

OpenGADGET3 User Meeting  
@ University of Ljubljana



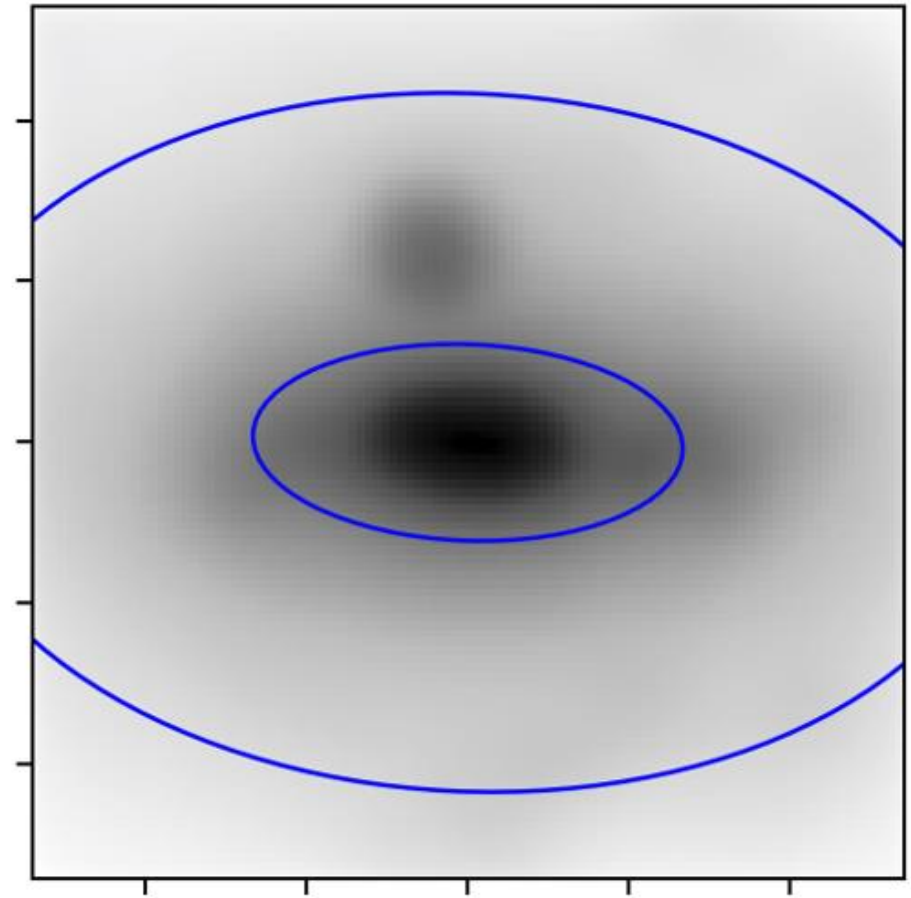
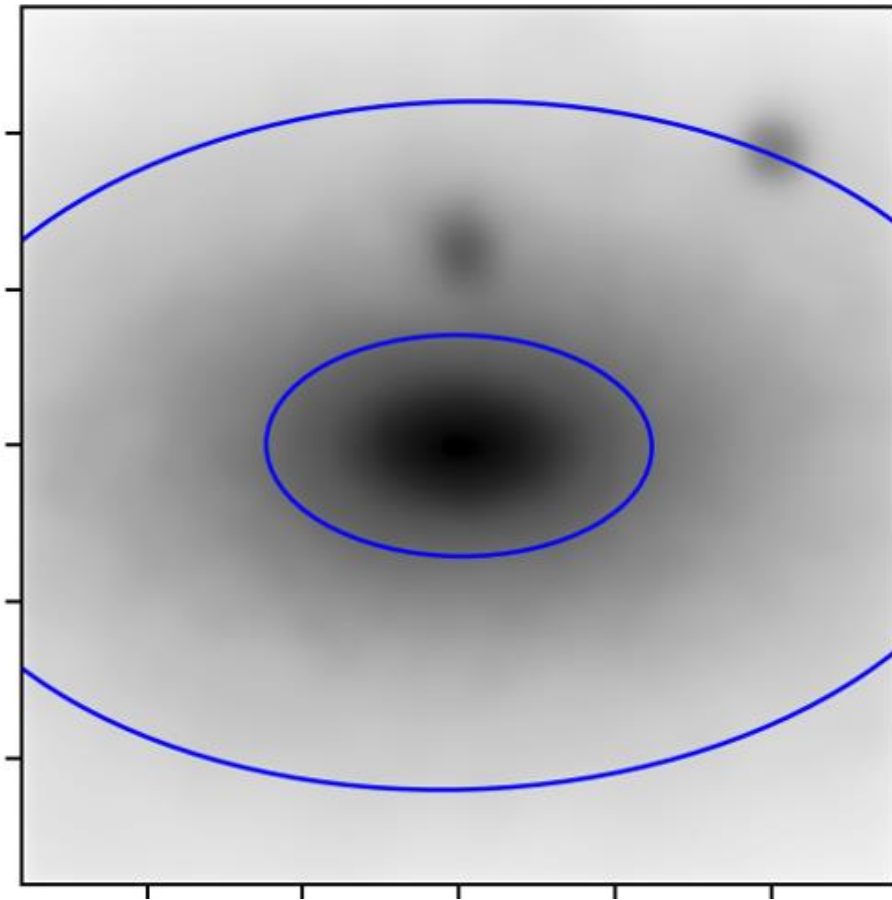
UNIVERSITY  
OF LJUBLJANA

# Stellar Populations of Shells and Streams - Where They Came from and How They Got There

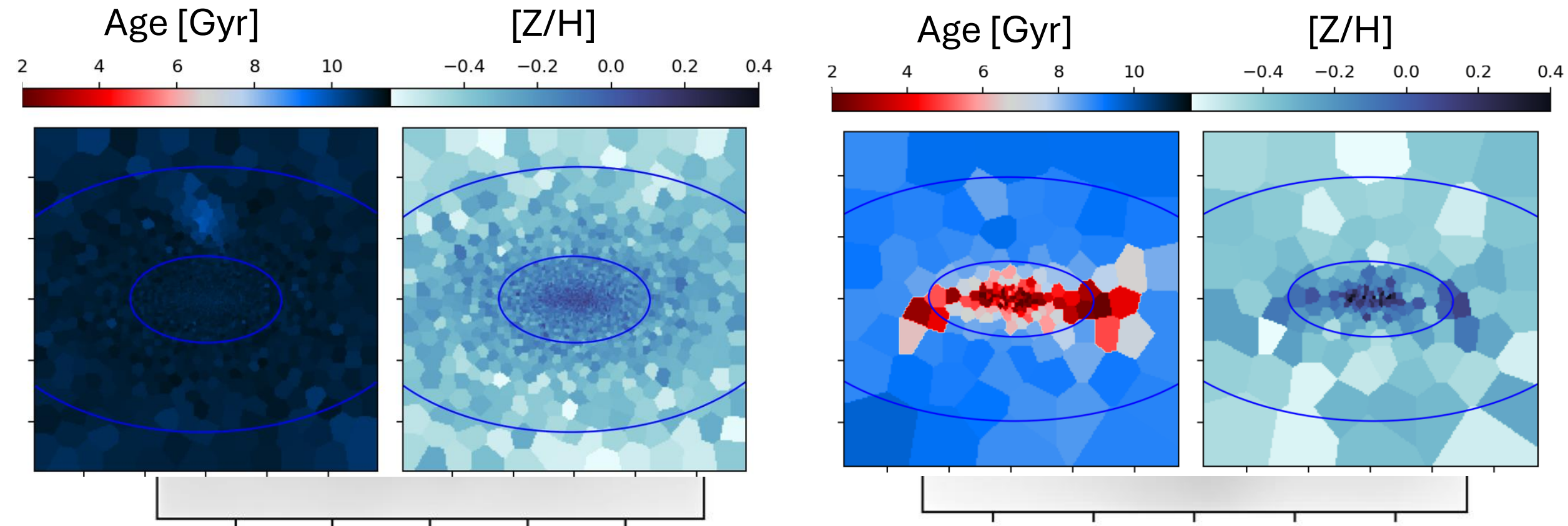
**Johannes Stoiber**

In collaboration with Rhea-Silvia Remus, Lucas M. Valenzuela and Lucas C. Kimmig

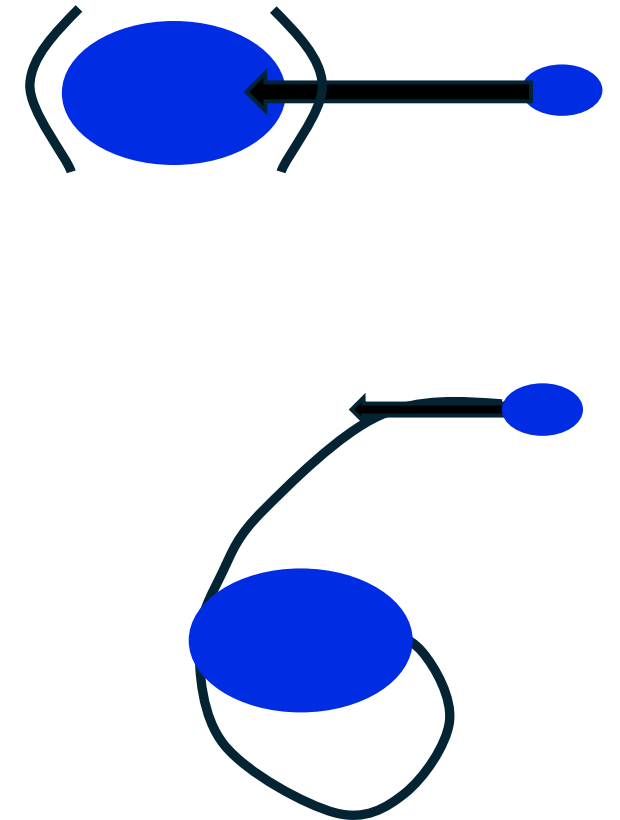
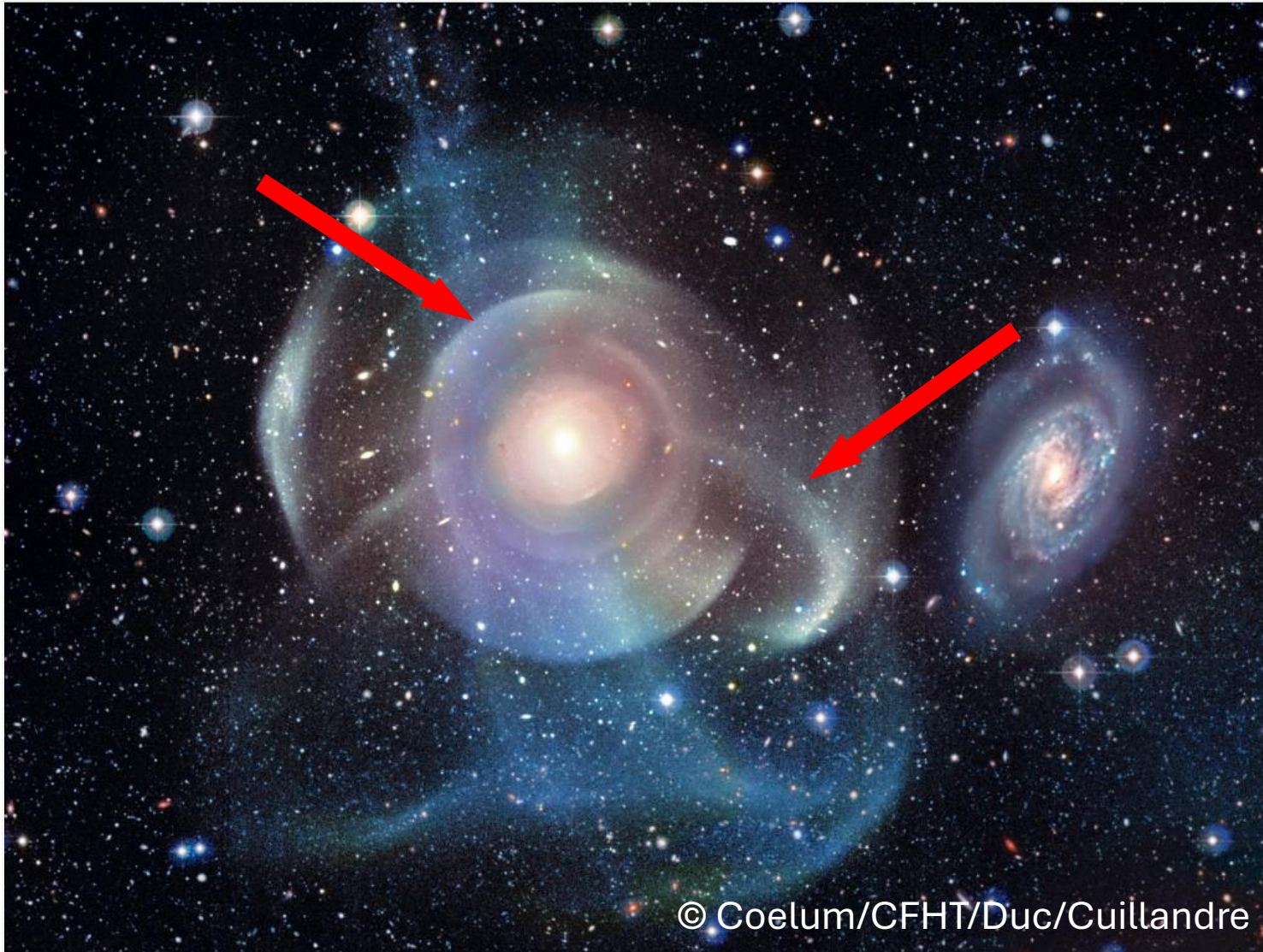
# Motivation



