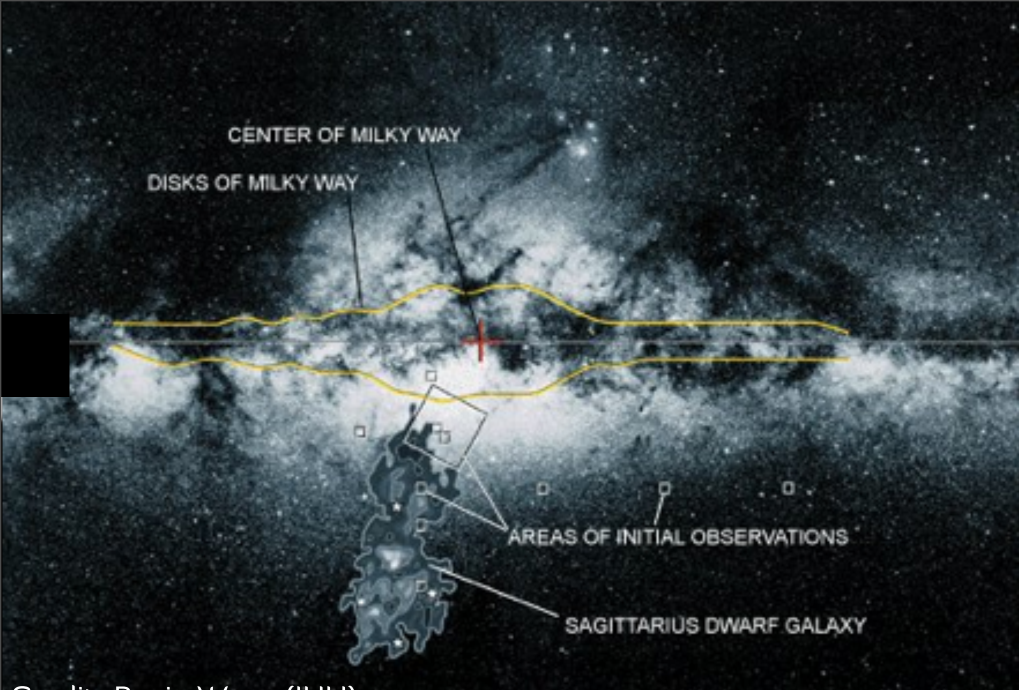
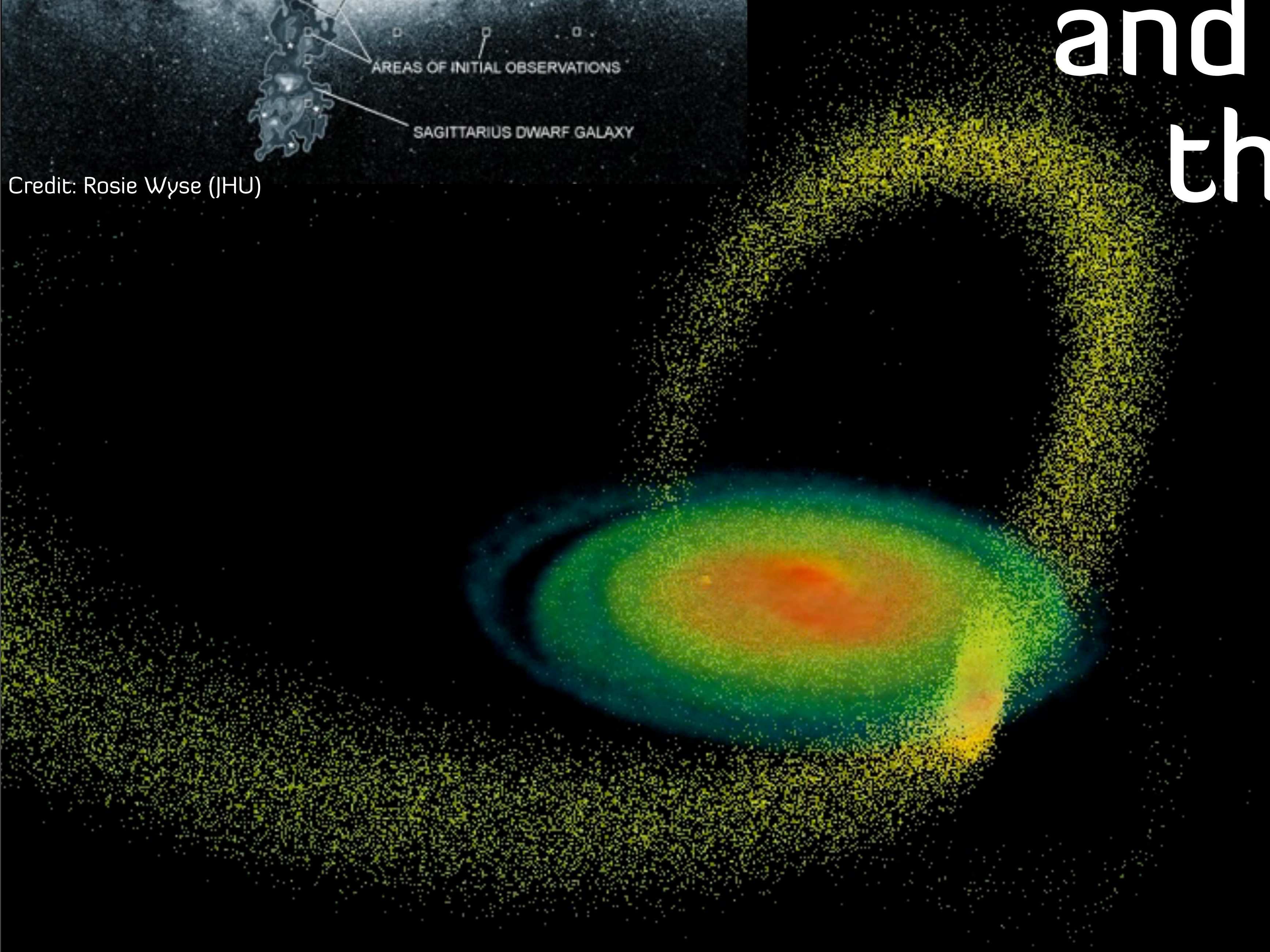


Credit: Rosie Wyse (JHU)

The Sagittarius Impact as an Architect of Spirality and Outer Rings in the Milky Way



(nature in press)

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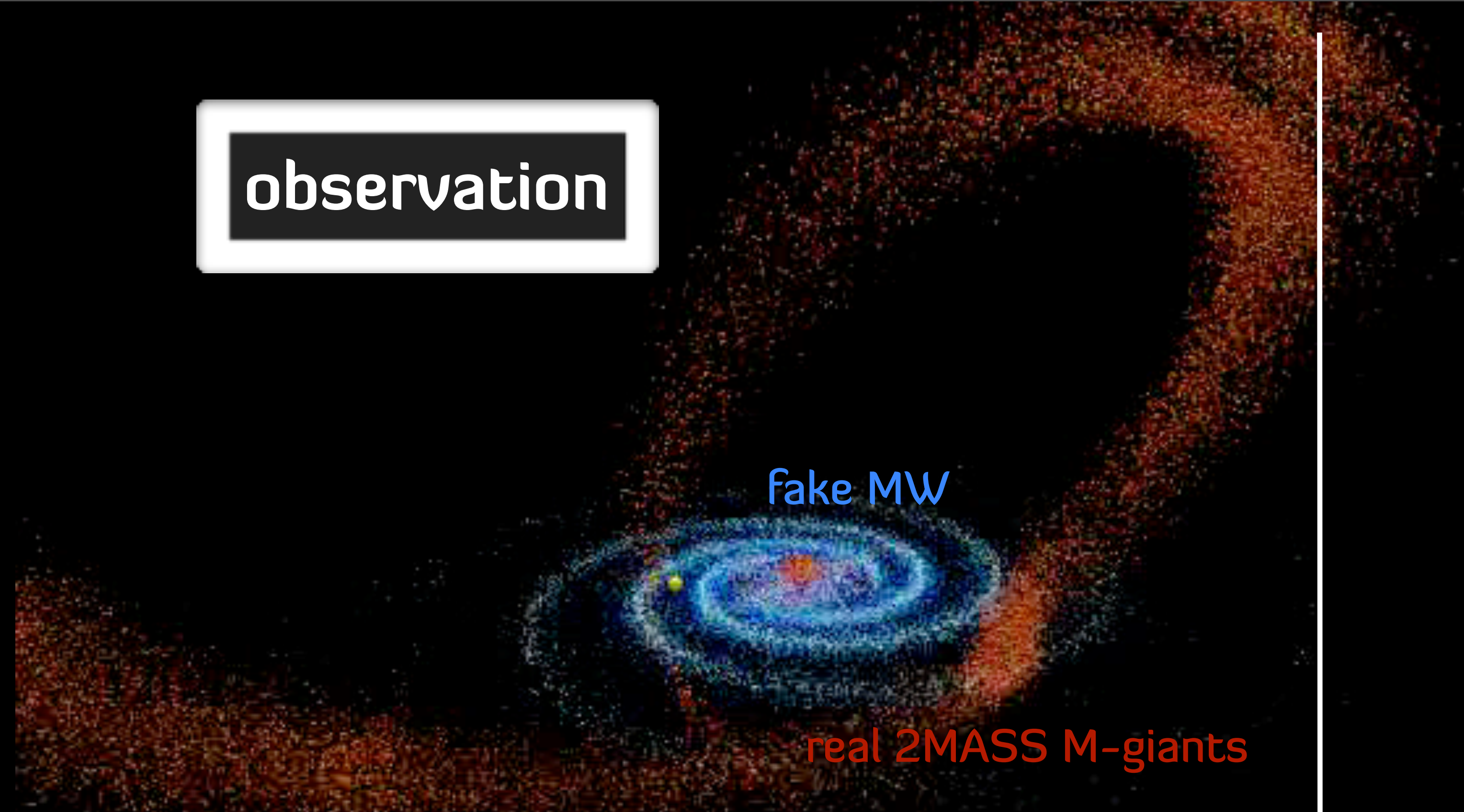


