Extra-Galactic Gravity from Streams (EGGS)

Nathaniel Starkman, with Jake Nibauer, *Sarah Pearson, Sirui Wu*, Mike Walmsley, Lina Necib, and Jo Bovy.

Euclid, Starkman et al. 2025 — circulating in Euclid

MIT KAVLI INSTITUTE

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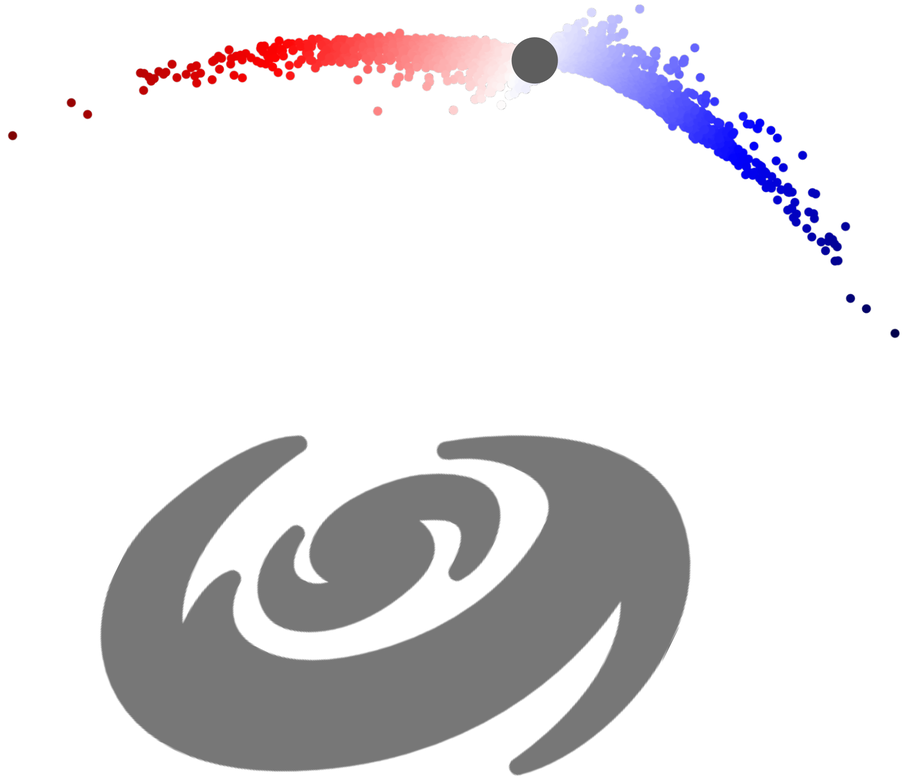
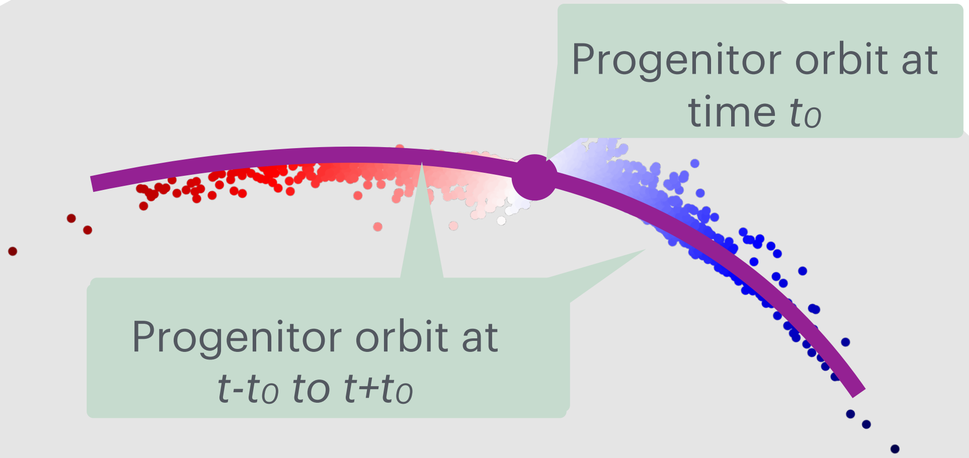
Stellar Streams Form Around Galaxies

- In a Tidal Field (Galaxy potential)
- A Progenitor (Globular Cluster or Dwarf Galaxy)
- Gradually disrupts
- Forming a Stellar Stream



