How Gaps Grow in Tidal Streams

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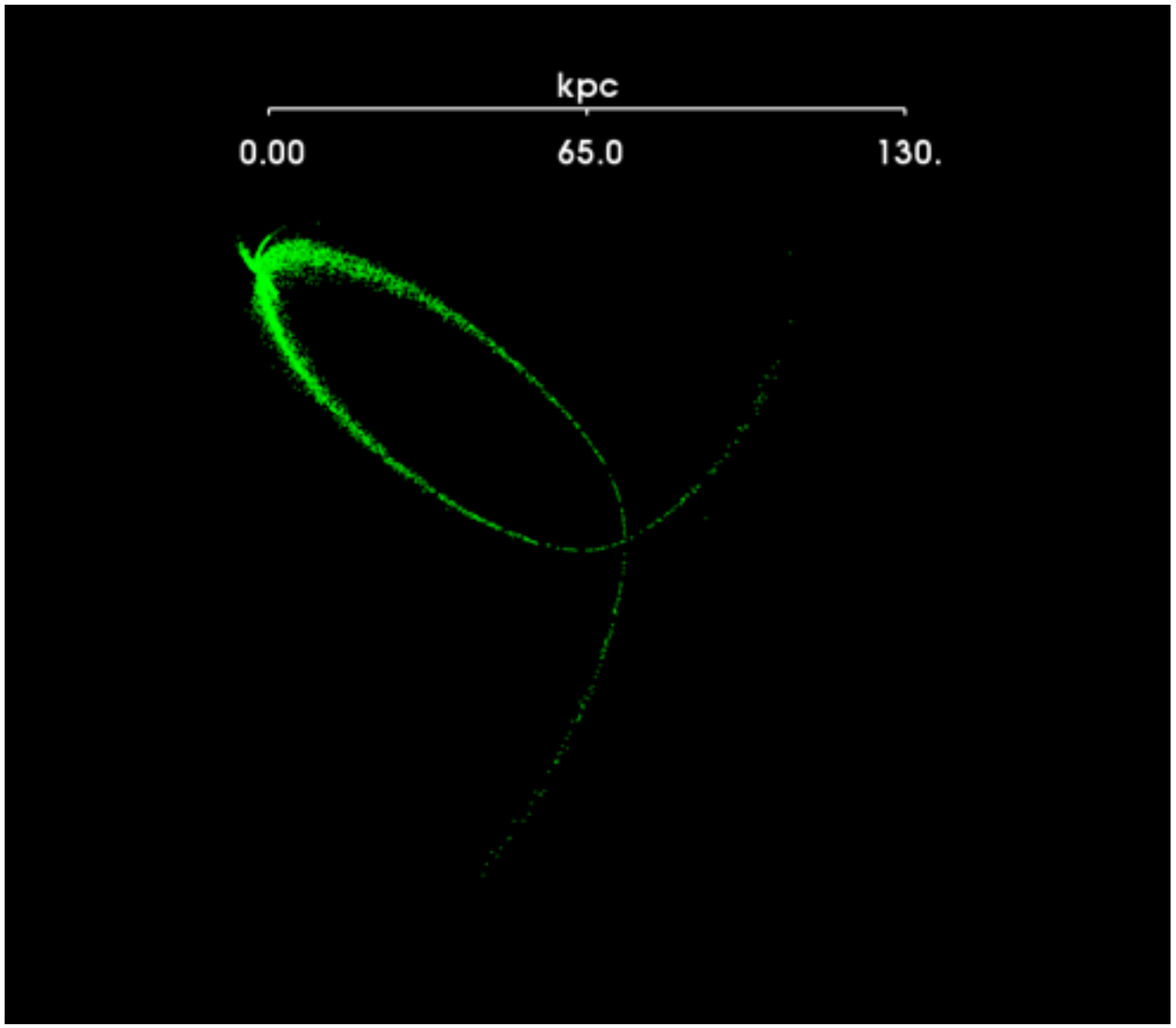
Institute of Astronomy, Cambridge

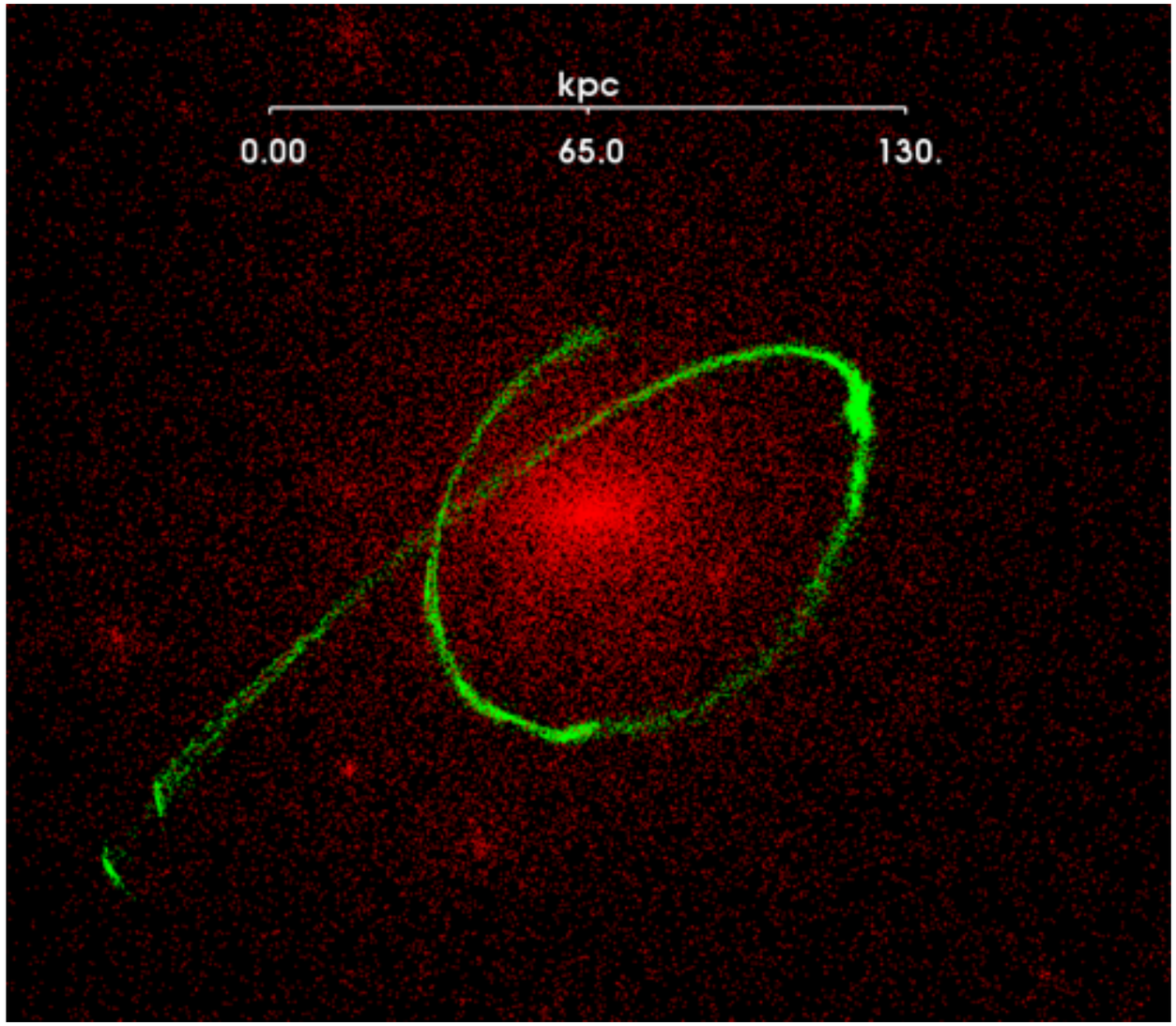
Milky Way and Its Stars, KITP, 2015

Erkal & Belokurov 1412.6035

Tidal Streams



Smooth Potential



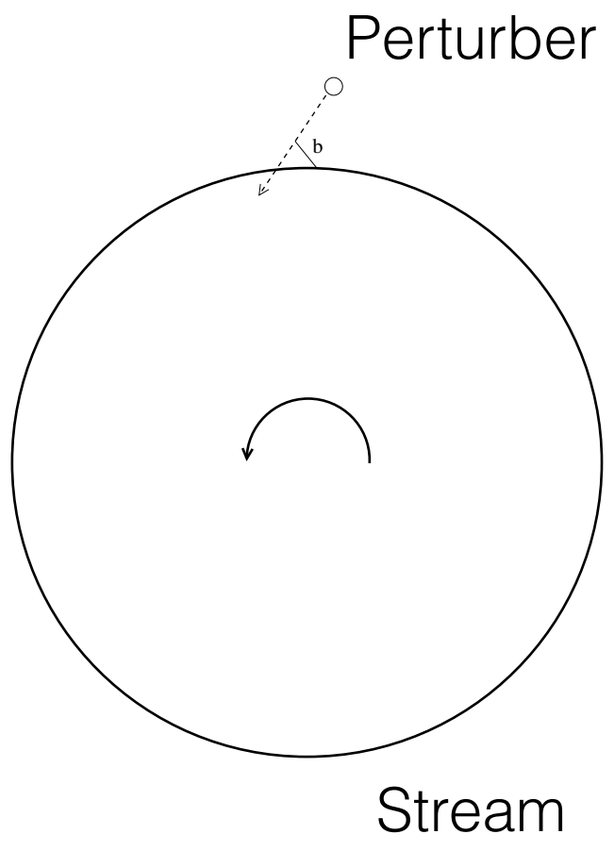
Lumpy Potential

Toy Model

Toy Model

Setup

- Stream on circular orbit
- No position/velocity dispersion
- Plummer sphere perturber
- Arbitrary spherical host potential
- Arbitrary impact geometry



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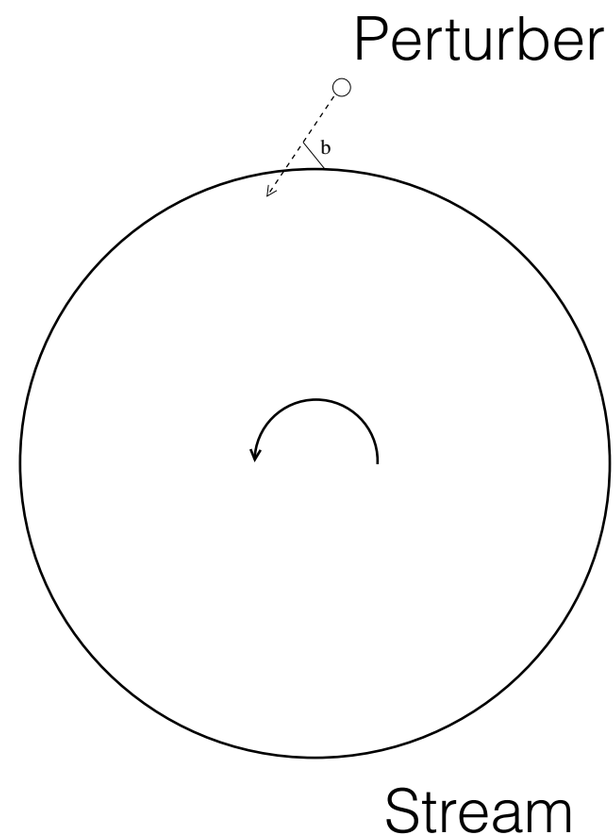

Approach

- Impulse approximation for velocity kicks
- Compute resulting orbits at first order
- Compute stream density
- Similar to Carlberg 2013, Yoon, Johnston, Hogg 2011