Credit: Steve Majewski, David Law, et al. 2005, 2010

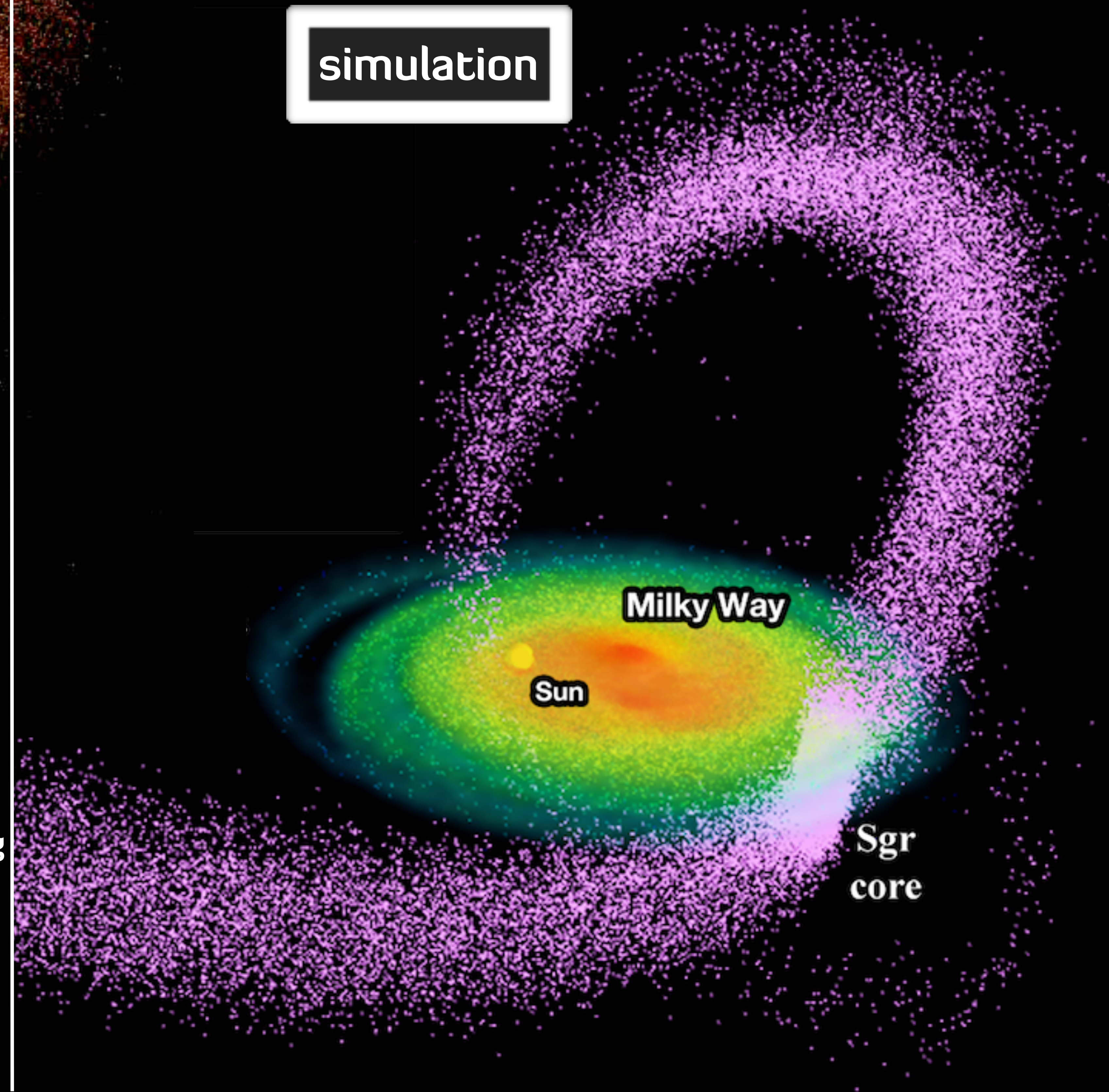
- stream modeling has always used static Milky Way potential, DM-less dwarf to test halo triaxiality/shape, etc.

- our collisionless experiment simulates a globally stable Milky Way at very high resolution:

particle mass ≃ 10^4 M_{sun}, parsec-scale force softening

- two bracketing cases for a cosmologically-realistic infalling Sagittarius dwarf galaxy with dark matter:

Light Sgr ≃ $10^{10.5}$ M_{sun}, Heavy Sgr ≃ 10^{11} M_{sun}



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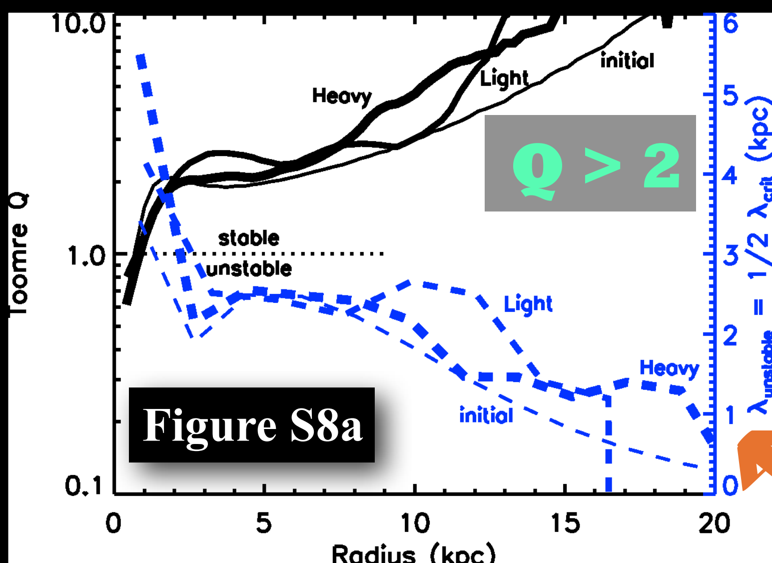
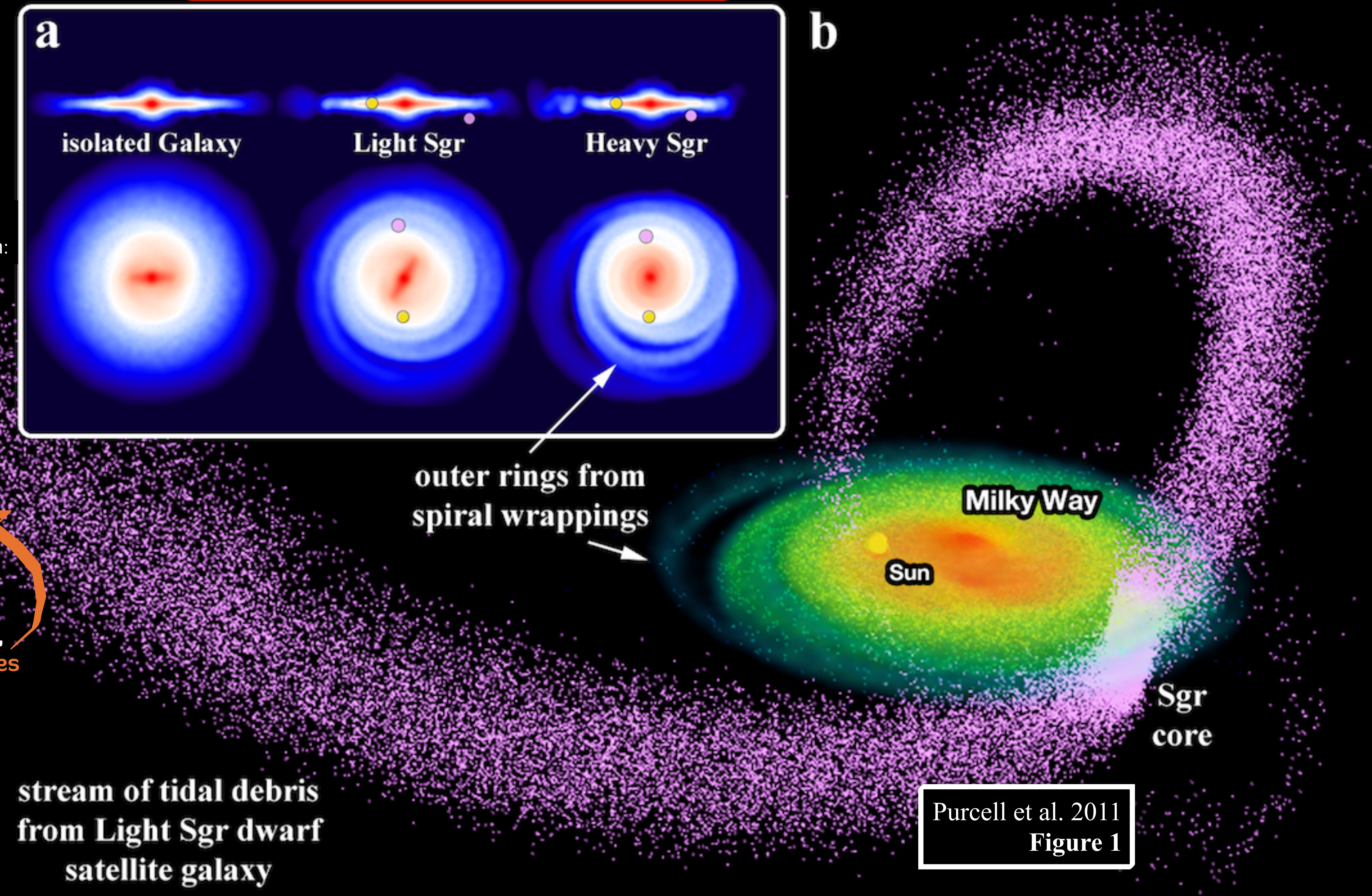
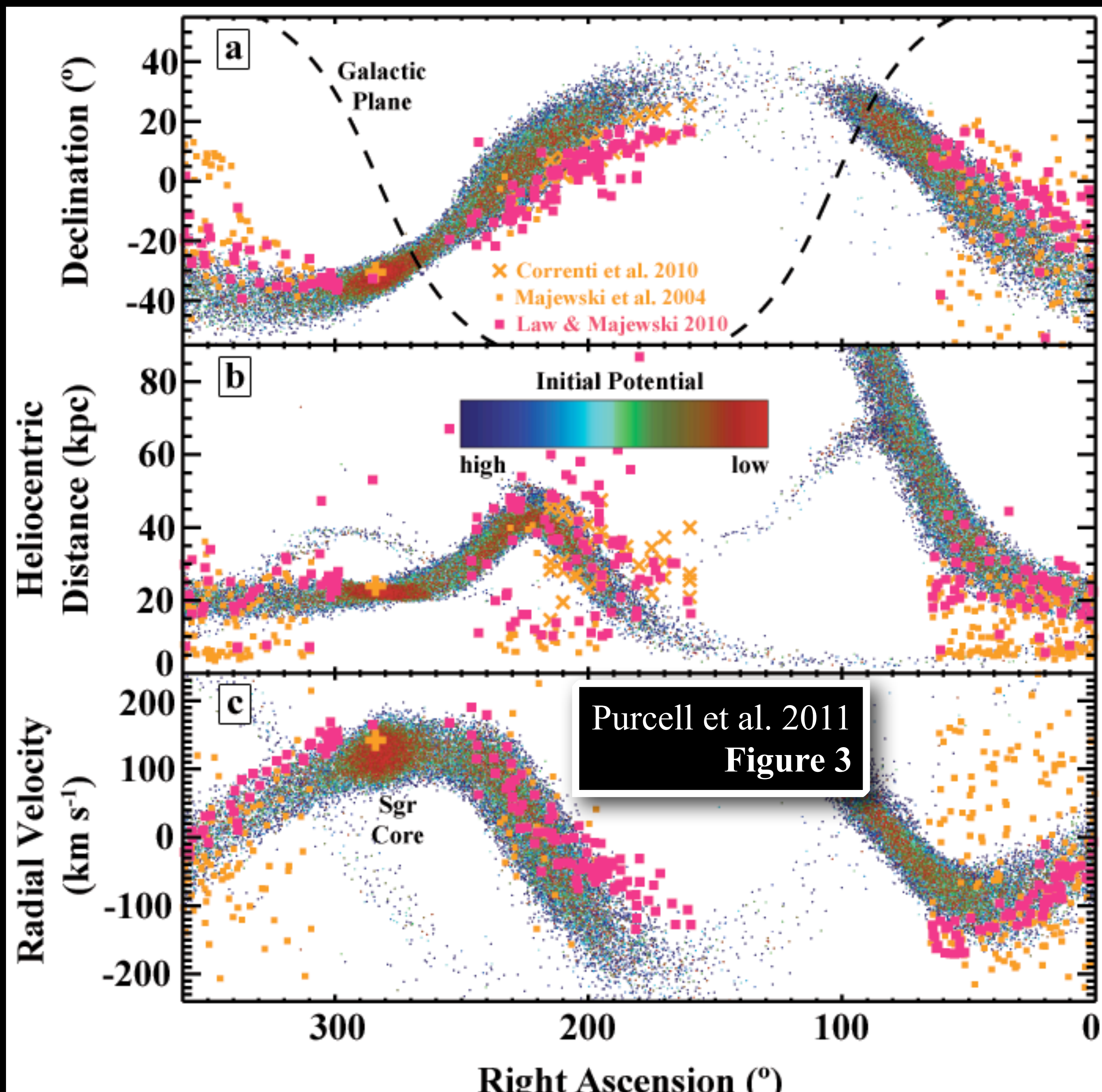
✦ our collisionless experiment simulates a globally stable Milky Way at very high resolution:

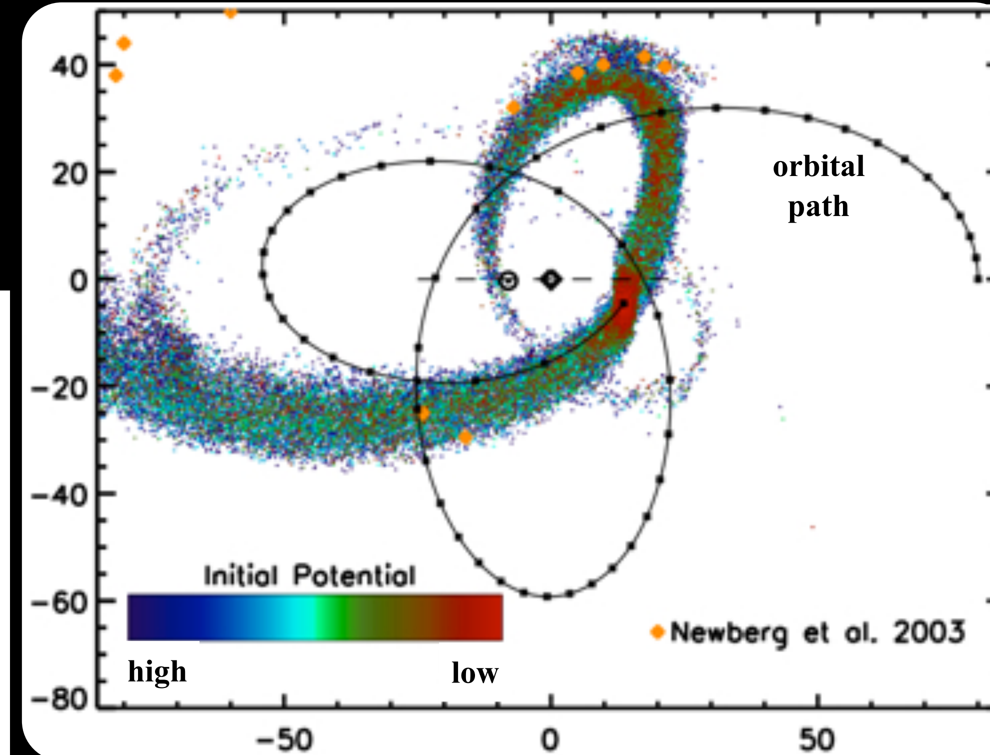


stable to long-wavelength perturbations, only susceptible to short-wavelength modes on small scales (at radius of Sgr impact)



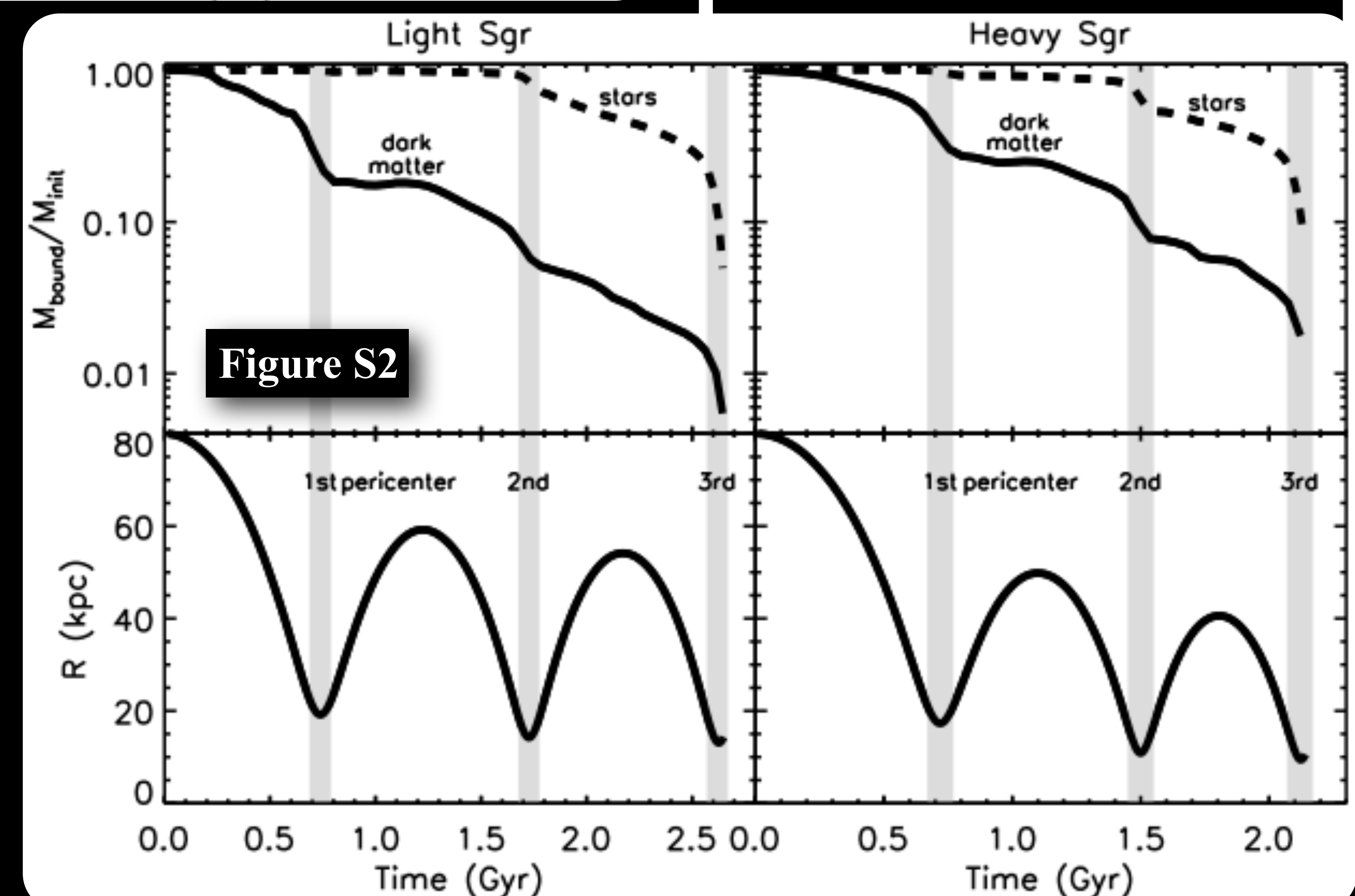
simulated stream/orbit in good agreement with a variety of observational data sets



