The Connection between Star Formation and Metallicity Evolution in Barred Spiral Galaxies

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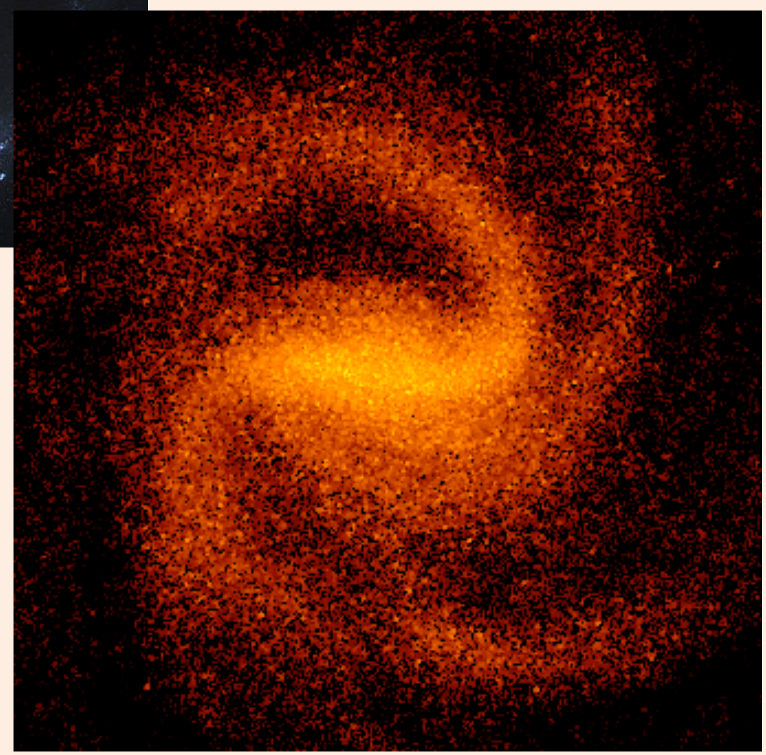
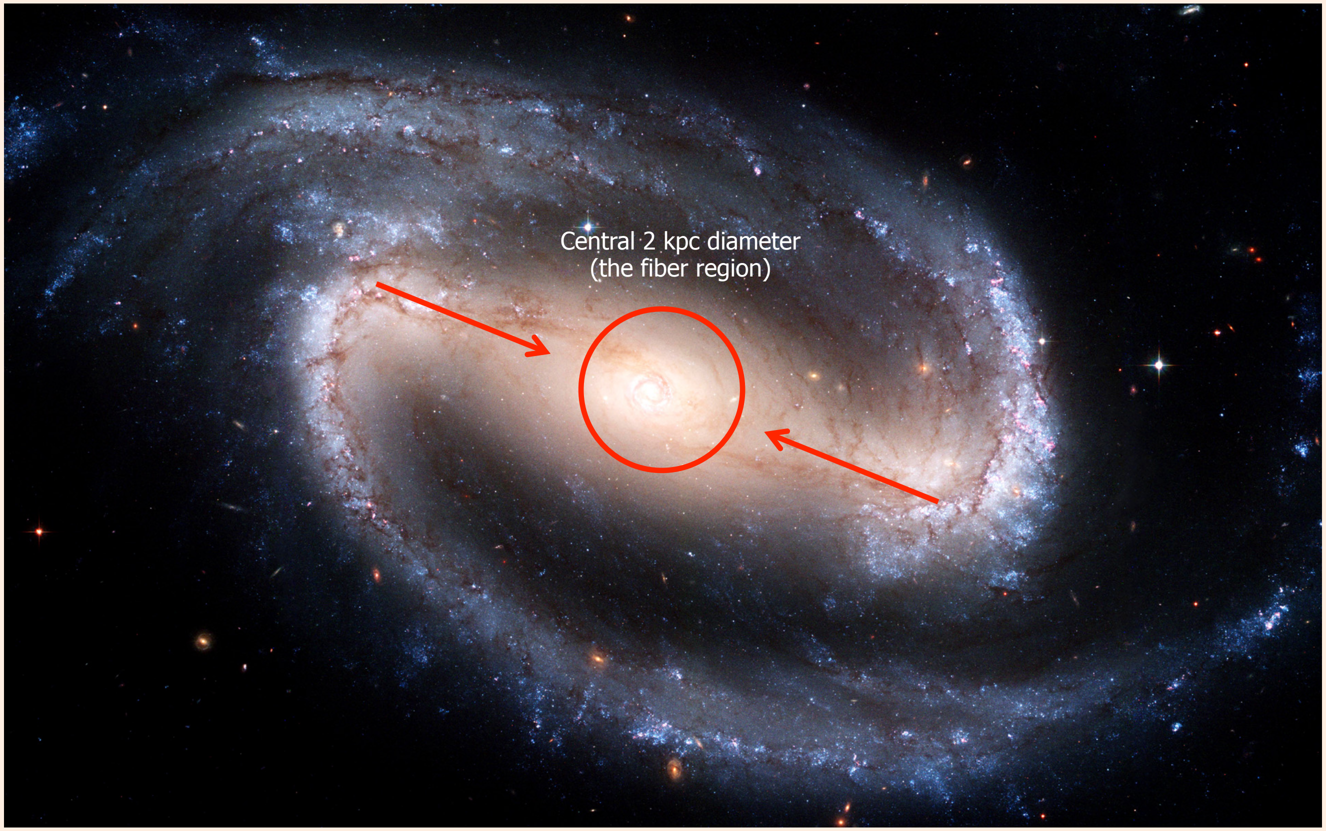


Dwingeloo, September 3rd, 2015

Evolution of spiral galaxies: the basic scenario



- The bar produces a gravitational torque.
- Gas loses angular momentum and flows toward the central region.
- The SFR in the central region increases.
- Central stars produce and release metals.
- The central regions of barred spiral galaxies have enhanced SFR and metallicity (and possibly AGN activity) compared to unbarred spiral galaxies.

Recent observations.

Ellison et al. (2011): 294 barred galaxies in SDSS.

Galaxies with stellar masses M > 10^{10} M_{sun} show an increase in central SFR and central metallicity.

Galaxies with stellar masses M < 10^{10} M_{sun} show an increase in central metallicity, but no increase in SFR.

Wang et al. (2012): 3757 galaxies, including 1555 barred, in SDSS.

Stellar masses M > 3 x 10^{10} M_{sun}: some barred galaxies show an increase in central SFR, others do not. Feedback effets?

The basic scenario is too simplistic.

