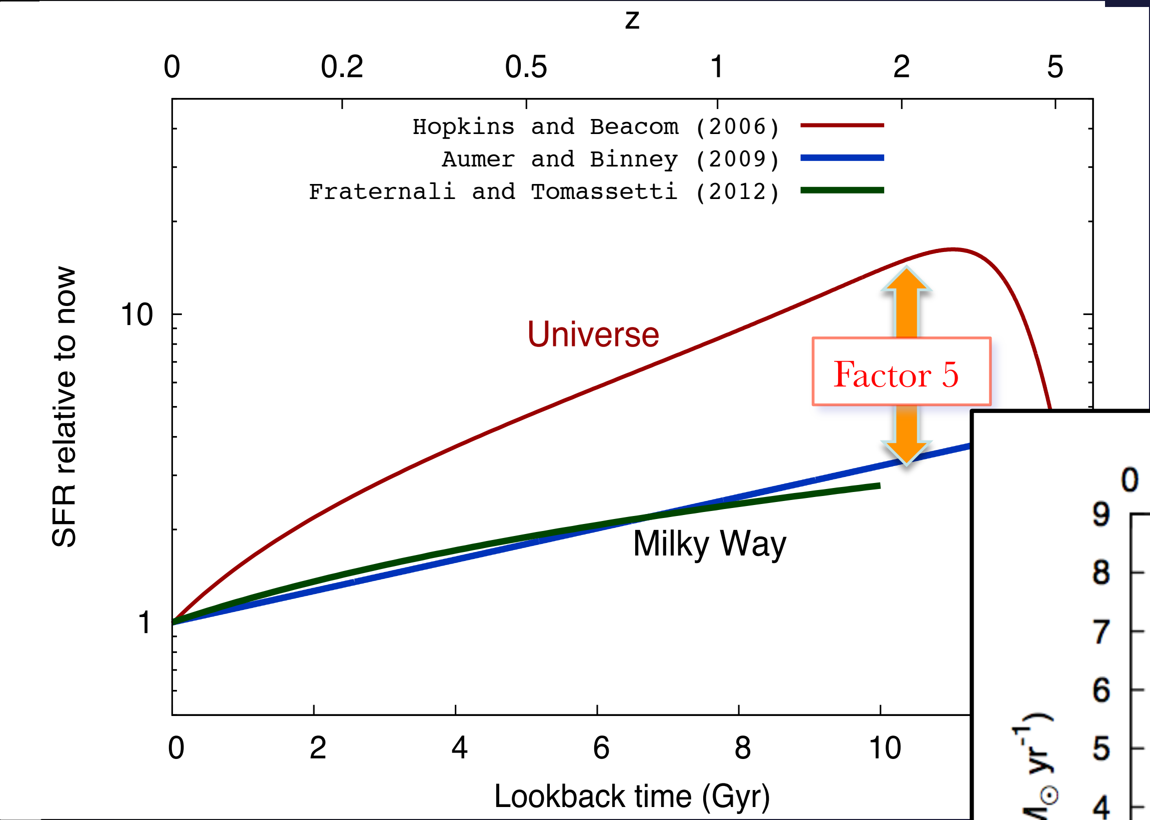
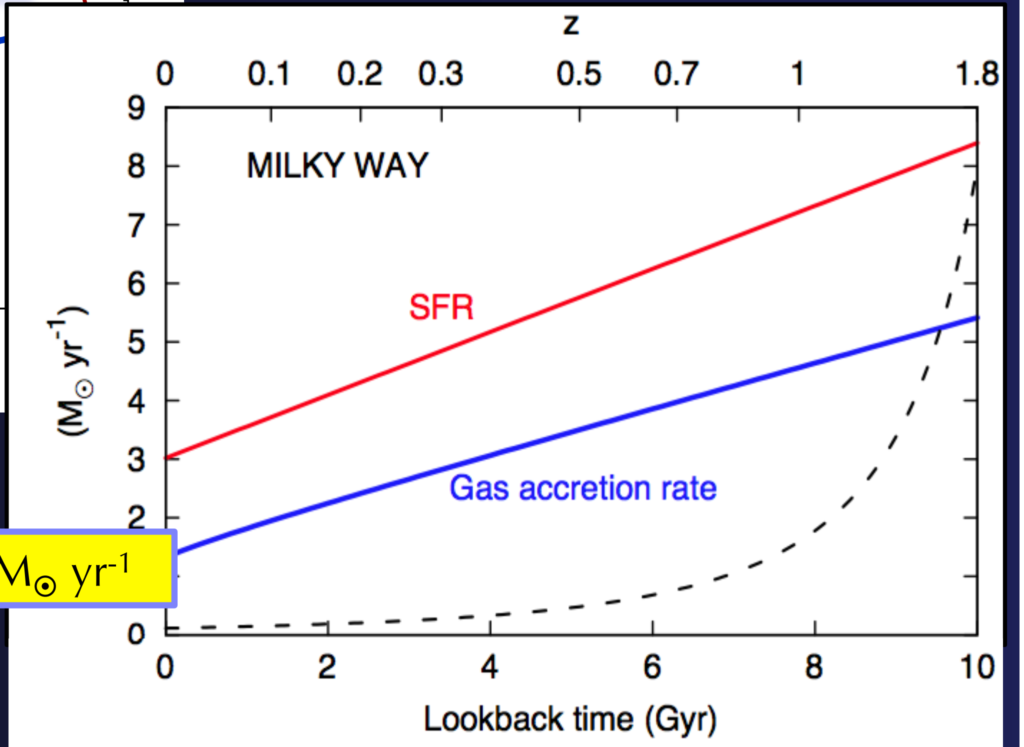
Disk-halo connection and gas accretion

Filippo Fraternali

Department of Physics and Astronomy, University of Bologna, I
Kapteyn Astronomical Institute, University of Groningen, NL