# Motivation



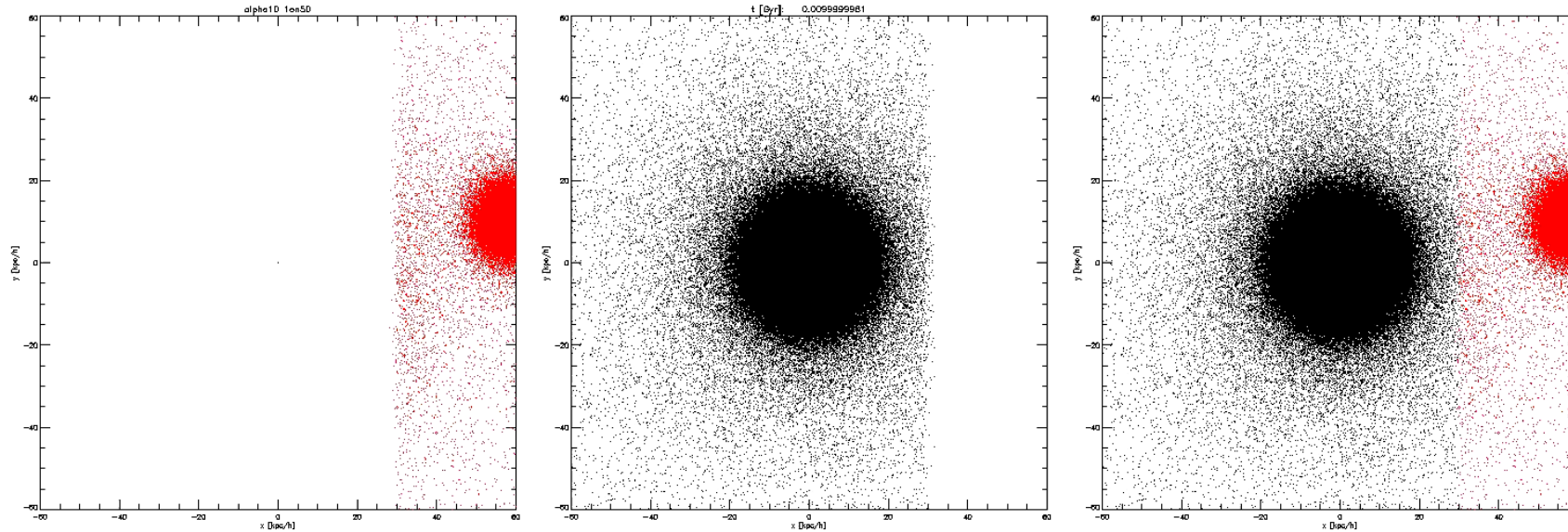
# Motivation



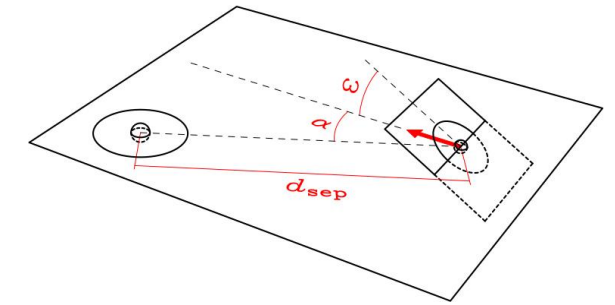
# Shells and Streams: How do they form

Mass Ratio: 1:50

$\alpha = 10^\circ \rightarrow$  Shells



Karademir et al., 2019



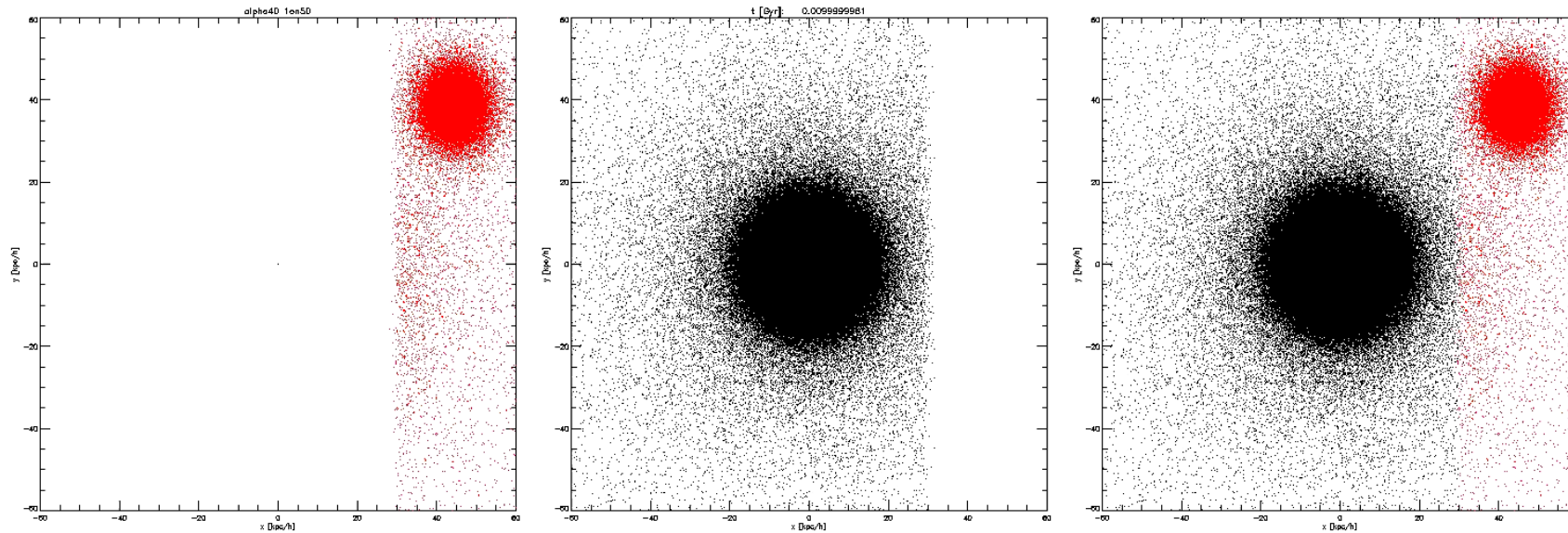
Karademir et al., 2019

# Shells and Streams: How do they form

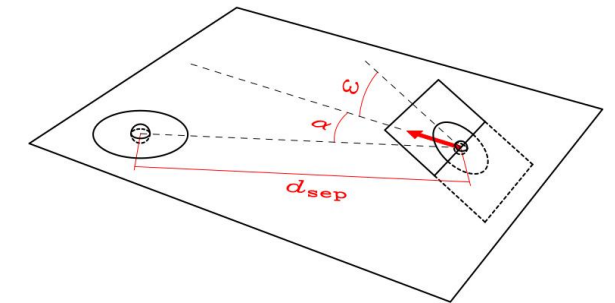
Mass Ratio: 1:50

$\alpha = 10^\circ \rightarrow$  Shells

$\alpha = 40^\circ \rightarrow$  Streams

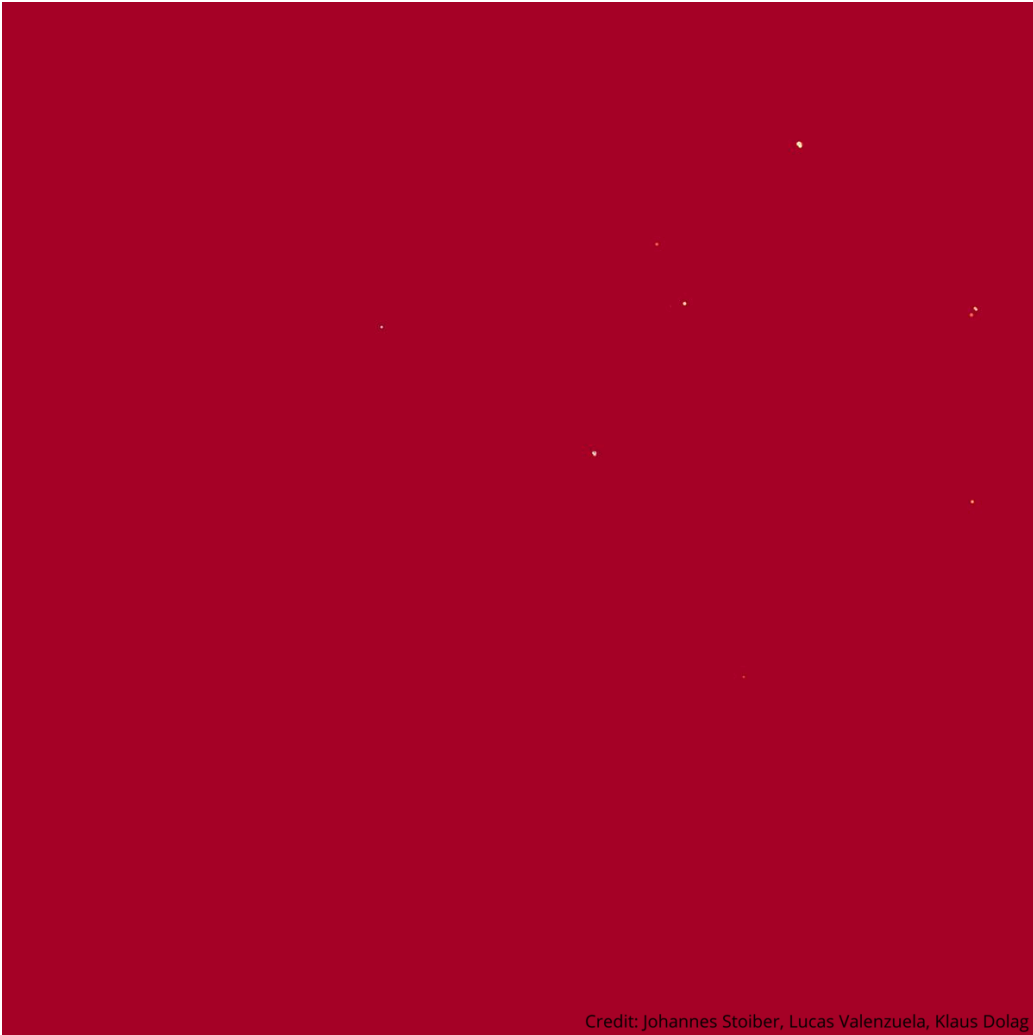


Karademir et al., 2019



Karademir et al., 2019

# Simulation: MAGNETICUM Pathfinder

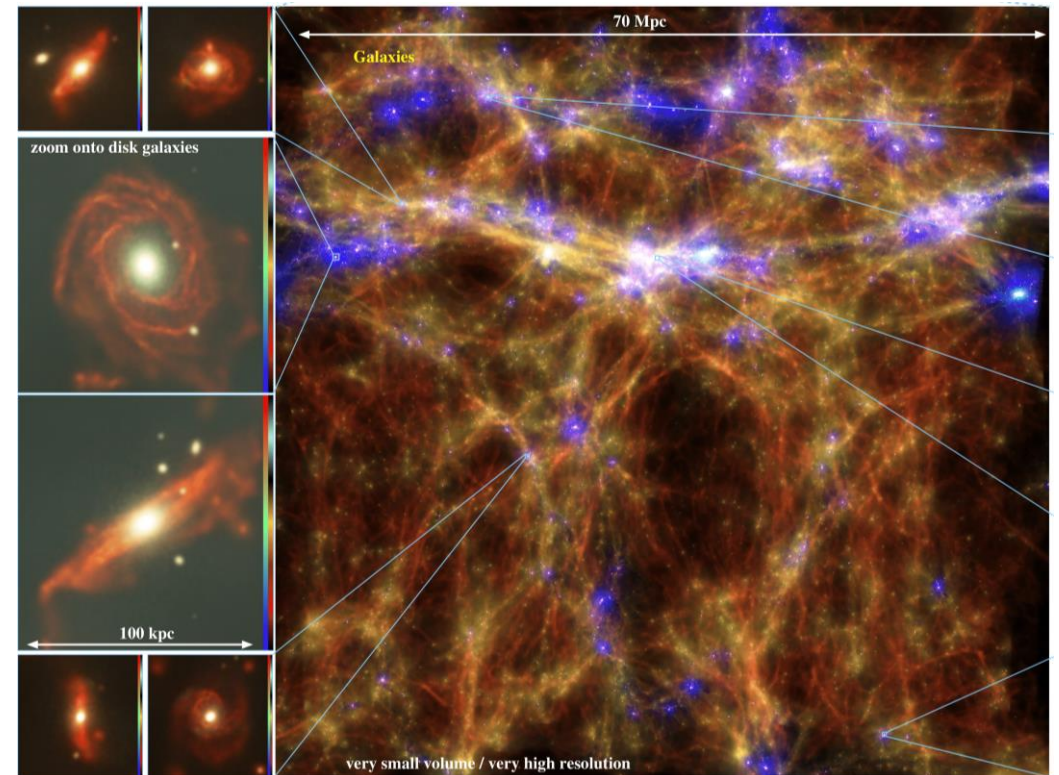


Credit: Johannes Stoiber, Lucas Valenzuela, Klaus Dolag

Box4 uhr:

$$\langle m_* \rangle \approx 1.4 \times 10^6 M_\odot$$

- Valenzuela and Remus, 2024:  $M_* > 2.4 \times 10^{10} M_\odot \rightarrow$
- 21 Shell Galaxies, 62 Stream Galaxies

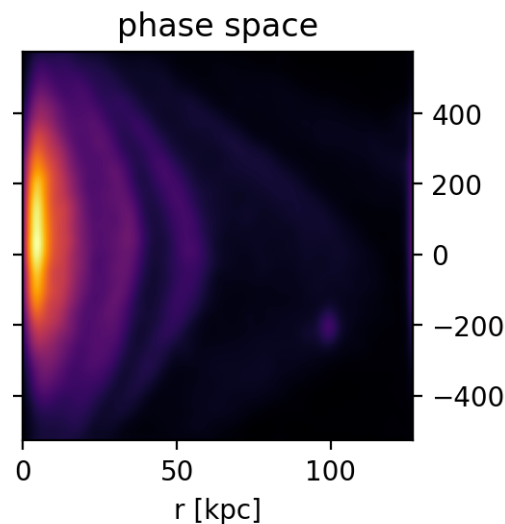
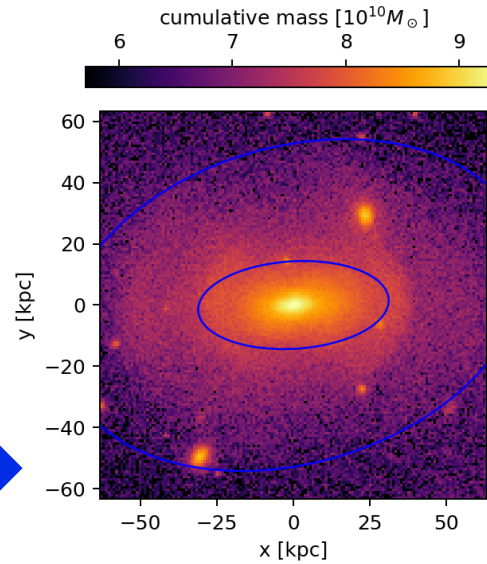


# Going 2D – Mixing Observations and Simulations

Snapshot  
136  
Magneticum  
Box4 (uhr)

JuliaCosmoSims  
Packages by  
Lucas Valenzuela

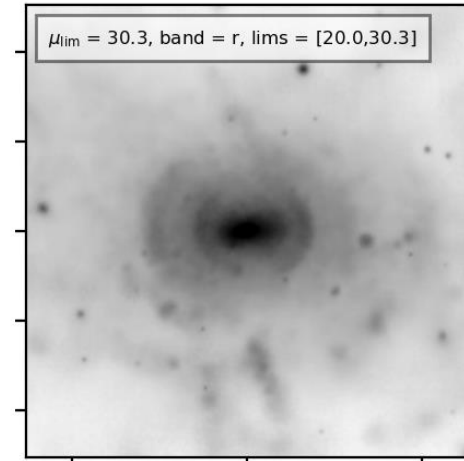
Robust Centering,  
Shape Calculation,  
Face-On Rotation



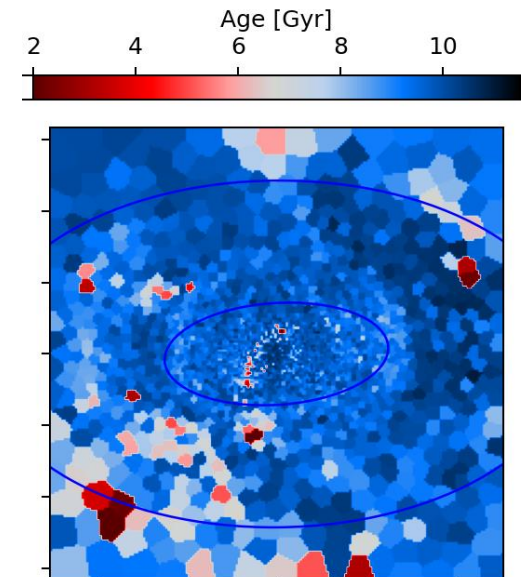
Stellar Mocks  
using *smooth3d* by  
Garreth Martin