Cartoon of Gap Formation

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Orbital Mechanics 101

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aka Football in Space

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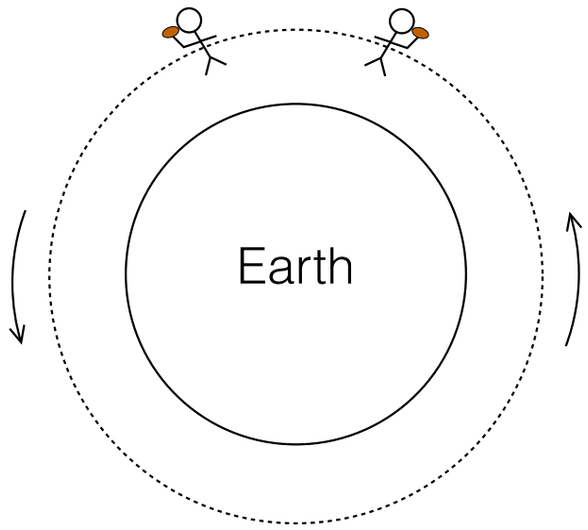

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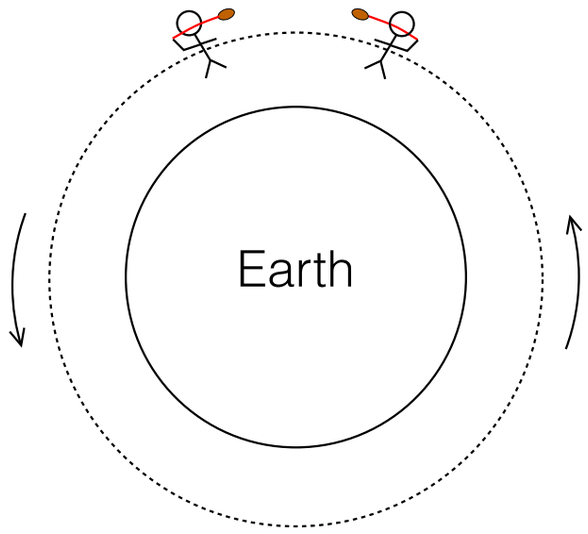

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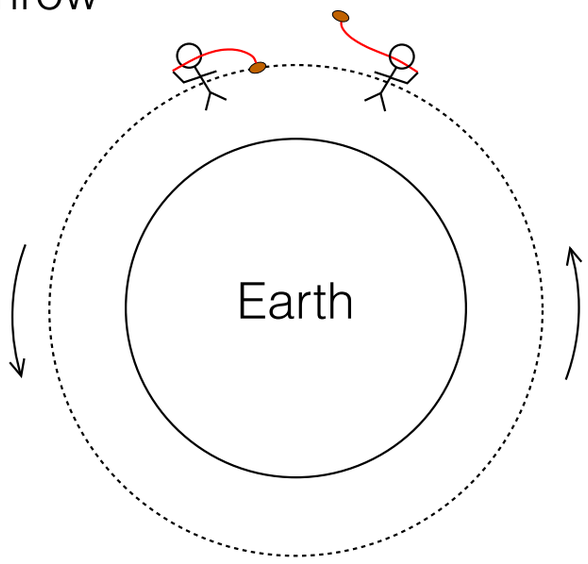

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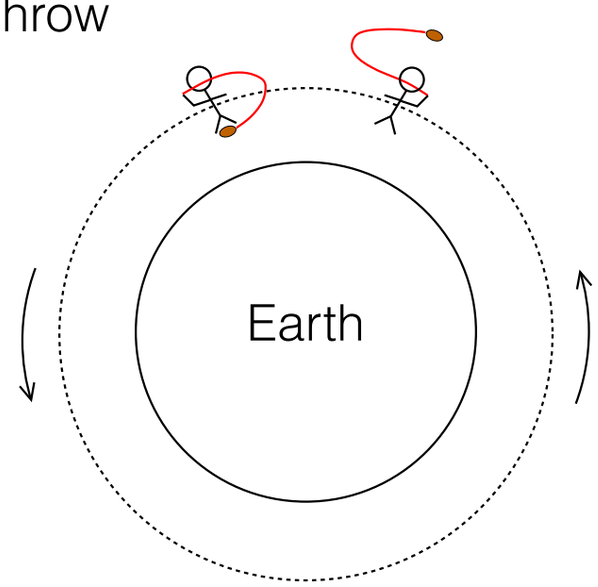

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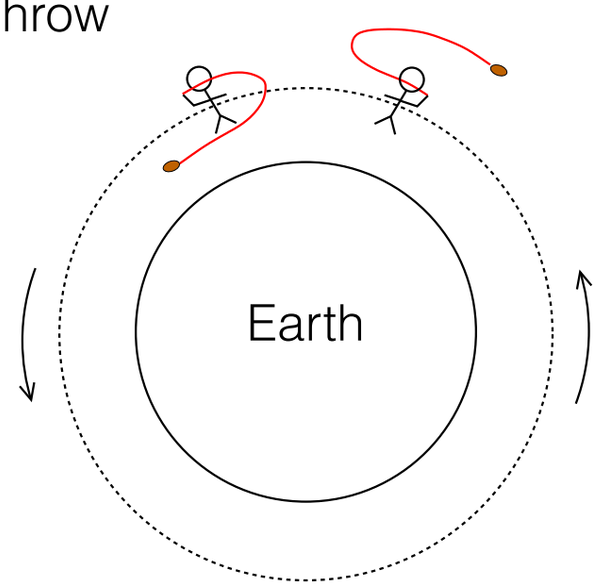

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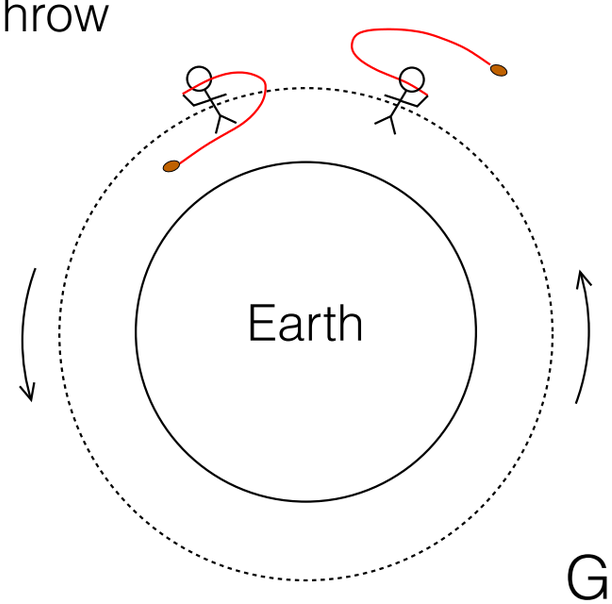

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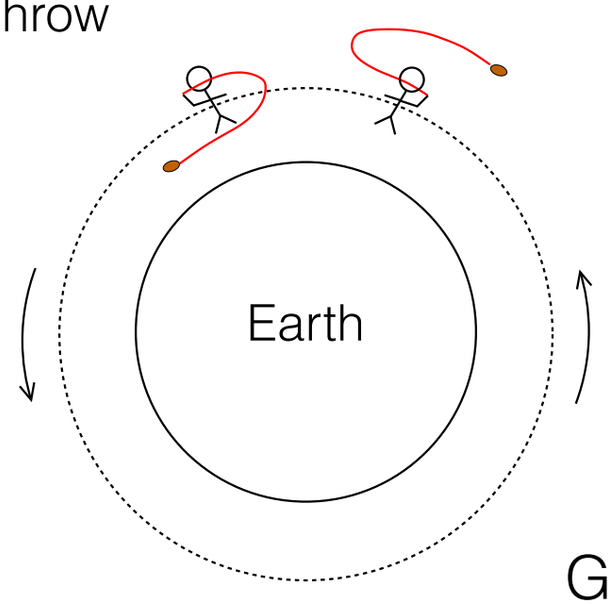

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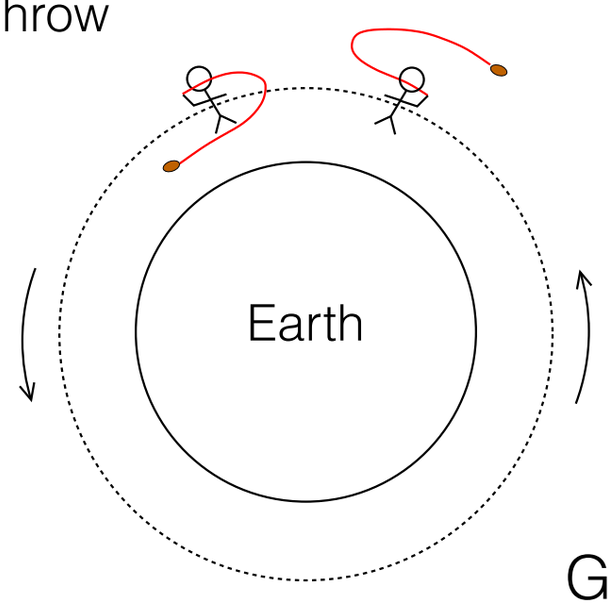

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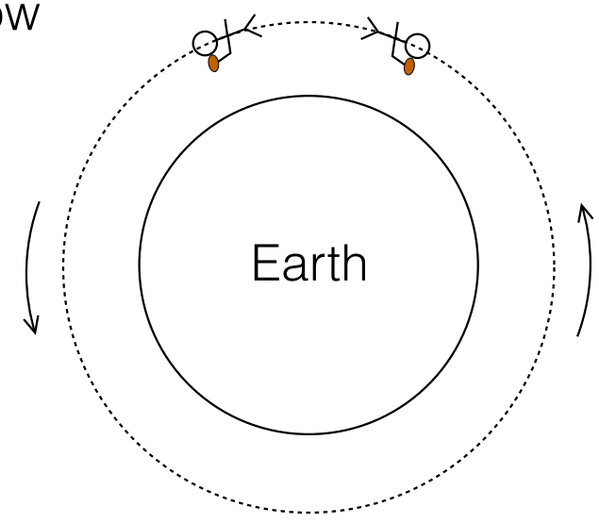

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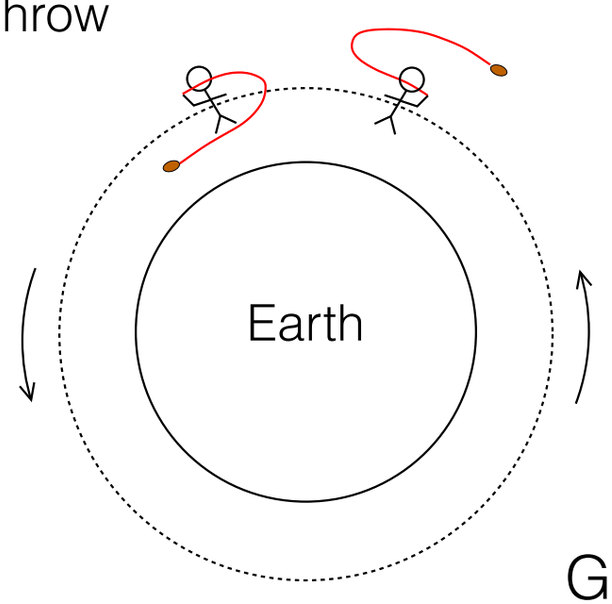

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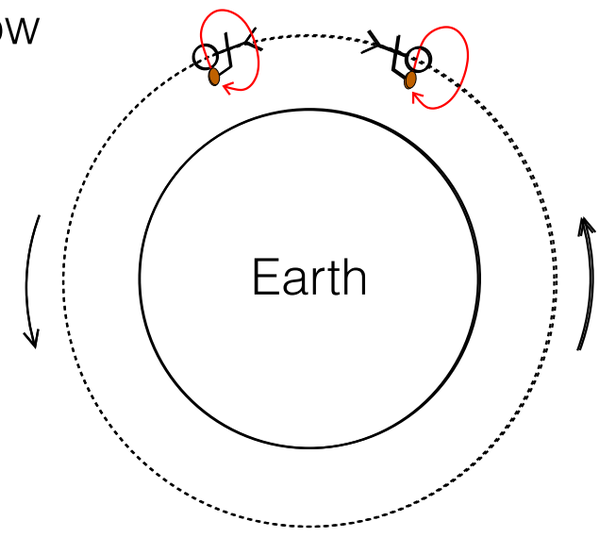

