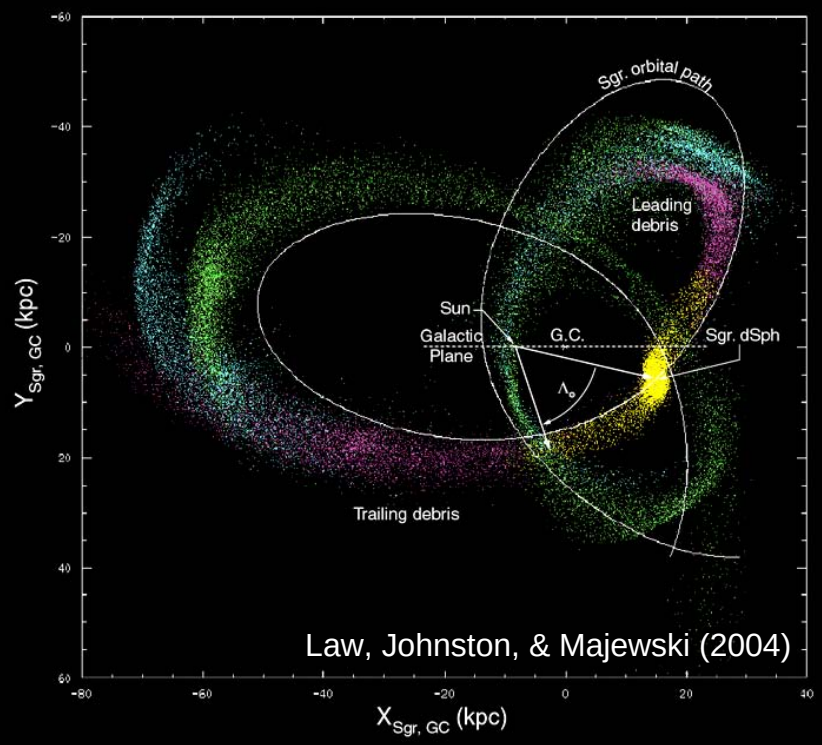
Does dark matter substructure destroy tidal streams?

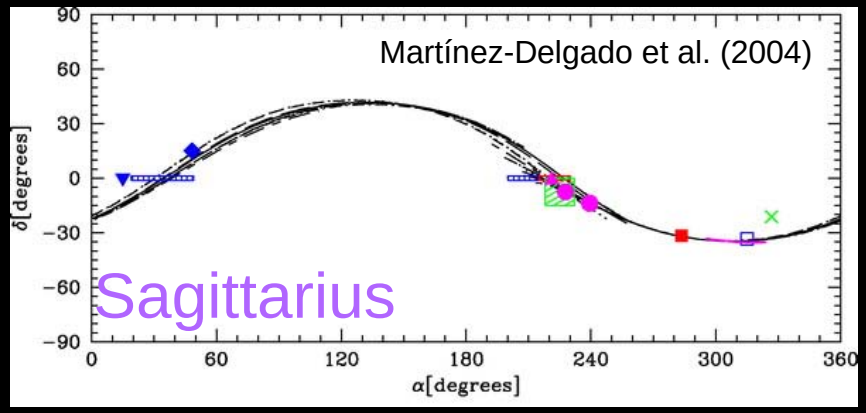
in collaboration with M. Valluri

Image credit: Martinez-Delgado & Perez

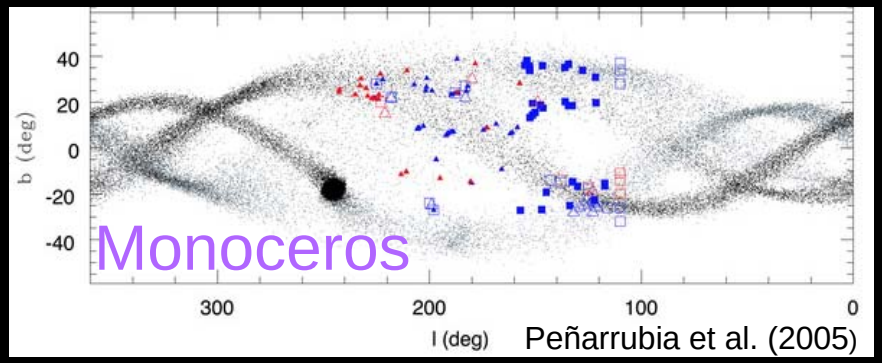
Observed Tidal Streams



Law, Johnston, & Majewski (2004)



