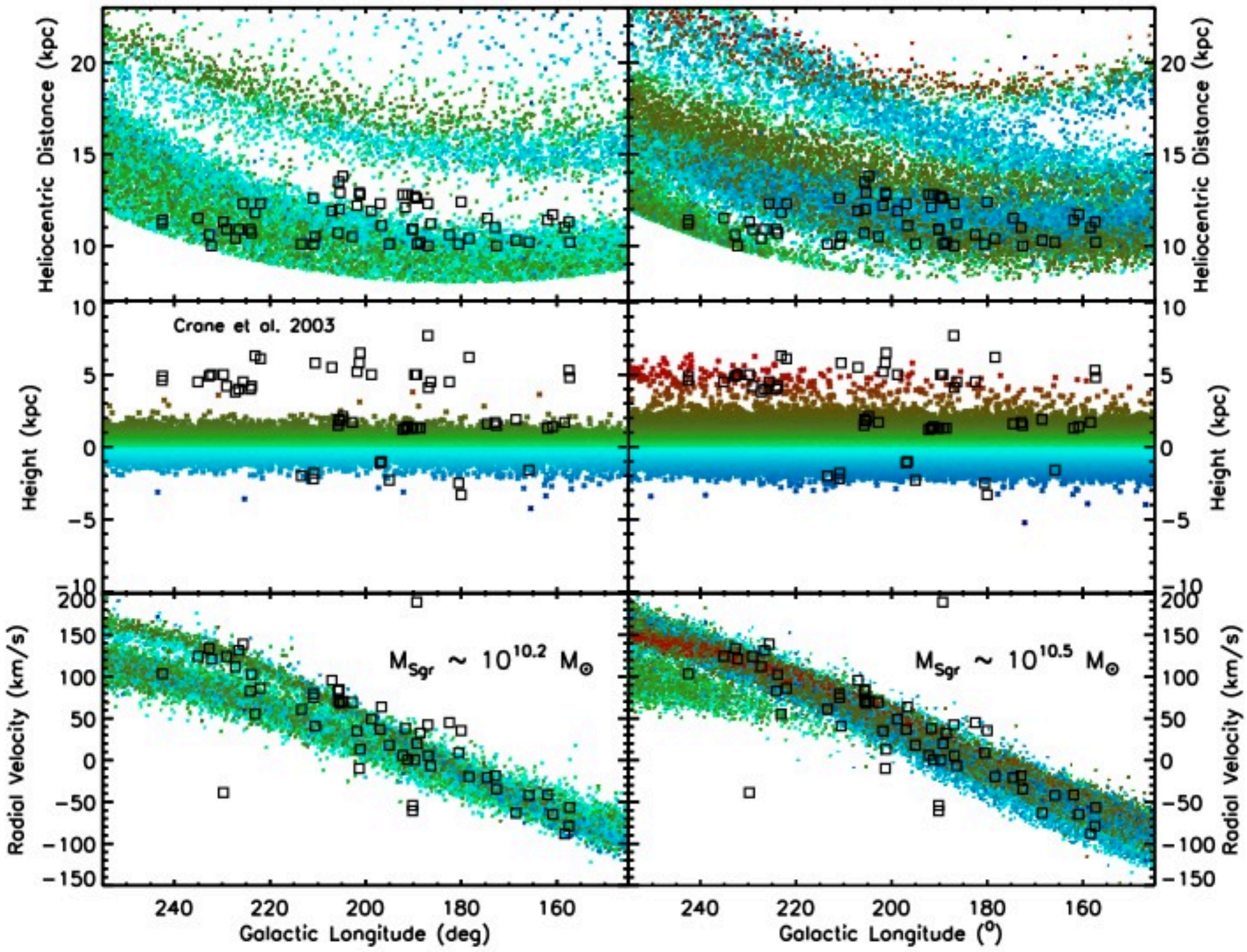


Scale height = 500 pc ✓

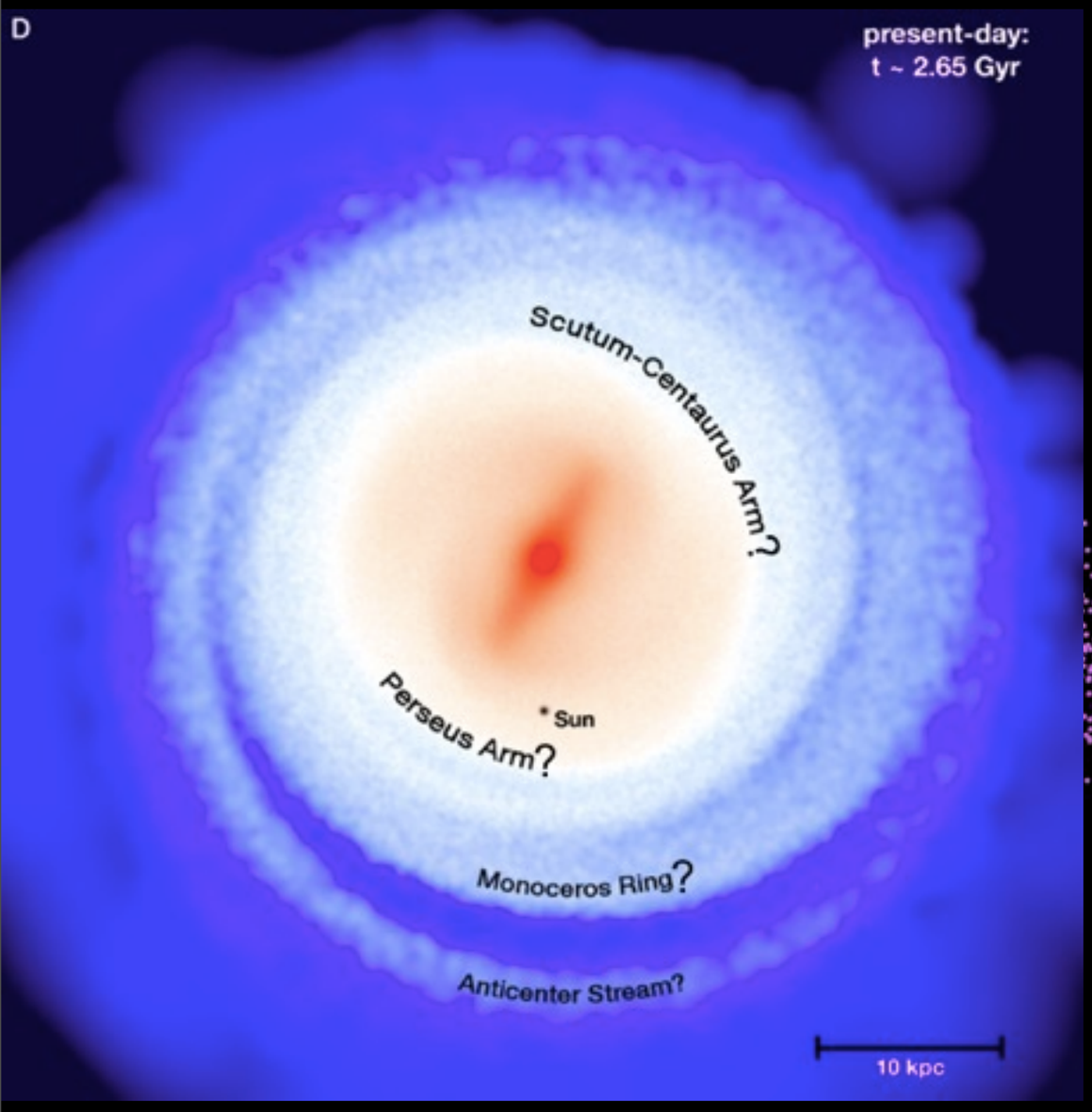
Velocity Ellipsoid = (37, 27, 20) km/s ✓

