Modelling the merger of the blue compact galaxy Haro 11

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Escape of Lyman radiation
from galactic labyrinths,
Crete 2023

Stockholm
University

Motivation

- Another perspective - numerical simulations
- Understand how specific features can arise in Haro 11
- Explore the formation of a blue compact galaxy

The Haro 11 galaxy

- High-z analogue
- Closest (z~0.02) confirmed LyC-leaker
  (Bergvall et al. 2006; Leitet et al. 2011)
- Currently undergoing a merger
- A few distinct features of Haro 11 to constrain simulations:
  - One extended tidal tail
  - Three knots of stars
  - Complex kinematics
  - Morphology, SFR, masses

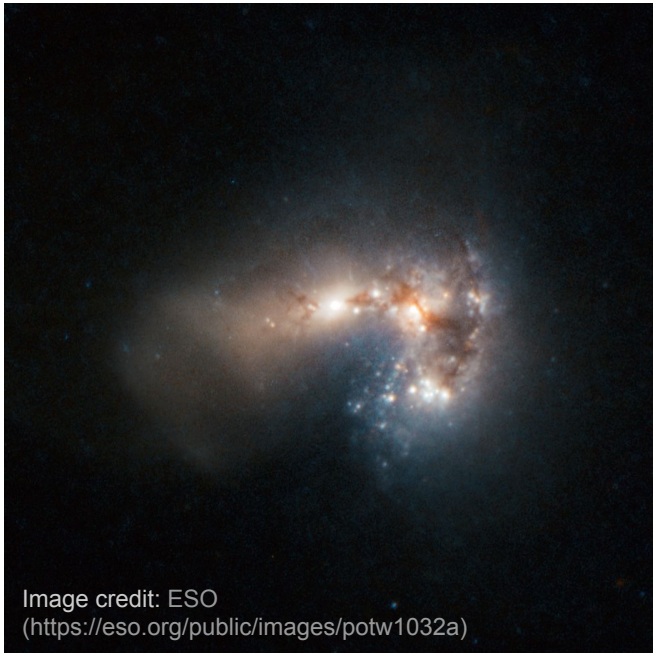
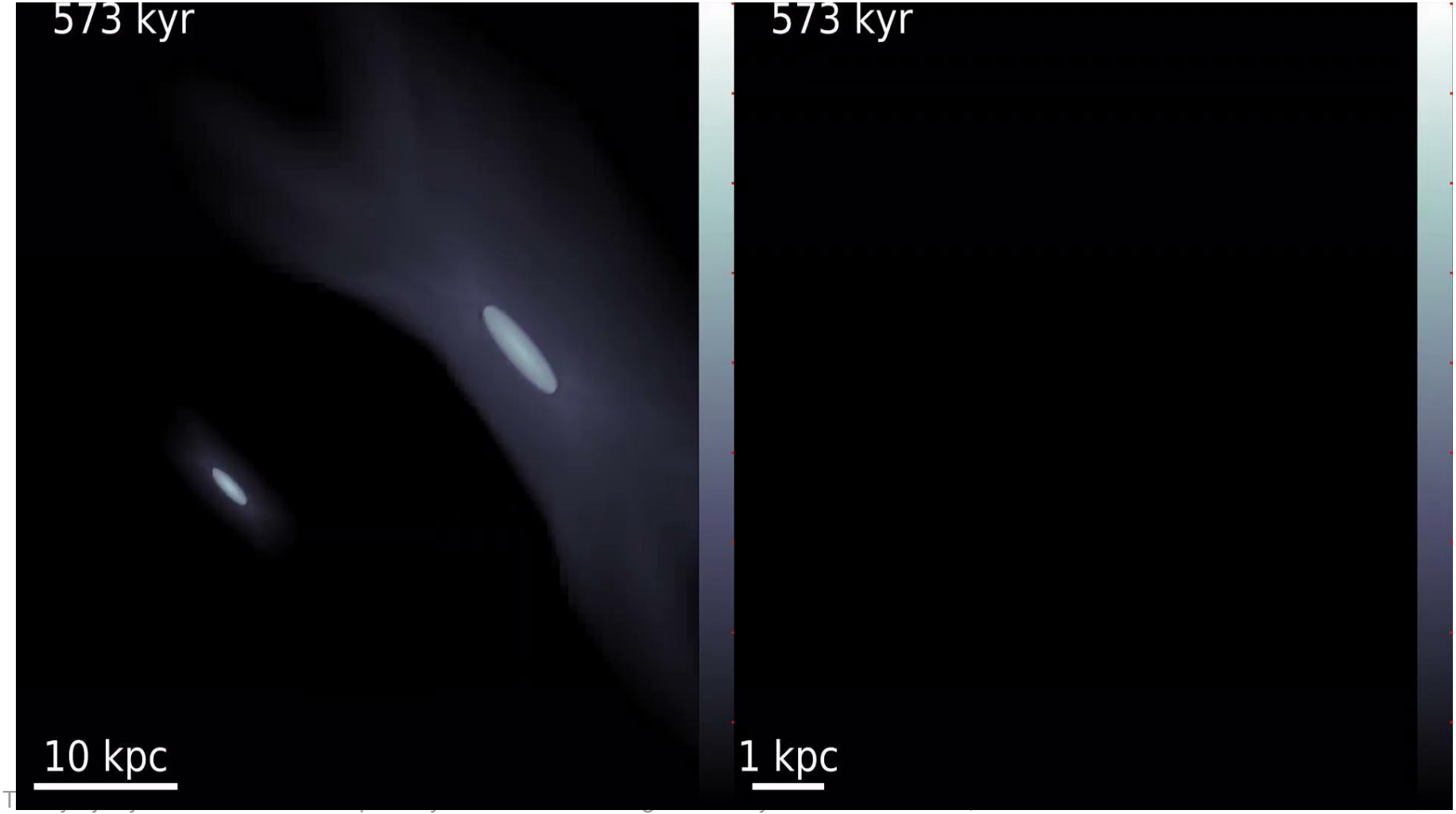
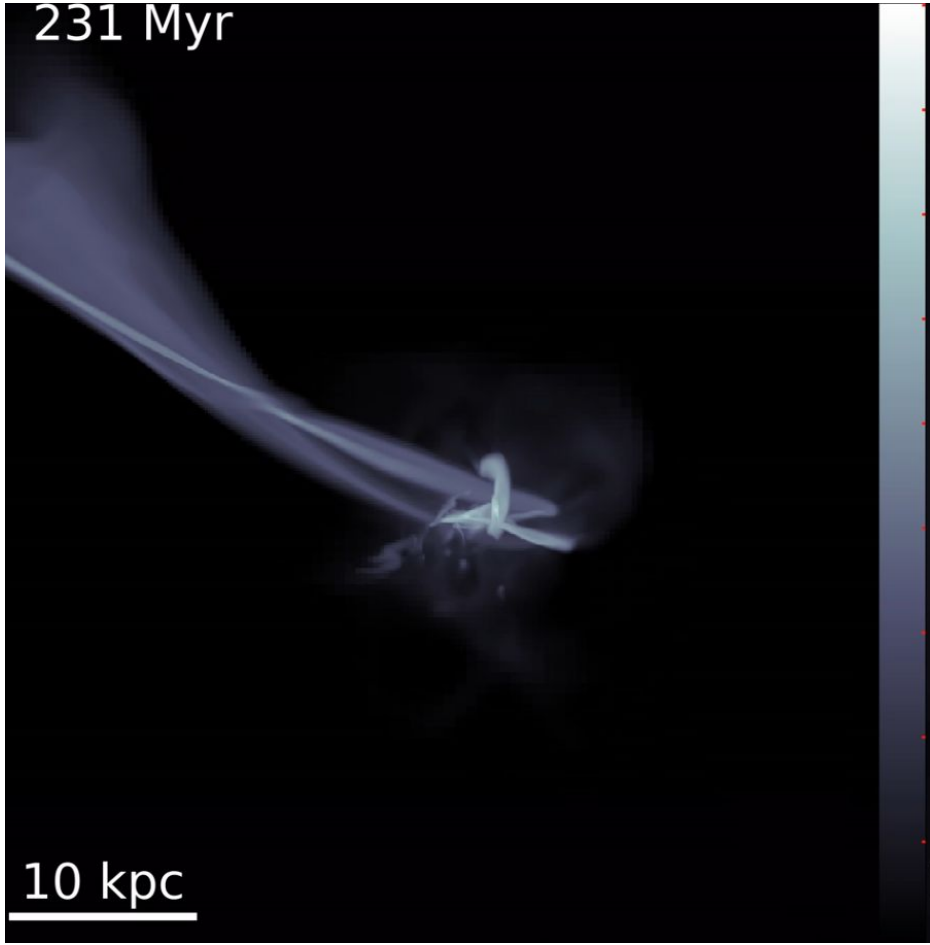