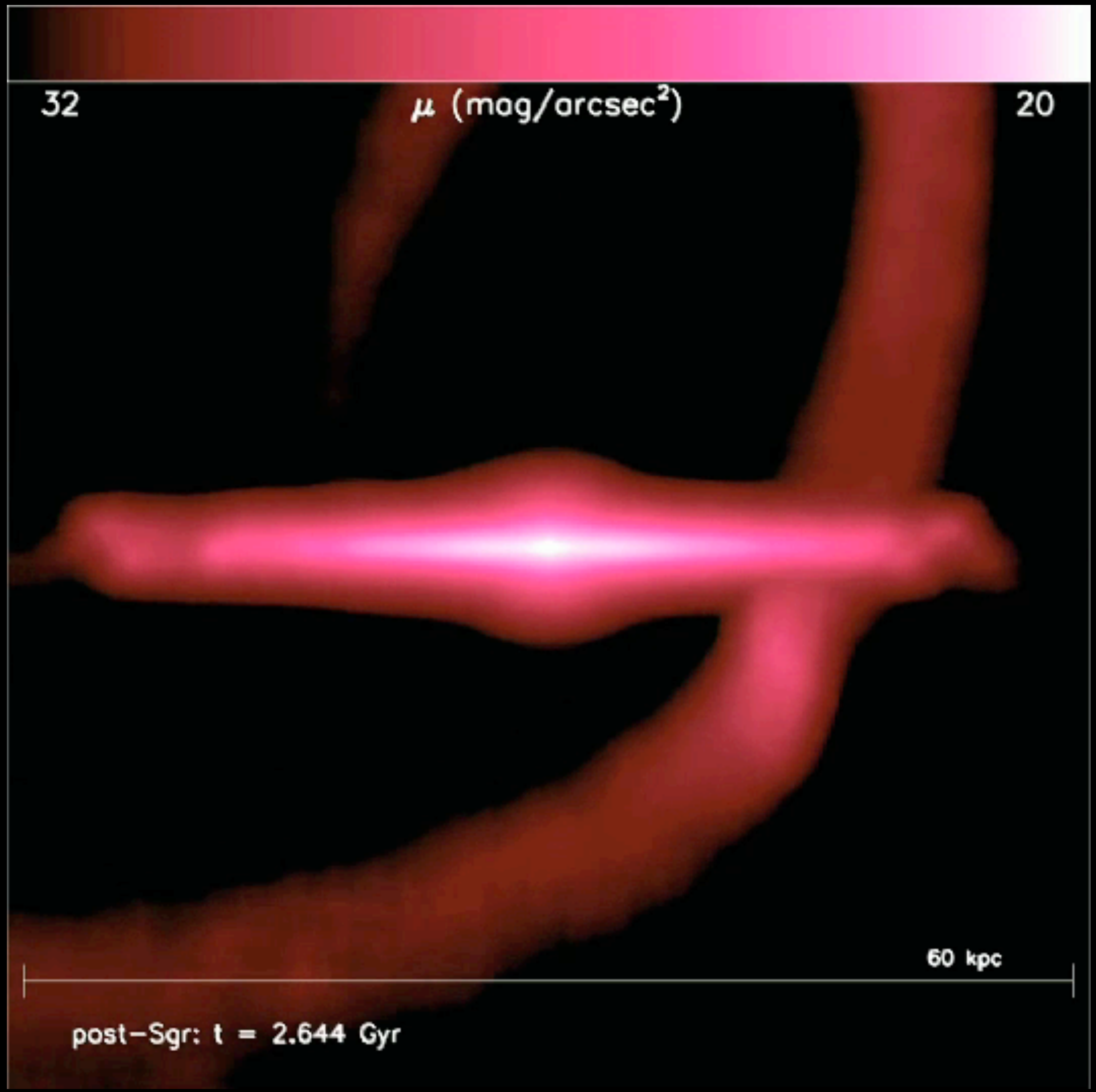


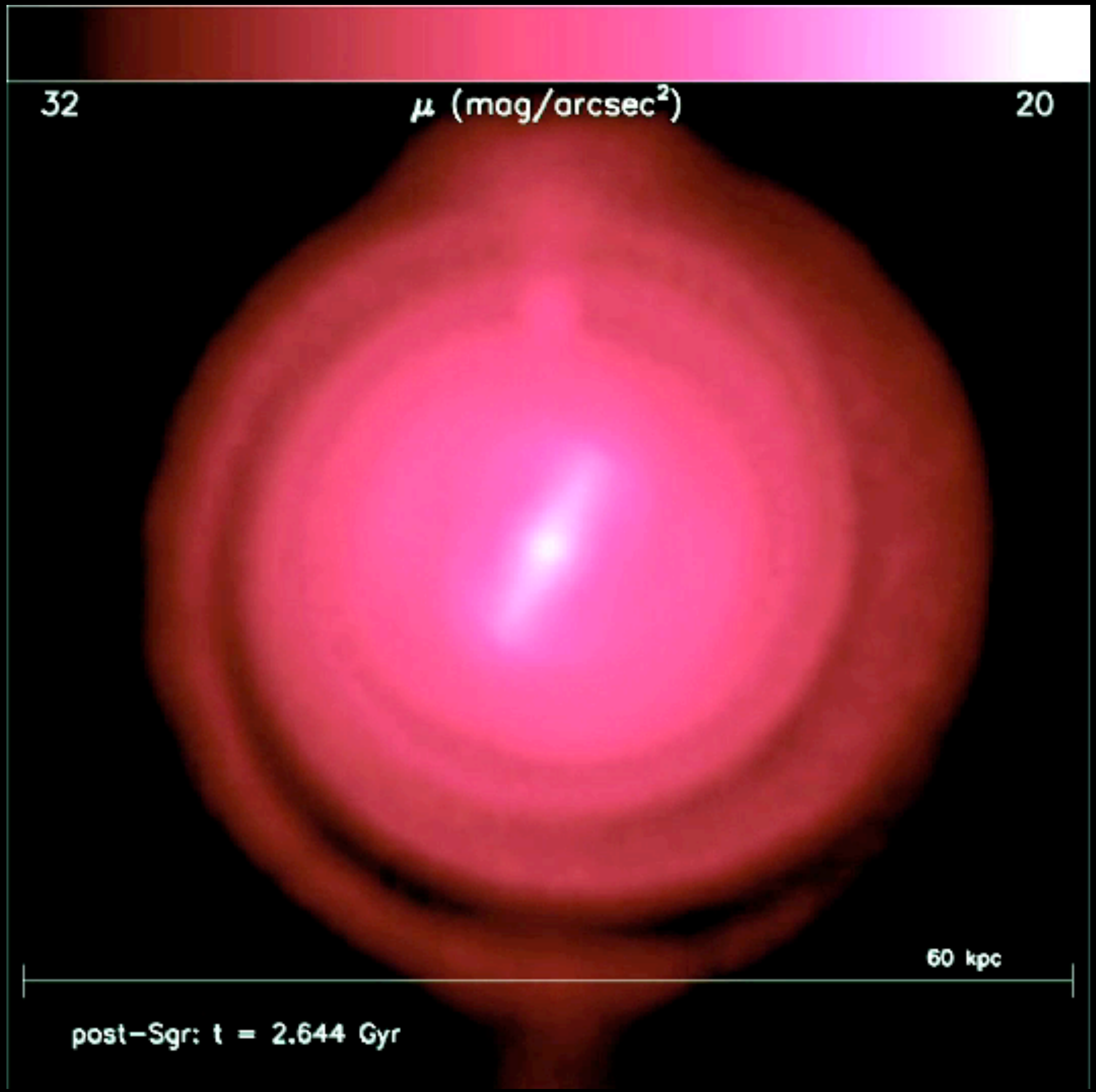
tightly-bound stars are stripped preferentially later, but mass loss does occur at all radii throughout

Sgr dwarf has lost more than 99% of dark mass, and ~80-90% of stellar mass by the present-day