SFH Universe vs Milky Way





Short gas consumption time-scale
~2 Gyr for every galaxy *(Bigiel+ 2012)*

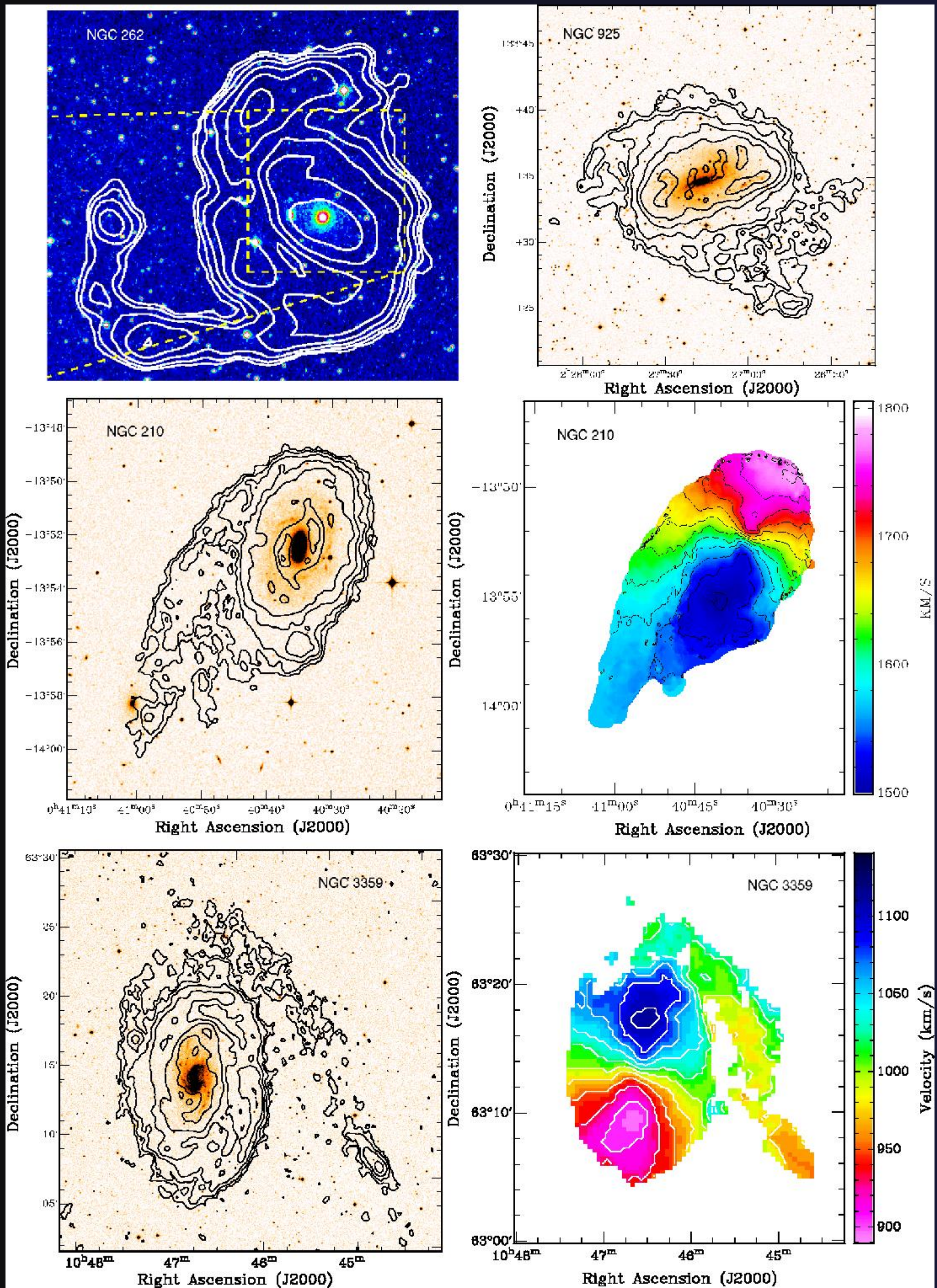
~1 $M_\odot$ yr^{-1}

Fraternali & Tomassetti 2012, MNRAS

Cold gas accretion

Minor mergers

Accretion from minor mergers



Sancisi, Fraternali, Oosterloo, van der Hulst 2008, A&ARv

Using the WHISP catalogue

Disturbances detected in ~25% of galaxies

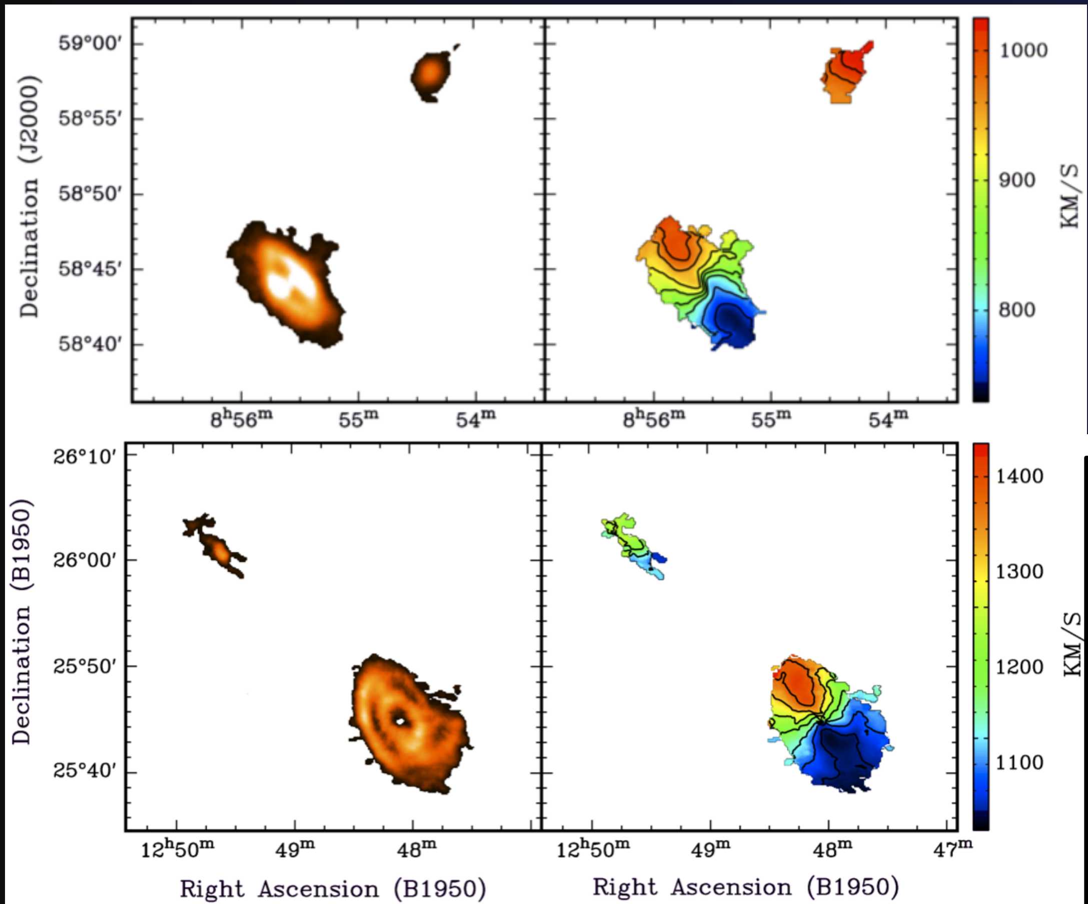
IF
masses ~ 1-10 x 10^8 $M_{\odot}$
life times ~ 1-2 dynamical times

➡ Global accretion rate ~ 0.1-0.2 $M_{\odot}$/yr

Galaxy pairs in HI

WHISP catalogue: ~150 datacubes

Algorithm identifies main galaxies & satellites

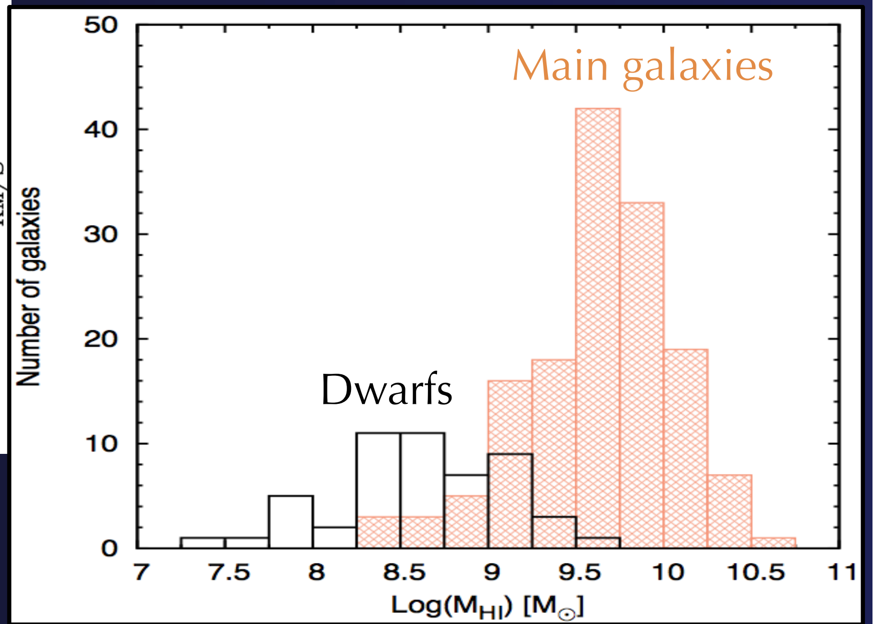


Di Teodoro & Fraternali, A&A, submitted

21% have dwarf companions

47 dwarfs: 40 already known, 7 new

All with optical counterparts

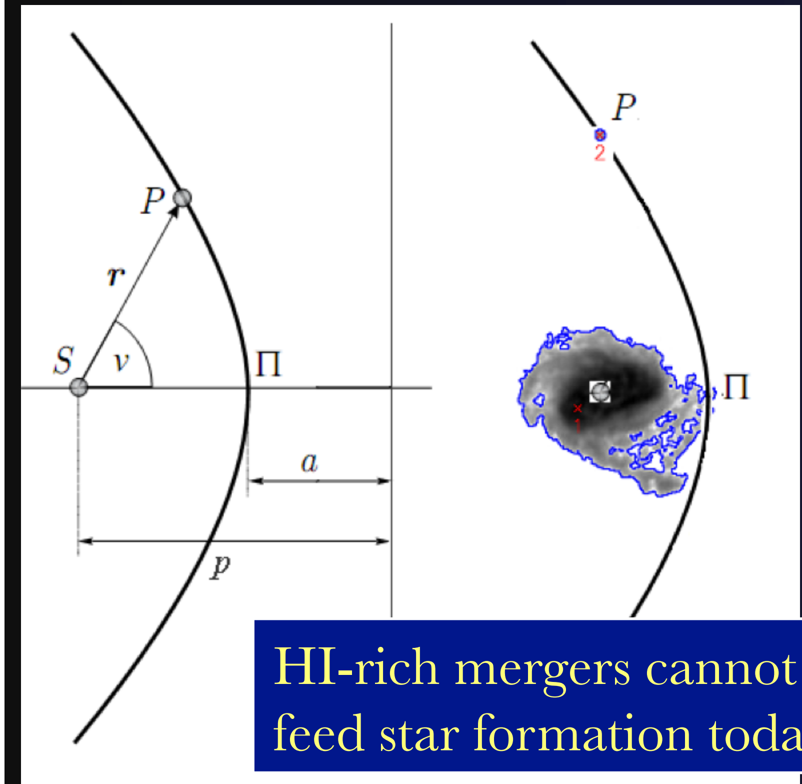


Accretion from minor mergers (revisited)