Streams → Galaxy Potential

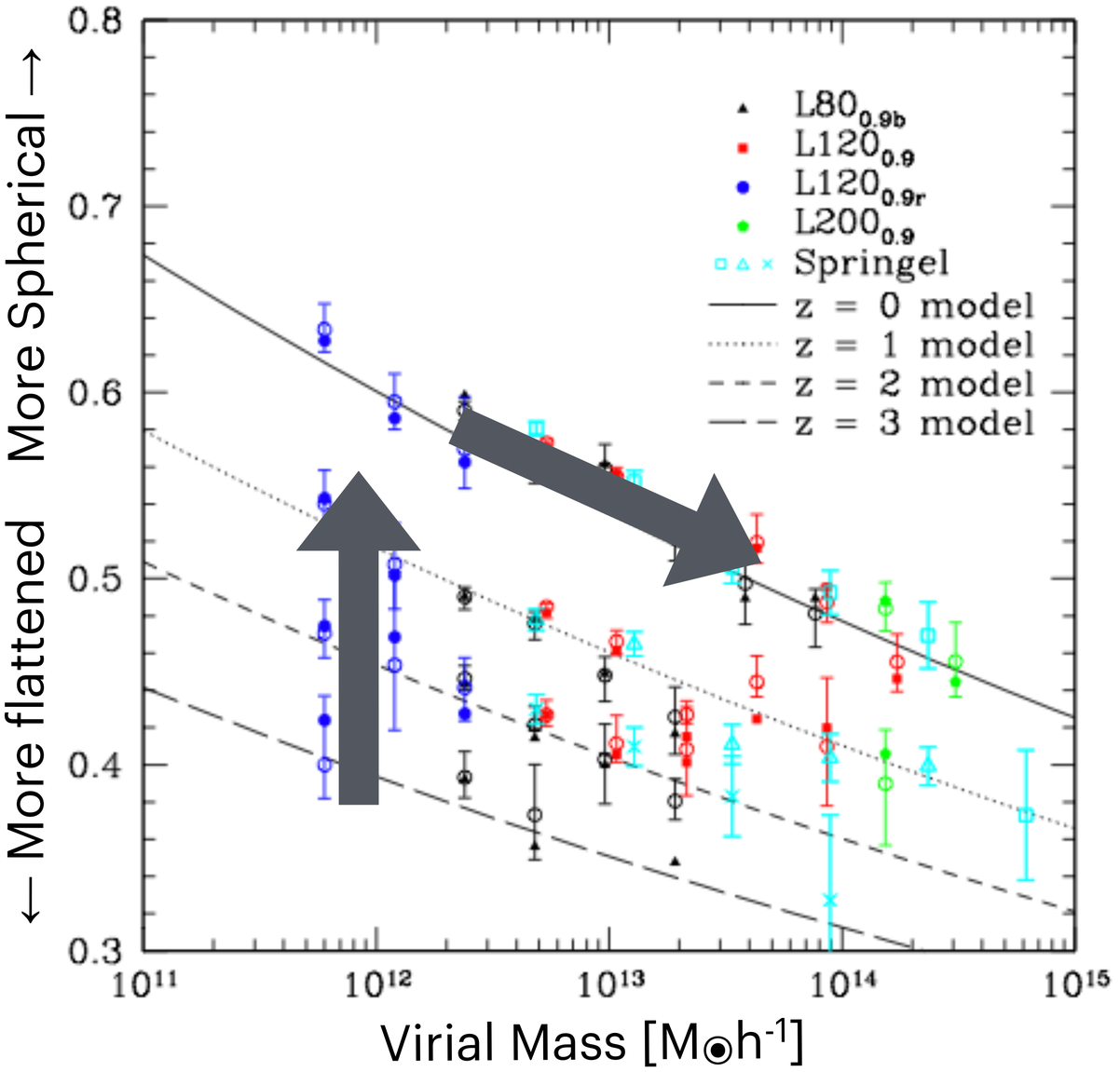
- Streams ∼ orbits (can model the difference)
- Orbit determined by potential.
- ❌ observe orbits,
  ✅ observe streams
- Thus streams → potential!
- potential: baryons + DM



Galaxies → Cosmology

- ΛCDM halos are triaxial, not spherical
- Theory predicts shape dependence:
  - ⬆Mass ⇒ ⬆Flattening
  - ⬇Redshift ⇒ ⬆Spherical
  - …