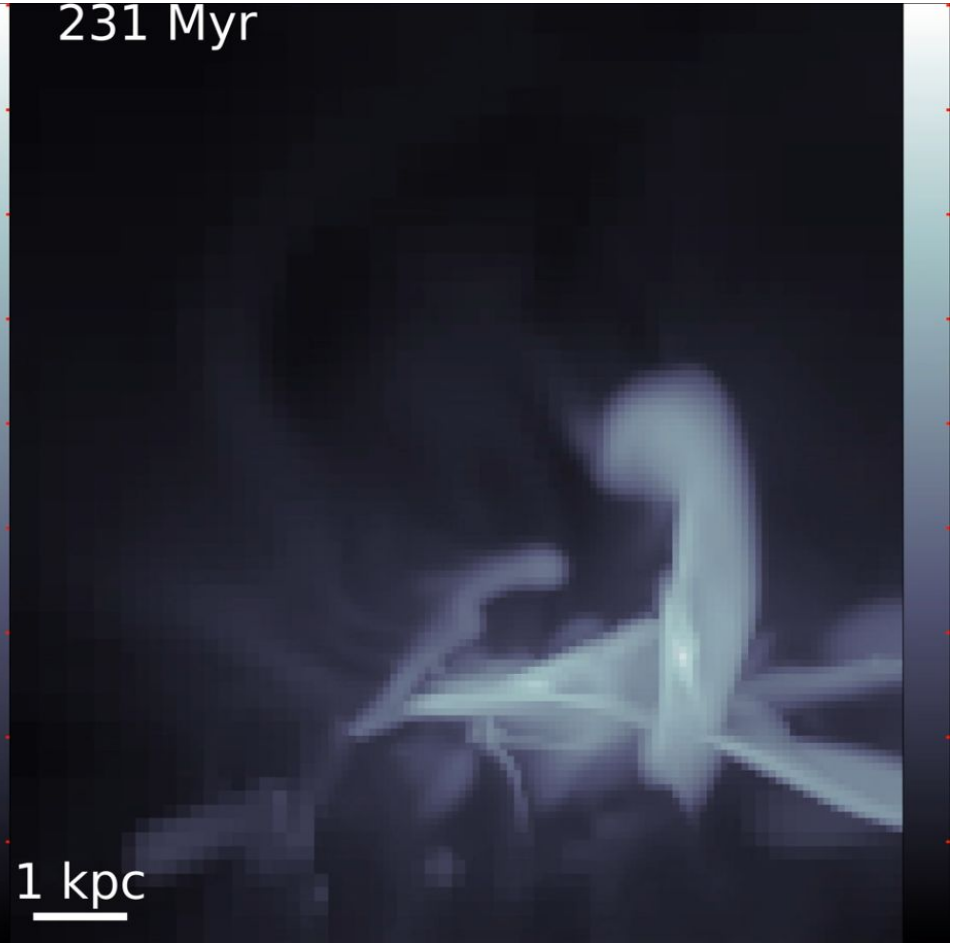
Image credit: ESO
(https://eso.org/public/images/potw1032a)

Simulation setup

- Using the *N*-body+hydro code RAMSES (Teyssier 2002)
- Simulation suite - star formation, stellar feedback (recipe from Agertz+13)
- Isolated disc galaxies
- Low resolution, ~40 pc (Adaptive Mesh Refinement)
- Parameter study - tweak parameters, run simulations, observe their impact
  - Example parameters: position, velocity, rotation axis, masses, density
- Use observations to constraint the ICs


573 kyr
573 kyr
10 kpc
1 kpc


231 Myr
10 kpc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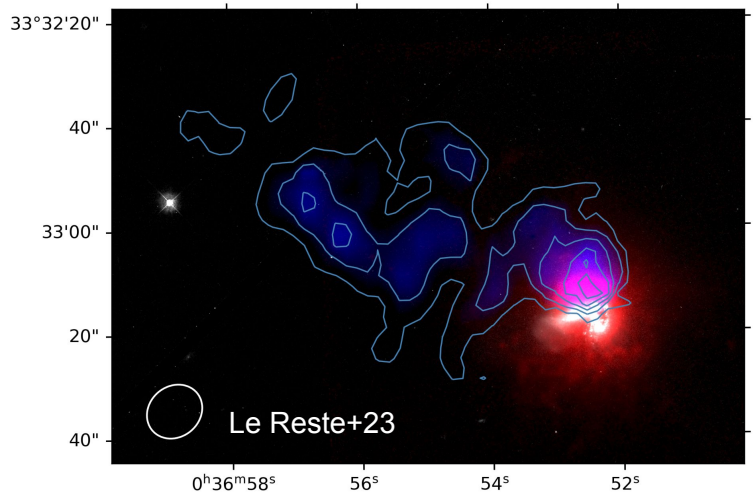
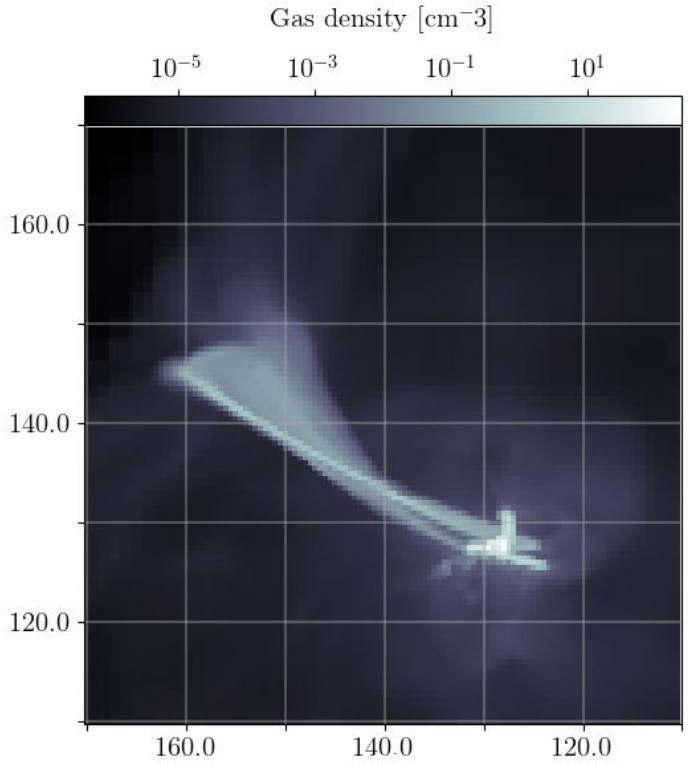
Morphology - tidal tail