Martínez-Delgado et al. (2004)

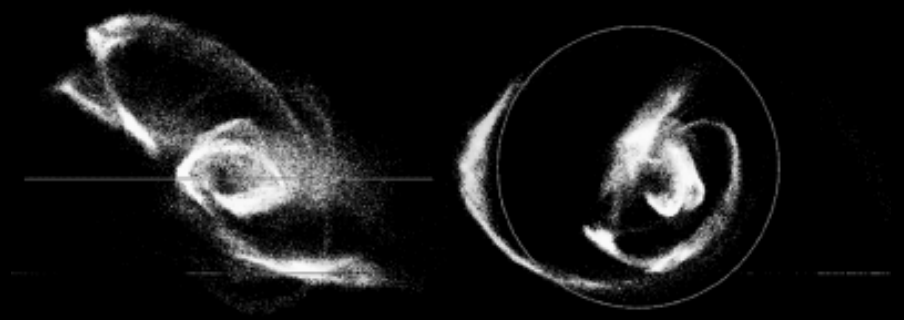


Peñarrubia et al. (2005)

Dark matter substructure

ΛCDM predicts abundance of satellites

Image credit: A. Kravtsov

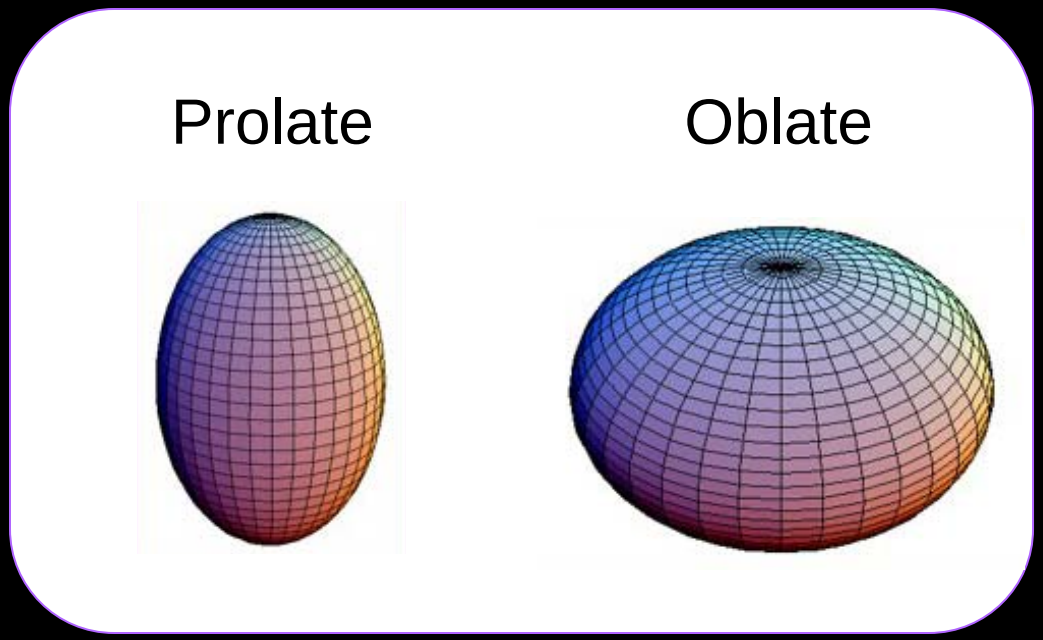


Mayer et al. (2002)

Would substructure destroy coherent streams?

Previous work: e.g., Johnston, Spergel, & Haydn (2002), Mayer et al. (2002), Ibata et al. (2002)

Is halo shape important?



- In a spherical potential, orbits are confined to a plane
- In a non-spherical potential, orbits can precess out of the plane
- Orbits at large radii see halo shape

Tidal streams could be excellent probes of the halo shape

e.g. Johnston et al. (2005), Helmi (2004), Ibata et al. (2001), Martinez-Delgado et al. (2004), Law et al. (2005)

But precession could destroy coherence

e.g. Mayer et al. (2002), Ibata et al. (2002)

What most determines the degree of disruption?