Very conservative assumption:
all satellites merge in the shortest time possible

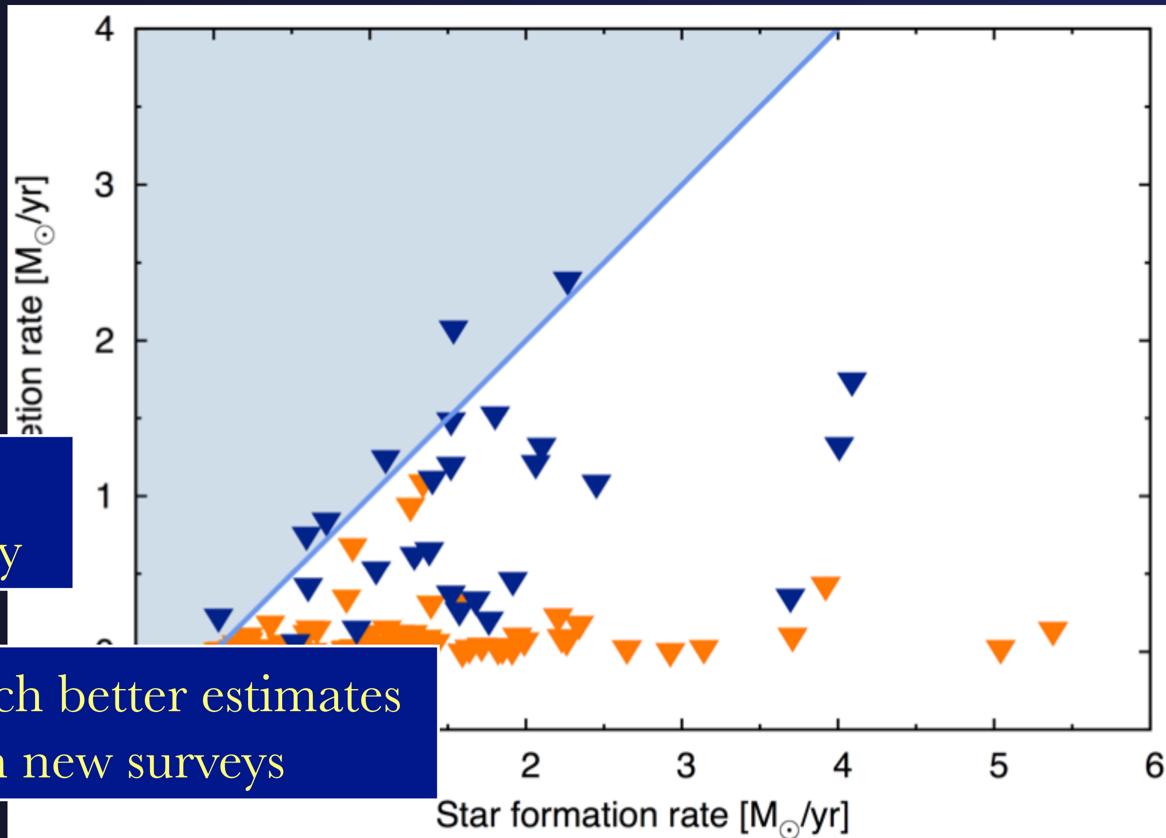
→ Upper limit to accretion
$<< 0.23\ M_\odot/yr$

Compare to average SFR = $1.35\ M_\odot/yr$



HI-rich mergers cannot feed star formation today

$$\dot{M}_{\rm acc} < M_{\rm HI}/t_{\rm min}$$



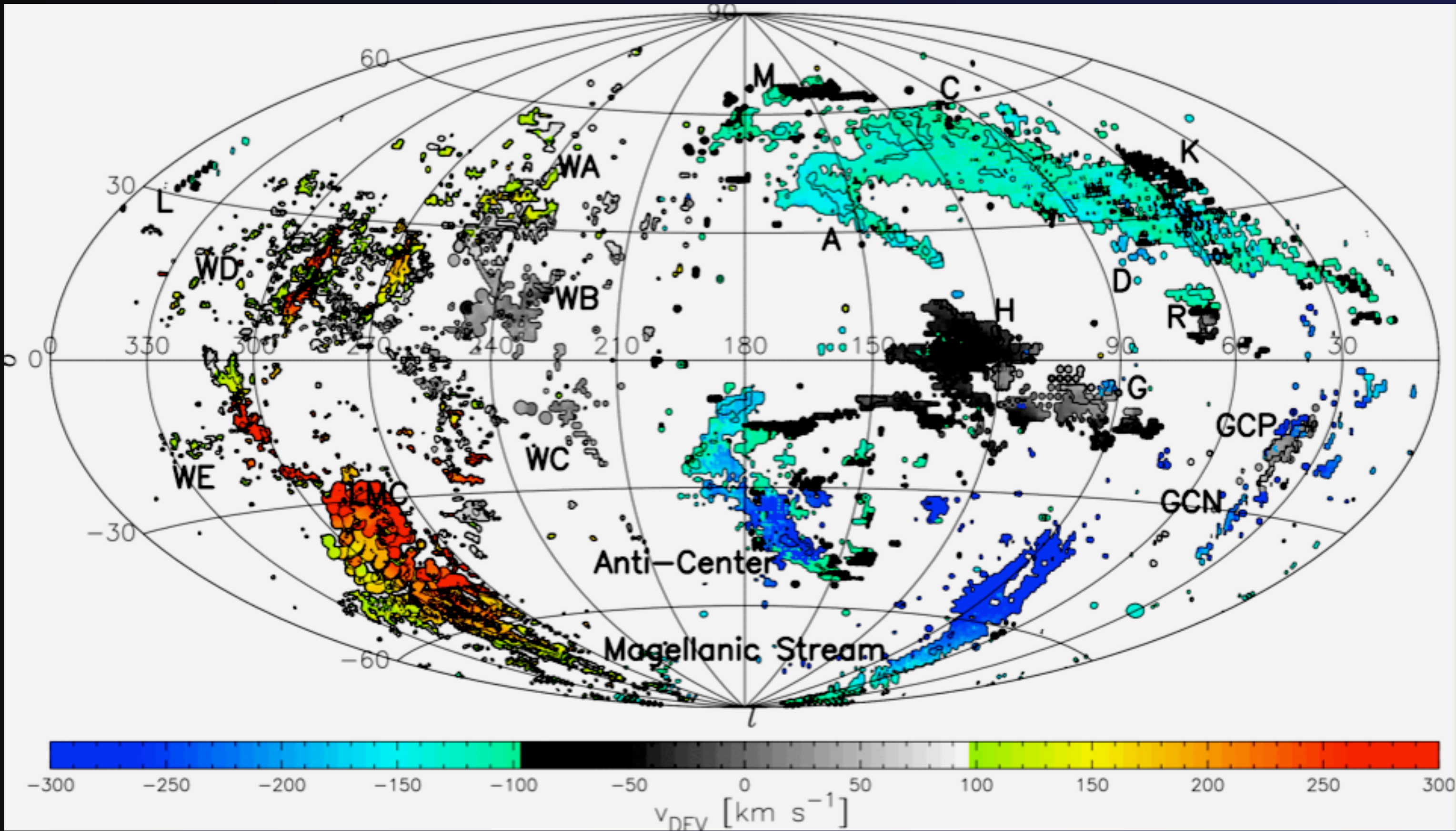
Much better estimates with new surveys

Di Teodoro & Fraternali, A&A, submitted

Cold gas accretion

HI clouds

HI High Velocity Clouds



Wakker et al. 2007, 2008; Tripp et al. 2003

Typical Distances: ~10 kpc

h~few-10 kpc

Z~0.1-0.4 $Z_\odot$

M<10^7 $M_\odot$

Accretion from High Velocity Clouds

→ ~ 0.08 $M_\odot$/yr   Includes He and factor 2 of ionised gas!