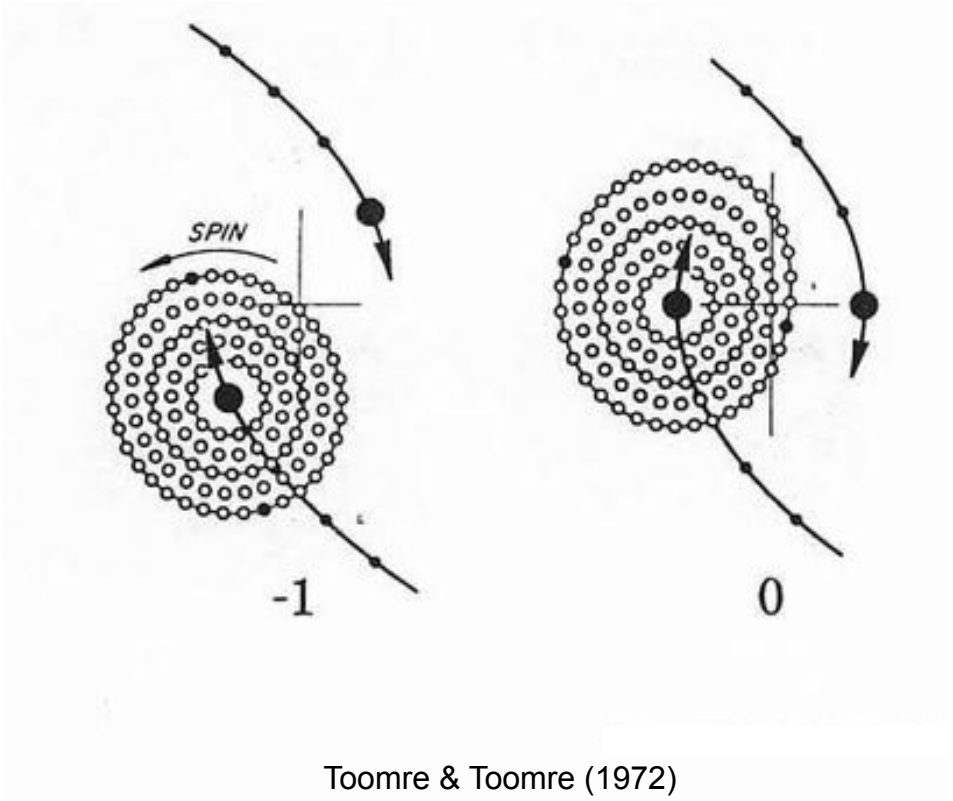
- Has been observed in HI with MEERKAT
- One tidal tail, ~30-40 kpc long (Le Reste+23)
- ~40-80 % of HI mass within tail (Le Reste+23)
- How to only get one tidal tail?



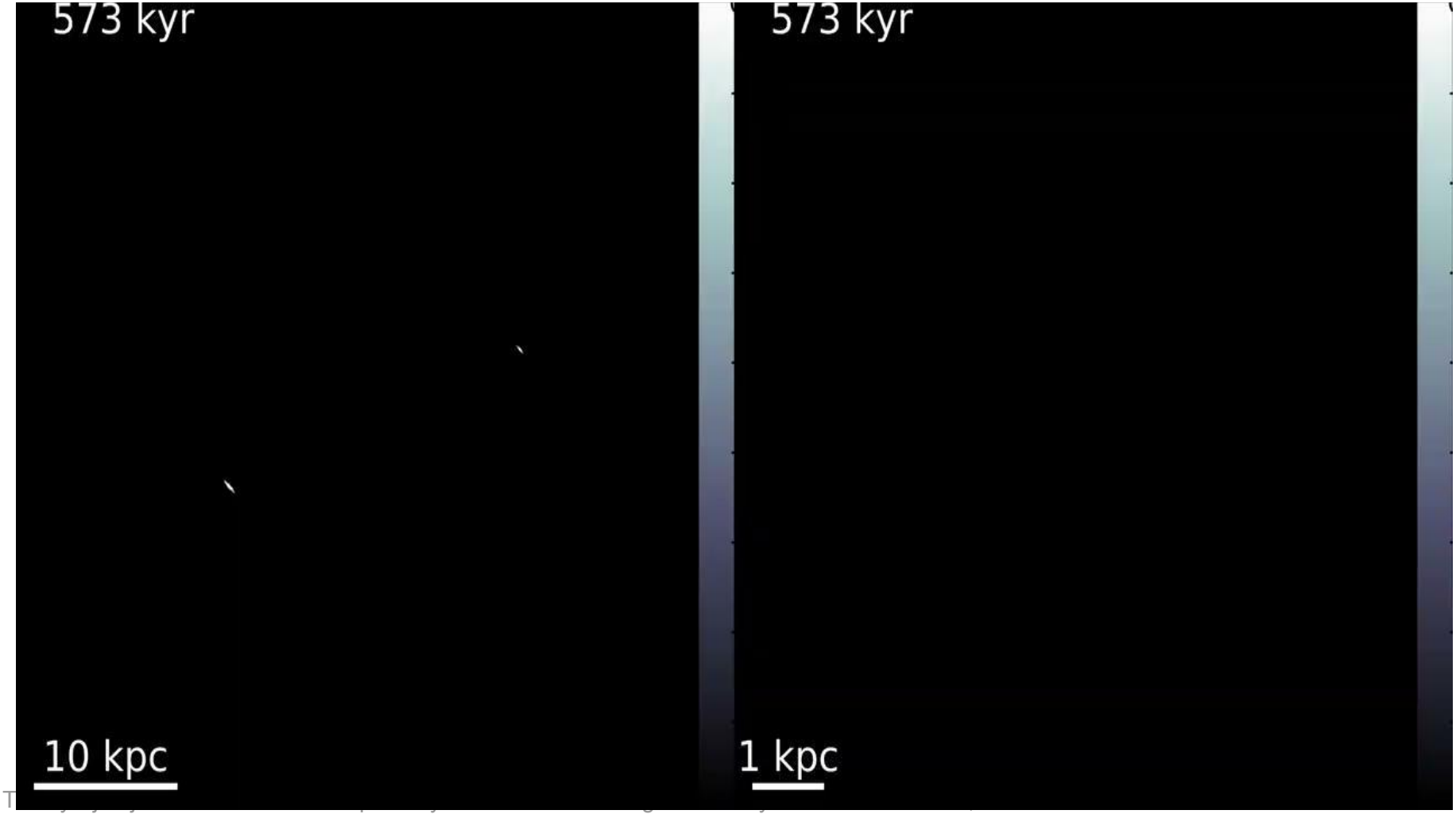


Prograde/retrograde motion

- Retrograde motion slightly perturbs
- Prograde motion causes a resonant response by the disc
- **Discs with prograde motion are more efficiently stripped**



Toomre & Toomre (1972)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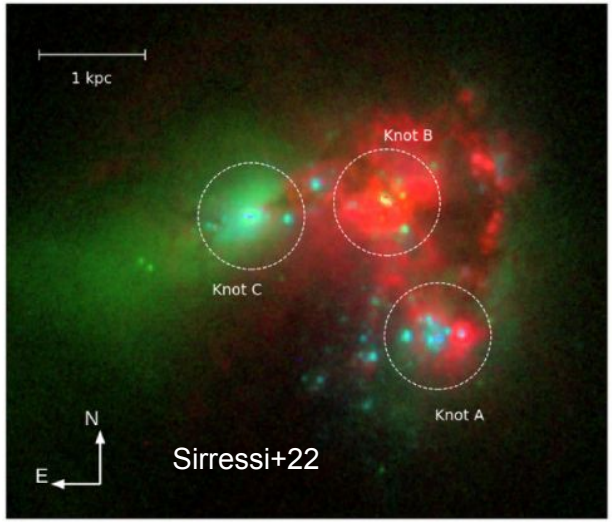
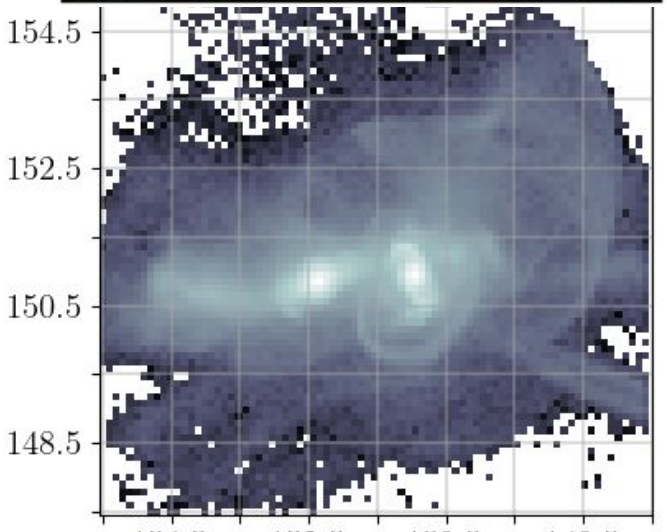
Morphology - inner structure

- General inner gas/stellar structure
  - “Bent” shape
  - Three knots
  - “Ear” between knot A & B
- Likely that Knot A is part of a disc where B is its nucleus
- Knot B/C are leaking LyC (see Lena’s talk)
- Knot B might contain an AGN (Gross, Prestwich & Kaaret 2021)





