

High-Redshift Clumpy Disks & Bulges in Cosmological Simulations

AstroPH:0907.3271

Daniel Ceverino (HU)

Avishai Dekel (HU) , Frederic Bournaud (CEA),

Reem Sari(HU), Tobias Goerdt(HU), Anatoly Klypin (NMSU)

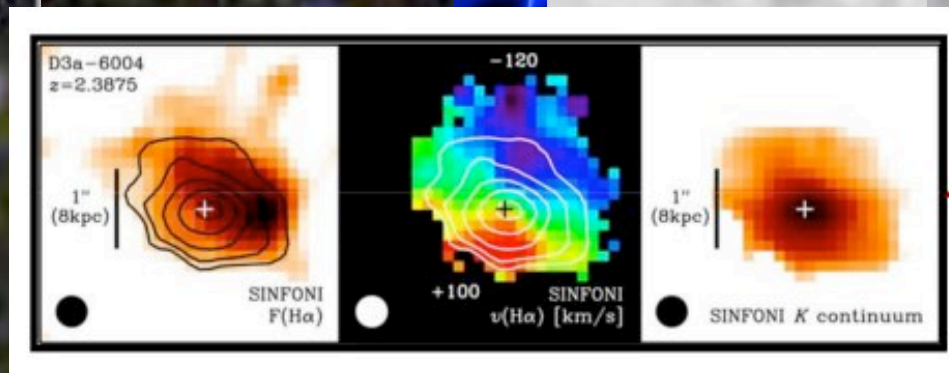
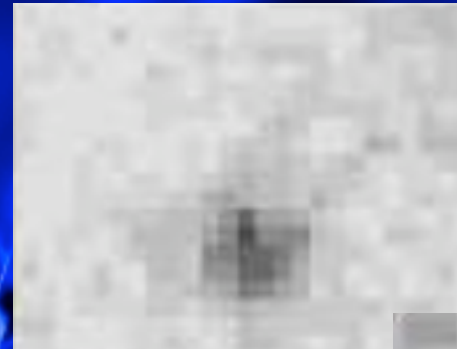
Toledo, 2009

From Disks to Bulges

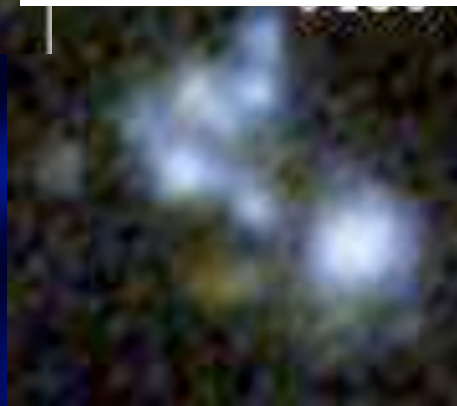
Rest-frame
UV



Rest-frame
visible



Elmegreen et al. 2009



Genzel et al. 2008



Cosmological Simulations of Galaxy Formation

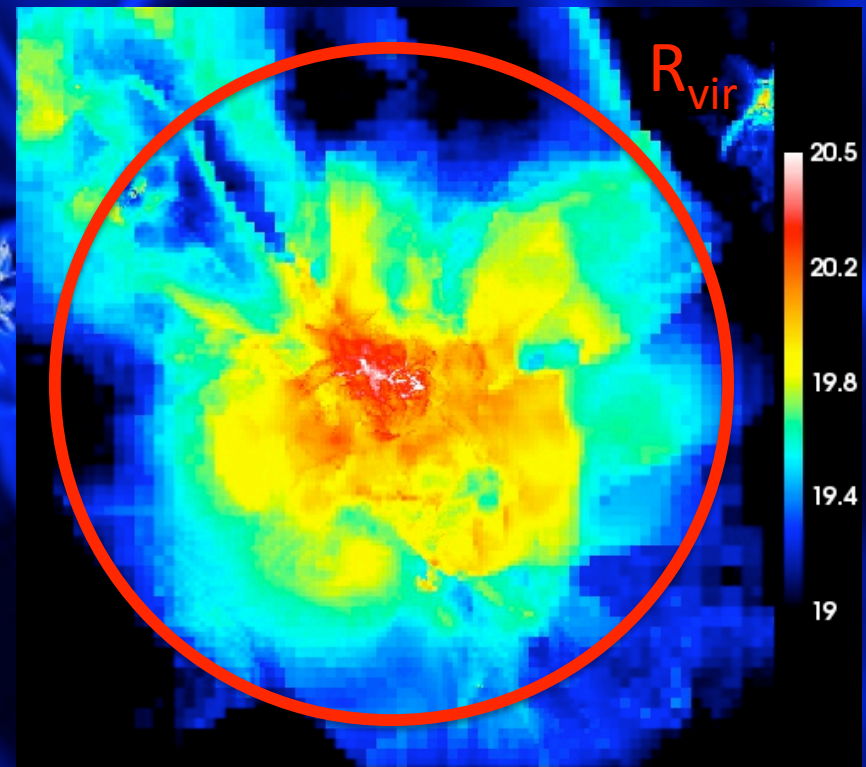
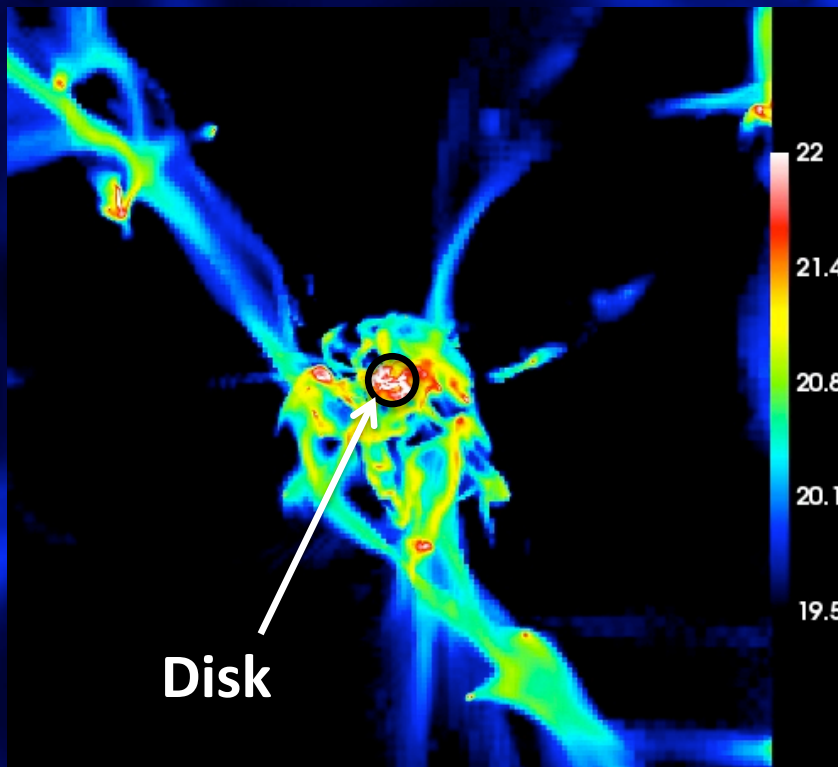
- AMR code: HYDRO-ART (Kravtsov et al 1997, Kravtsov 2003)
- Gas Cooling, Star Formation, Stellar Feedback (Ceverino & Klypin 2009 for details)
- Set of simulations: 3 halos of $3-4 \times 10^{12} M_{\odot}$ at $z=0$ in a $20 h^{-1} \text{Mpc}$ comoving box.
- Maximum resolution of 30-70 pc