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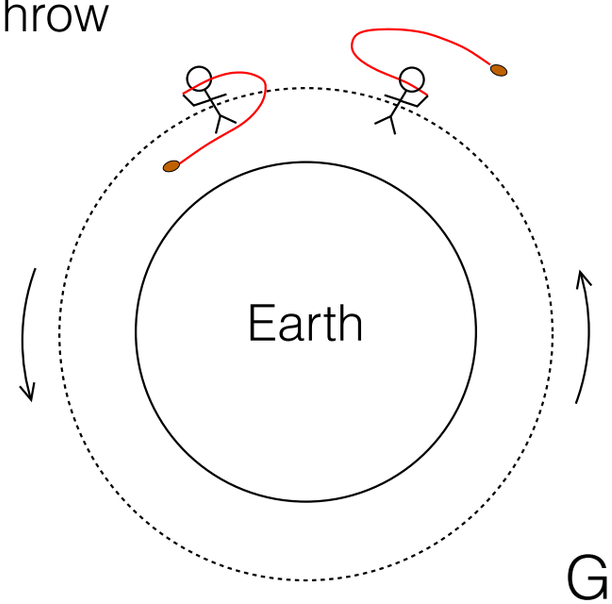

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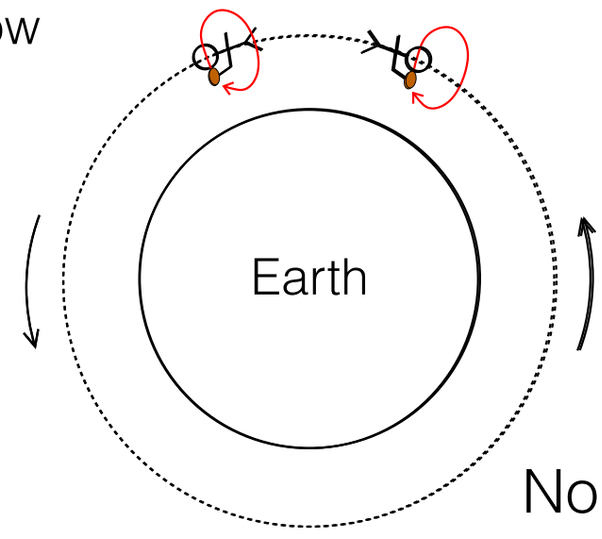

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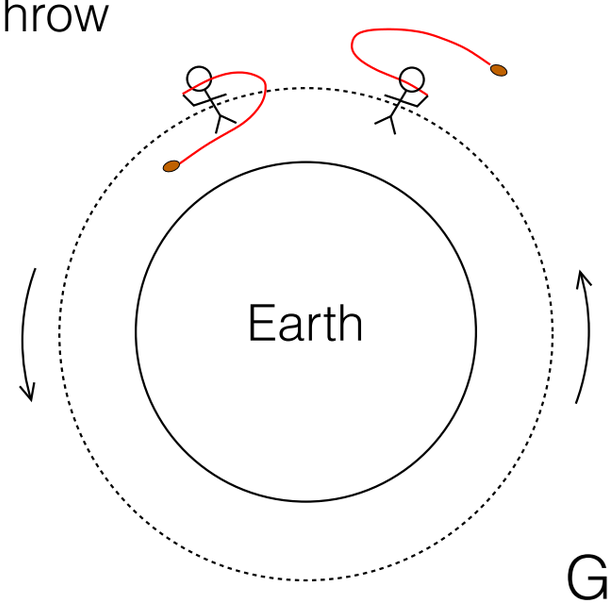

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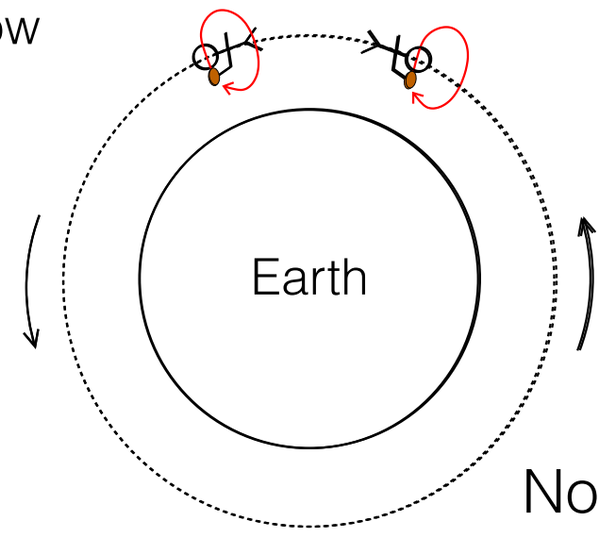

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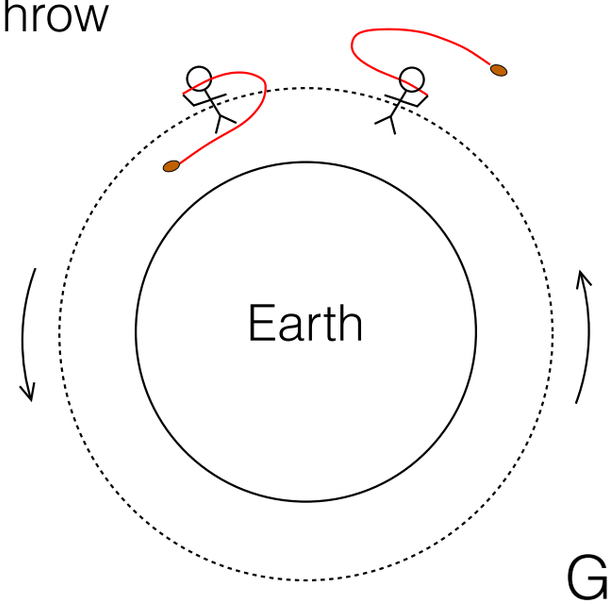

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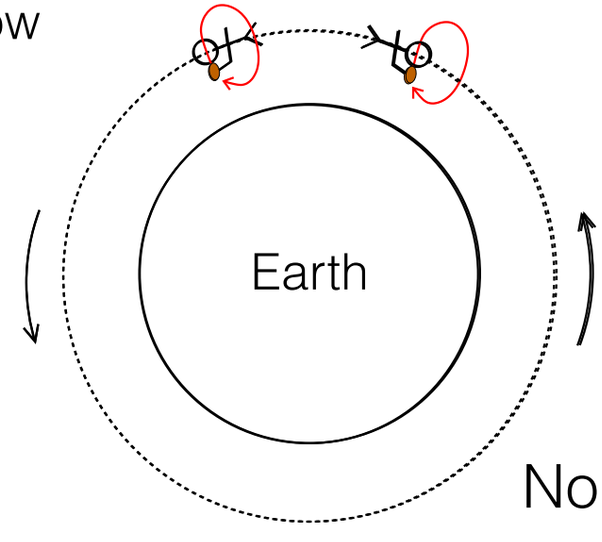

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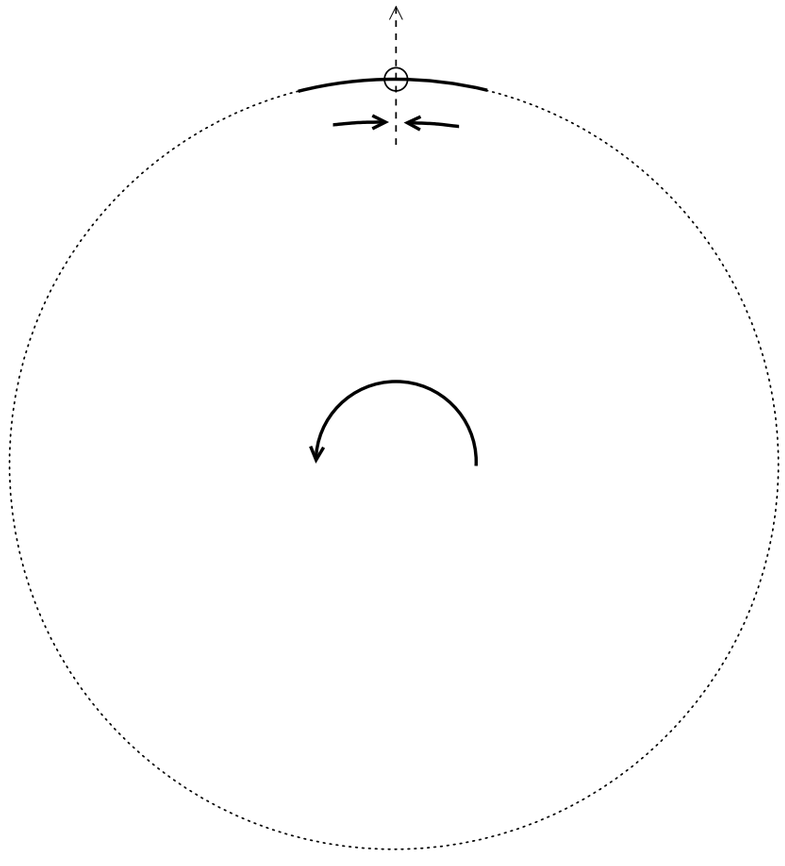
Gap Formation (also in Space)

1) Flyby



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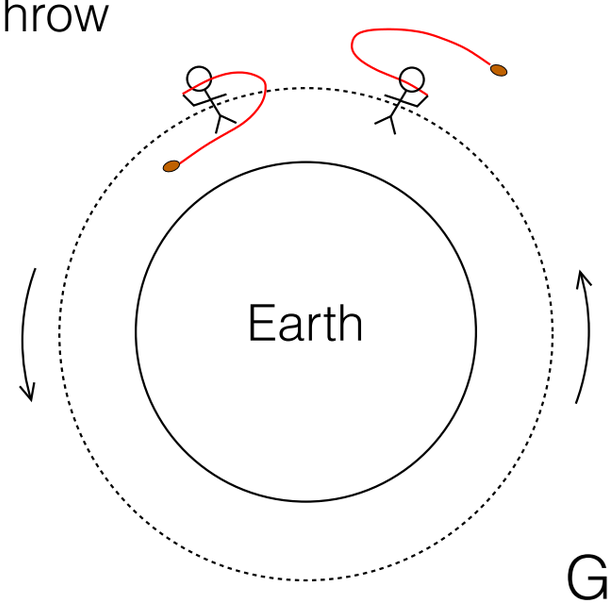

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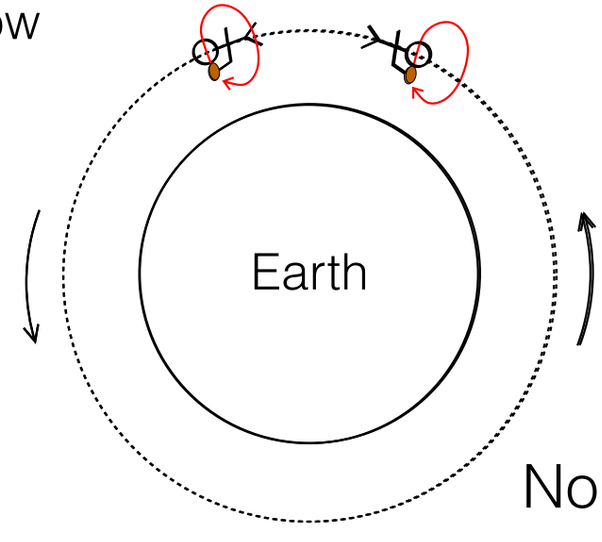