HI HVCs cannot feed SF

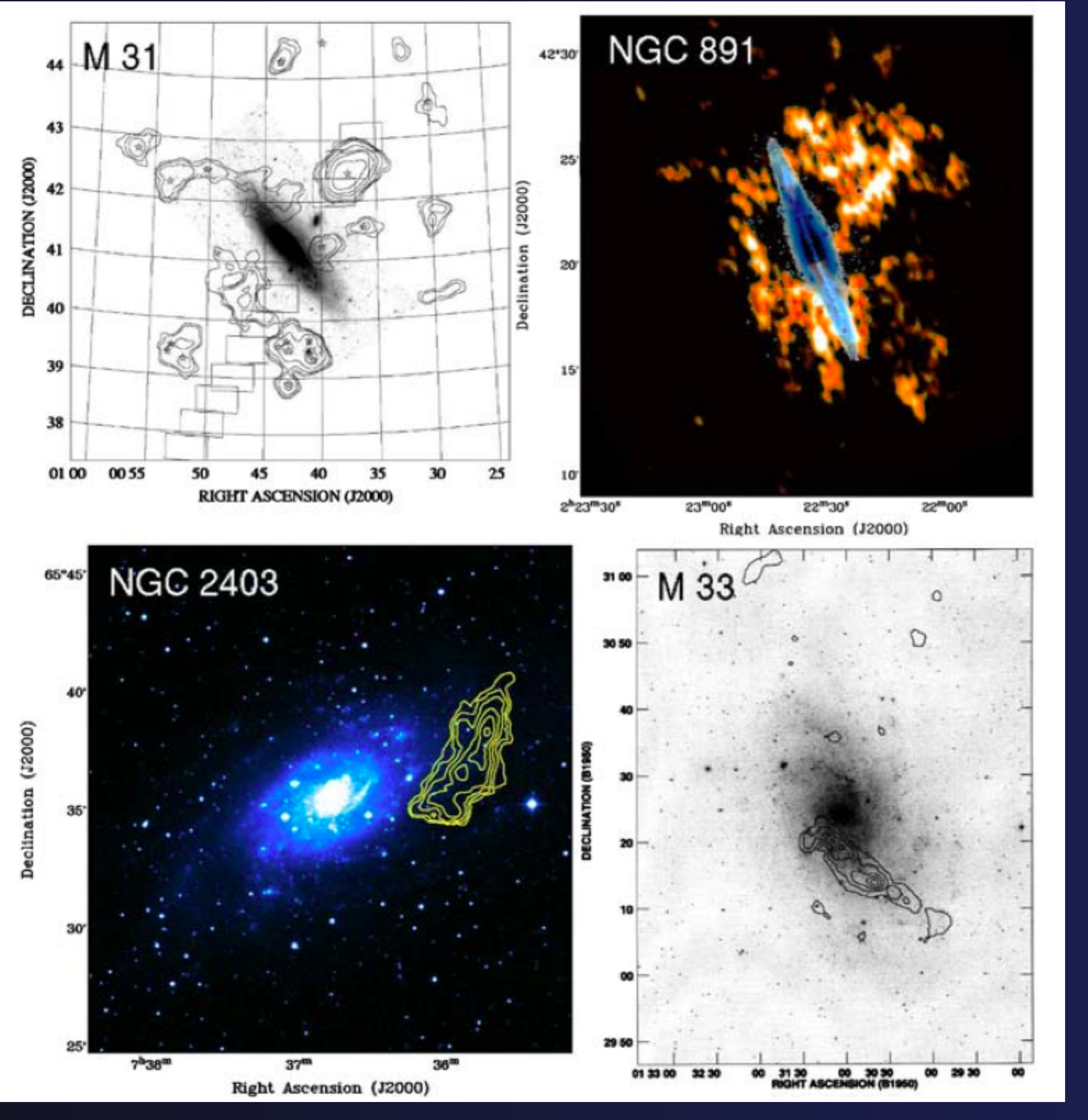
Putman, Peek, Joung 2012, ARA&A

HVCs around galaxies

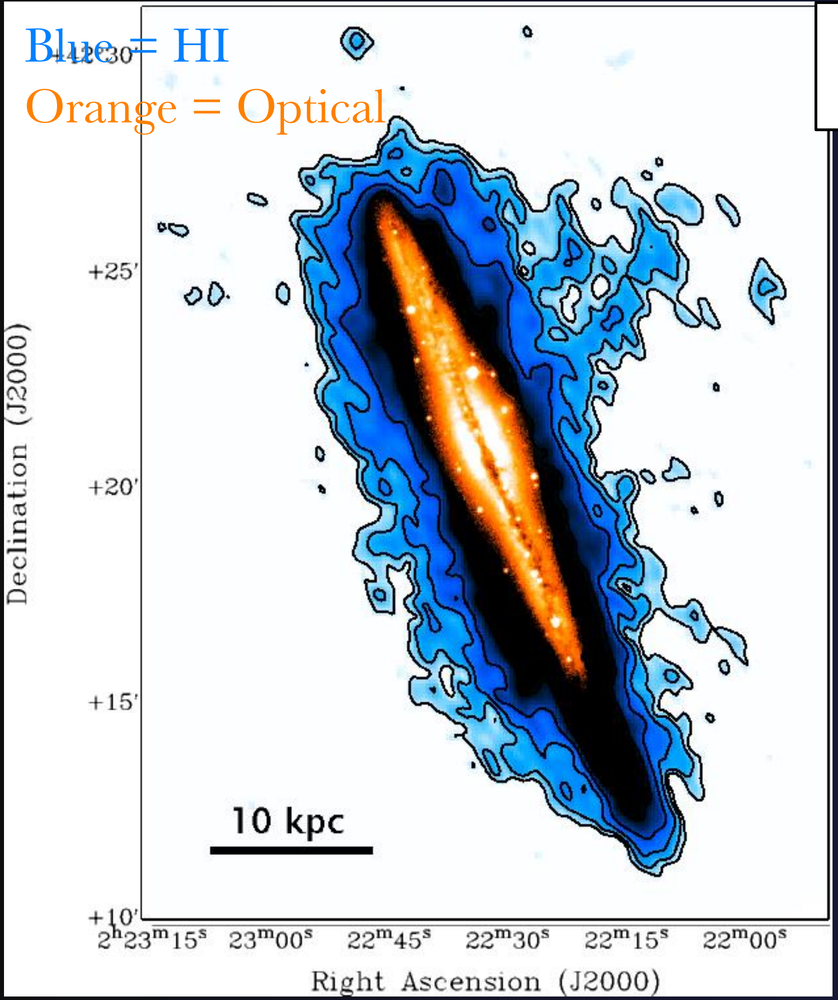
Thilker+ 2004

Fraternali+ 2002

Sancisi+ 2008, A&ARv

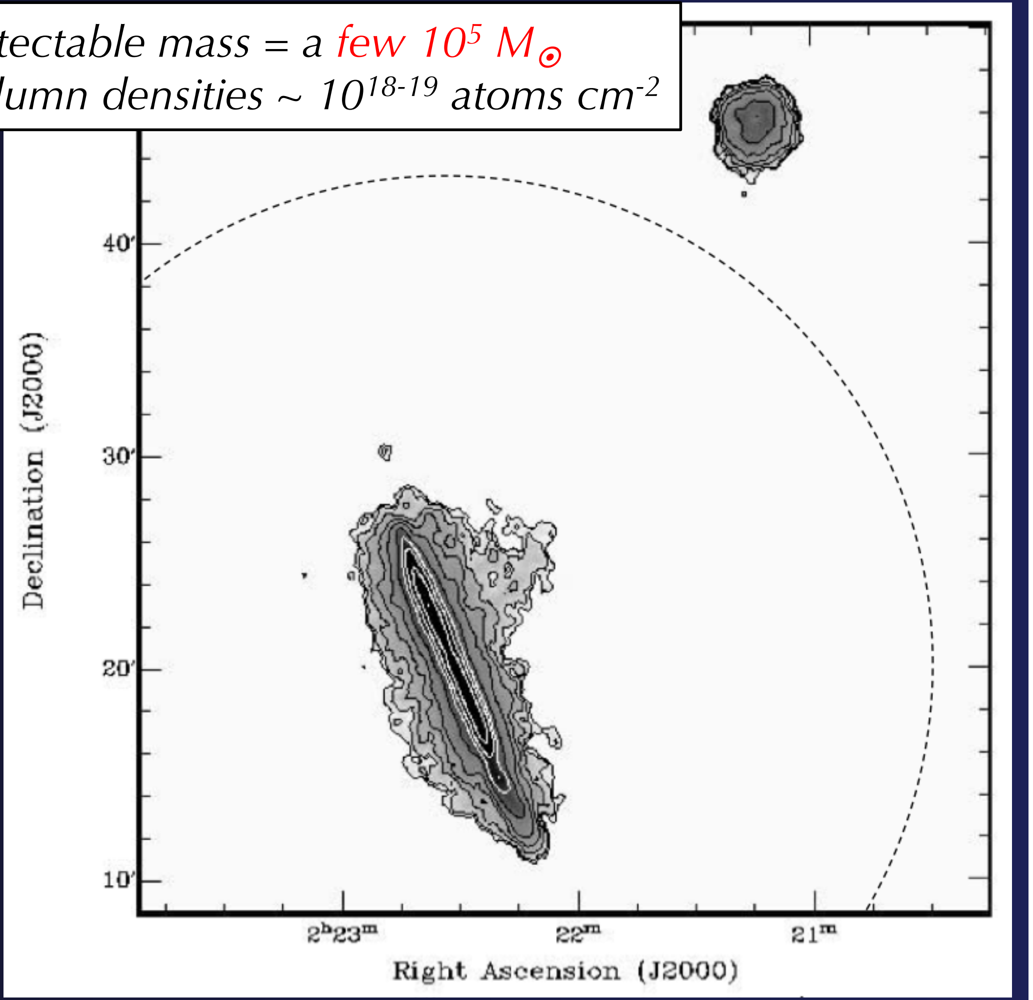


NGC 891: where is the accretion?