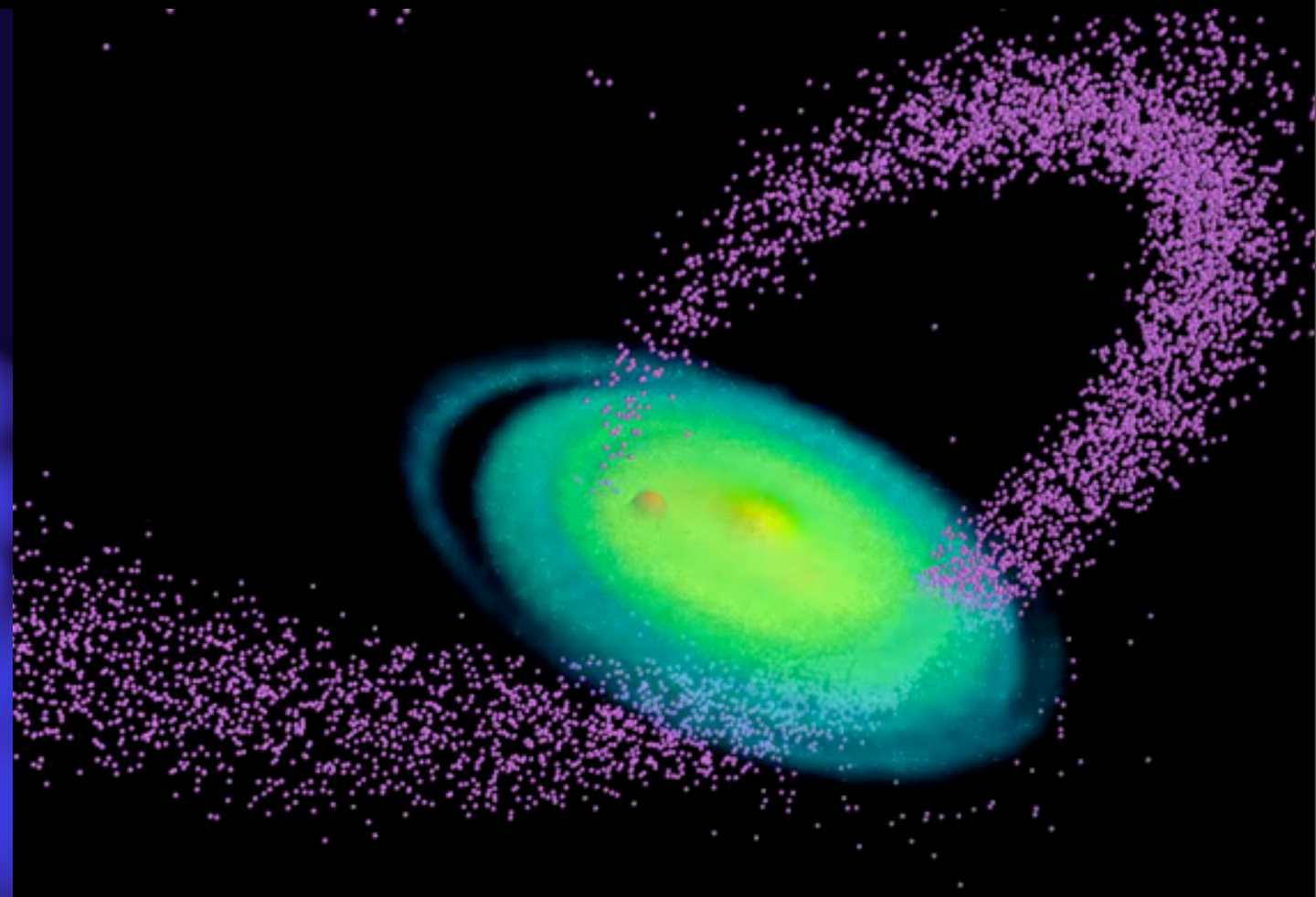
Did the Sag impact Create Monoceros Ring?