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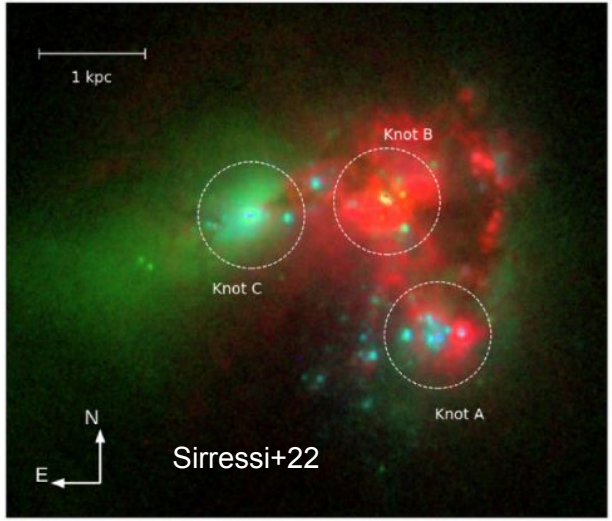

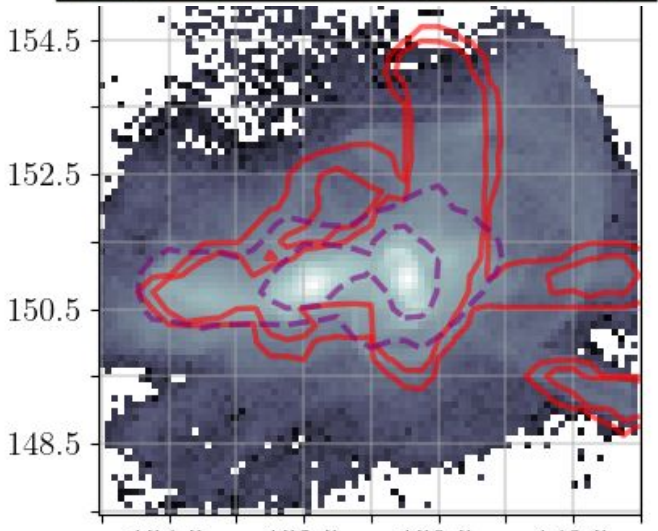

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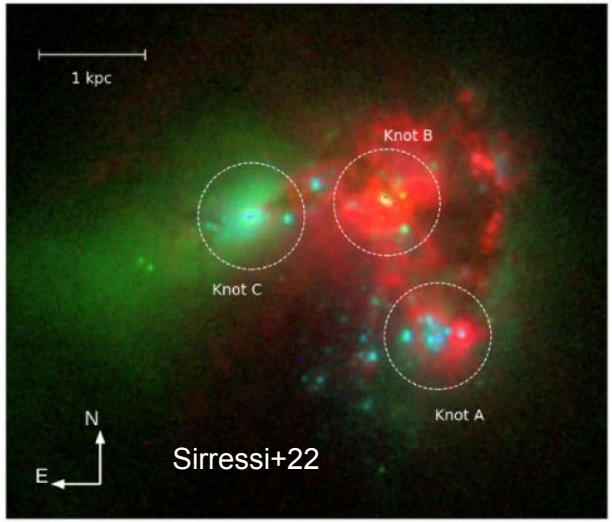
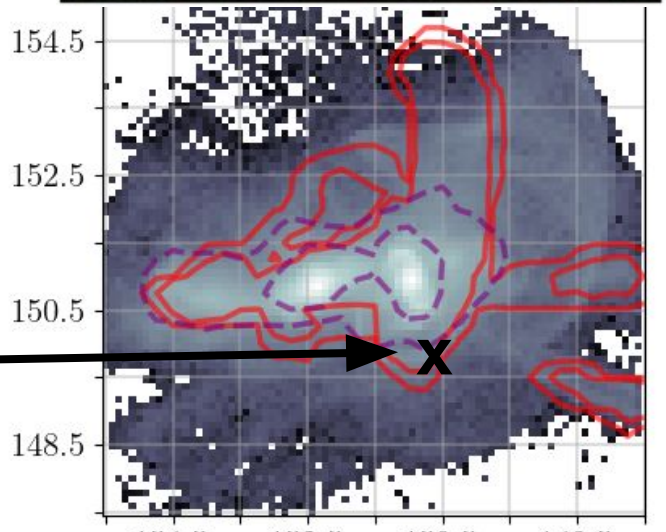
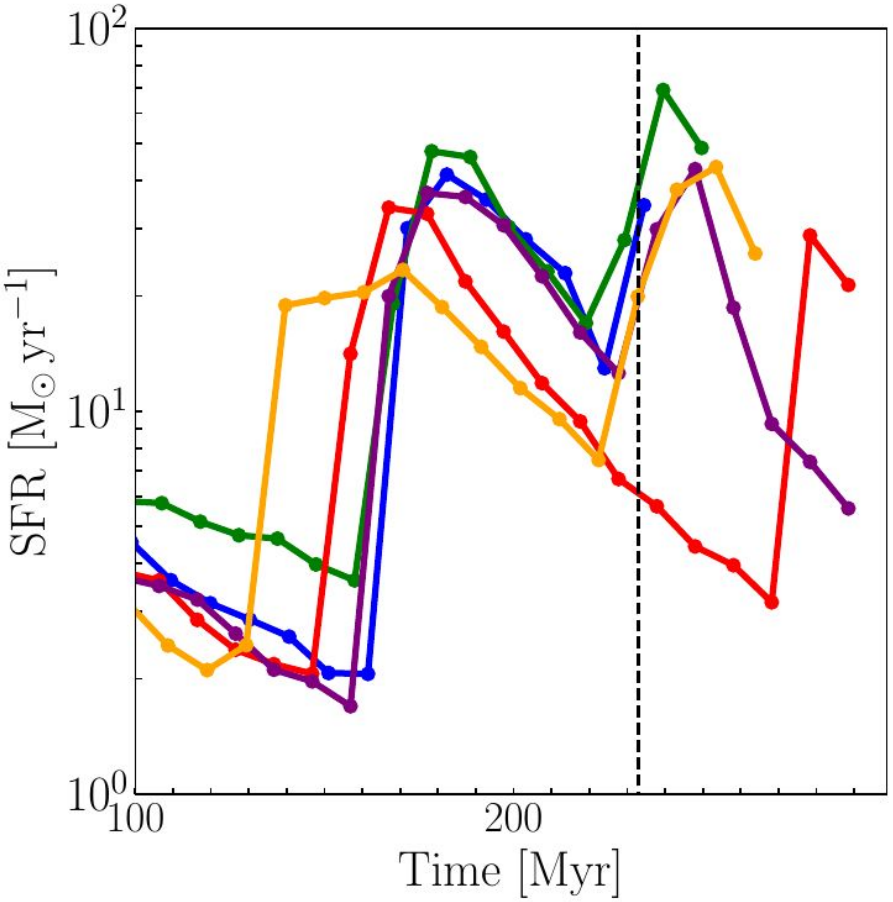




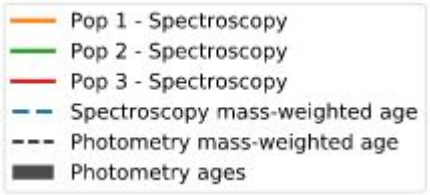
Stellar properties

- Current SFR burst of ~20-30 Msun/yr (Hayes+07, Madden+14)
- Formation of stellar populations aligns with SFR bursts from close encounters (Renaud+14)
- Thus a peak in stellar populations of a certain age may coincide with a burst

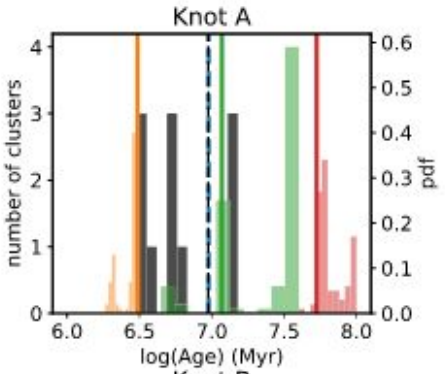


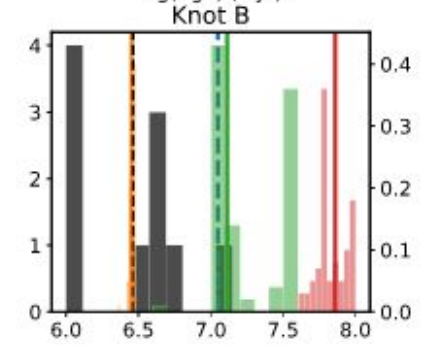
Stellar properties

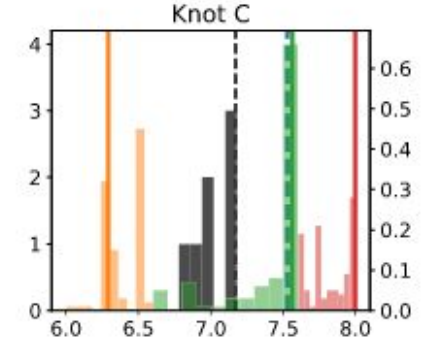
- Individual knot analysis
- Knot masses are within range of observations (Siressi+22)