Oosterloo, Fraternali, Sancisi 2007, AJ

Detectable mass = a few $10^5\ M_\odot$
Column densities ~ 10^{18-19} atoms cm^{-2}



Filament from flyby? (*Mapelli+ 2008*)

Galactic fountain kinematics (*Fraternali & Binney 2008*)

Z (HI) ~ $Z_\odot$ (*Bregman et al. 2013, ApJ*)

See also HALOGAS results

Floating HI clouds?

Observations of others groups

Pisano et al. 2004, Chynoweth et al. 2009 NO clouds of $M_{HI} > 10^6 M_\odot$

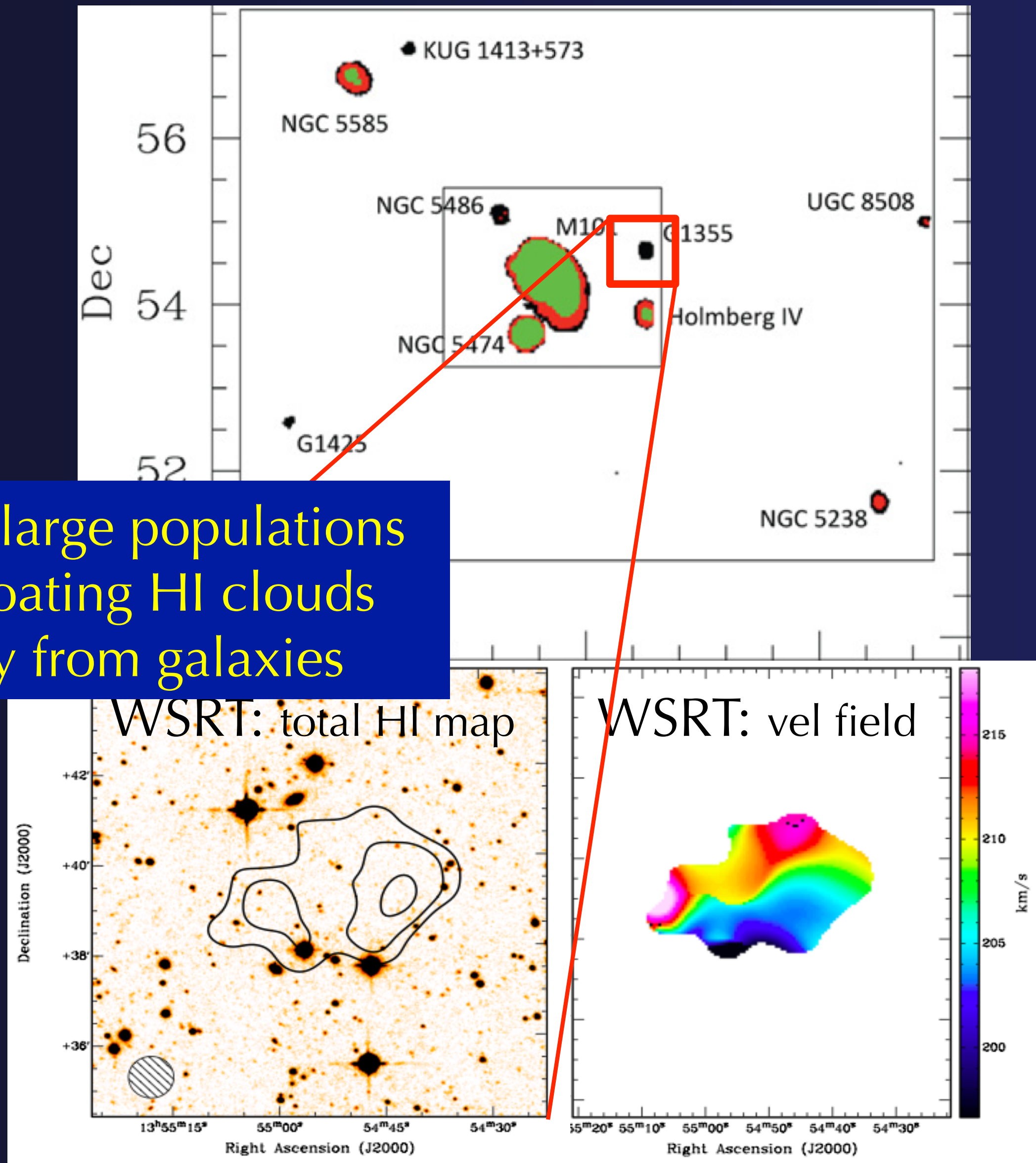
Large blind HI surveys

HIPASS - *Zwaan et al. 2005*
No *isolated* HI clouds

WSRT - *Kovac et al. 2009*
Small region
No clouds down to $10^6 M_\odot$

ALFALFA - *Haynes et al. 2011*
15000 detections
<2% of detections
without optical counterpart

Very deep GBT observations of M101
$N_{HI} \sim 10^{17}$ cm^{-2}



NO large populations of floating HI clouds away from galaxies

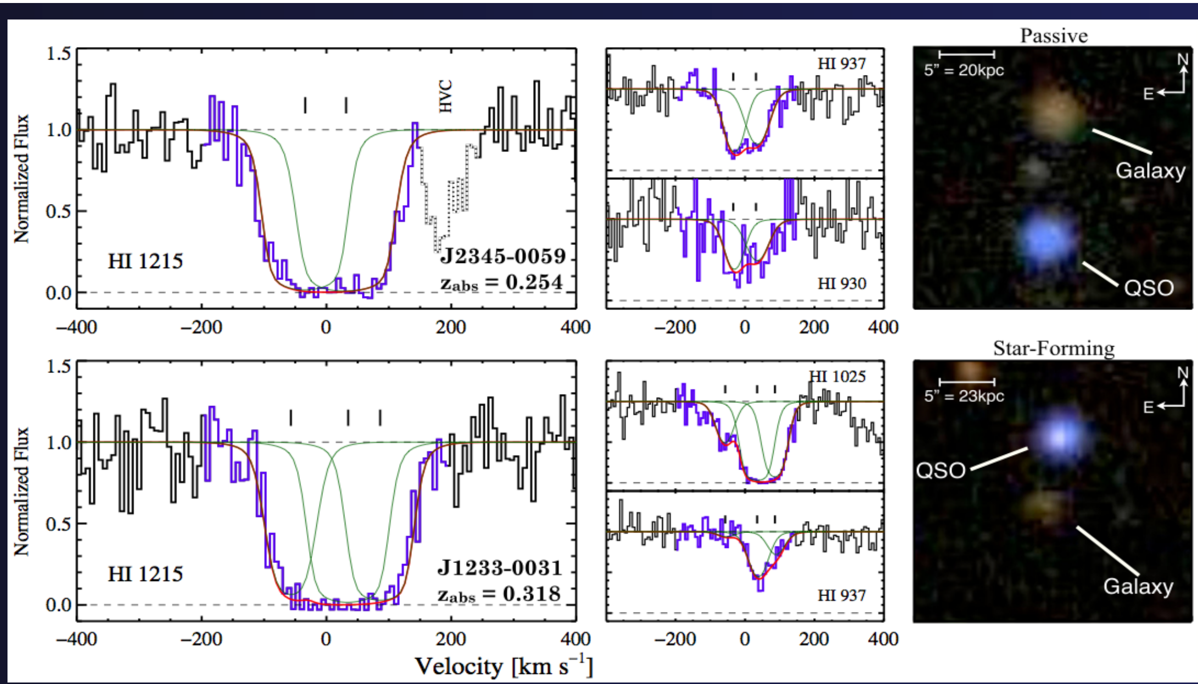
Oosterloo+ 2013, A&A-L

Circumgalactic gas
(low N)