Light Sag M = 1.5e10 M_{sun} | Heavy Sag M = 3.e10 M_{sun}



Conclusions

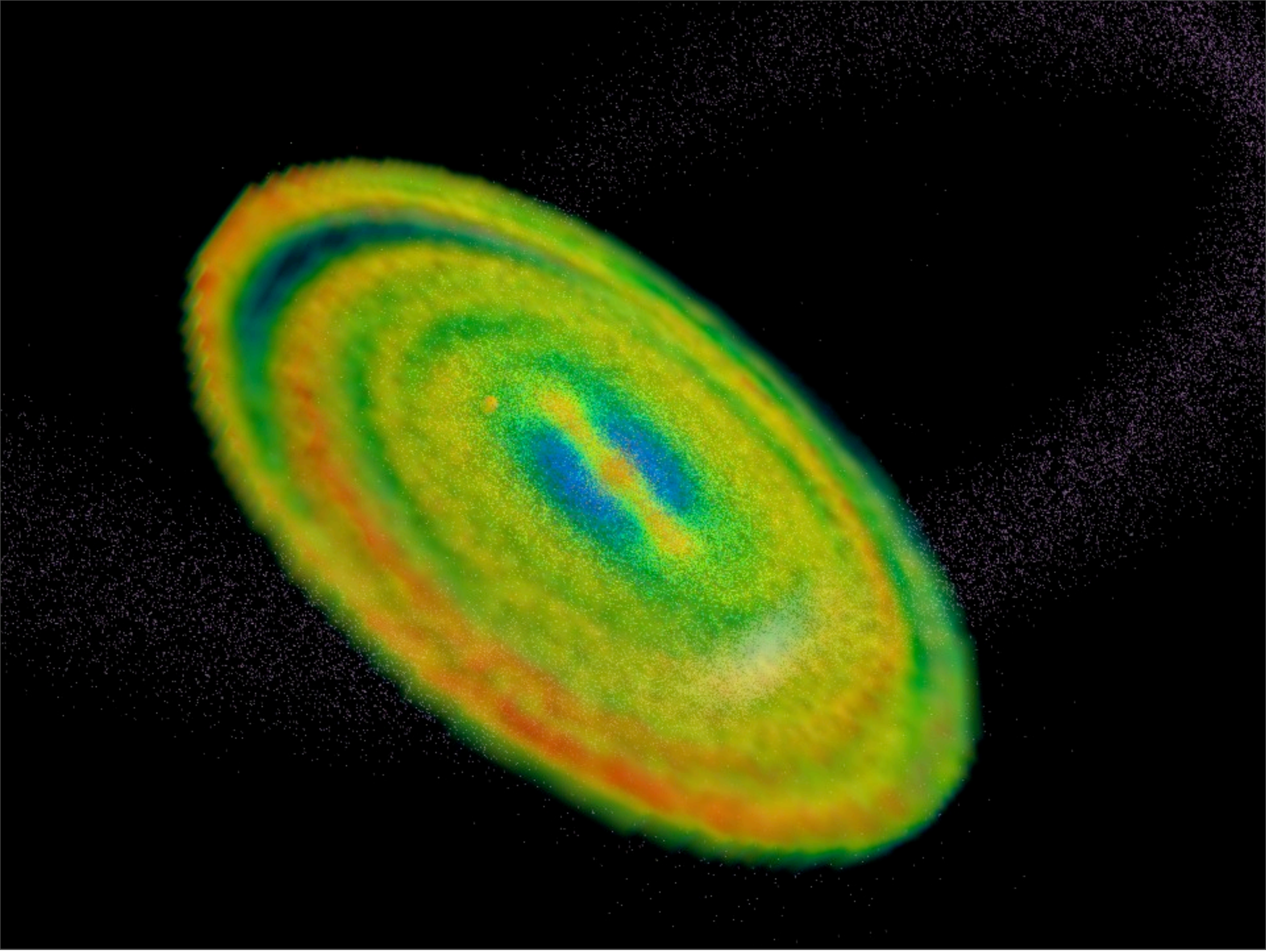




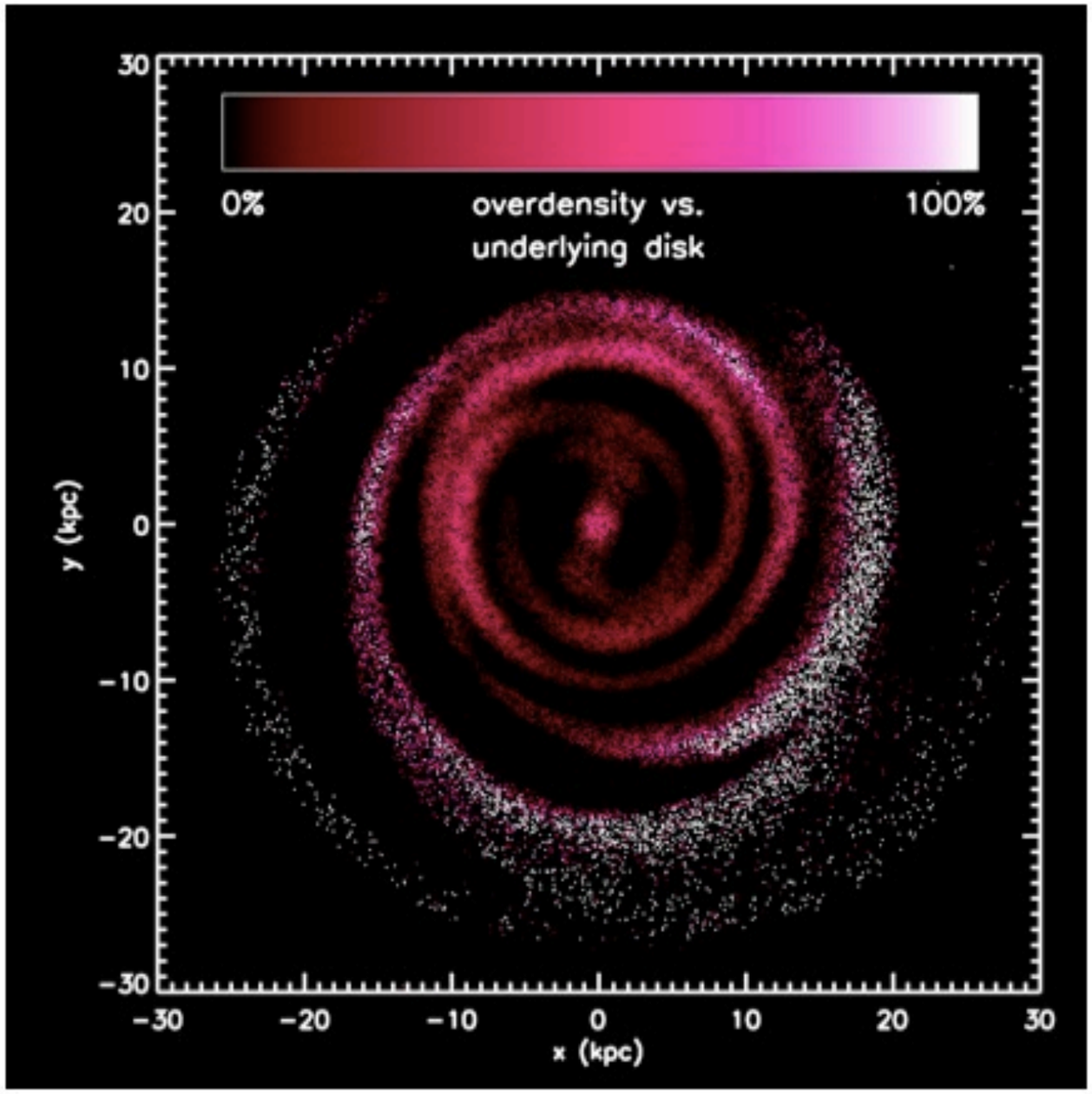
Purcell, JSB, Tollerud 2010

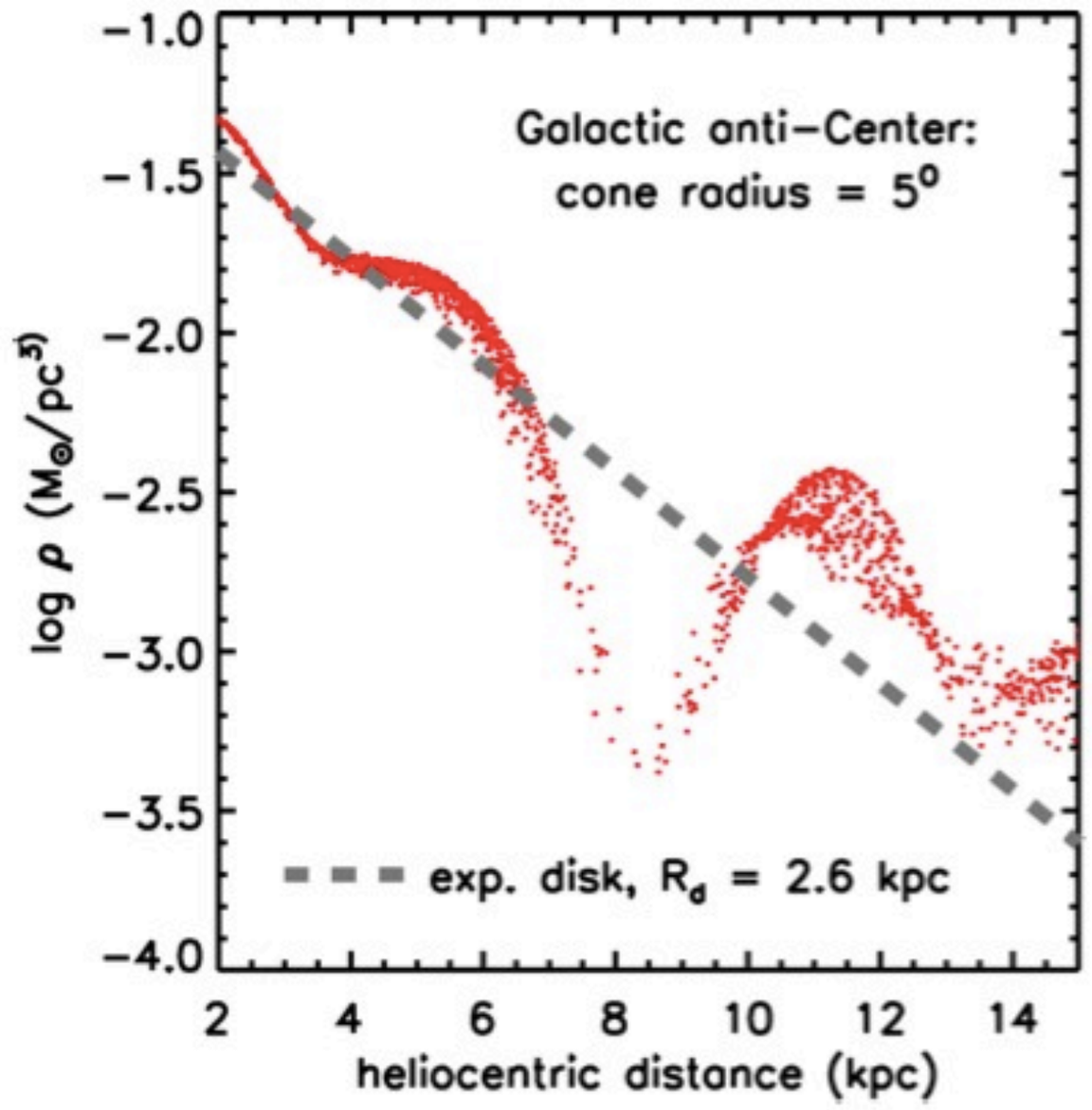
