NANCY GRACE ROMAN SPACE TELESCOPE

ADAS, or SCUDS II: Automated Analysis of Tidal Debris in External Galaxies

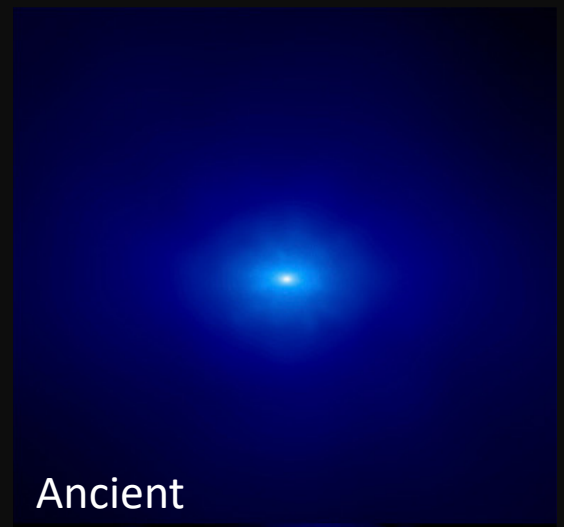
Shifra Mandel

Supported by NASA

through the WINGS (*WFIRST Infrared Nearby Galaxy Survey*) collaboration

PI: Ben Williams

What can we learn from tidal debris?



Johnston et al. (2008)

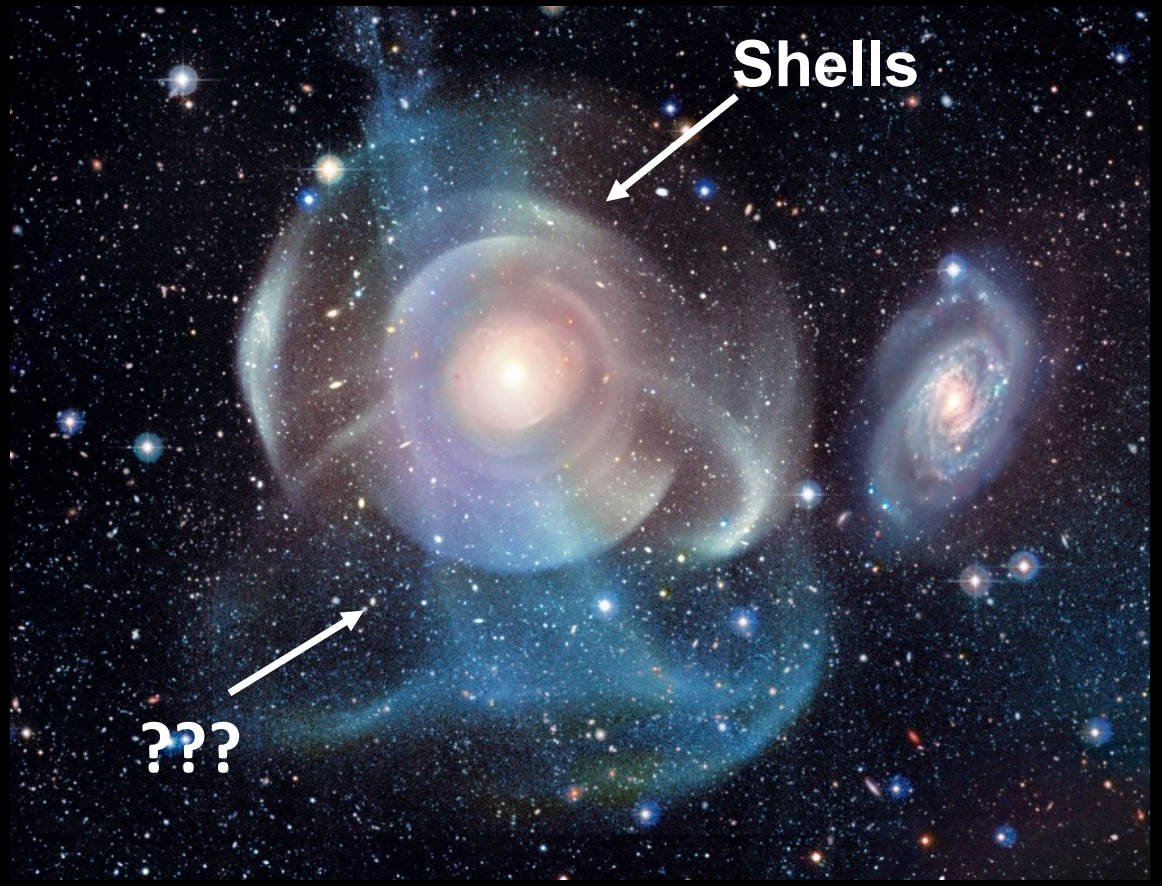
The State of LSB Tidal Debris Detection/Analysis

Roman (and other upcoming surveys) will provide a wealth of LSB tidal debris substructures, allowing us to study galactic accretion in unprecedented detail

Credit: WFIRST

What do we need in order to determine merger histories from tidal debris substructures?

- **Systematic** surveys: large, **statistically robust** sample –
- Visual (manual) classification: scalability/consistency
- **Automated** classification/analysis: **efficient, consistent, statistical**



NGC 474. Image Credit: CFHT, Coelum, MegaCam, J.-C. Cuillandre (CFHT) & G. A. Anselmi (Coelum)

Recent work on detecting & classifying tidal debris

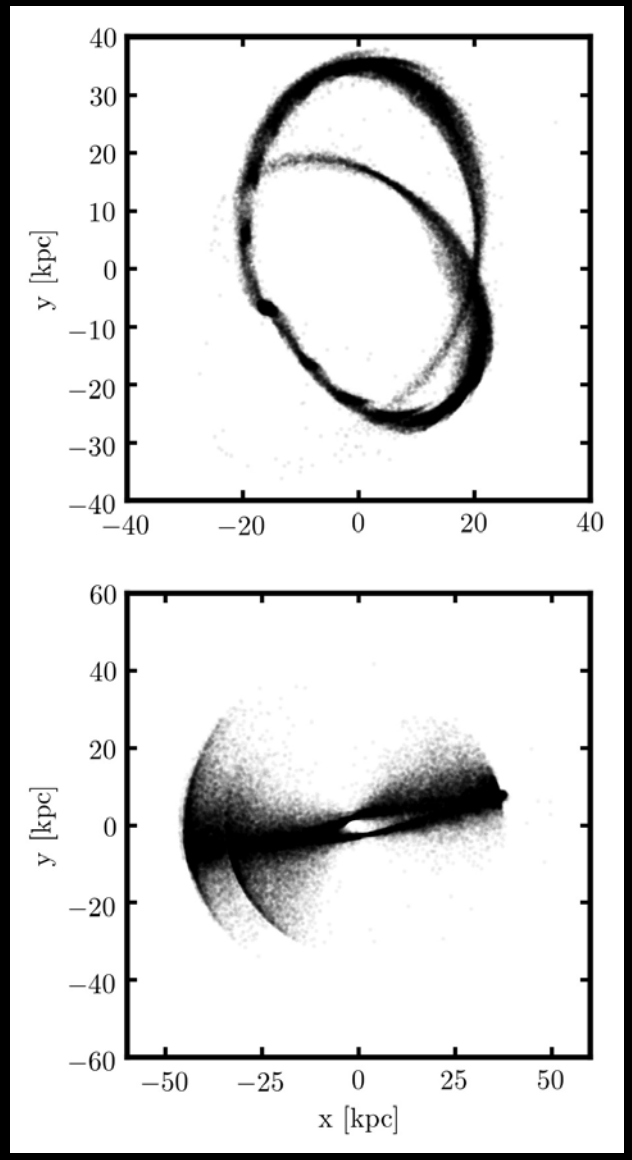
Capabilities	Martin+ 2014: PAndAS (photometry + kinematics)	Kado-Fong+ 2018: HSC Survey	Walmsley+ 2018: CNN	Stellar Stream Legacy Survey (Martinez-Delgado+ 2021)	**Our work** (Mandel+ 2022)
Detection of stellar streams	Yes	Yes	Yes*	Yes (CNN)	**No**
Classification (morphology)	Visual	SCUDS I - limited	No	Visual/"image matching"	**Yes**
Properties (measurements)	Surface brightness	No	No	No	**Yes**
Efficiency (scalability)	Local only; manual analysis	Yes	Yes	Partly (identification)	**Yes**