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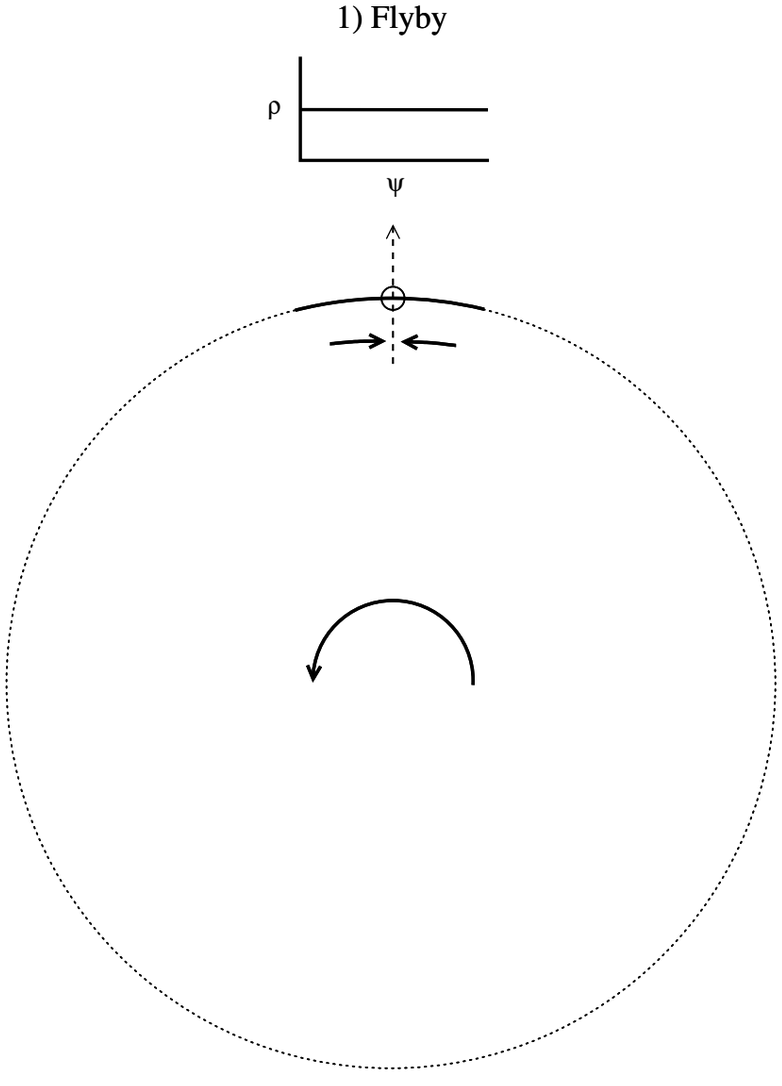

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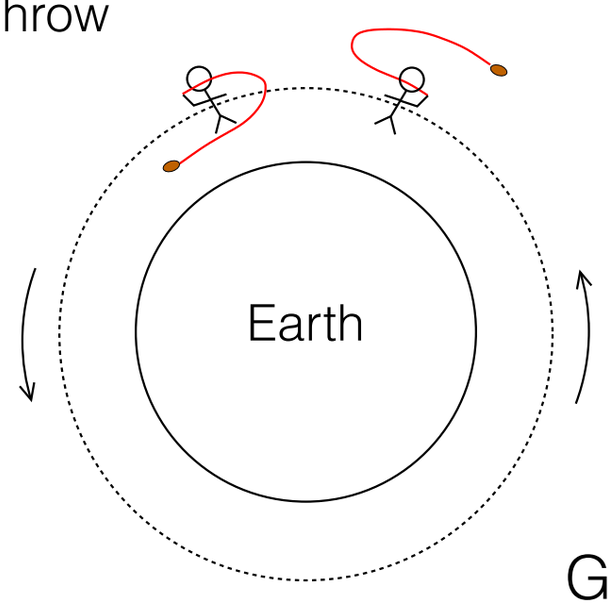

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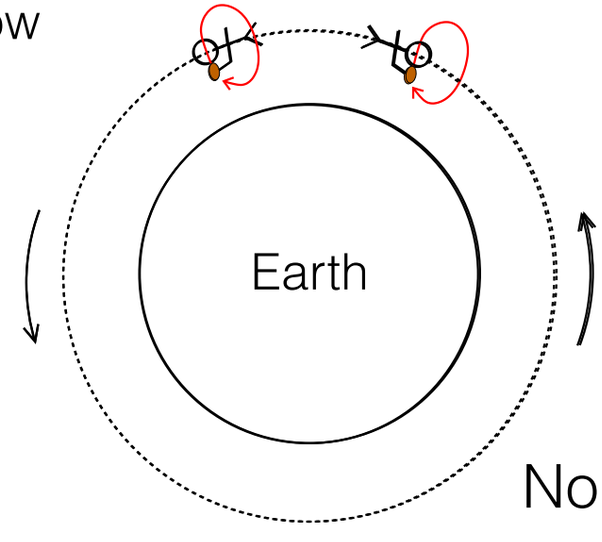

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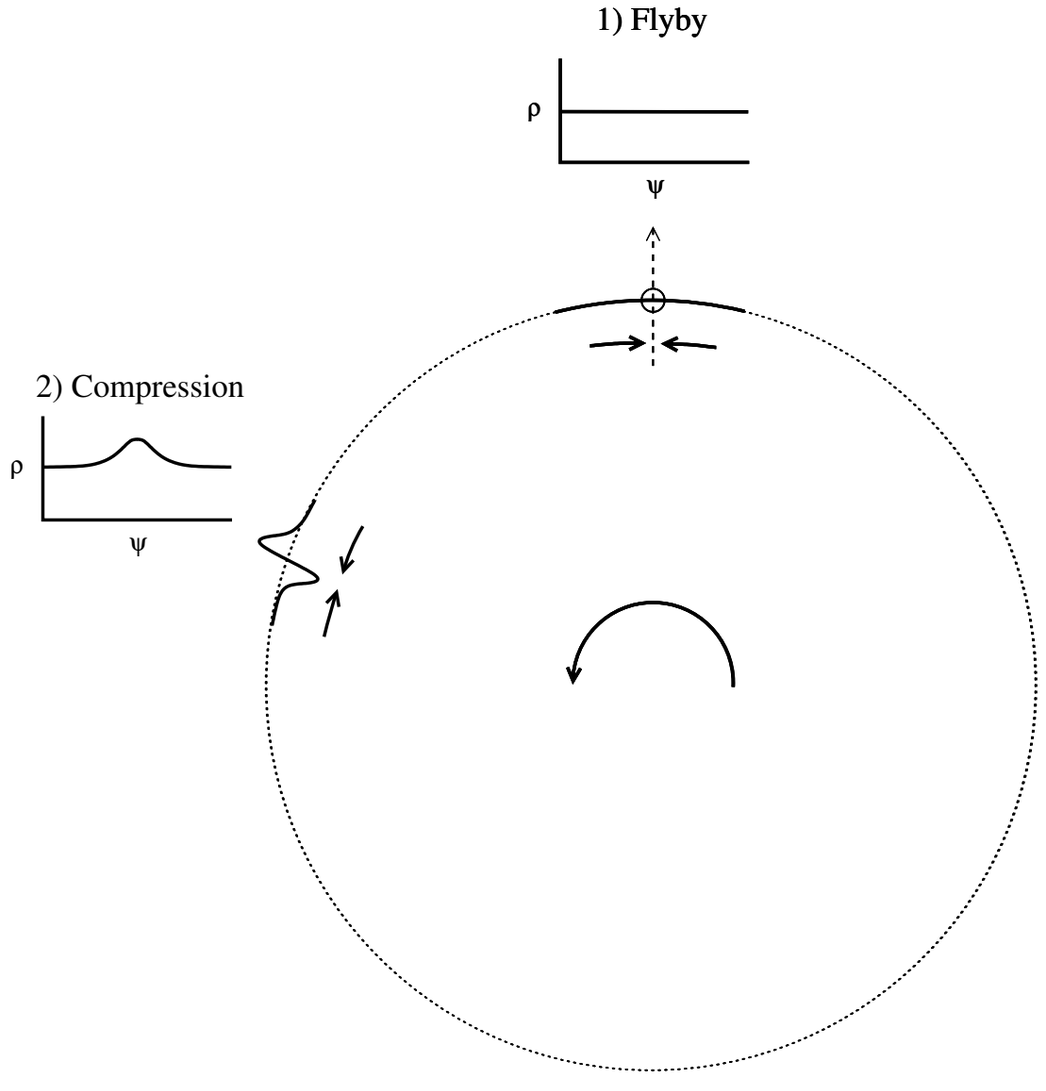

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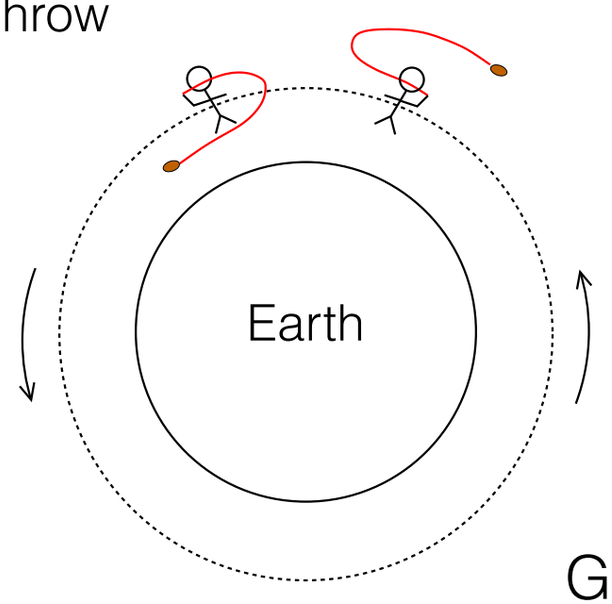

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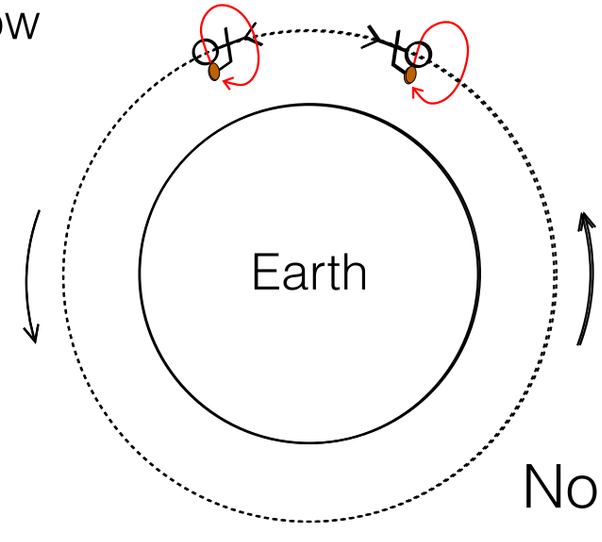

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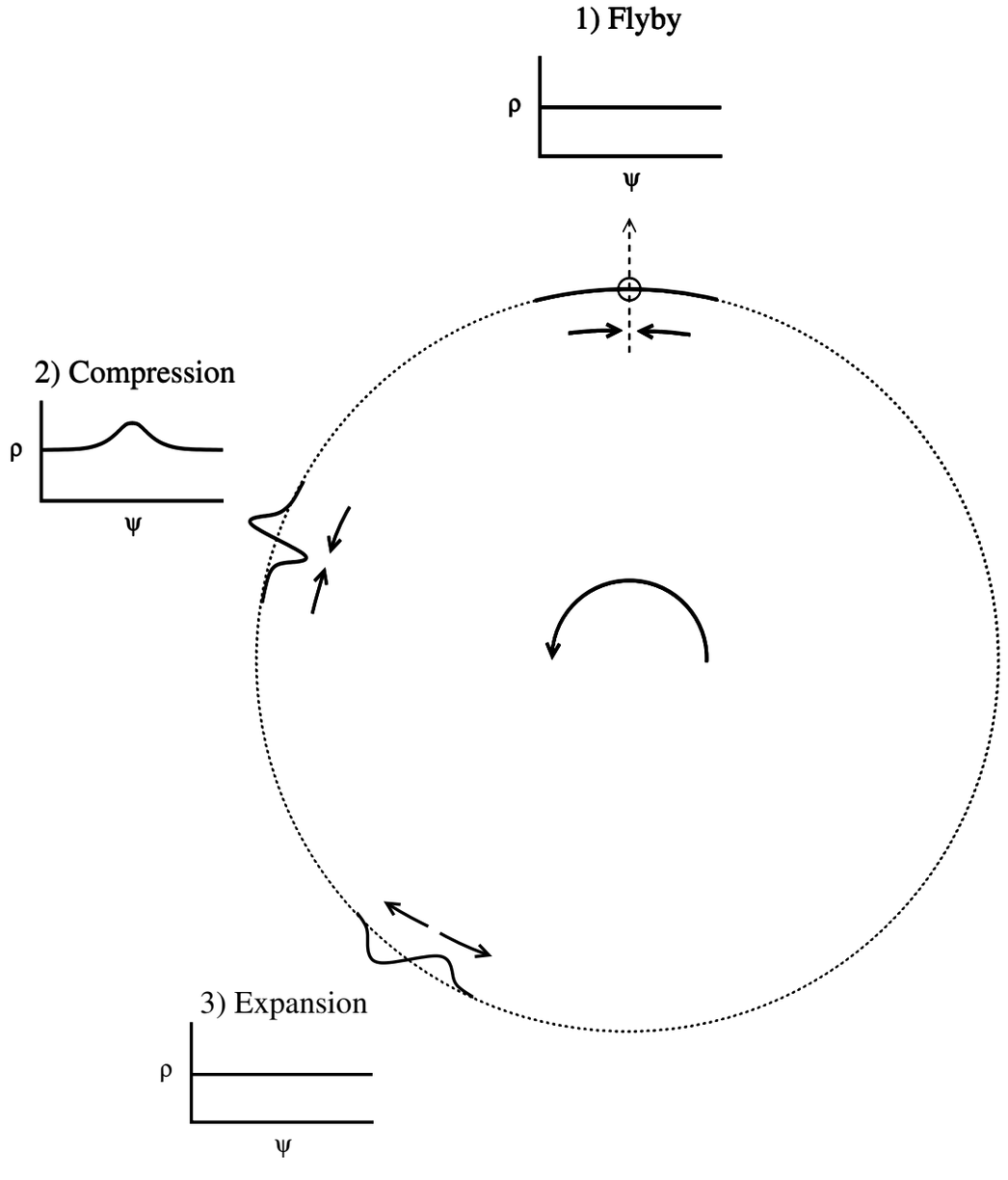