Sagittarius = an architect of structure in the Galaxy

Wednesday, August 18, 2010



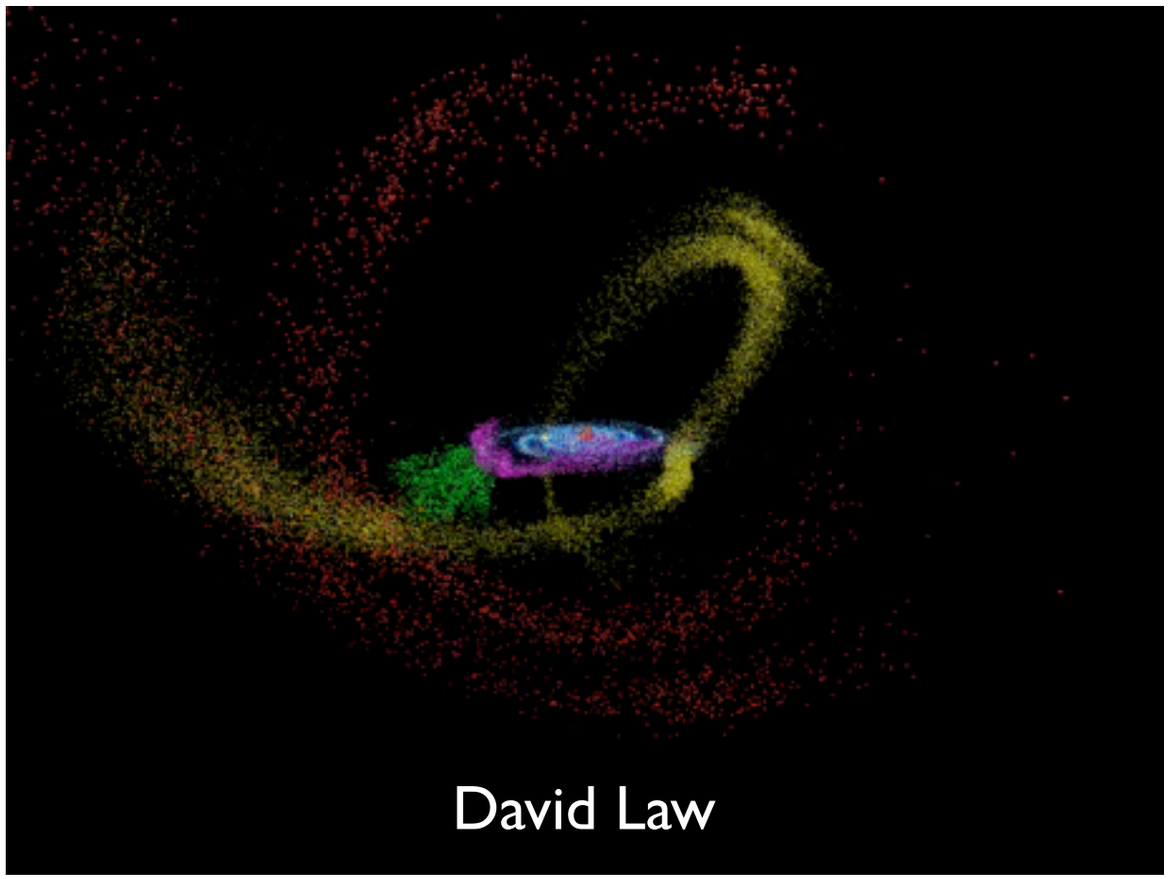
Wednesday, August 18, 2010


0%
overdensity vs.
underlying disk
100%
y (kpc)
x (kpc)
30
20
10
0
−10
−20
−30
−30
−20
−10
0
10
20
30