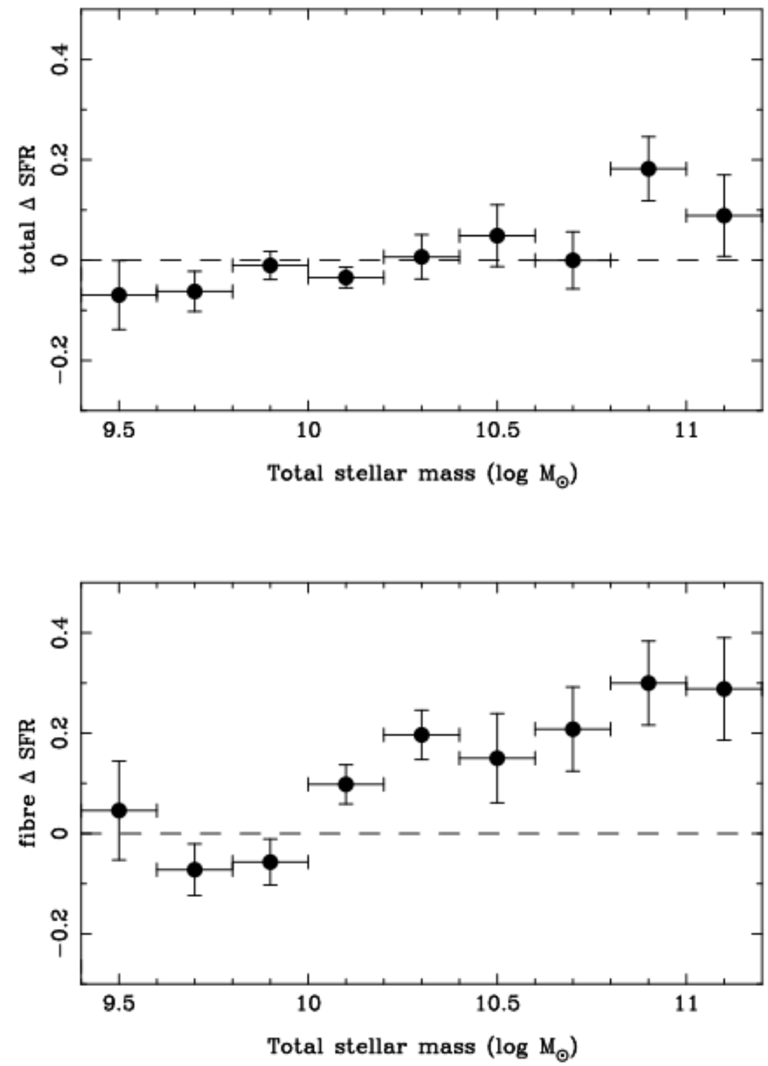


Figure 3. The star formation rate offset of barred spirals from the SFR–mass relation of unbarred spirals. The top panel shows the offset between total SFR in barred and unbarred galaxies at a given total galactic stellar mass (as a function of total galactic stellar mass). The lower panel shows the offset between fibre SFRs in barred and unbarred galaxies at a given fibre stellar mass (as a function of total galactic stellar mass). Error bars in this and all the figures in this paper are the standard error on the mean.

Goal of this projet: using numerical simulations to study the SFR and the chemical enrichment at the center of barred spiral galaxies.

First series of simulations:

Initial conditions: disc containing 10^{10} M_{sun} of gas et 4 x 10^{10} M_{sun} of stars, inside a dark matter halo. Radial metallicity gradiant.

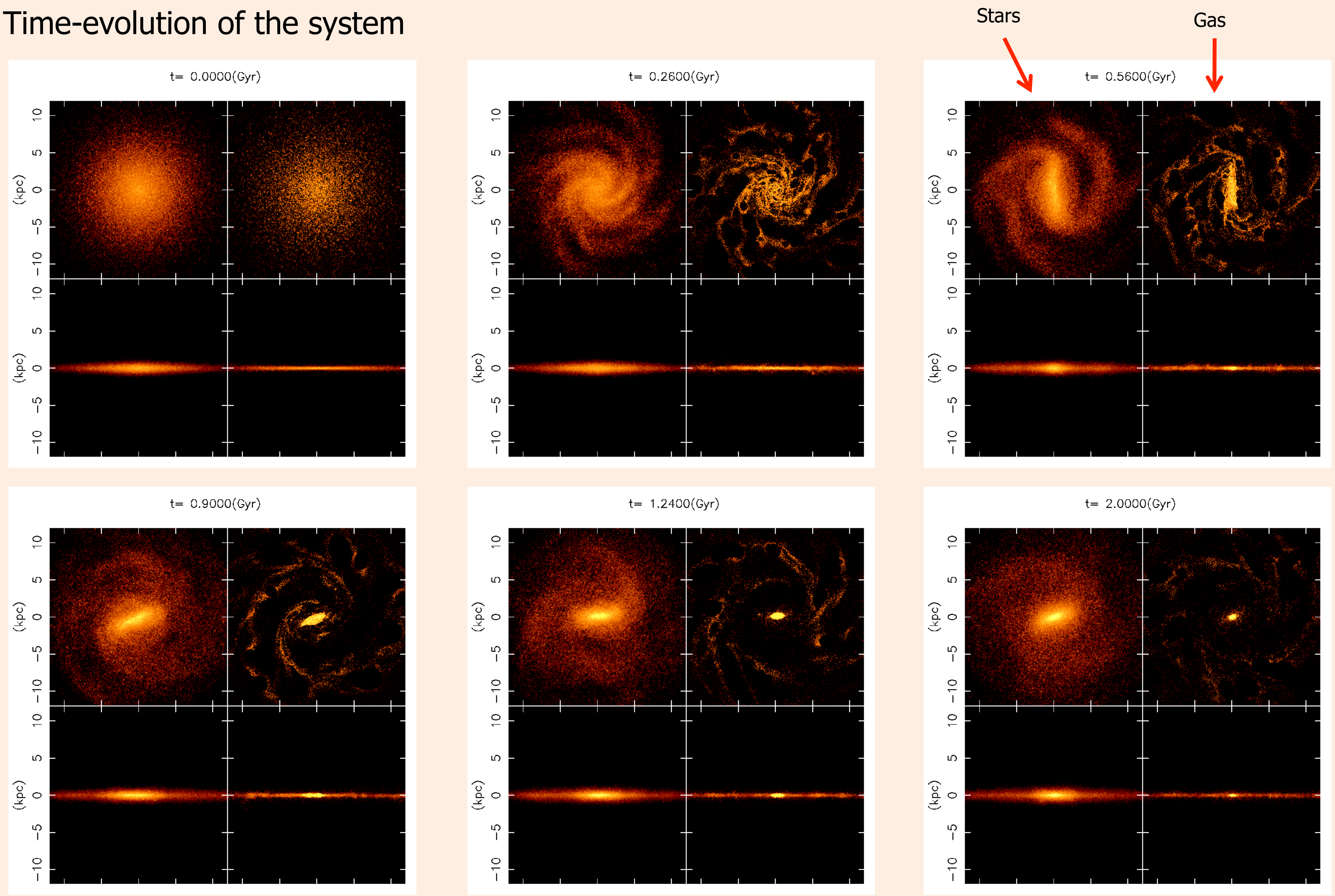
Algorithm: GCD+

- Gravity
- Hydrodynamics
- Star formation
- Feedback (SNe and stellar winds)
- Chemical enrichment

Central region: diameter de 2 kpc.

