Disk-halo connection and gas accretion

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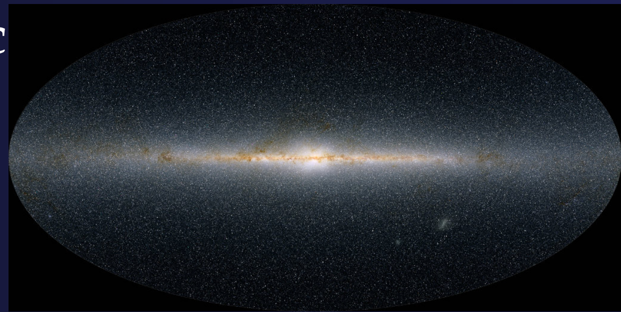
The case for gas accretion

1. There is very little gas in the Milky Way disc

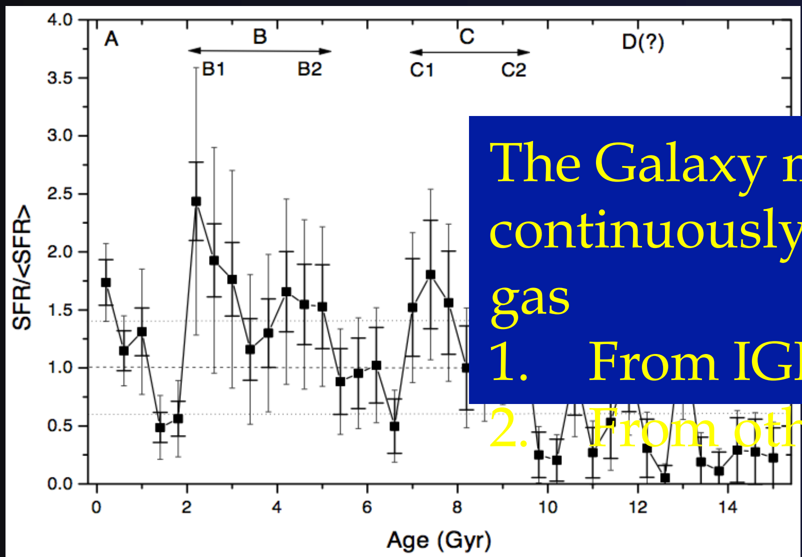
$M_{*,\rm disc} \sim 5 \times 10^{10} M_\odot$

$M_{\rm cold\,gas} \sim 6 \times 10^9 M_\odot$

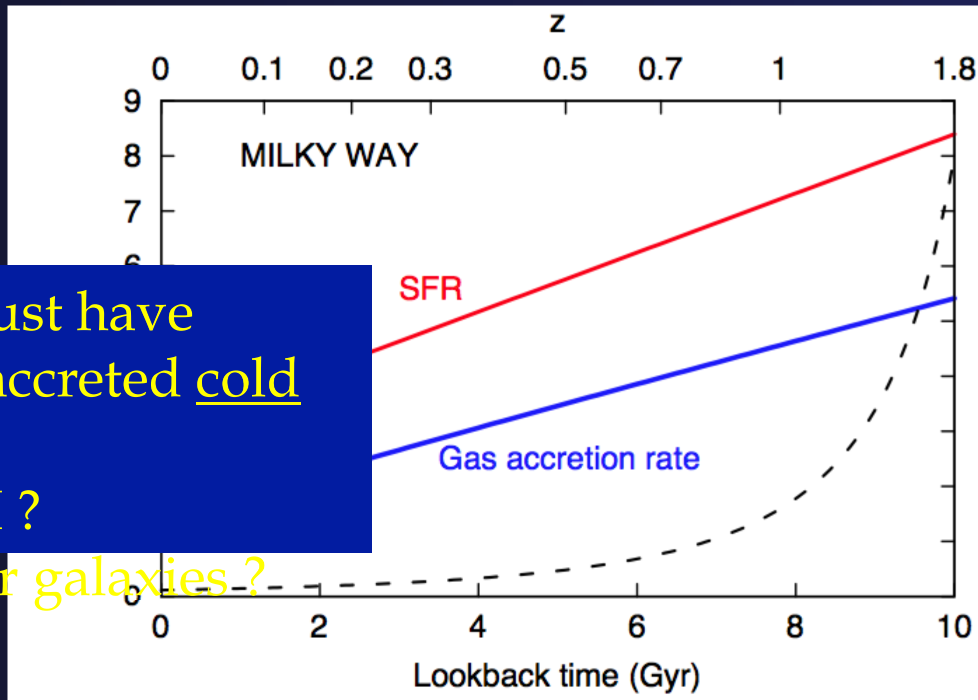


2. The SFR has remained fairly constant

$\mathrm{SFR} \sim 2 - 3\, M_\odot\, \mathrm{yr}^{-1}$



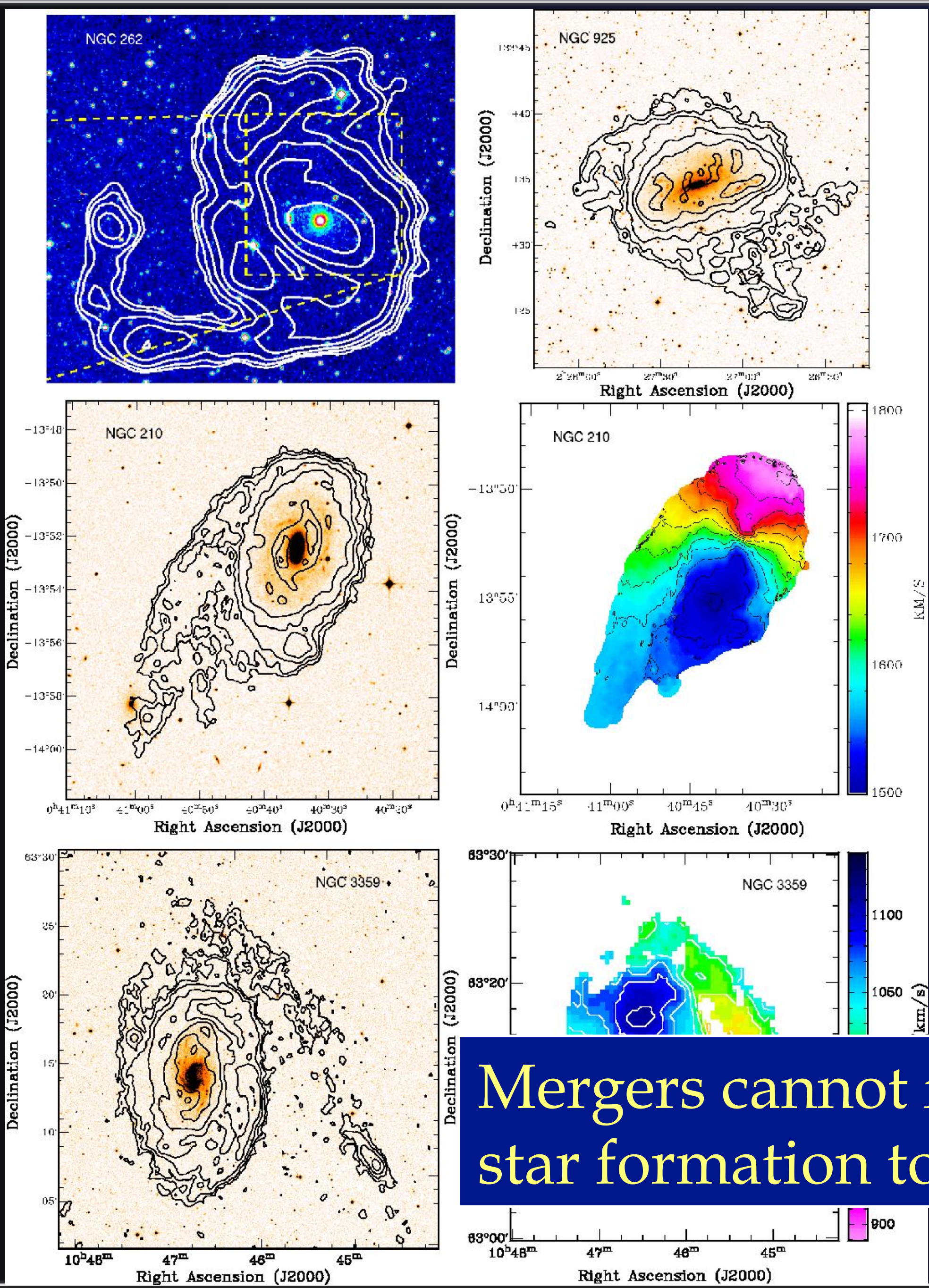
Rocha-Pinto+ 2000



Fraternali & Tomassetti 2012, MNRAS, submitted

The Galaxy must have continuously accreted <u>cold</u> gas

1. From IGM ?
2. From other galaxies ?



Accretion from minor mergers

Using the WHISP catalogue

Detected in ~25% of galaxies
Masses ~ 1-10 x 10^8 M_O
Life time ~ 1-2 dyn times

→ Global accretion rate ~ 0.1-0.2 $M_\odot$/yr

New estimate with automatic search:

→ Firm upper limit < 0.1 $M_\odot$/yr

Di Teodoro & Fraternali, in prep.