Observational tests beyond the Local Group remain difficult



Allgood et al. 2006

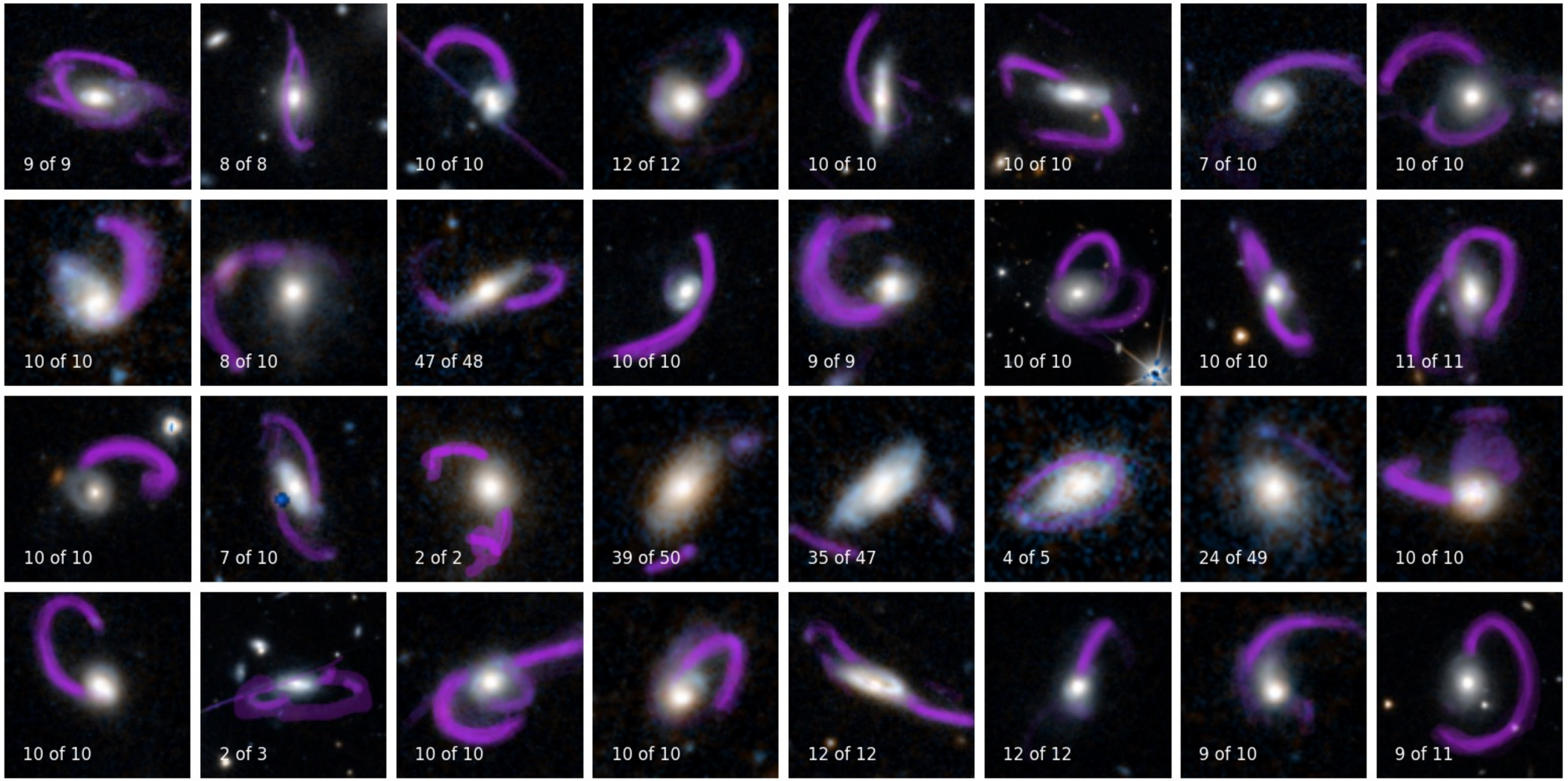
Streams are Hard to Find in Data

(Zooniverse)

Characterizing Streams in Euclid

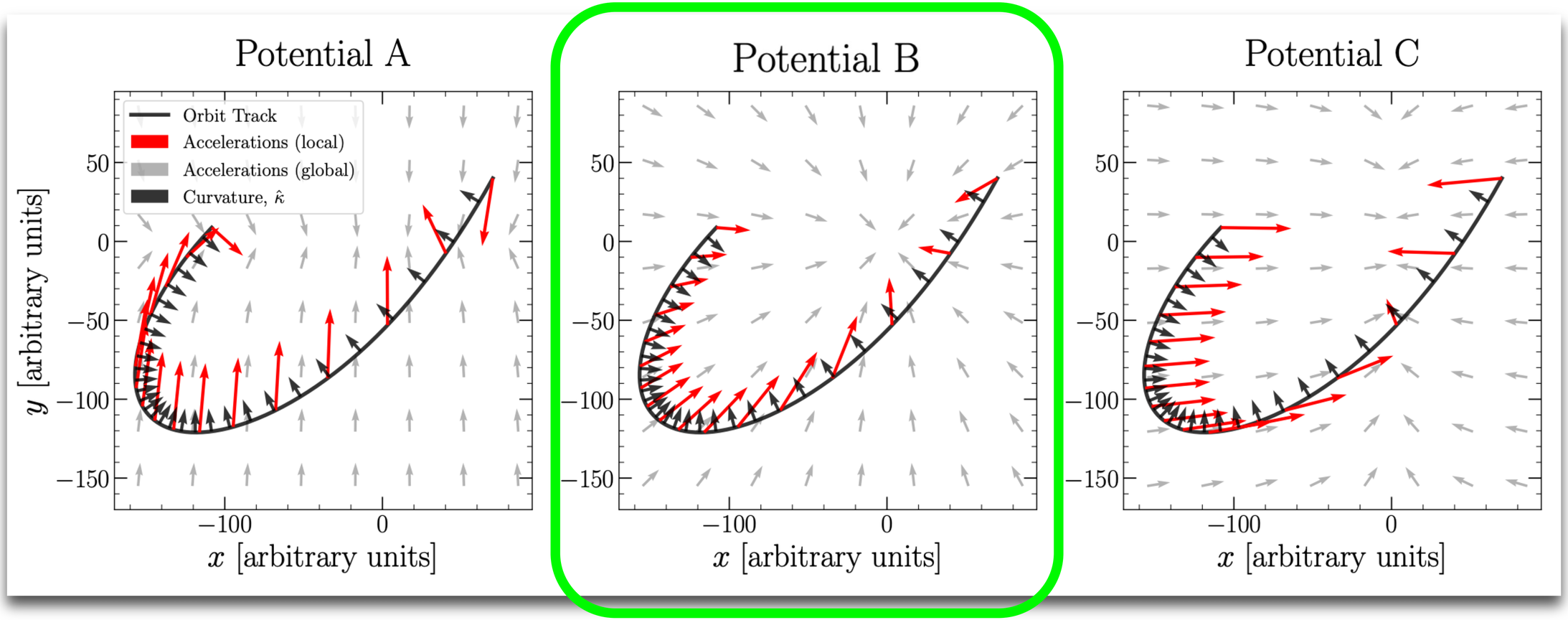
- New Zooniverse-affiliated tool
- Brush for annotating streams, bars, spirals, etc
- Identify and characterize streams
- Aggregate annotations from many people