Martin et al., 2022

faceon



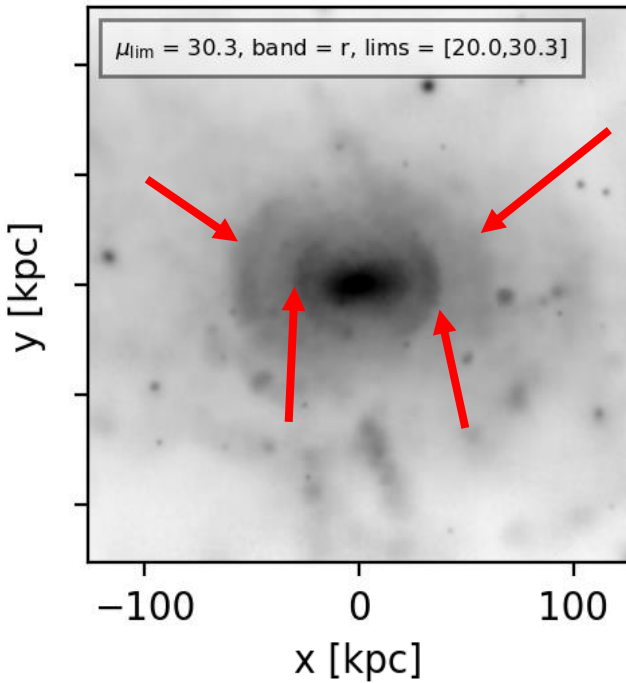
Voronoi Maps  
of Stellar  
Population  
Properties,  
e.g. Age