- Orbital path / halo shape
  - allowed orbital paths (depends on shape of potential)
  - phase space properties of orbit (resonant v. chaotic)
  - precession
- Substructure
  - perturbs smooth potential, may cause heating, destroy coherence

Halo shape vs. Substructure

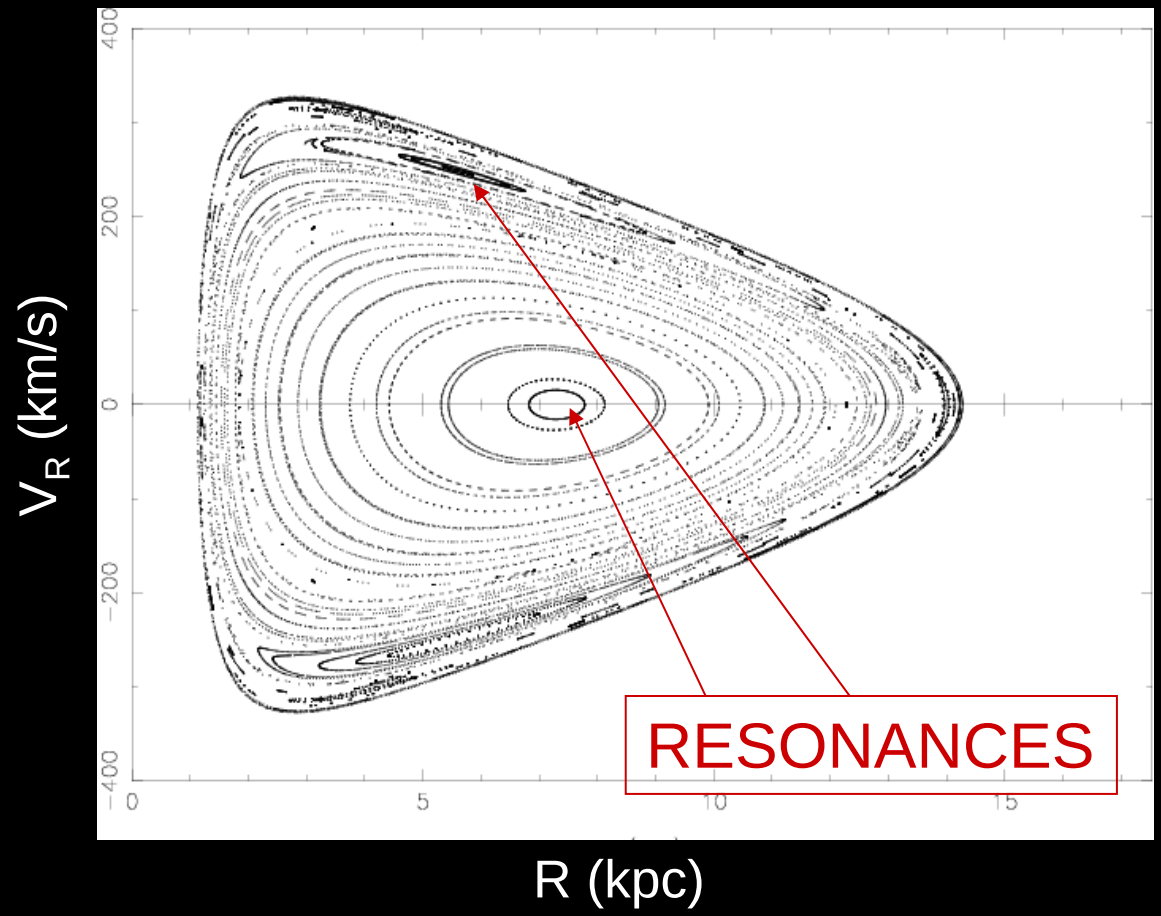
What can we learn from observations of streams?

- What types of orbits lead to coherent streams?
- Can we expect streams to survive in any scenario with substructure?