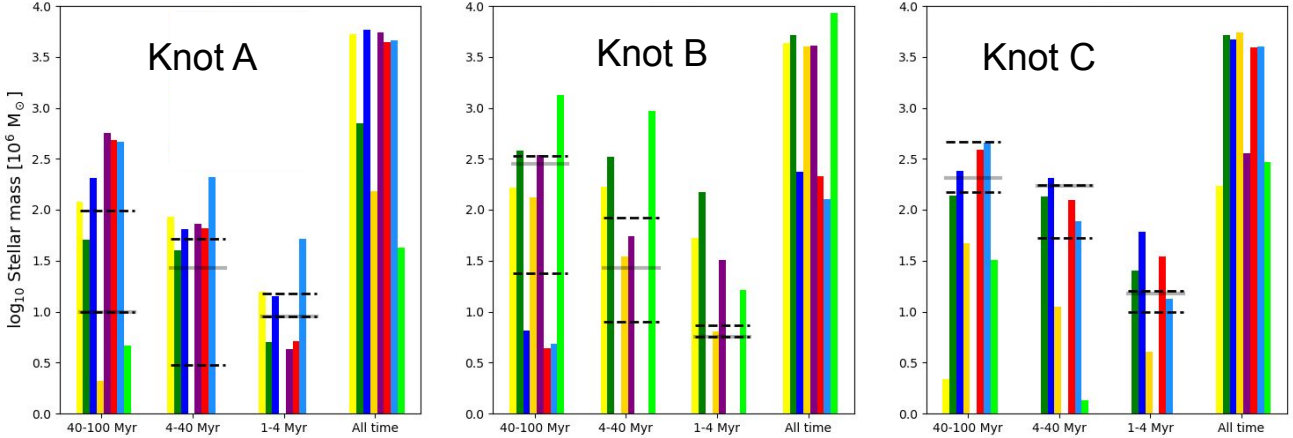


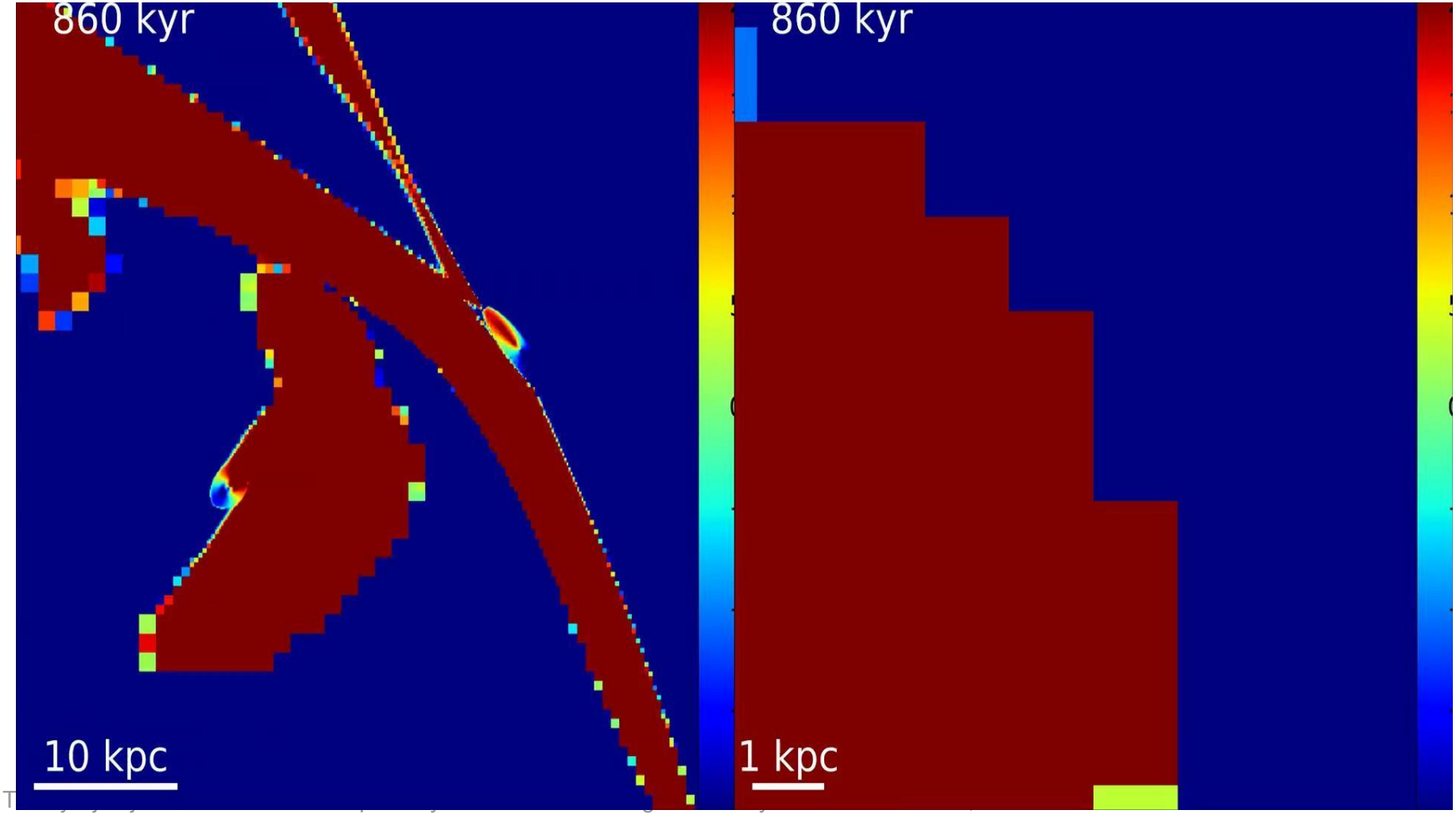
Siressi+22







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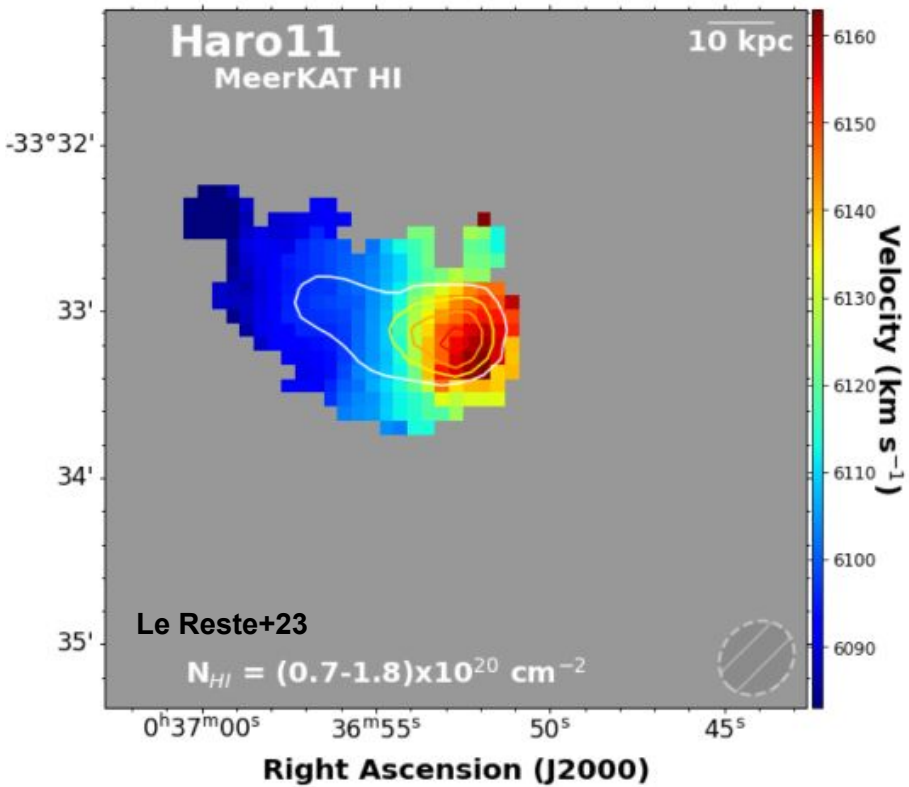
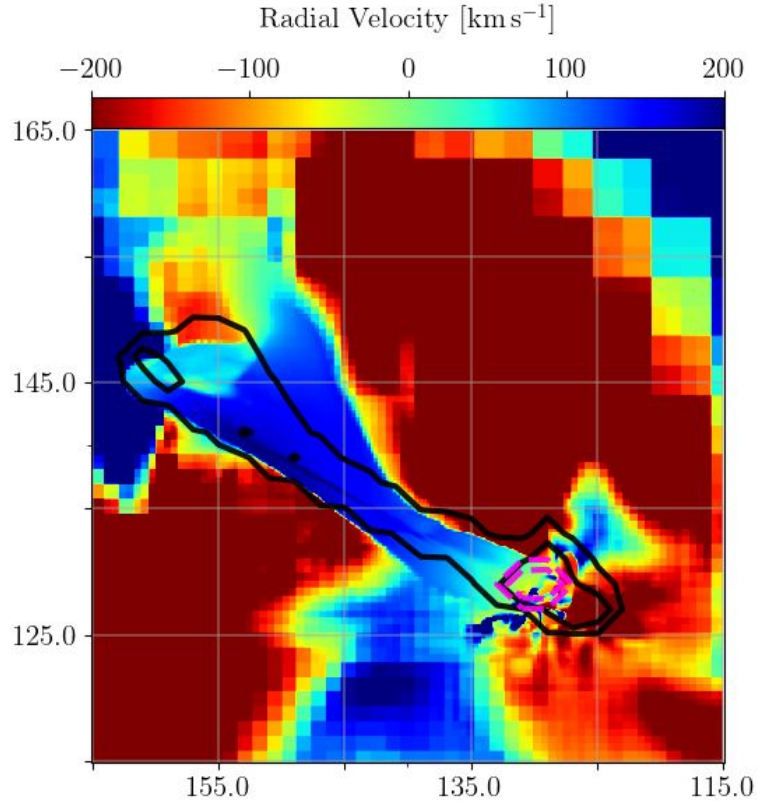