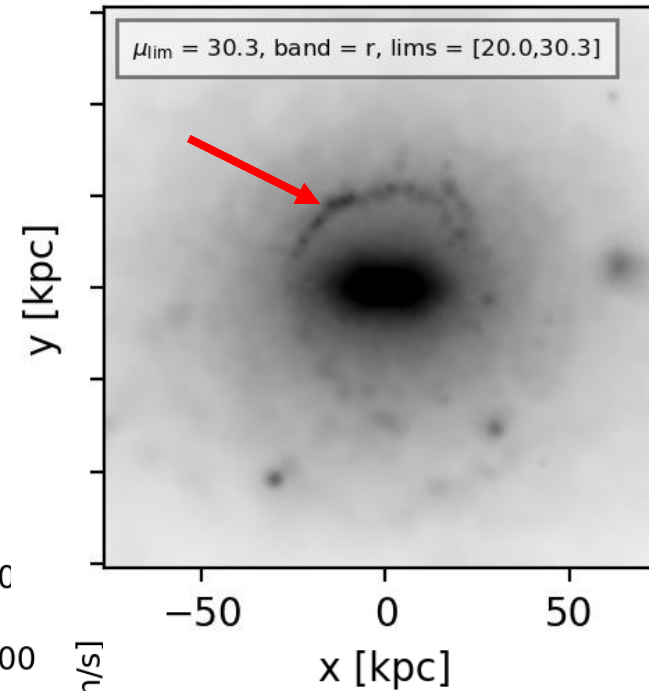
# Going 2D – Posterchild Galaxies

faceon



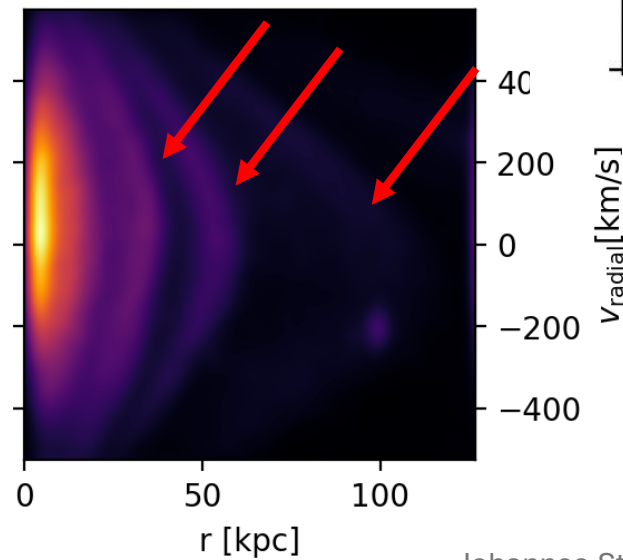
## Shell Galaxy

faceon

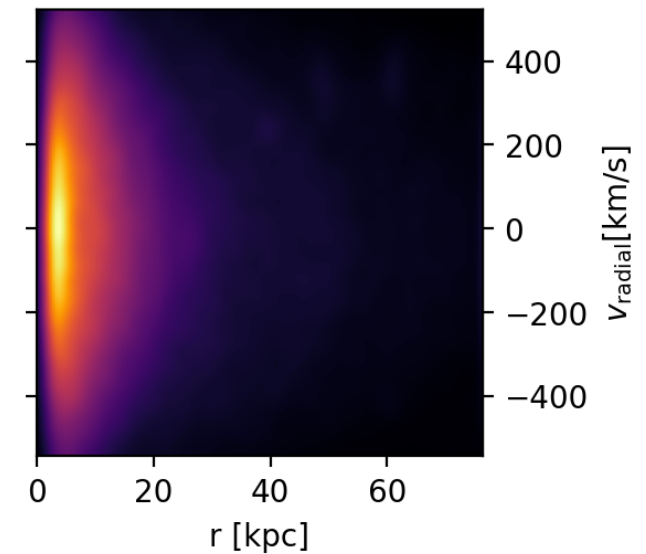


## Stream Galaxy

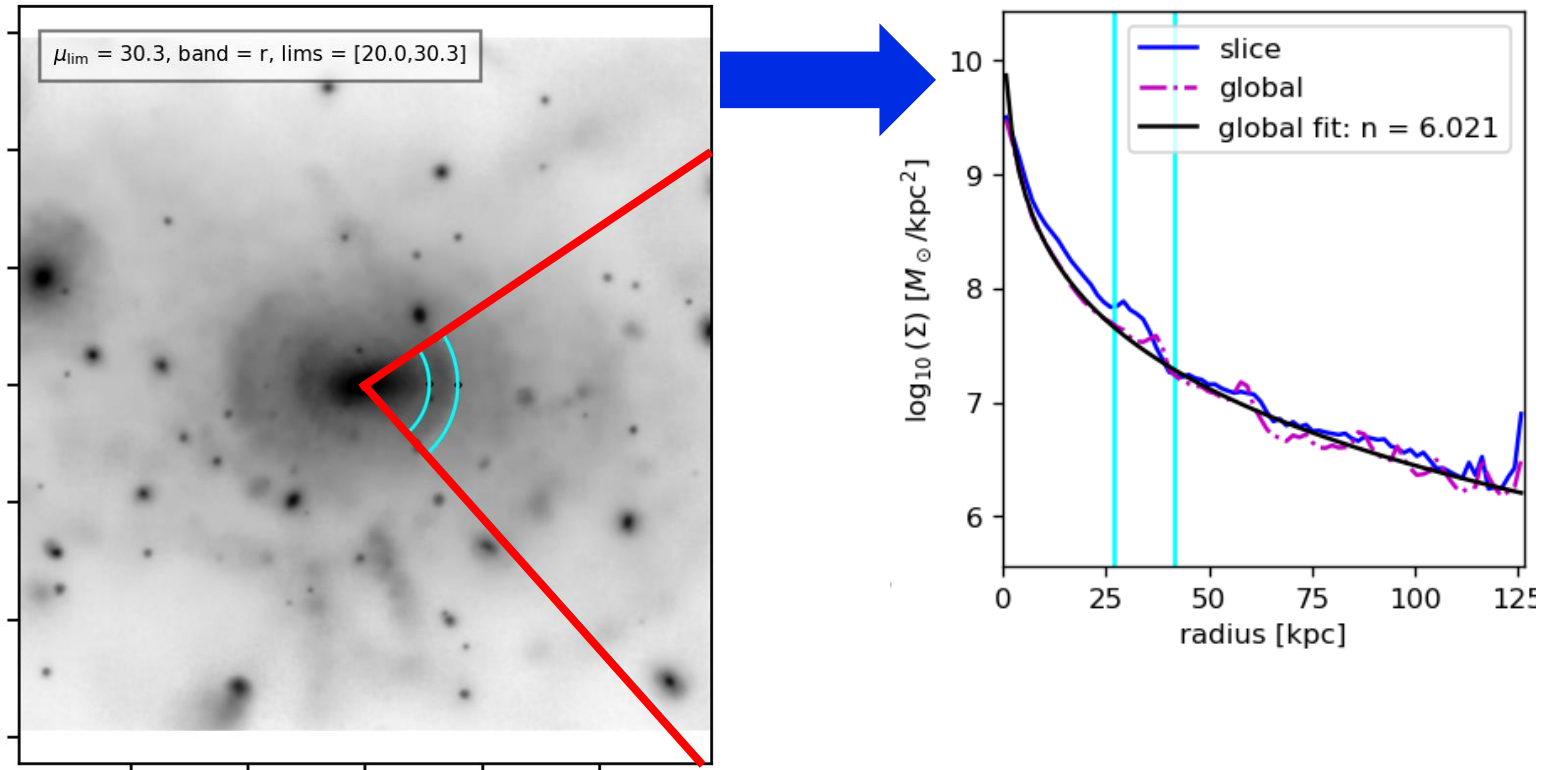
phase space



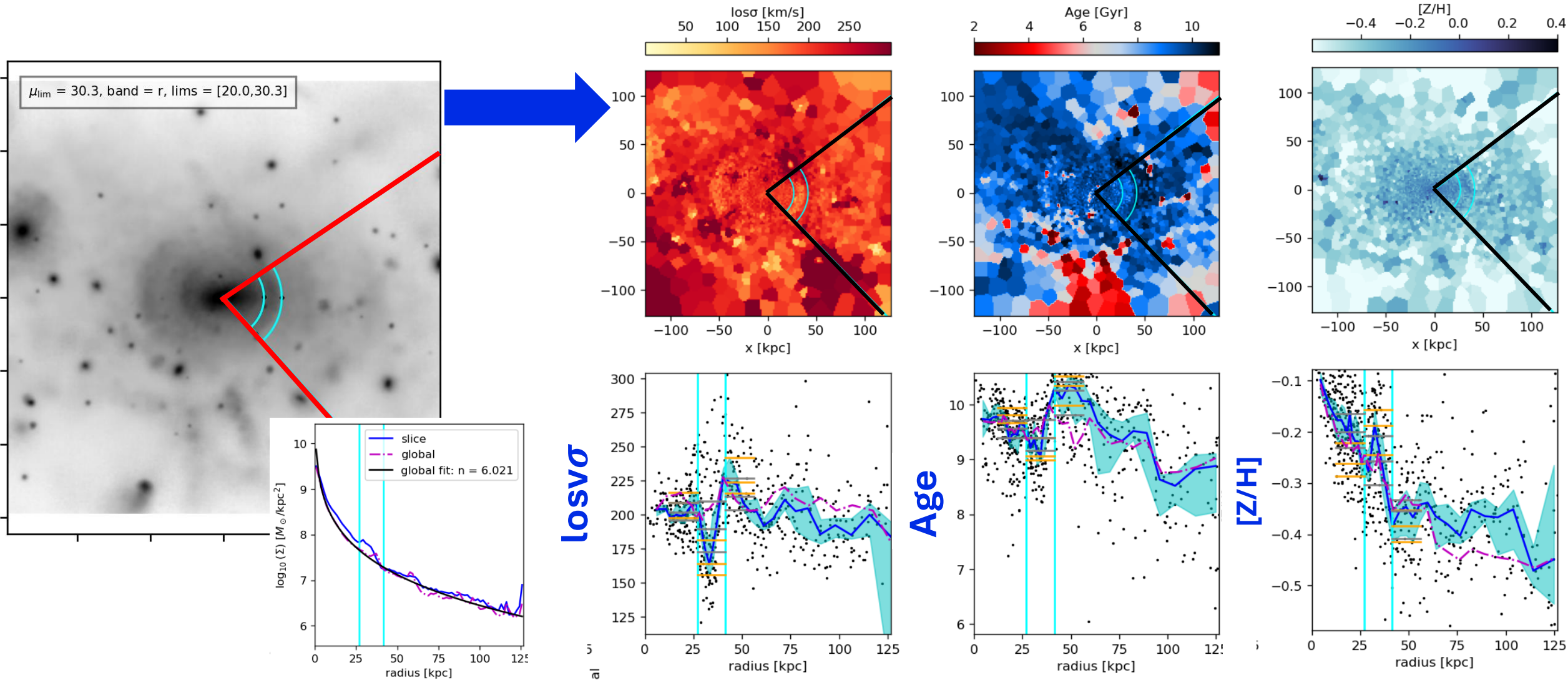
phase space



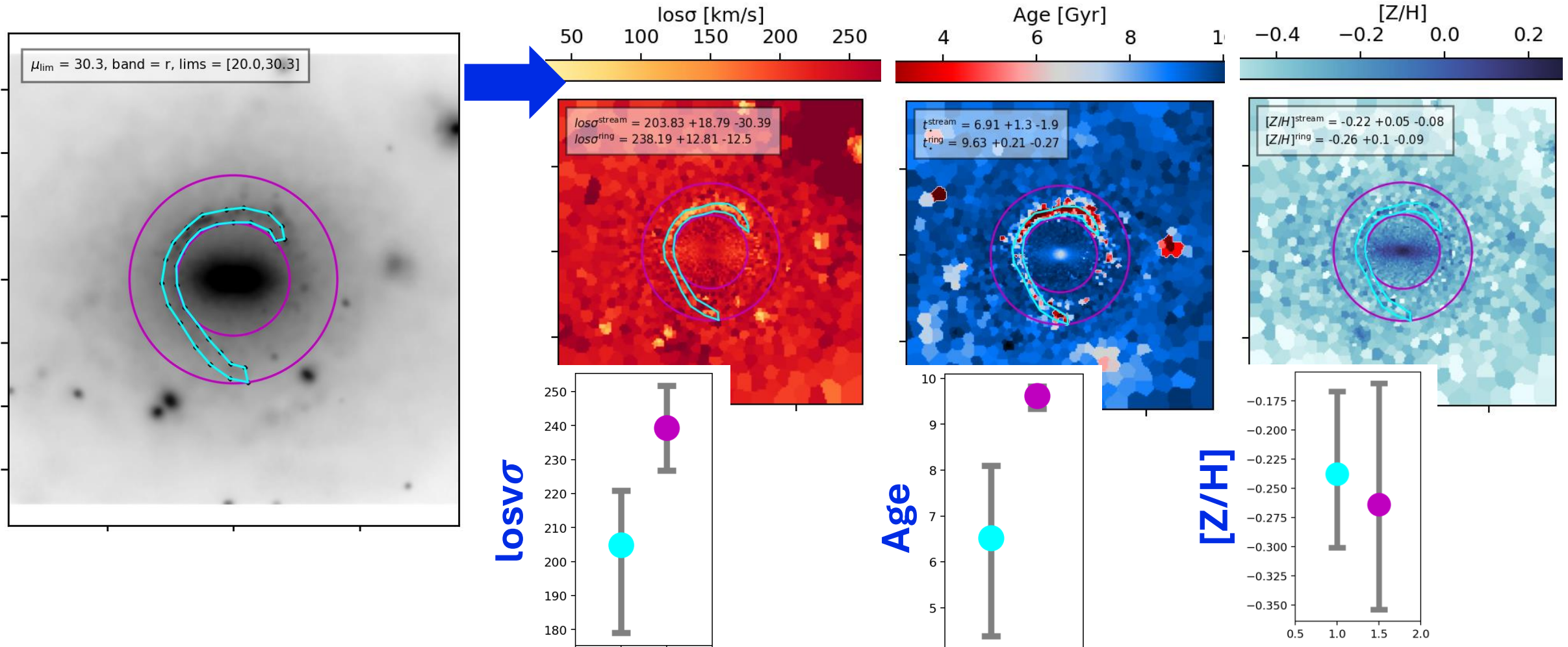
# Shells - Radial Profiles



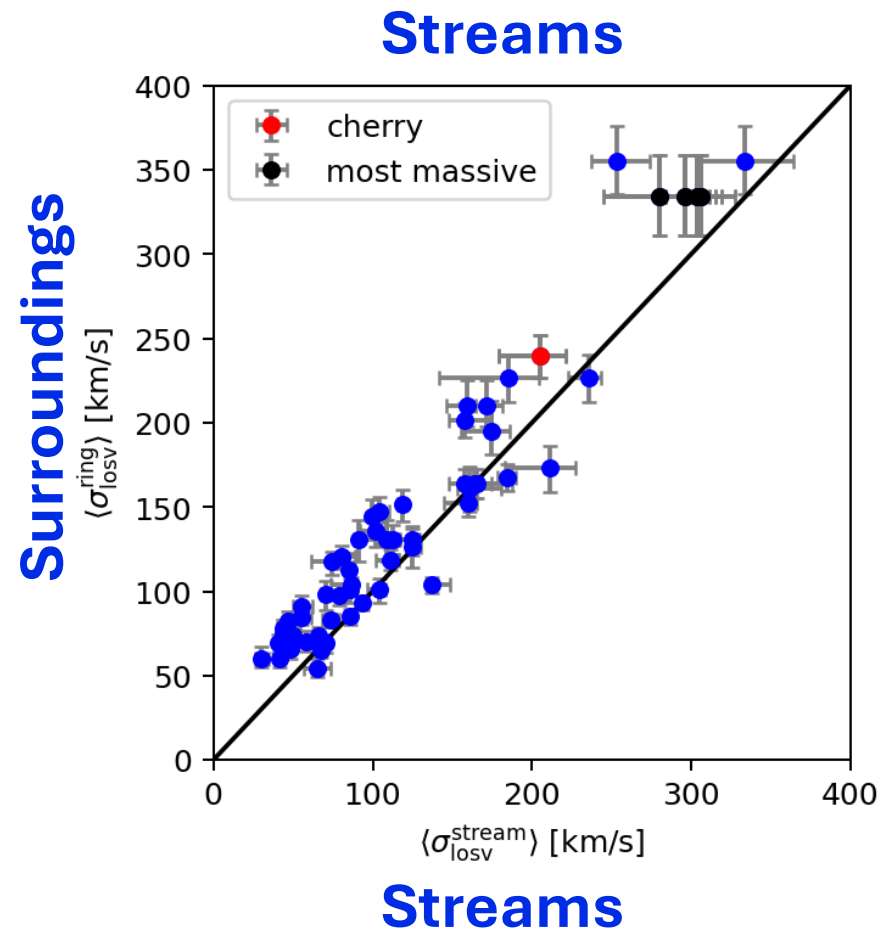
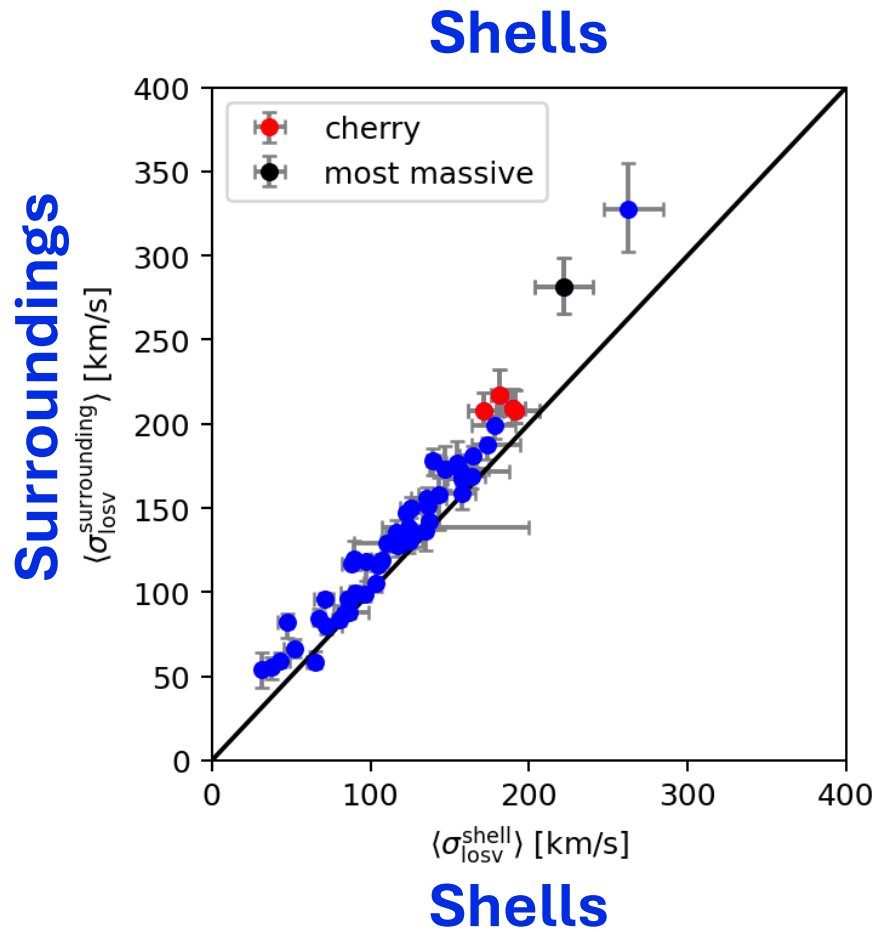
# Shells - Radial Profiles



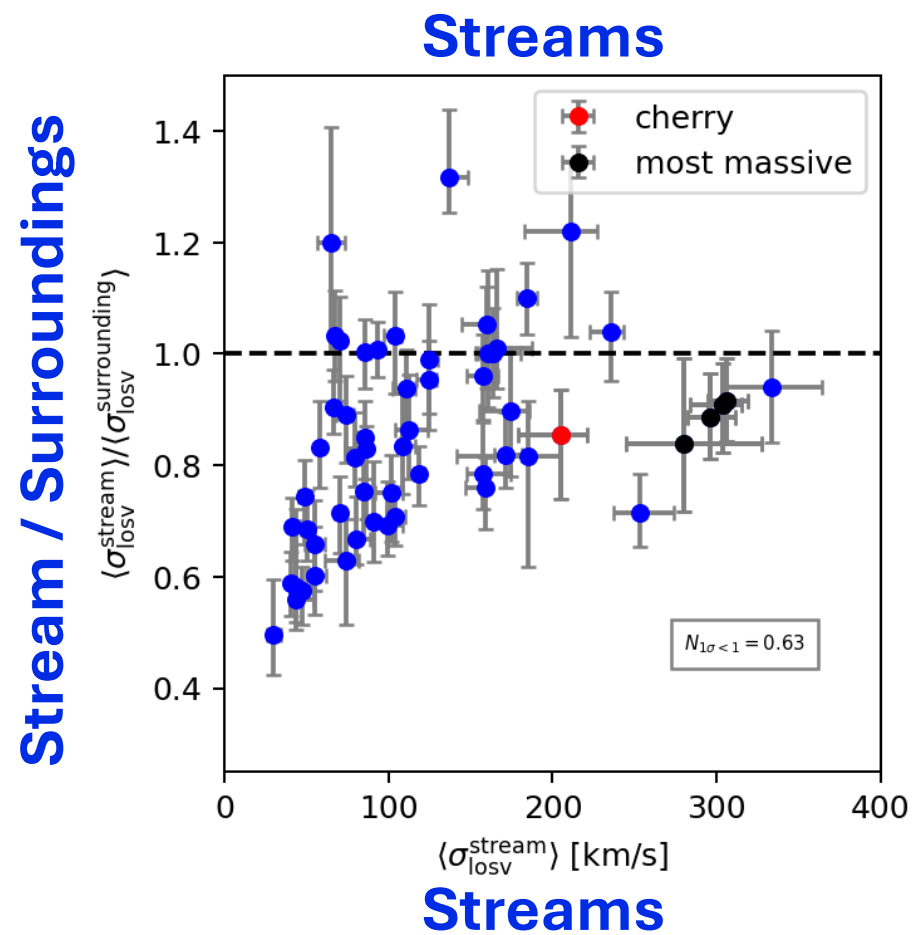
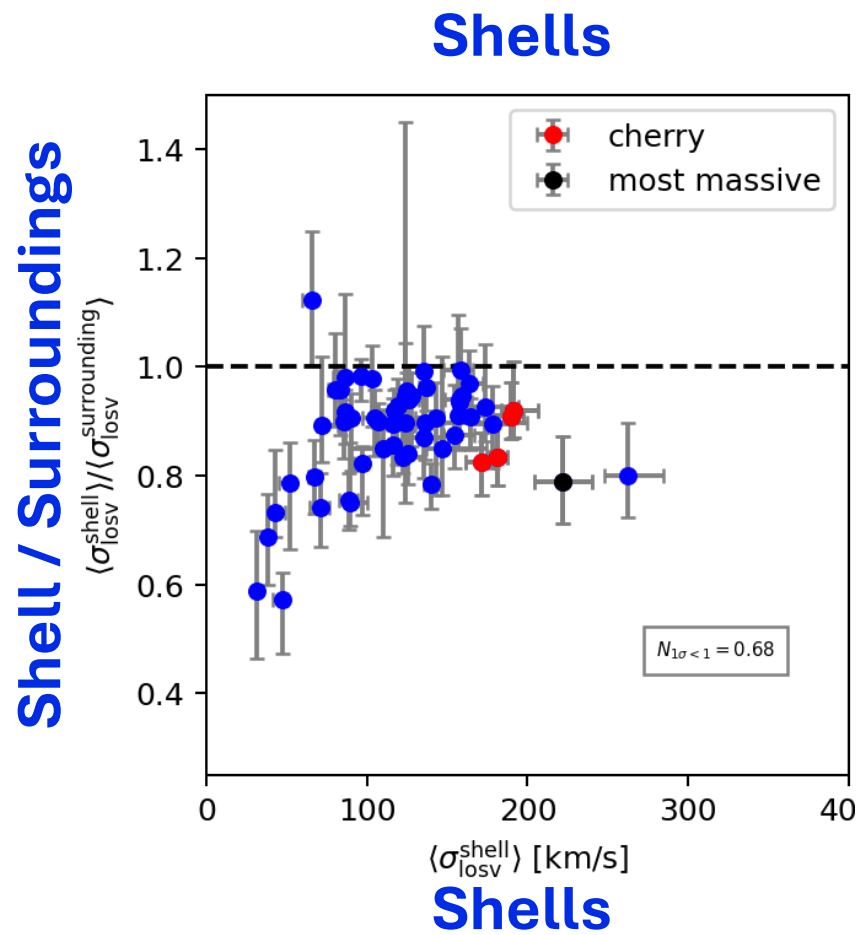
# Streams – Polygon Annotation