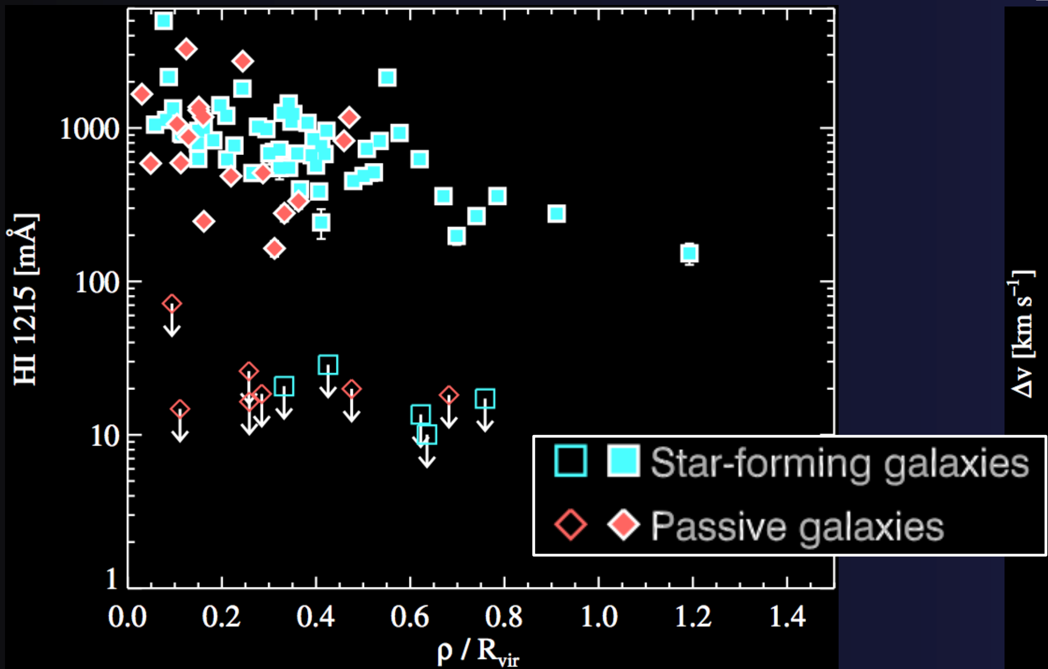
Lyα absorbers

HST/COS data

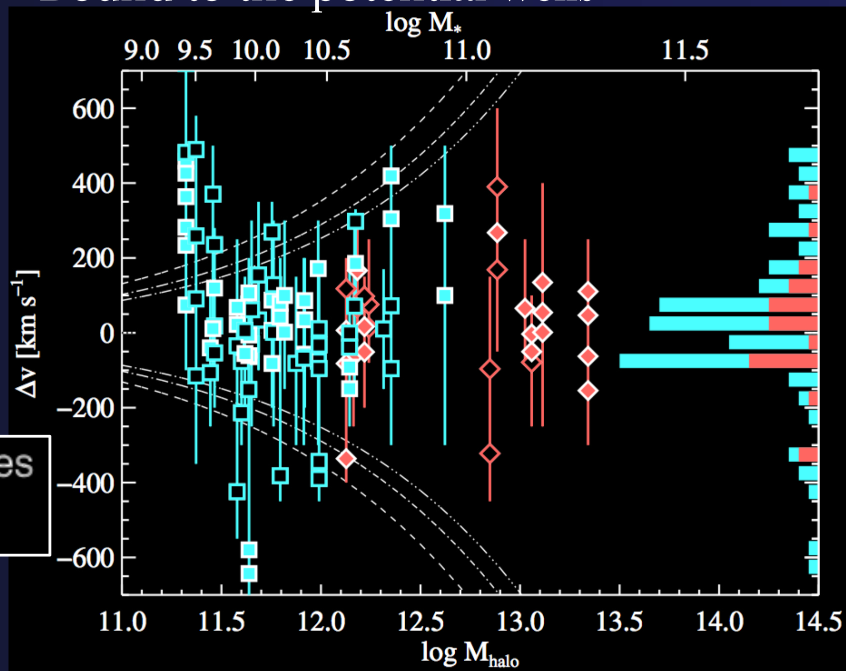
Thom+ 2012, ApJL



Impact parameters



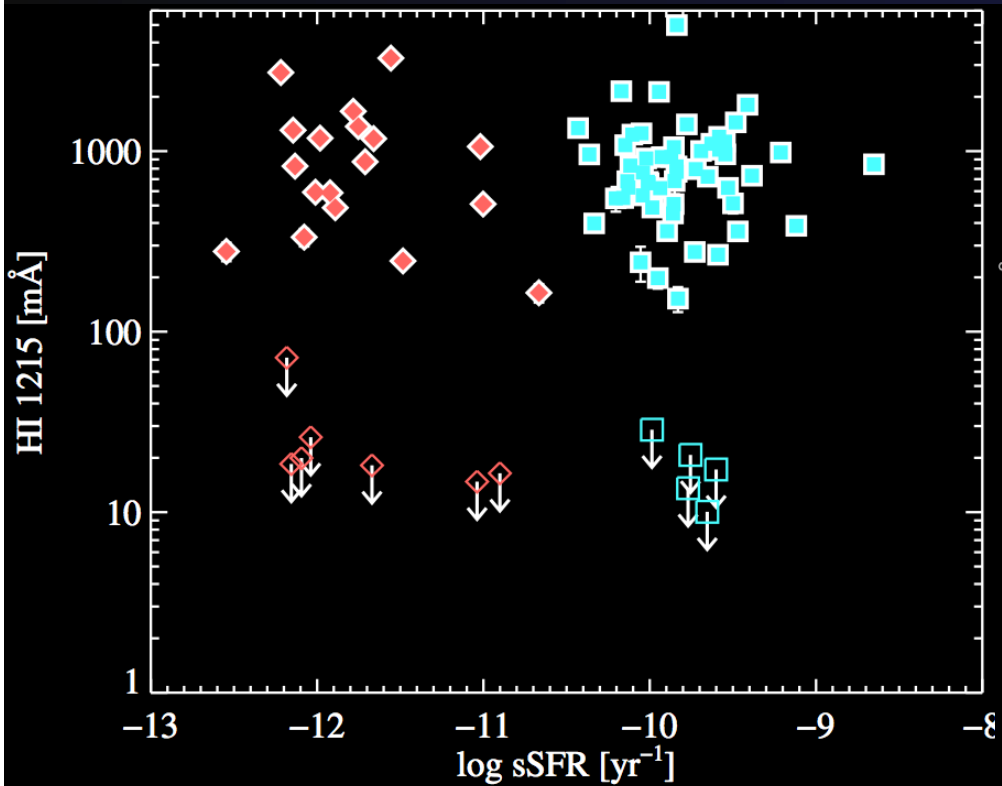
Bound to the potential wells



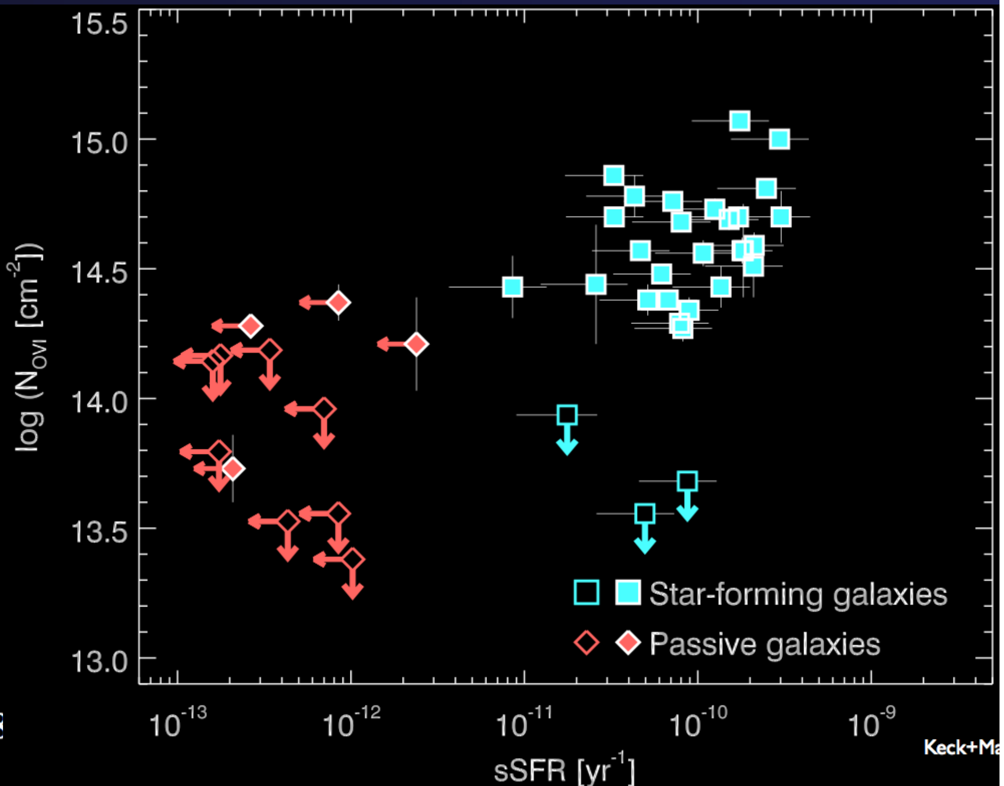
Early types vs star-forming

Cold gas (log(T)<5)