Some Zooniverse-found Tidal Features



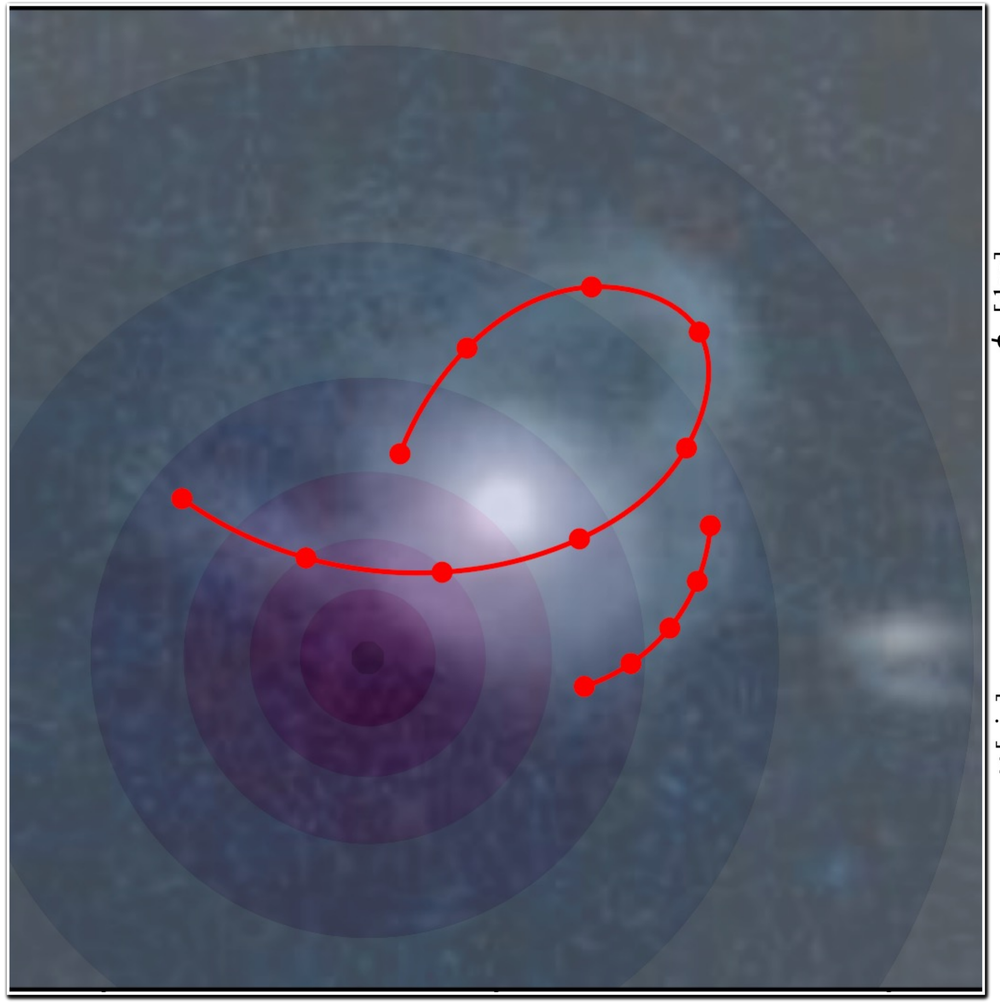
Curvature is a Measure of Acceleration

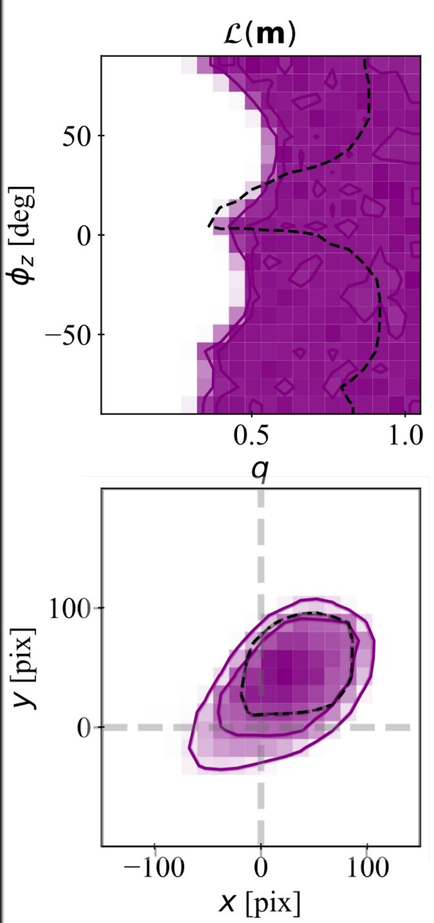
aka Measuring a Potential from a Stream

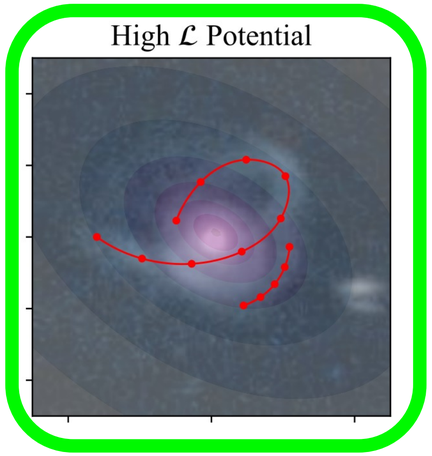


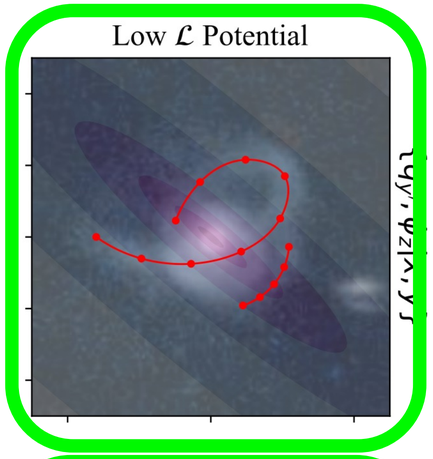
Nibauer et al 2023

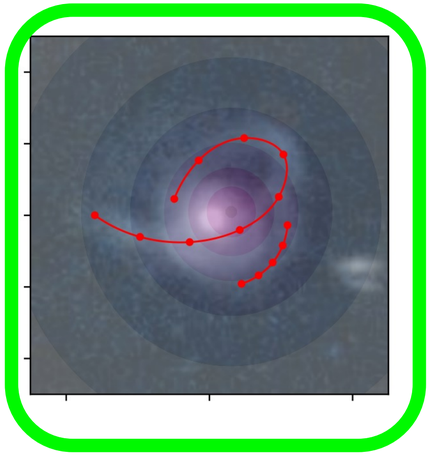