Cold Streams & Hot halos

at $z=2.3$

160 kpc

$M_{\text{vir}} = 4 \cdot 10^{11} M_{\odot}$



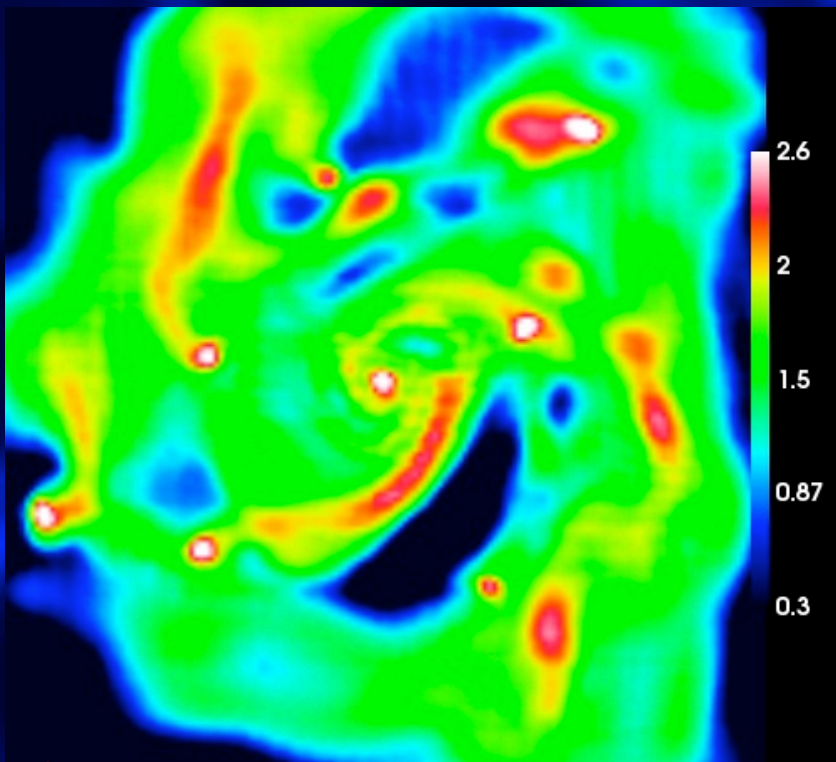
Cold Gas ($T < 5 \cdot 10^{4.7} \text{ K}$)

Hot Gas ($T > 10^{5.5} \text{ K}$)