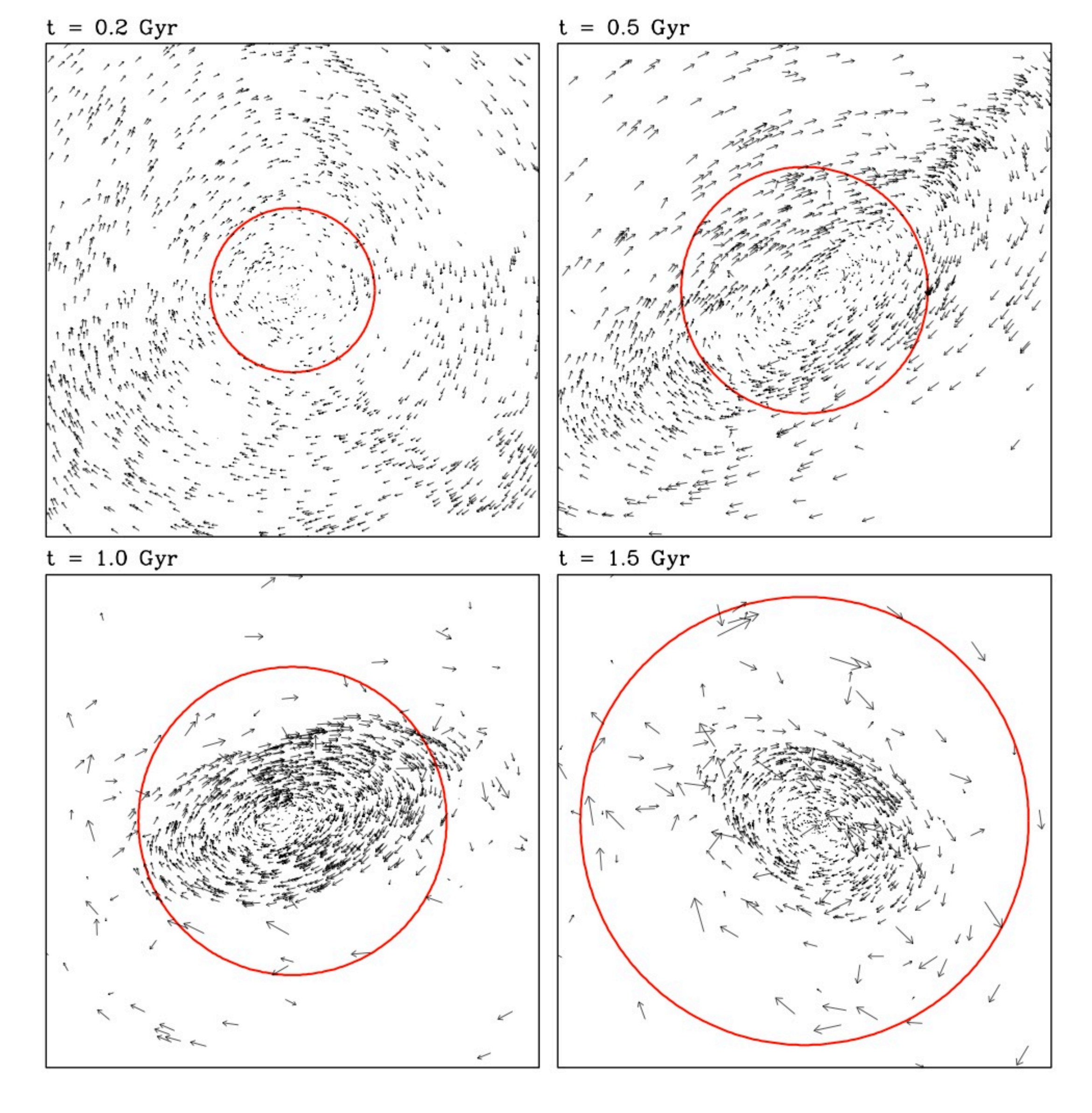
The bar forms by instability.

Time-evolution of the system



Stars: the bar is maintained over a period of 2 Gyr.
Gas: the bar shrinks with time.

Velocity field of the gas particles

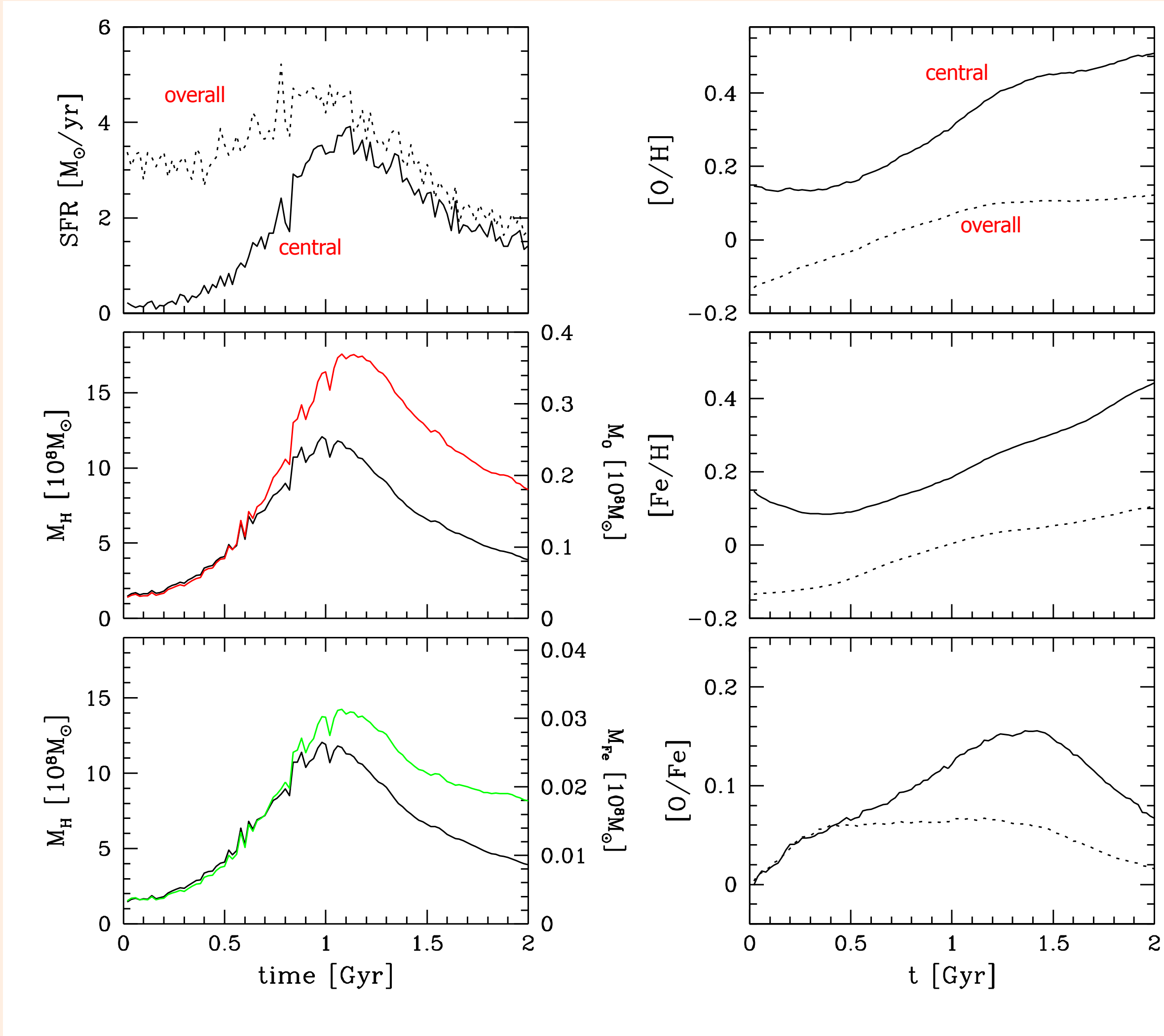


The gas moves along elliptical orbits over the entire length of the bar (the stars too).

