# The Dynamical History of the Feeble Giant, Crater II

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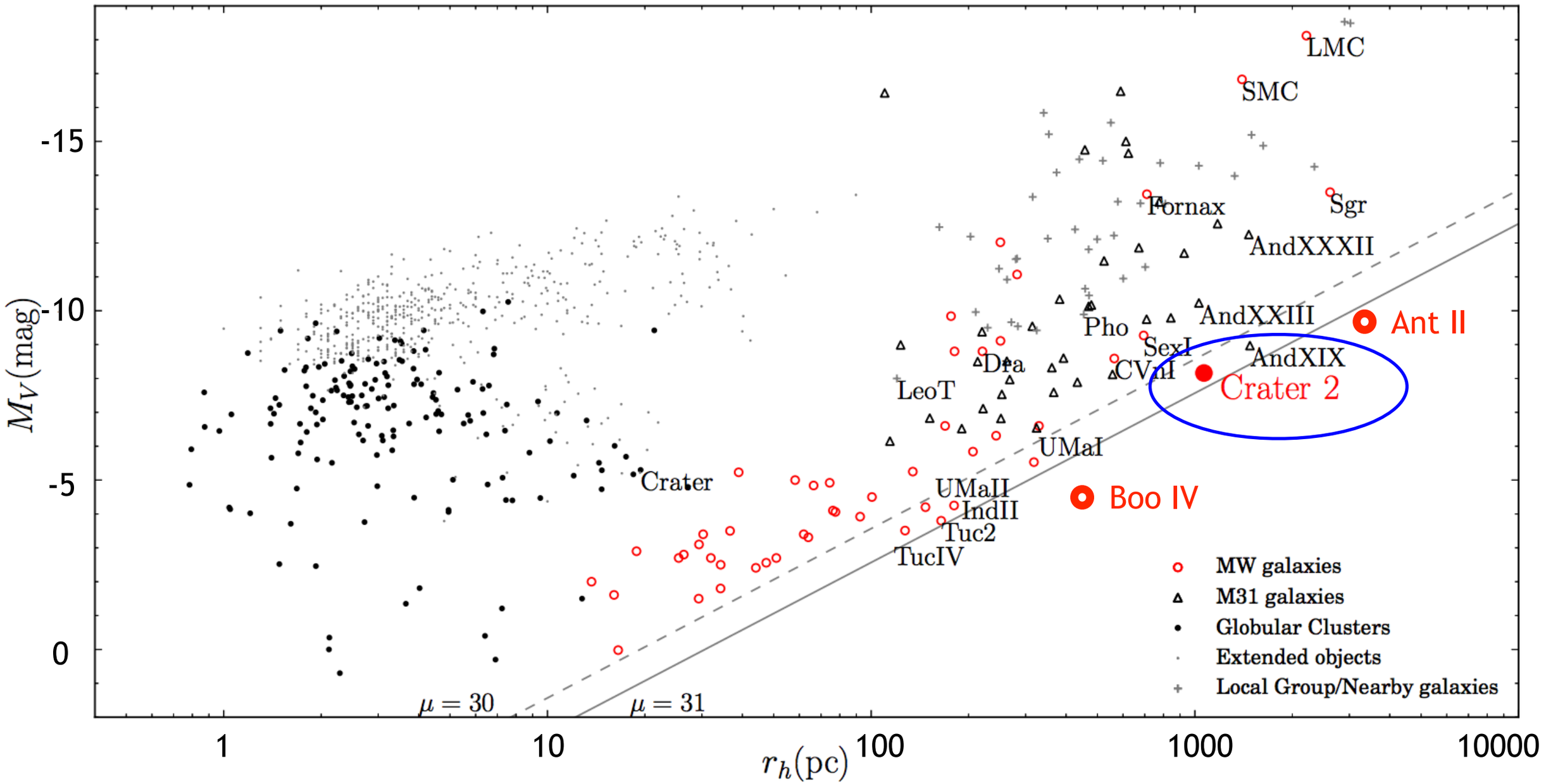
# Ultra-Diffuse Galaxies as Probes of Dark Matter Cosmology

HST image of NGC 1052-DF2
by Pieter van Dokkum et al.

- Uptick in Ultra Diffuse Galaxy (UDG) discovery in last ~decade
  - $r_h$ > 1.5 kpc
  - $\mu$ > 24 mag arcsec$^{-2}$
- Important sites for testing dark matter models and influence of tides

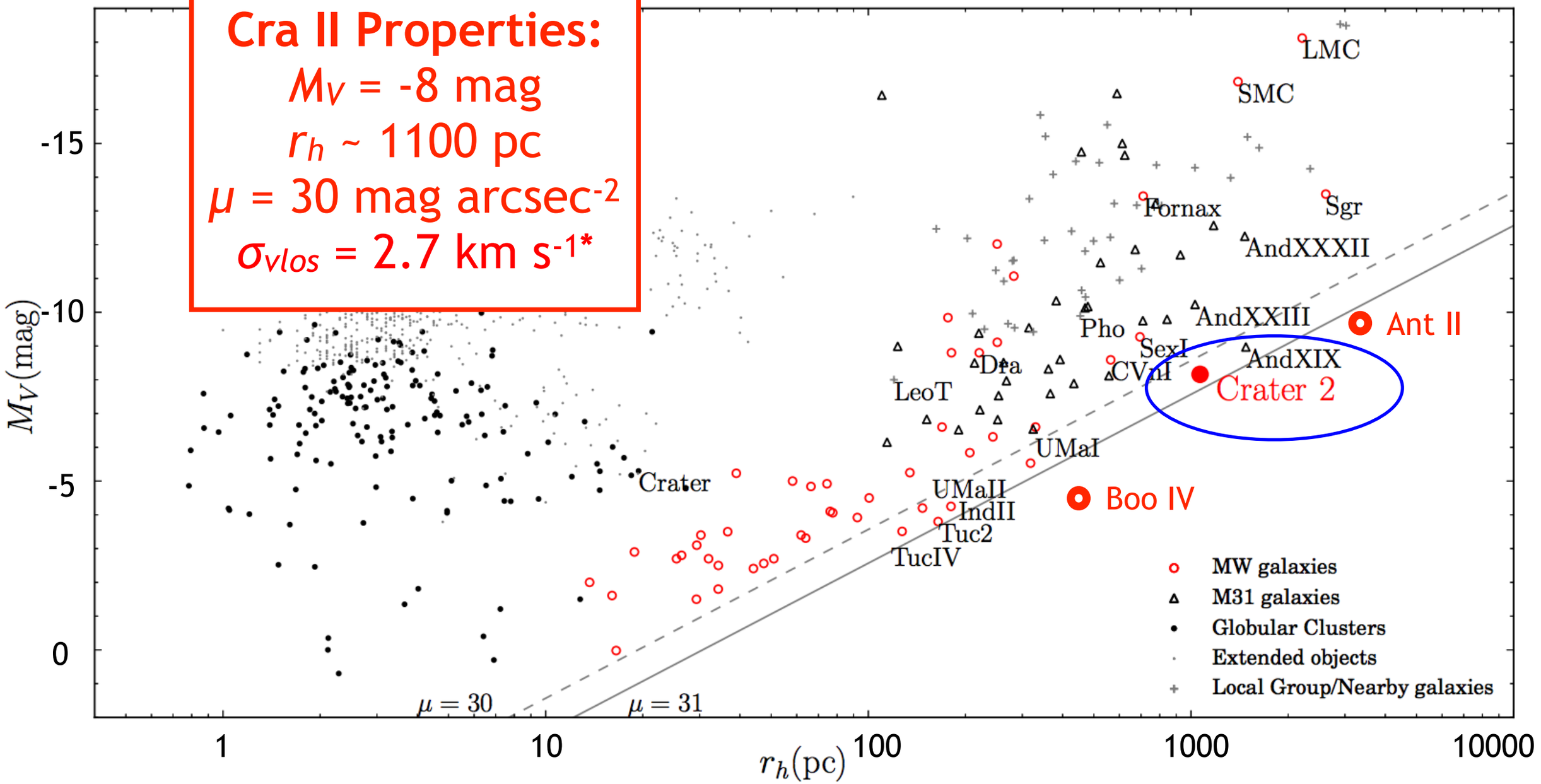
# Crater II, the "Feeble Giant"




Adapted from Torrealba+16

# Crater II, the "Feeble Giant"

**Cra II Properties:**
$M_V$ = -8 mag
$r_h$ ~ 1100 pc
$\mu$ = 30 mag arcsec$^{-2}$
$\sigma_{vlos}$ = 2.7 km s$^{-1}$*

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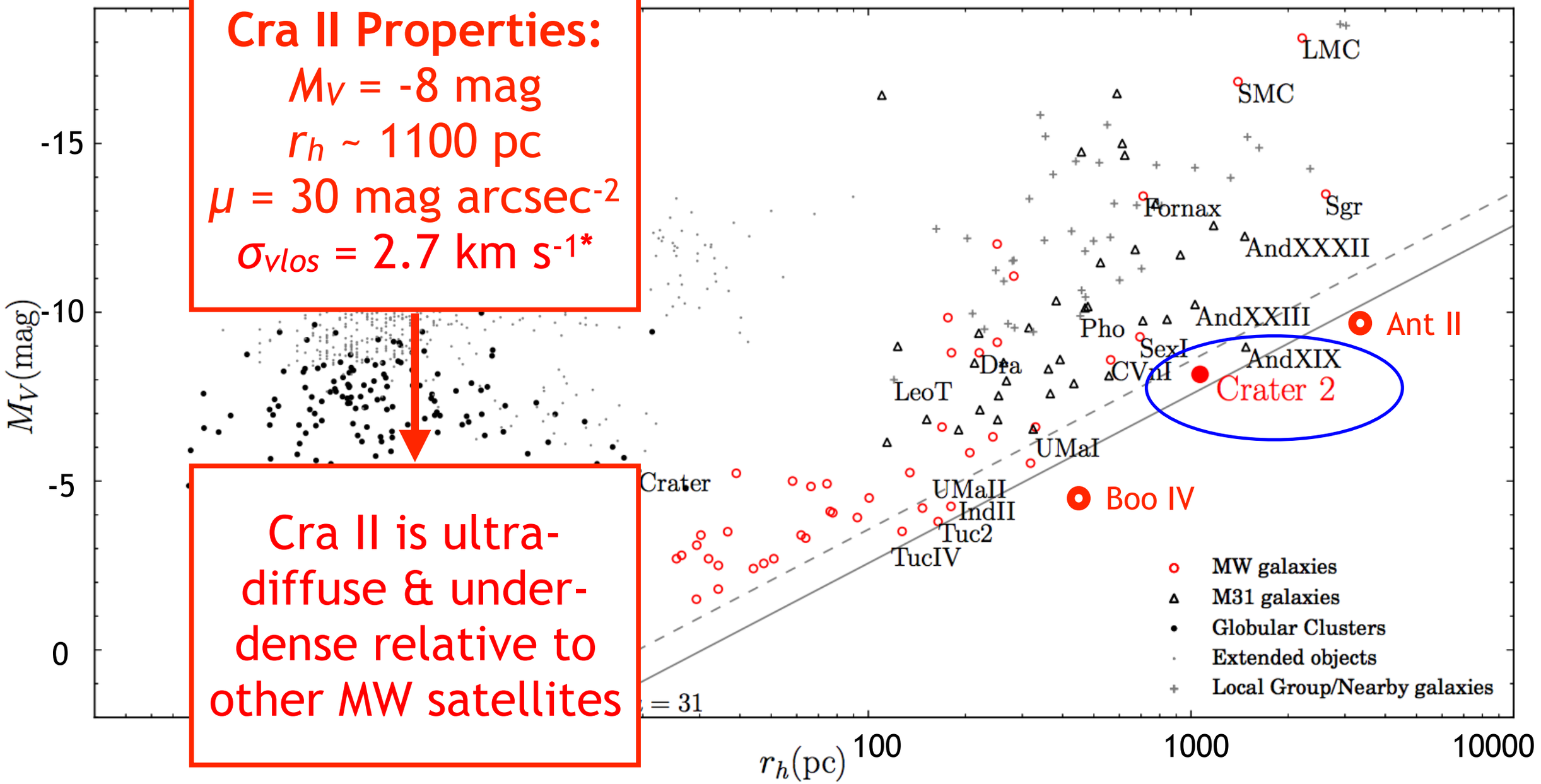


Cra II is ultra-diffuse & under-dense relative to other MW satellites

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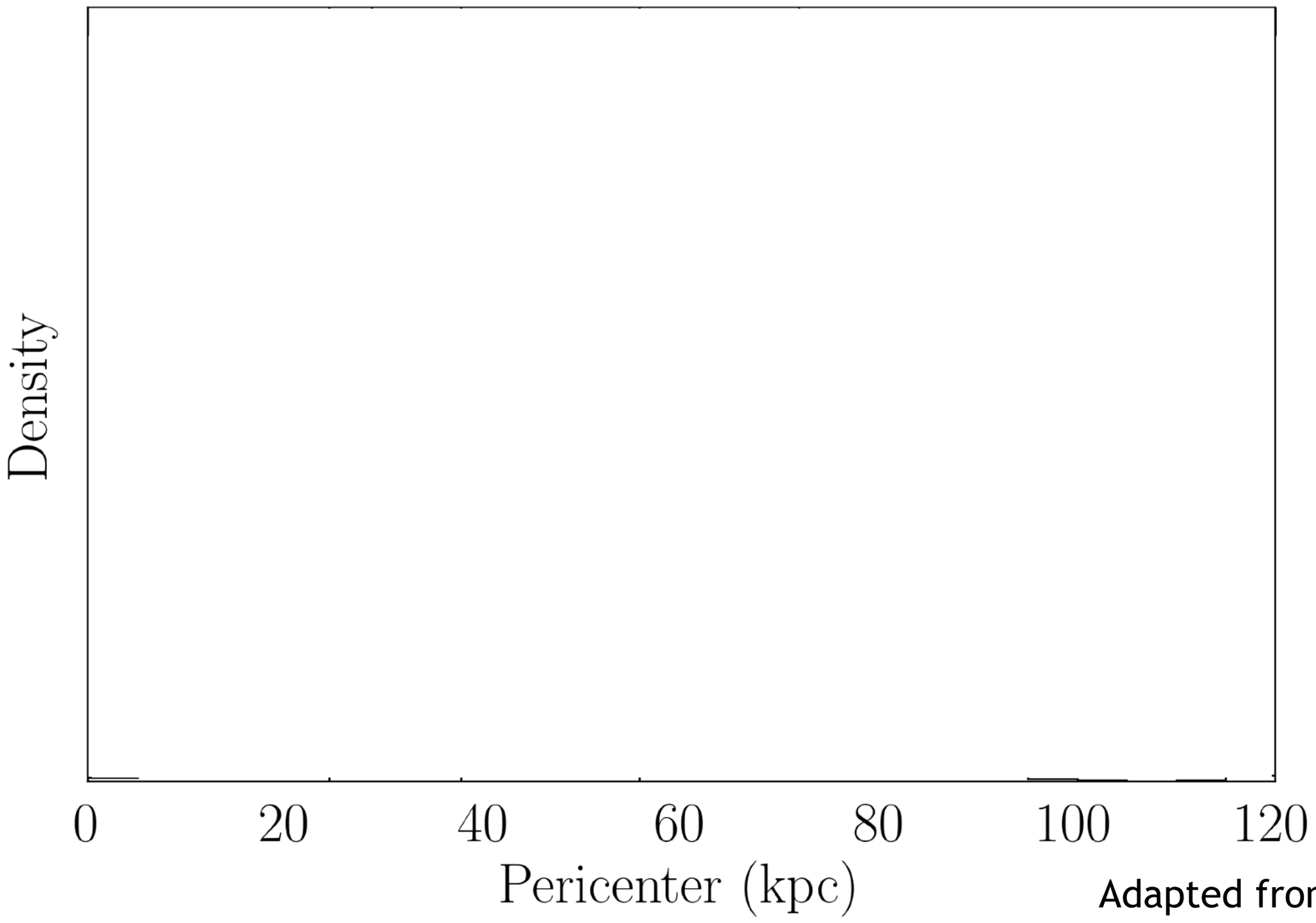
- Second answer: Crater II has experienced severe tidal stripping (Sanders+18, Fattahi+18)
  - *Gaia DR2* provides full 6D phase space information for Crater II; we can now test this second hypothesis!
  - *Unique* thing we can do for Local Group UDGs!