- Libraries of orbits are generated for different halo shapes to more fully explore possible scenarios
- Individual orbits are selected based on their phase-space properties
- Tidal disruption is simulated with and without dark matter substructure

Phase Space Properties

a “surface of section plot” can be used to map out the full range of possible orbits of satellites in the dark matter halo



Simulations

N-body tree code GADGET-2 (V. Springel)

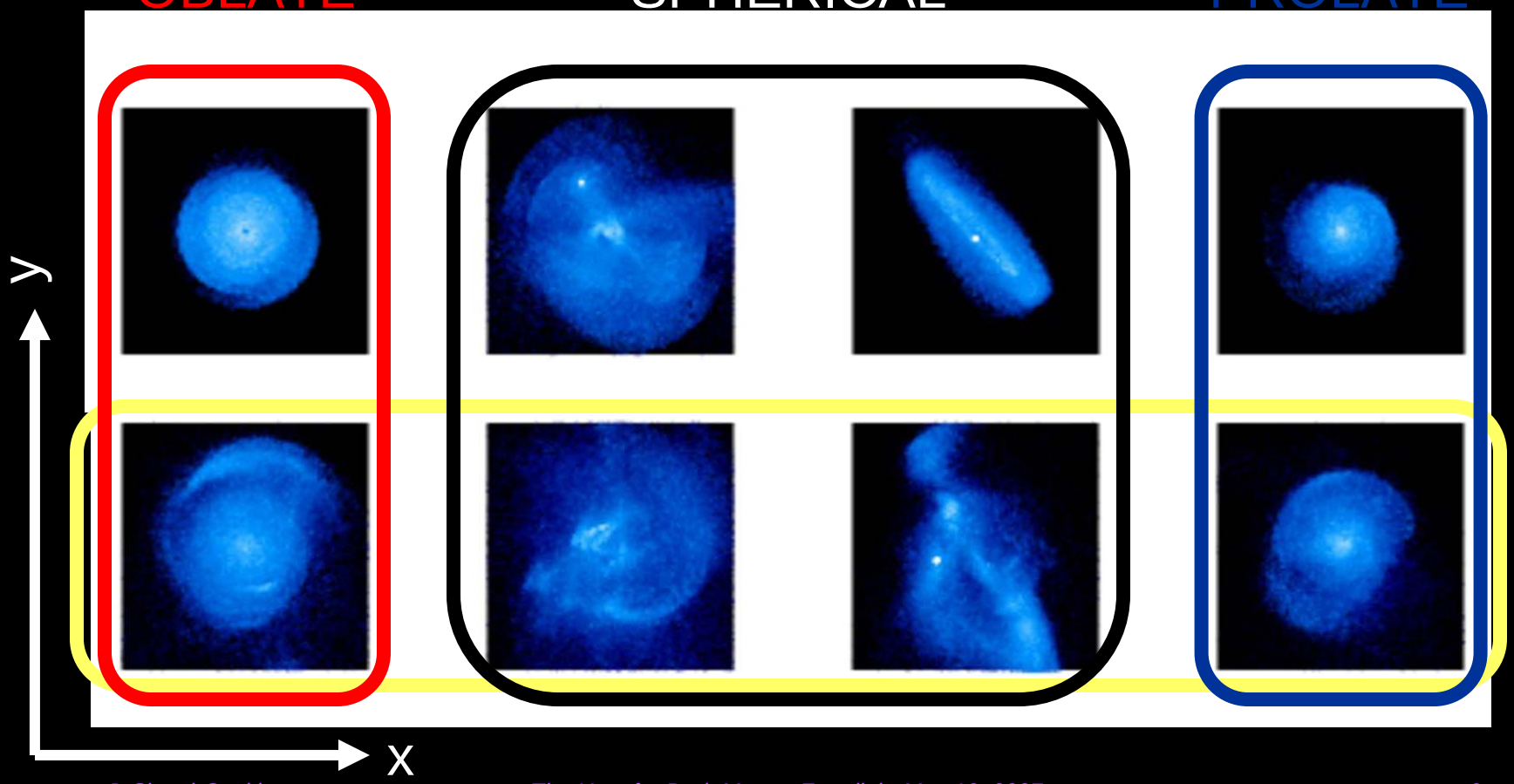
- Static Milky Way potential:
  - Halo, disk, and bulge
  - Total mass ~ 10^{12} M_{solar}
- Satellite:
  - NFW profile
  - Initially 500k particles, 10^{10} M_{solar}
  - Tidally stripped to produce 'remnant' in quasi-equilibrium with host potential, ~ 150k particles
  - ~ 5 Gyr integration
- Dark matter substructure:
  - Softened point masses from cosmological N-body simulation