Mergers cannot feed star formation today

Sancisi et al. 2008, A&ARv

Only reservoir: the WHIM corona

$M_{\rm vir} \sim 2 \times 10^{12} M_\odot$ → $M_{\rm b} \simeq 3.4 \times 10^{11} M_\odot$

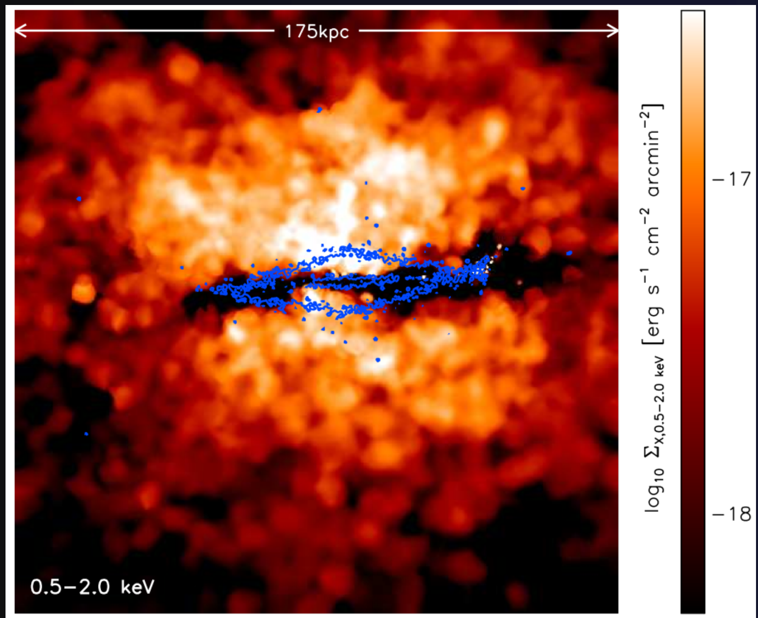
$\frac{\Omega_{\rm b}}{\Omega_{\rm m}} = 0.17$

$M_{*,\rm disc} \sim 5 \times 10^{10} M_\odot$

$M_{\rm cold\ gas} \sim 6 \times 10^{9} M_\odot$

$M_{\rm missing} \sim 2.8 \times 10^{11} M_\odot$

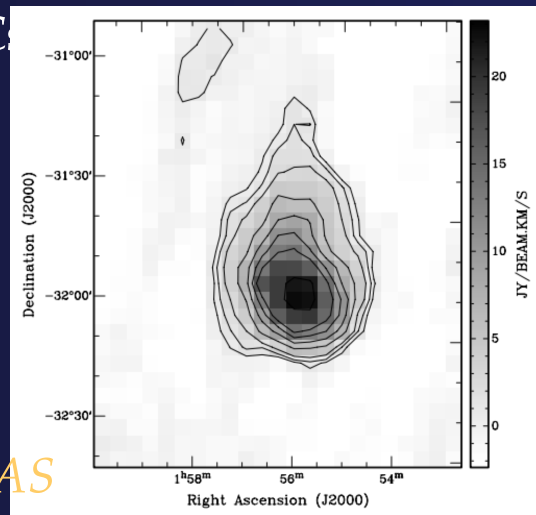
Cosmological hydro simulation



Crain et al. 2010, MNRAS

Indirect evidence:

- Confinement of HVCs
- Cooling species: e.g. OVI, Si III, C IV
- Segregation of dSphs/dIrrs
- Head-tail shape of HVCs

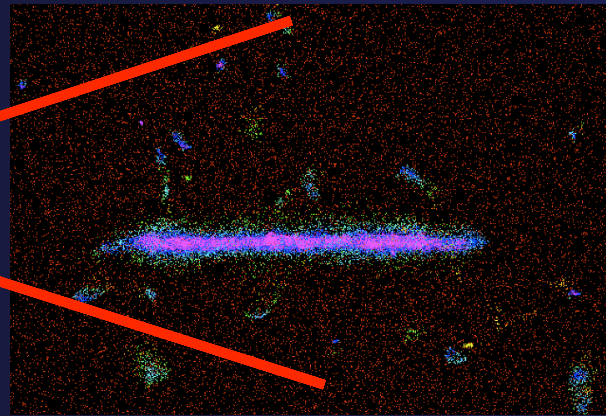


Putman et al. 2011, MNRAS

How does the corona cool?

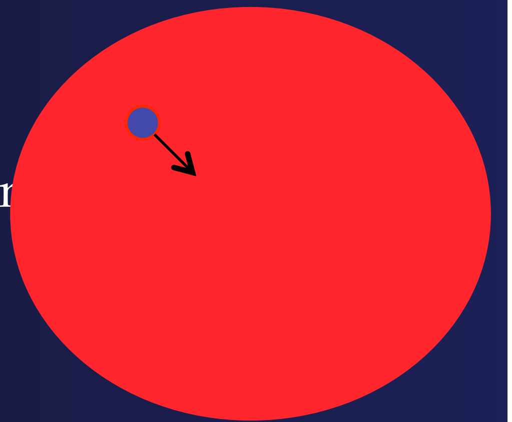
~~Thermal instability?~~

Maller & Bullock 2004, ApJ
Kaufmann et al. 2006, MNRAS
Peek, Putman & Sommer-Larsen, 2008, ApJ



NO! Perturbations do not grow

Malagoli et al. 1987, ApJ — definition of the theory
Binney, Nipoti & Fraternali 2009, MNRAS — linear, non-rotatin
Nipoti 2010, MNRAS — linear, rotating coronae

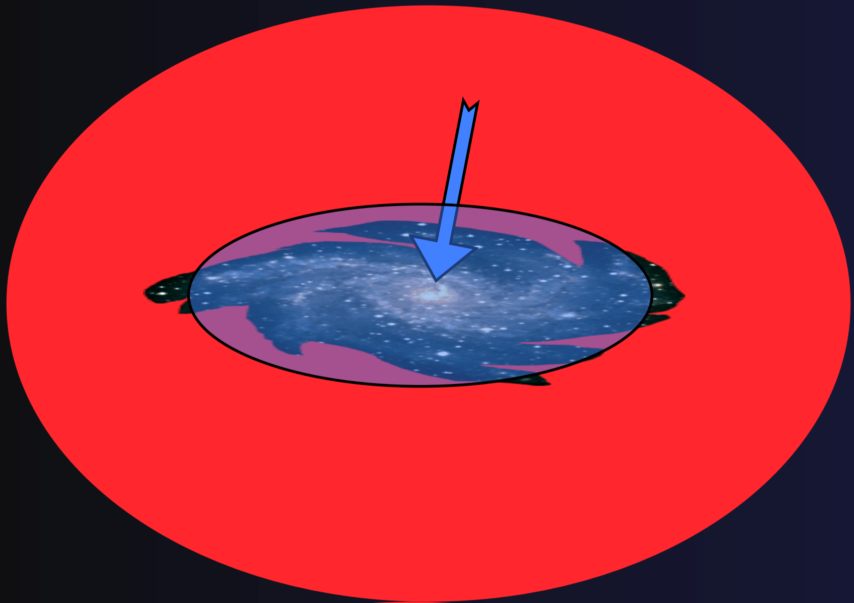


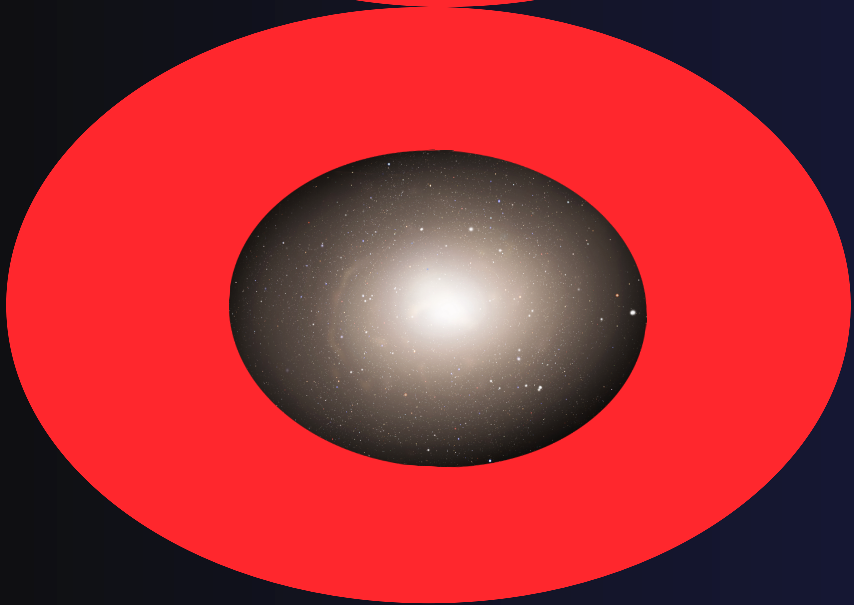
Overdense regions move to equilibrium location faster than the instability can grow

Joung, Bryan & Putman 2011, ApJ — AMR simulations

Coronae do not cool via thermal instability

How should the corona cool?