*76% completeness, 20% contamination

Summary of ADAS Algorithm

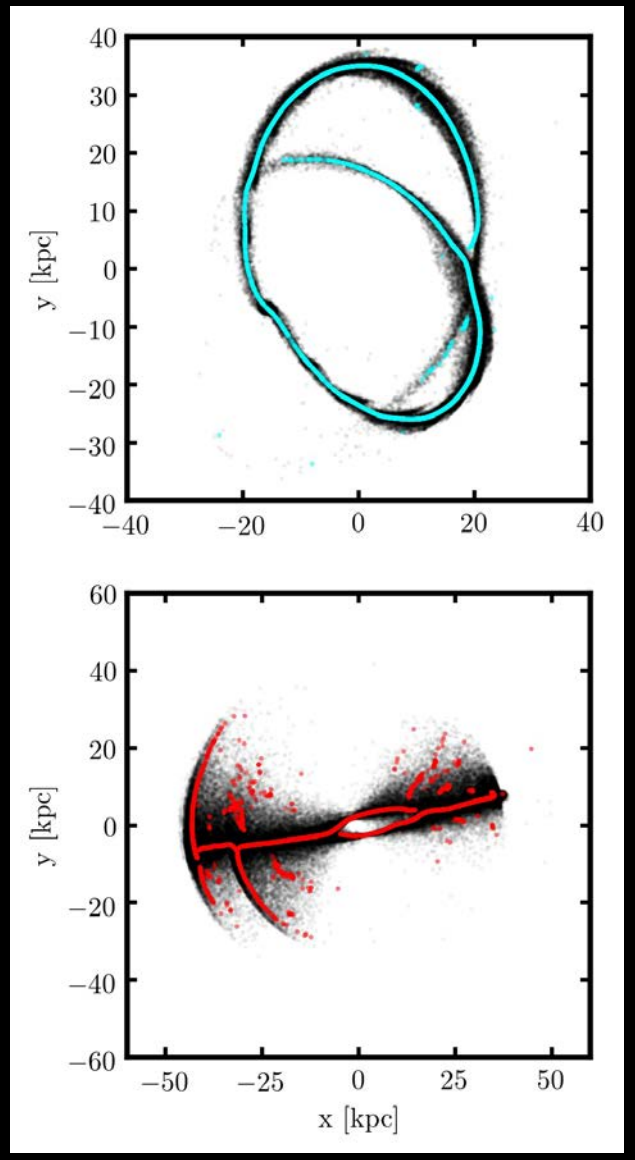
Automated Detection and Analysis of Structure

Step 1: Identify structure with SCUDS II (Hendel & Johnston 2018)

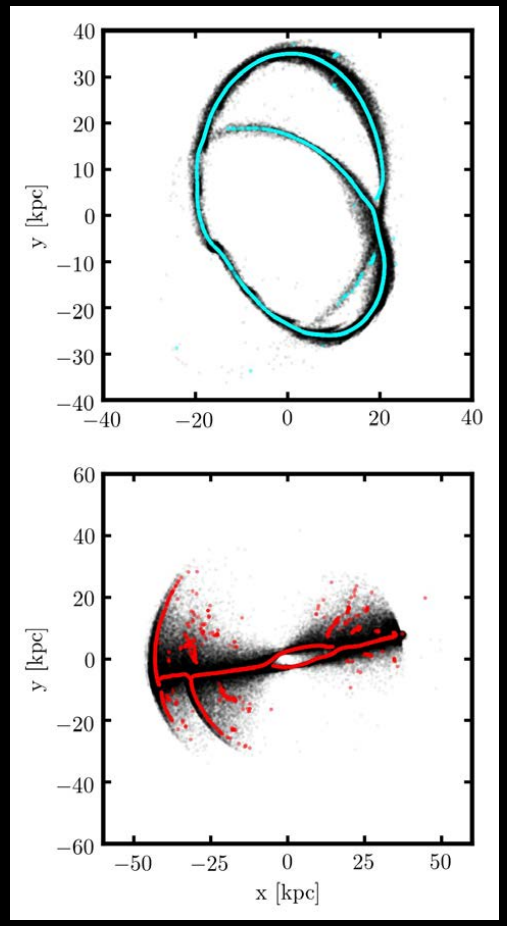


- N-body simulations → snapshots
- Mean shift: ”Start points” → density gradient → ***principal curves***

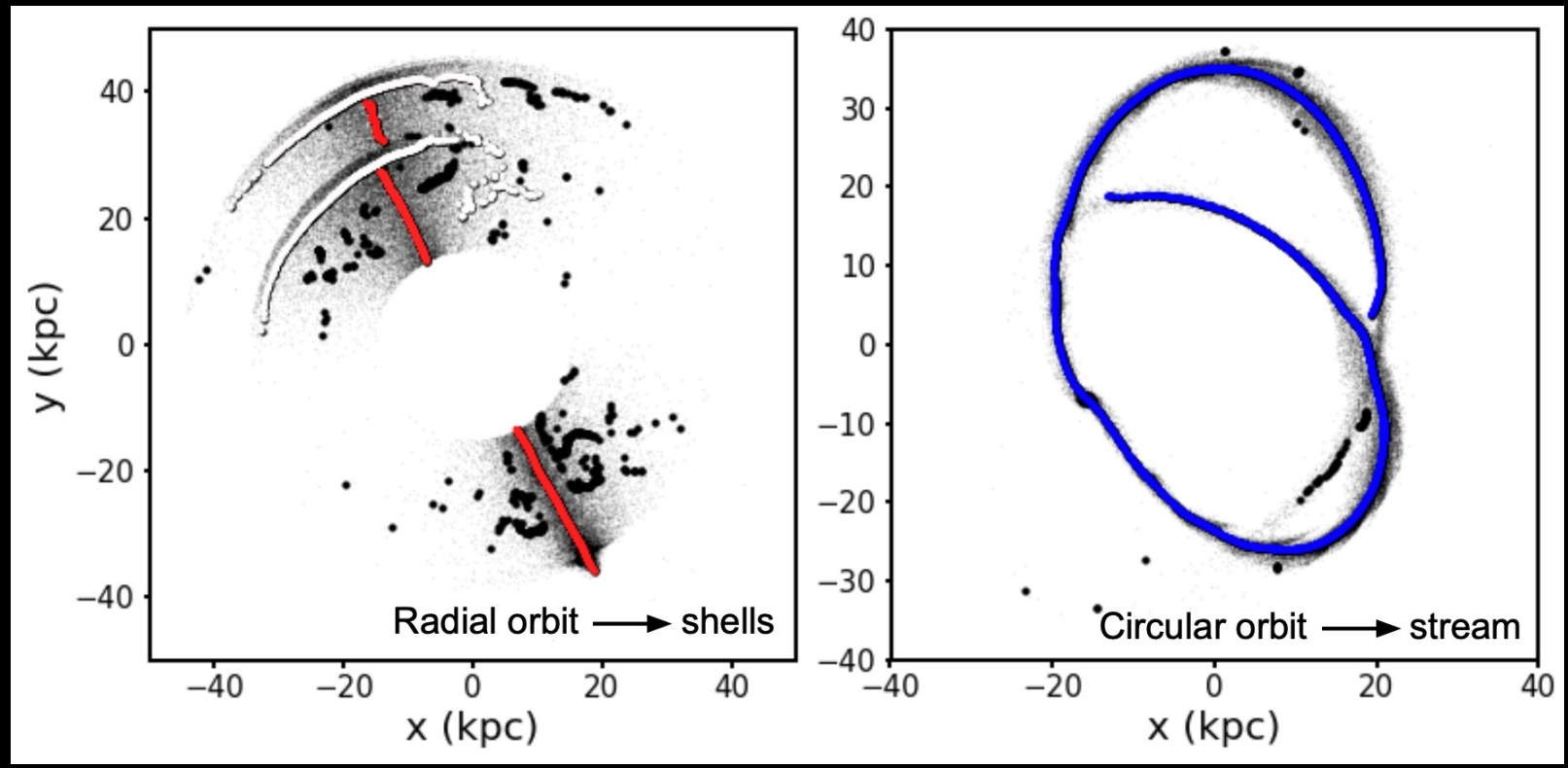
- “**Ridge points**” & tangent vectors



Step 2: Connect ridge points to form features using proximity + alignment; eliminate “noise”