# Velocity Dispersion

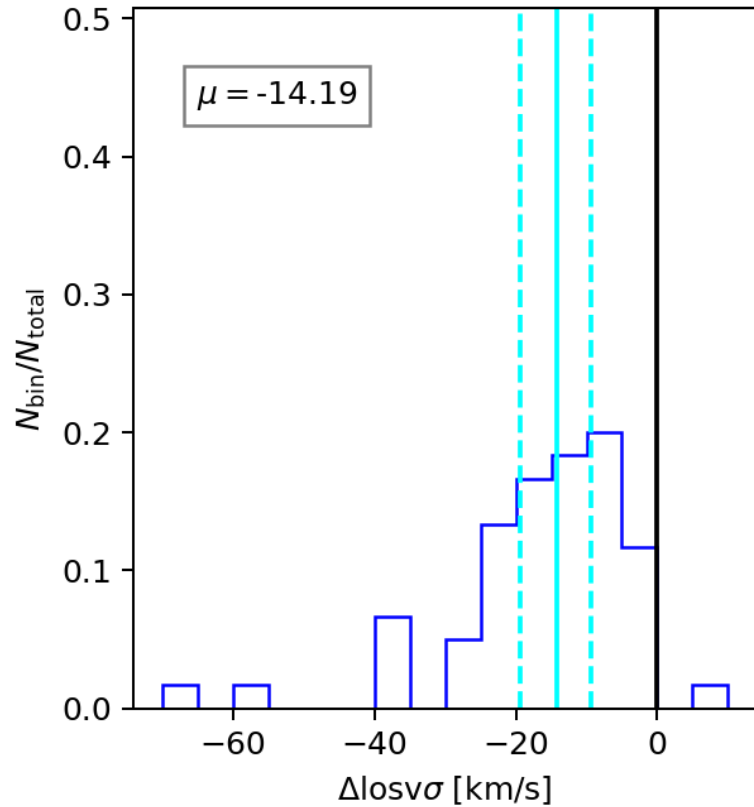


# Velocity Dispersion



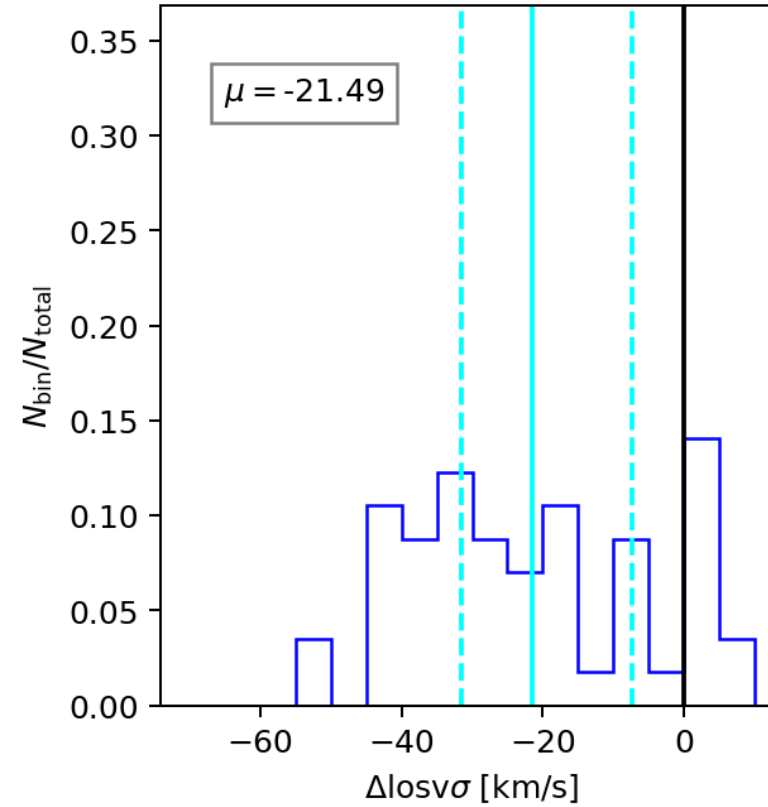
# Velocity Dispersion

## Shells



## Shell - Surroundings

## Streams



## Stream - Surroundings

# Stellar Populations Summary

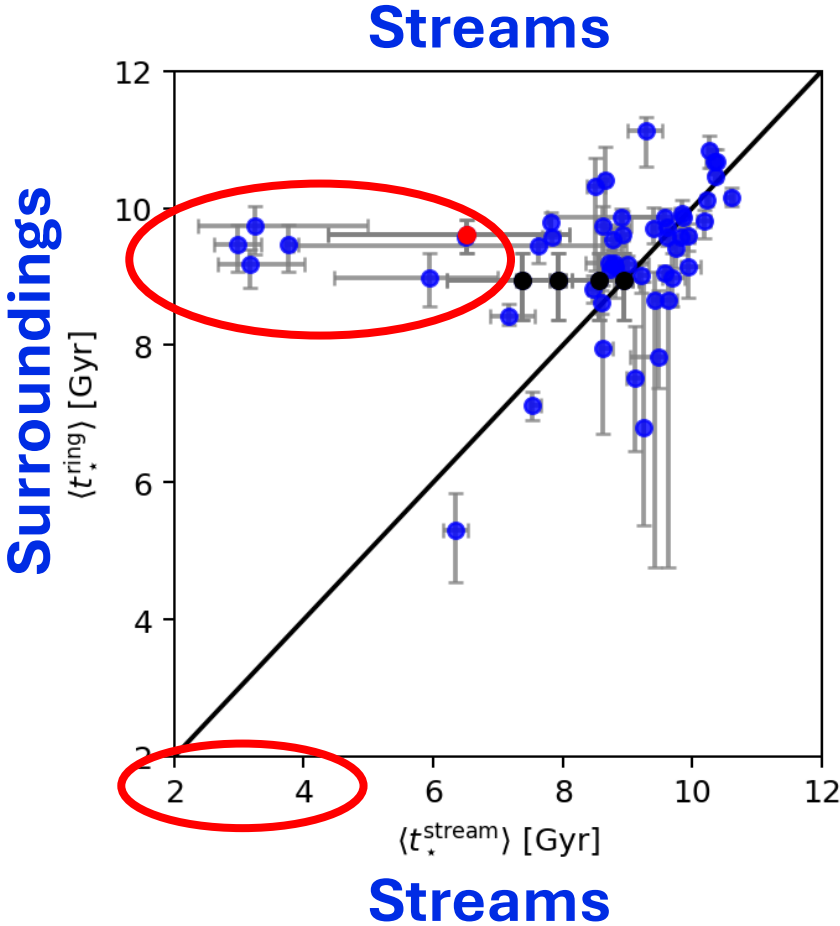
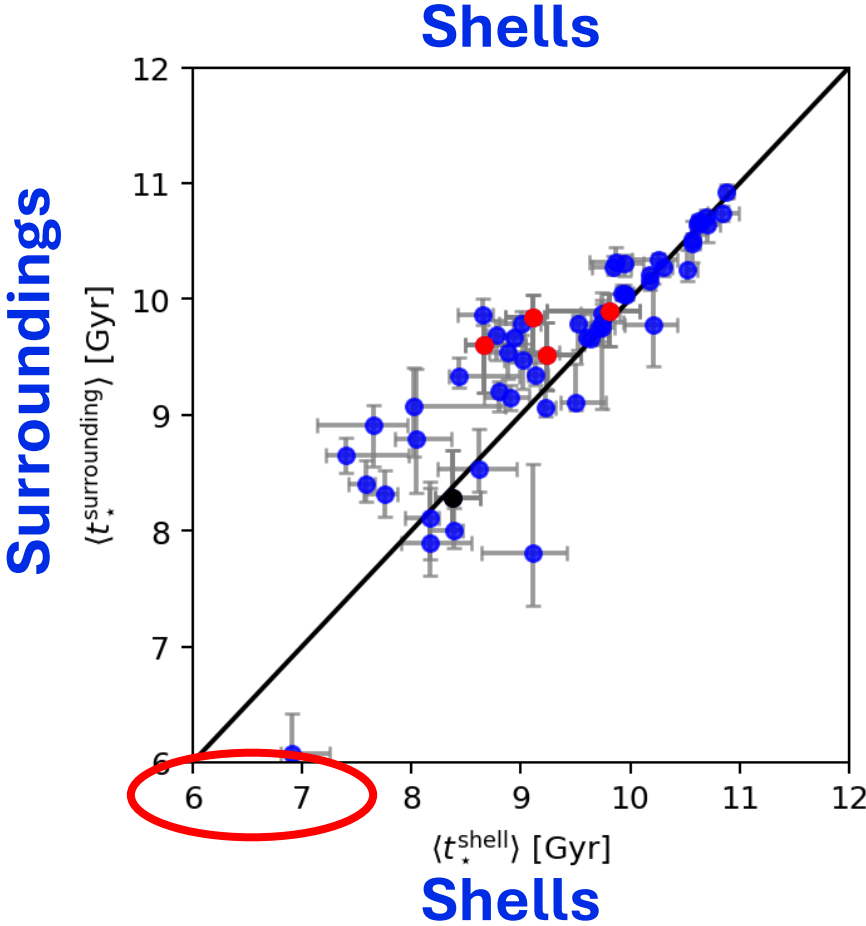
---