The place where WHIM corona should cool is the very centre (high density)
-> feeds BH, NOT star formation

INSTEAD it should cool:

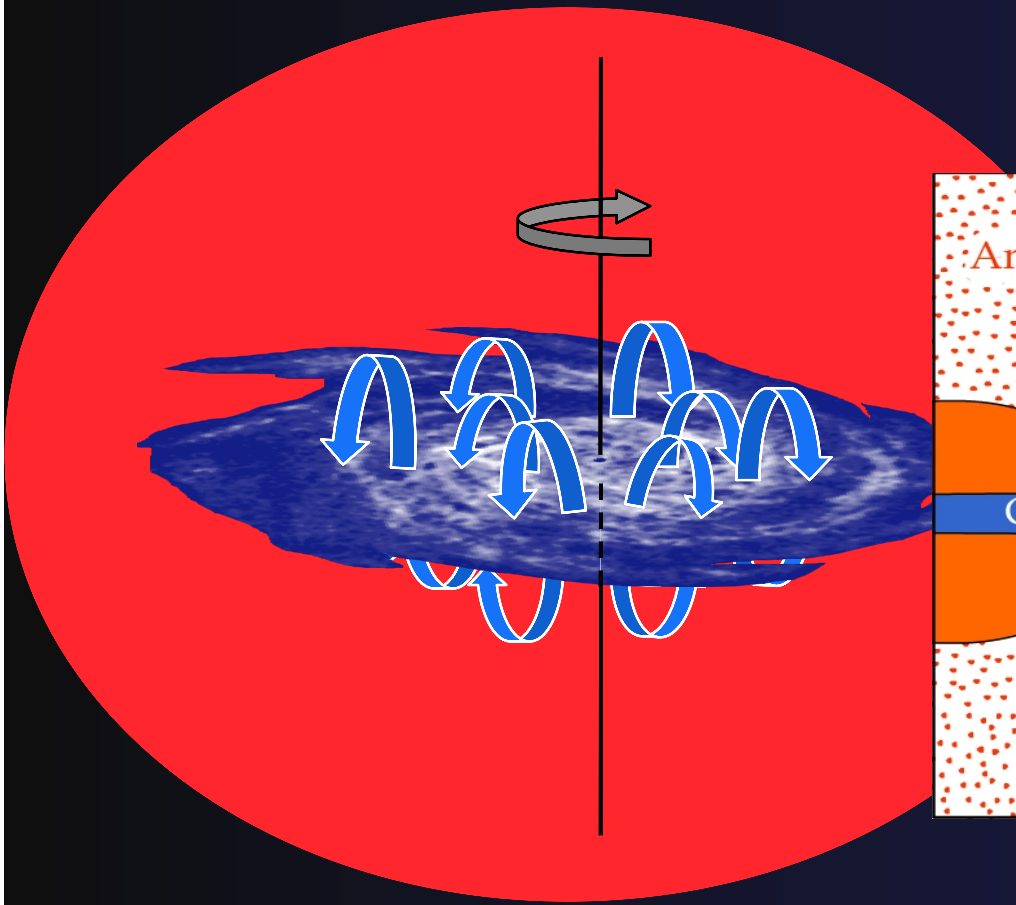
1. All over the disc
2. Not too far above the disc

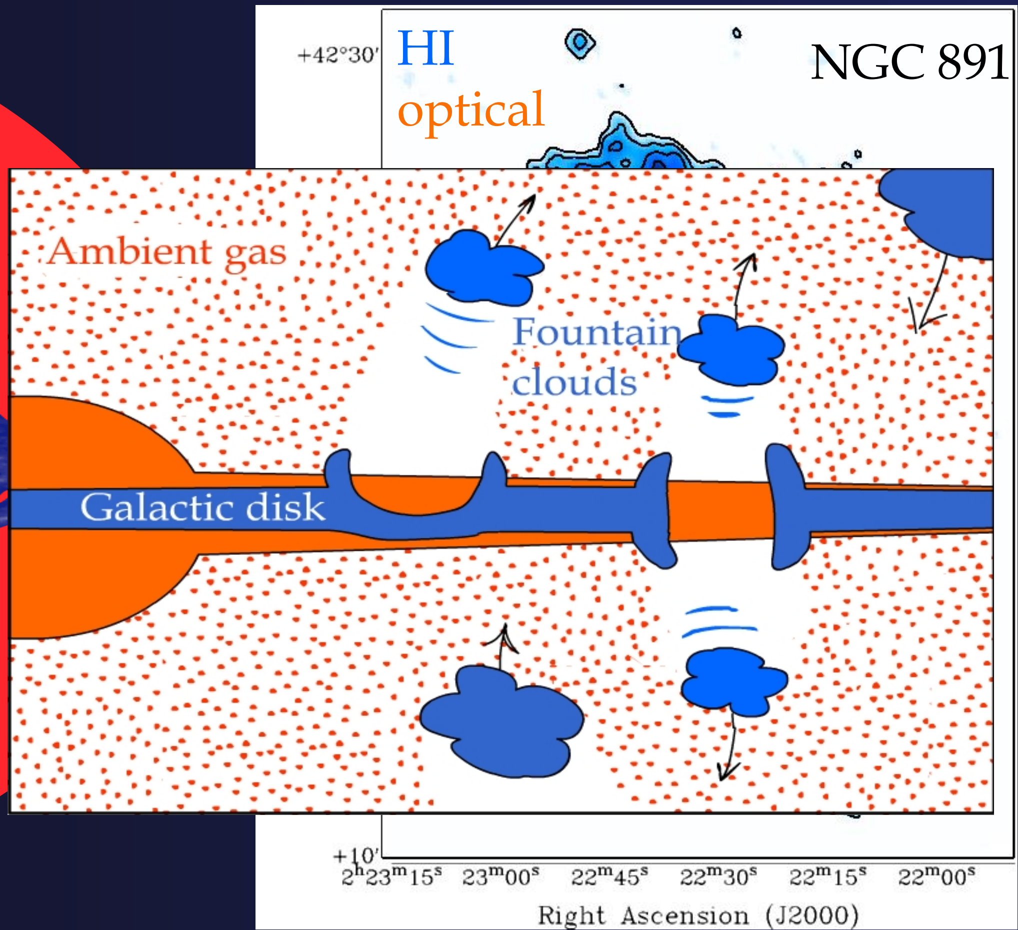
Also why in ellipticals there is very little cold gas?

Cooling is related to the presence of a star forming disk

Interplay between disc and corona

Galactic fountain ejecting gas





Oosterloo, Fraternali, Sancisi 2007

Galactic fountain models

Shapiro & Field 1976, Bregman 1980, Houck & Bregman 1990, Collins et al. 2002, Fraternali & Binney 2006/08, Melioli et al. 2008/09