# Obtaining the Orbital Properties of Crater II

- condition for tidal stripping of satellite's stellar component is $r_{tidal} \sim r_h$
  - $r_{tidal} \sim R_{GC}^{1/3}$
    - pericenter of satellite orbit indicates how close satellite approaches Galactic Center
- Conduct Monte Carlo simulation of possible orbital pericenters using: weighted average proper motion, MW halo mass, satellite distance*

*Also see Fritz+18 & Kalliyavalil+18 for Cra II orbit inference

# Possible Pericenter Values for Cra II Orbit

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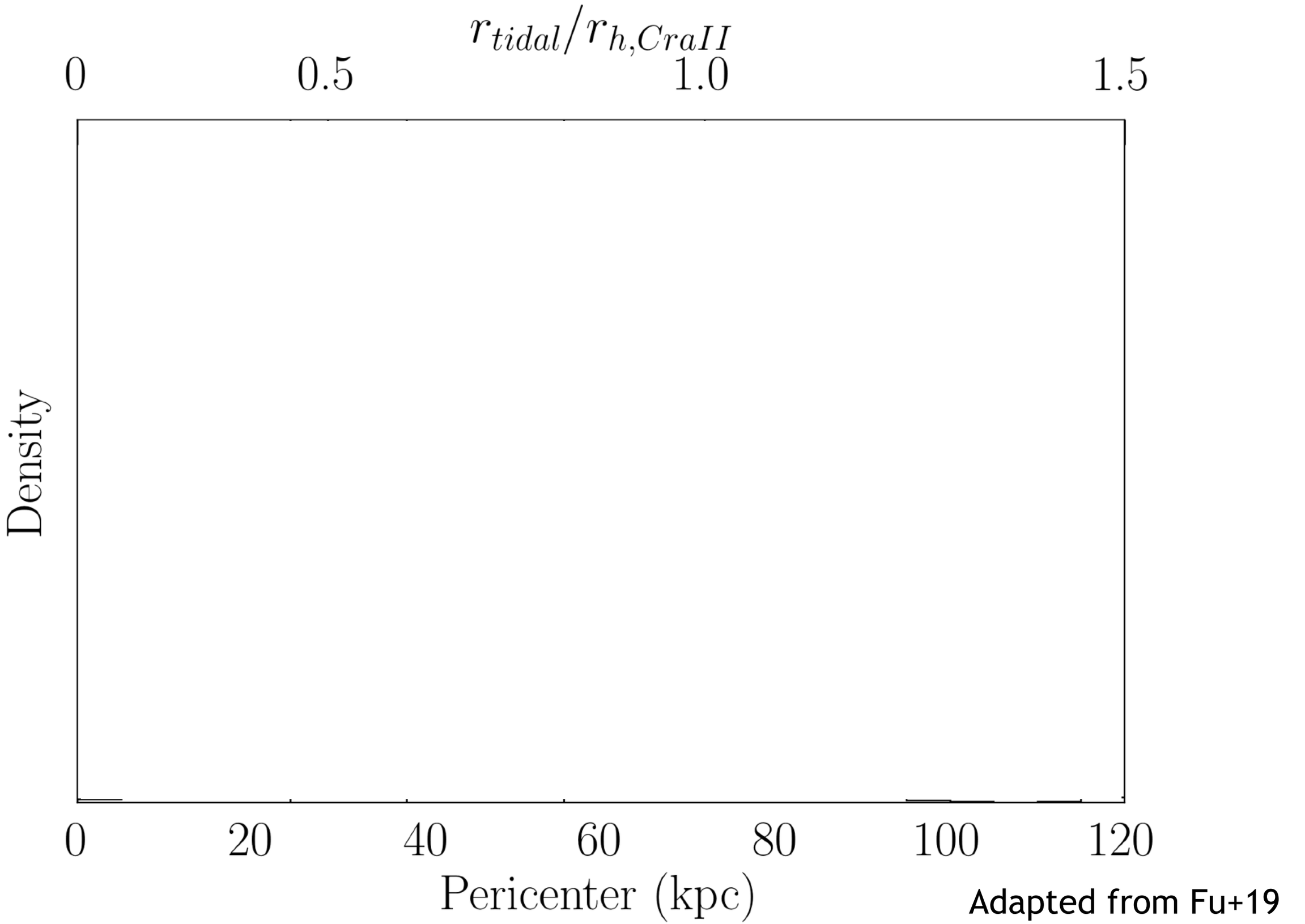


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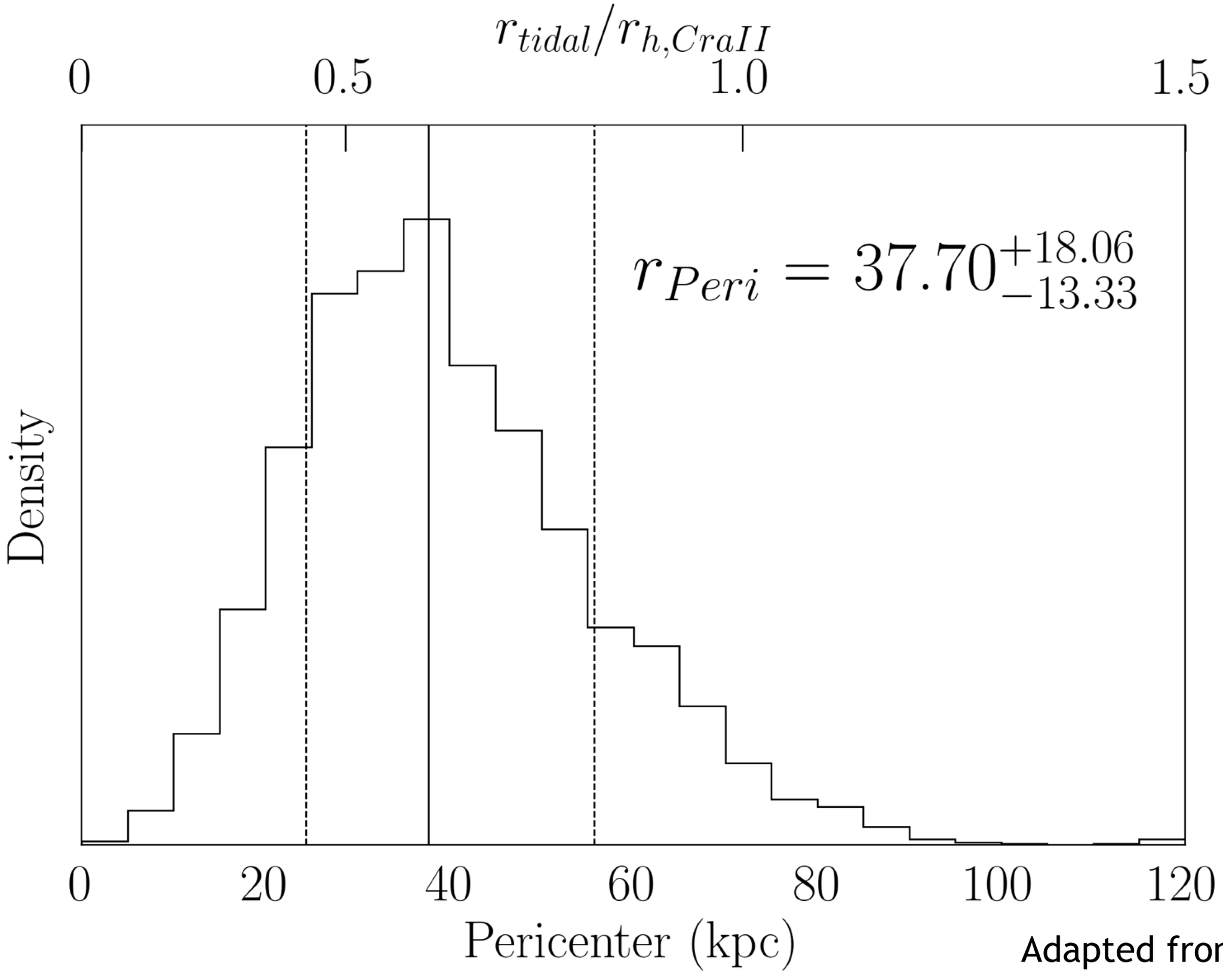


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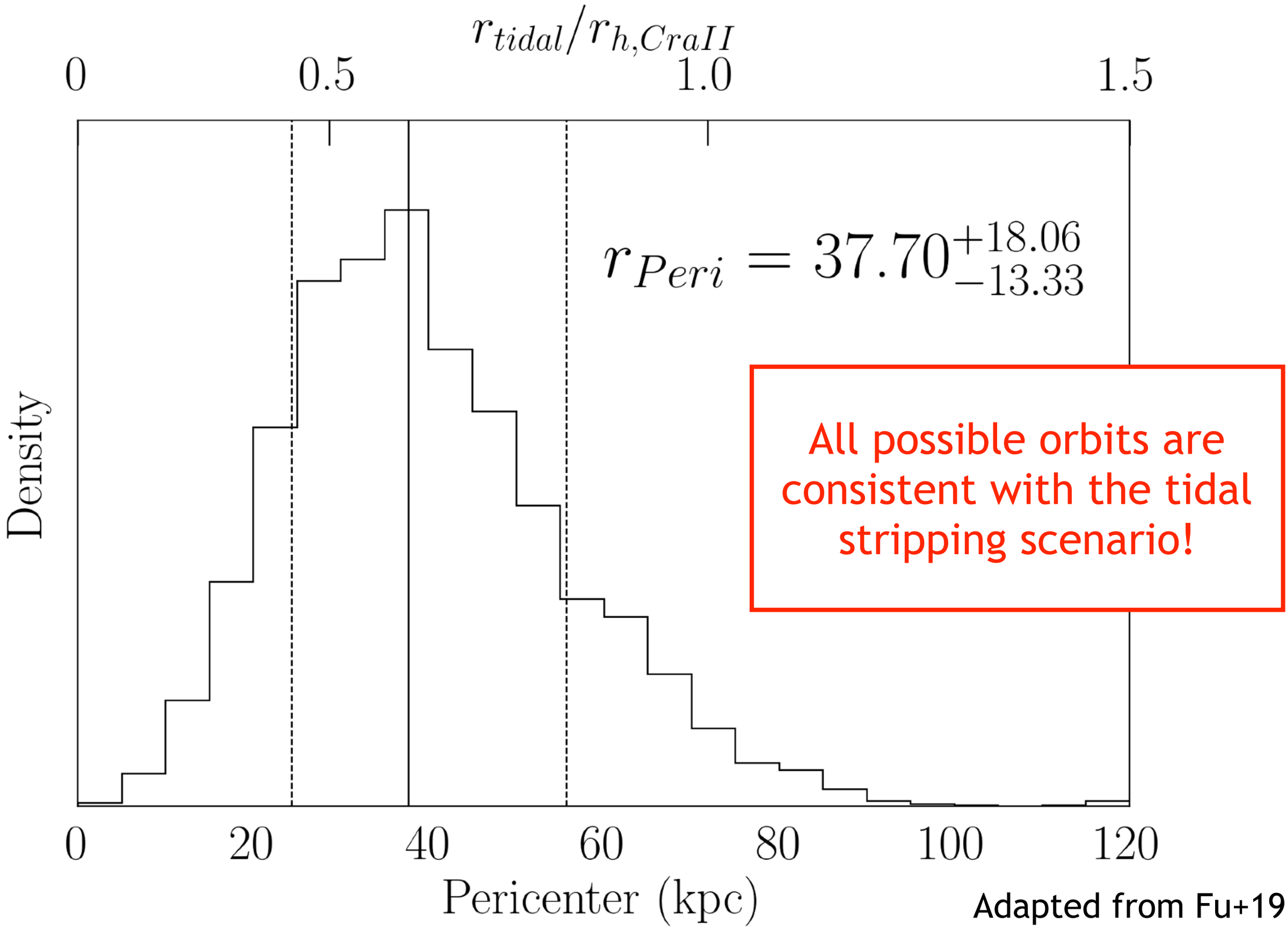
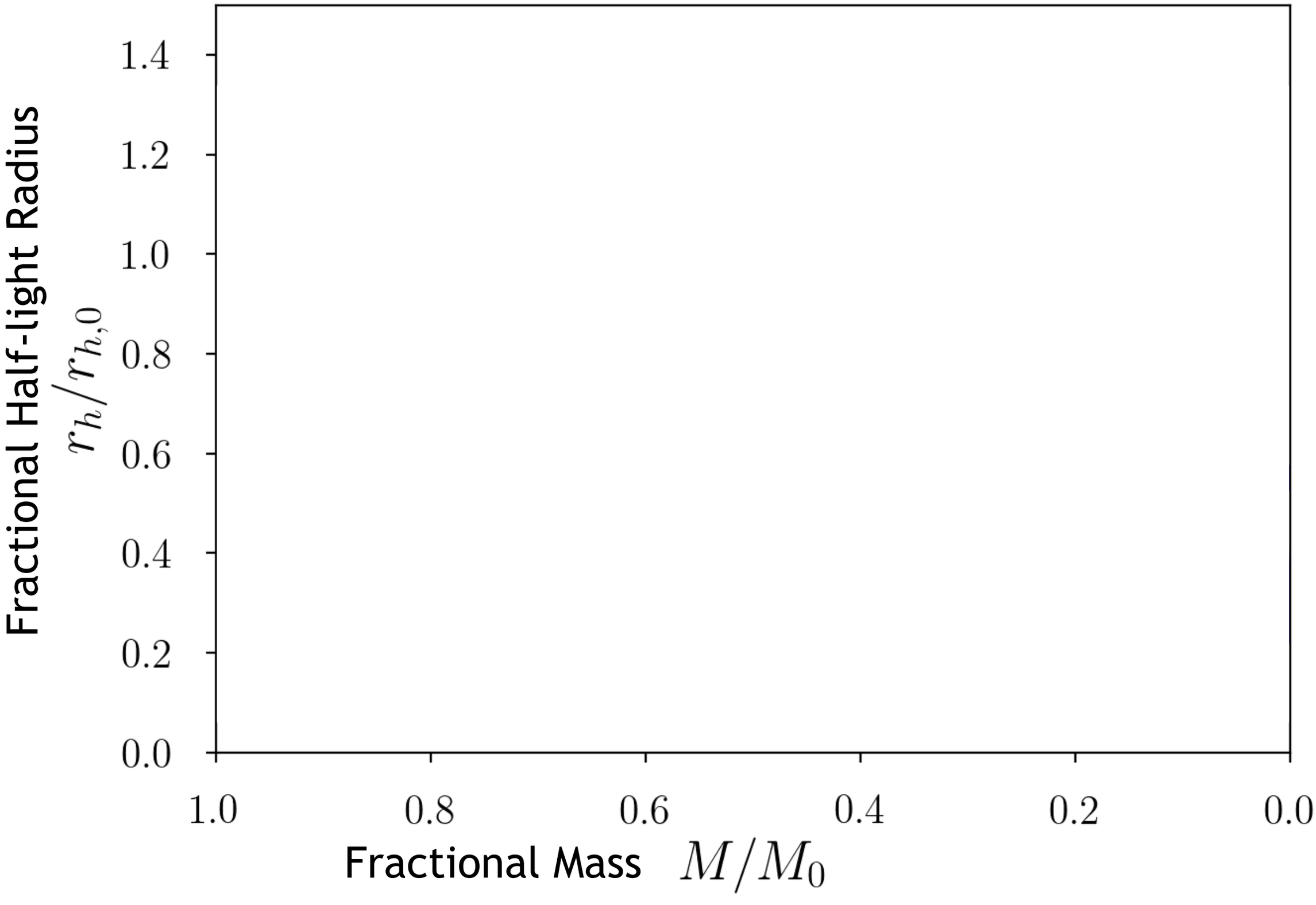