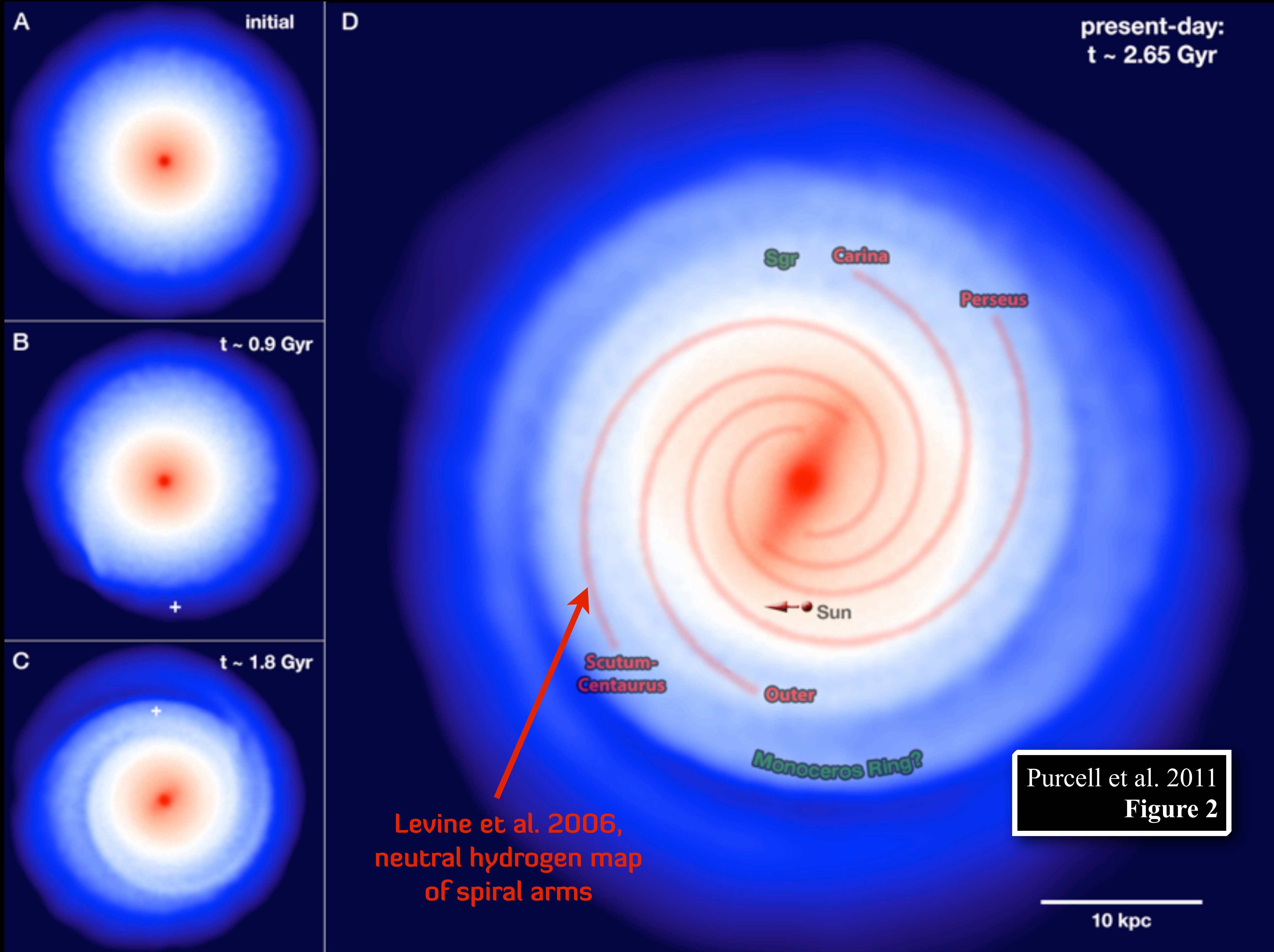


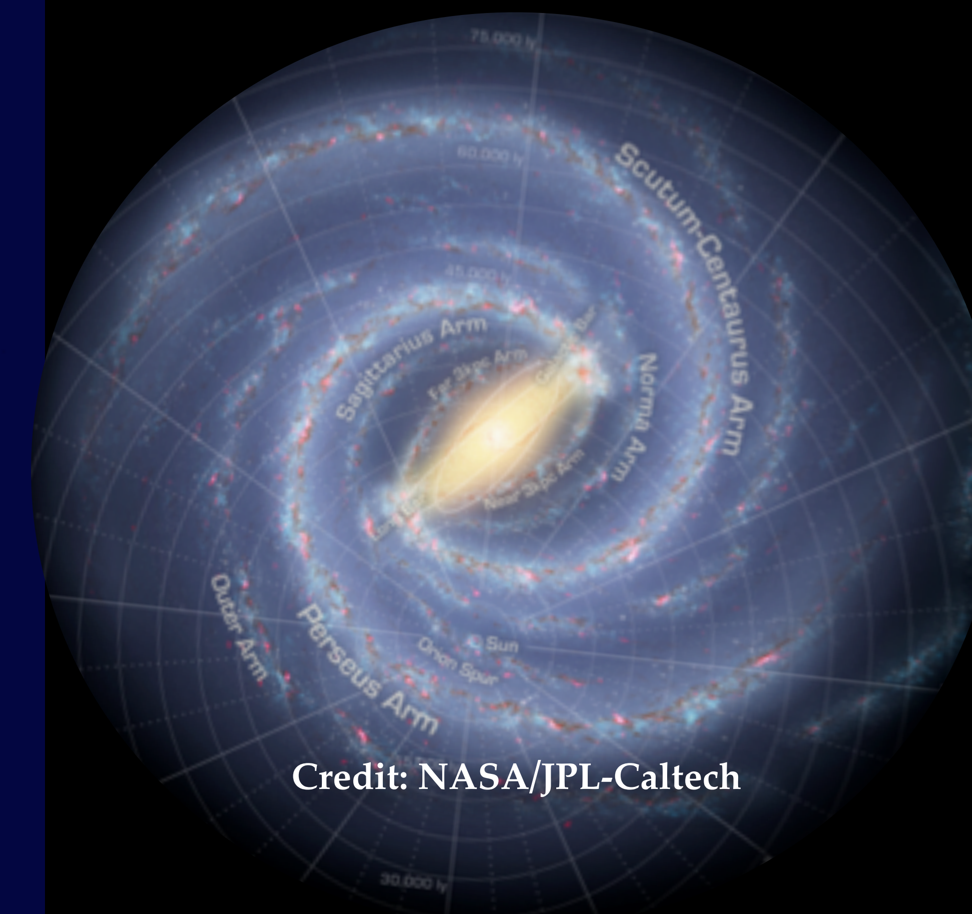
impact on the Galactic disk

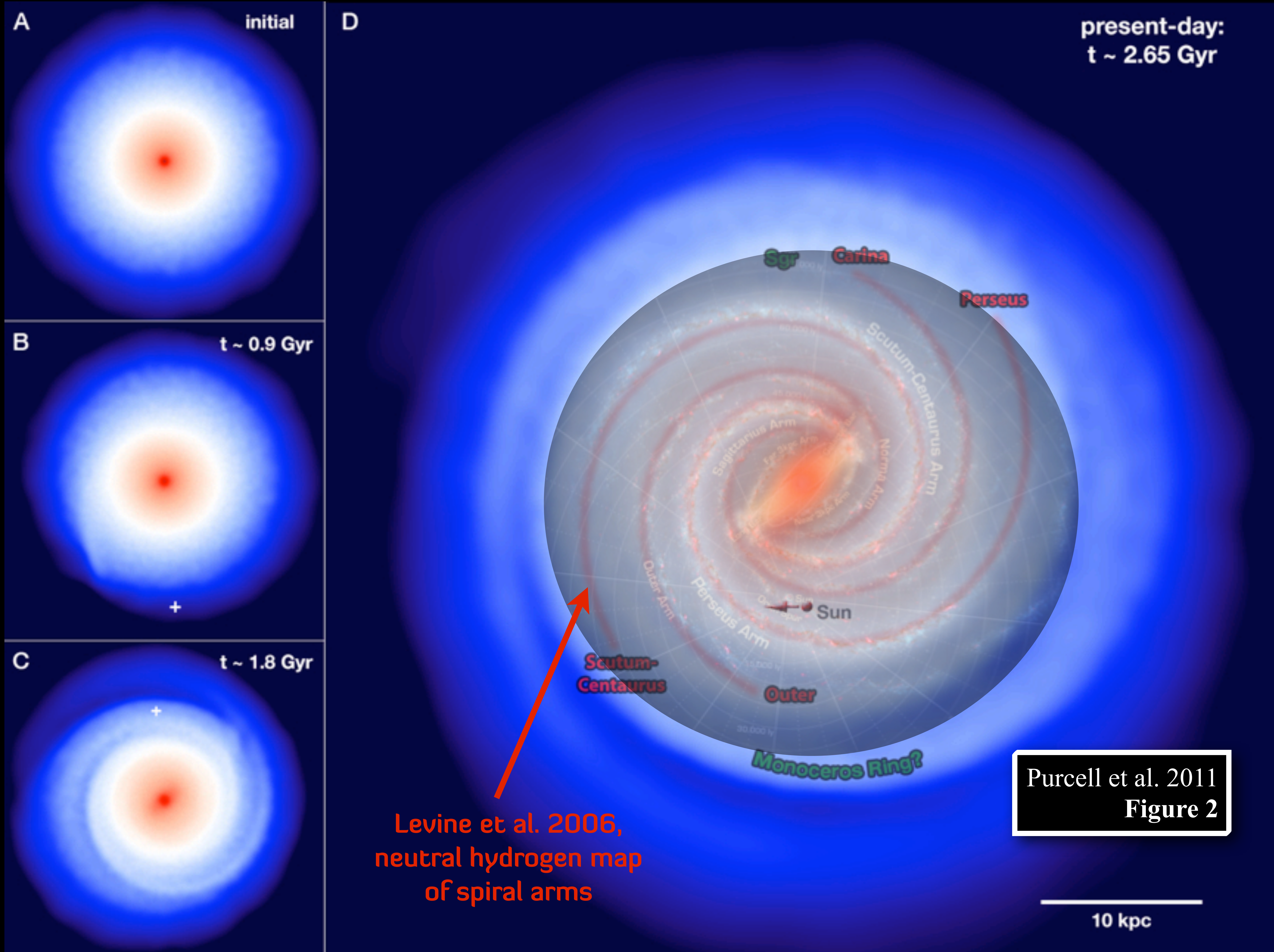




swing-amplified spirality

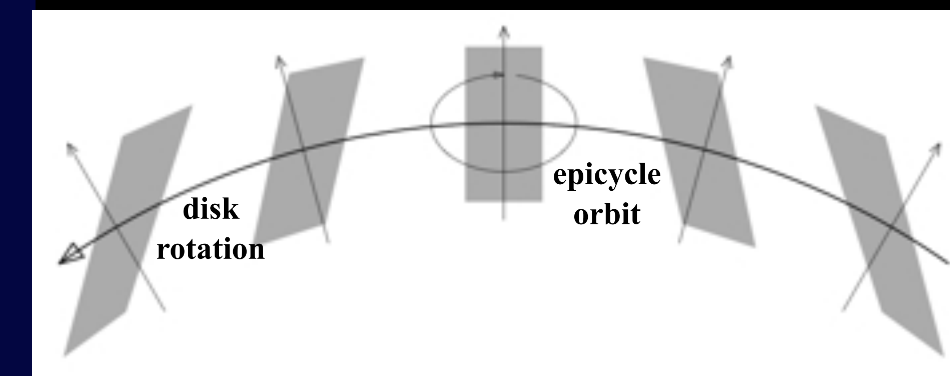






swing-amplified spirality