Gravitationally unstable disks

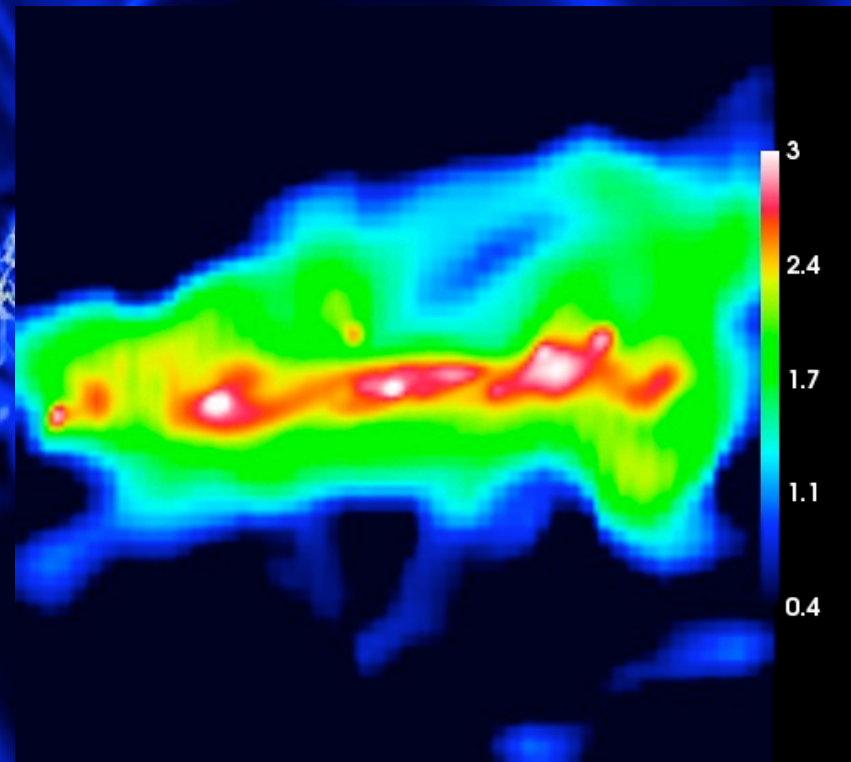
Max. resolution
of 70 pc

Gas Surface Density in $\log (M_{\odot}/\text{pc}^2)$



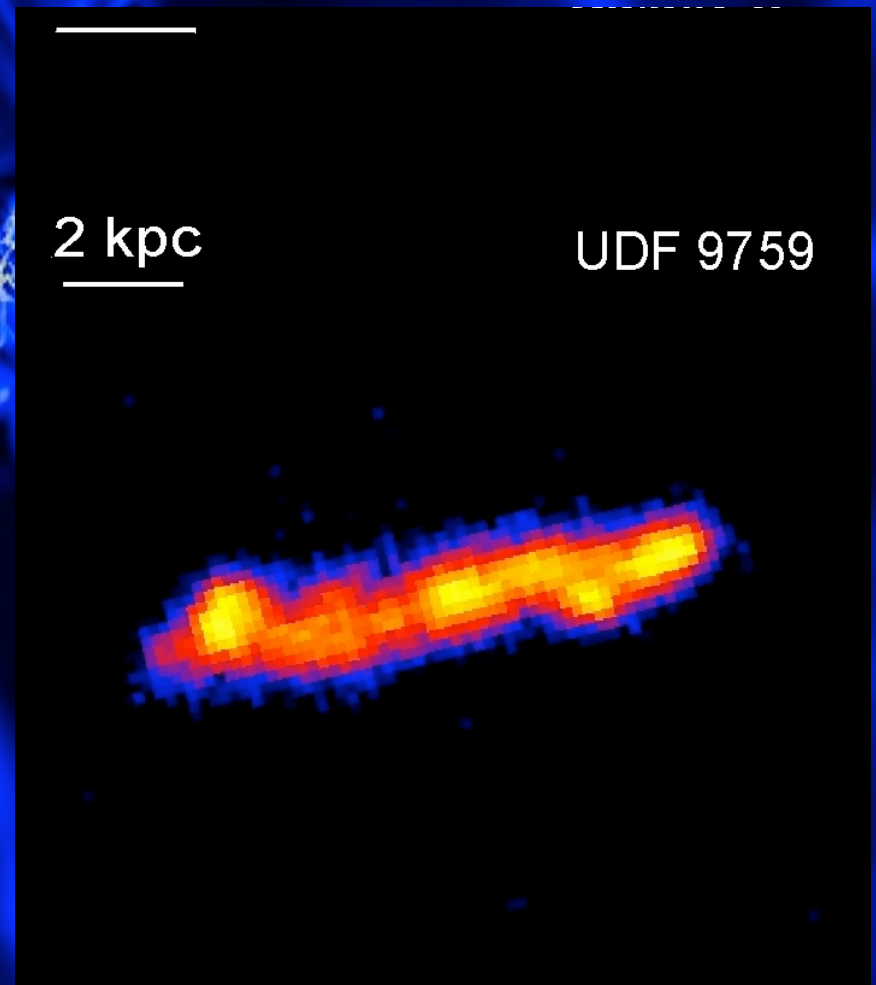
10 kpc