All possible orbits are consistent with the tidal stripping scenario!

Adapted from Fu+19

# Self-Similar Tidal Evolution of Dwarf Galaxies



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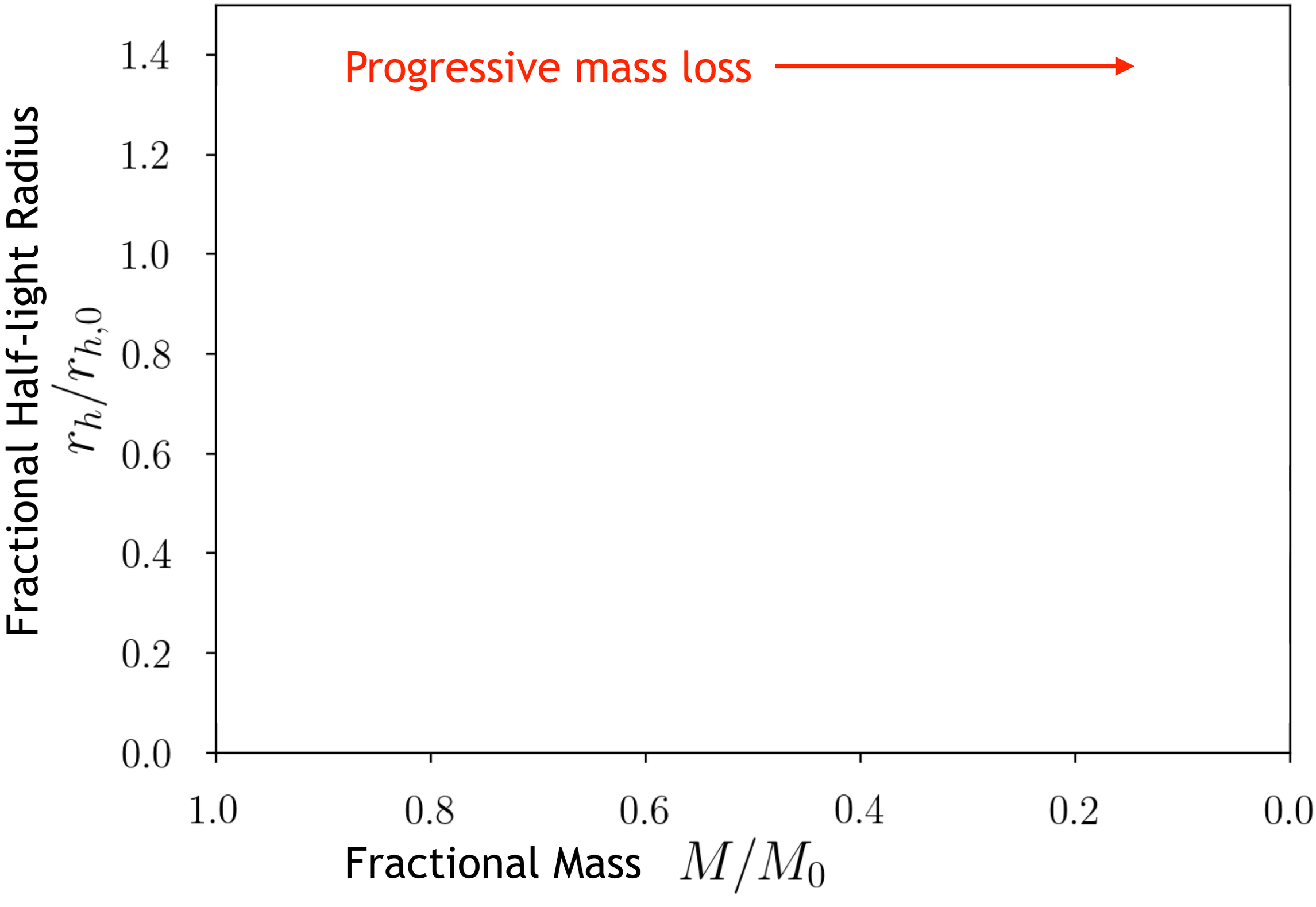

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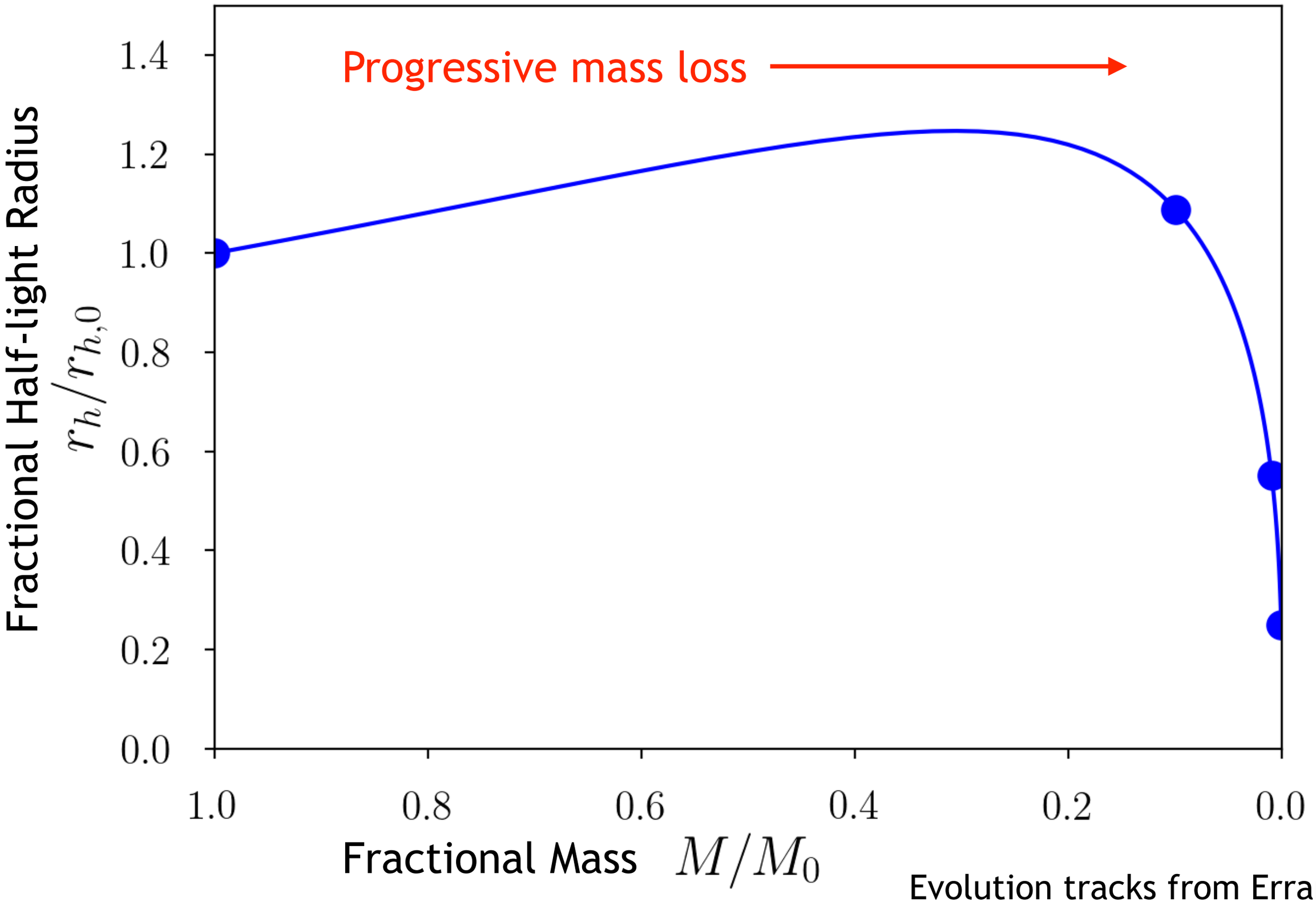


Evolution tracks from Errani+15

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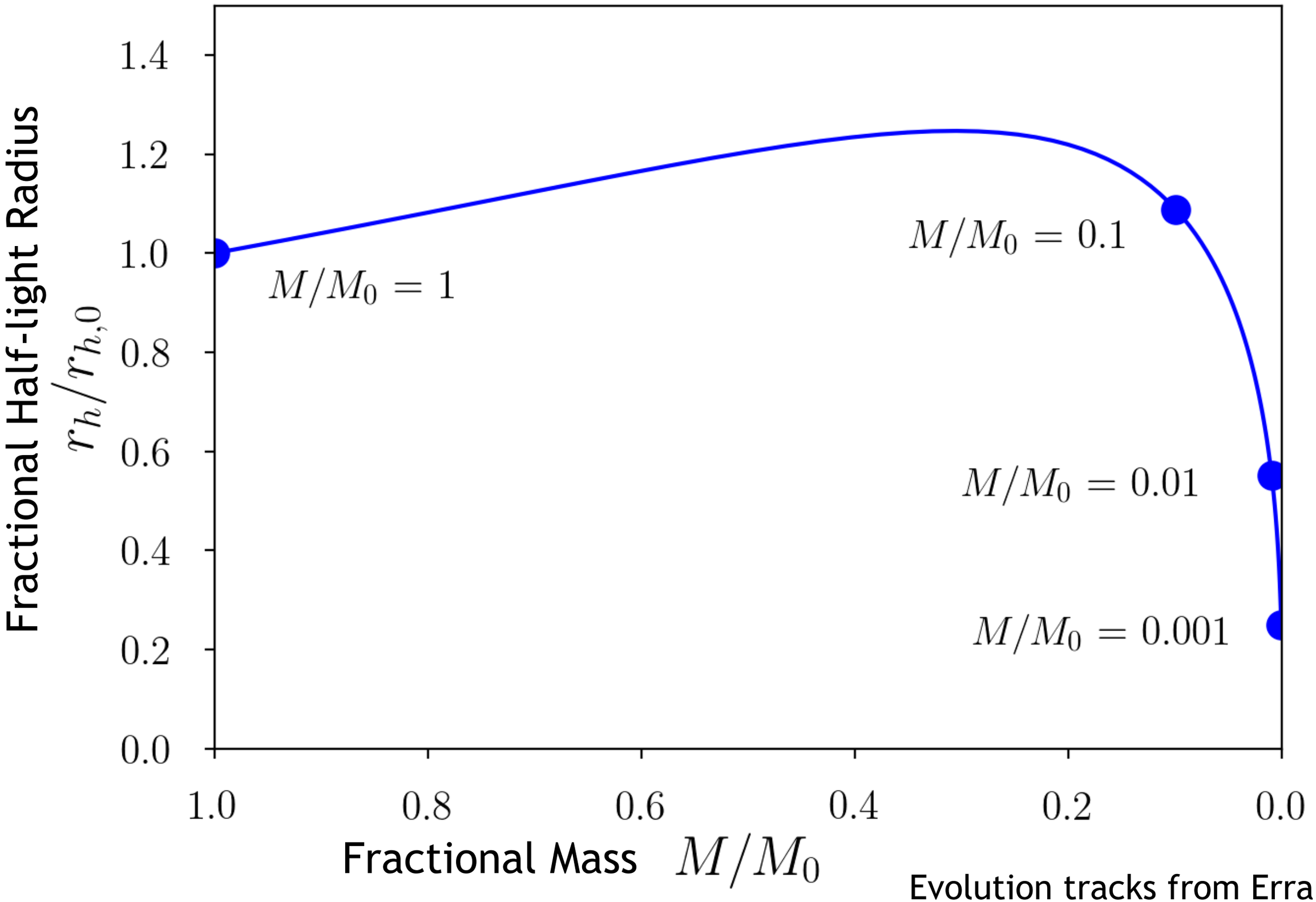