✦ gravitational perturbations augment unstable modes latent in the stellar disk



✦ excess non-circularity combined with differential rotation shear

↓

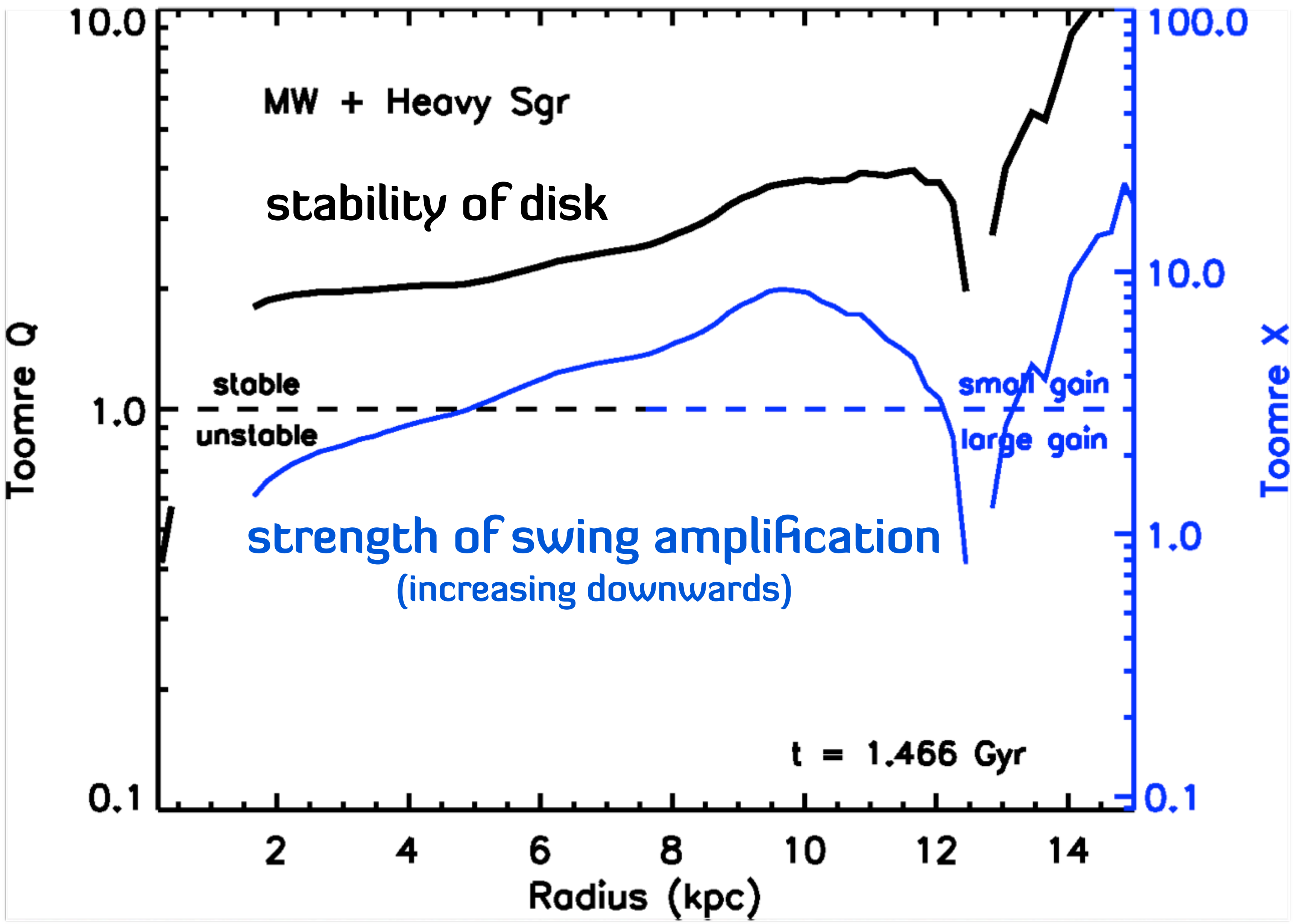
intermediate-scale spiral structure!