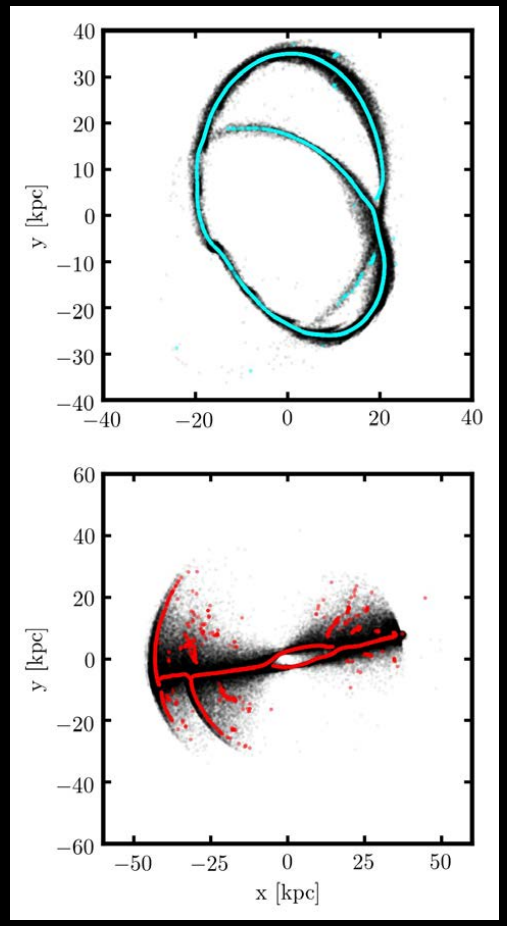


Step 1

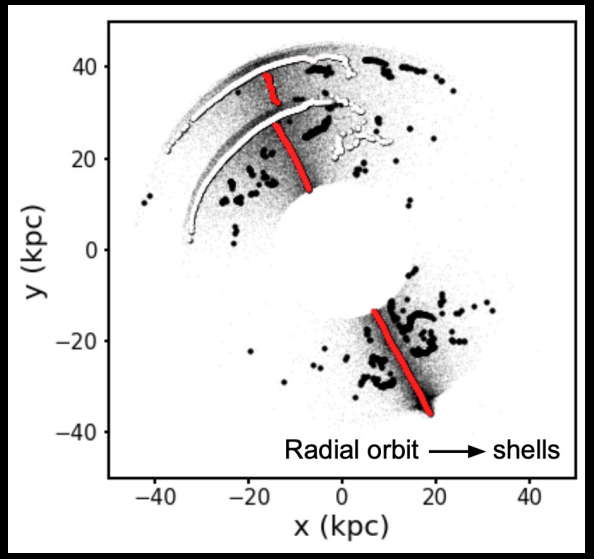


Step 2

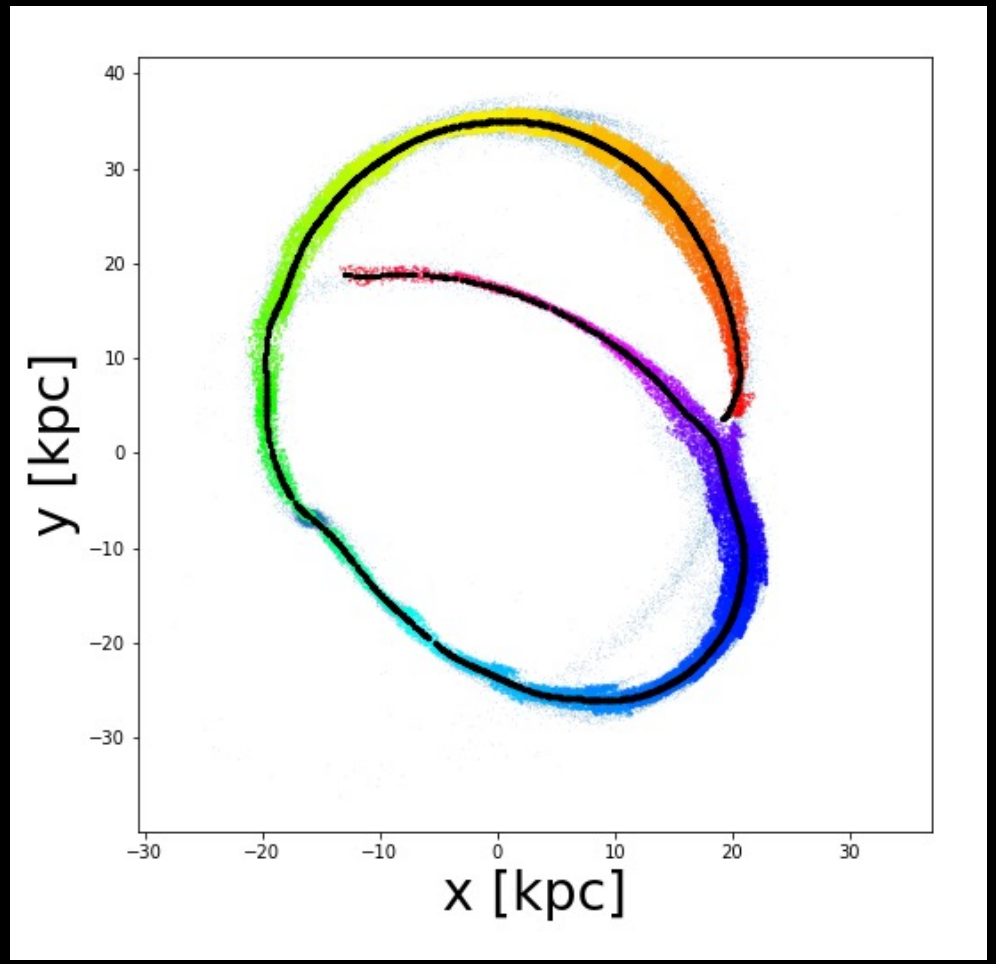
Step 3: Relate stars to individual structures