Some particles enter and exit the central region more than 20 times during the first 2 Gyr.

As the gas bar shrinks, the trajectories are eventually located entirely inside the central region.

Evolution of the central region



Increase in mass of O and Fe follows increase in mass of H until star formation kicks in:

Reduction of gas mass and production of metals

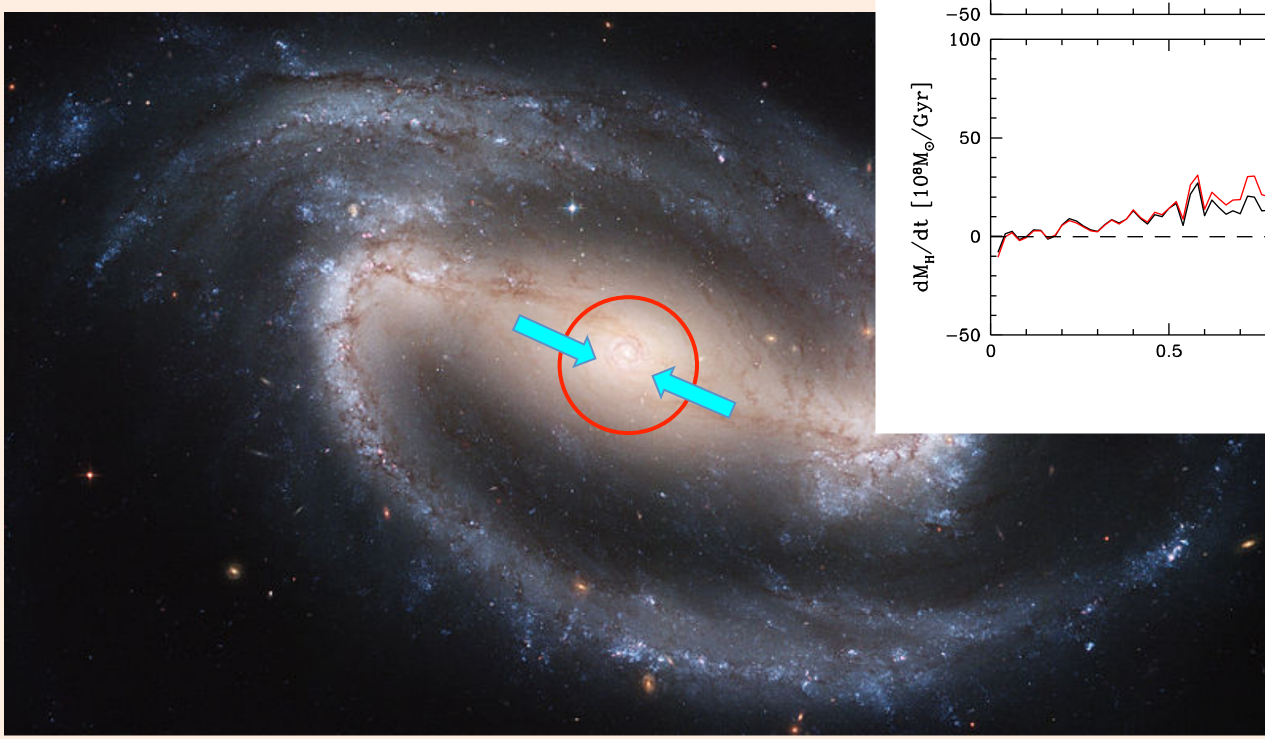
Initial drop in O and Fe abundance caused by infall of metal-poor gas.

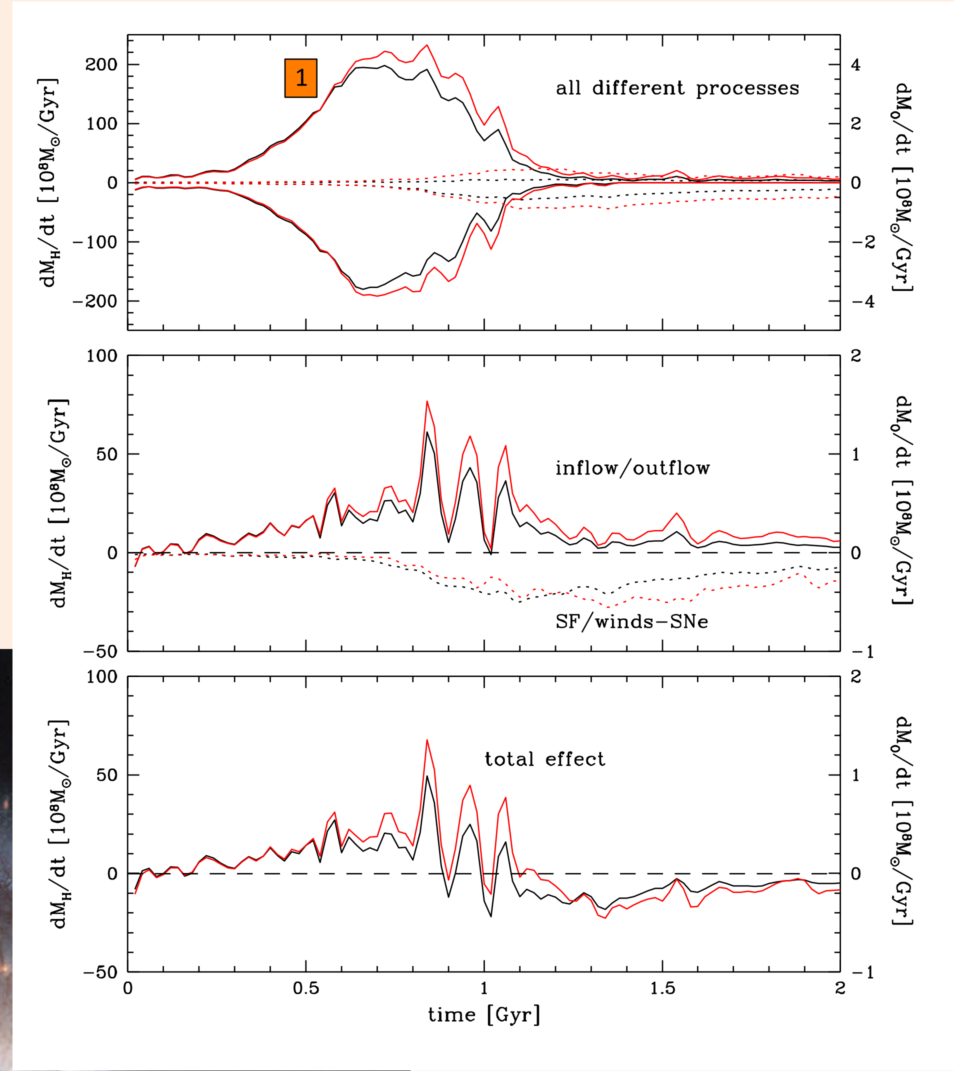
Reversed when star formation kicks in

[O/Fe] increases when Type II SNe dominates. Starts decreasing when Type Ia SNe become important.