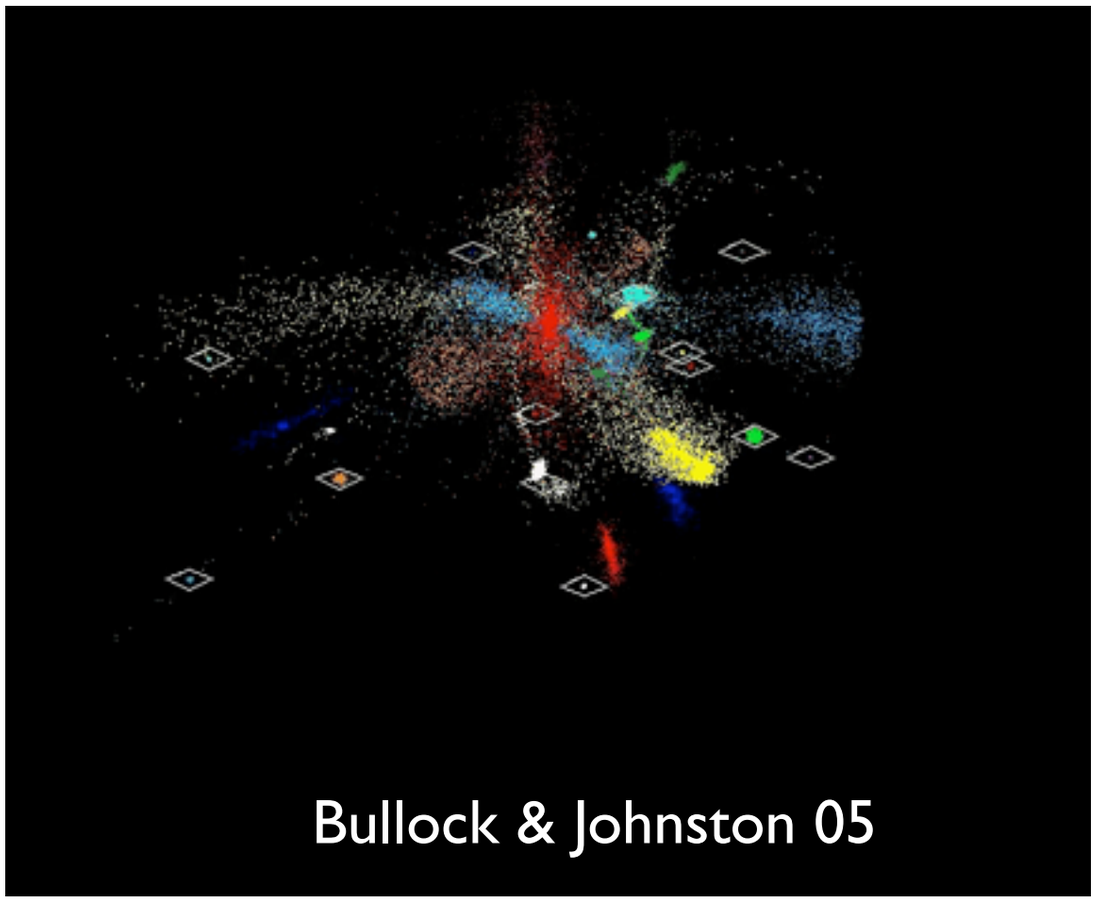

Galactic anti−Center:
cone radius = 5°
exp. disk, R_d = 2.6 kpc
log ρ (M⊙/pc³)
heliocentric distance (kpc)
−1.0
−1.5
−2.0
−2.5
−3.0
−3.5
−4.0
2
4
6
8
10
12
14

Halo Streams & Substructure

Halo substructure compares well to LCDM
e.g. Bell et al. (2008)



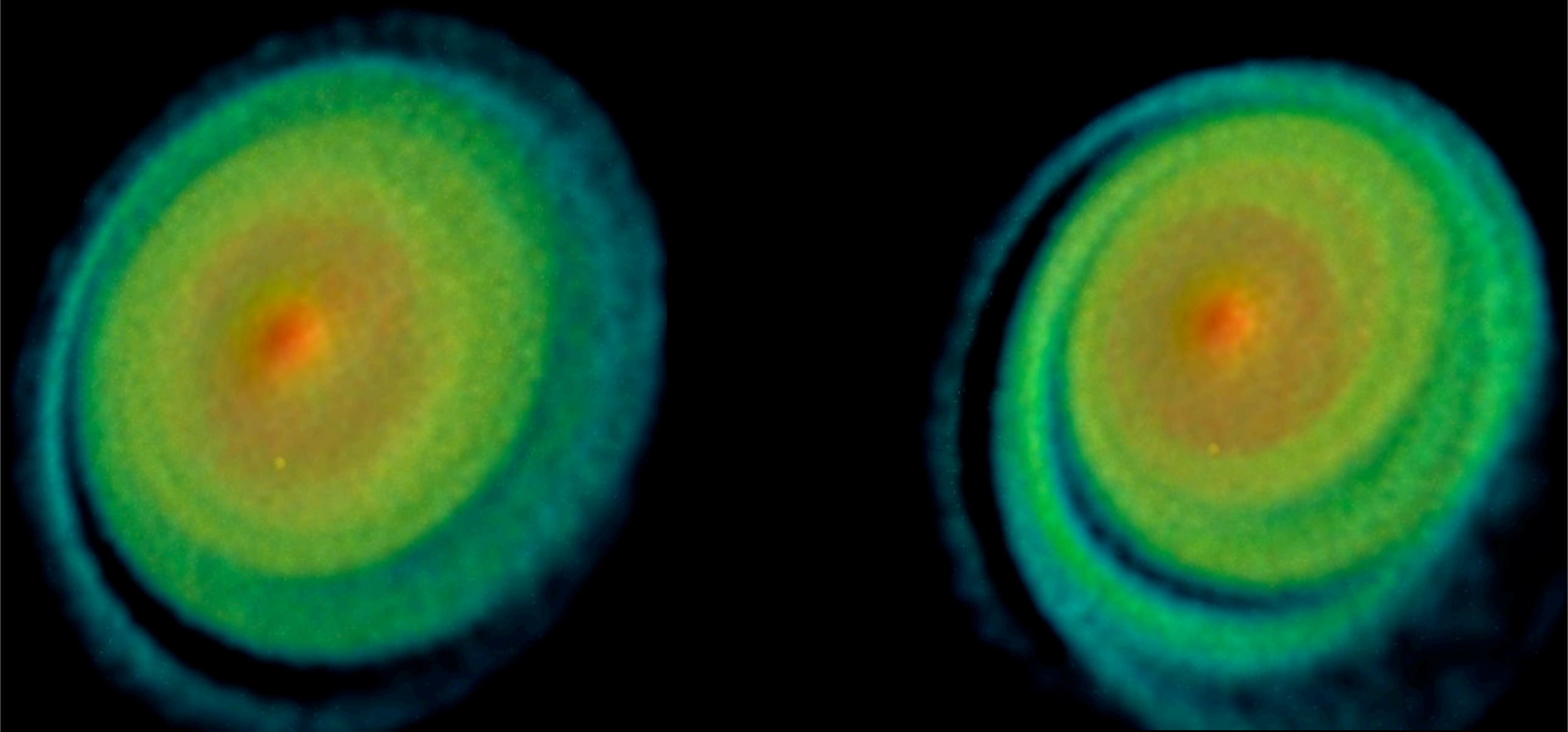
MW data + models engineered to match data