Step 1

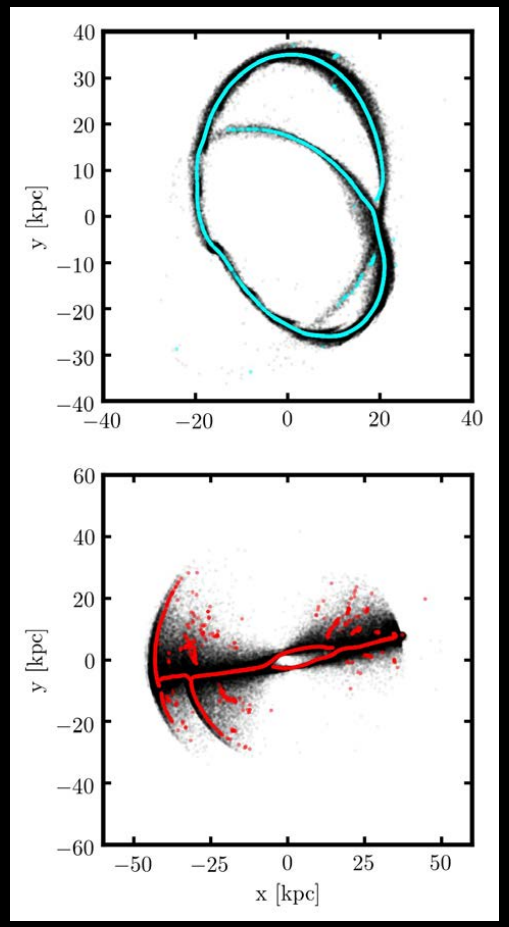


Step 2



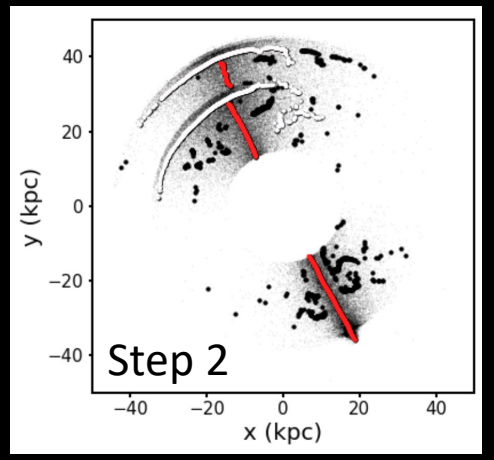
Step 3

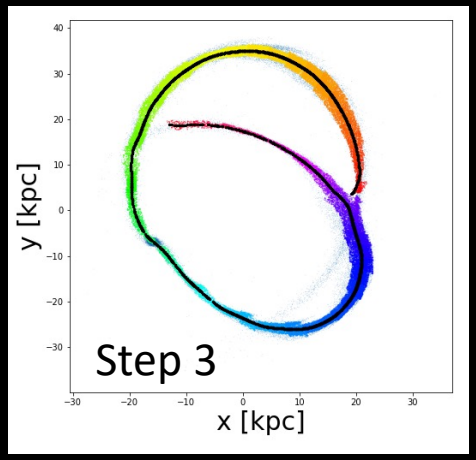
Step 4: Classify morphology

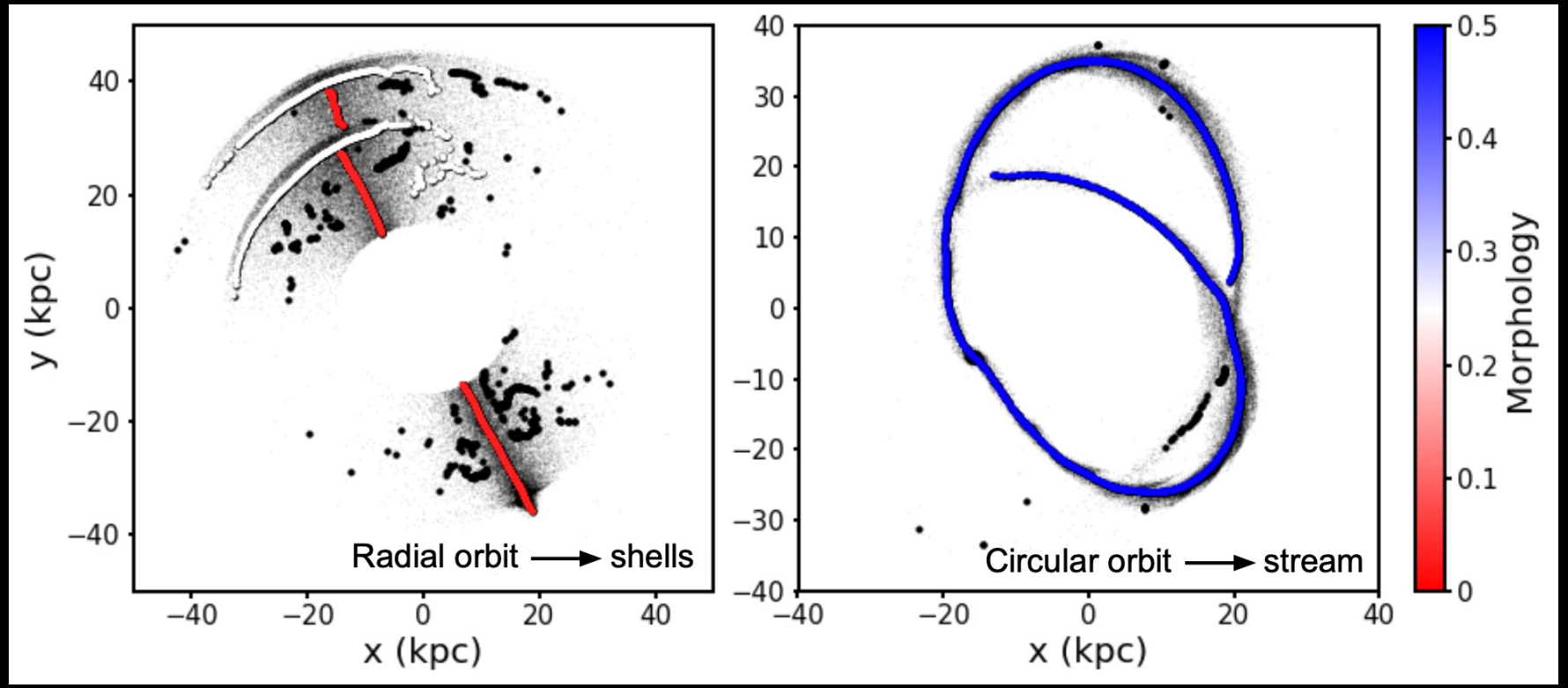


Step 1

- Symmetry
- Orientation

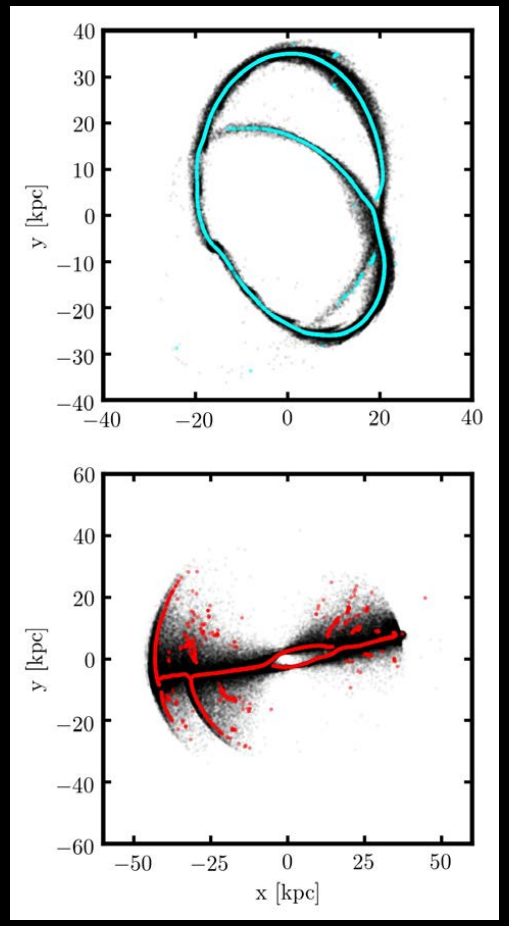




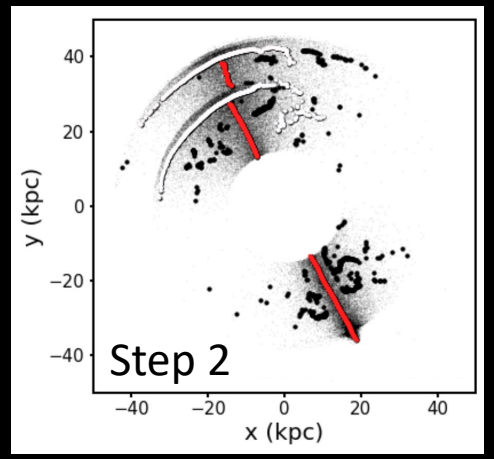