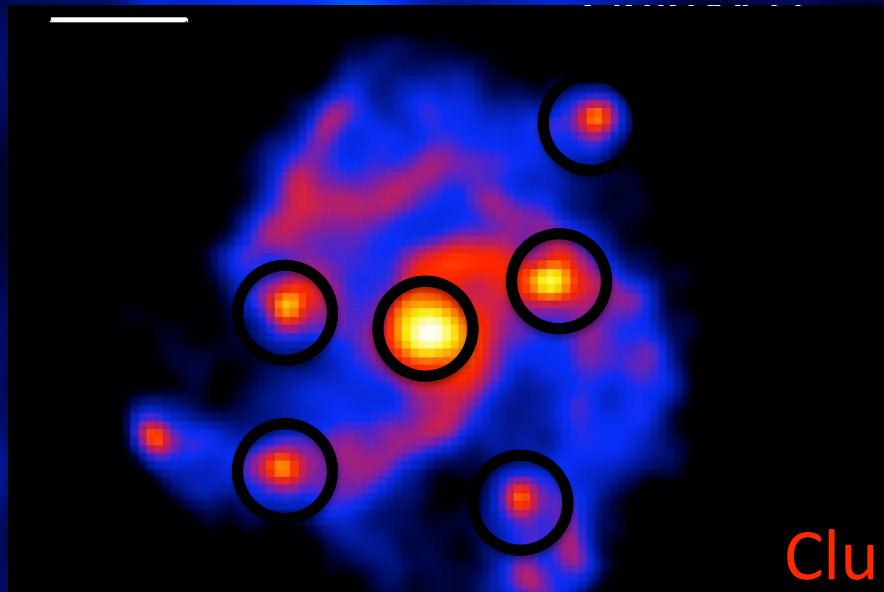
Face-on view



Edge-on view

Young Stars

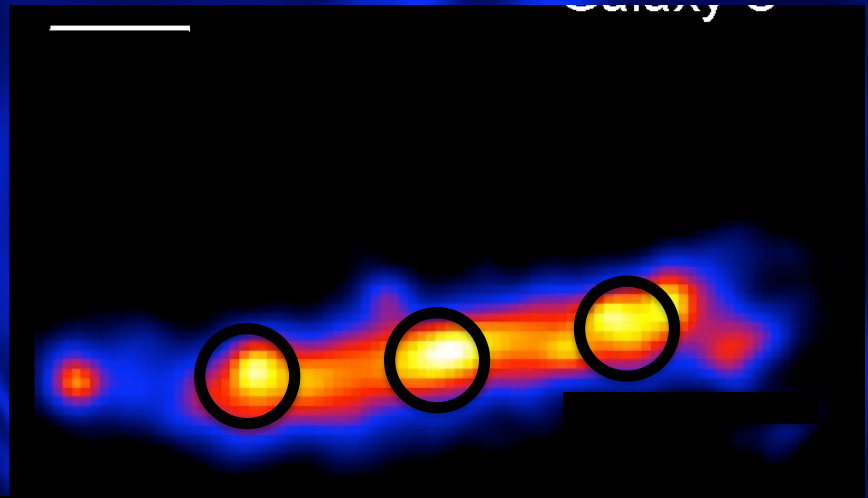




2 kpc

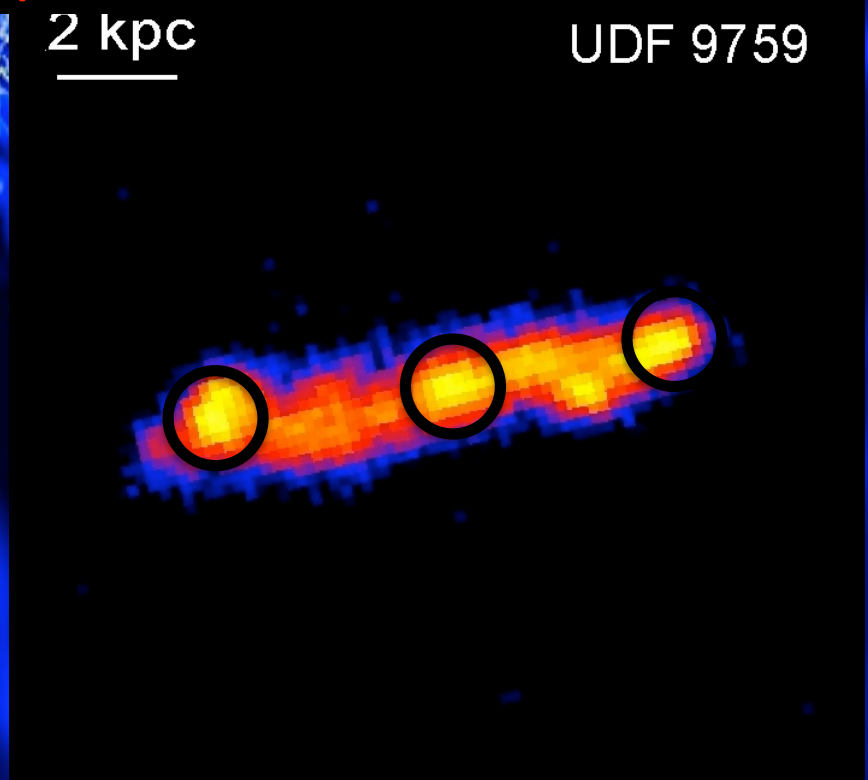
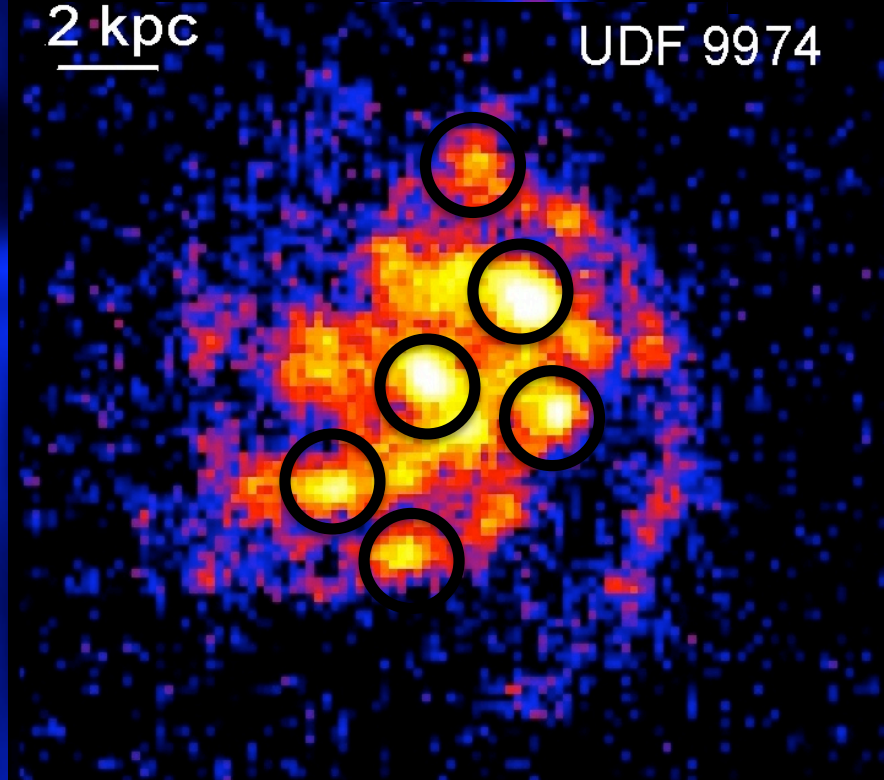
UDF 9974

Clumps !!