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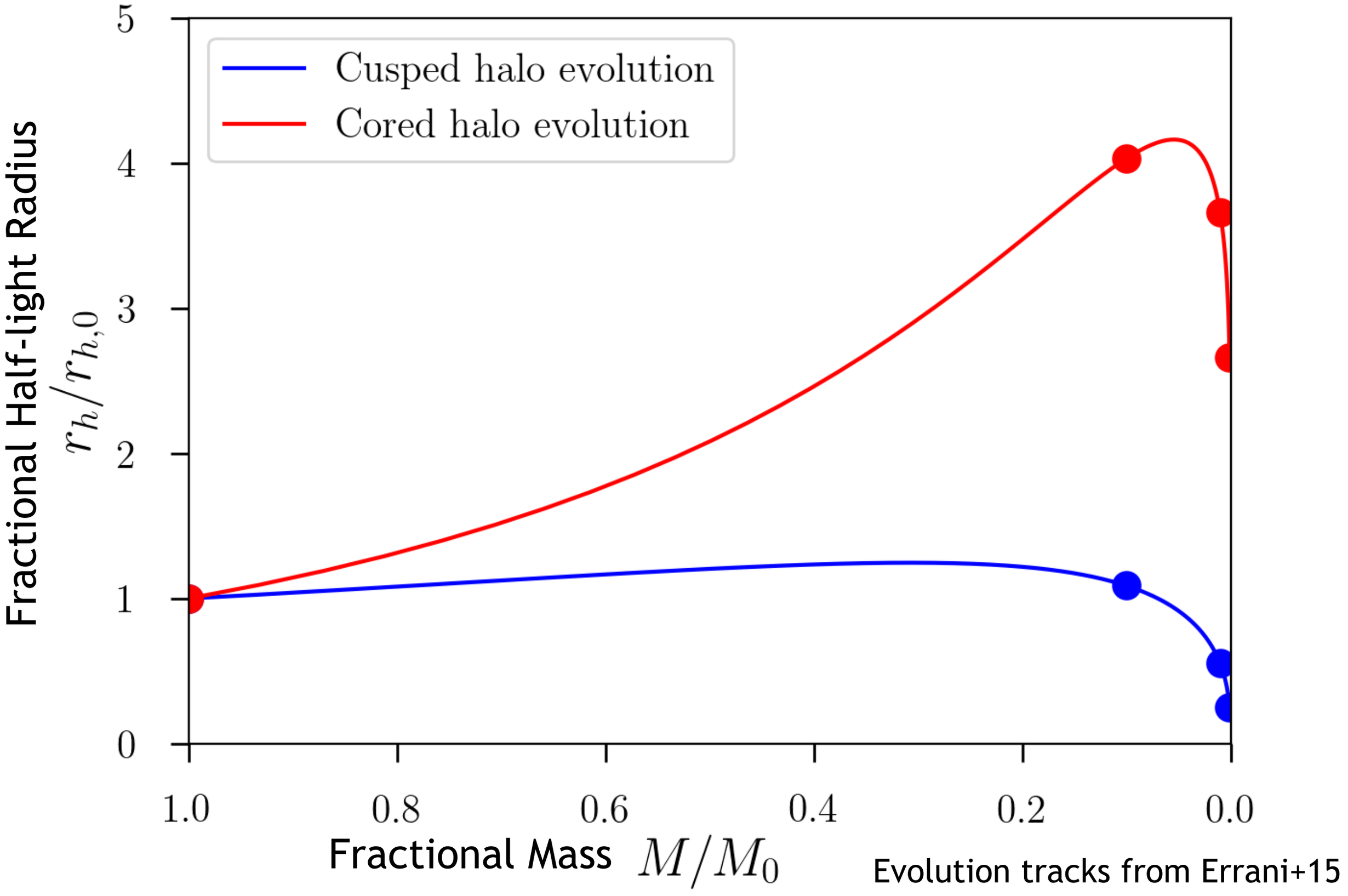


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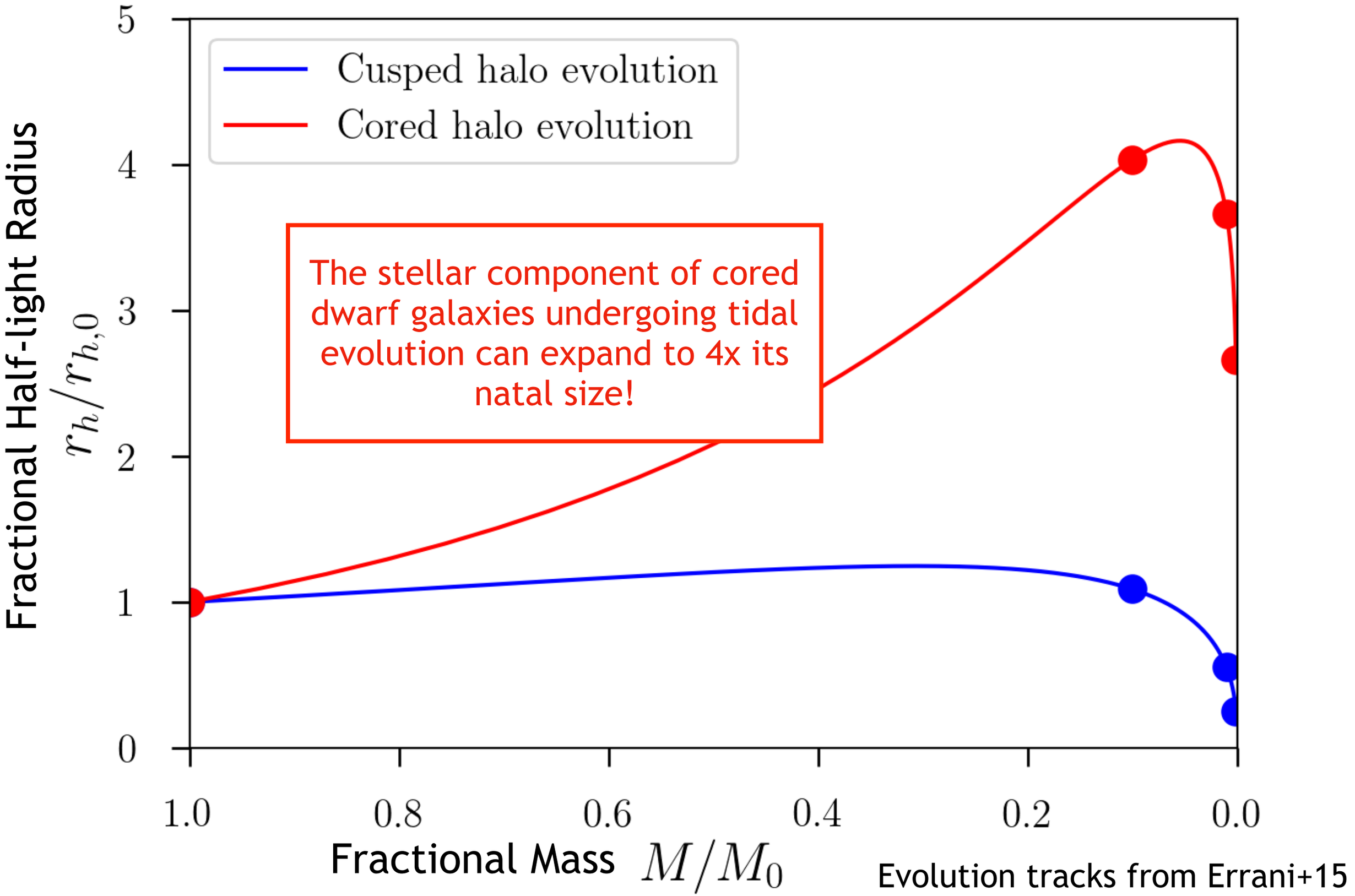


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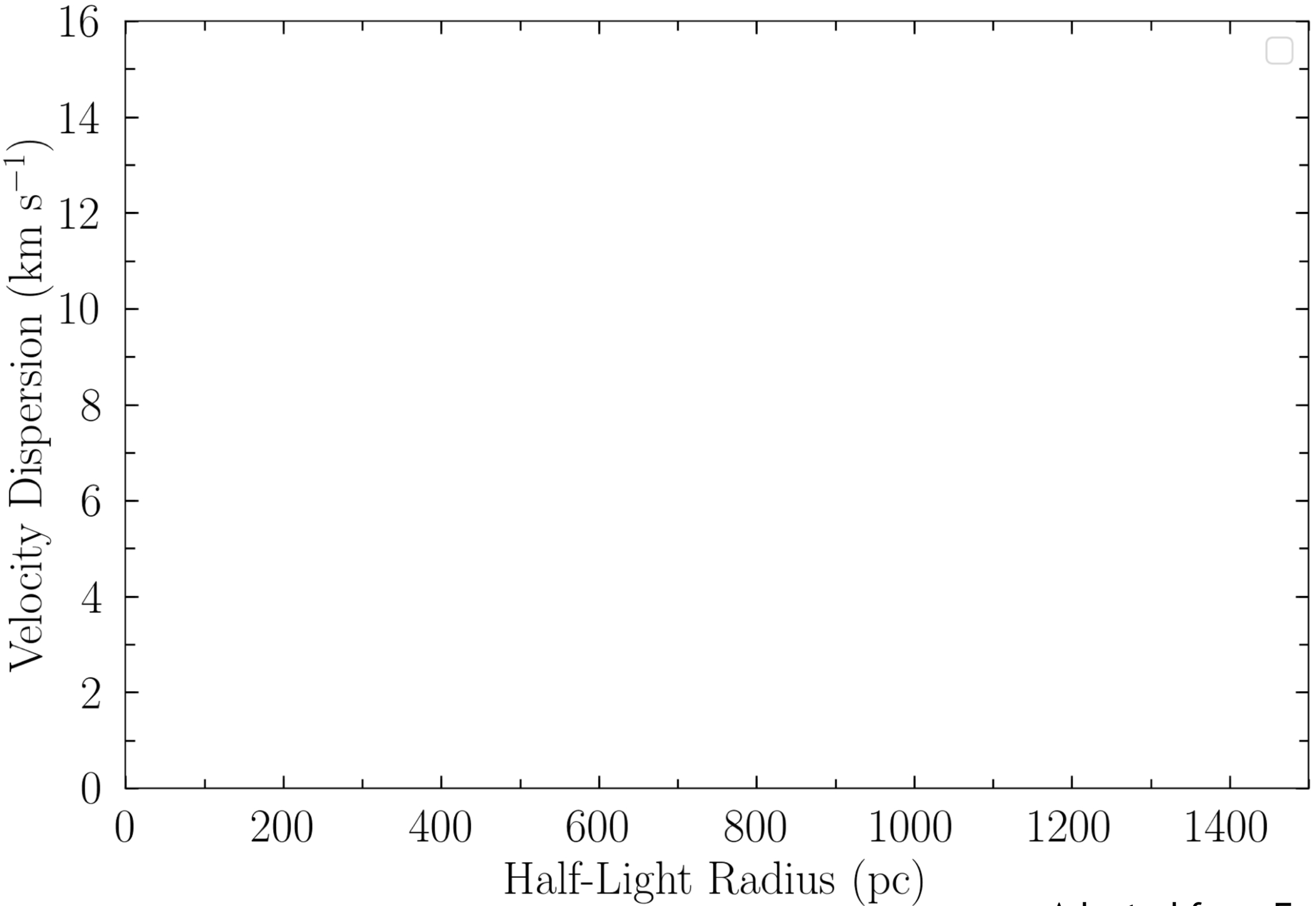
# Tidal Evolution of Cored DM Haloes

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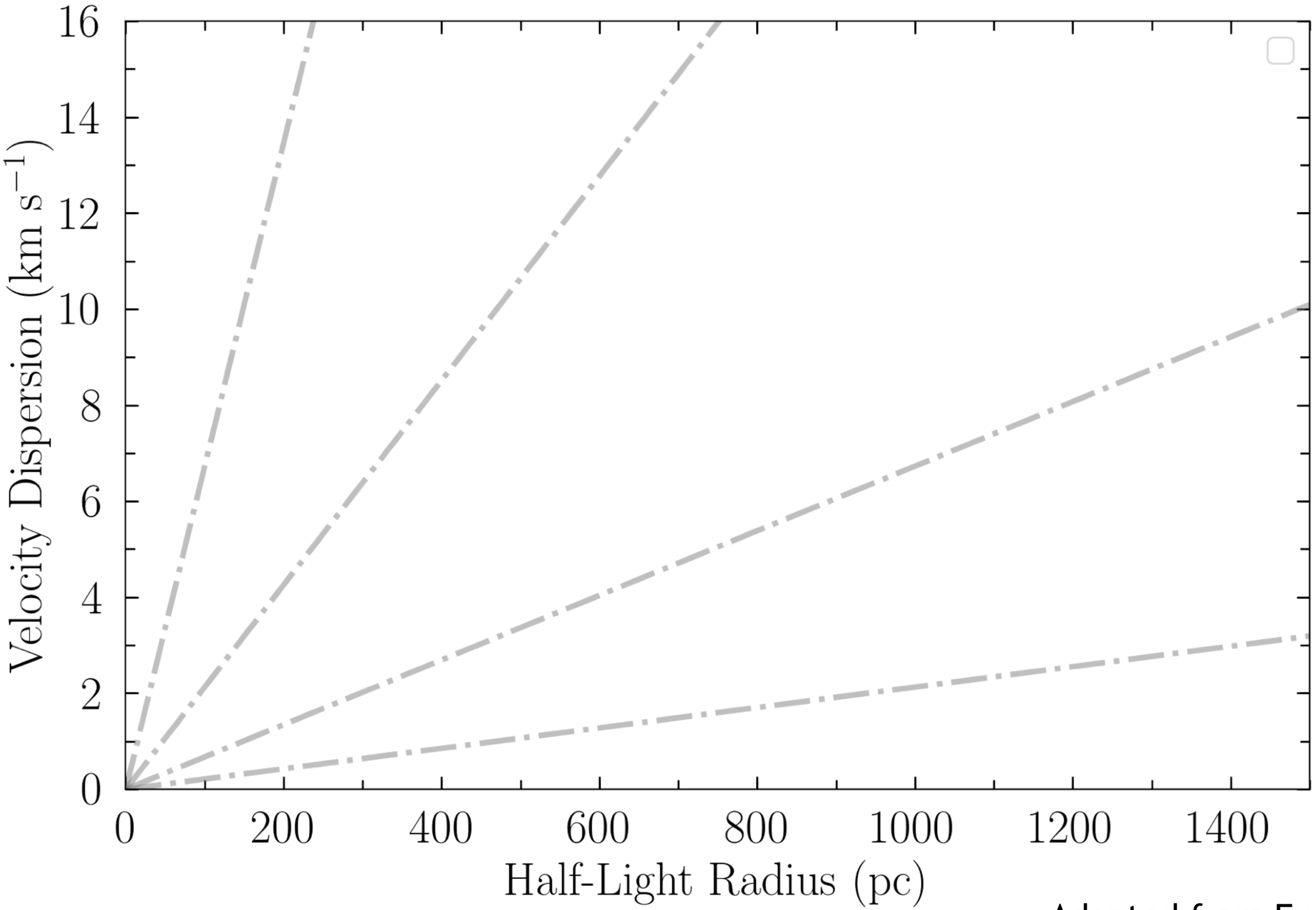