Good and Bad Fits to the Potential

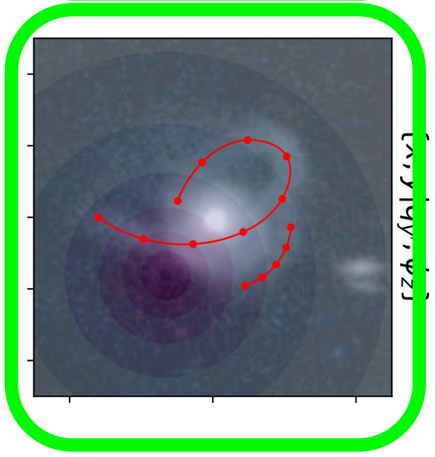








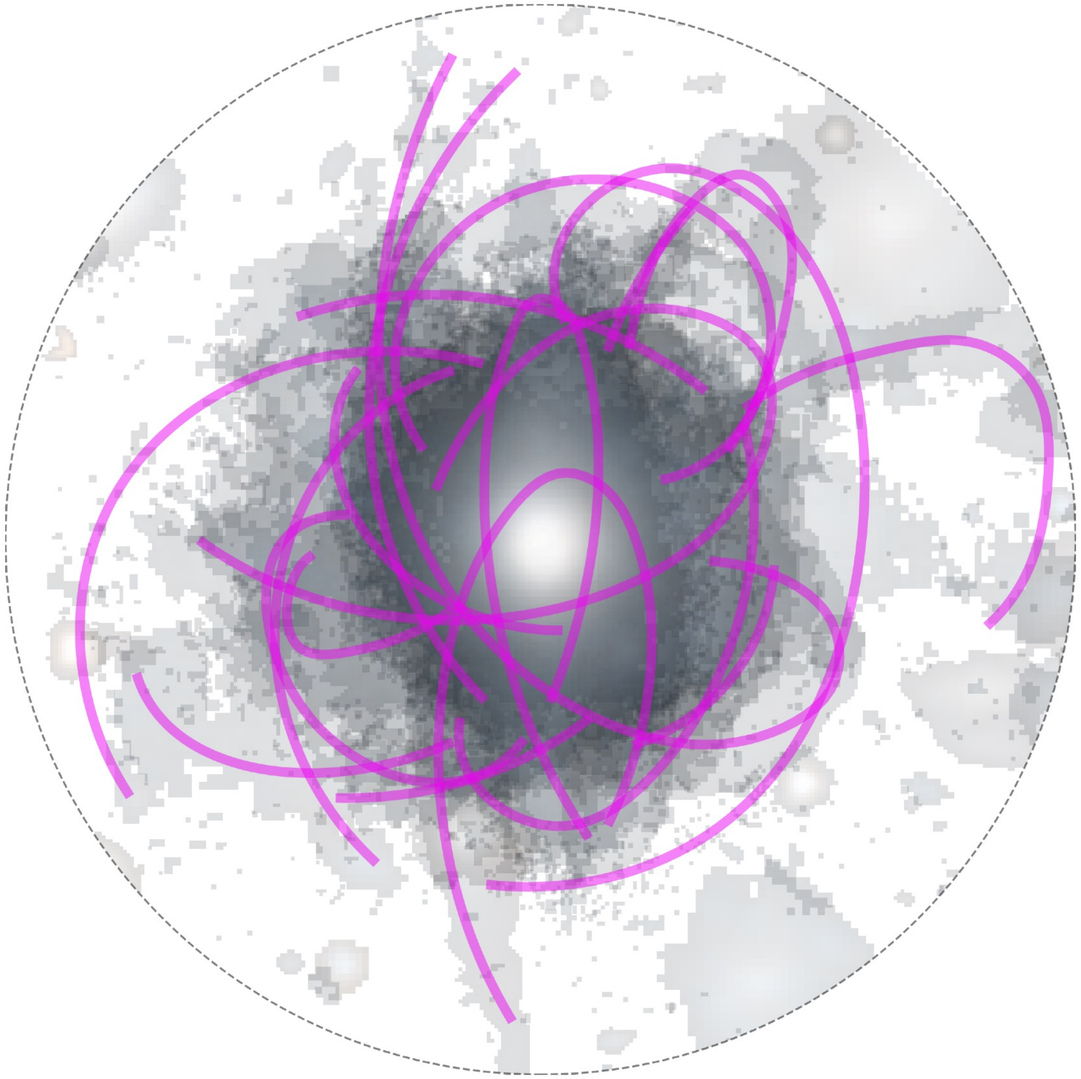




Stacking Galaxies

Population Statistics

- Individual halos → population statistics
- Stacking around centre-of-light
- Constraints on sub-virial scales
- Compatible with weak lensing
- Distribution of halo flattening and CoM