Rate of change of gas mass in central region.

1) Gas flowing into the central region

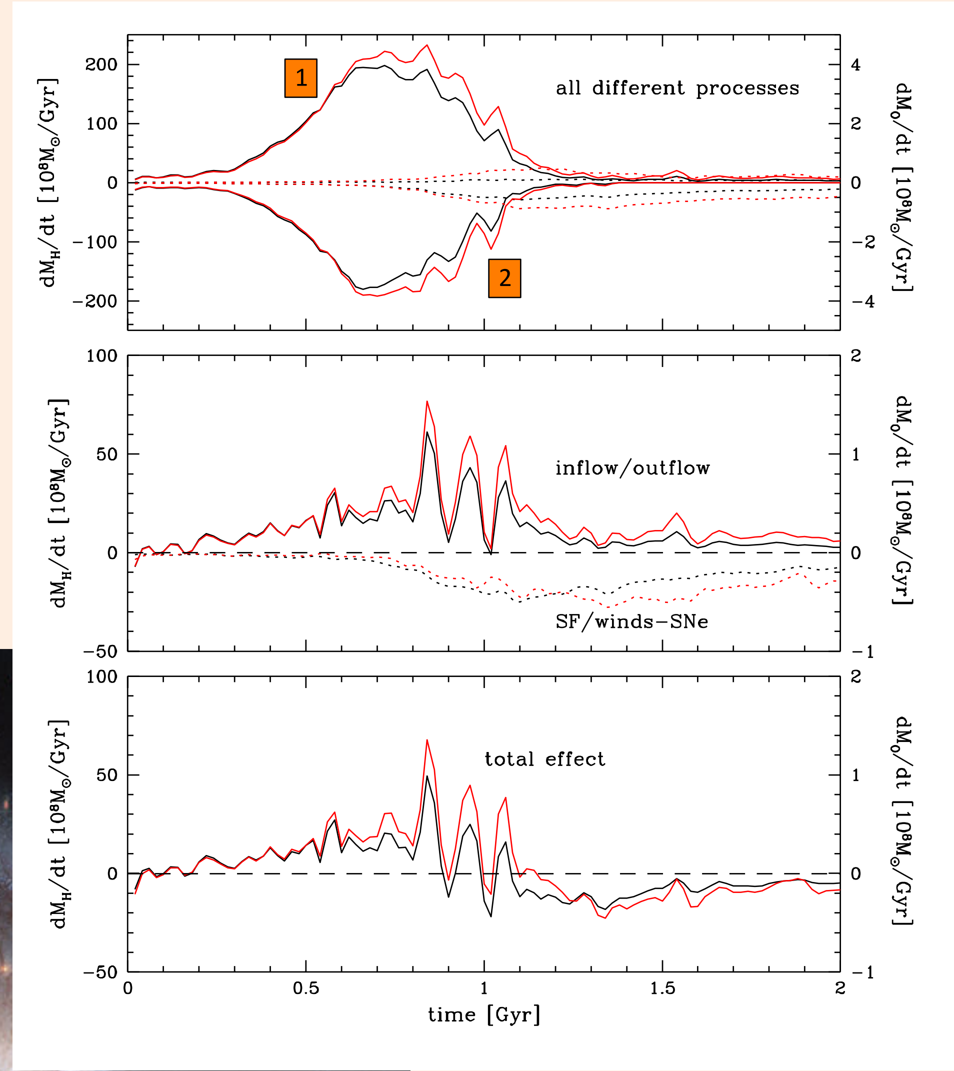


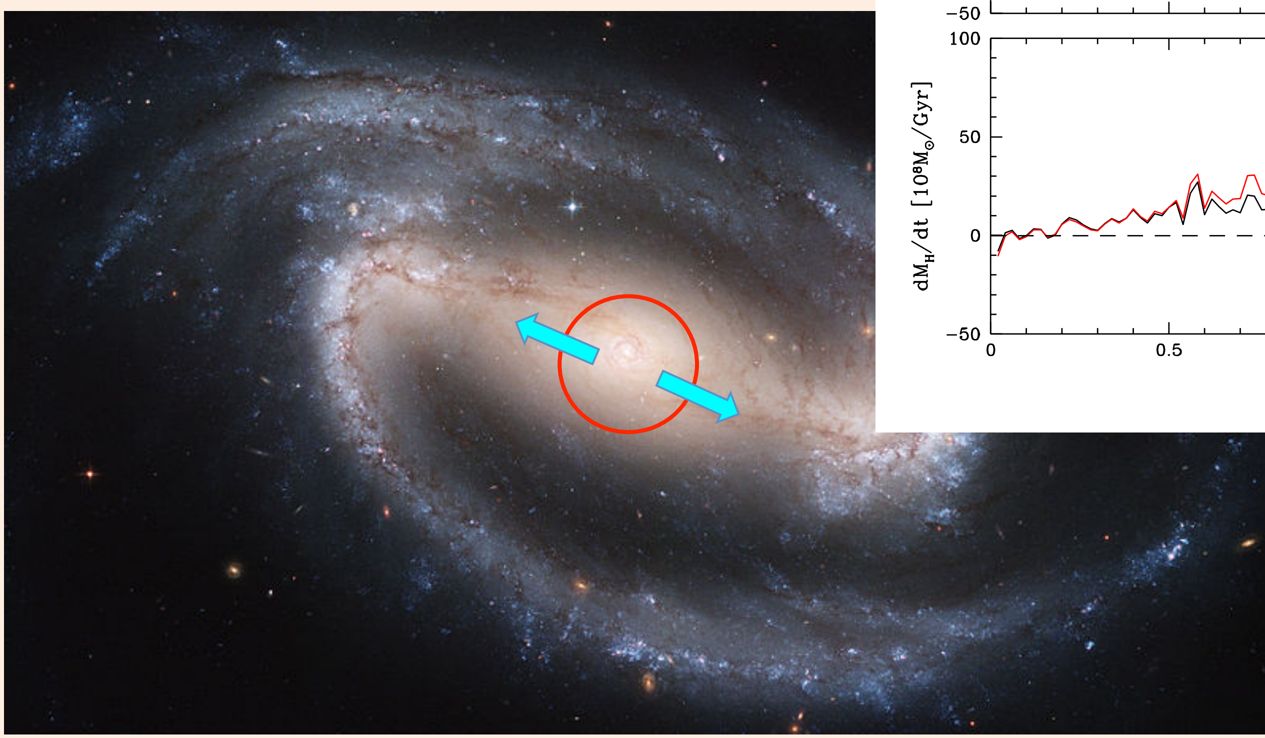


Rate of change of gas mass in central region.