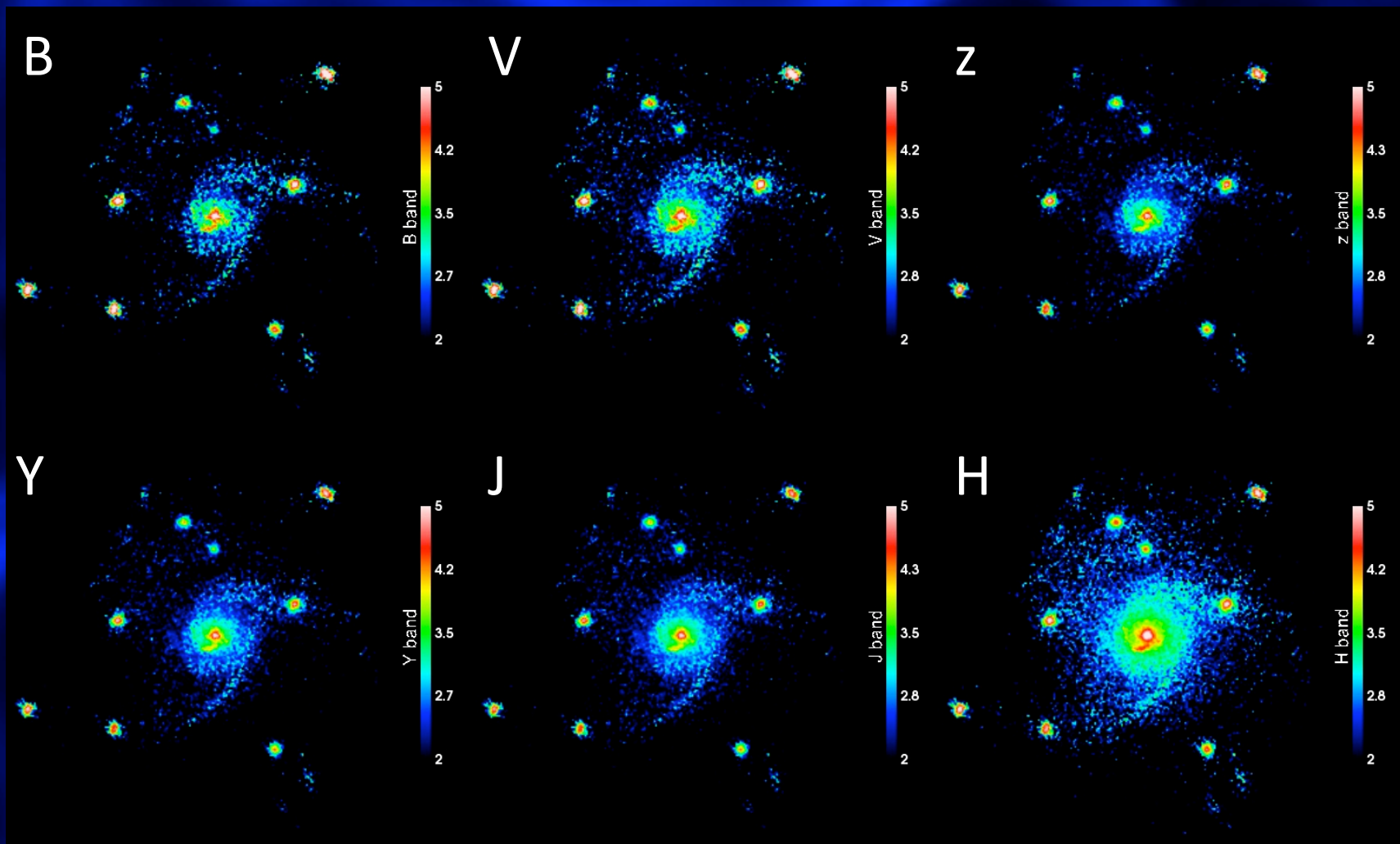


2 kpc

UDF 9759



HST bands images at $z=2.3$

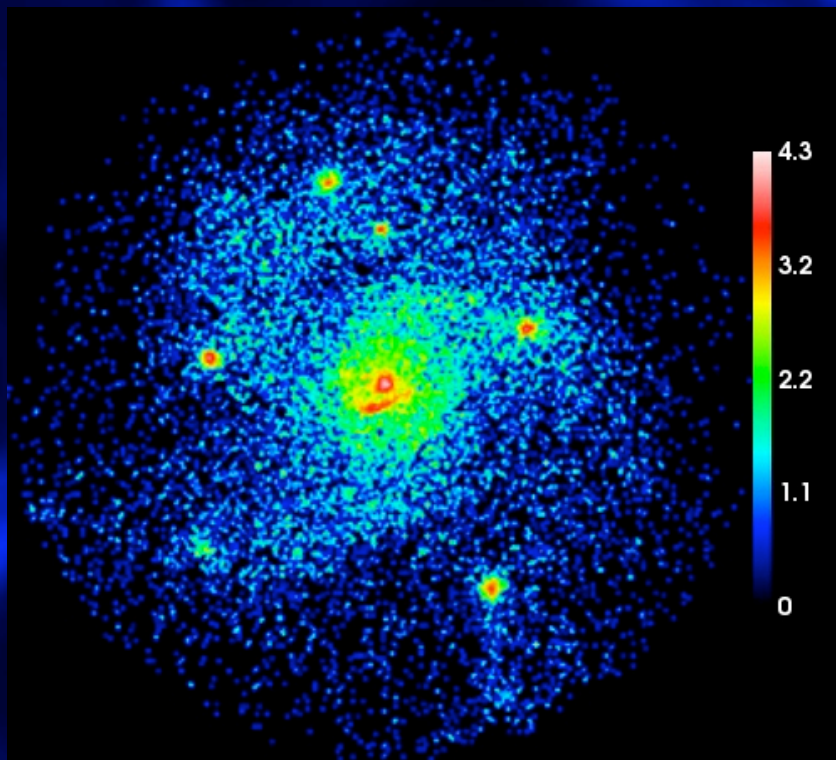


Morphology

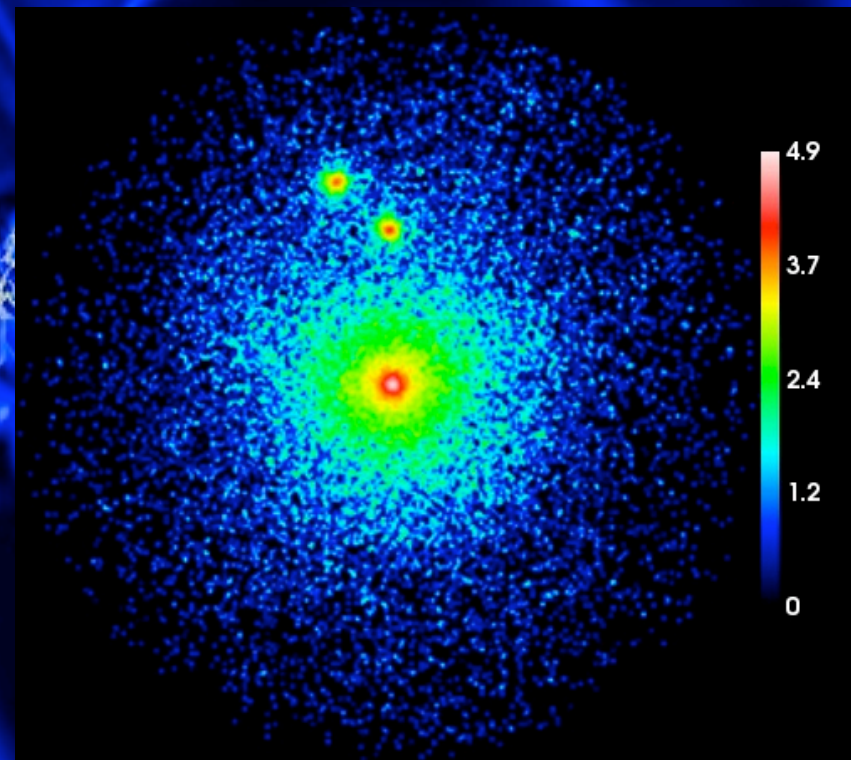
Clumpy disk

face-on