Fountain cloud through hot corona

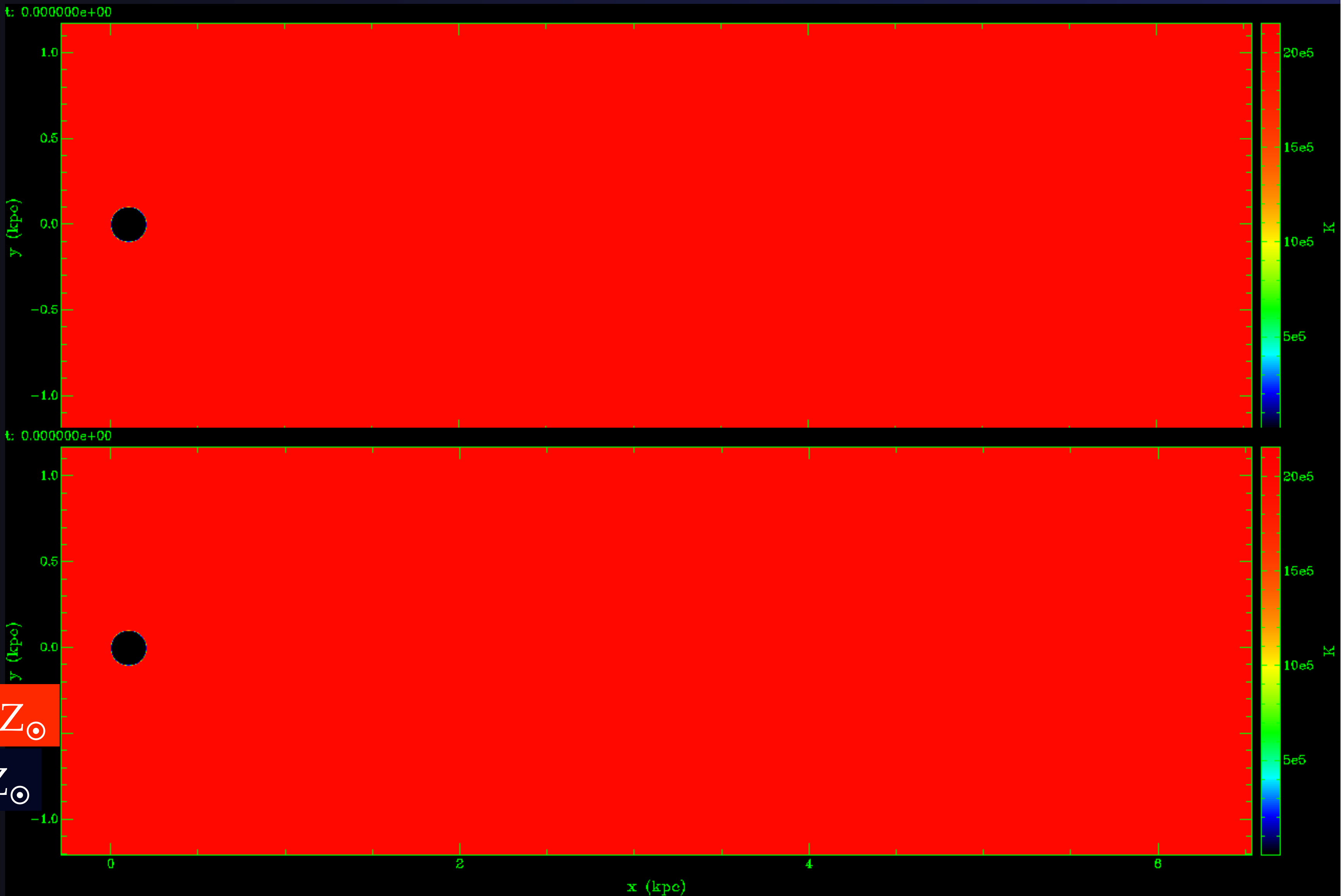
Grid code
Res: ~1 pc

Without cooling

With cooling

$Z_{corona}=0.1\ Z_{\odot}$

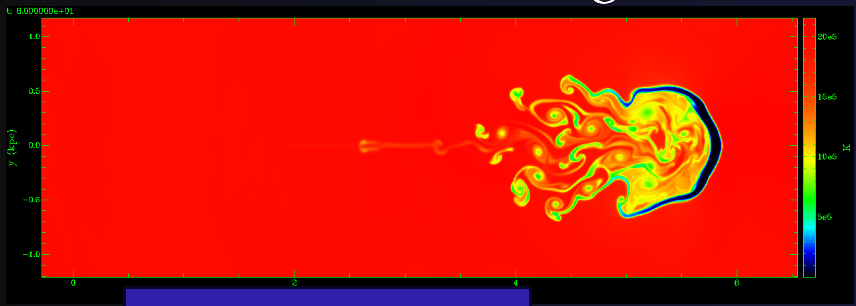
$Z_{cloud}=1\ Z_{\odot}$



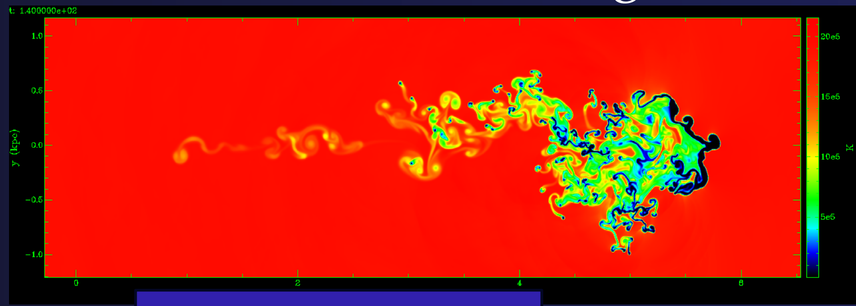
Marinacci et al. 2010, MNRAS

Mass transfer to the cold phase

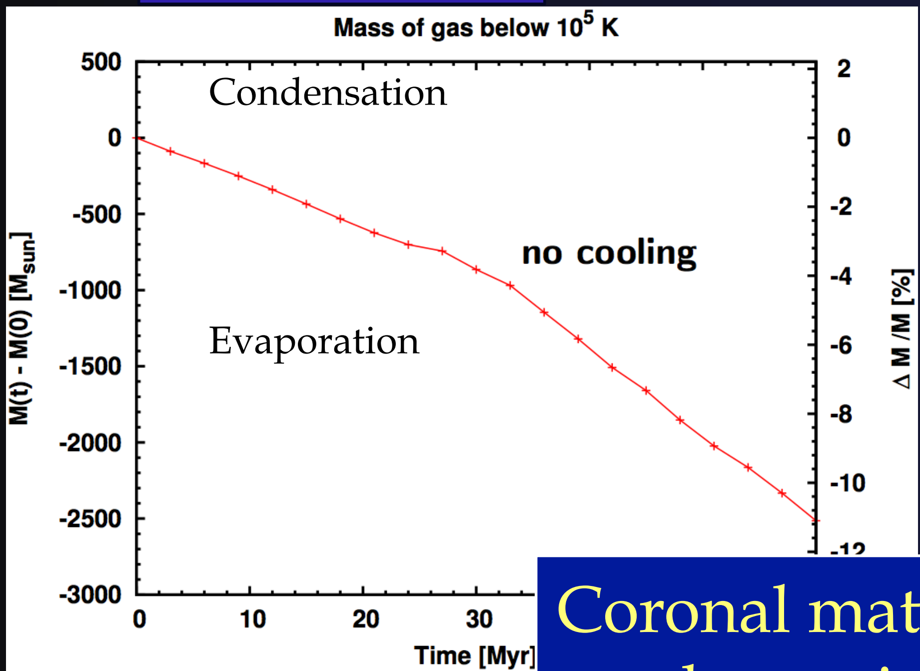
Without cooling



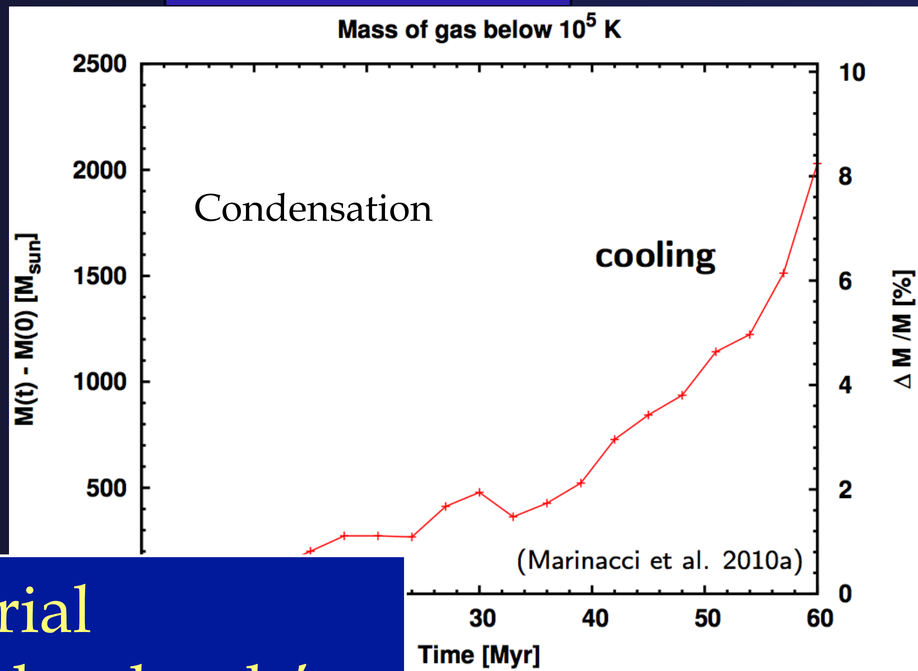
With cooling



Mass of cold gas

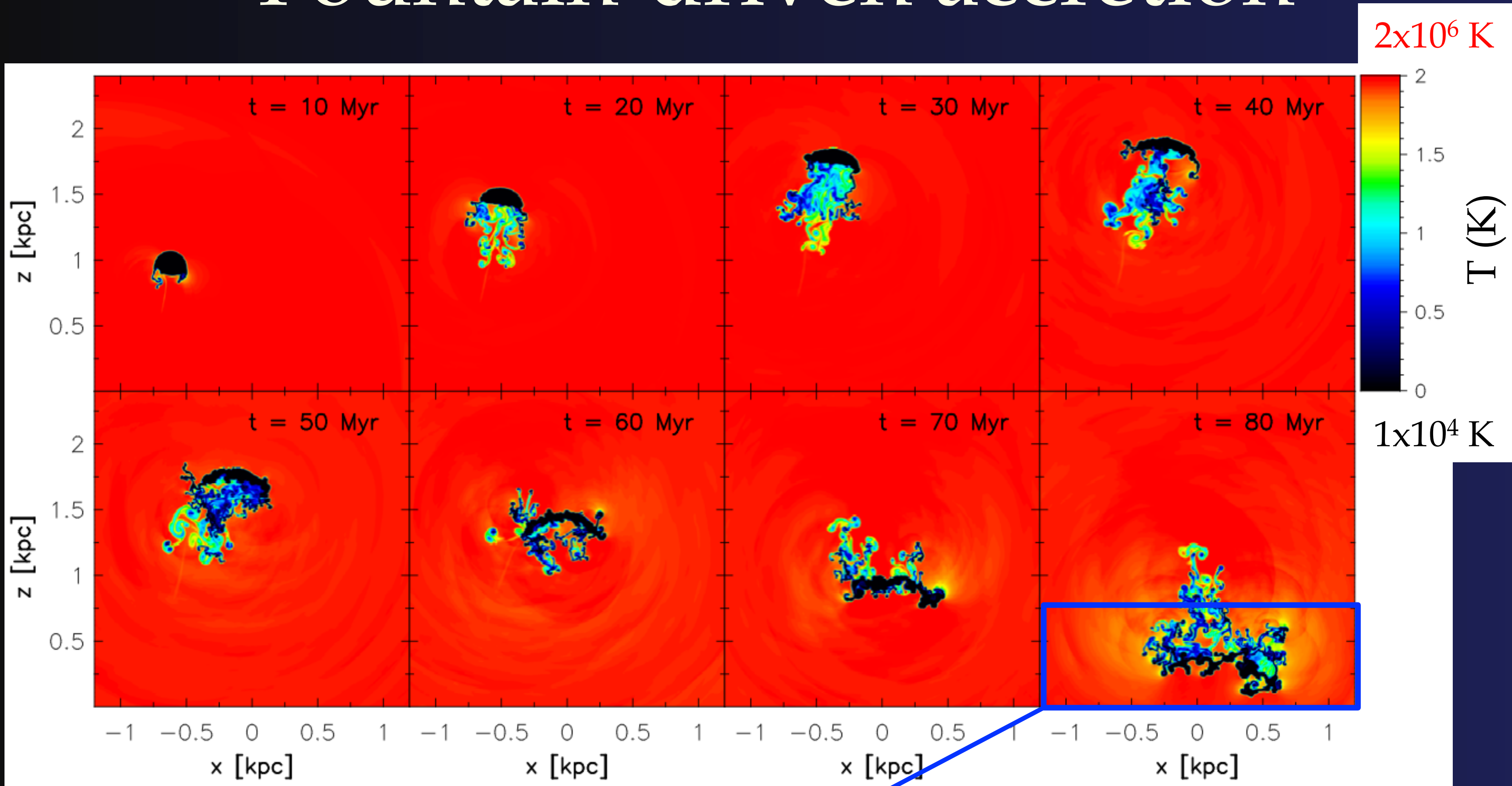


Mass of cold gas



Coronal material condenses in the clouds' wakes