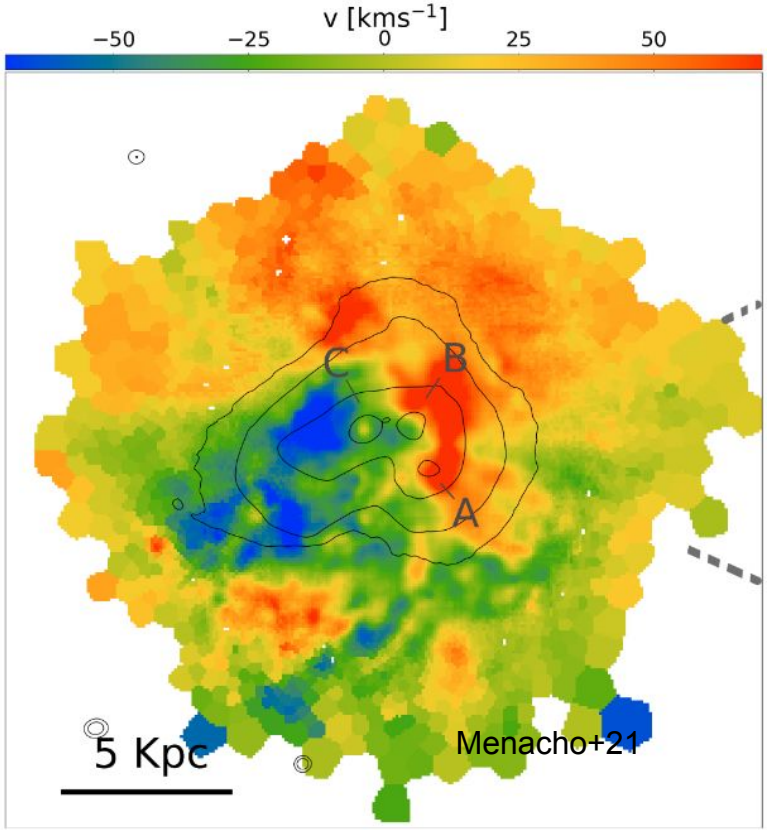
10 kpc
1 kpc

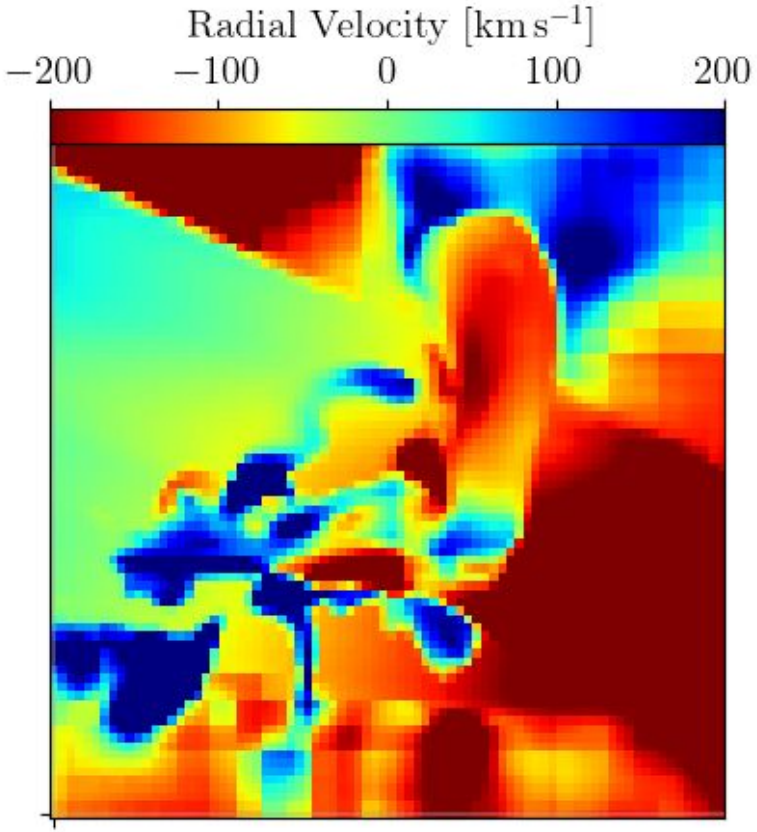
Kinematics - tidal tail





Kinematics - inner galaxy





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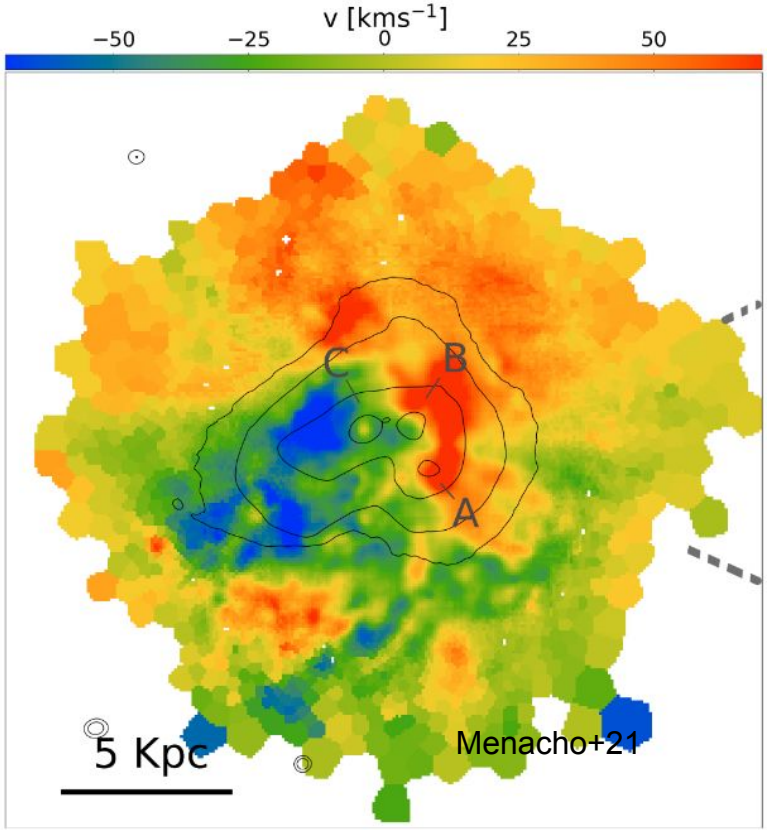