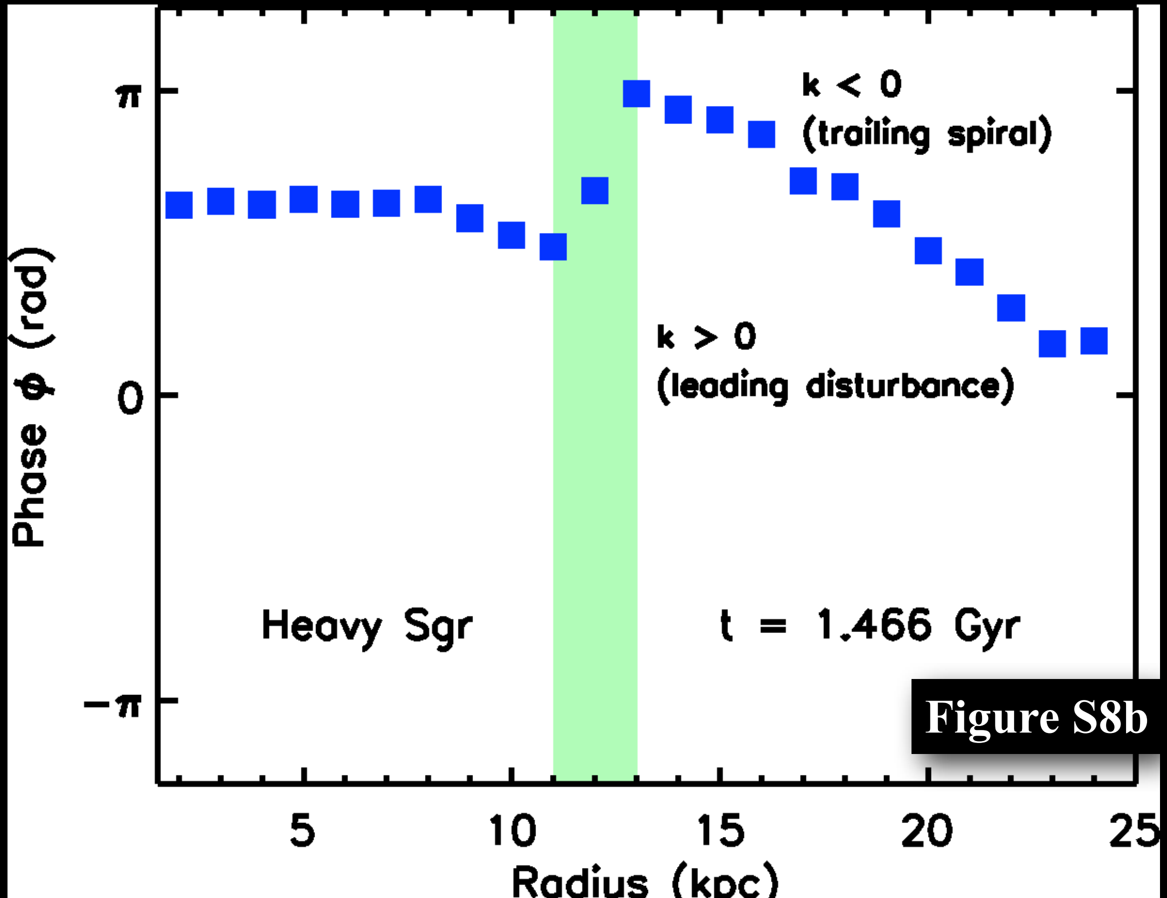
1st pericenter at R ~ 17 kpc

2nd pericenter at R ~ 12 kpc

swing-amplified spirality

stability parameters of disk

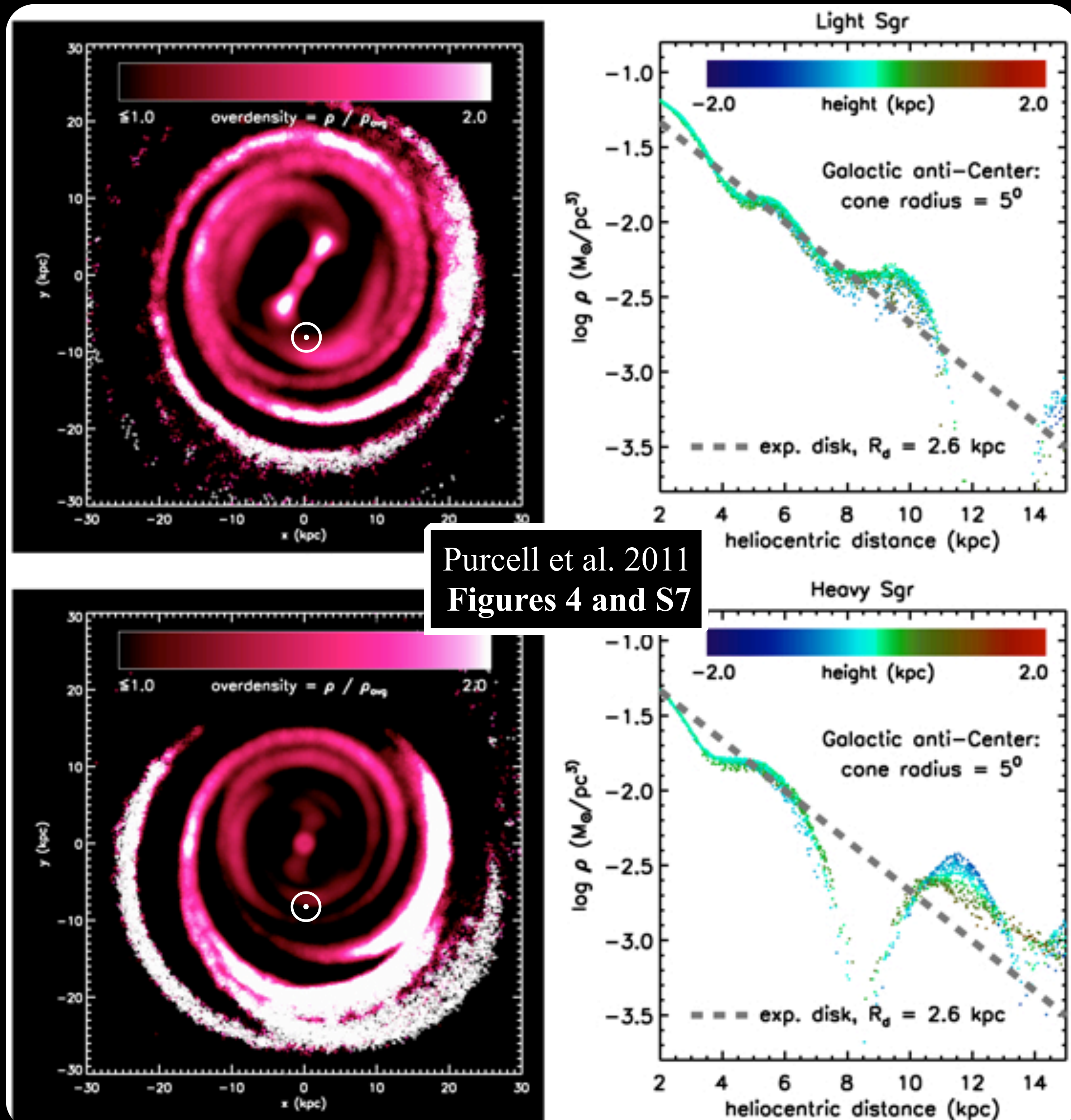


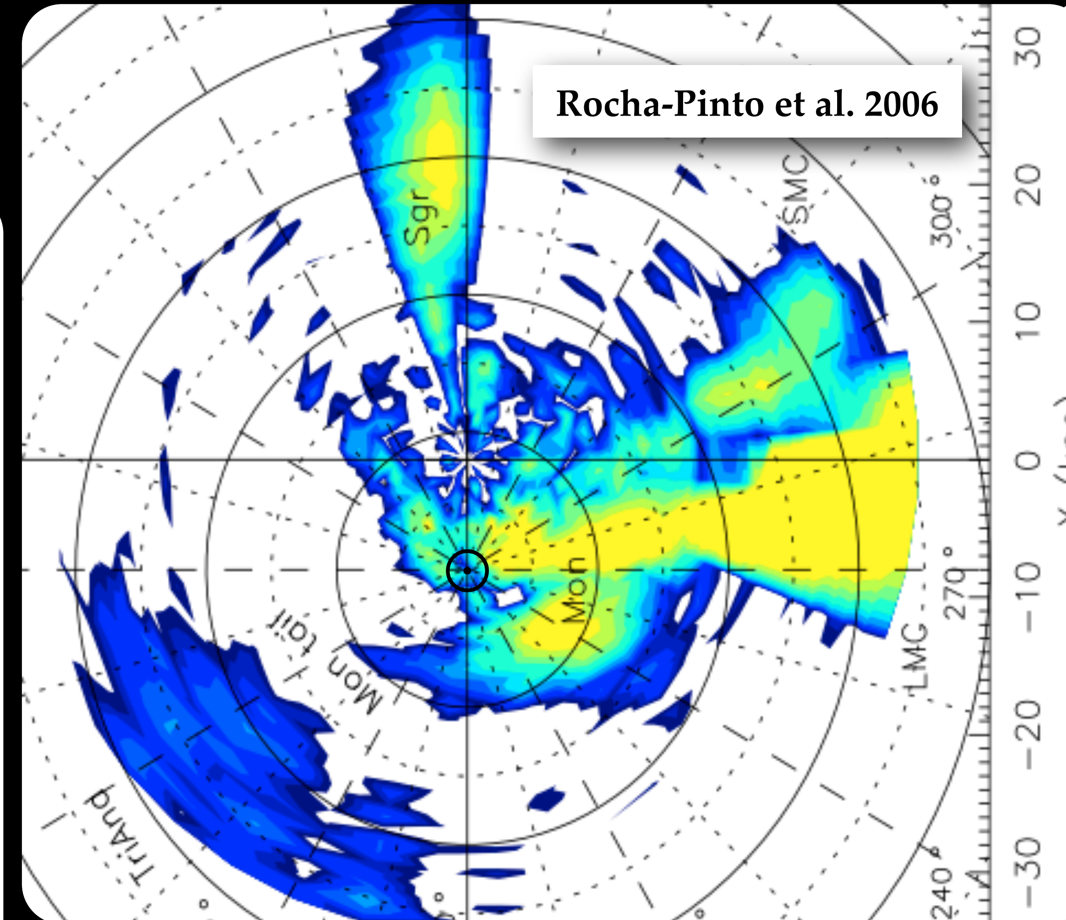


radial wavenumber k = dφ / dR

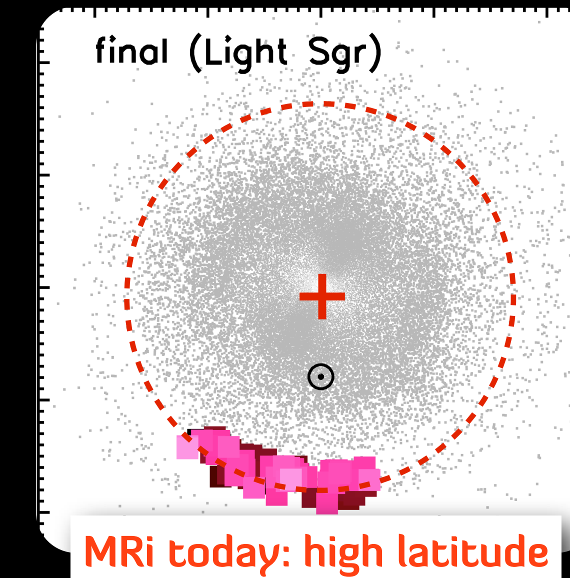
strong swing mechanics are greatly amplifying spiral wave-modes!

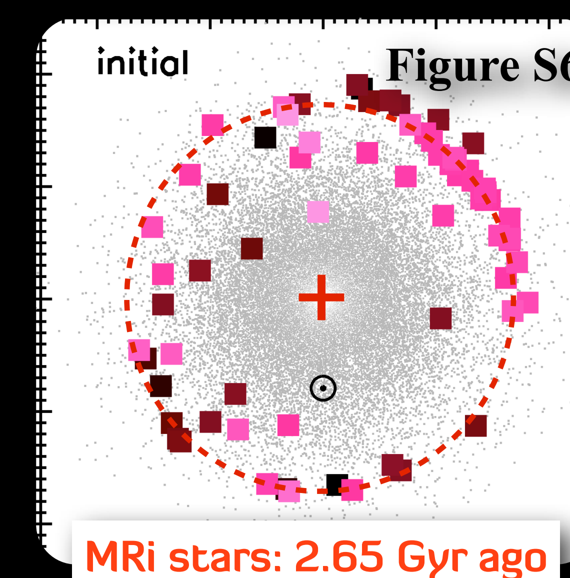
ring-like features in the outer disk





metallicity tracers may be a **red herring**: **radial mixing** can obscure the relation of **abundance** to **position** (modulo selection effects, large azimuthal variance)