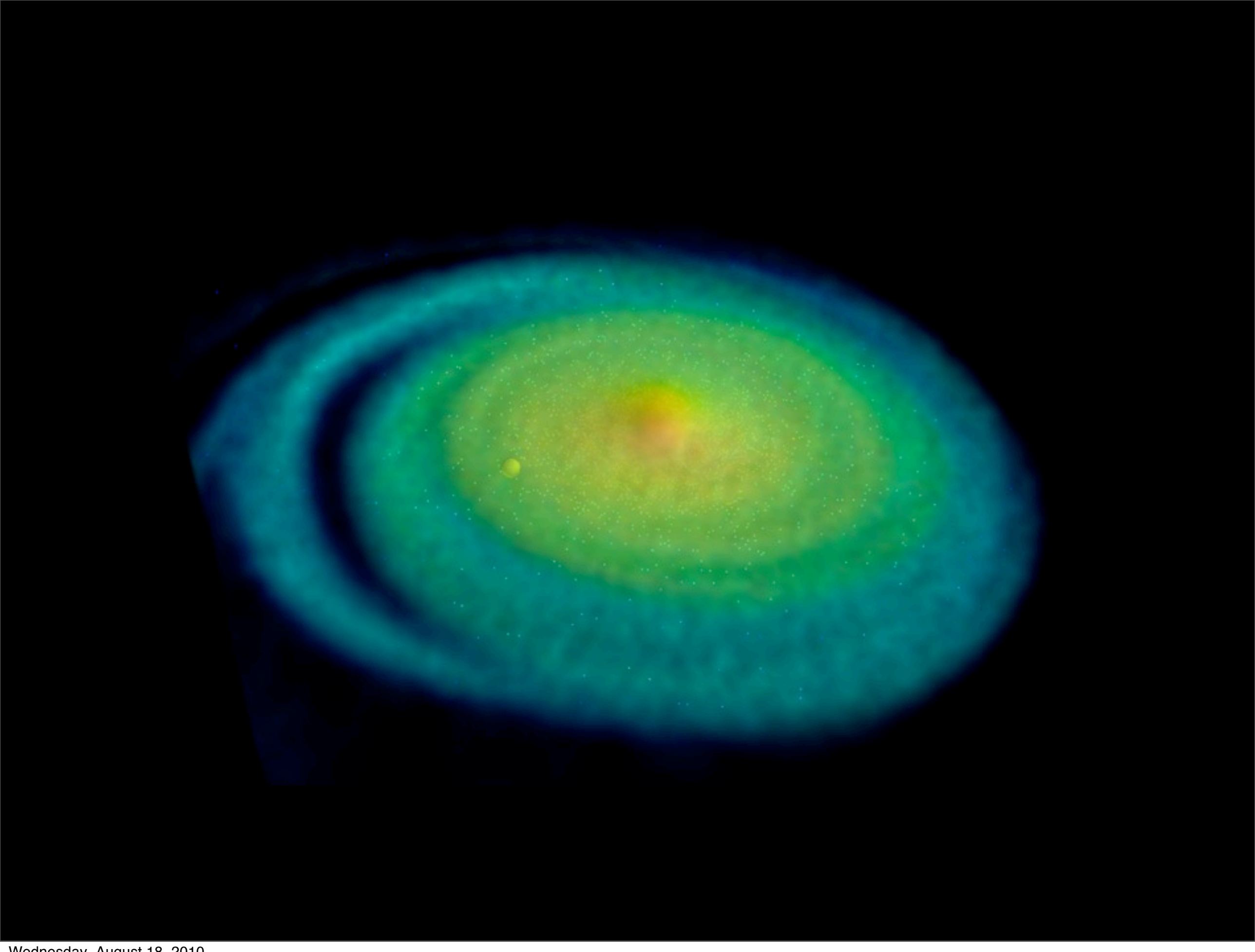


Random LCDM realization

Light Sag M = 1.5e10 M_{sun} Simulation

Heavy Sag M = 3e10 M_{sun} Simulation