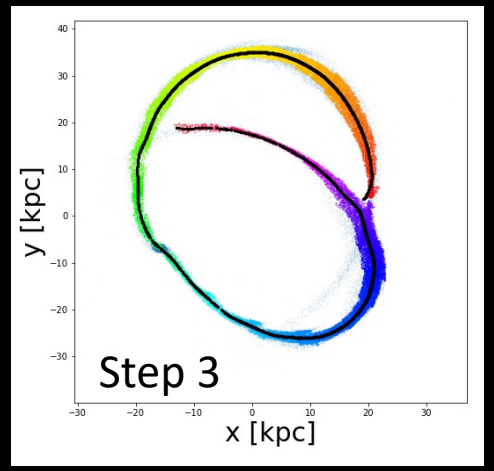
Step 4

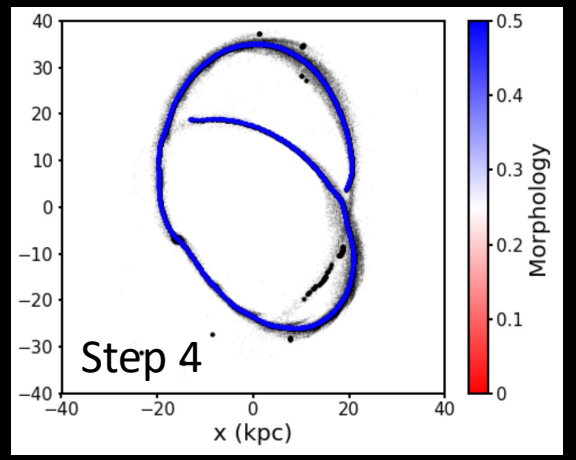
Step 5: Measure length, width, surface brightness of individual features

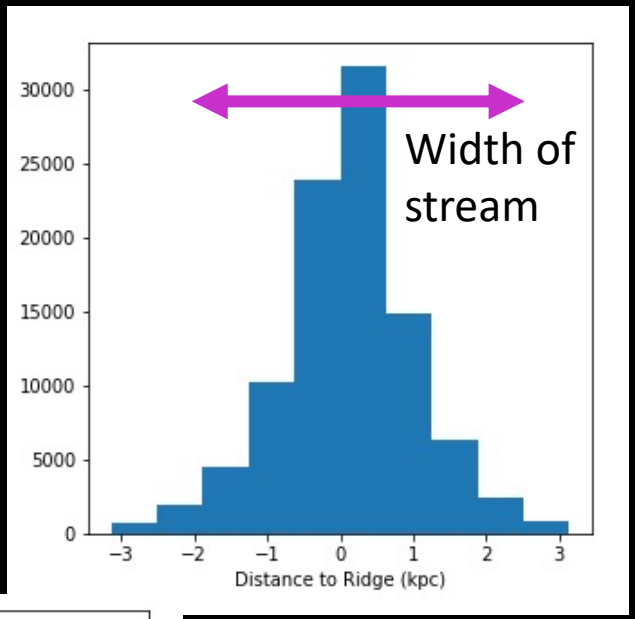


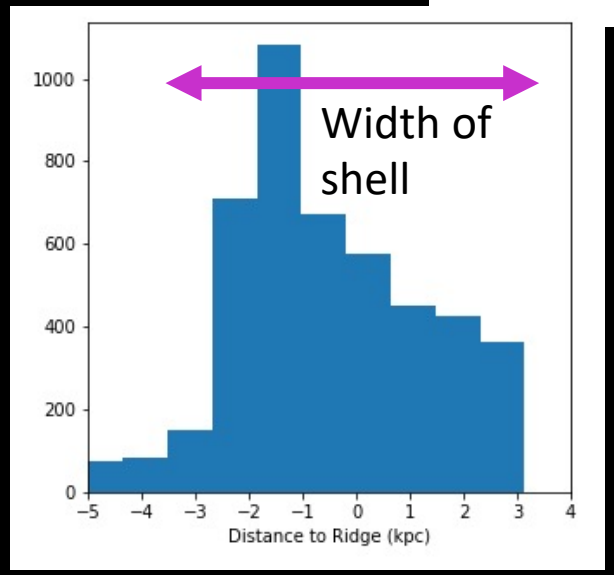
Step 1







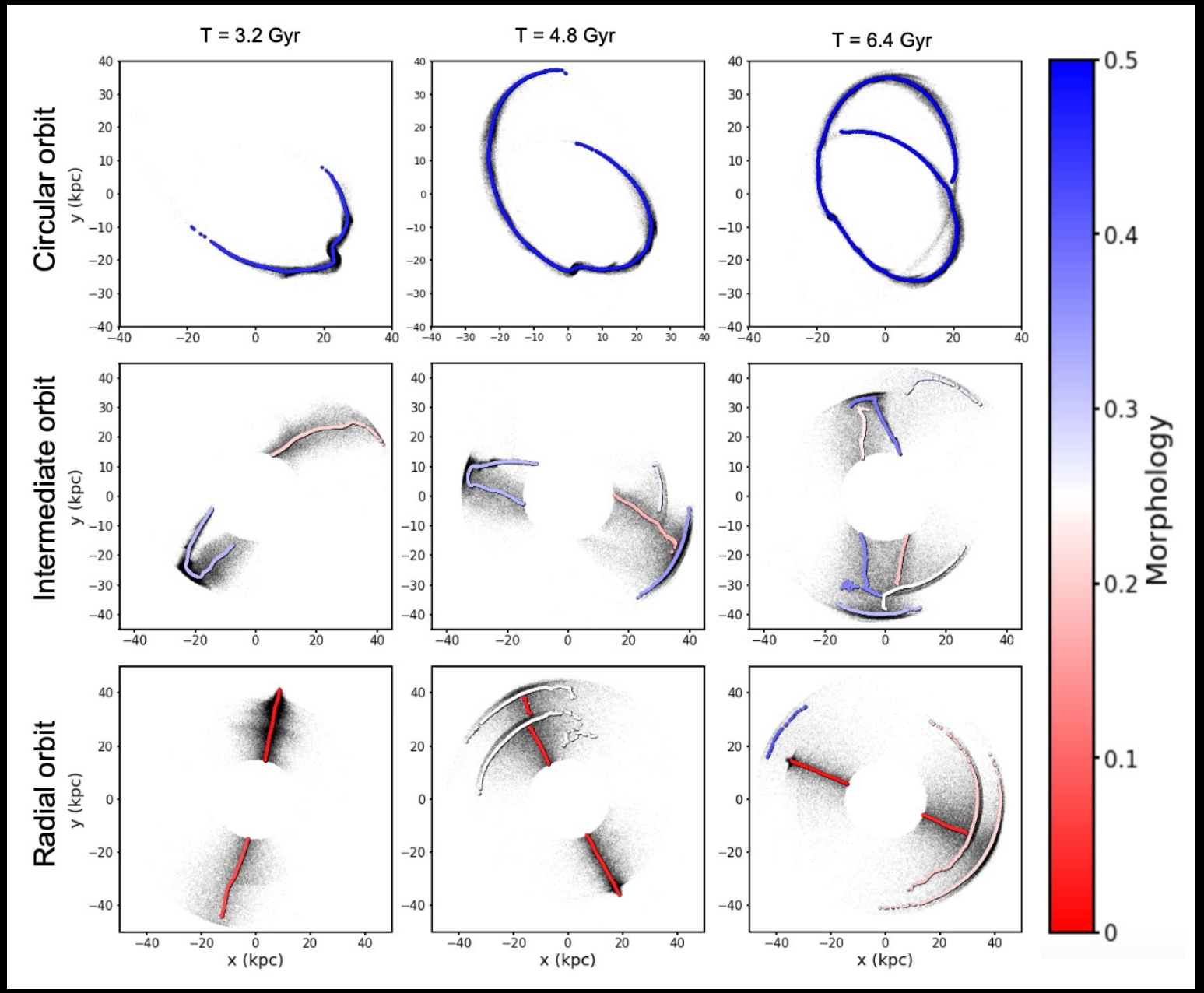




Width of stars for stream (above) and shell (left).