1) Gas flowing into the central region

2) Gas flowing out of the central region



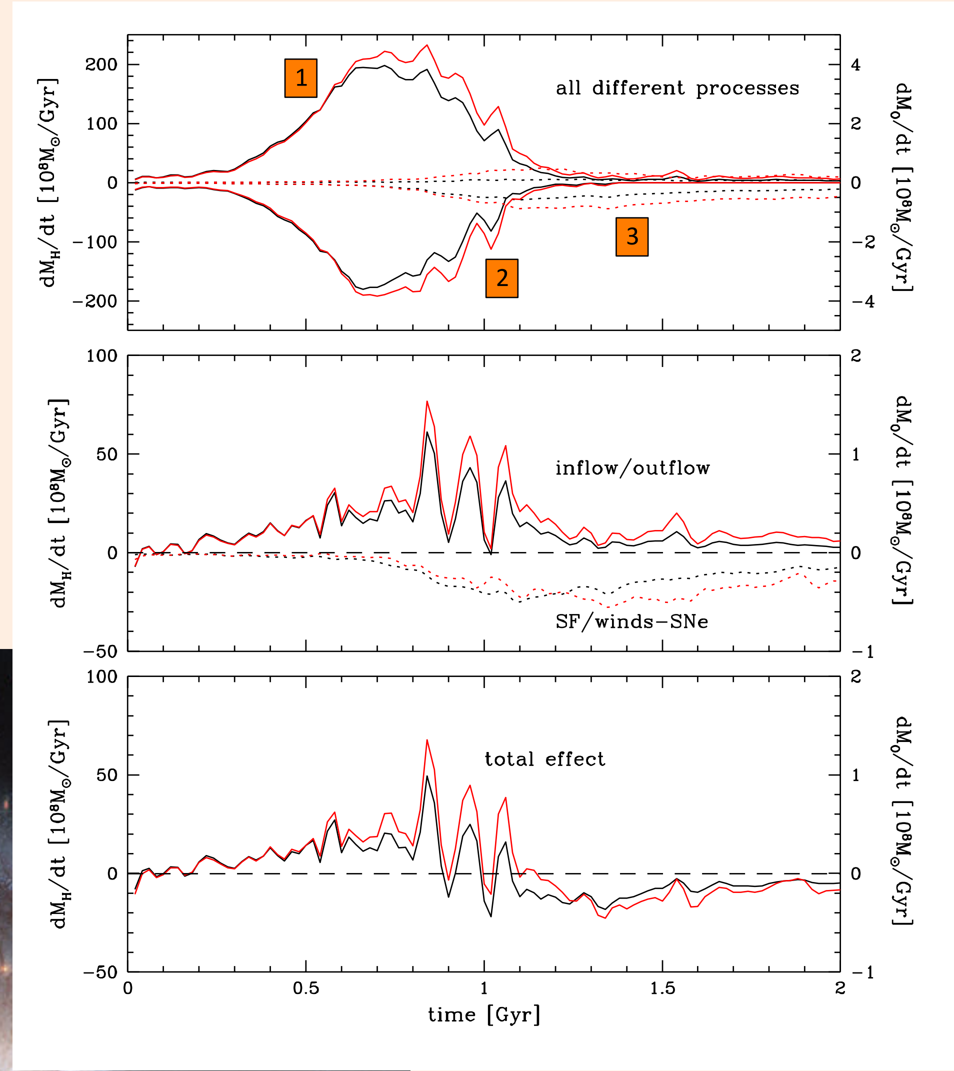


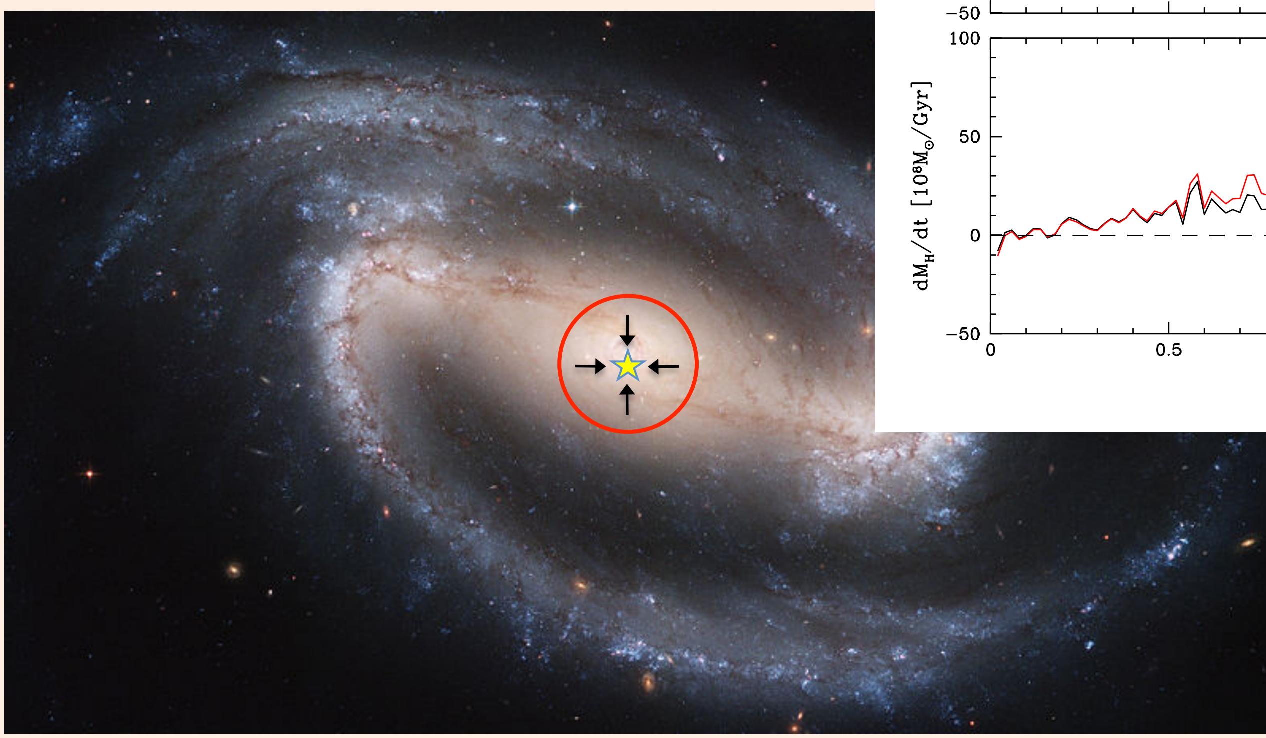
Rate of change of gas mass in central region.