Spheroid



100 - 300 Myr



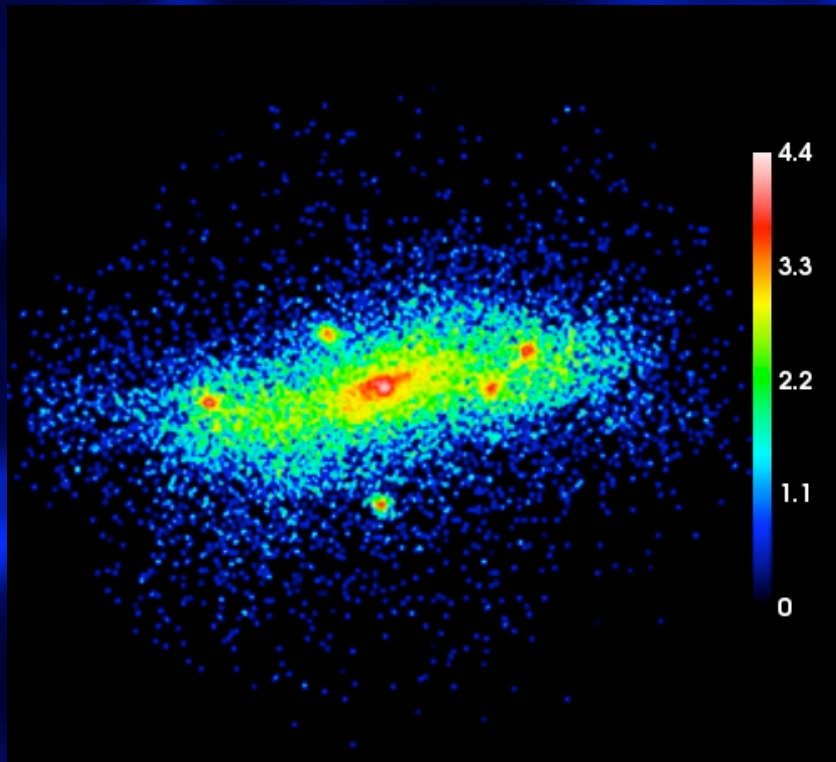
0.3 - 1 Gyr

Morphology

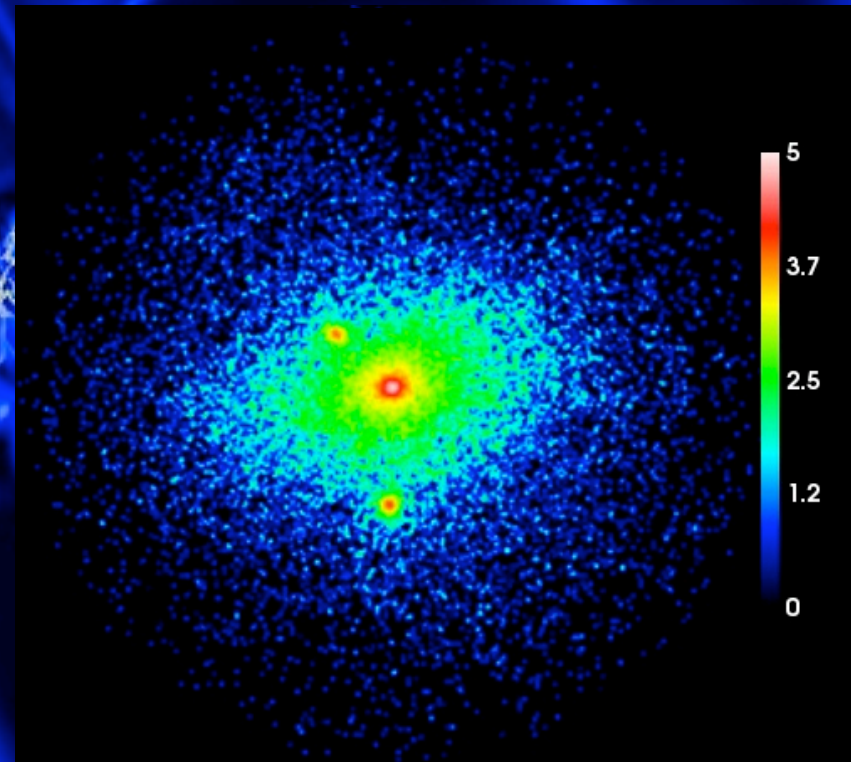
Clumpy disk

edge-on

Spheroid

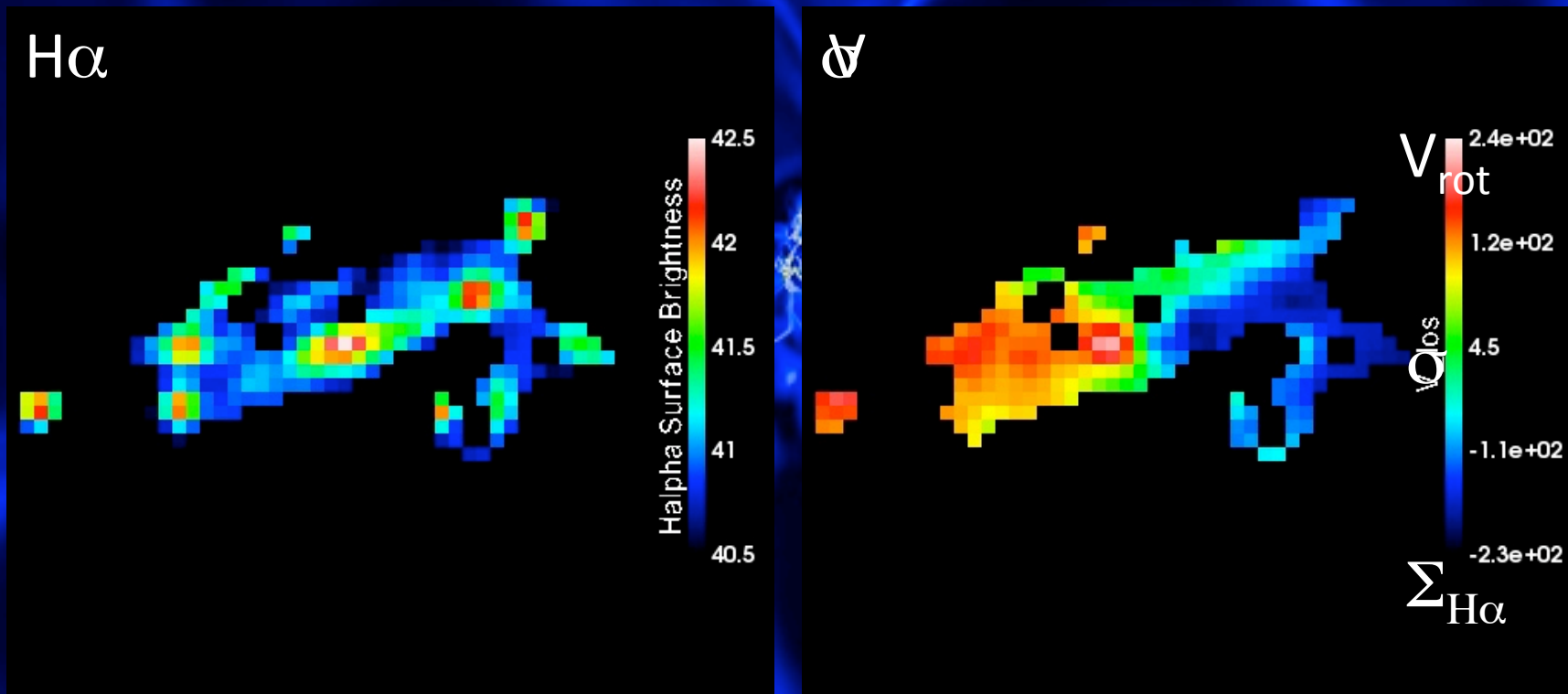