Fountain-driven accretion

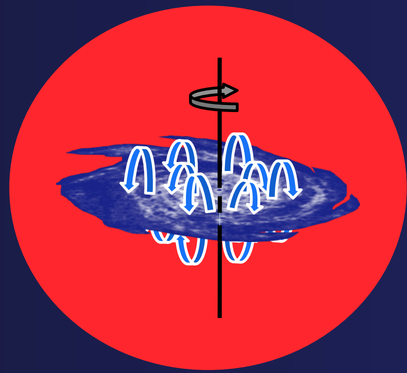


Marinacci, Fraternali et al., 2011, arXiv1110.3613

Mass of cold gas increased by ~20%

Modelling the whole disc

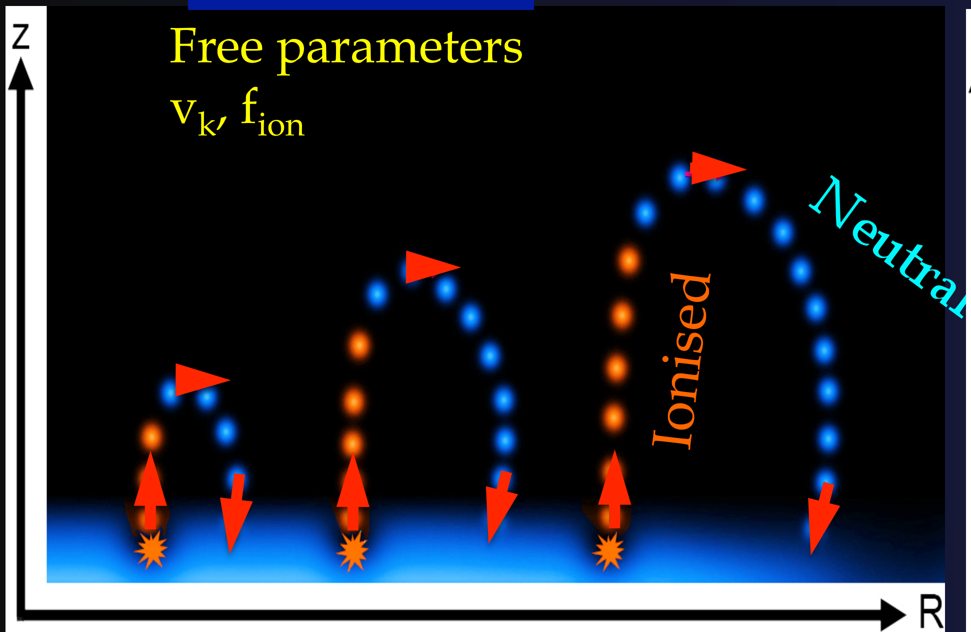
Global fountain model



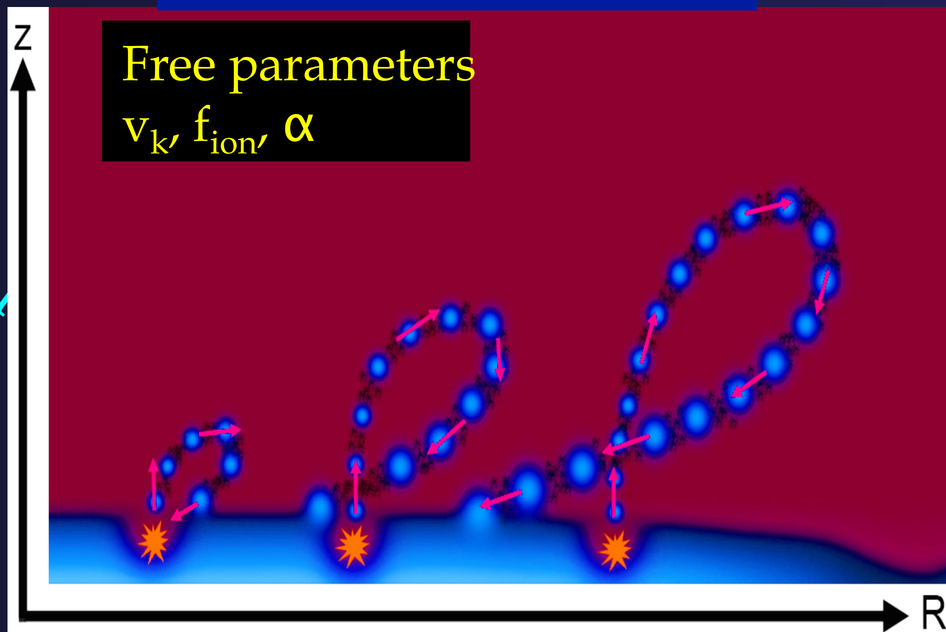
- Neutral and ionised gas (f_{ion})
- Distribution of kick velocities (v_k)
- Accretion onto wakes as $\dot{m} = \alpha\, m$ (α)
- Corona lags with respect to cold gas by 75 km/s
- Building of several models -> model cubes -> minimization residuals