1) Gas flowing into the central region

2) Gas flowing out of the central region

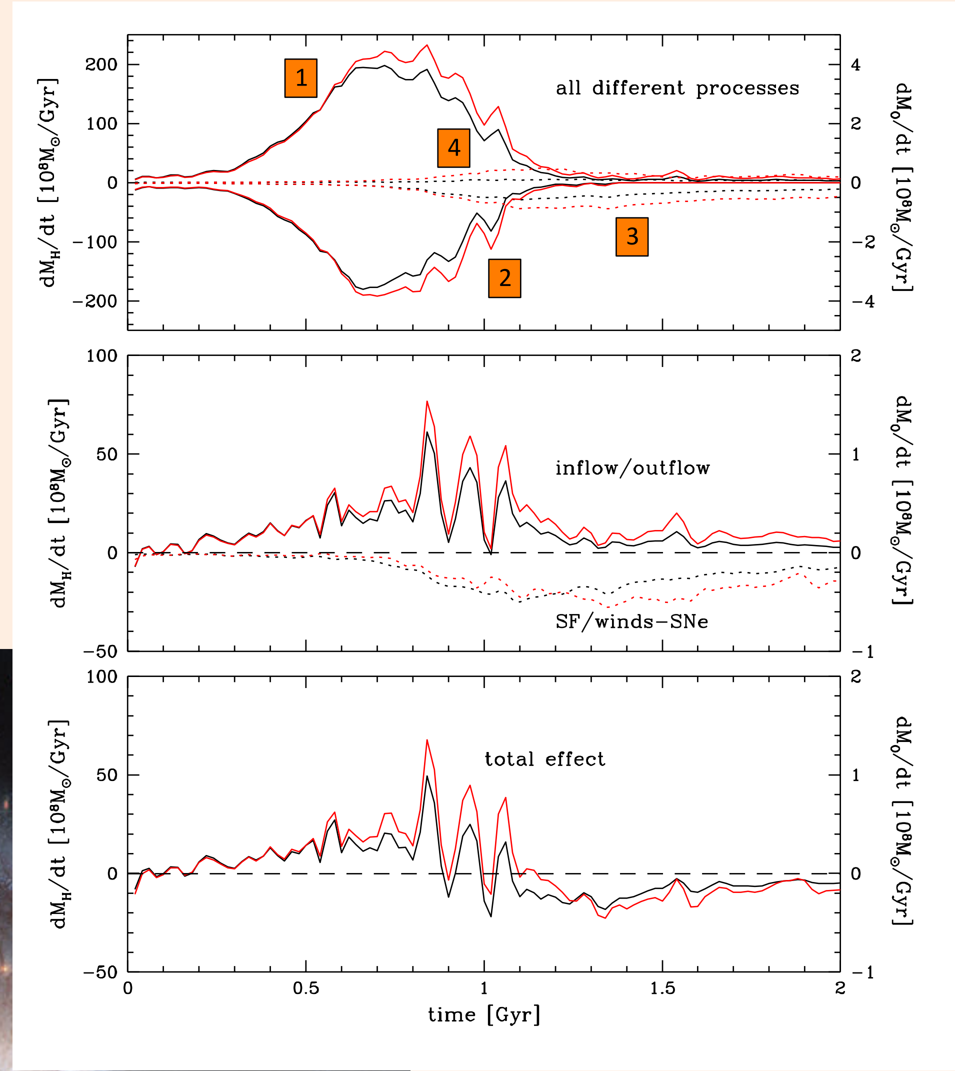
3) Gas turned into stars

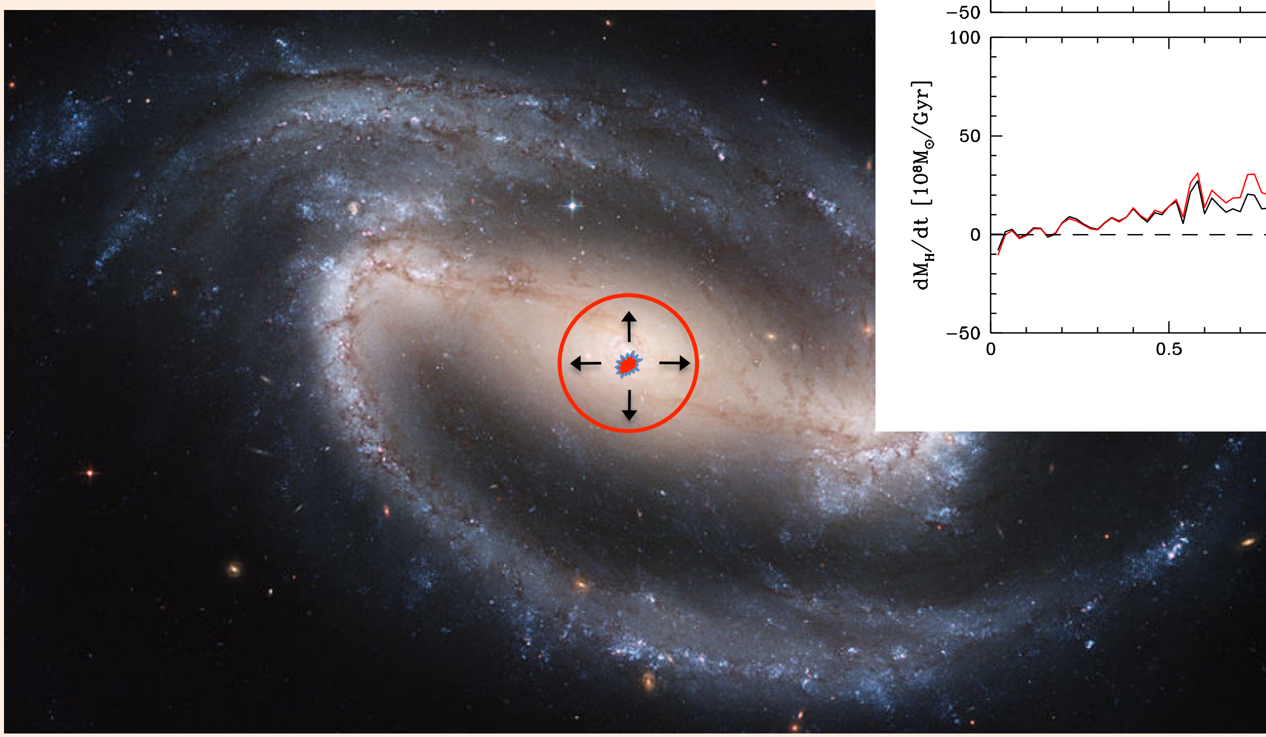


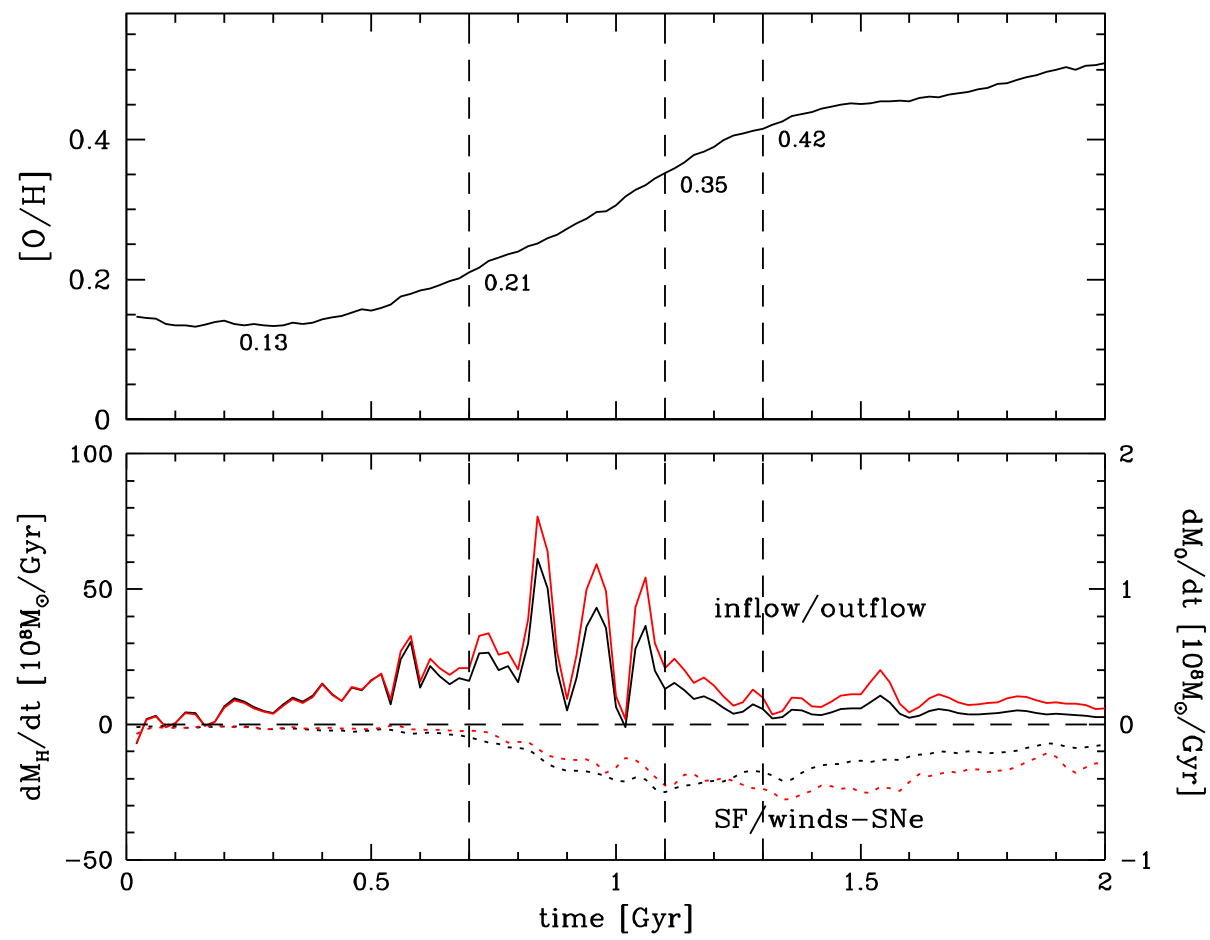


Rate of change of gas mass in central region.

1) Gas flowing into the central region
2) Gas flowing out of the central region
3) Gas turned into stars
4) Stellar outflows





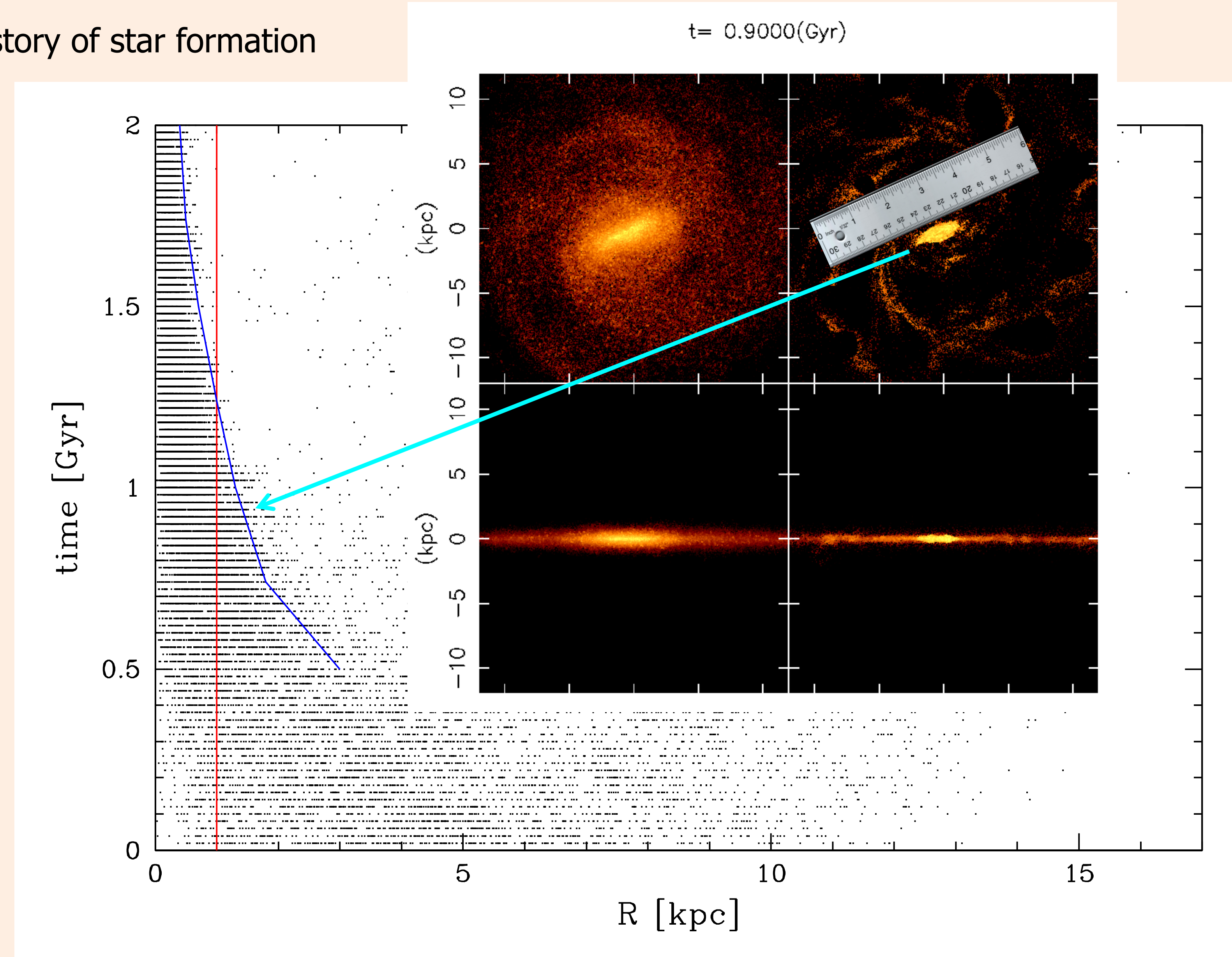


The central metallicity increases before central stars start to contribute!

Also, change of slope at t = 1.3 Gyr corresponds to shutdown of gas inflow.

This suggests that the stars producing these metals were not formed in the central region. Where did they formed?

History of star formation



Star formation takes place along the entire length of the bar,
not only in the central region.

Summary

Basic scenario:

- A bar forms by instability.
- Gas loses angular momentum and falls toward the central region.
- The gas in the central region turns into stars.
- These central stars produced metals, and enrich the gas in the central region.
- We expect a relation between central star formation and central metallicity.

Our results:

- A bar forms by instability.
- Stars and gas move along the bar on elongated orbits, moving in and out of the central region several times.
- The gas bar shrinks with time and is eventually contained entirely in the central region.
- Stars form over the entire length of the bar, resulting in metal enrichment over the entire length of the bar.
- As the gas bar shrinks, these metals are carried into the central region.
- We do not find a relation between central star formation and central metallicity. Instead, we find a relation between the final central metallicity and the global star formation. Central metals were produced all along the bar, and carried to the center by gas flows.

Dank u wel !