100 - 300 Myr

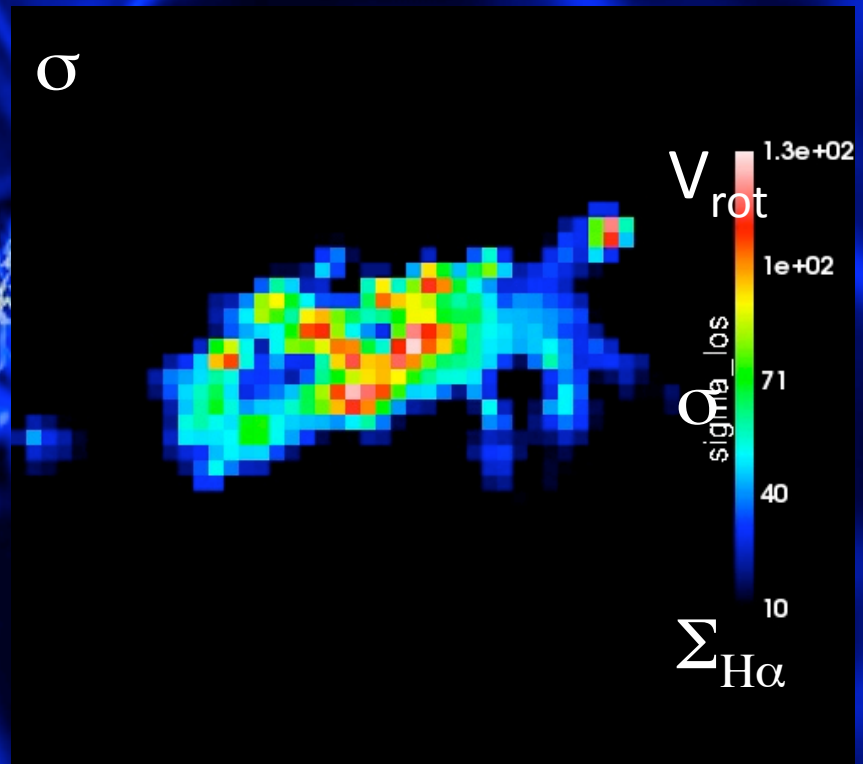
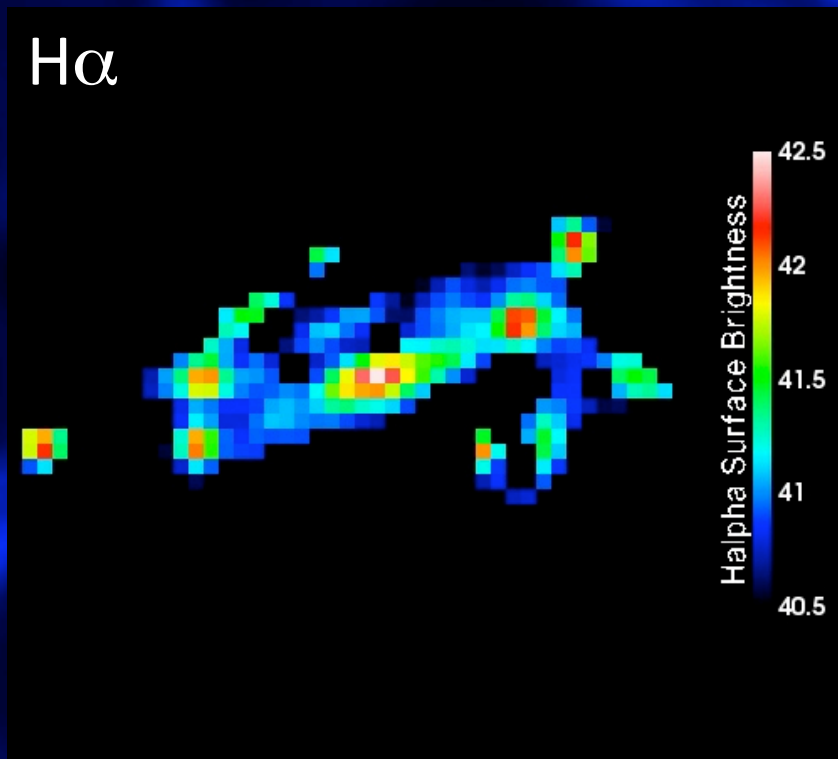


0.3 - 1 Gyr

H α kinematics

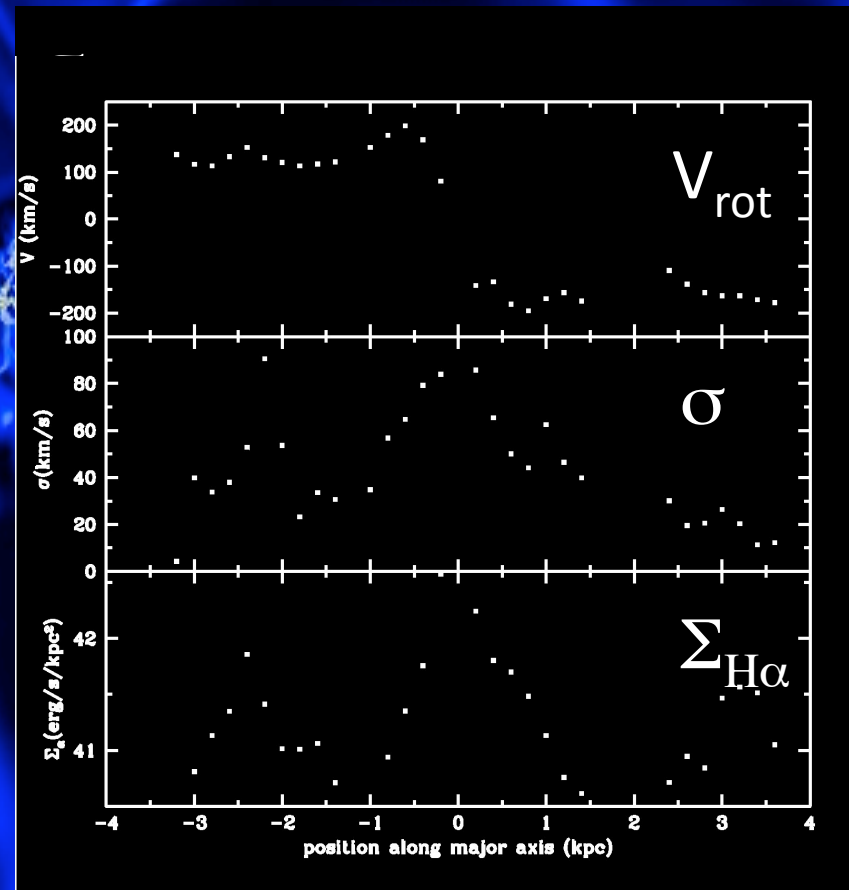
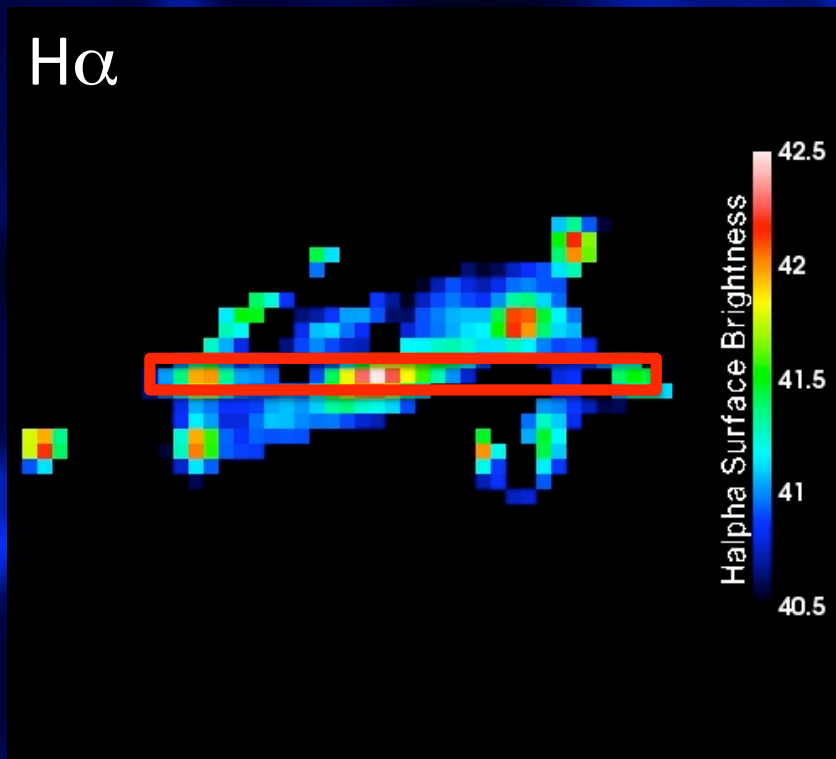