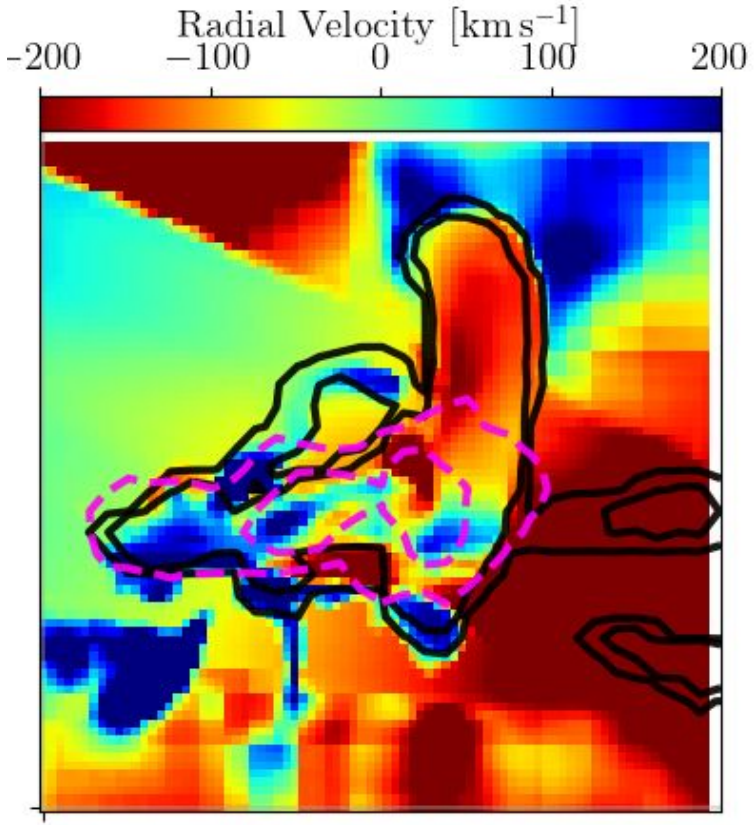

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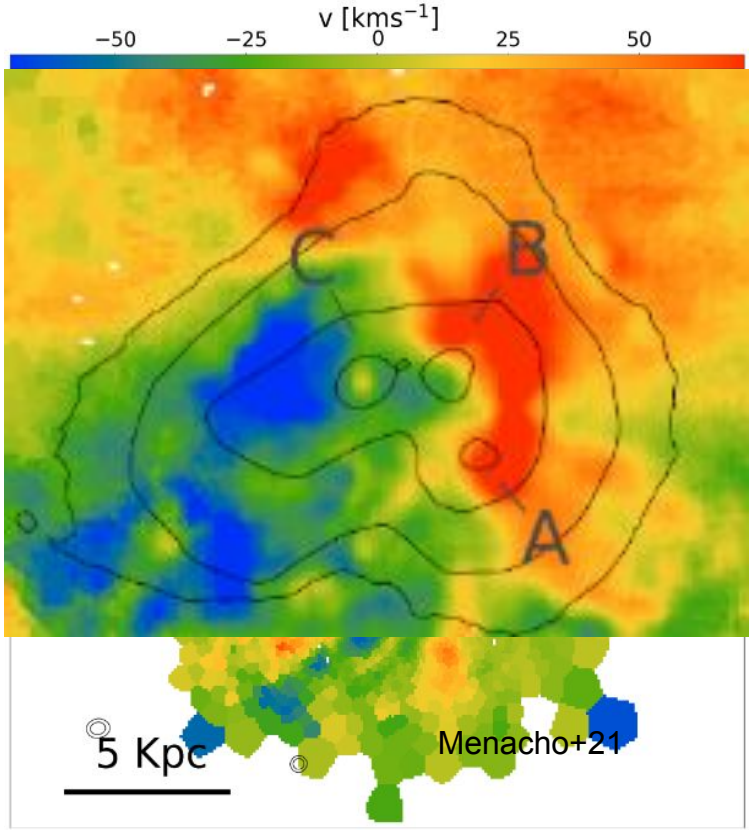
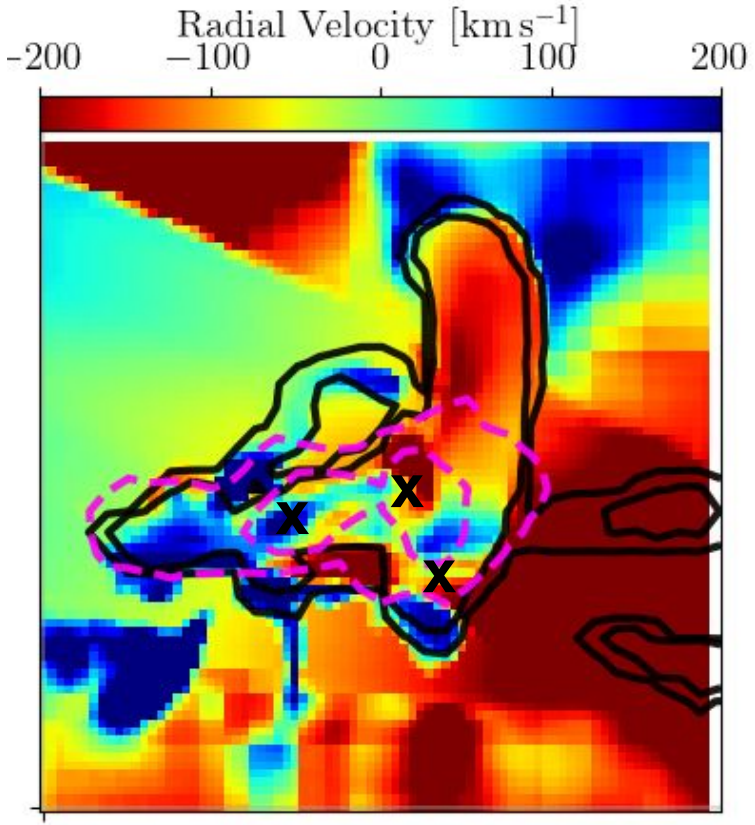


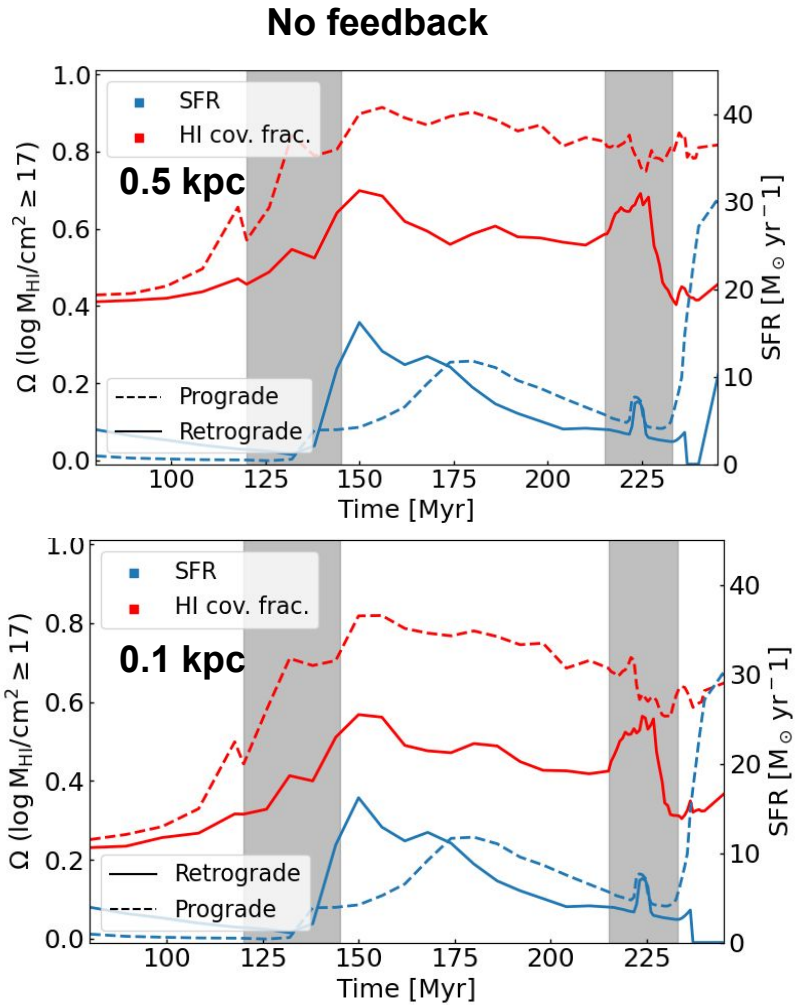


Covering fraction of ionising radiation

- Neutral HI with density>~10^17 cm^-2 is optically thick to ionising radiation
- Observe galaxy centres at many many sightlines
- Discoball analysis