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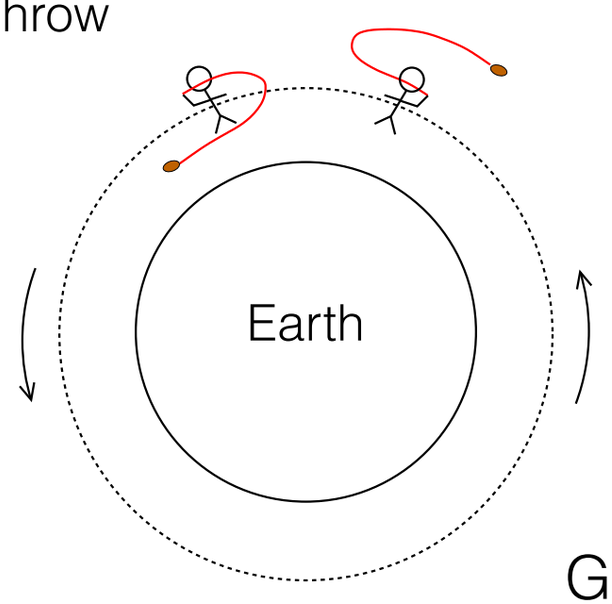

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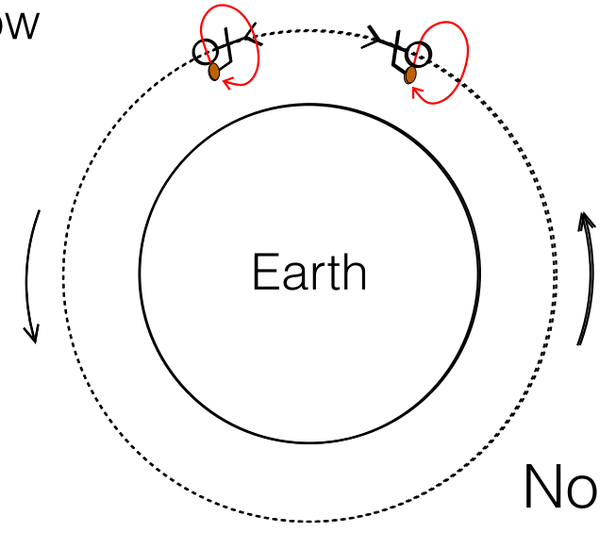

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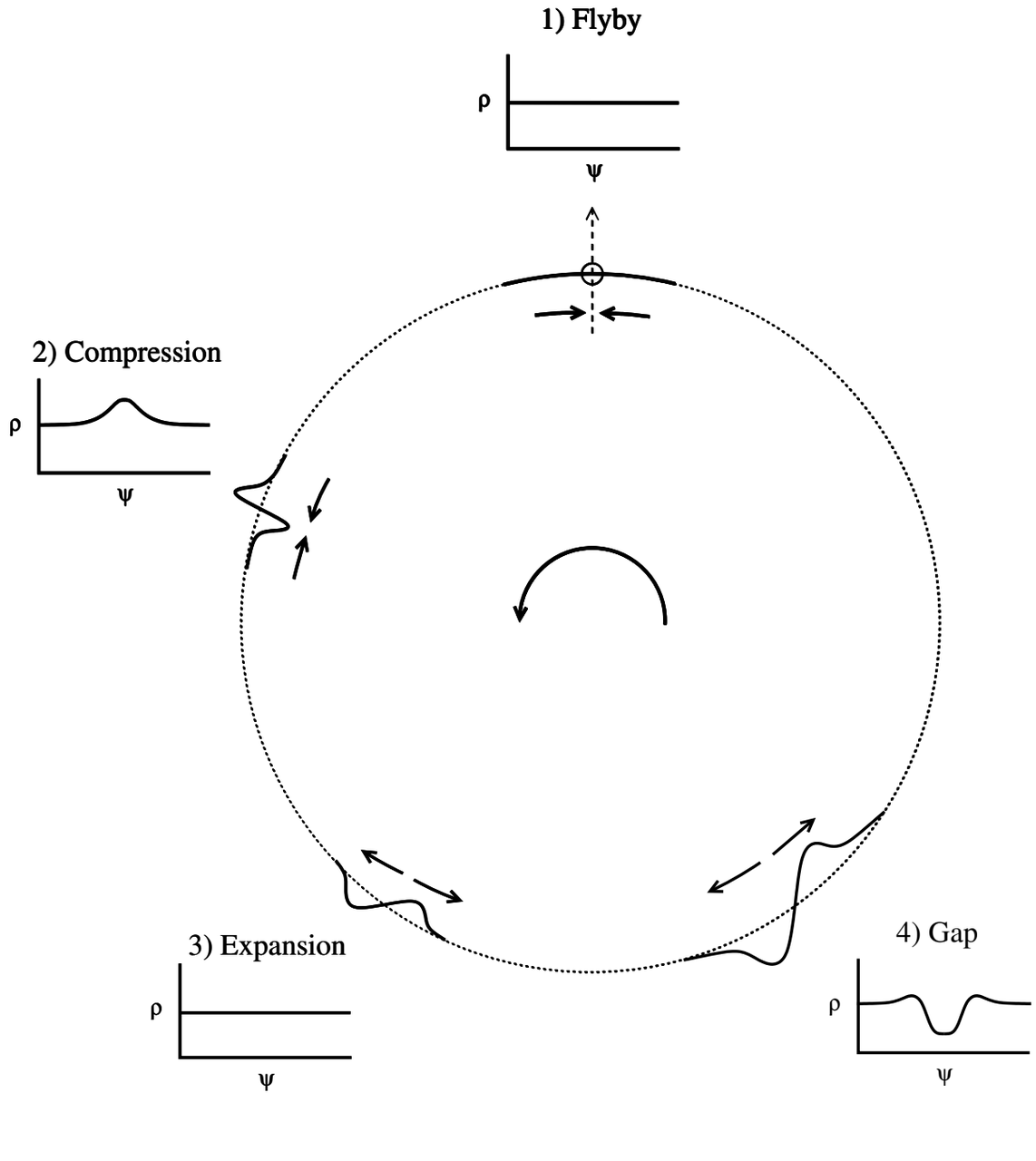

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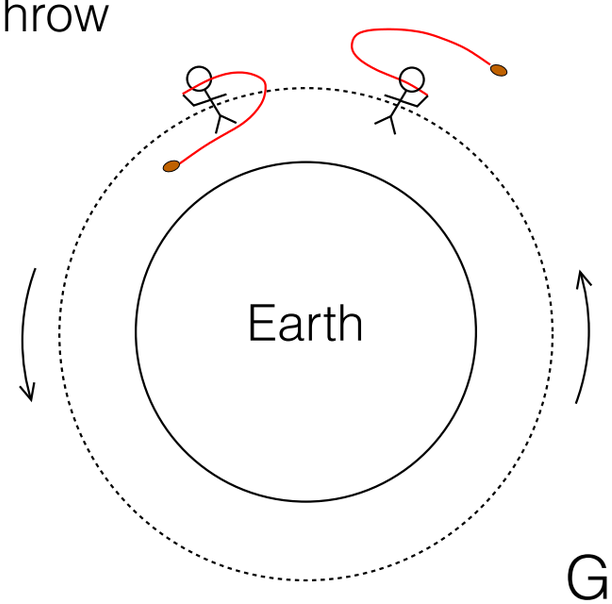

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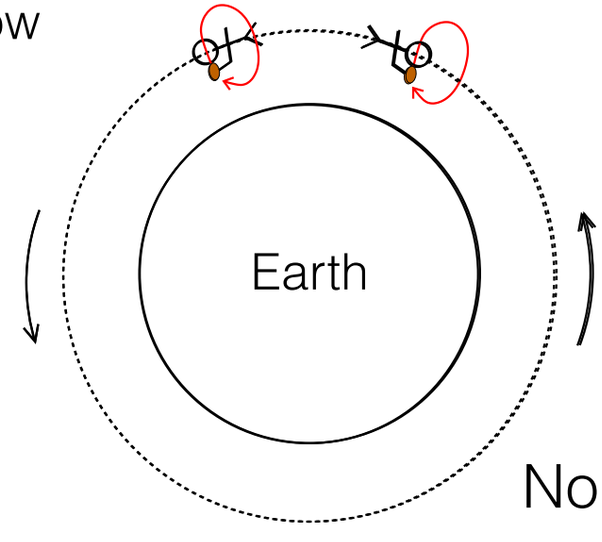

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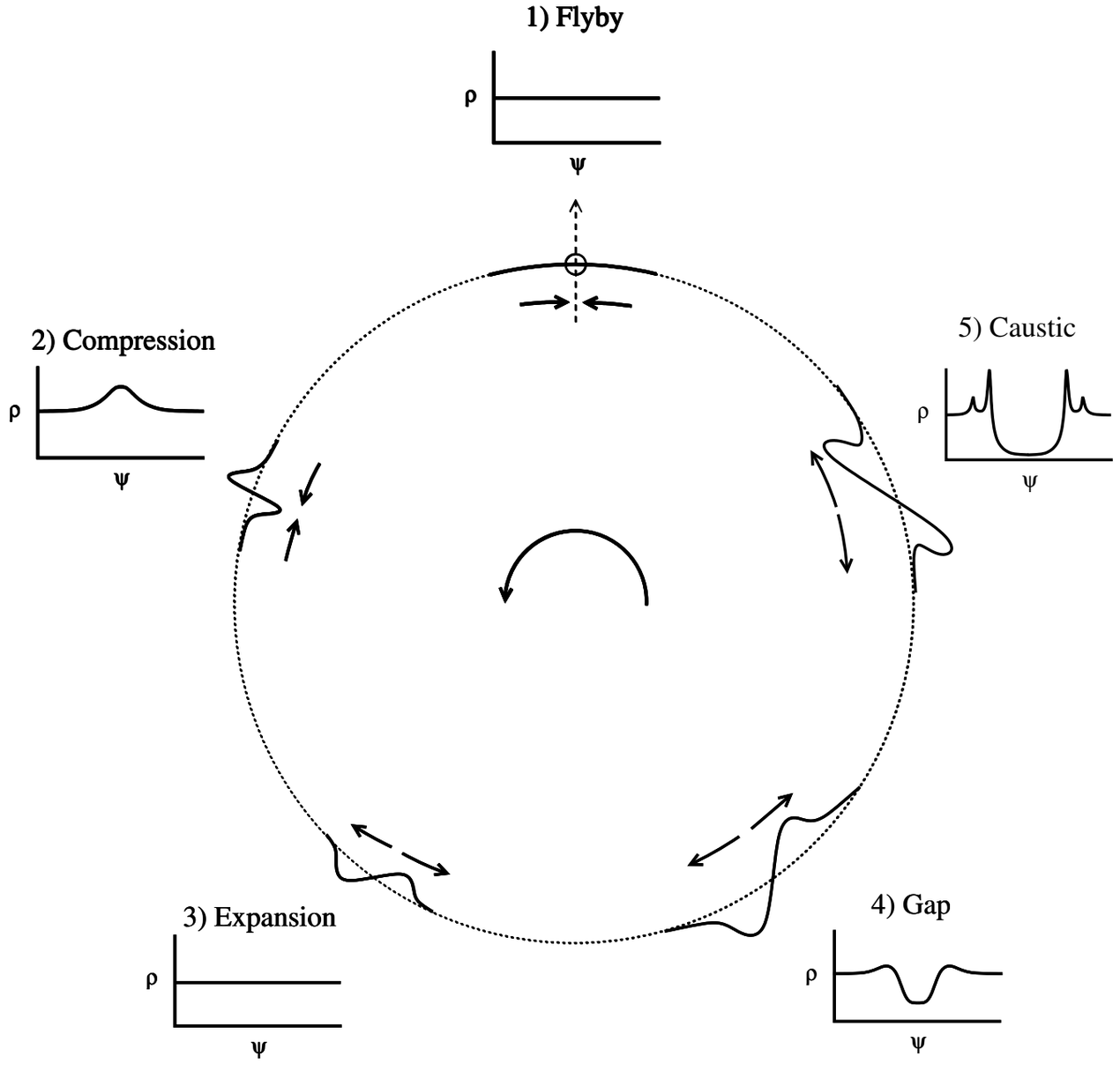