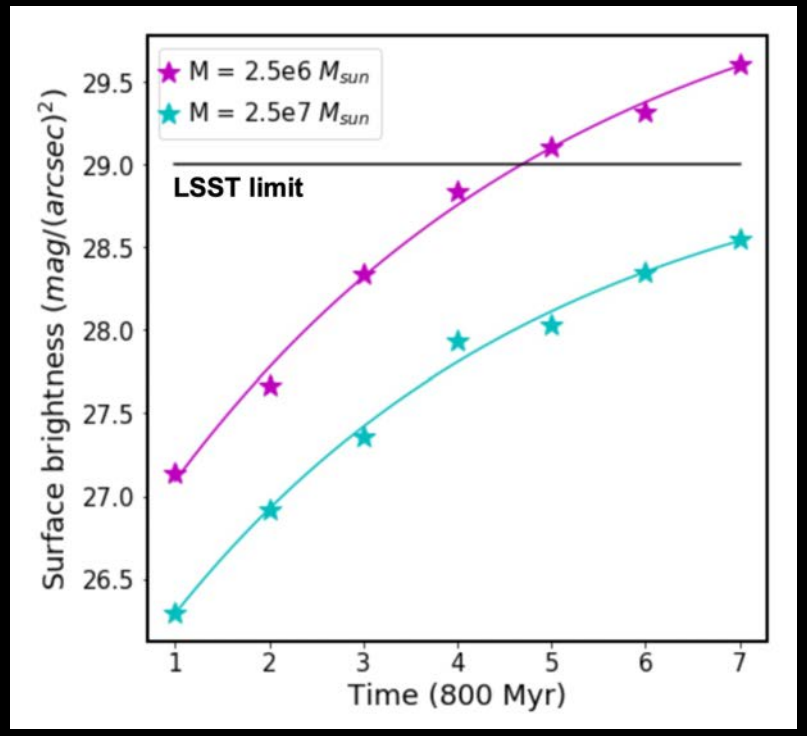
ADAS Results

- Length/angle subtended: age, orbit, mass
- Dispersion: mass ratio (+ age/orbit dependencies)
- Surface brightness: age, orbit, mass ratio
- Morphology: orbit (+ age for intermediate orbits)

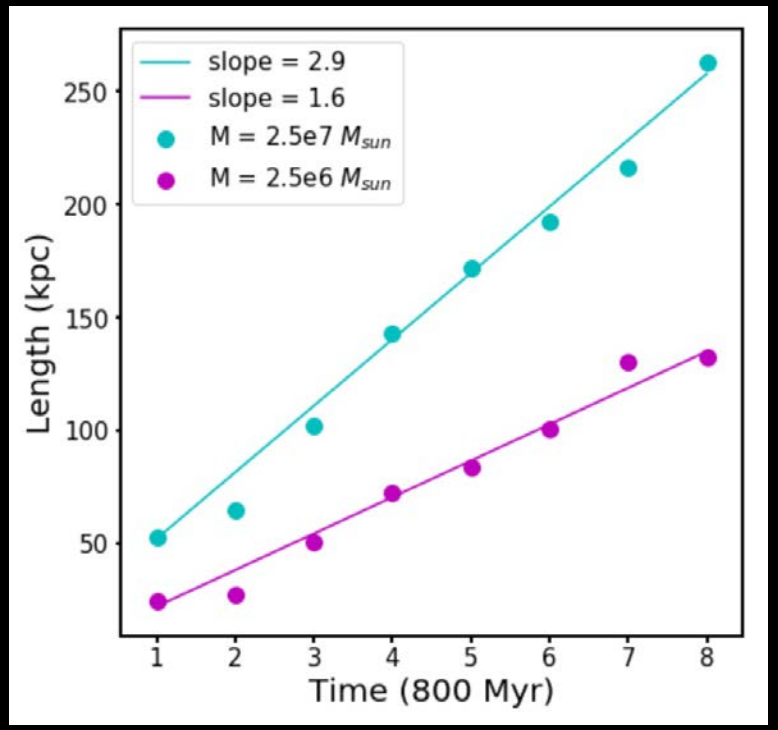


ADAS Results → Merger Histories

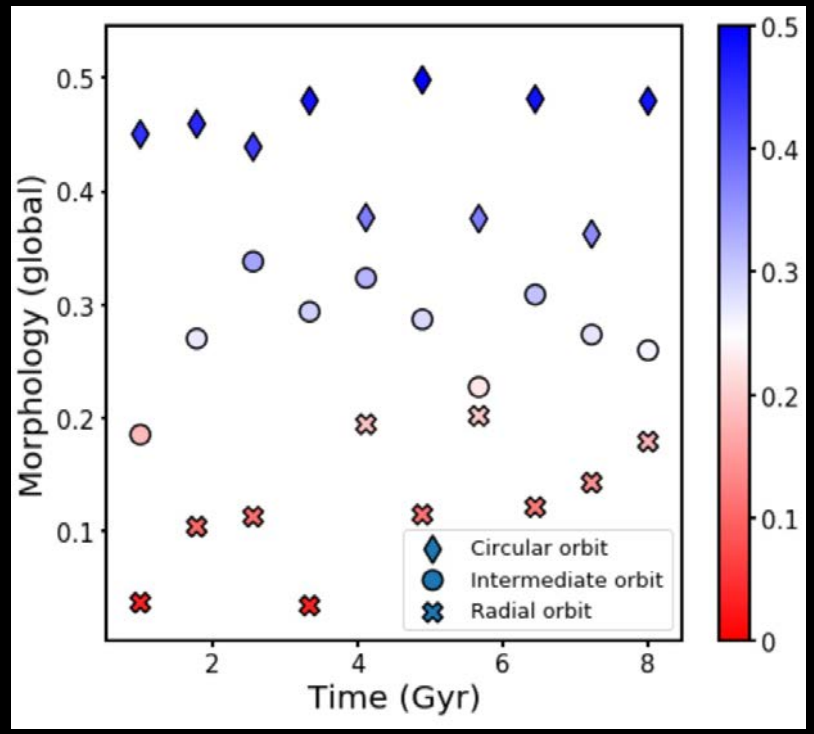
Surface brightness → age, orbit, mass ratio



Length → age, mass, orbit



Morphology → orbit



Future Work/Collaborations: Applying ADAS to Real Images

- **Simulated ROMAN background tests**
- HSC LSB image repository
- CNN classification training

Potential Applications for ADAS

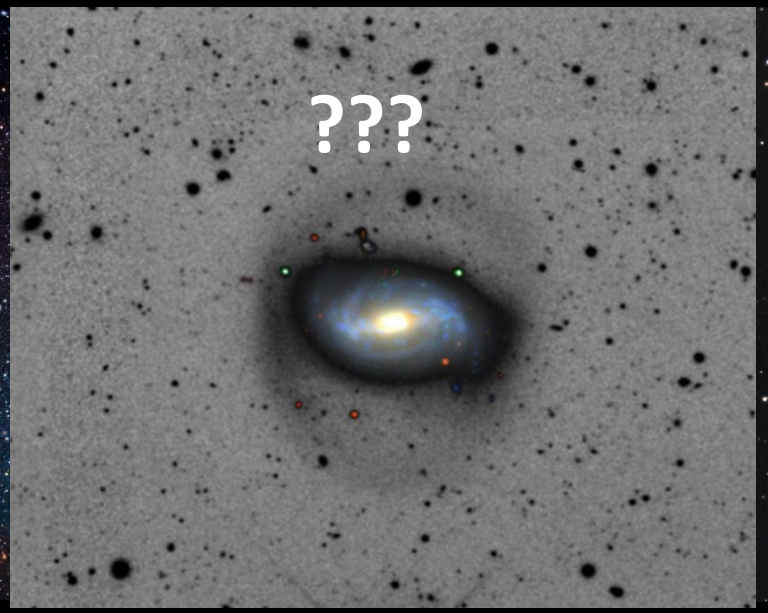
- Training for ML algorithms
- Search for gaps in thin streams
- Explore properties of simulation streams (e.g. FIRE)
- Explore whether satellite kinematics are correlated with tidal features