## Shells and Streams

→ **Depression in Velocity Dispersion**

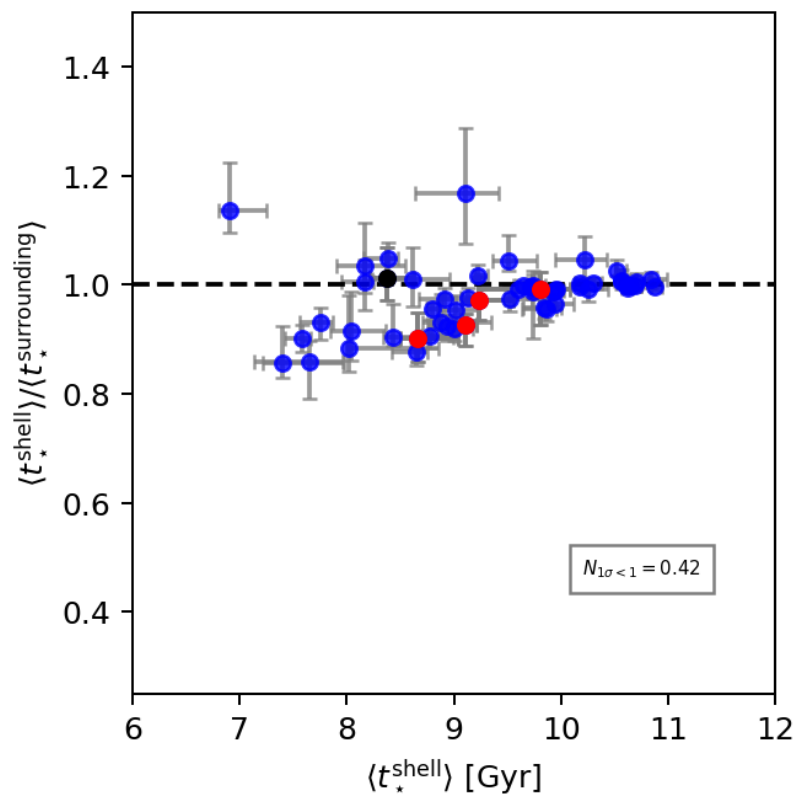


# Age



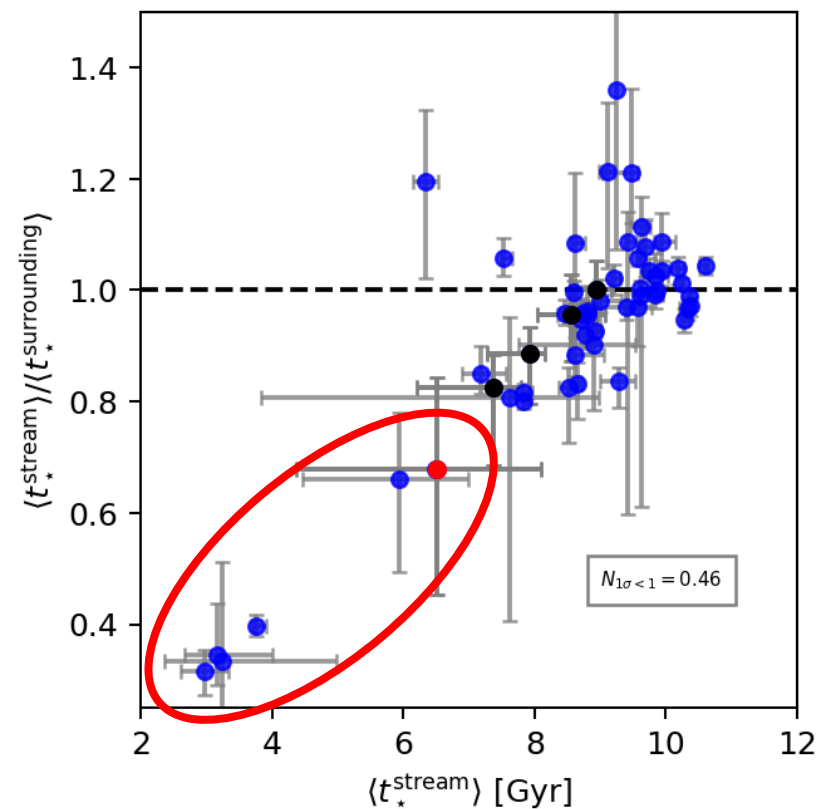
# Ages

Shell / Surroundings



Shells

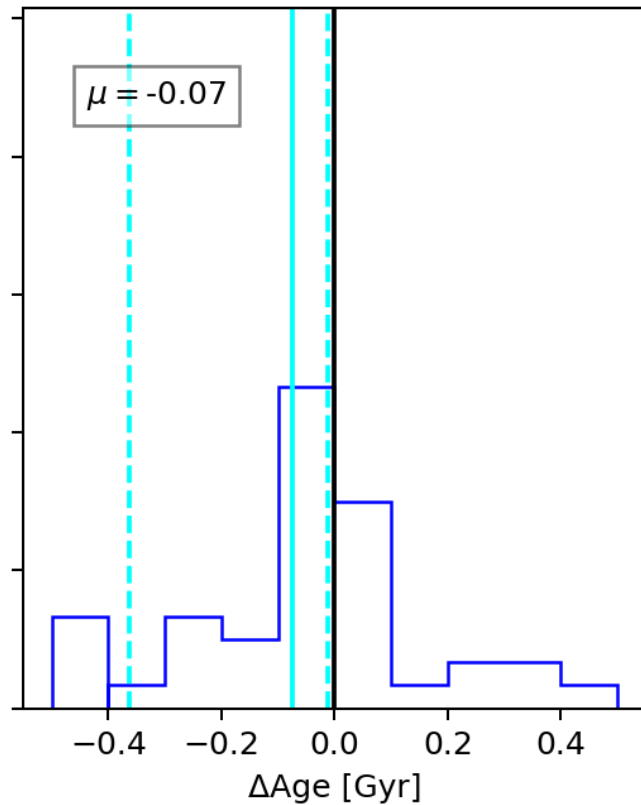
Stream / Surroundings



Streams

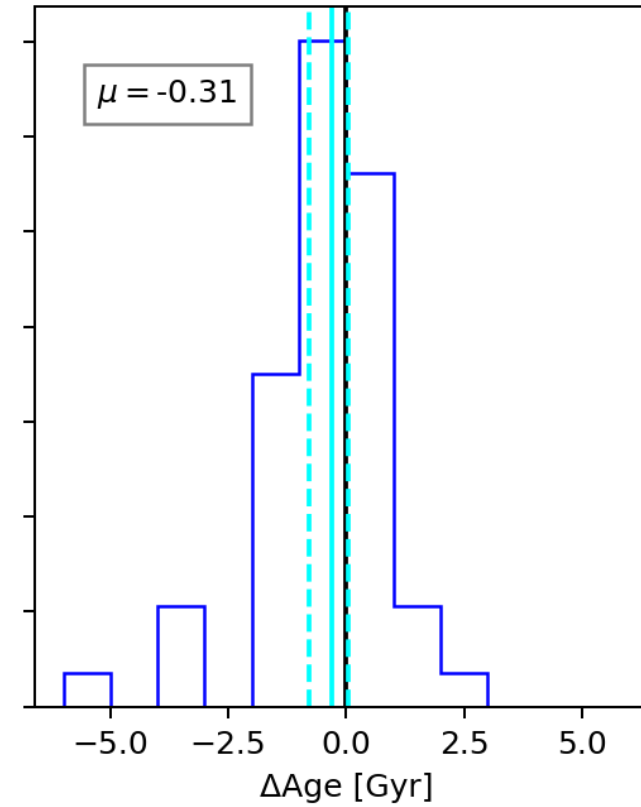
# Ages

## Shells



## Shell - Surroundings

## Streams



## Stream - Surroundings

# Stellar Populations Summary

---

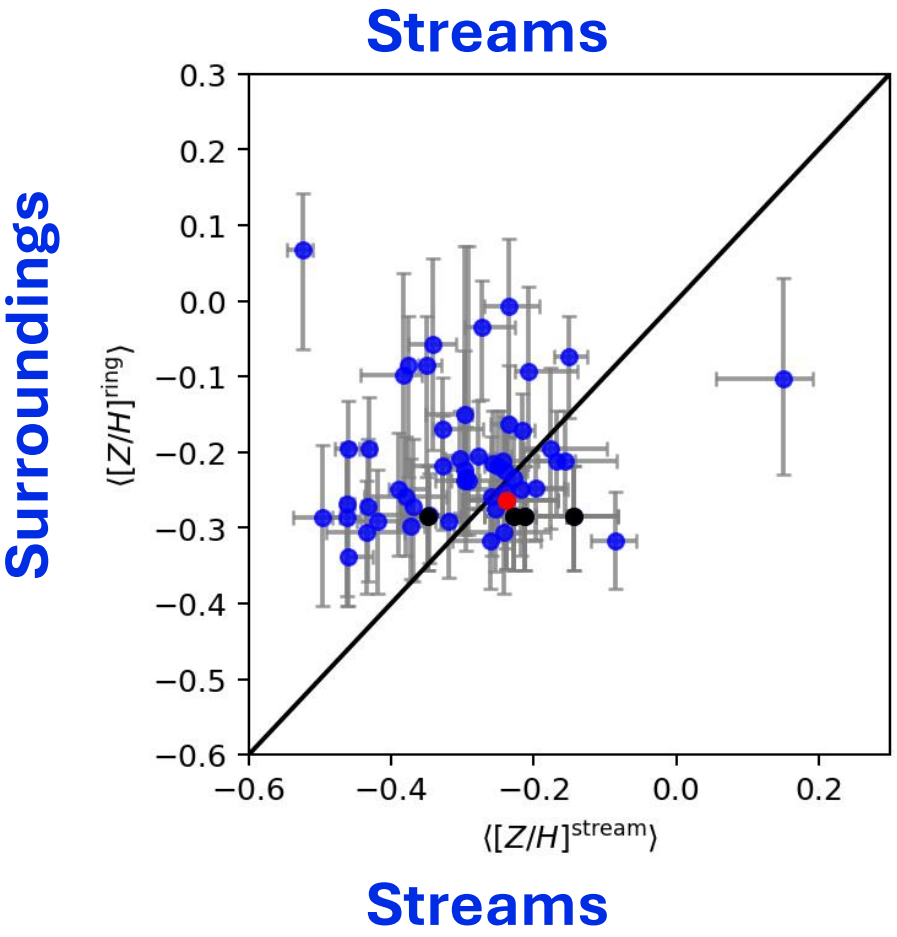
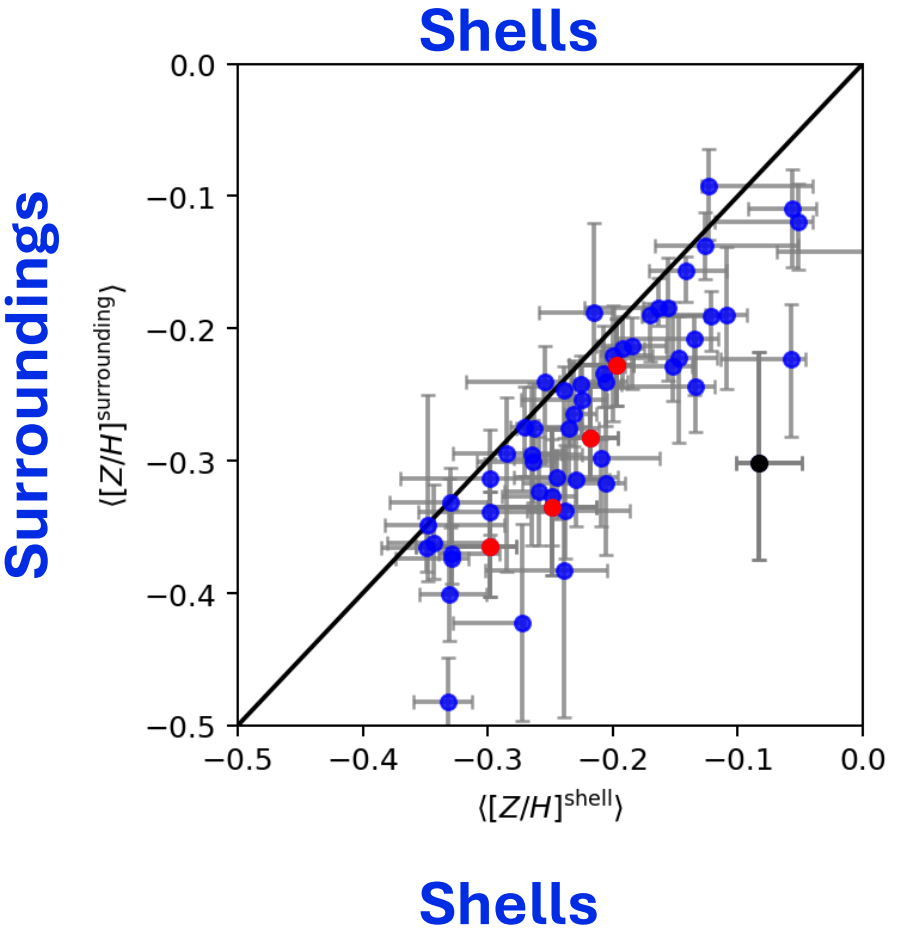
## Shells and Streams

→ Depression in Velocity Dispersion

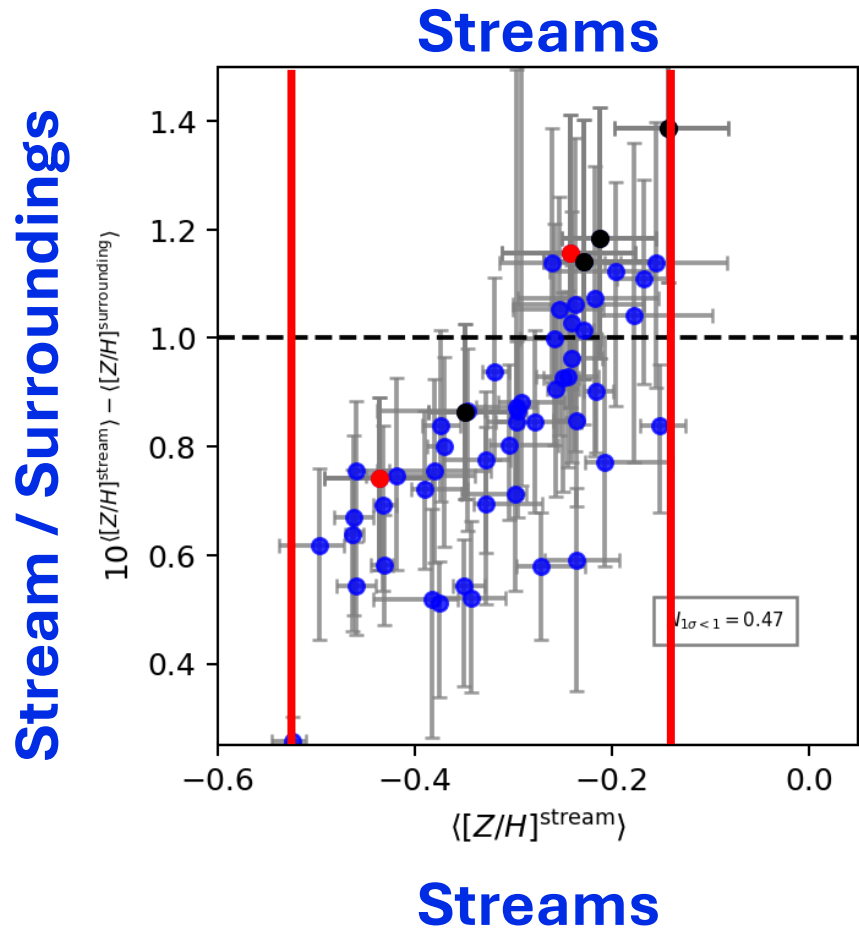
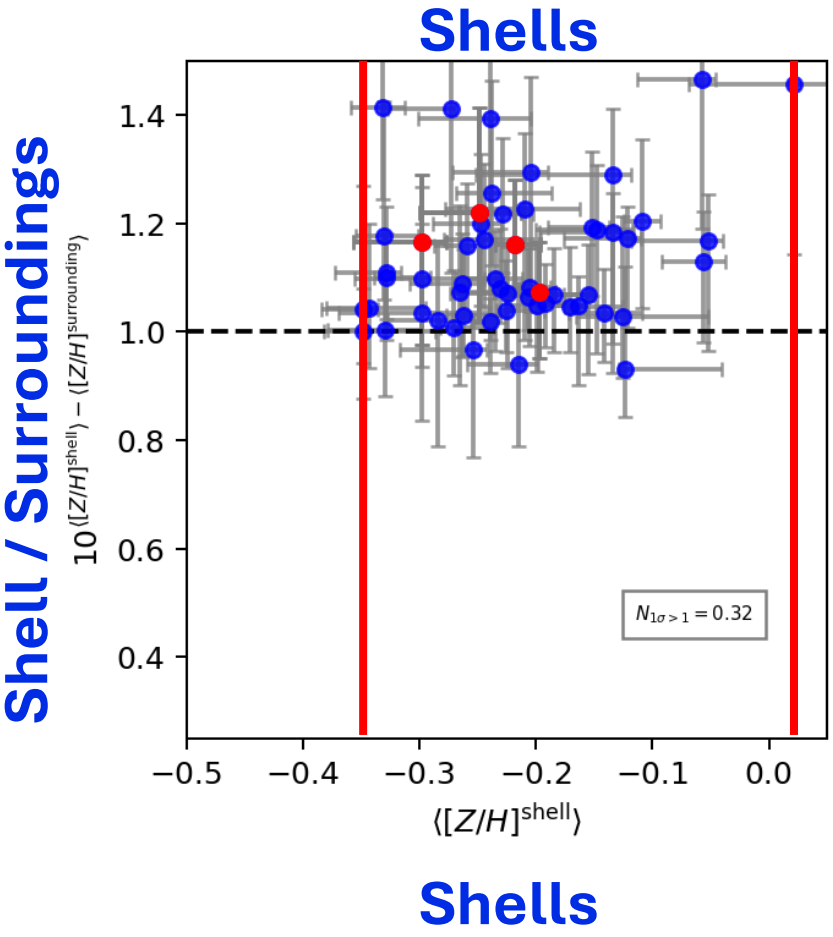
→ No Deviation of Age in a Single Direction

→ Streams can be very young

# Metallicity

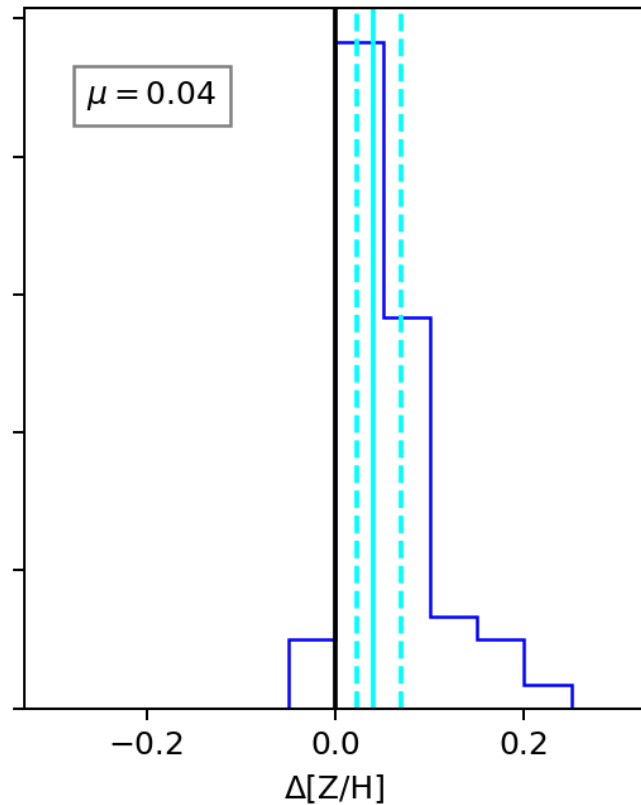


# Metallicity



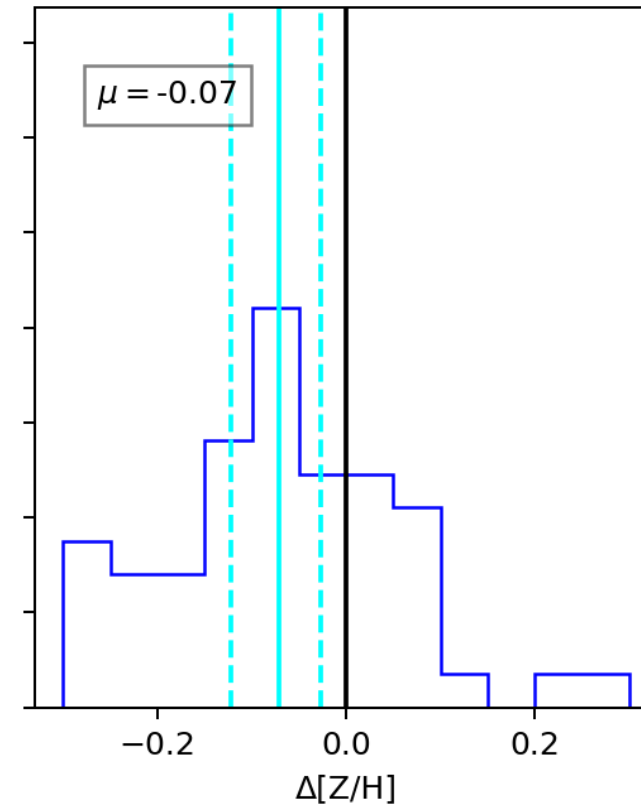
# Metallicity

## Shells



## Shell - Surroundings

## Streams



## Stream - Surroundings

# Stellar Populations Summary

## Shells and Streams

→ Depression in Velocity Dispersion

→ No Deviation of Age in a Single Direction

→ Streams can be very young

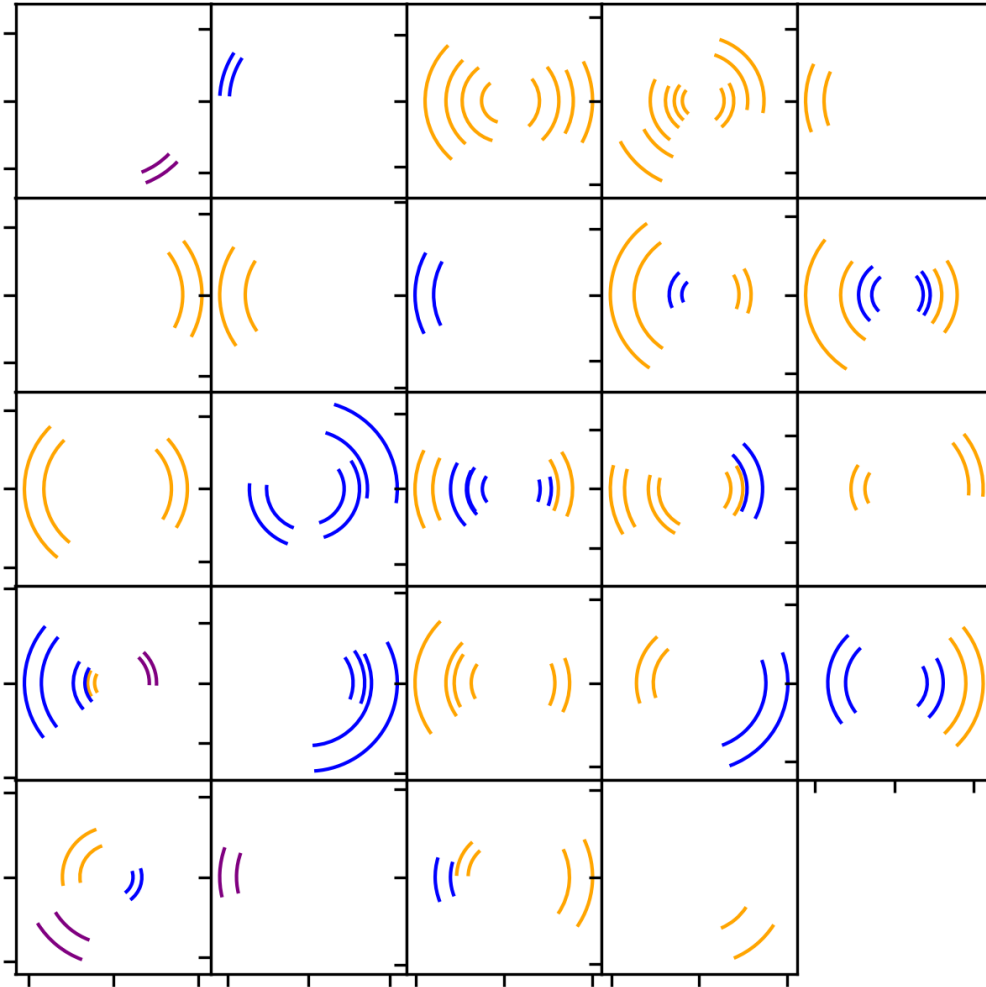
→ No Deviation of Metallicity in a Single Direction