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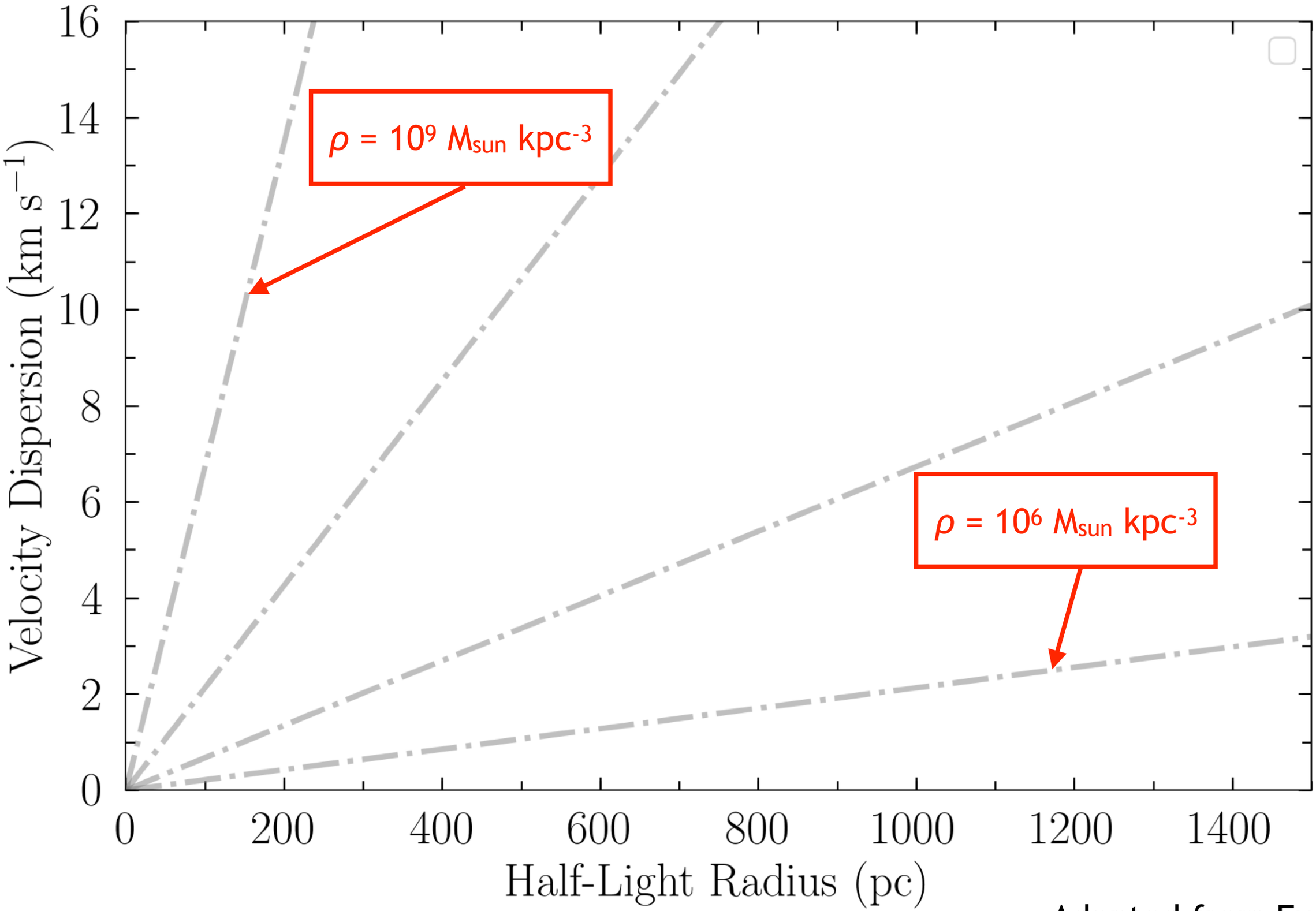


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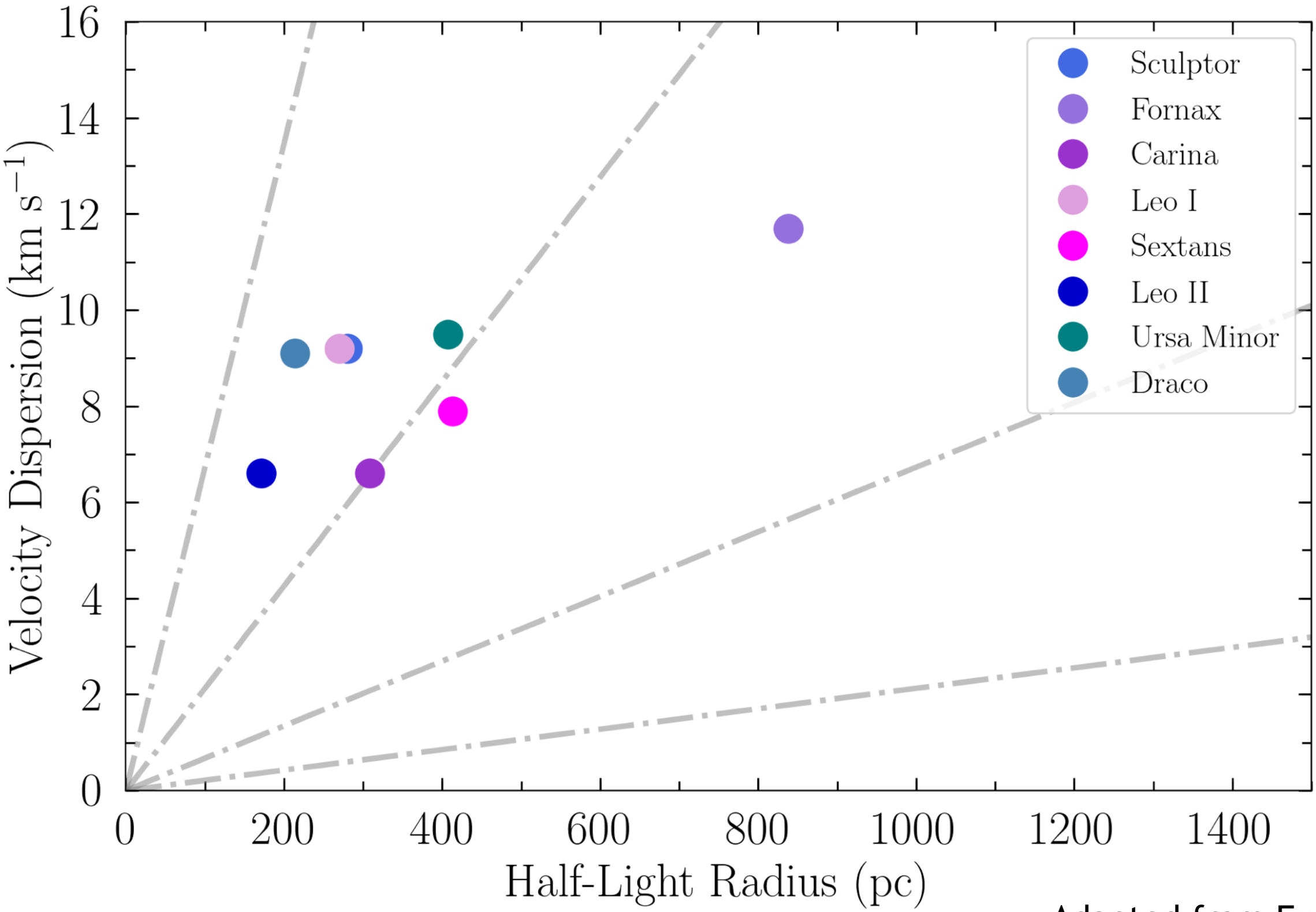


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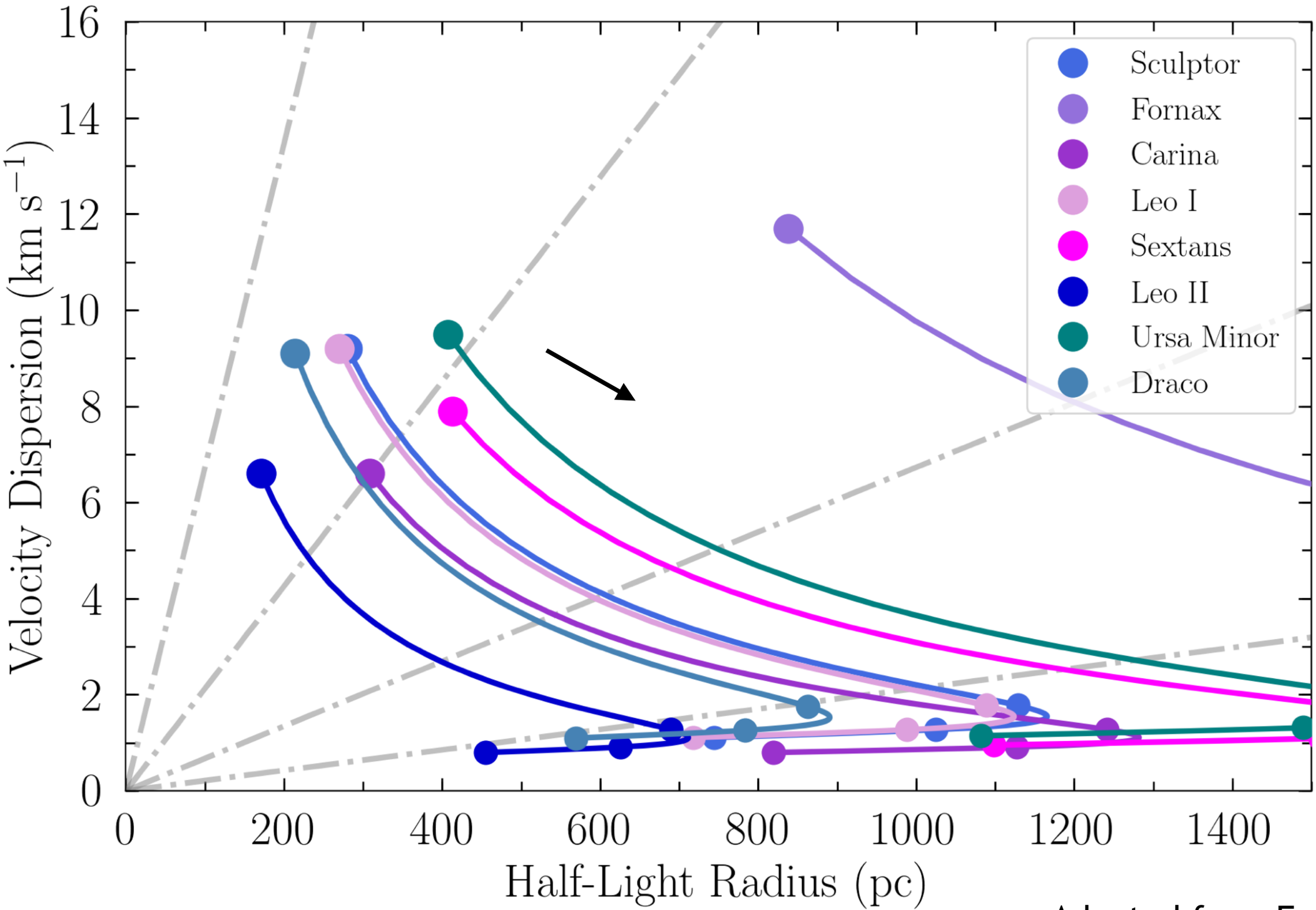