Idealized Example

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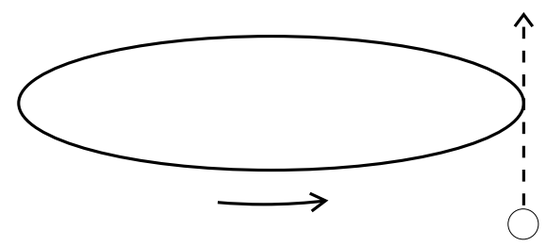
- Circular orbit at 30kpc, 190km/s
- Keplerian host potential
- 10^7 $M_\odot$ Plummer sphere, 250pc scale radius
- Direct impact



- 10^6 particles in Gadget-3

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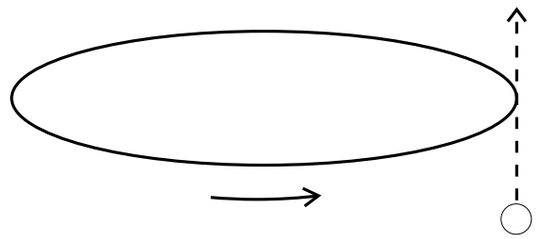

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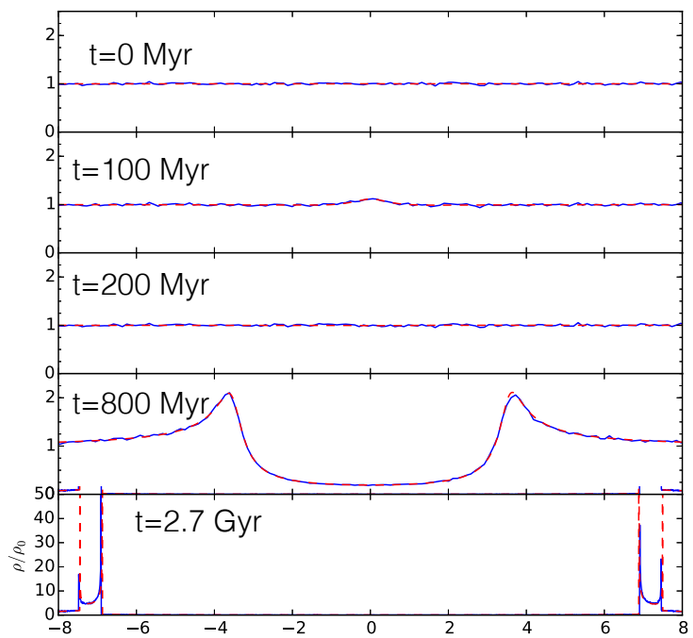
Density along stream



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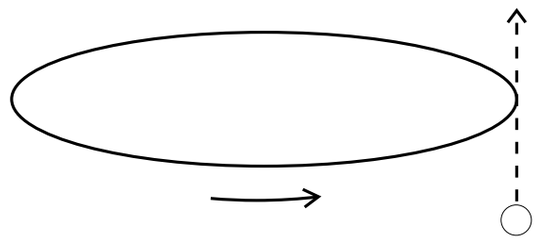

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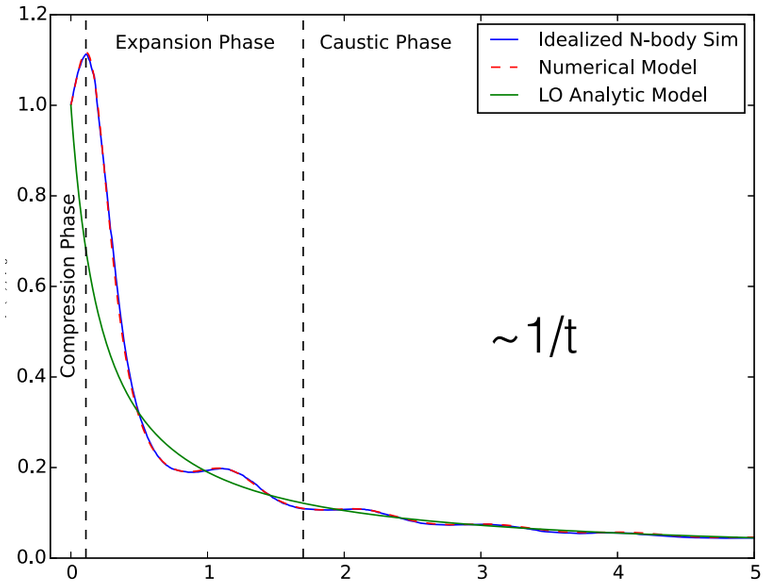

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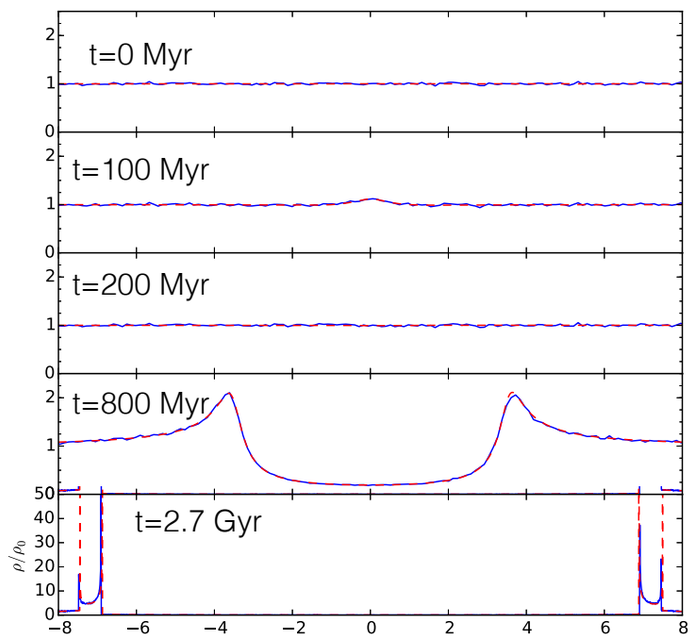

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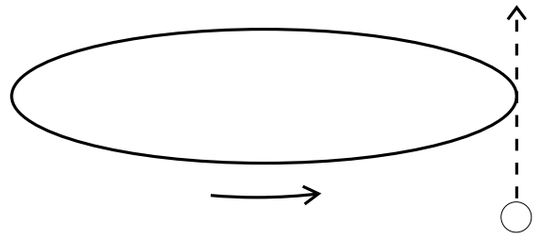

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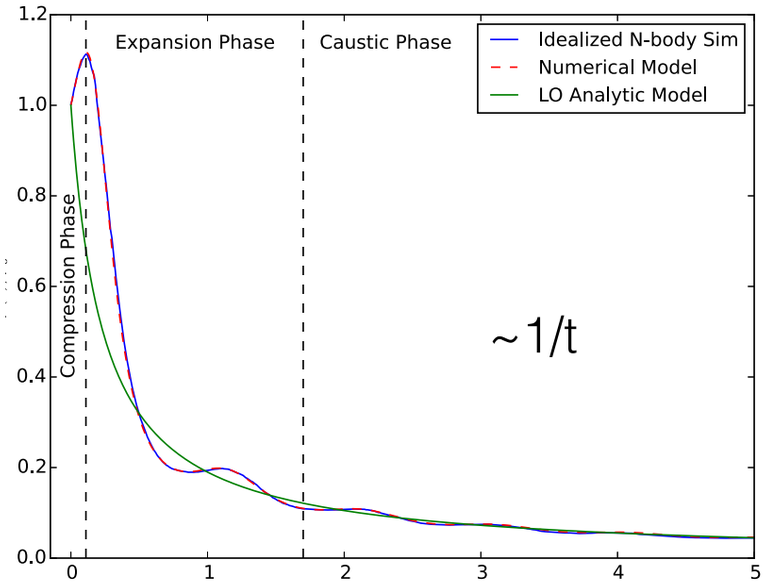

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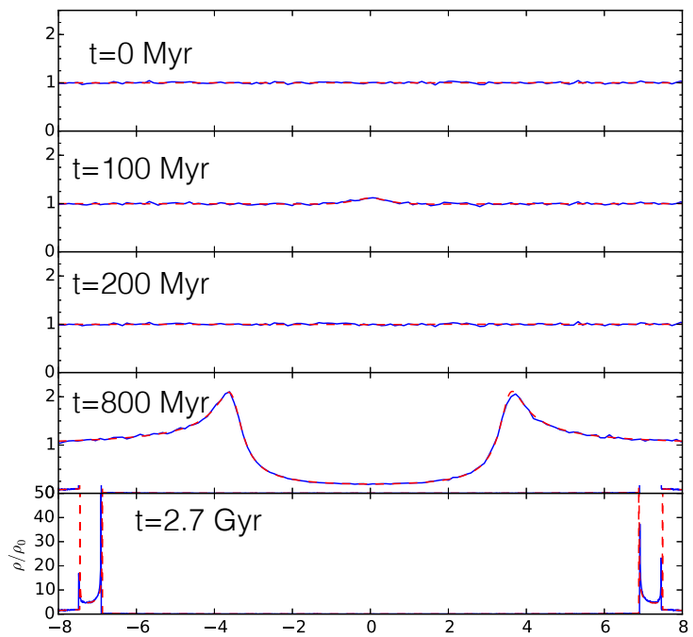
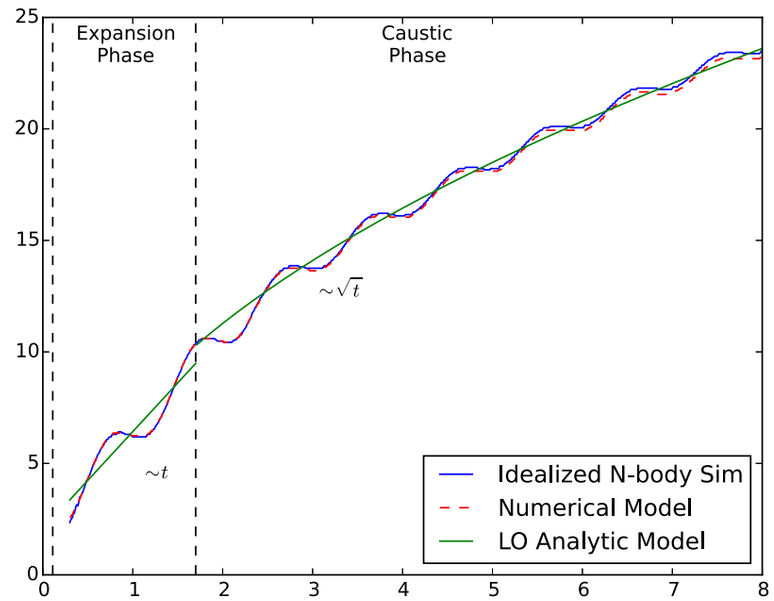