Backup

Requirements for (Limits of by-eye classification methods)

- **Systematic** surveys: large, **statistically robust** sample –
- Visual (manual) classification: scalability/consistency
- **Automated** classification/analysis: **efficient, consistent, statistical**

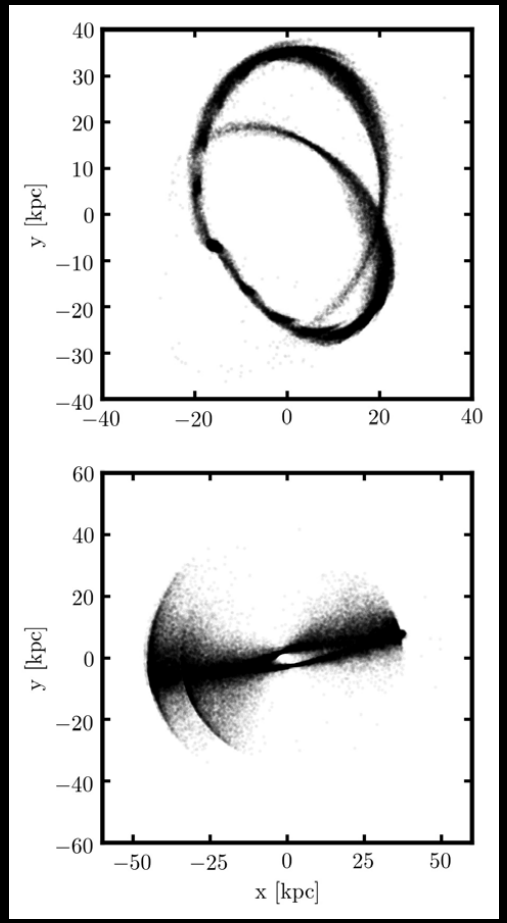
Image Credit: CFHT, Coelum, MegaCam, J.-C. Cuillandre (CFHT) & G. A. Anselmi (Coelum)



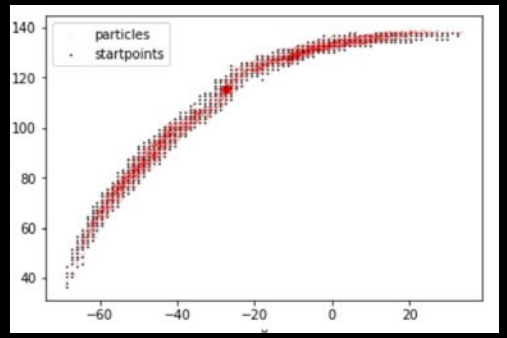
Martinez-Delgado+ 2021

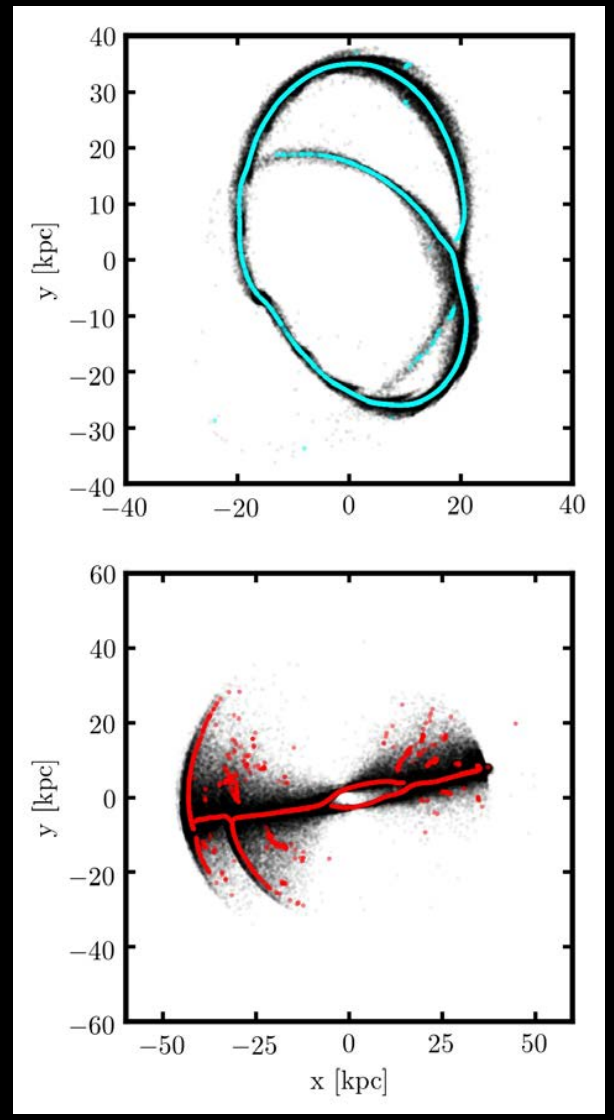
Image Credit & Copyright: R Jay Gabany (Blackbird Observatory) - collaboration; D.Martínez-Delgado (IAC, MPIA), J.Peñarrubia (U.Victoria), I. Trujillo (IAC), S.Majewski (U.Virginia), M.Pohlen (Cardiff)

Step 1: Detecting Structure with SCUDS II (Hendel & Johnston 2018)



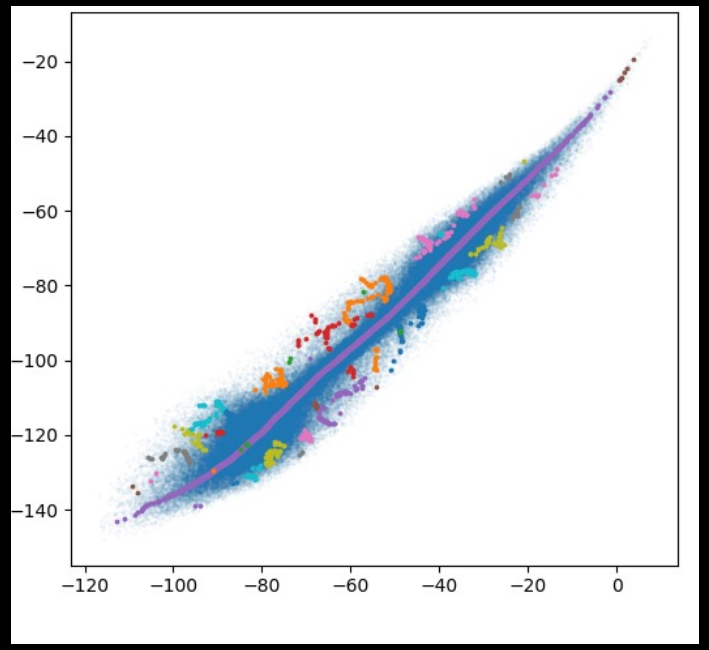
- N-body simulations -> snapshots
- Mean shift process:
  - Starting point grid
  - Converge to “principal curves” by following density gradient
  - Obtain
    - Ridge points
    - Tangent vectors
    - (very local) Morphology