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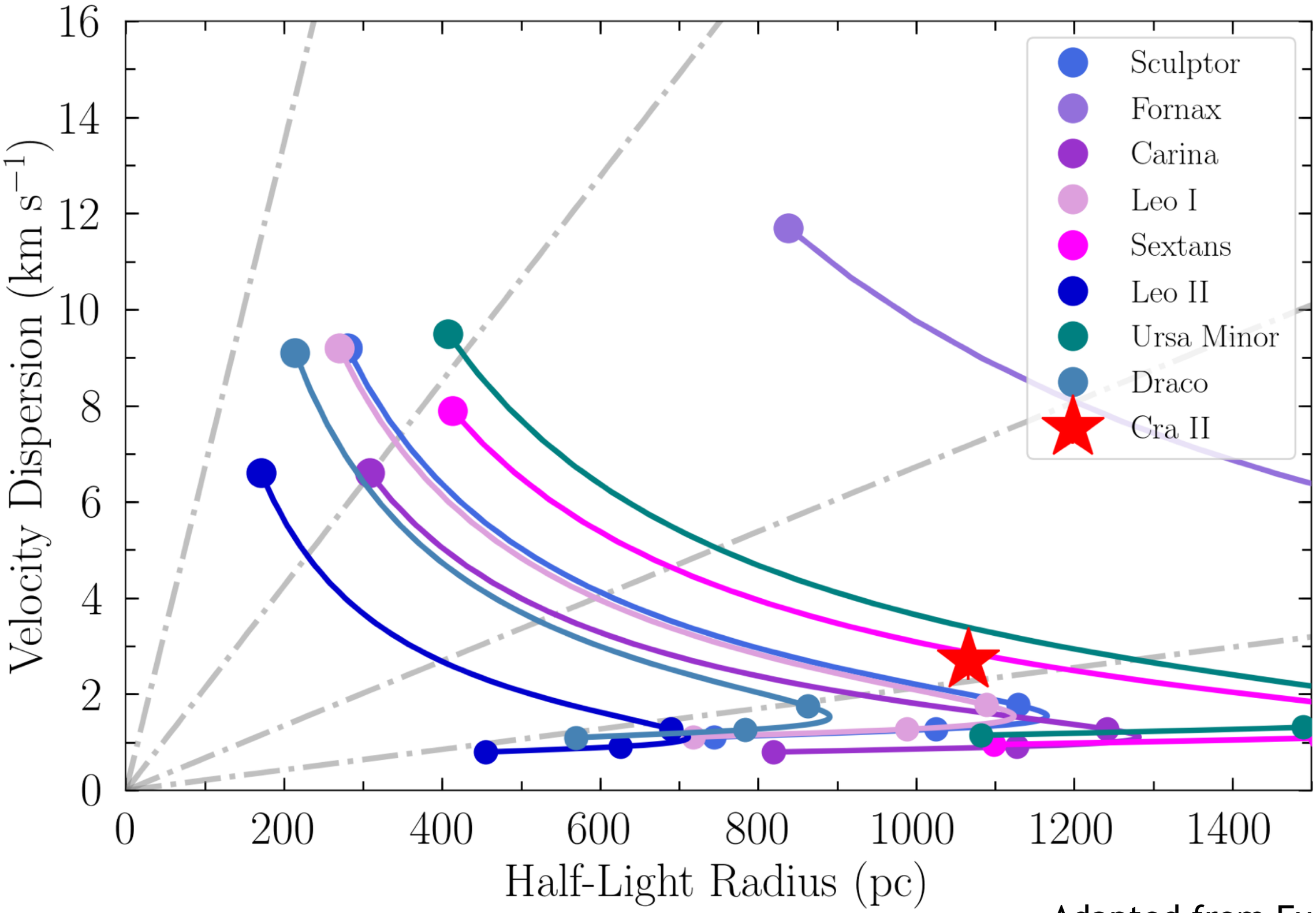


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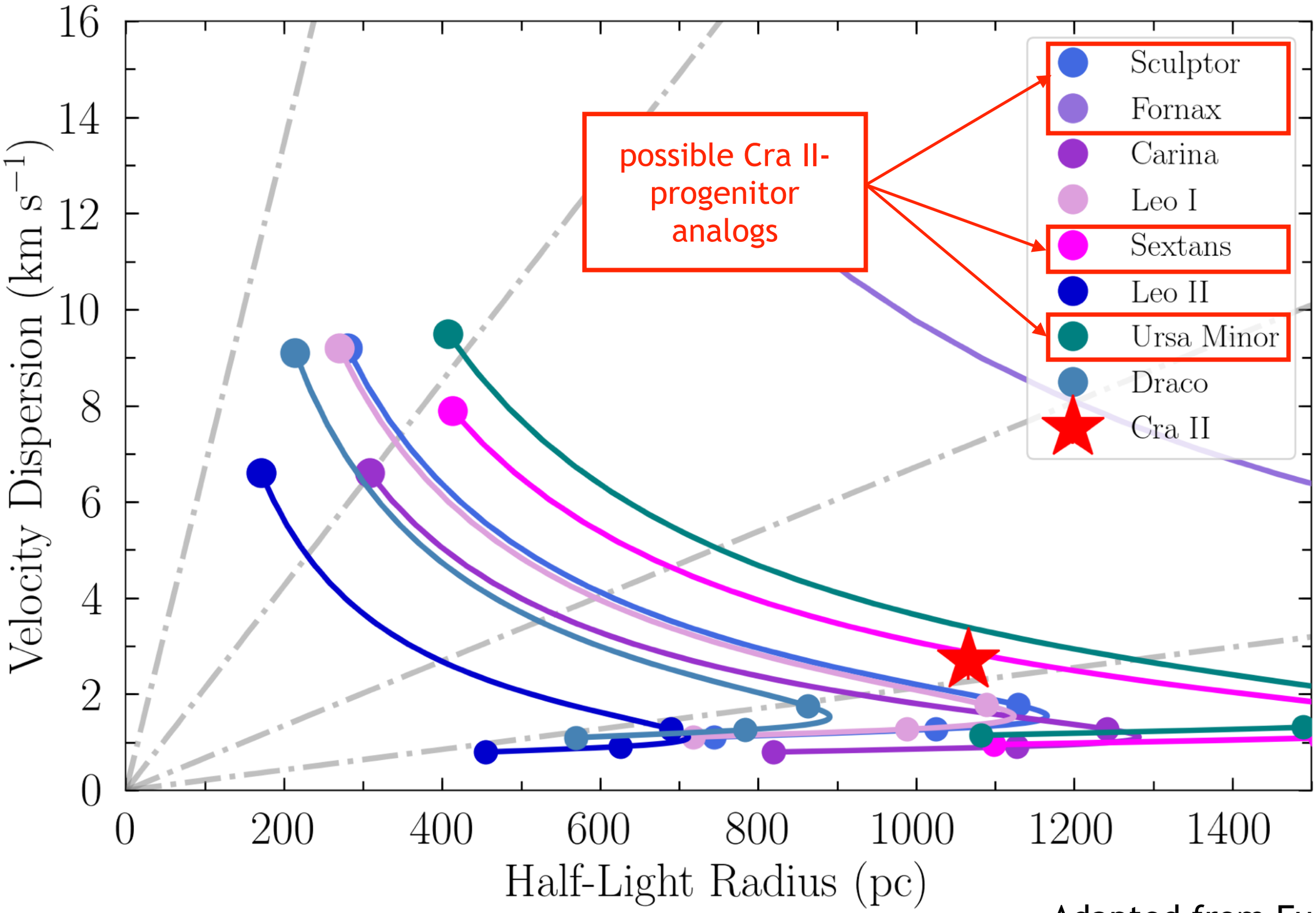


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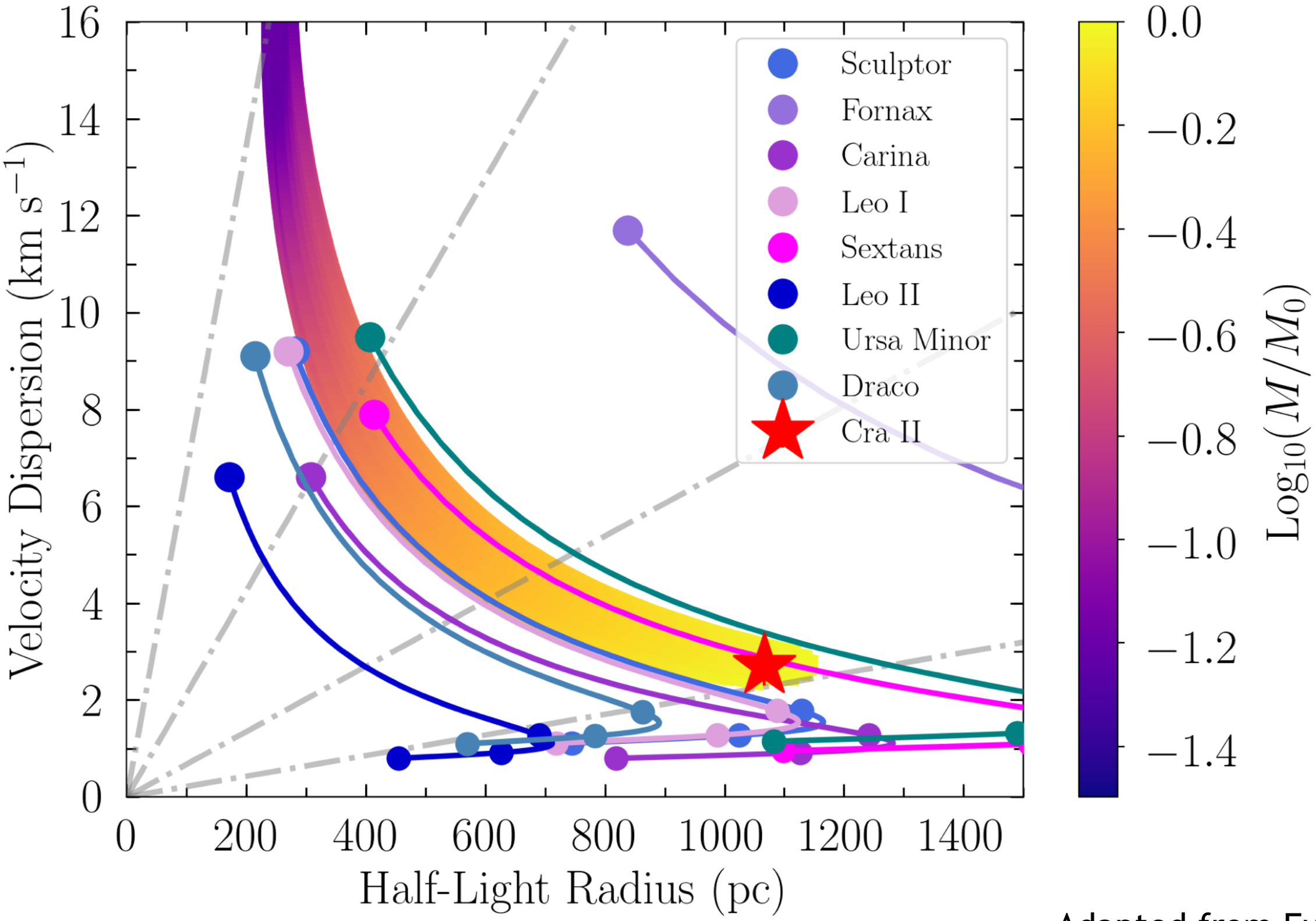


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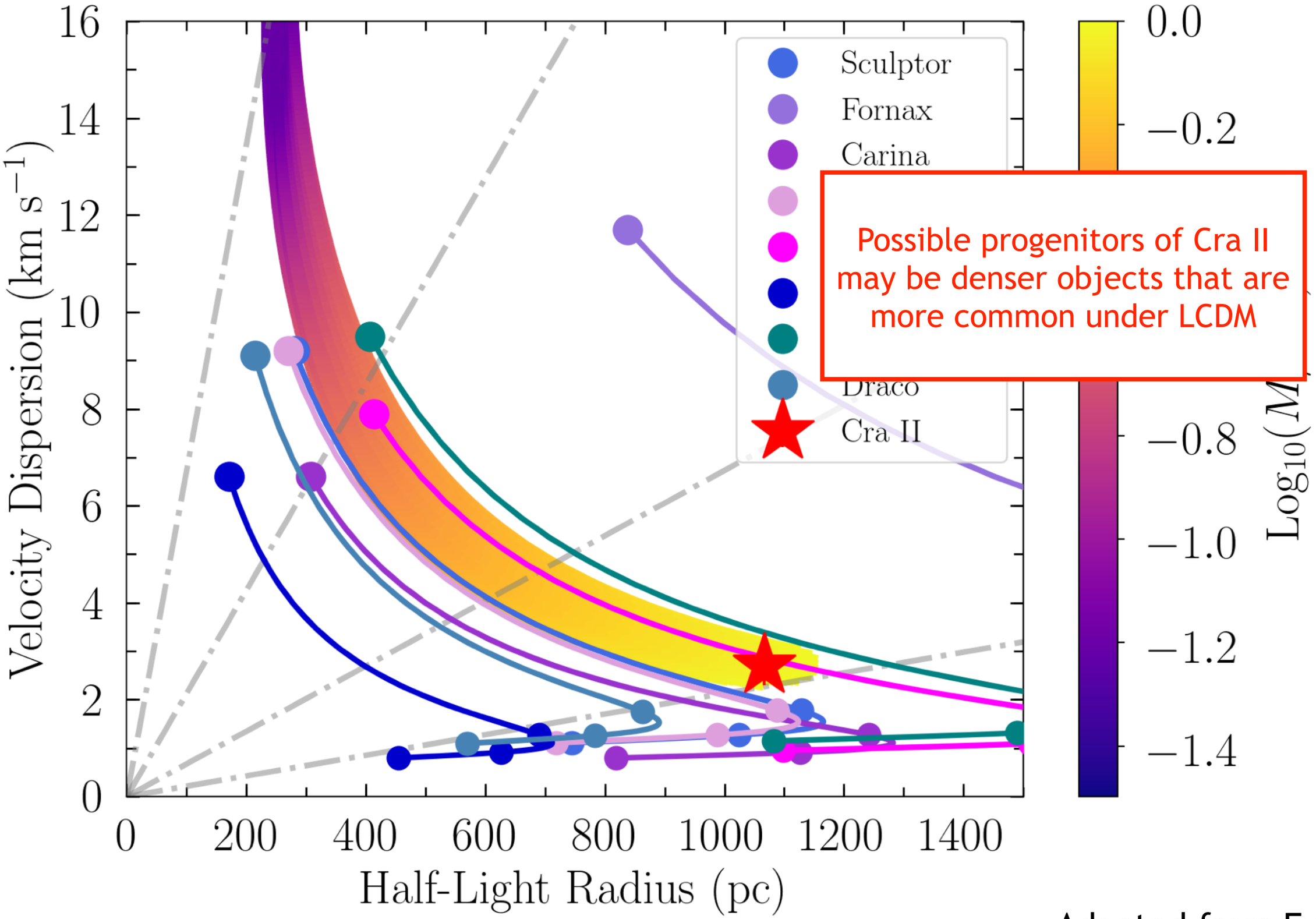