Tidal Debris

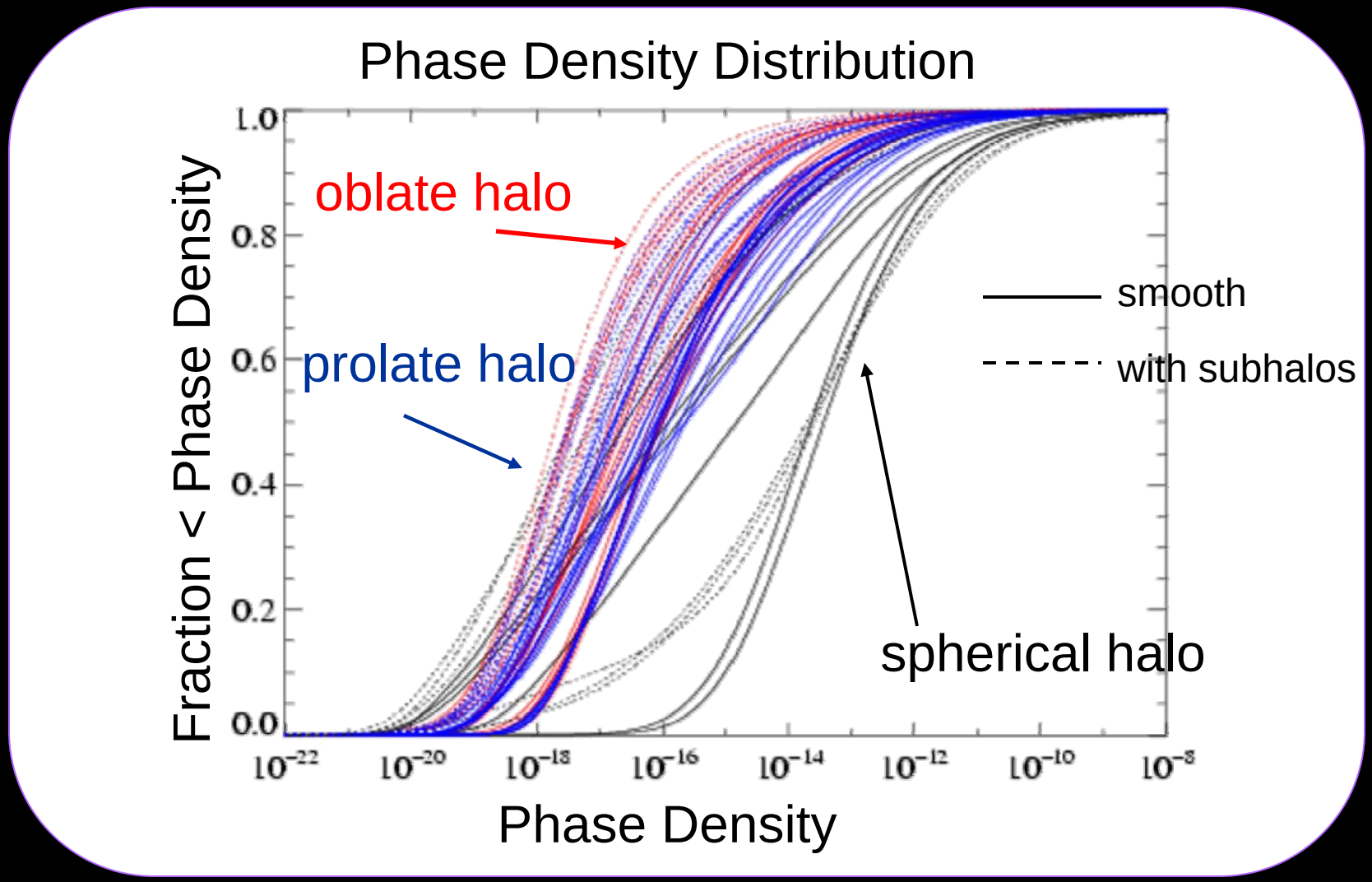
(selected orbits)

WITH SUBSTRUCTURE

OBLATE SPHERICAL PROLATE



Phase Density of Debris



Limitations

- Static host potential
- No dynamical friction
- Evolution of Milky Way mass distribution (may be problematic for simulations longer than ~ 5 Gyr)
- Modeled dark matter component only
- Could halo shape and substructure produce distinct signatures in other observables?

☐Conclusions

- Halo shape and specific orbital path are more important for tidal disruption than the presence or absence of subhalos
- Orbits near phase space resonances may be less susceptible to disruption, particularly in a spherical potential
- Substructure appears to be consistent with tidal streams

Thanks to D. Rudd, B. Robertson, A. Kravtsov, and S. Kazantzidis!