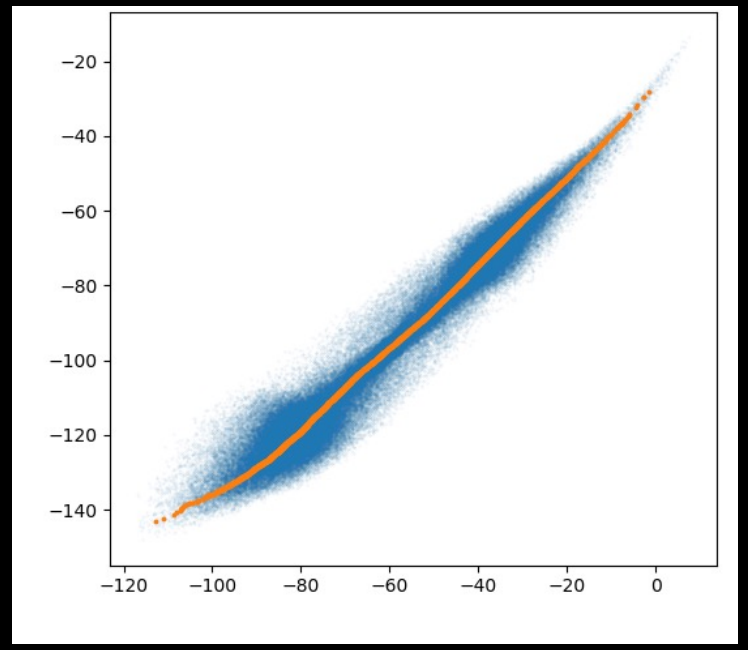


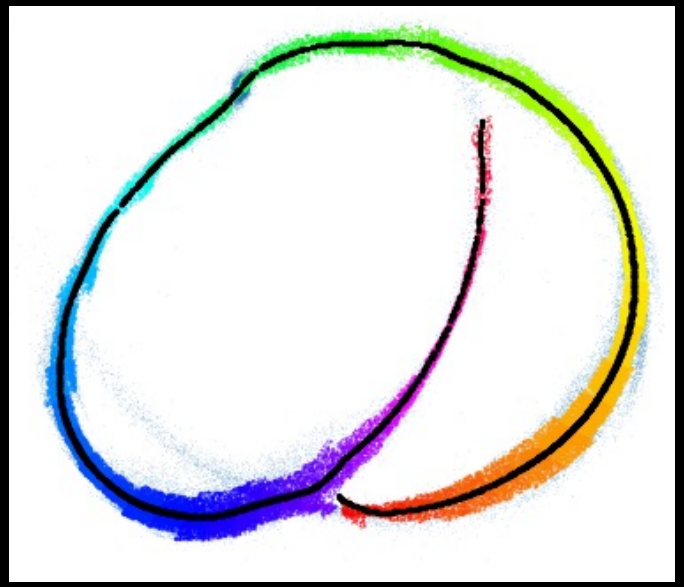


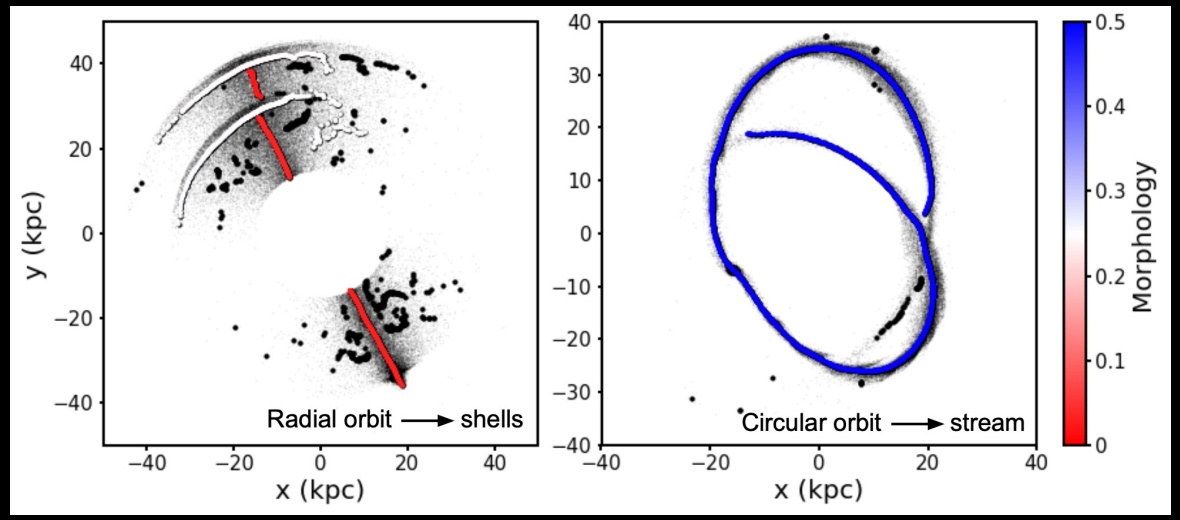
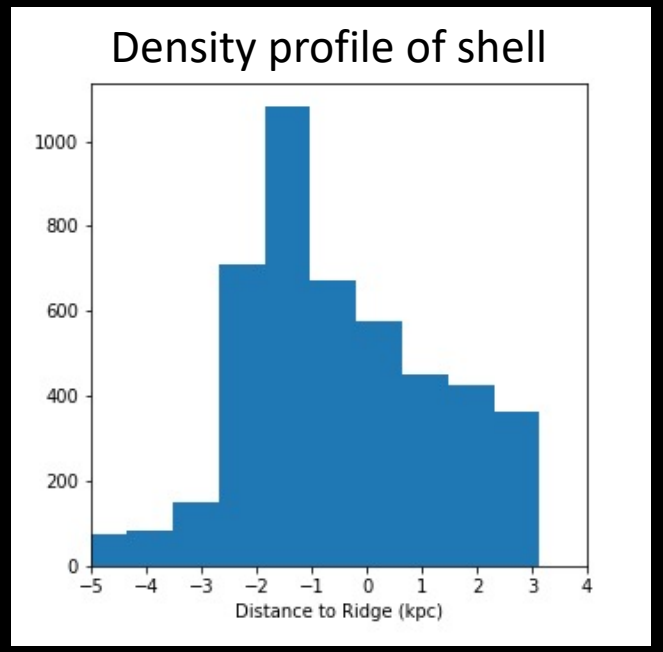
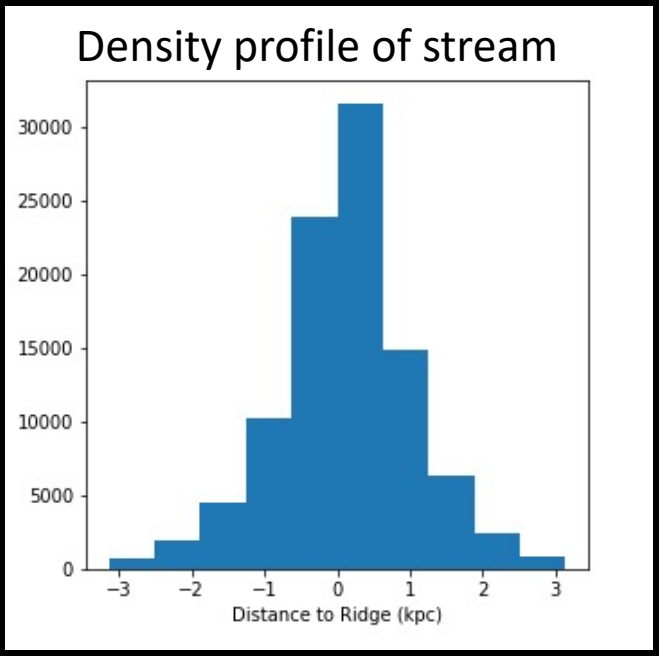
Part II: ADAS (Automatic Detection & Analysis of Structure)

1. Connect features using proximity + alignment in ridge points
2. Sort significant features from noise
3. “Assign” particles/stars/pixels to appropriate feature/ridge points







Part II: ADAS (Automatic Detection & Analysis of Structure)

- Step 4: Classify feature morphology
- Step 5: Measure length, dispersion (local & global), surface brightness of individual features
    - Morphology metric: symmetry + “radiality”