→ Shells more metal rich than Streams

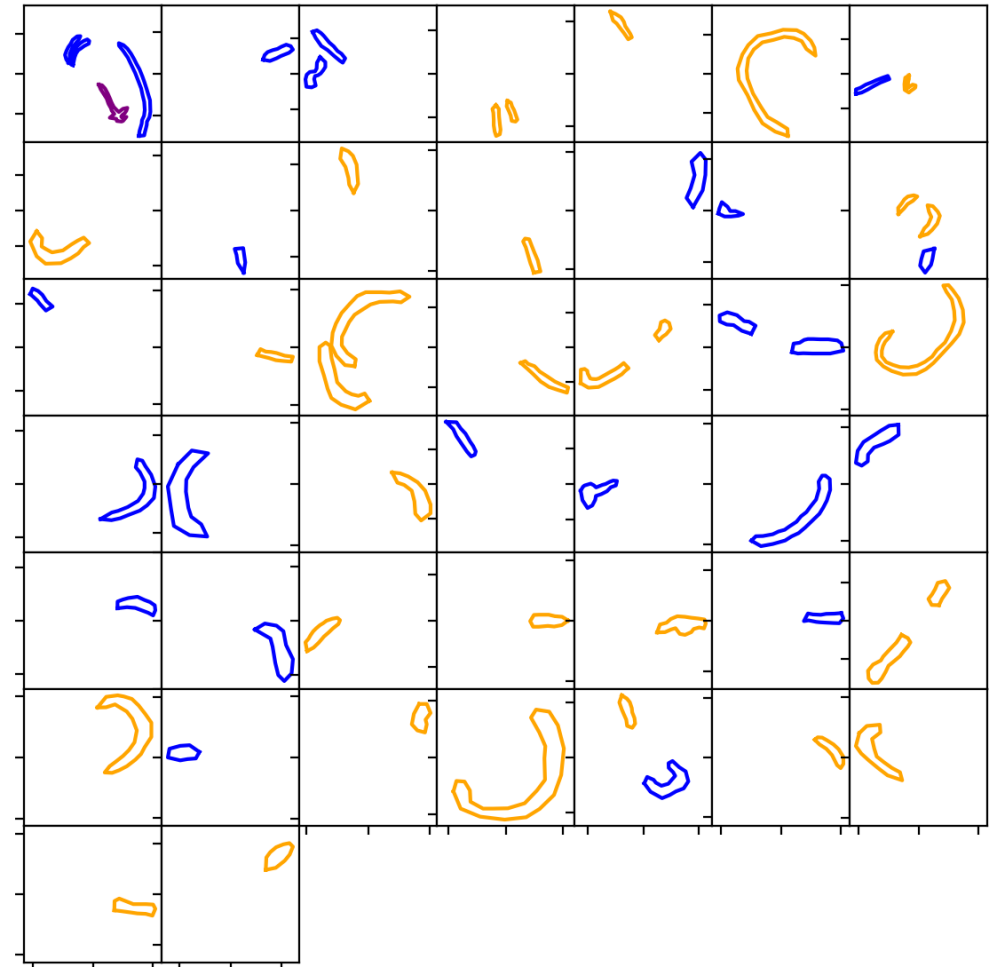


# Shells and Streams – Morphology and Position

## Shells

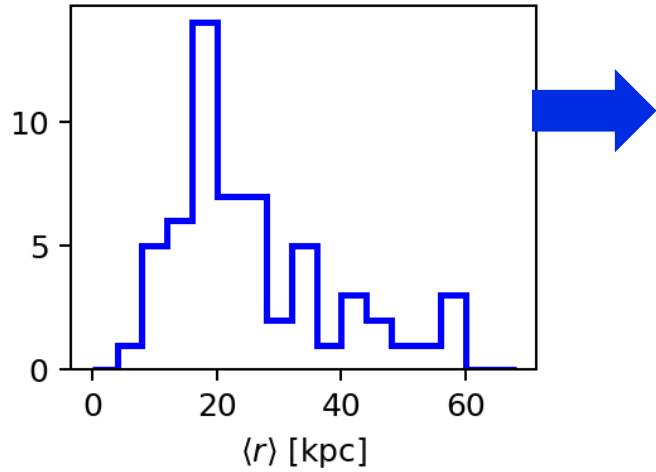


## Streams



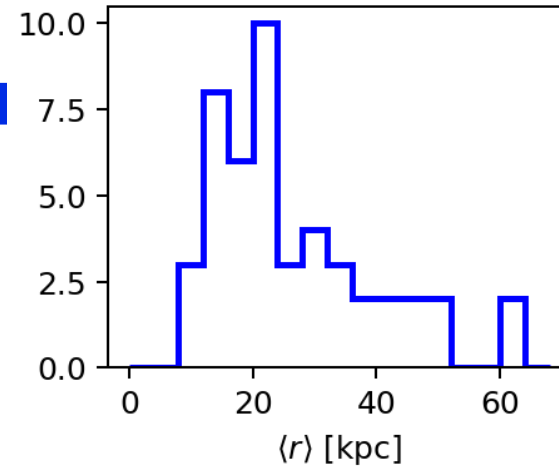
# Shells and Streams – Morphology

**Shells**

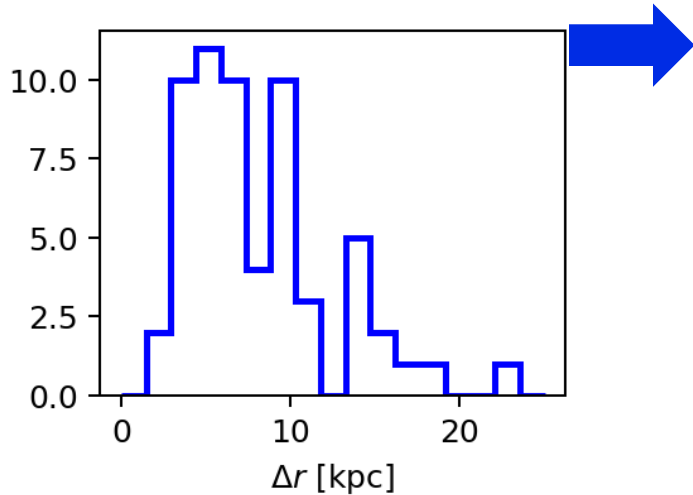


**Similar Radii**

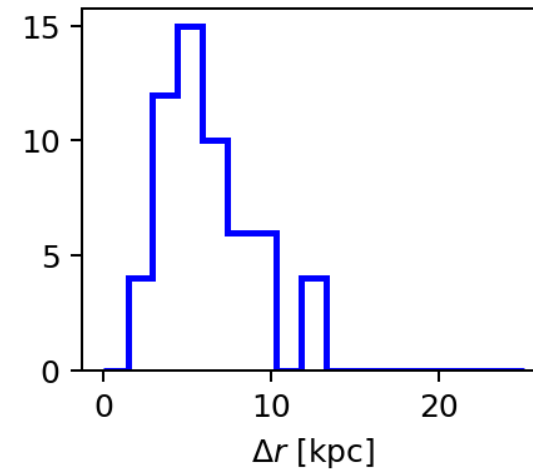
**Streams**



**Mean Radius**



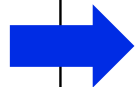
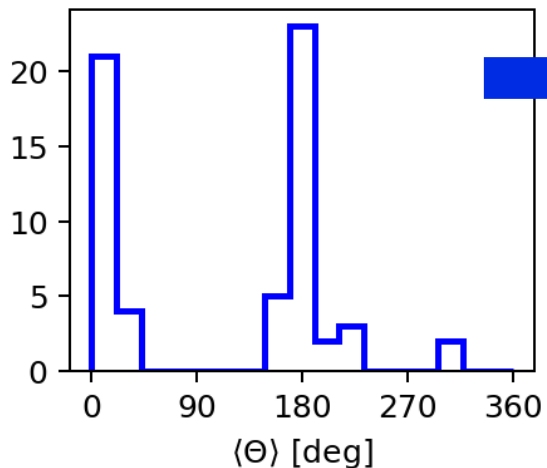
**Similar Widths**



**Radial Widths**

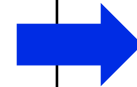
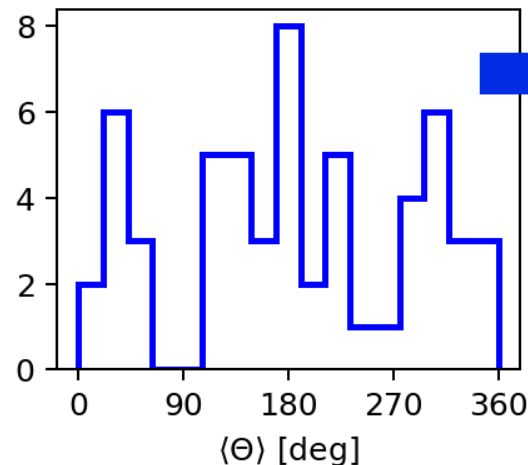
# Shells and Streams – Position

## Shells

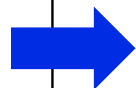
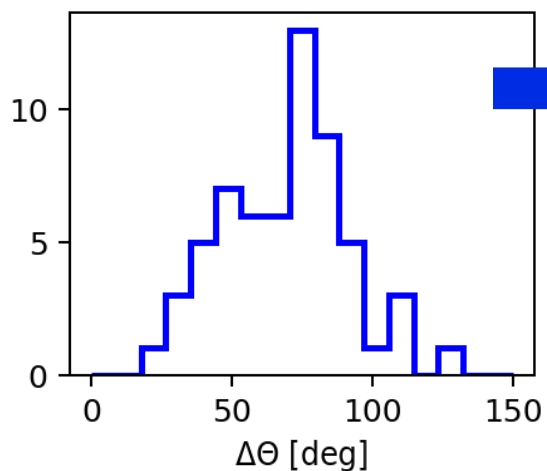


Along Major Axis

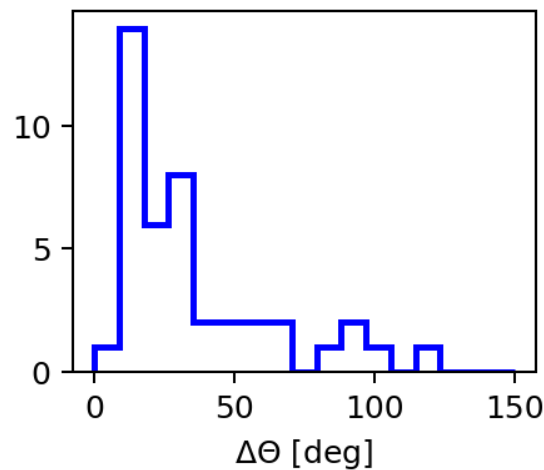
## Streams



Everywhere Mean Angle



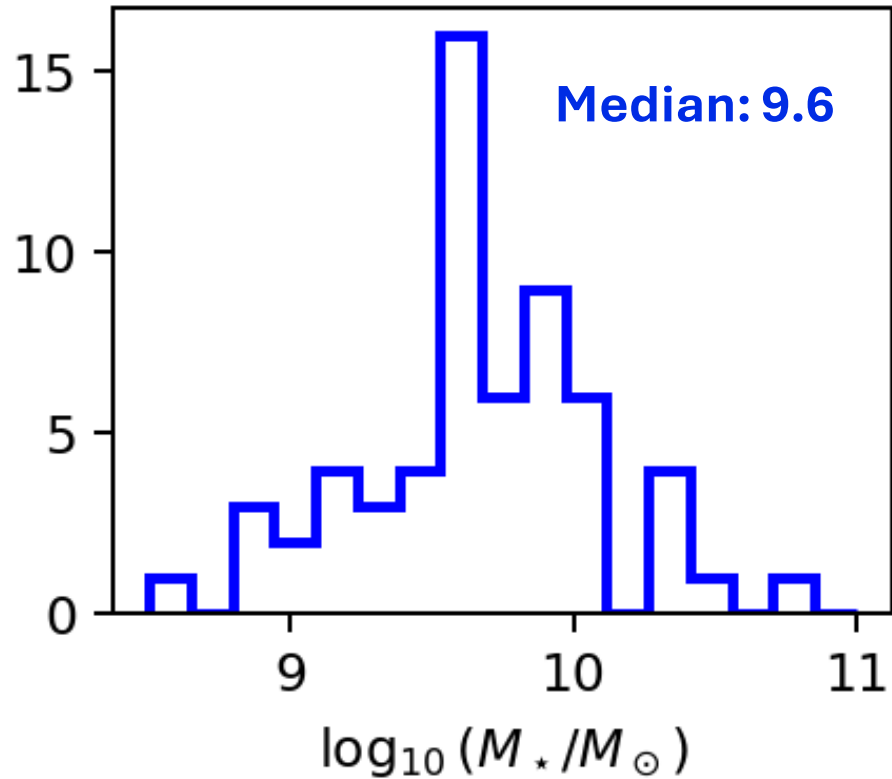
Spread over more degrees



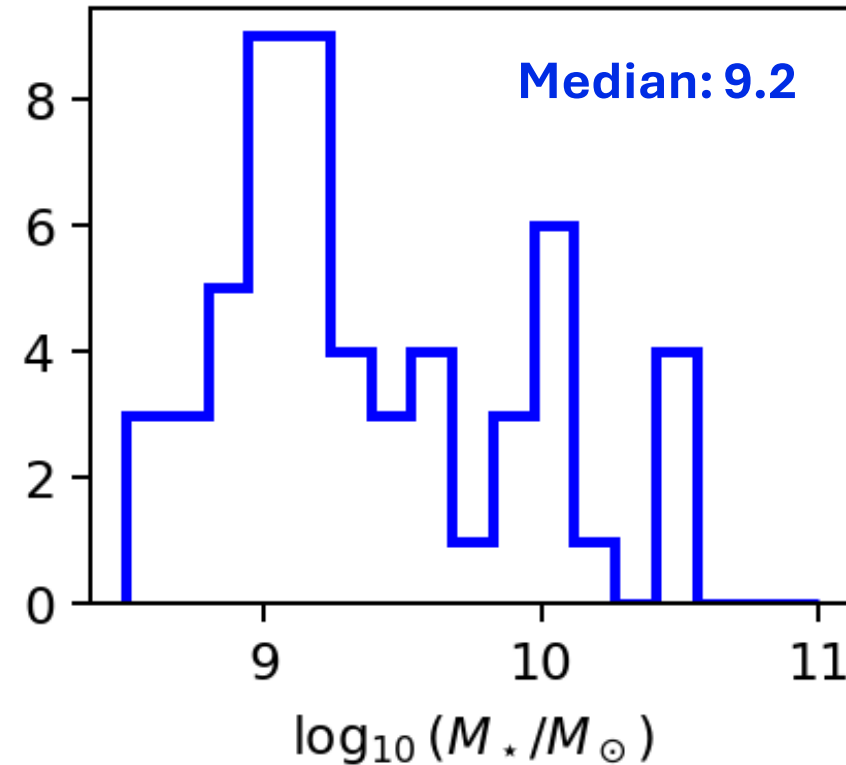
Angular Widths

# Shells and Streams – Stellar Mass

## Shells



## Streams



**Shells more massive**

# Shells and Streams – Morphology Summary

---

## Shells

→ Appear mostly along the Major axis (face on)