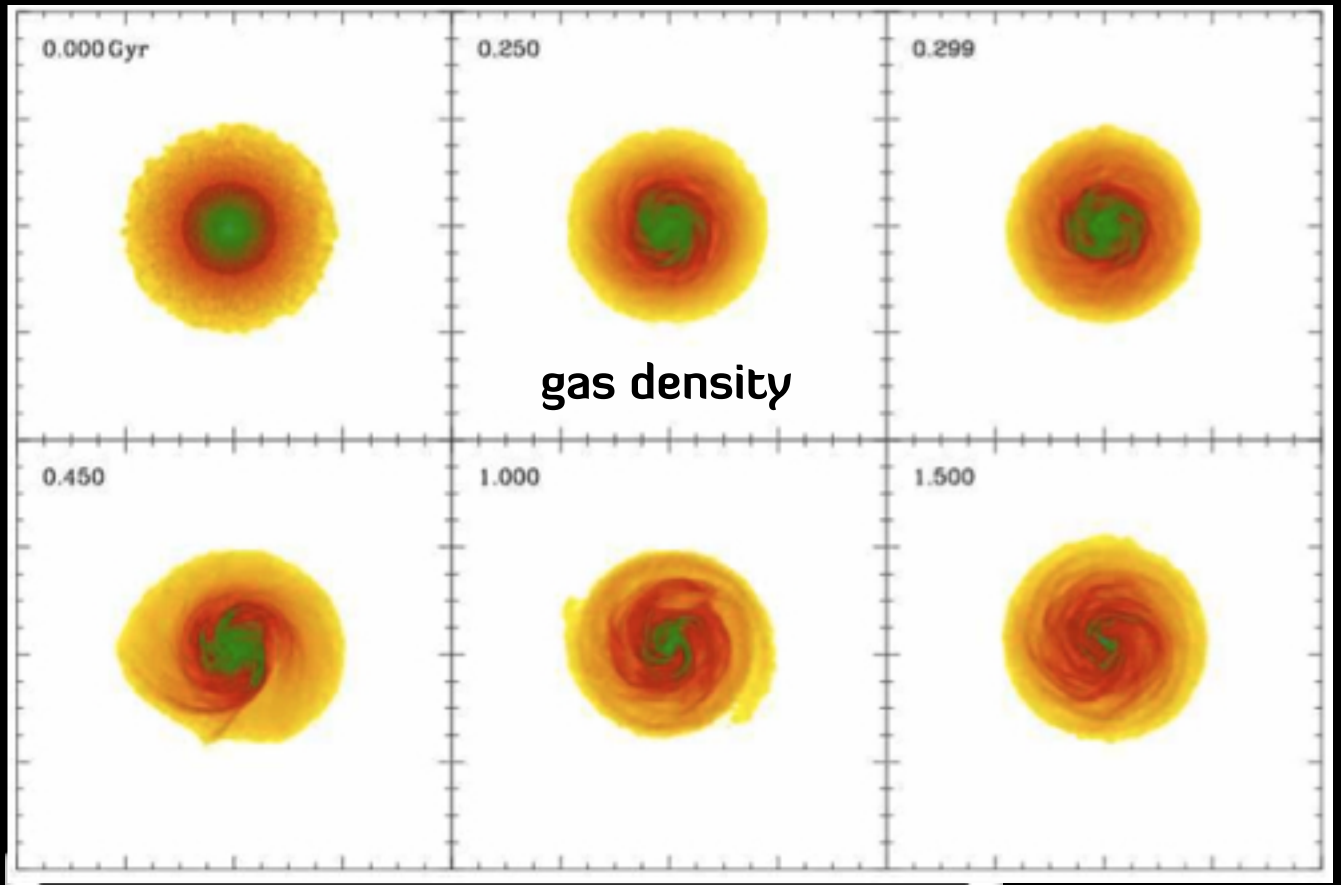




"multiple tributaries"

- **overdense** spiral-arm wrappings exist above and below the plane
- **Monoceros** and **Tri-And** stream features are **nearby wrappings of known spiral arms** (Scutum-Centaurus and Perseus?)
- future observations **at Galactic longitudes 30° < l < 180°** will fully map these arms and fill out the picture a little more...

future work: hydrodynamical treatment



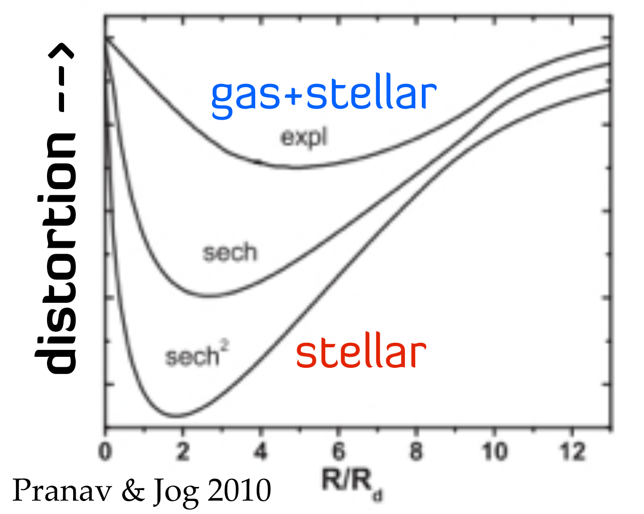
1:100 perturber with pericenter ~15 kpc (Chakrabarti & Blitz 2009)

probable effects:

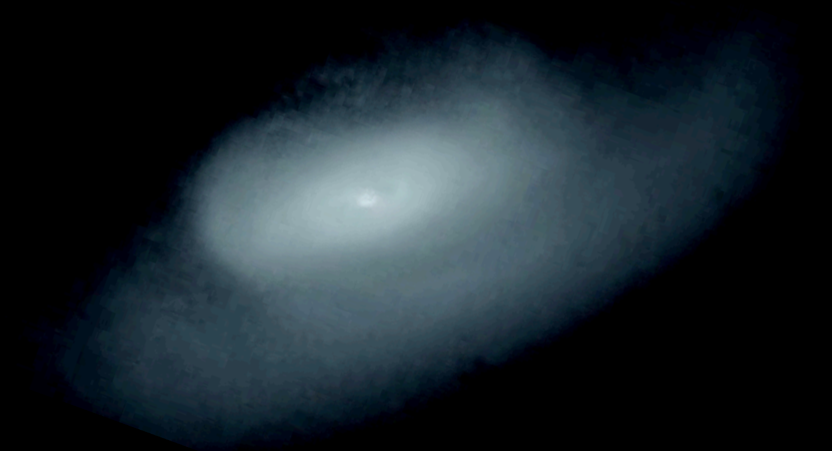
✦ gas disk reinforces swing amplification since the stellar disk is

to disk galaxies what a soundboard is to a piano. It organizes and augments the chaotic aspects of spiral galaxies . . . whenever the stellar disk is presented with a relatively flat spectrum of gravitational noise from the gas clouds, it picks out and augments the spatial frequencies which it prefers. And . . . it is this bias which leads to pictures that human astronomers happen to prefer as well" (Toomre & Kalnajs 1991).

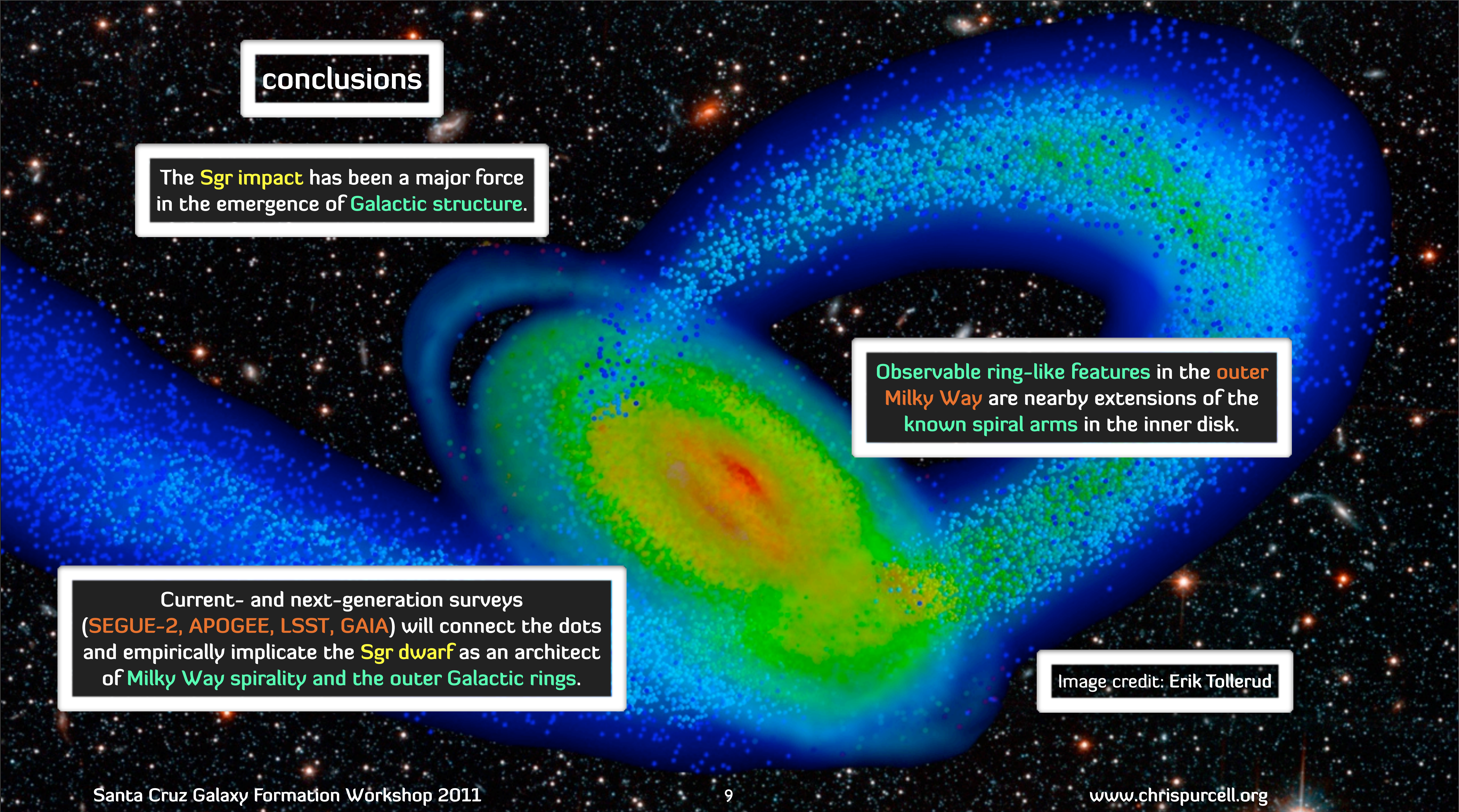
✦ steeper (and more realistic) vertical density profiles very near mid-plane = self-gravity weaker and disk response more severe



✦ **fresh star formation** replenishes **circularity**, extending transient lifetimes



more flaring/warping in disk outskirts, enhanced/extended spiral-arm production are the likely outcomes of Sgr+hydro sims



conclusions

The Sgr impact has been a major force in the emergence of Galactic structure.

Observable ring-like features in the outer Milky Way are nearby extensions of the known spiral arms in the inner disk.

Current- and next-generation surveys (SEGUE-2, APOGEE, LSST, GAIA) will connect the dots and empirically implicate the Sgr dwarf as an architect of Milky Way spirality and the outer Galactic rings.

Image credit: Erik Tollerud