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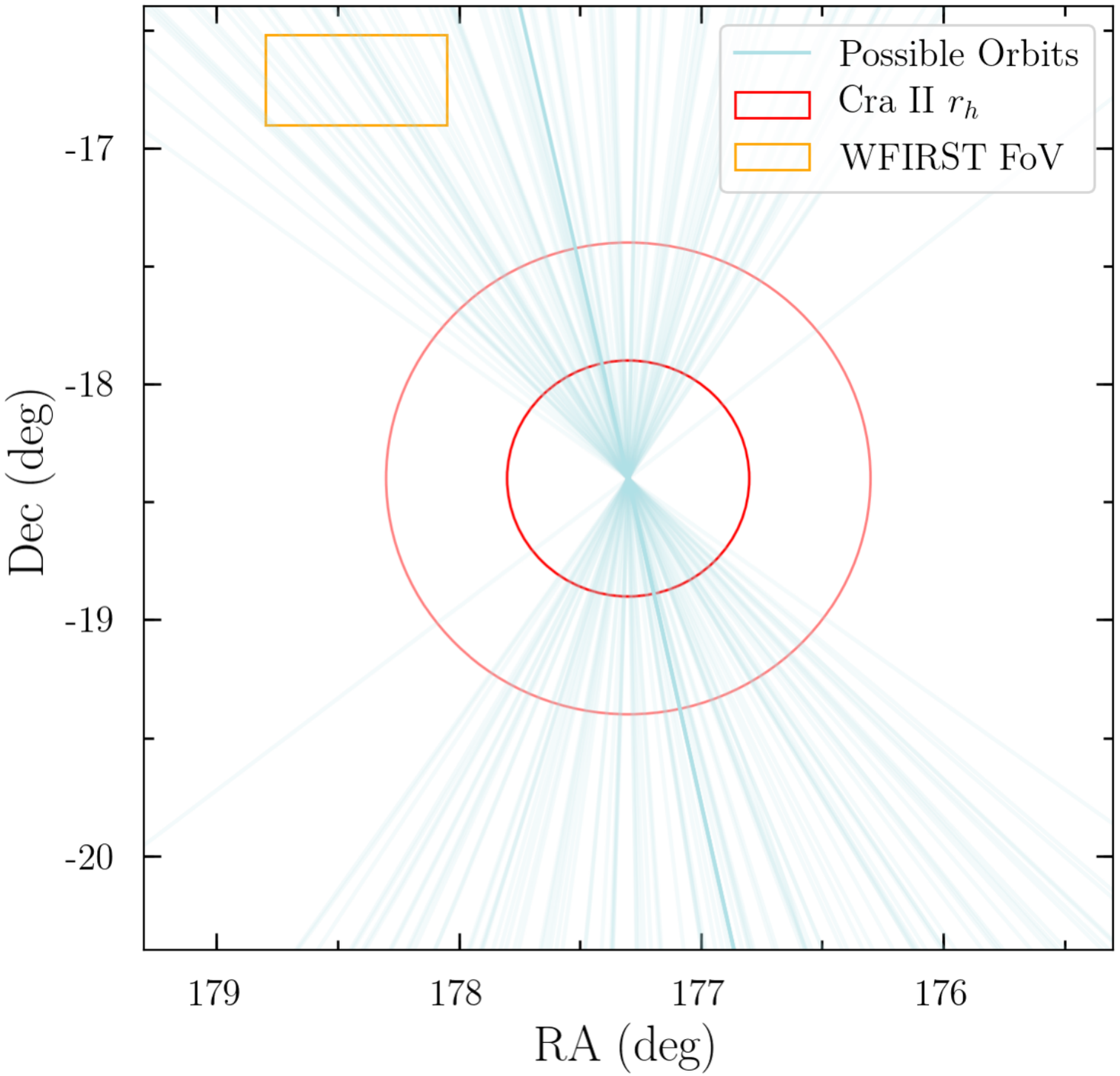
# Studying Cra II in era of WFIRST




- Deep, wide-field astrometry complements *Gaia*, *HST*
  - predicted precision <25 $\mu$as yr$^{-1}$
- Targeted search for tidal debris to refine tidal stripping hypothesis
- Search for tidal features around analogous diffuse galaxies
  - role of tides in sculpting UDGs?

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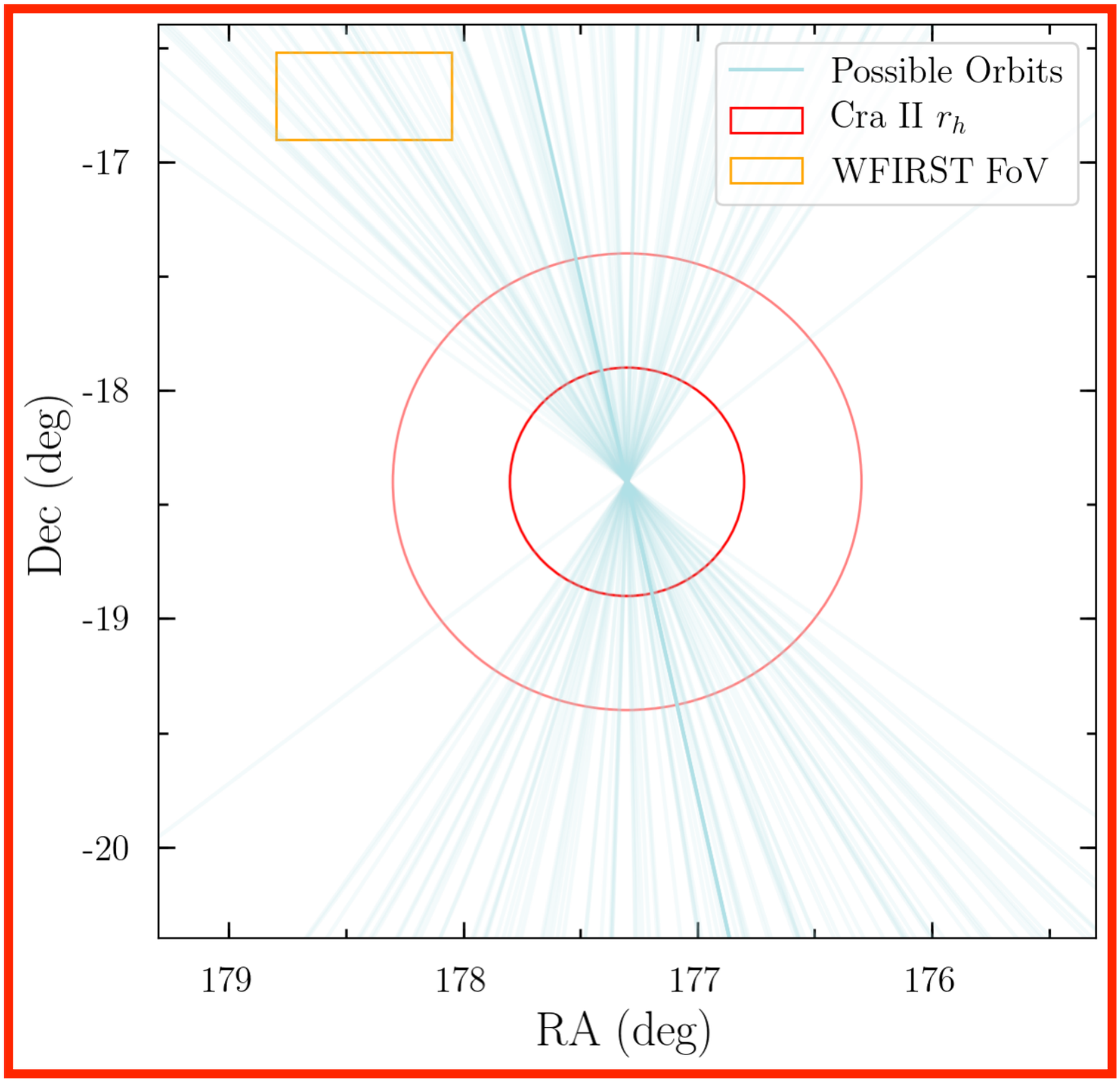


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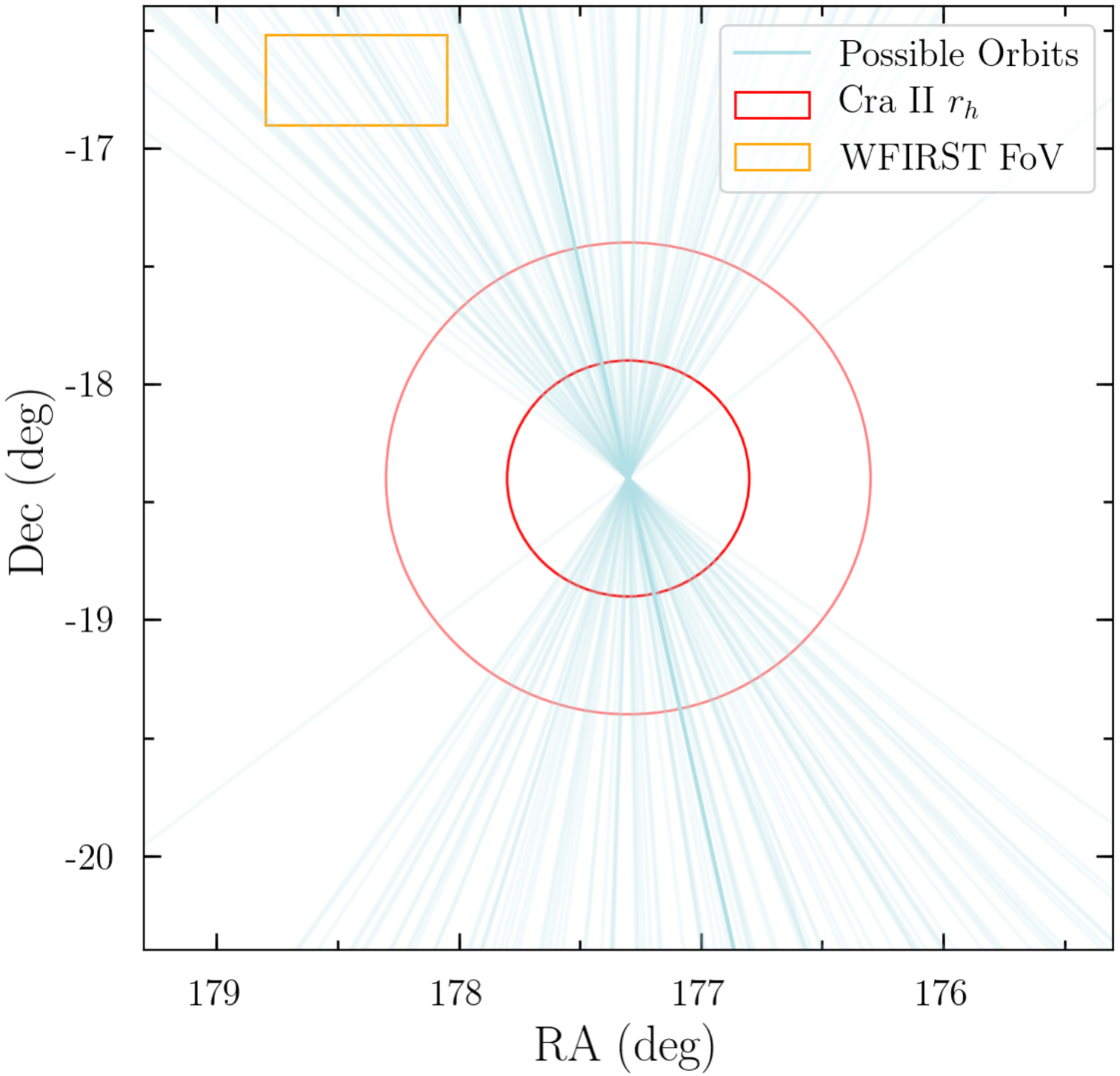


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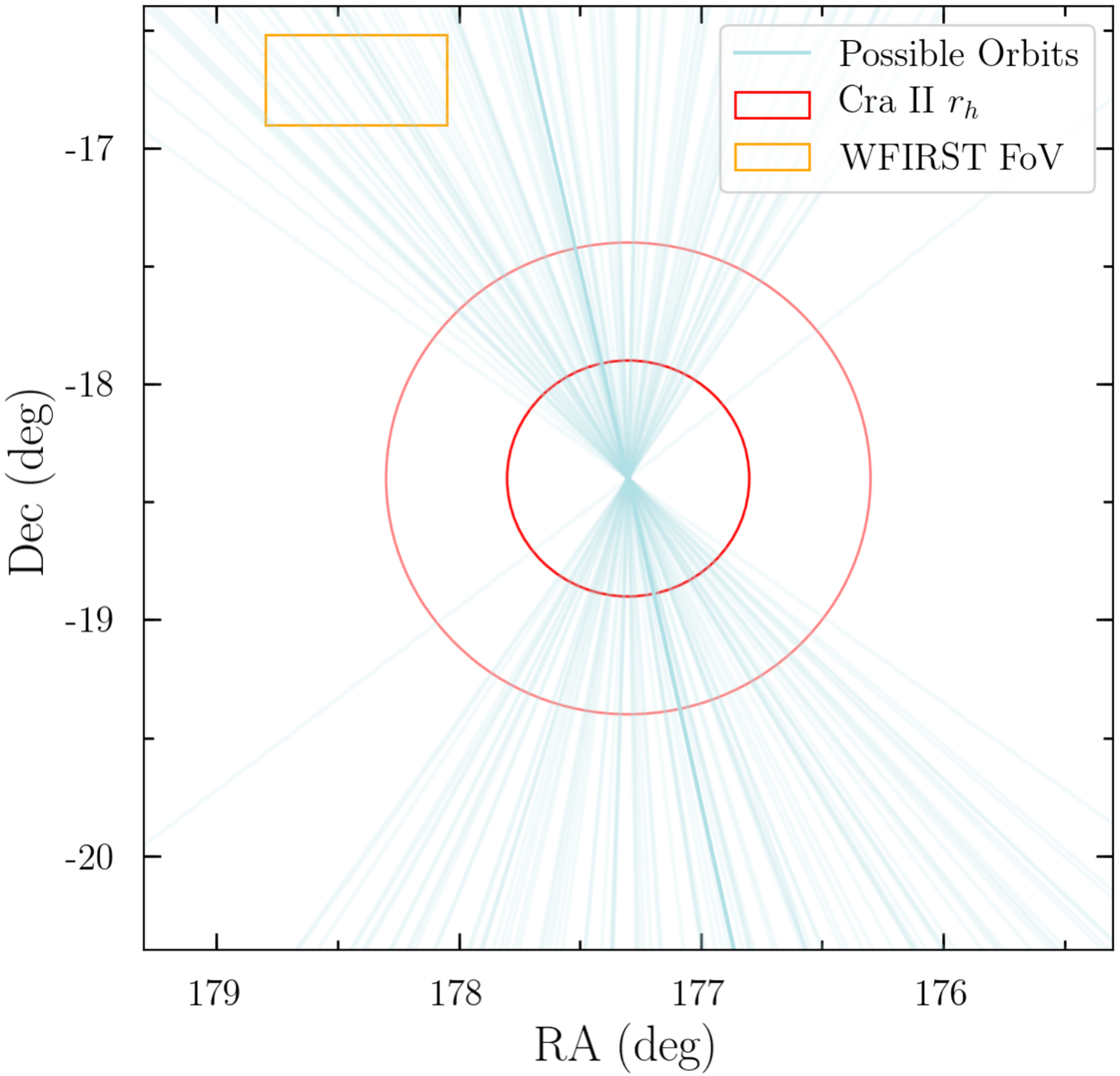