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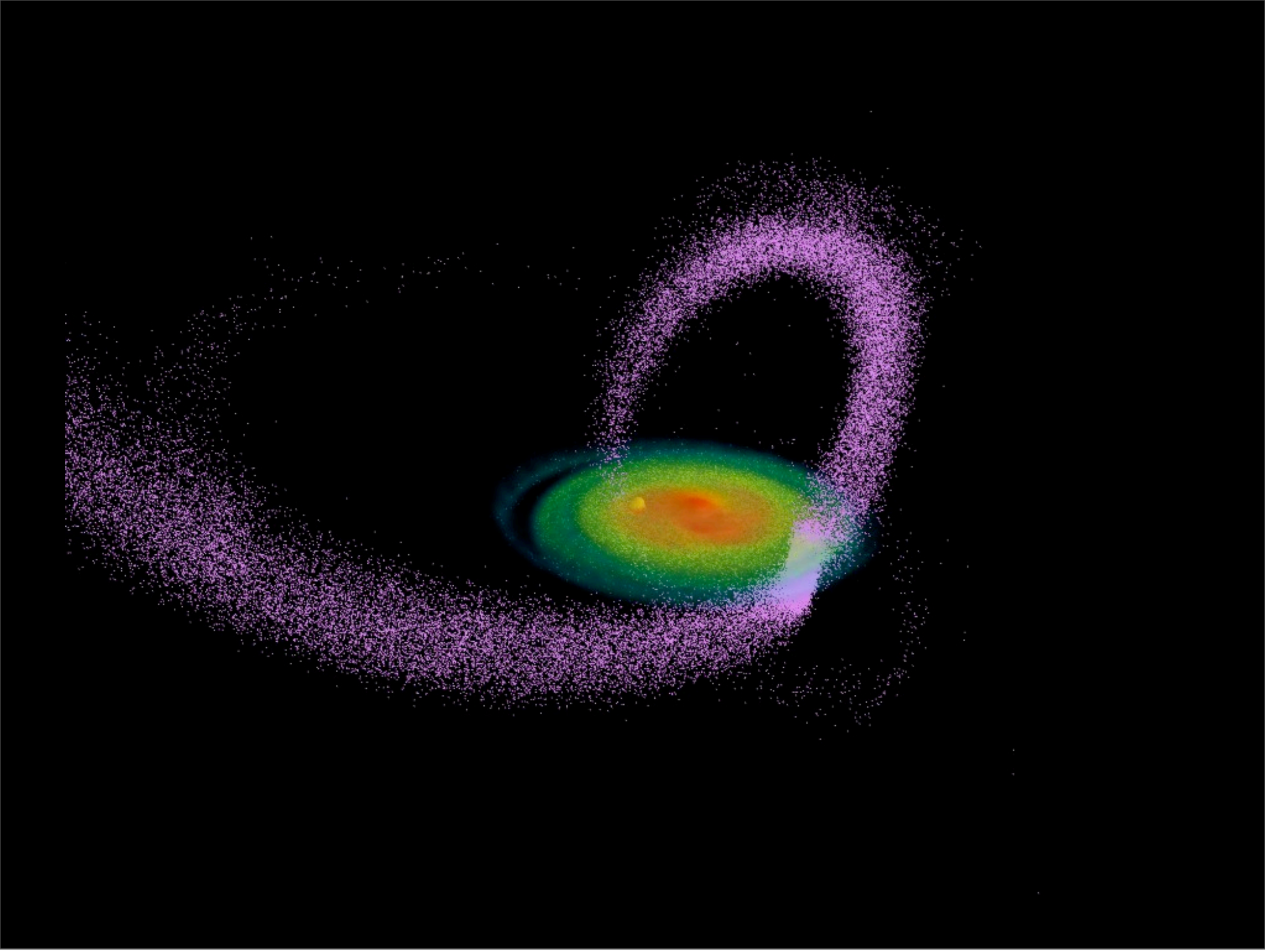
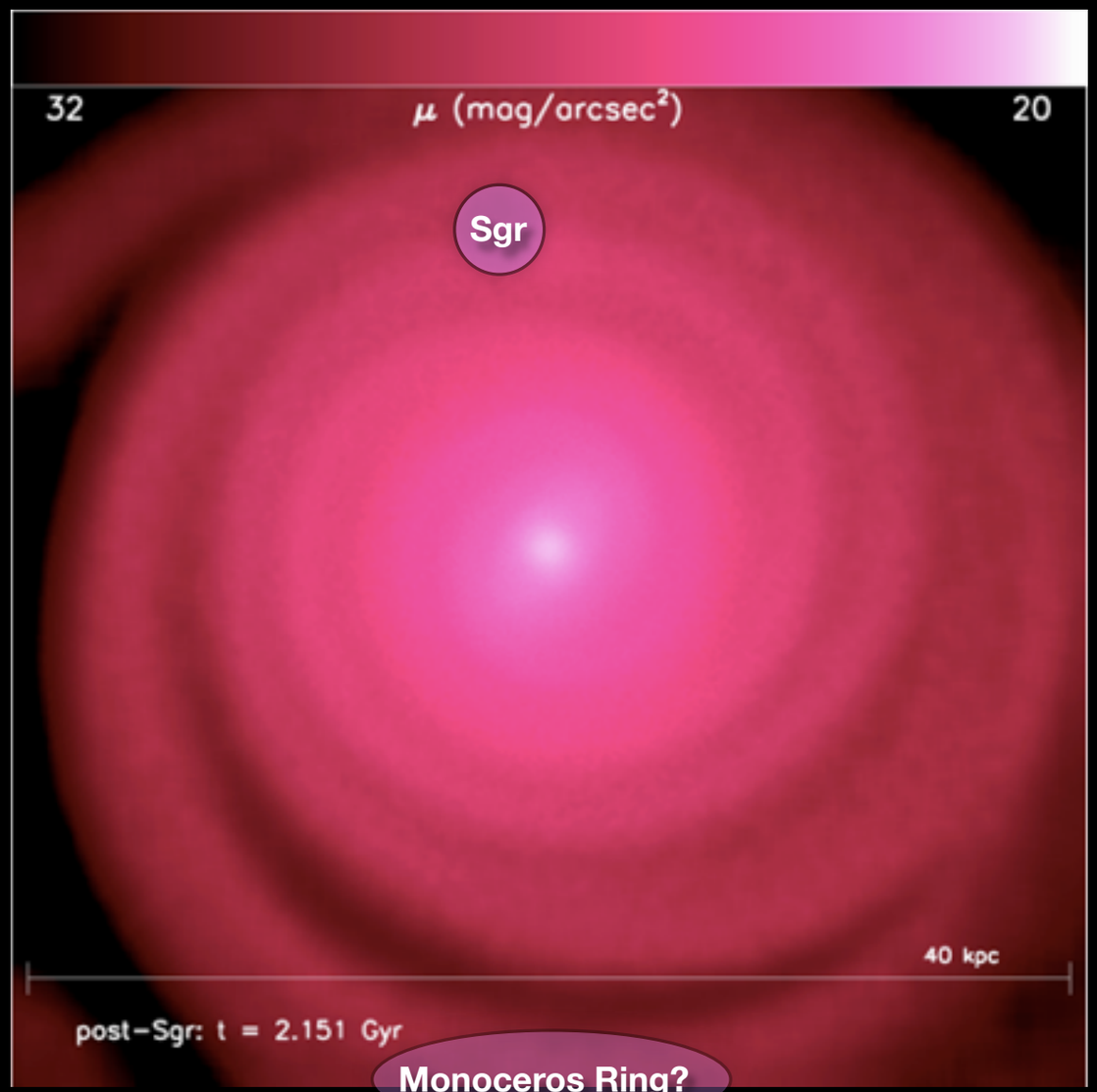