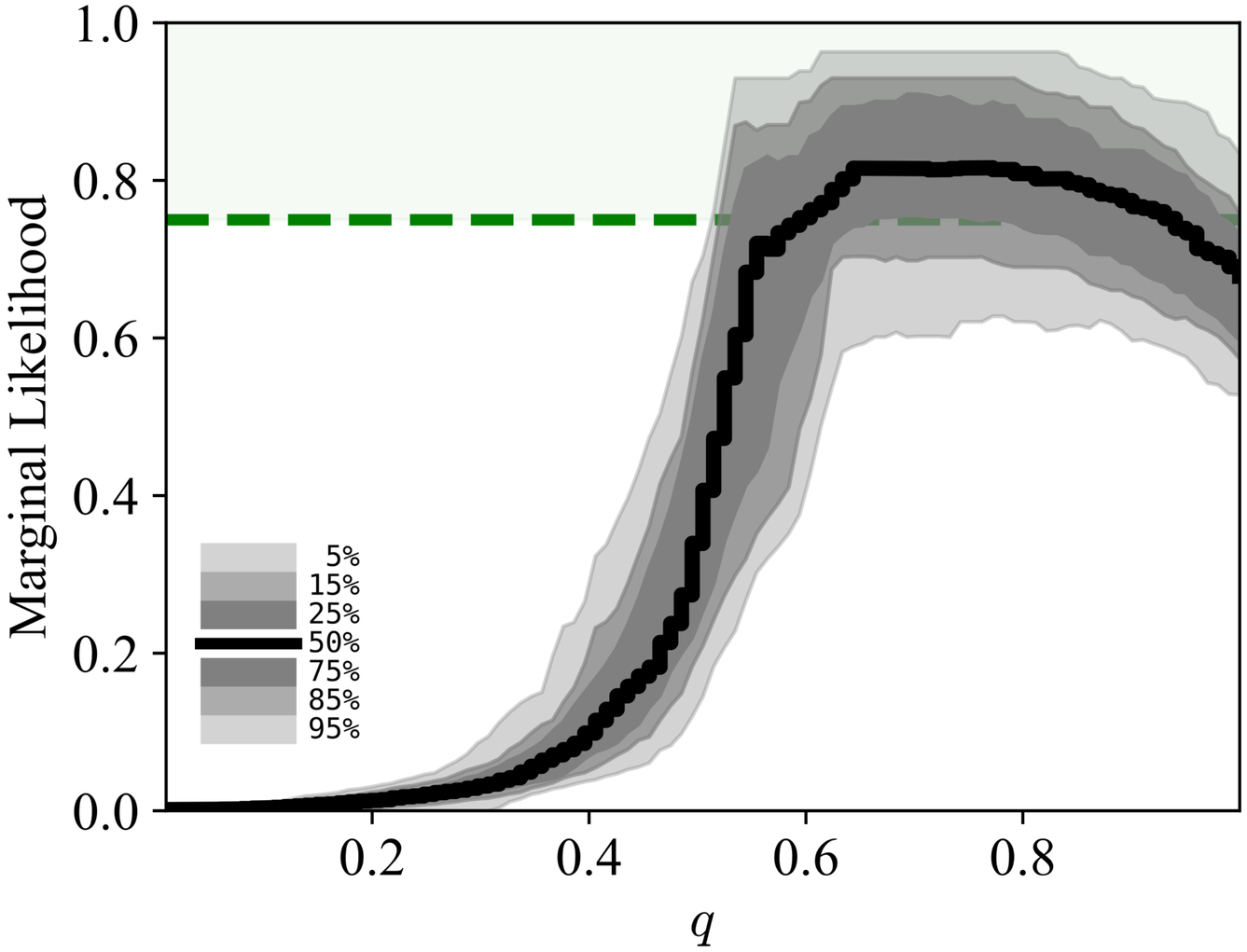


Halo Flattening Consistent with Expectations

✓ Excludes very flattened haloes

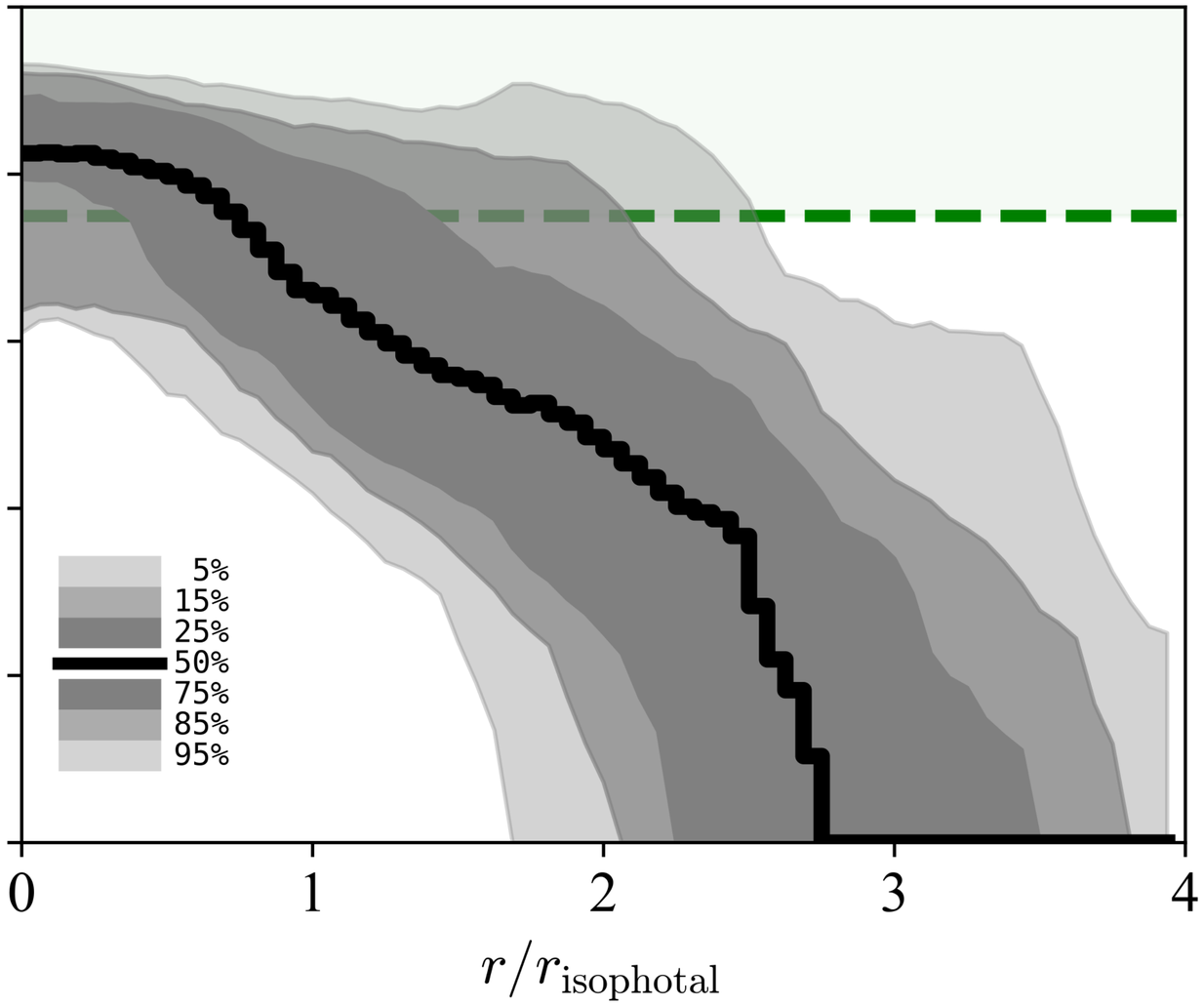
✓ Projected flattening $\$q \sim 0.8\$$