with LA

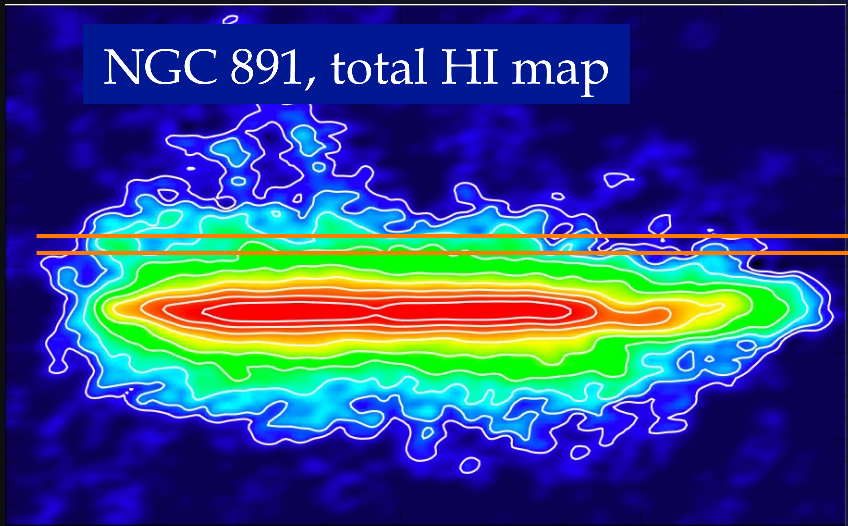
Pure fountain



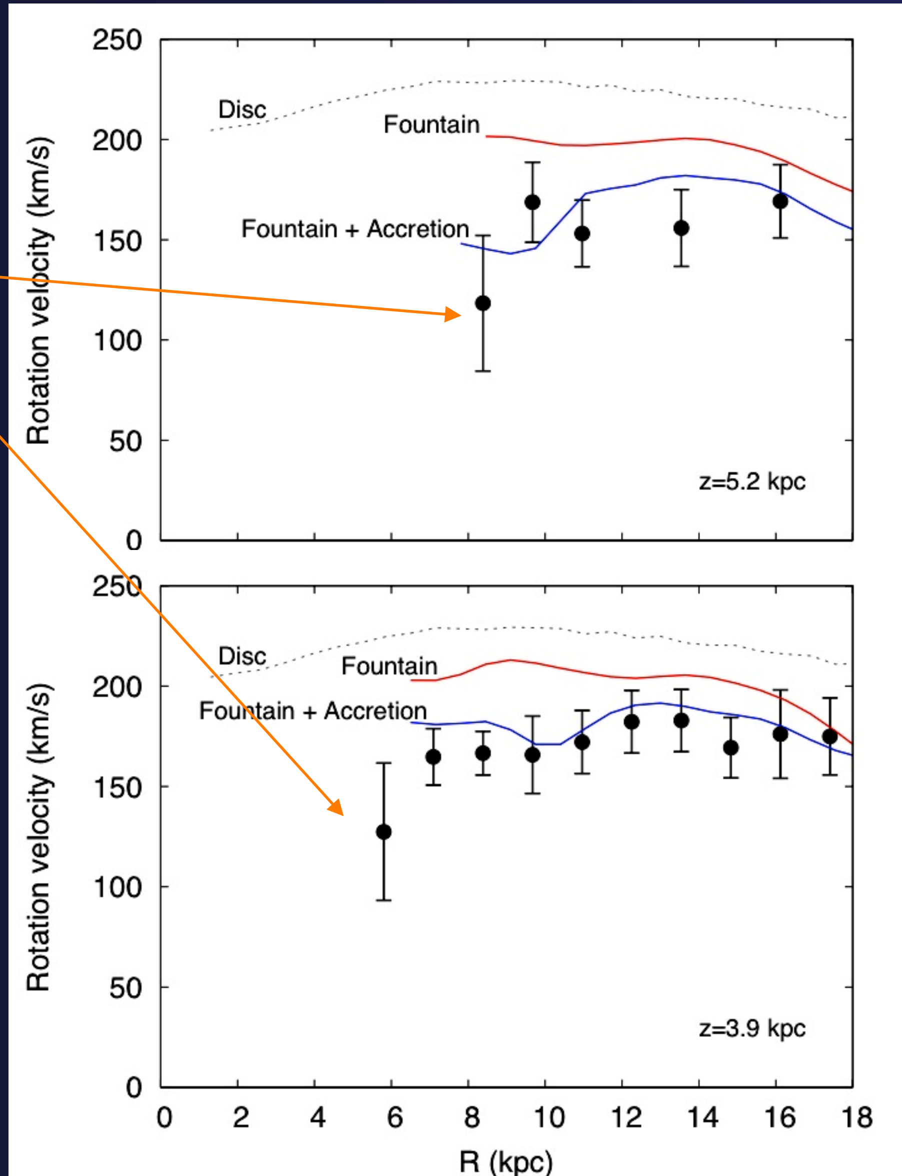
Fountain + condensation



Early model: application to NGC891



Fraternali & Binney 2008, MNRAS



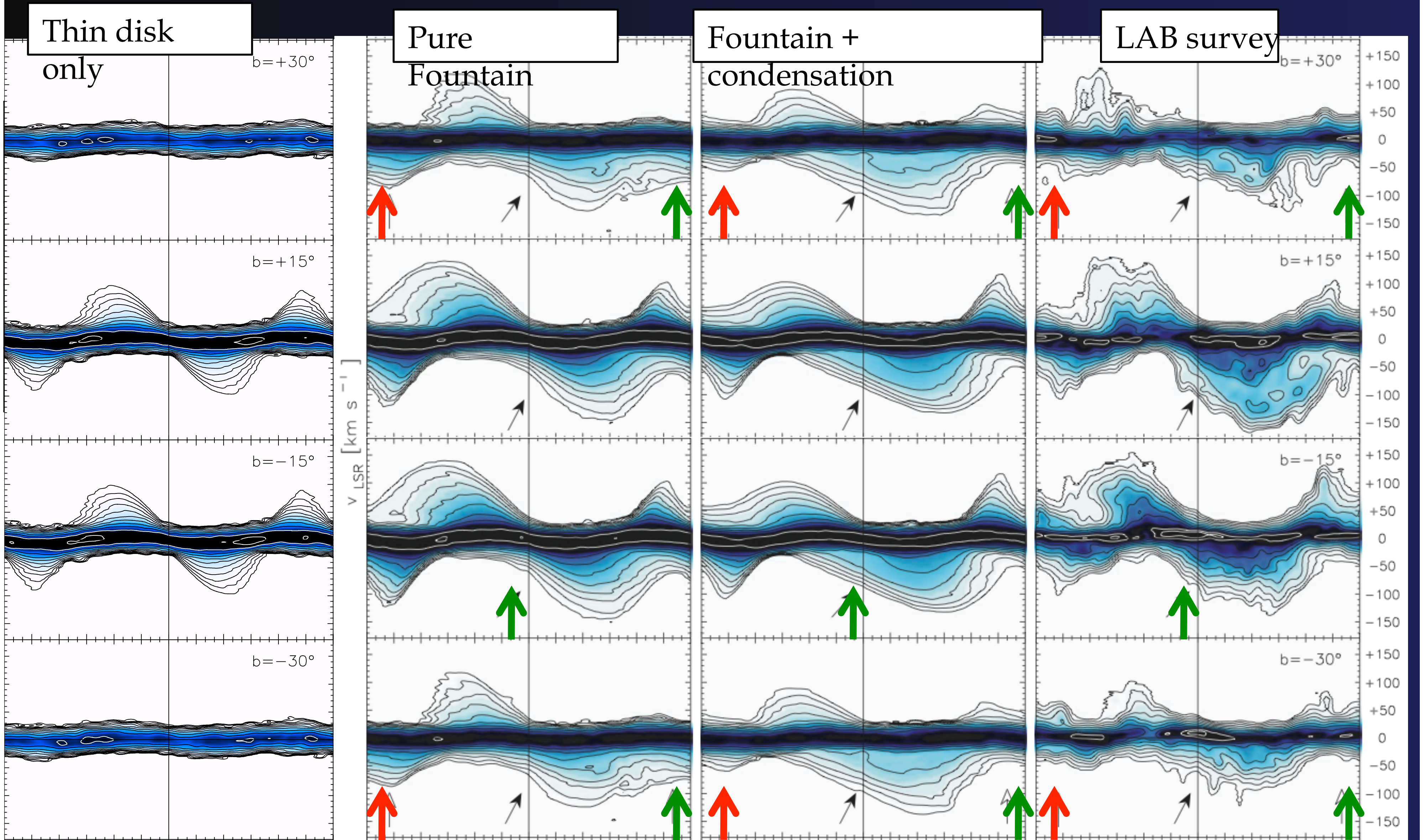
Best-fit Accretion Rate ~ 3 $M_{\odot} yr^{-1}$