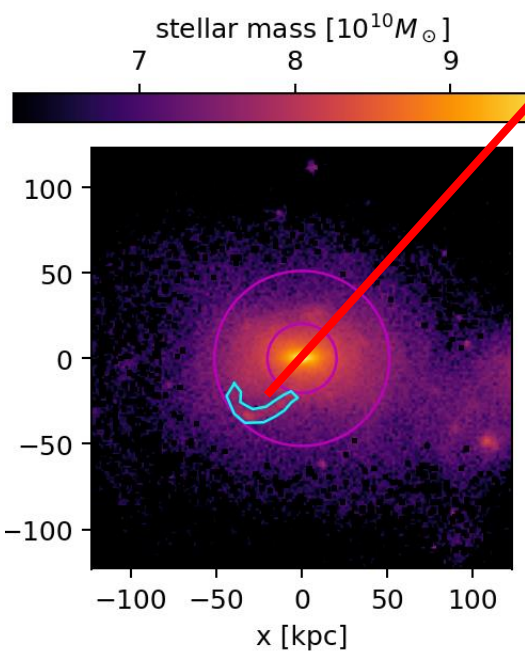
→ More Massive

## Streams

→ Appear all around the Galaxy (face on)

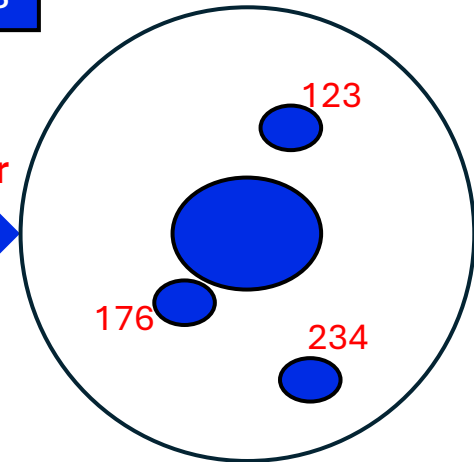
# Where They Came from and How They Got There

## Find Progenitor:



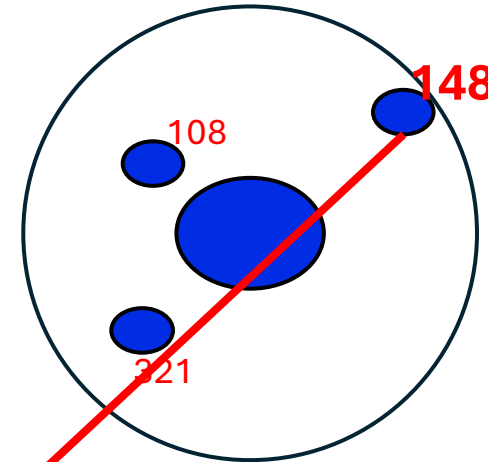
FeatureIDs

First Progenitor



Snap 132

First Progenitor



Snap 116

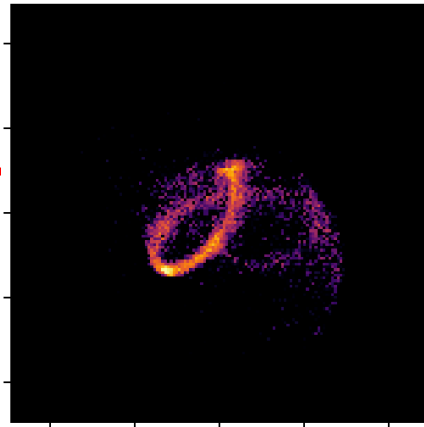
Progenitor

Confirmation?

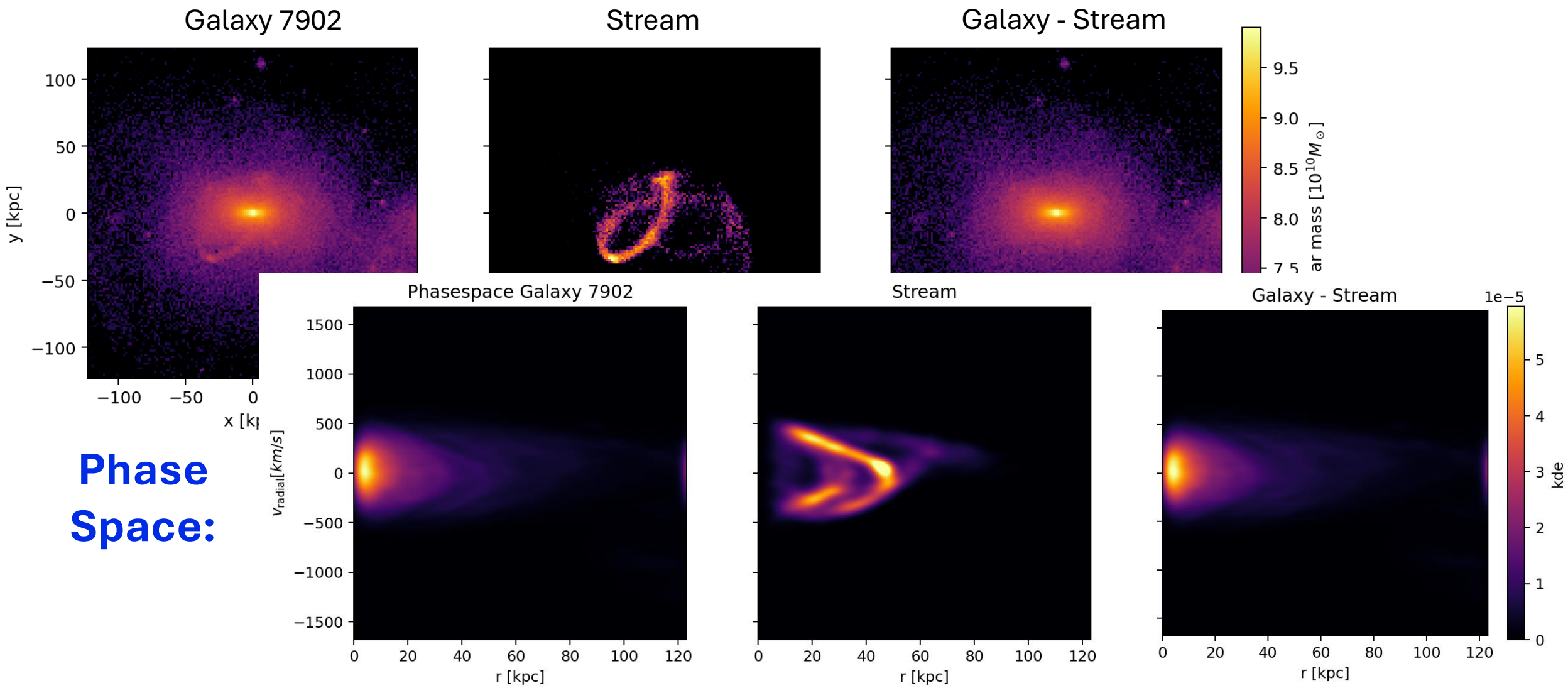
ProgenitorIDs

Yes!

Snap 136

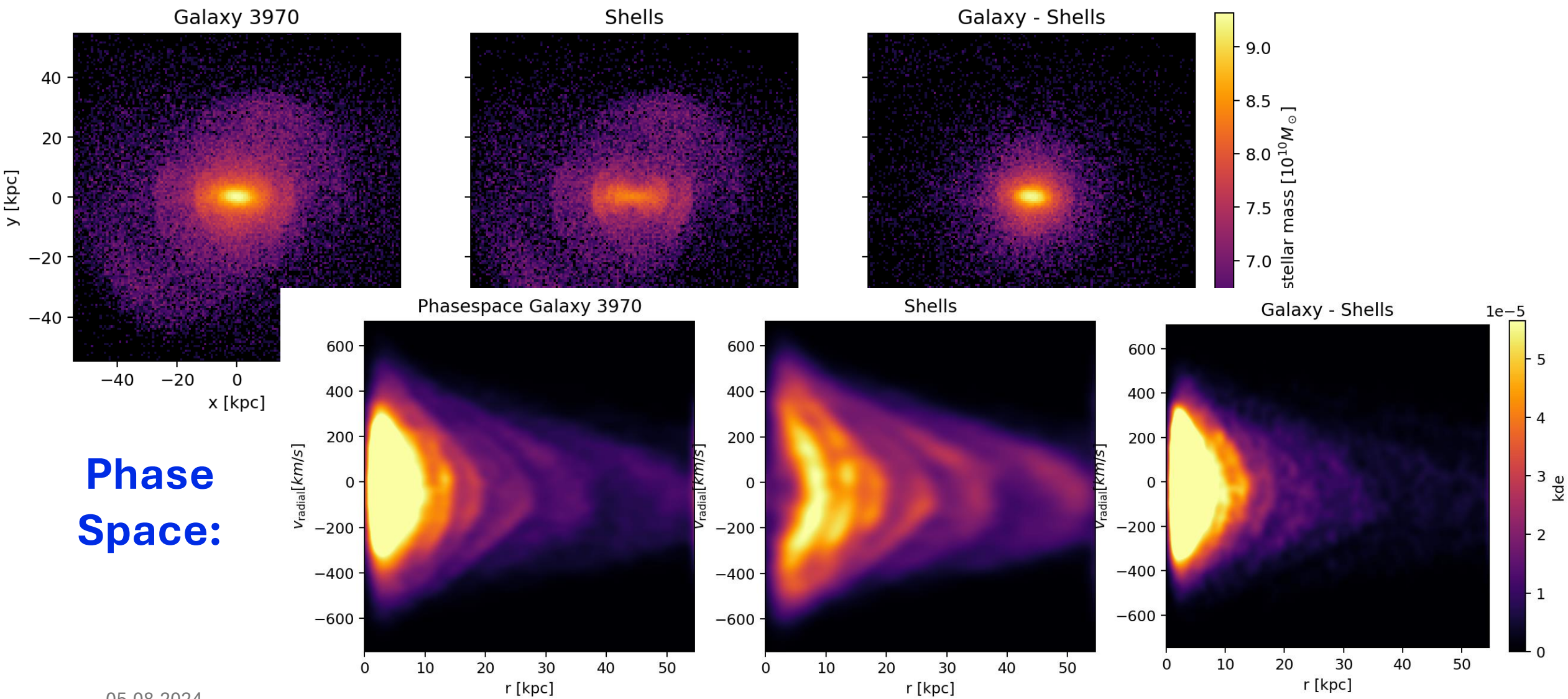


# Where They Came from and How They Got There



**Phase Space:**

# Where They Came from and How They Got There



**Phase Space:**



# “Where they come from” - Summary

---

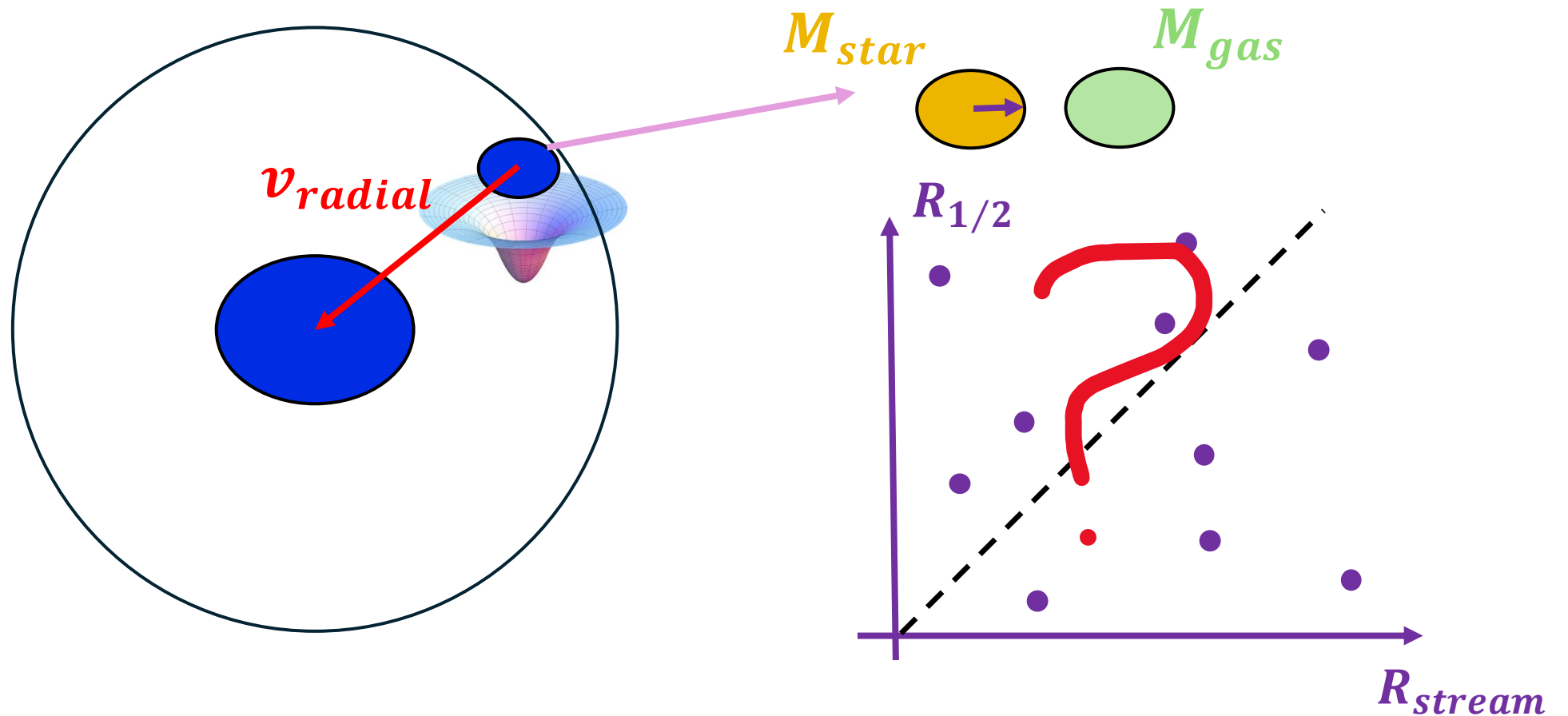
## **Shells and Streams**

**→ Consist of accreted Stars**

**→ We can accurately find their Progenitors**

# “Where they come from” – Ongoing Work

## Progenitor:



# Summary

## Stellar Population Properties

### Shells and Streams

- Depression in Velocity Dispersion
- No Deviation of Age in a Single Direction
- Streams can be very young
- No Deviation of Metallicity in a Single Direction
- Shells more metal rich than Streams

## Morphology and Position

### Shells

- Appear mostly along the Major axis (face-on)
    - More Massive
- ### Streams

- Appear all around the Galaxy (face-on)

## Progenitors

### Shells and Streams

- Consist of accreted Stars
- We can accurately find their Progenitors