- Matches ΛCDM expectations
- Larger samples will sharpen population-level tests.



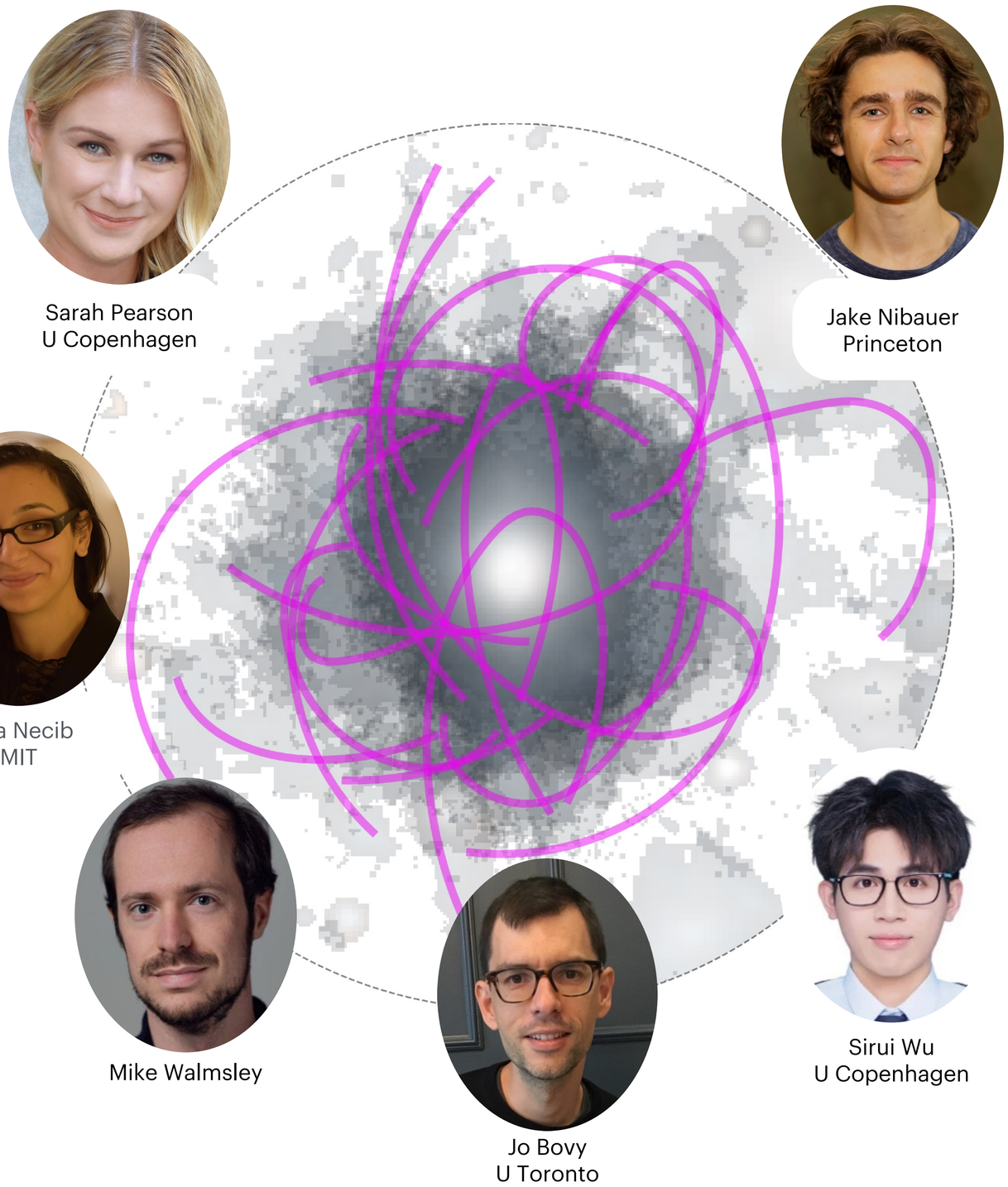
DM Alignment Consistent with Expectations