Gap size (°)



Realistic Example

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- Stream generated by progenitor on circular orbit at 10kpc
- NFW host potential
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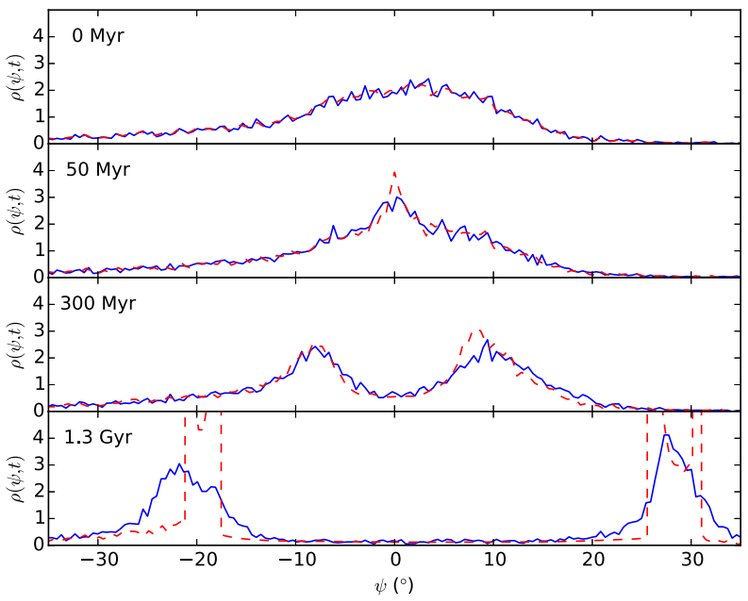

Sky angle (°)

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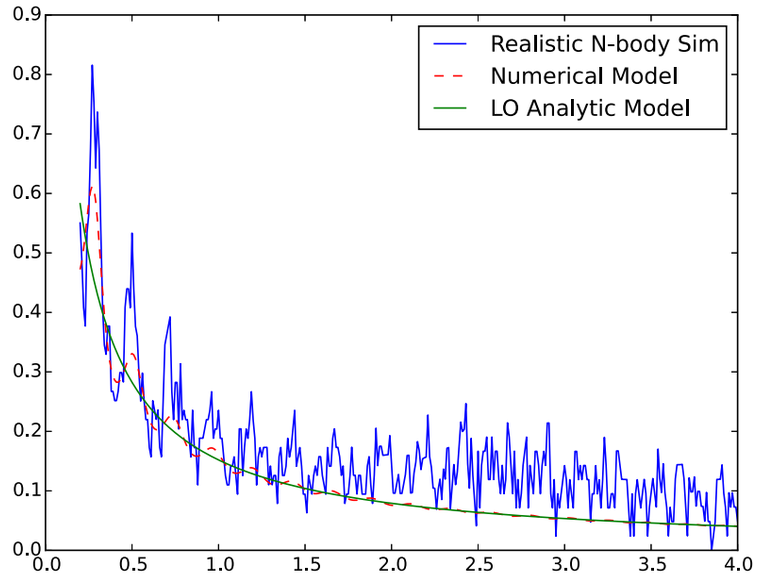
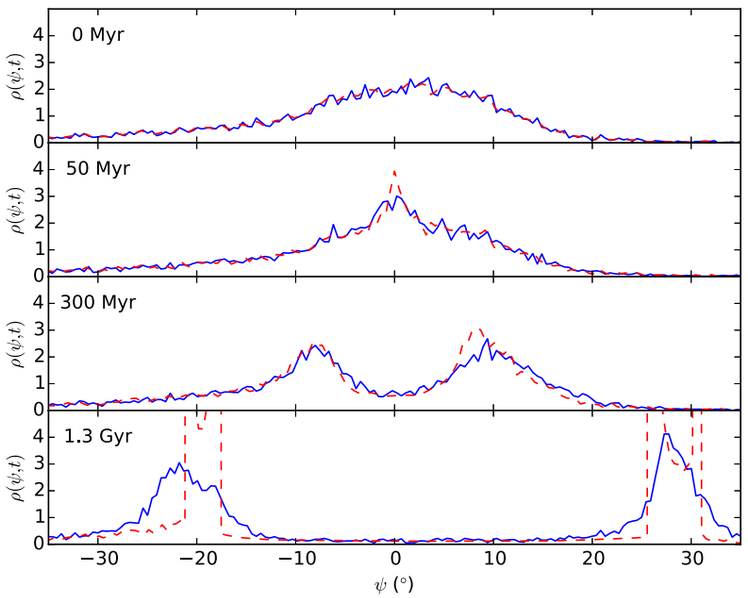


Time in Gyr

Density along stream



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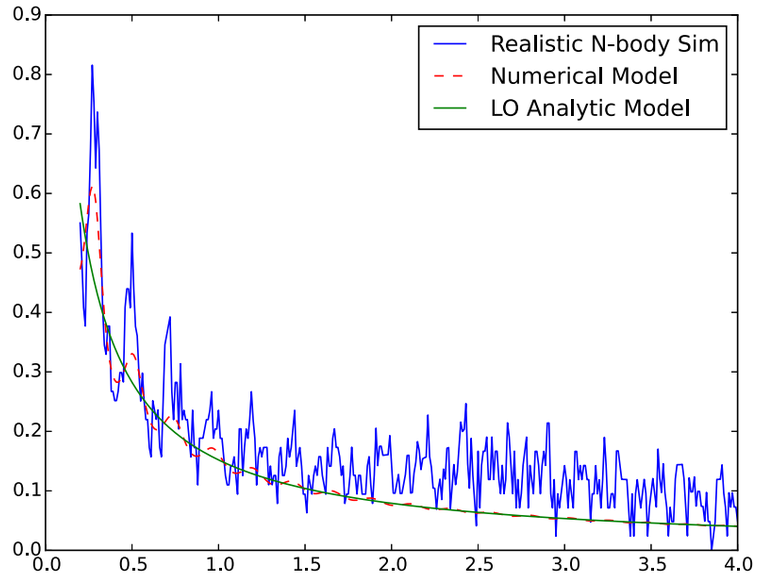

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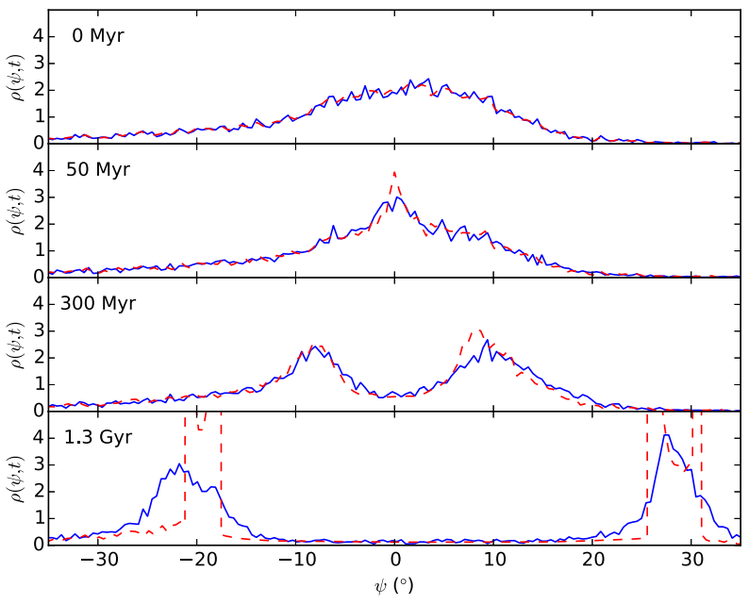
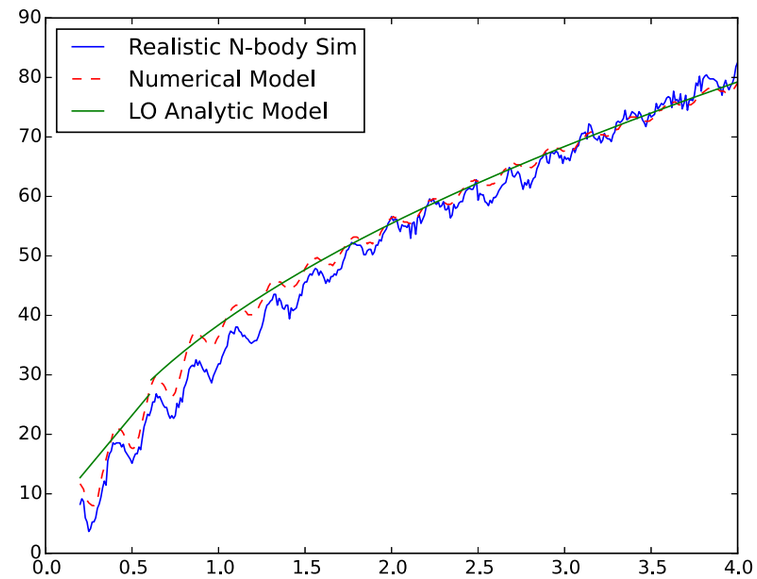


Sky angle (o)

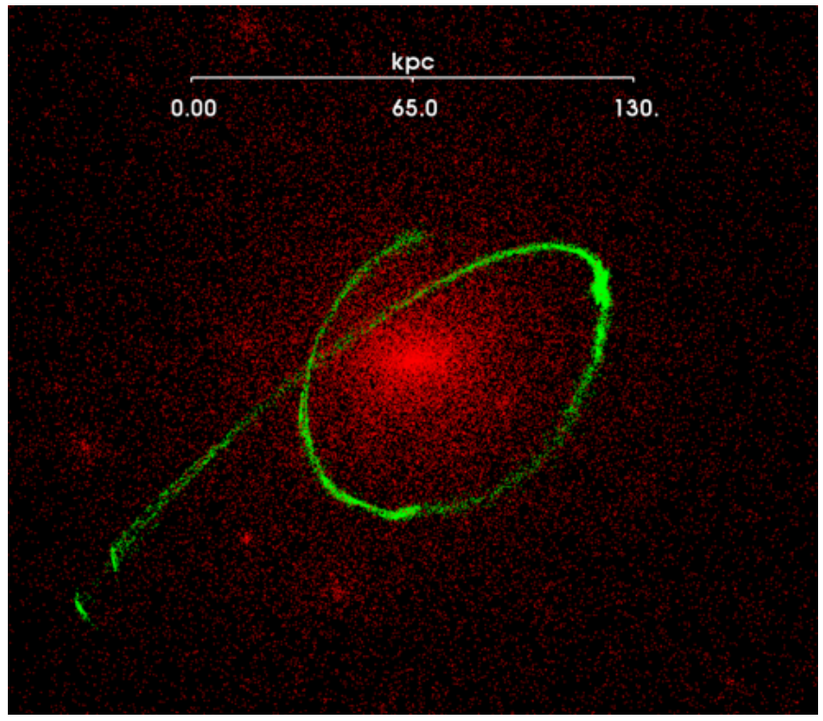
Gap size (o)