Hot gas (log(T)~5.5)



Thom+ 2012, ApJL

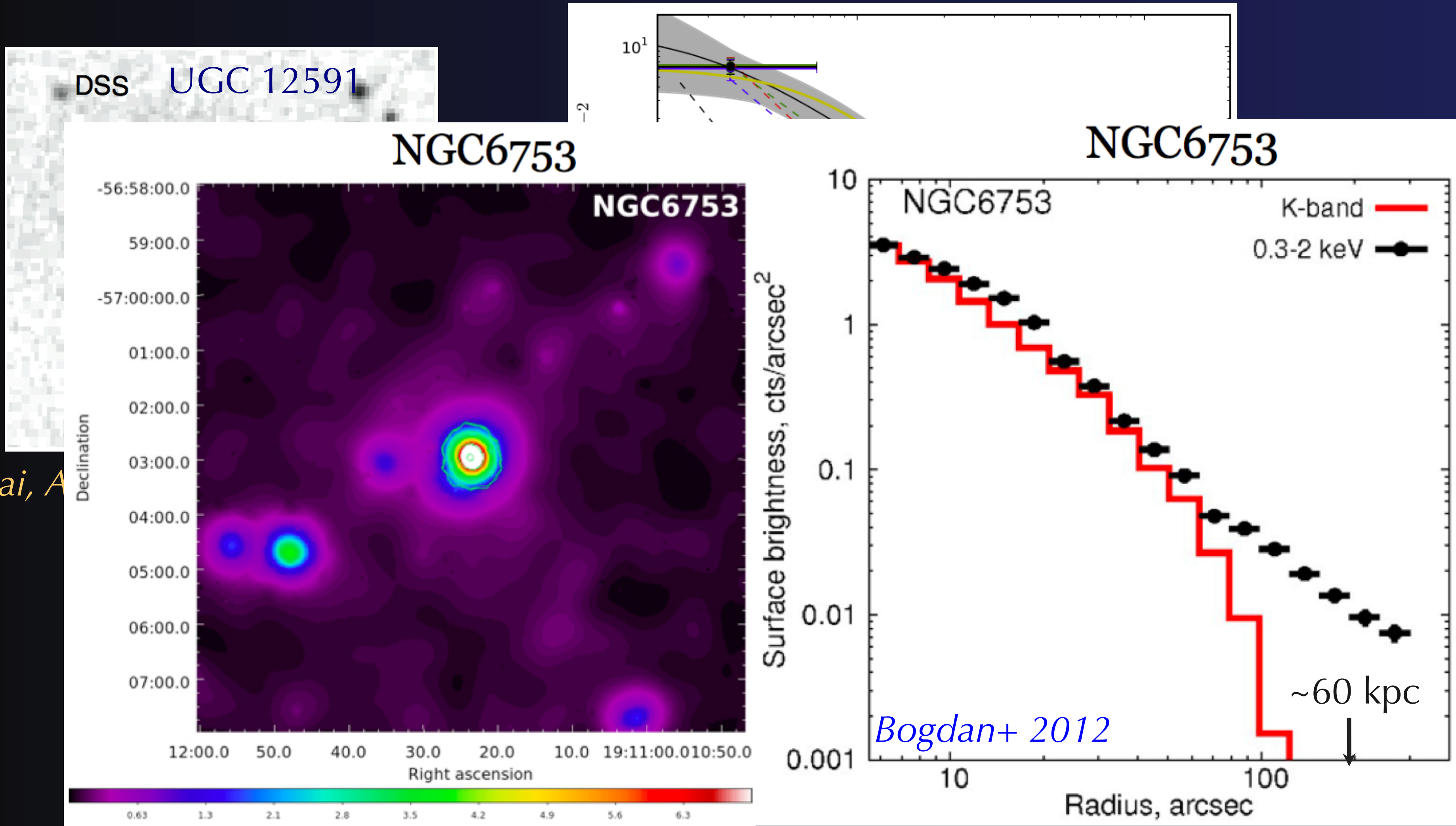


Tumlinson+ 2013

Werk+ 2013

Is this *cold* gas used for star formation?