Compare to SFR ~ 4 $M_{\odot} yr^{-1}$

Halo gas:
- ~90% from fountain
- ~10% accreted

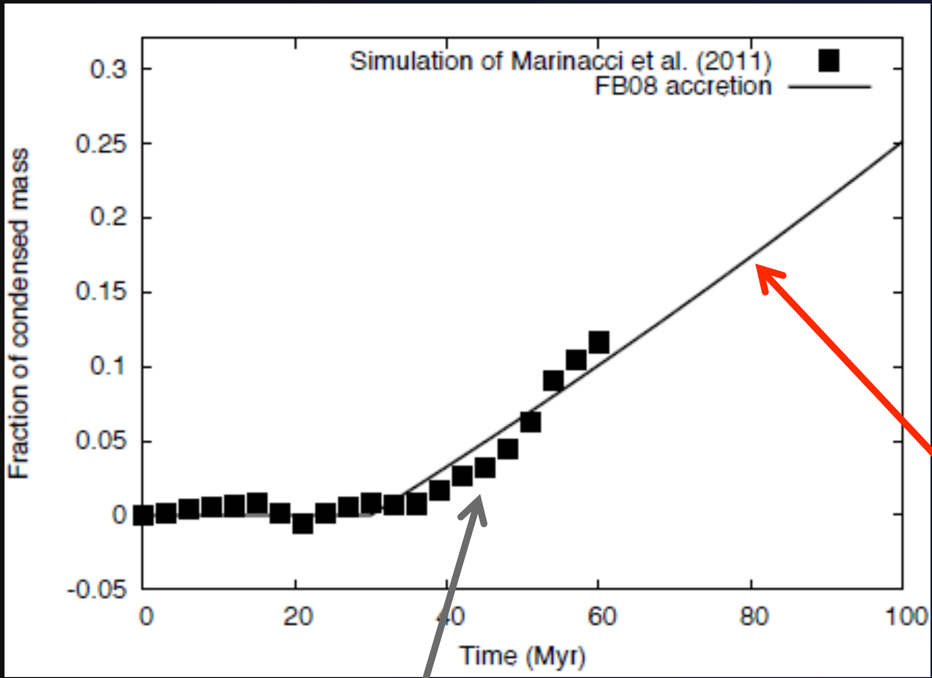
Application to the Milky Way

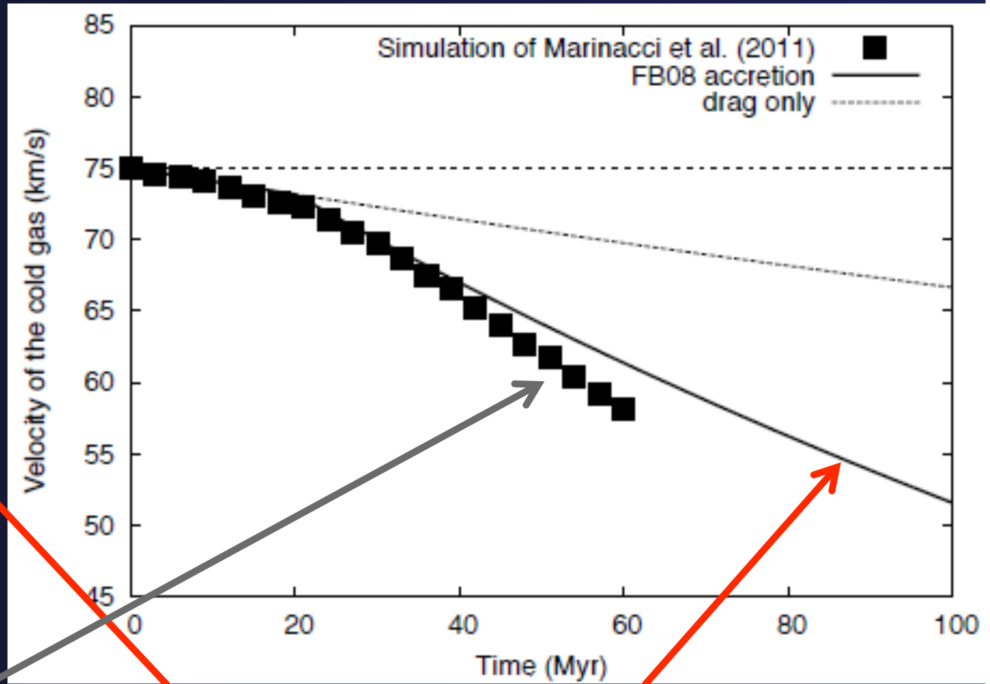
Best models



Marasco, Fraternali & Binney 2011, MNRAS

Agreement with hydro simulations

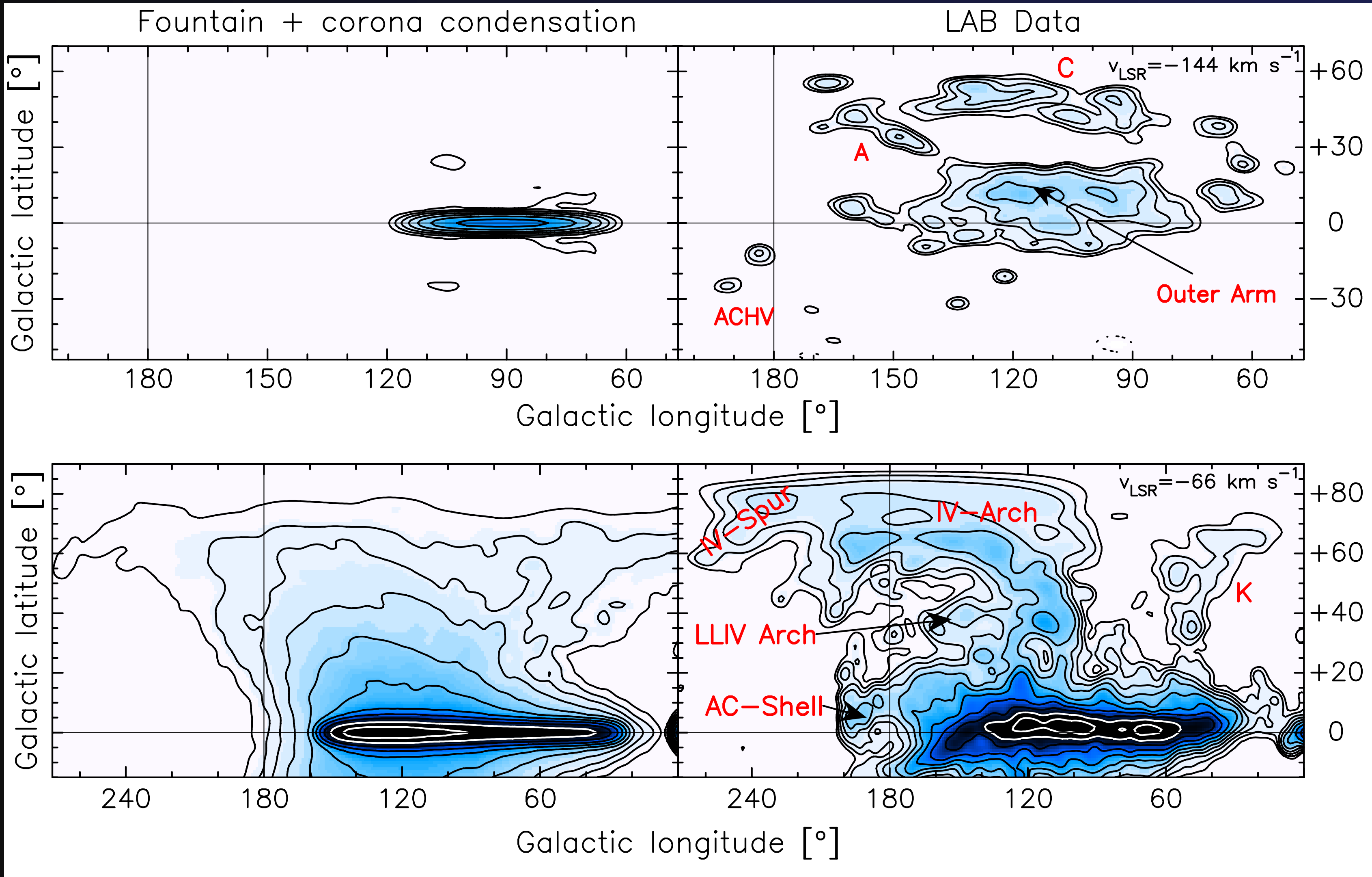




Hydrodynamical simulation of a single cloud

Parameter α from fitting the LAB survey over the whole galaxy

High and Intermediate velocity clouds



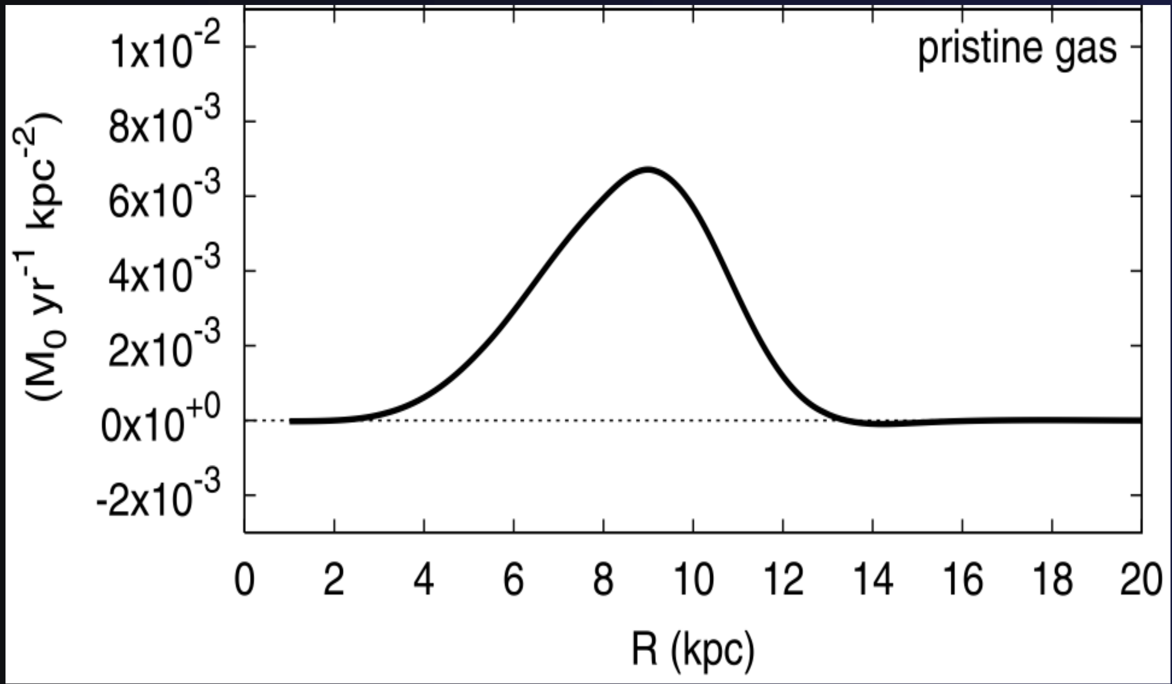
HVCs

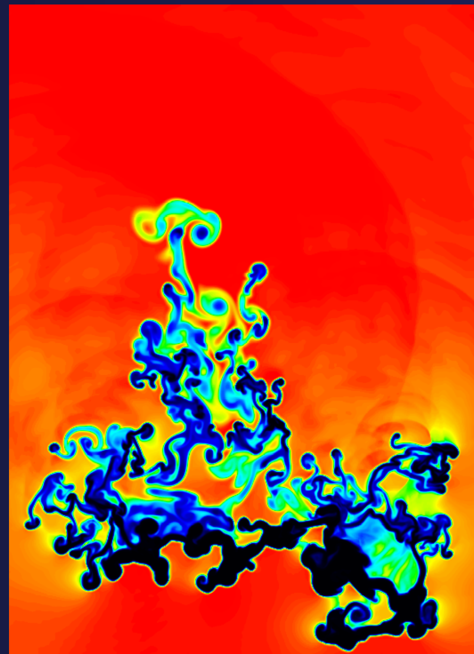
IVCs

Marasco, Fraternali & Binney 2011, MNRAS

Location of the gas accretion