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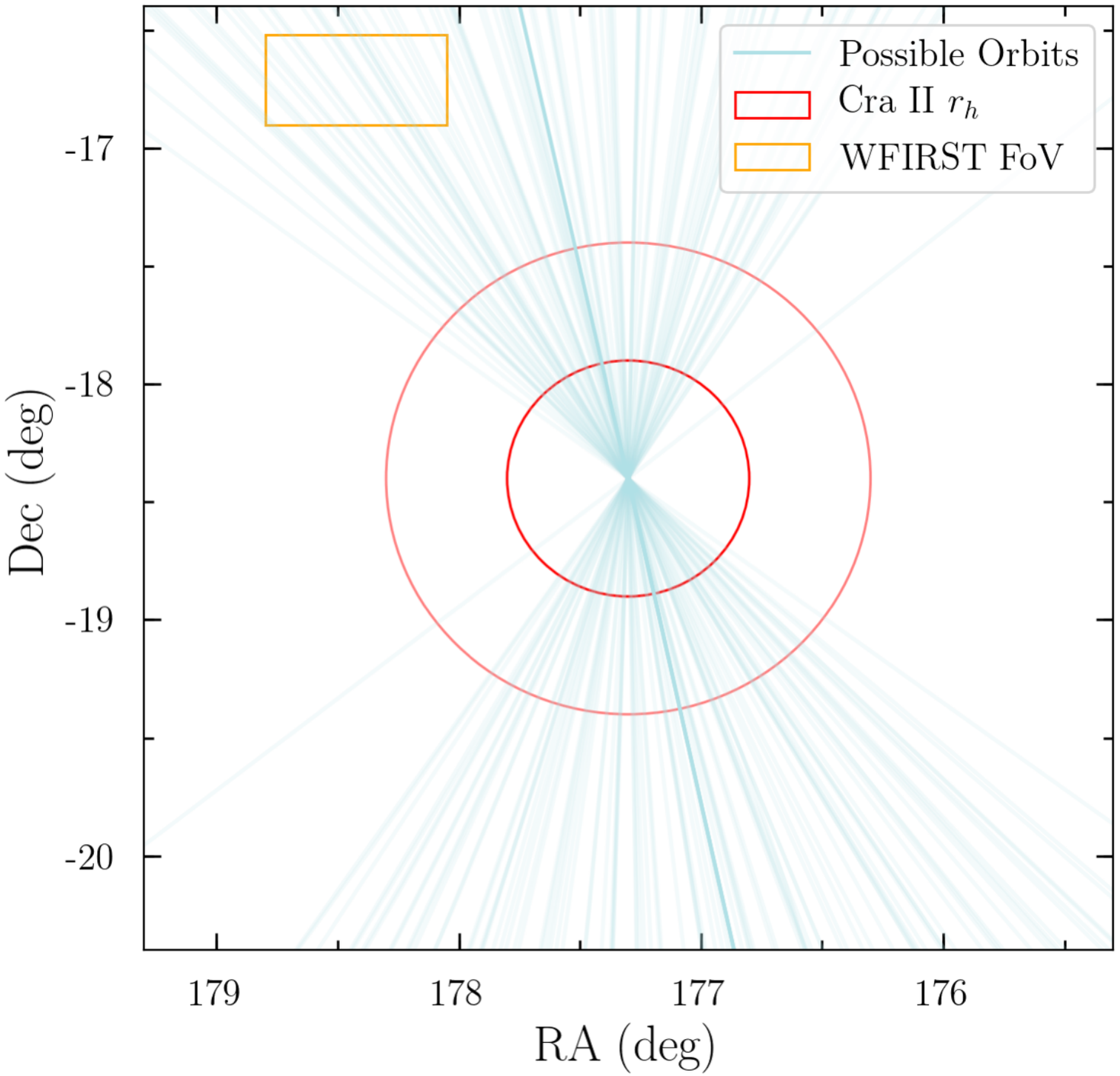


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# Conclusions

- Large-scale photometric + astrometric surveys are expanding our census of low surface-brightness MW satellites

- We can explain the diffuse, underdense ("feeble") properties of Cra II under LCDM as the remnant of a tidally stripped cored dark matter halo

  - New lines of inquiry re: how tides complicate DM particle inference from halo properties (e.g. Amorisco19, Broadhurst+19, Kahlhoefer+19, Errani+19)

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# Back-up slides

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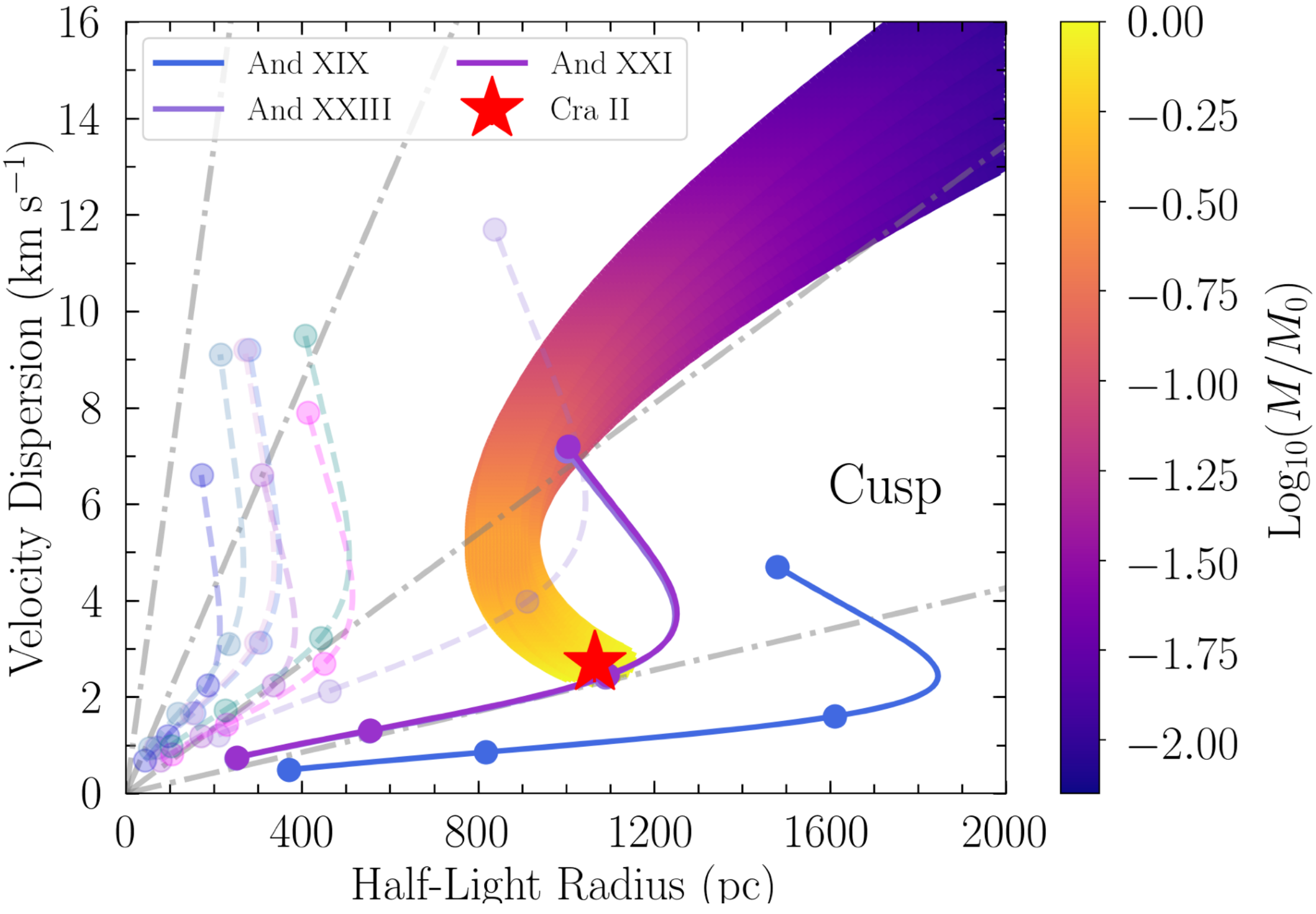
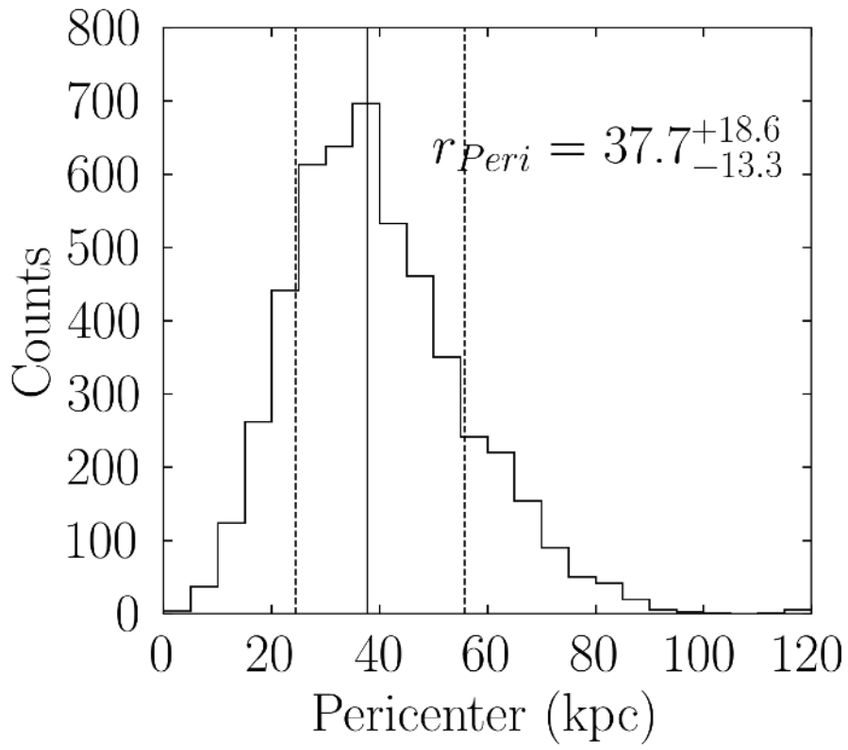
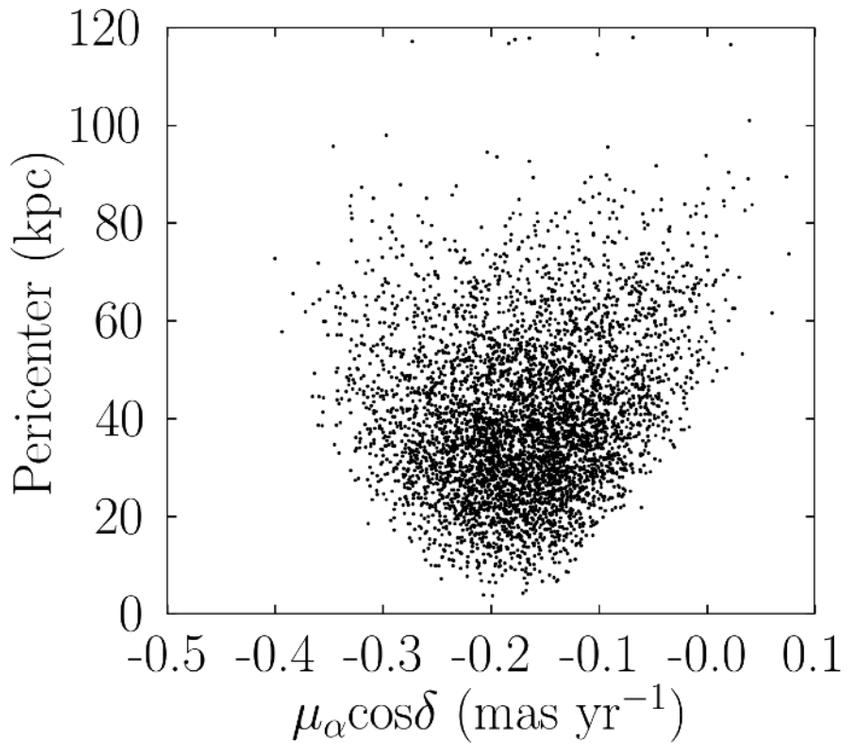
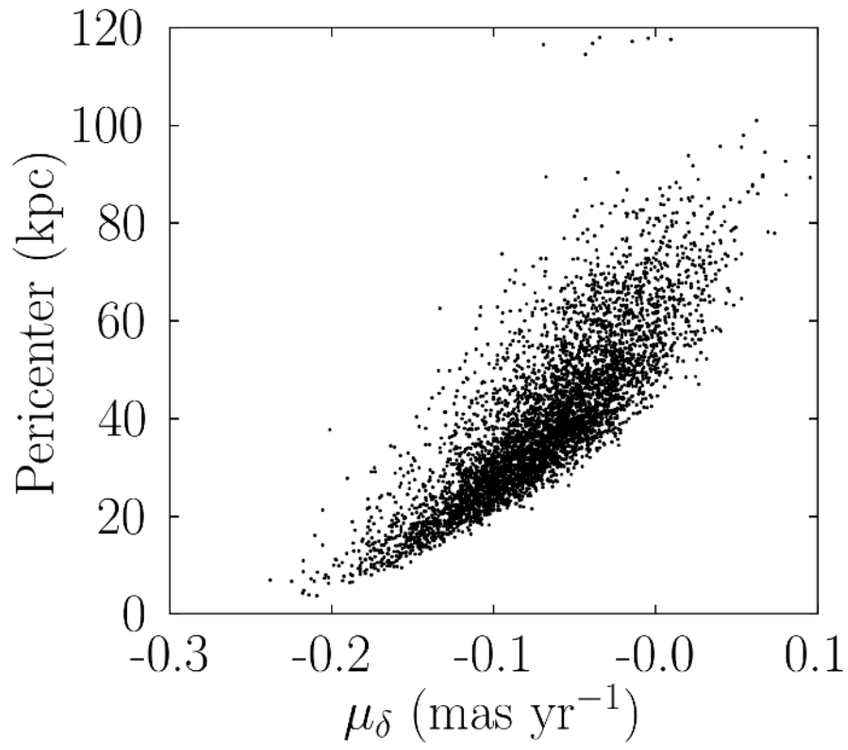


# Pericenter-Proper Motion Correlations

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