H α kinematics

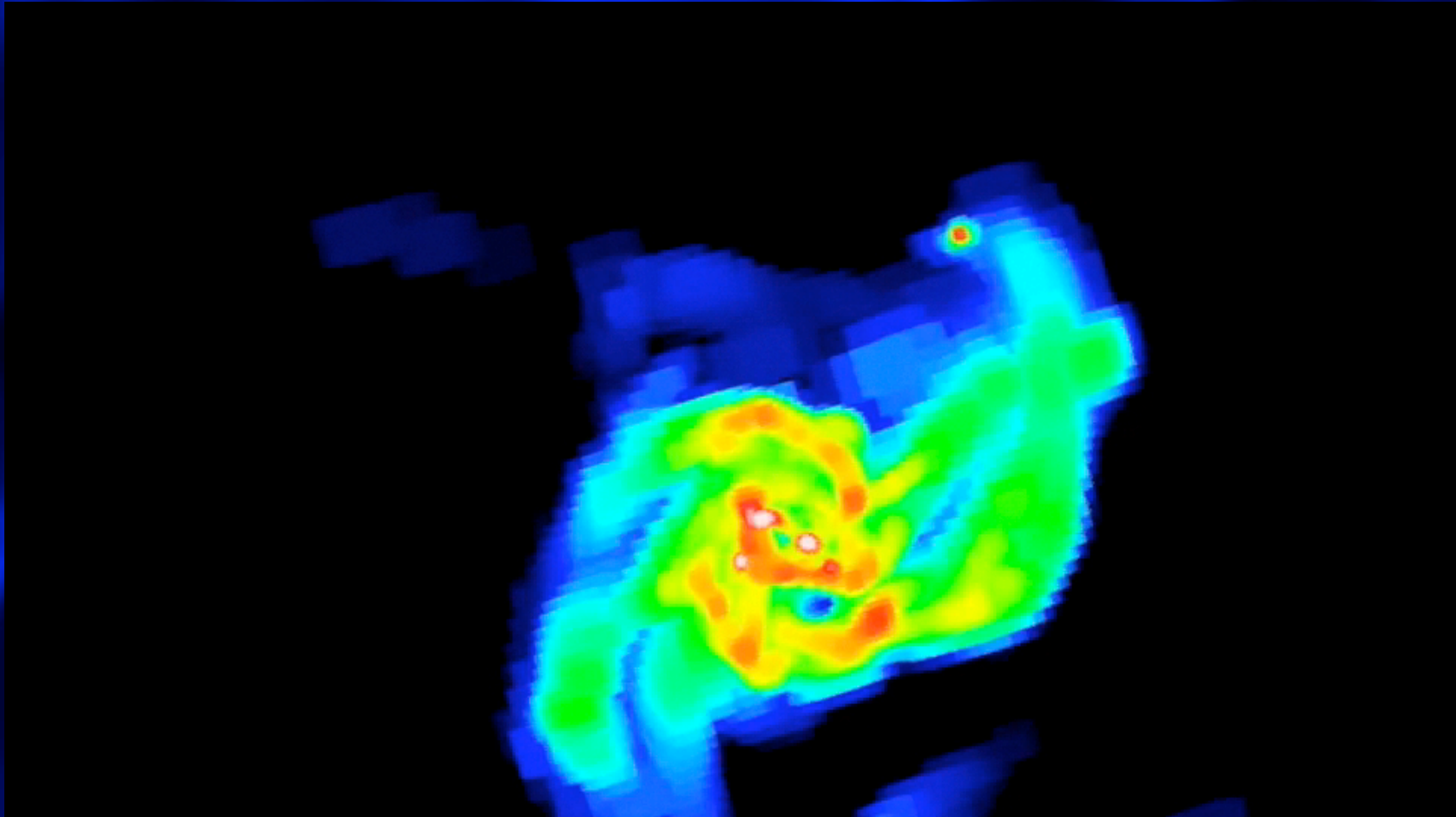


H α kinematics

long-slit along major axis



Clumps Evolution for 400 Myr



Summary

- **Cosmological Cold Streams** feed gravitationally-unstable disks between $z=3-1$.
- **Giant clumps** ($10^7-10^8 M_{\odot}$) form by disk instabilities.
- They migrate to the center and contribute to the growth of a **bulge/spheroid**.
- **Steady State** for several Gyr due to a continuous, cosmological gas accretion.



The End

(FIN)