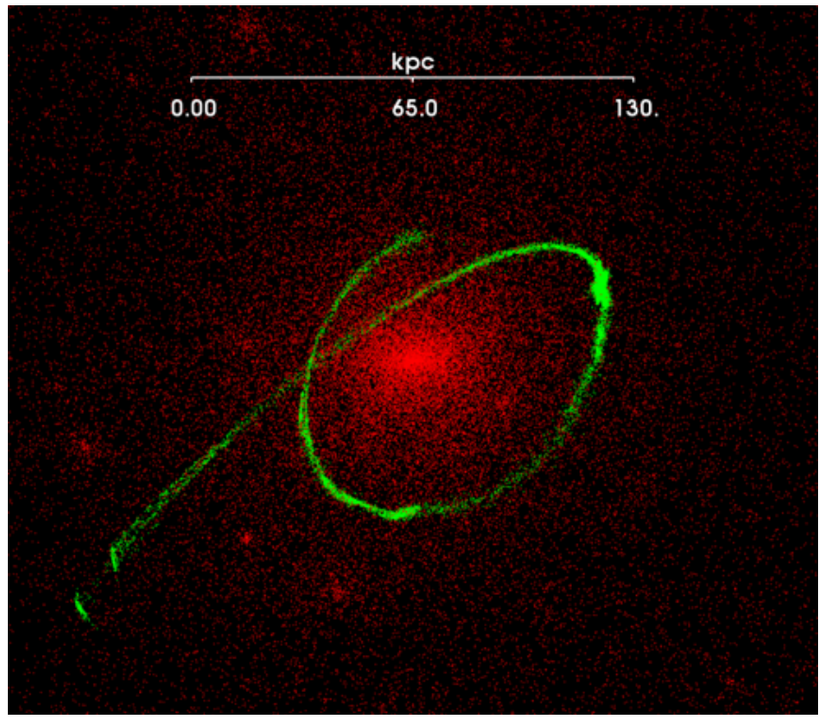
Time in Gyr

Recovering Subhalo Properties

Recovering Subhalo Properties

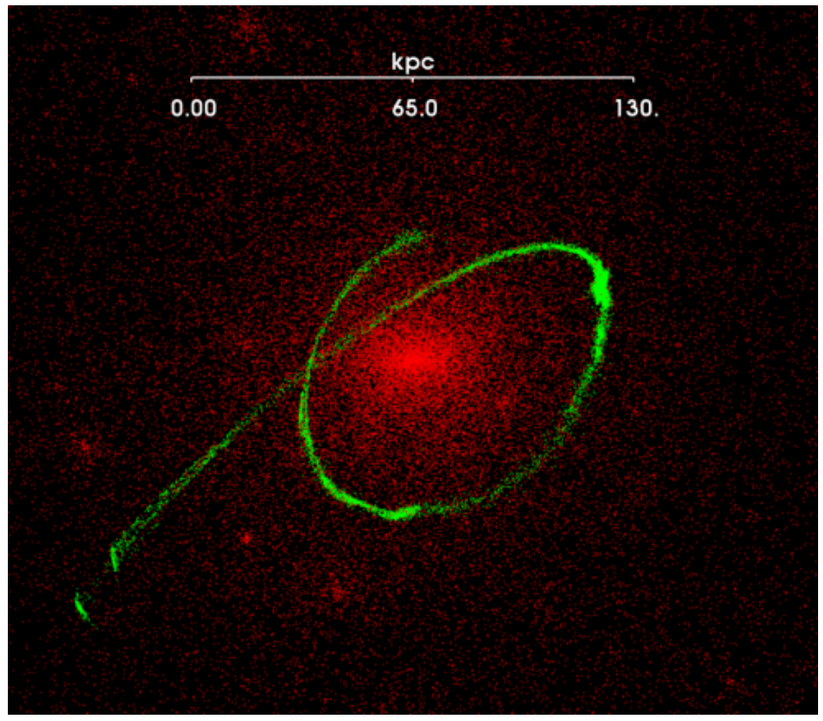


Recovering Subhalo Properties



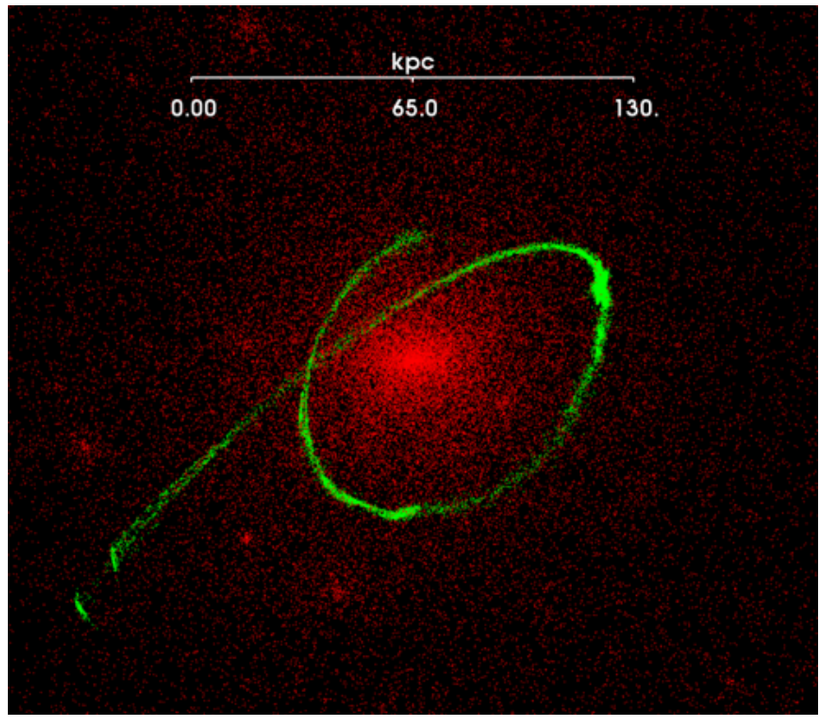
Recovering Subhalo Properties

- Gap depends on 7-d parameter space



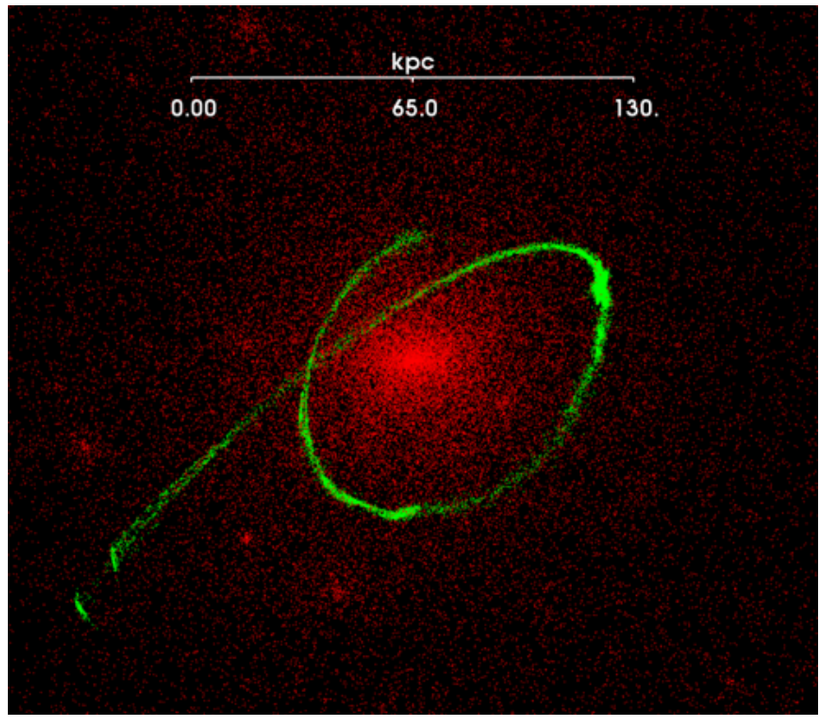
Recovering Subhalo Properties

- Gap depends on 7-d parameter space
- Gap profile constrains 3 combinations



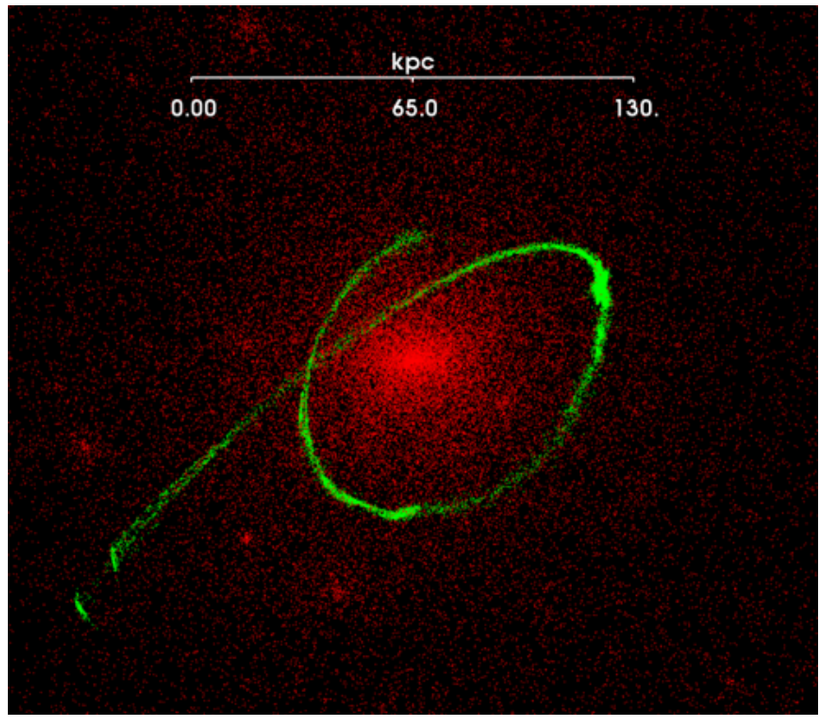
Recovering Subhalo Properties

- Gap depends on 7-d parameter space
- Gap profile constrains 3 combinations
- Size-mass relation



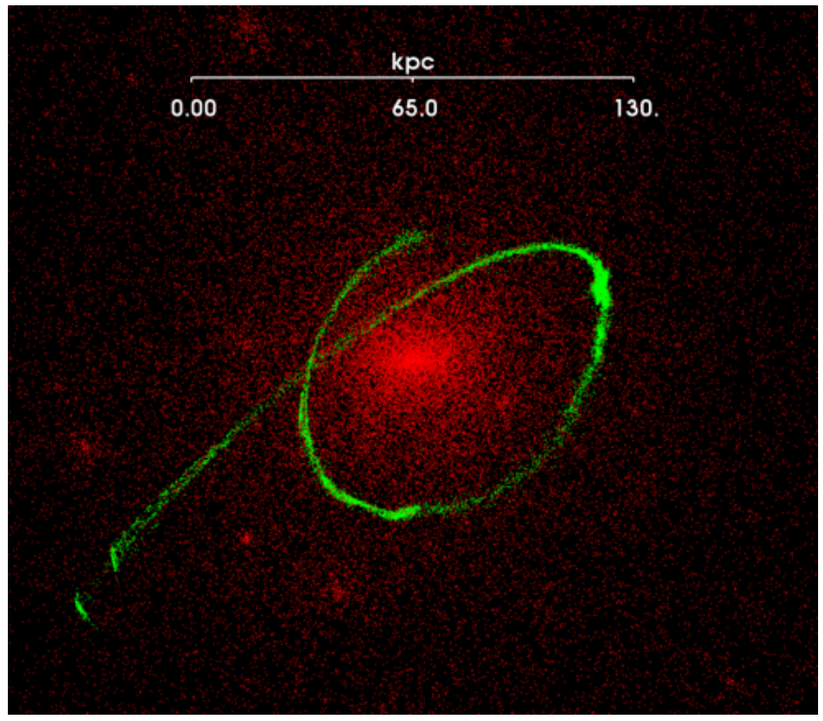
Recovering Subhalo Properties

- Gap depends on 7-d parameter space
- Gap profile constrains 3 combinations
- Size-mass relation
- Priors: halo mass function, subhalo position and velocity distribution



Recovering Subhalo Properties

- Gap depends on 7-d parameter space
- Gap profile constrains 3 combinations
- Size-mass relation
- Priors: halo mass function, subhalo position and velocity distribution
- In progress…



Conclusion

- Gap model works for idealized and realistic streams on circular orbits
- Allows for arbitrary impact geometry and arbitrary spherical potential
- Large degeneracy in inferring subhalo properties
- There’s hope to constrain substructure with additional priors

Gaps and Streams Discussion

- When can we start to trust gaps in observed streams (1%,10%, 50% gap)?

- How does interaction with substructure affect mass estimates from streams?

- When should we worry about the evolving Milky Way mass when estimating mass from streams?