Wednesday, August 18, 2010

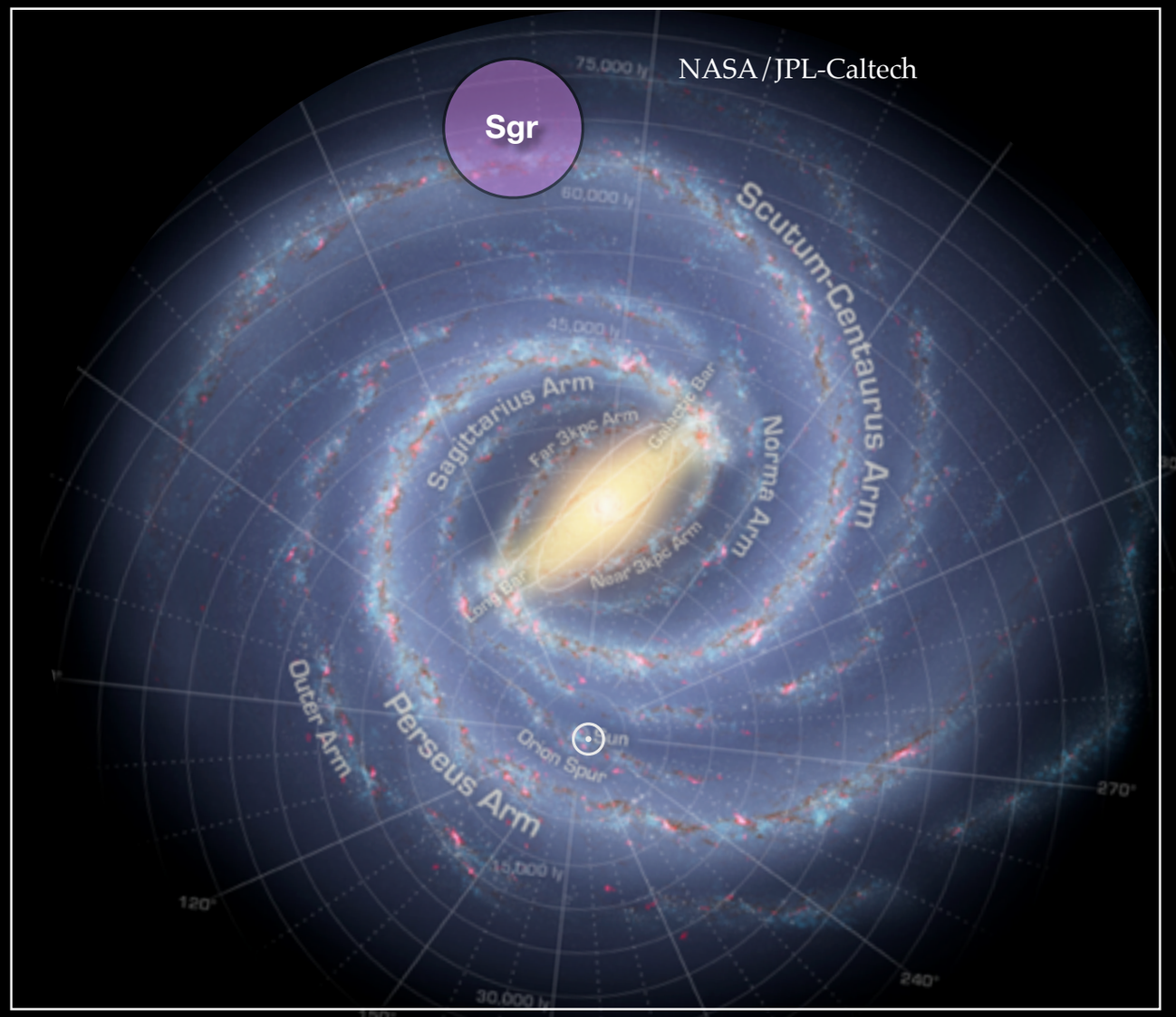
Heavy Sag M = 3.e10 M_{sun} Simulation



Scale height = 510 pc

Velocity Ellipsoid = (37, 27, 20) km/s

Milky Way Disk

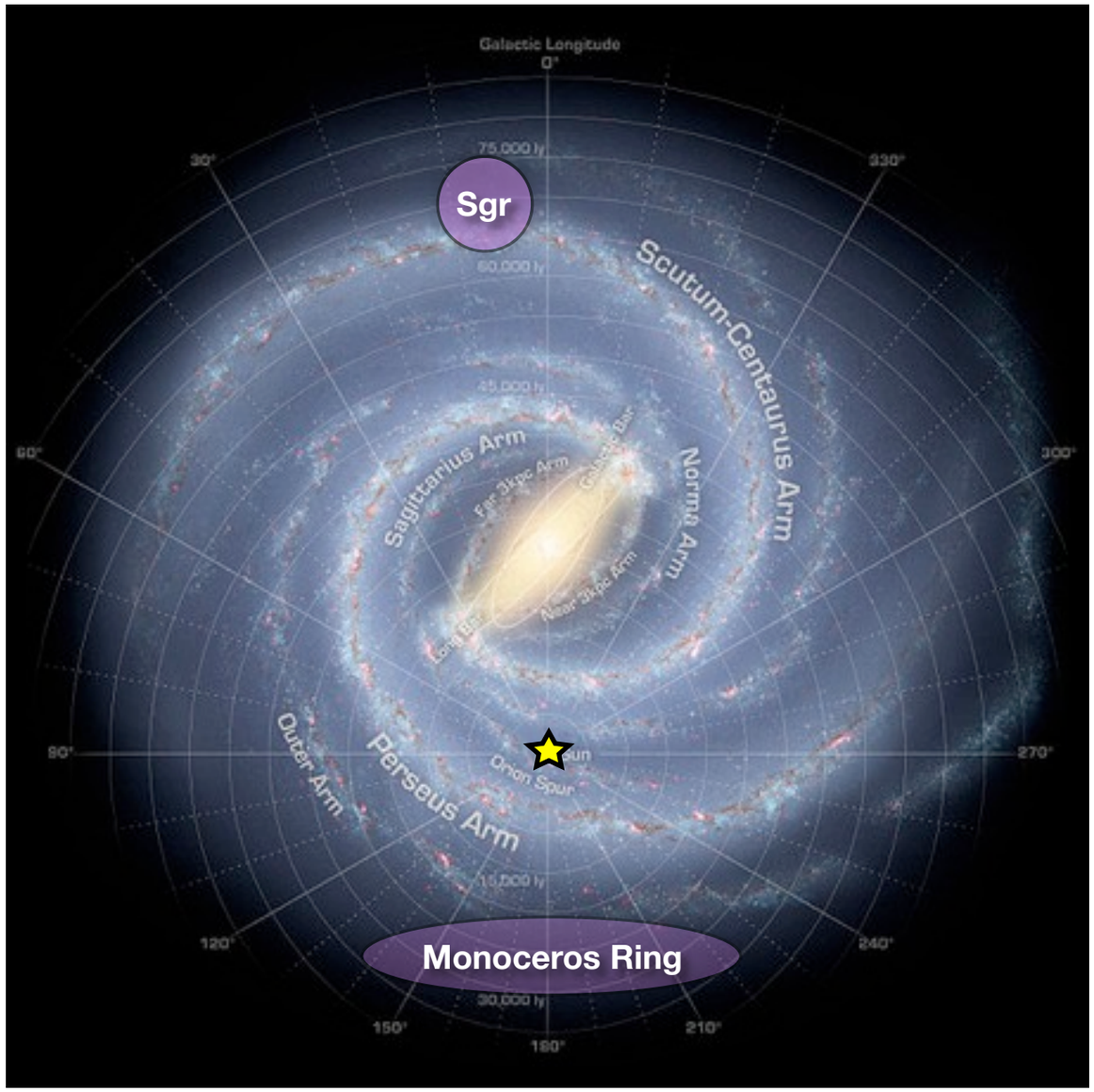


Scale height ~ 400 pc

Velocity Ellipsoid ~ (35, 32, 20) km/s

Near-Field Cosmology

What do all of these mergers do to the disk?



Near-Field Cosmology

Halo Streams & Substructure