Infall rate of coronal gas

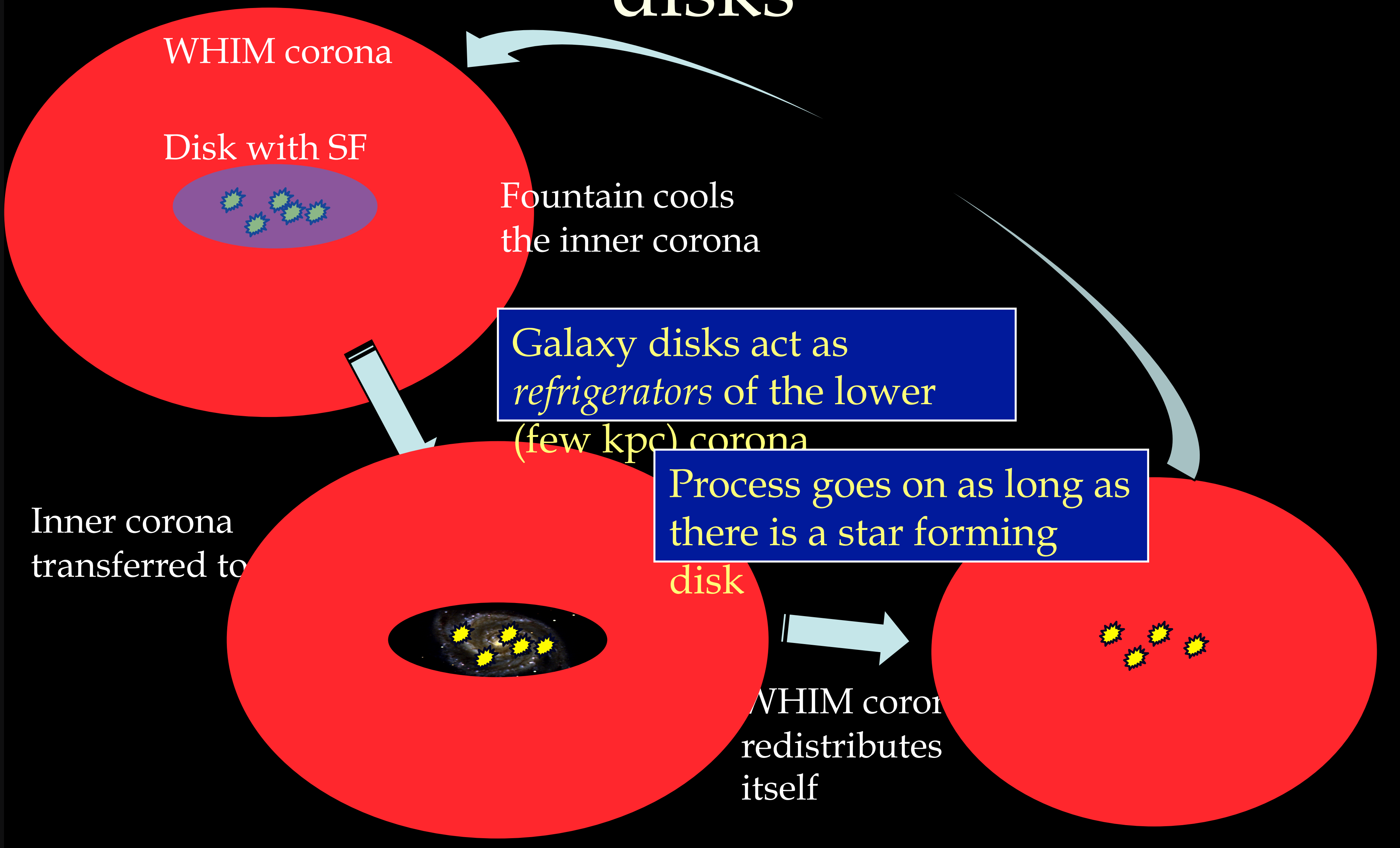




$$\dot{\mathrm{M}}_{\mathrm{acc}} \sim 2\,M_{\odot}\,\mathrm{yr}^{-1}$$

Marasco, Fraternali & Binney 2011, MNRAS

Progressive transfer of WHIM to disks



Conclusions

- Hot coronae interact strongly with the galactic fountain gas
  -> mass and momentum transfer

- Mechanism: *SF -> Galactic fountain ->*
  metals mix with the lower corona -> cooling
  -> more SF

- Excellent fit of HI data of the Milky Way $\dot{M}_{\rm acc} \sim 2\, M_\odot\, {\rm yr}^{-1}$

- Disc galaxies accrete gas from the WHIM coronae *because* they have a star forming disc