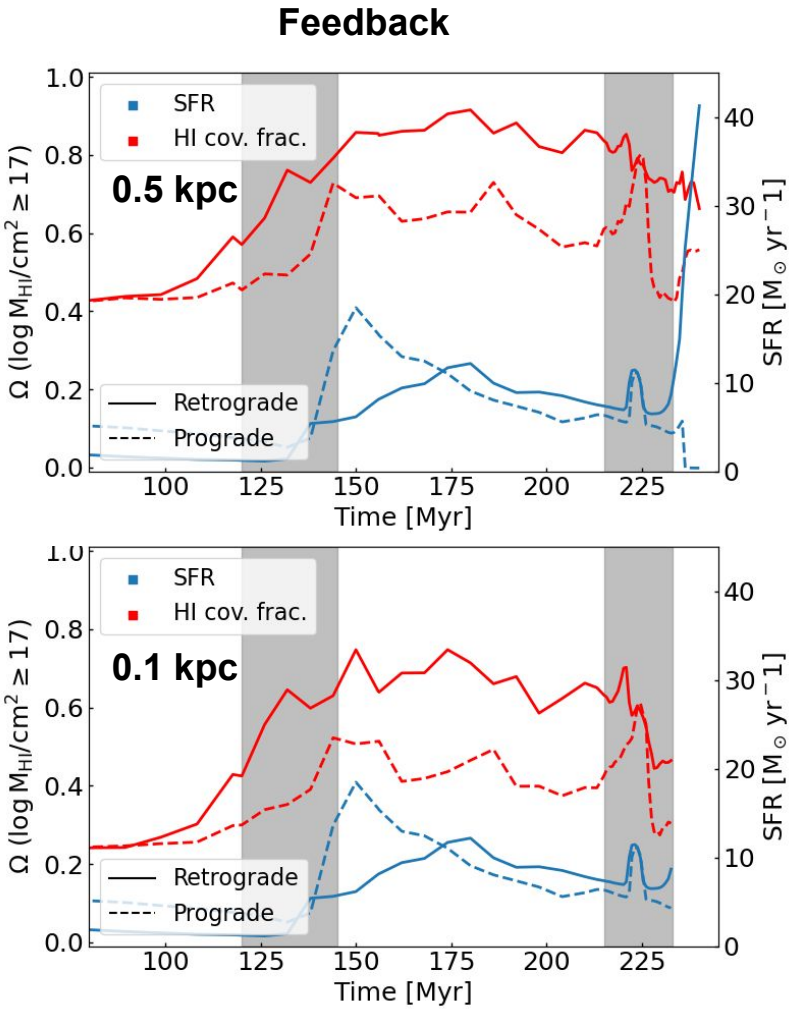
Covering fraction

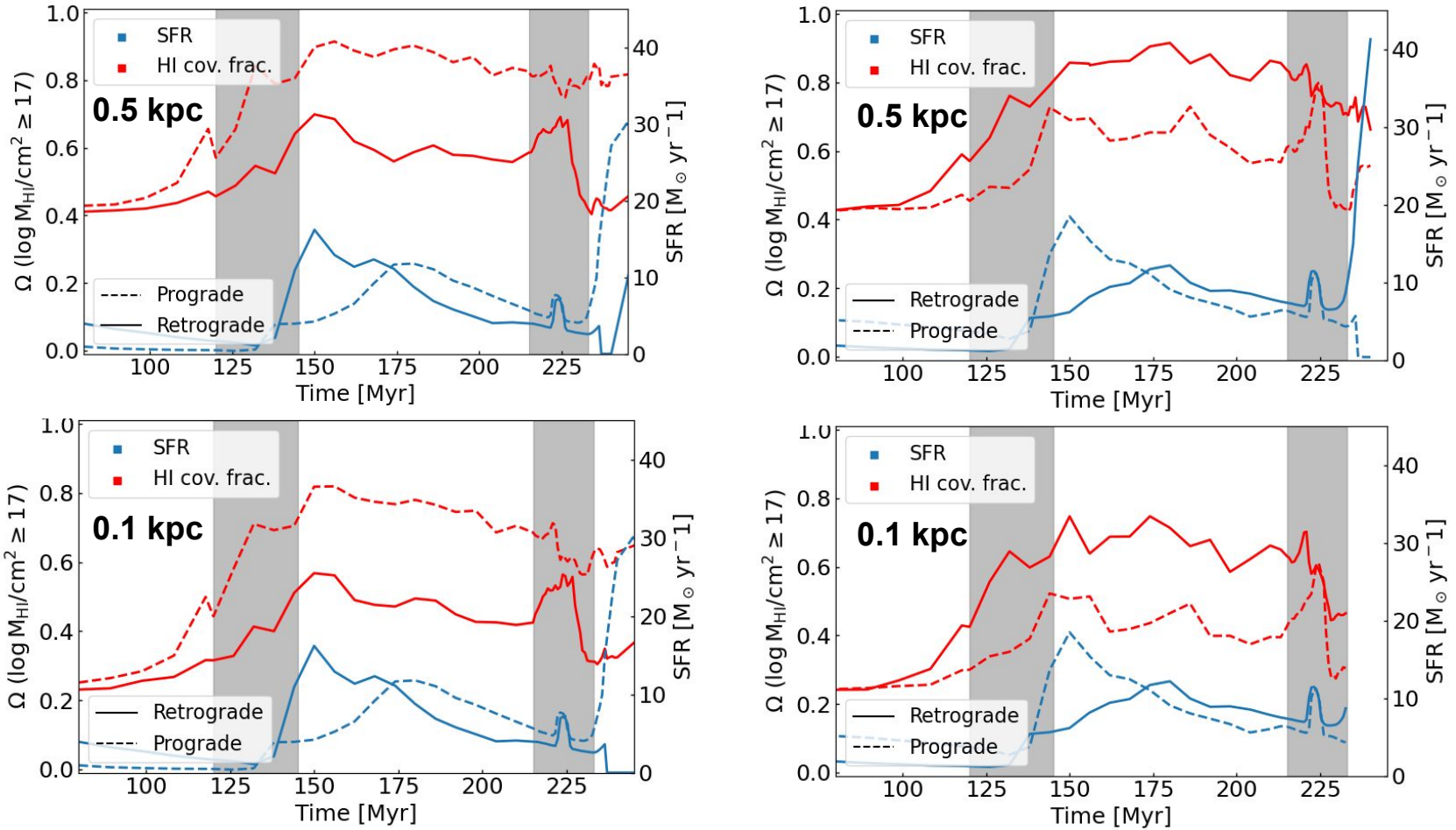
- Simulations without feedback
- No significant change between beam sizes of 0.5 kpc and 0.1 kpc
- Prograde galaxy has a lower covering fraction after the 2nd interaction



Covering fraction

- Effect of stellar feedback
- Mean covering fraction of stellar feedback affected only for 0.1 kpc beam size
- Dip in covering fraction overlaps with SFR peak




No feedback
Feedback
0.5 kpc
0.1 kpc
SFR
HI cov. frac.
Prograde
Retrograde
Ω (log M_HI/cm^2 ≥ 17)
SFR [M_⊙ yr^-1]
Time [Myr]

Summary & outlook

- Manage to reproduce several properties of Haro 11 with numerical simulations by smashing dwarfs into each other
- Simulations us a possible formation scenario for Haro 11 and its features

- Higher resolution of existing simulations underway
- Lyα transfer using RASCAS (Michel-Dansac+2020)
- Study the outflows and its connection with escape fractions