- Consistent alignment between baryonic and dynamical centres.
- Large displacements disfavoured.
- Consistent with expectations.
- Test for DM models, Modified Gravity
- Caveat: most exciting are single, large-offset systems, like Bullet Cluster.

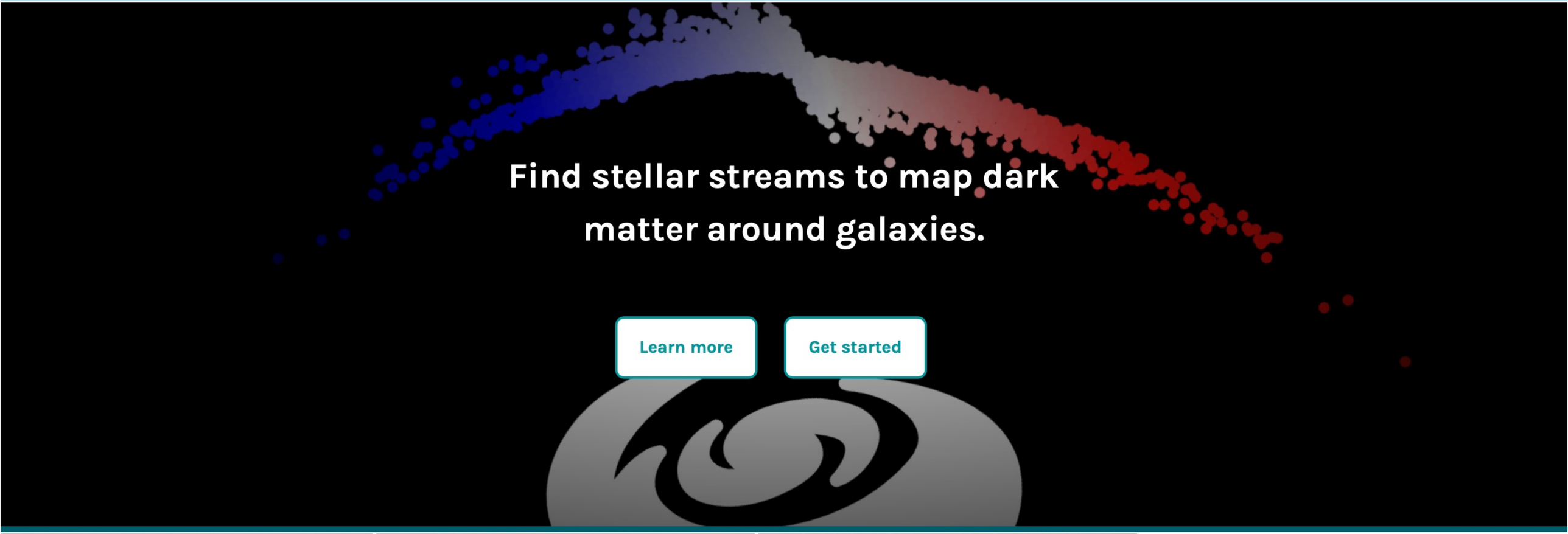


Conclusions

- **Paper is circulating now in Euclid**
- **Scaling up:** Citizen science (Zooniverse) + ML stream detection across Euclid.
- **Theory Improvements:** using more information, e.g. curvature magnitudes.
- **Takeaway:** A fast, minimal-assumption probe of dark matter halo geometry and cosmology

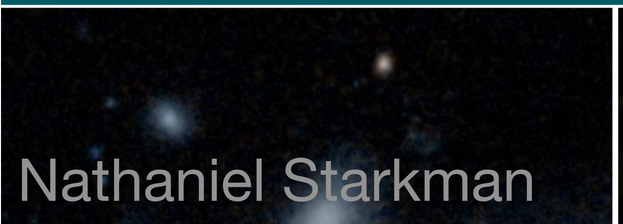


Try out **drawing on these streams** with the Experiment platform - click here and select the Stellar Streams workflow. Experiment is external to Zooniverse. See this blog post for details.



Find stellar streams to map dark matter around galaxies.

Learn more Get started



20 people are talking about **Stellar Stream Identification** right now.

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