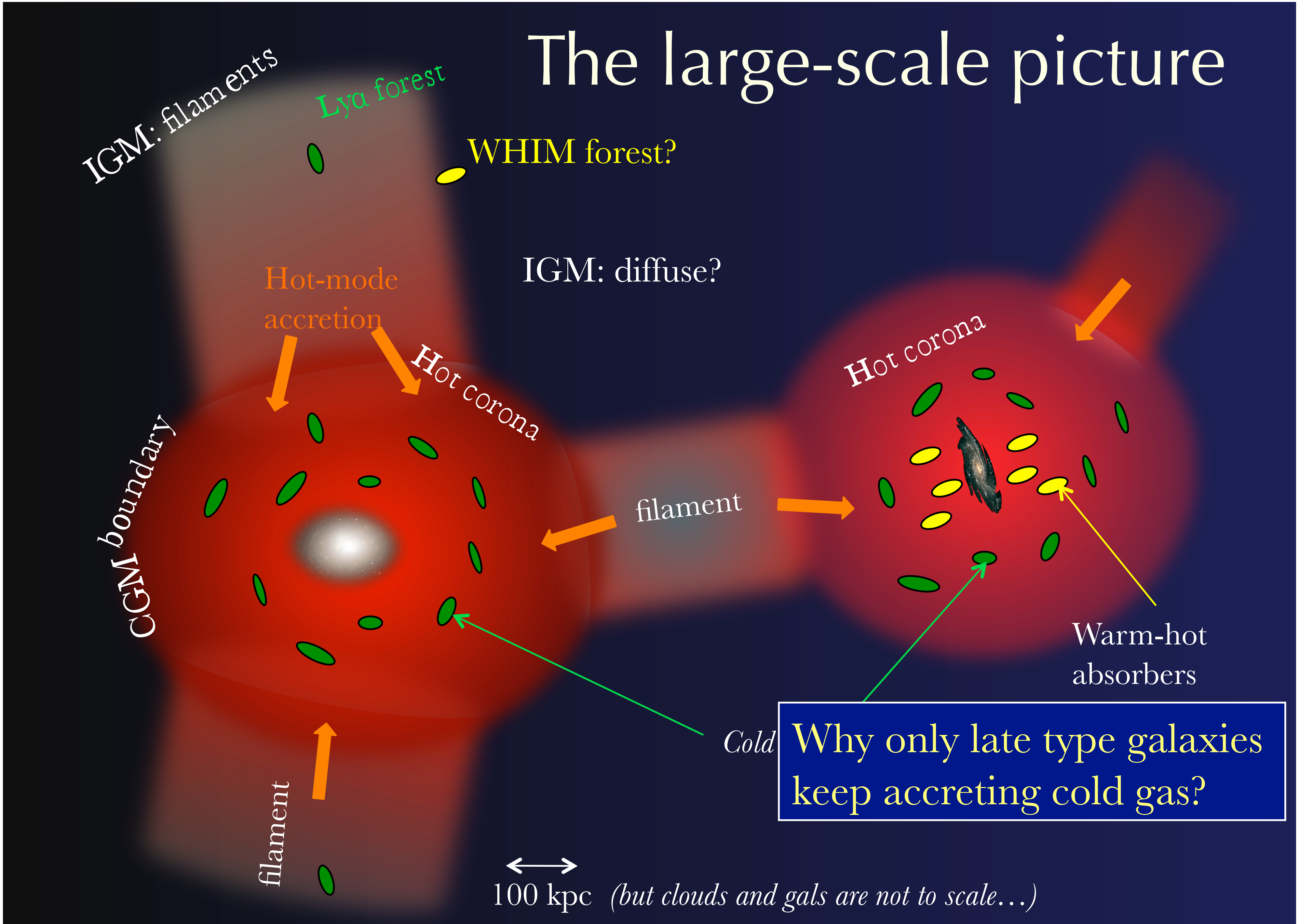
Hot coronae around disc galaxies



Stacking ROSAT *Anderson+ 2013*
Corona of the MW *Gatto+ 2013*

- Corona detected out to almost 100 kpc
- Mass ~ M_b of the discs

The large-scale picture



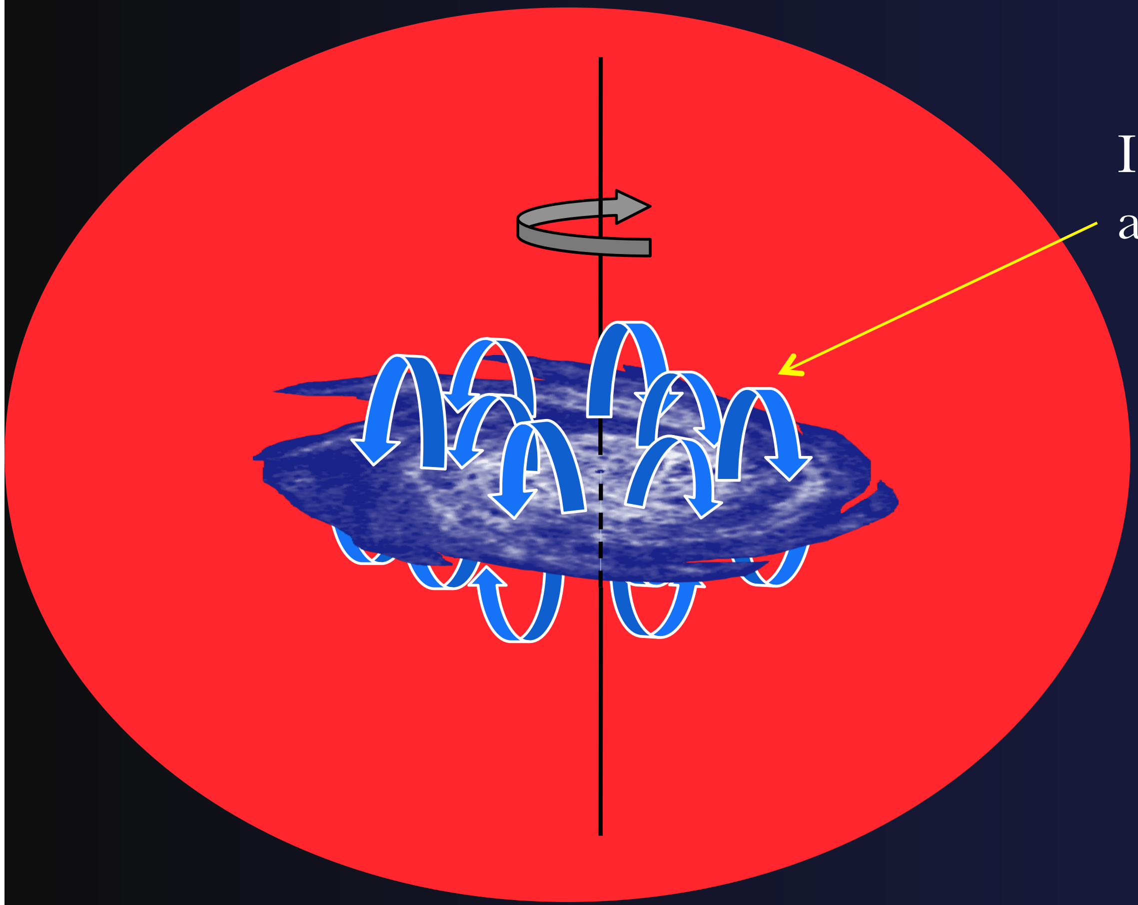
Why only late type galaxies keep accreting cold gas?

(but clouds and gals are not to scale…)

Supernova-driven gas accretion

(positive SN feedback)

Disc-corona interplay



Interface layer where disc and coronal materials mix

Cooling time of the corona (typically very long) decreases dramatically because it is mixed with:

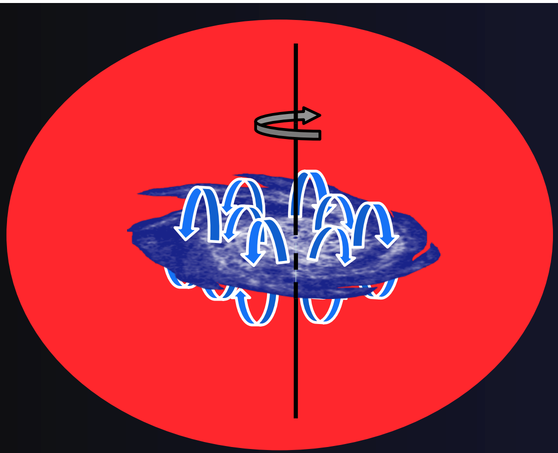
1. *cold* gas
2. High Z gas

Fraternali & Binney 2008, MNRAS

Marinacci, et al. 2010, 2011, MNRAS

Marasco, Fraternali & Binney 2012, MNRAS

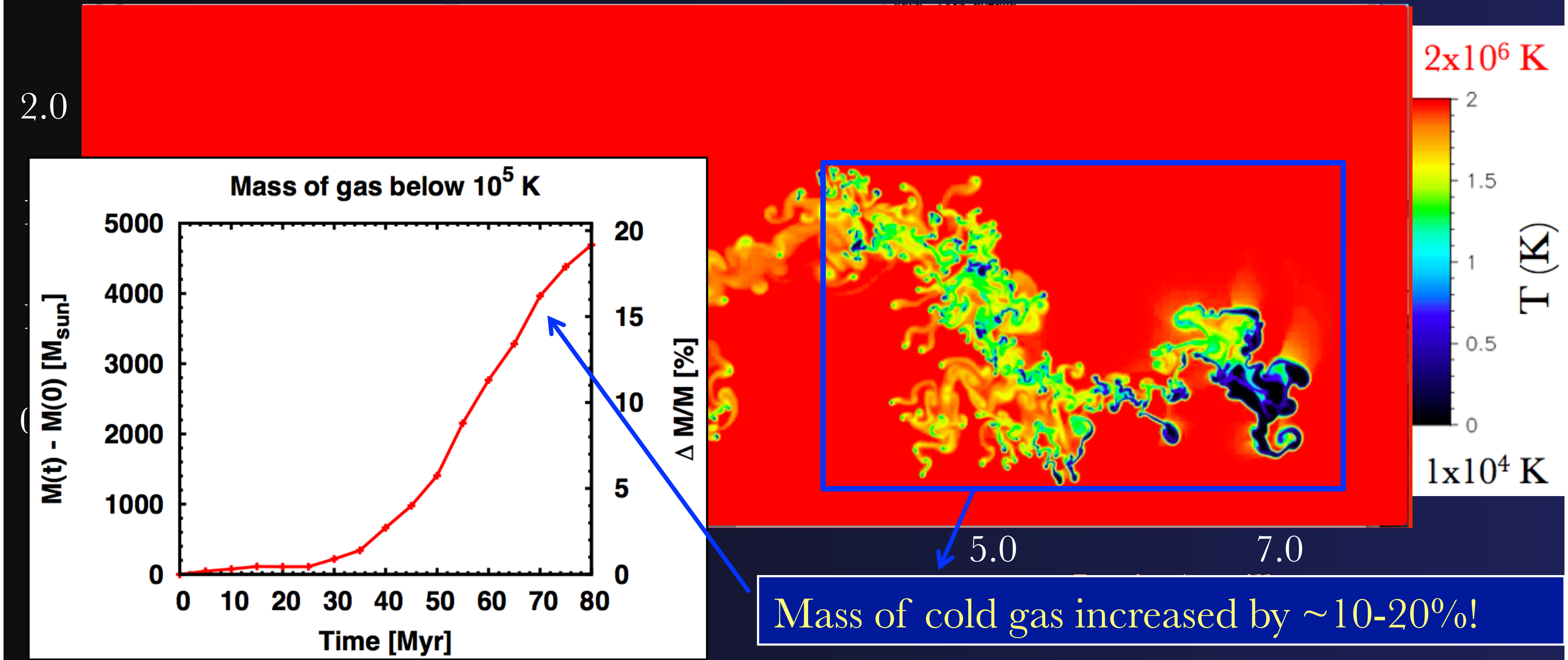
Disc-cloud corona interaction



T_{corona}=2x10^6 K Z_{corona}=0.1 $Z_\odot$

Z_{cloud}=1 $Z_\odot$

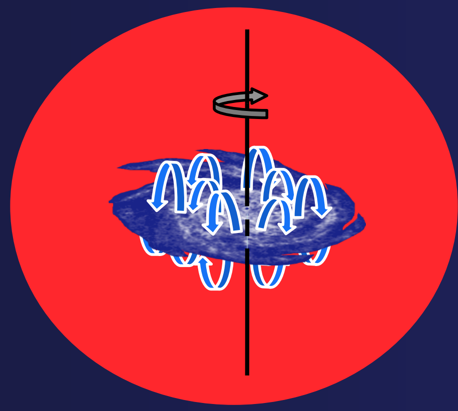
1 pc x 1 pc Grid!



Mass of cold gas increased by ~10-20%!

Marinacci, et al. 2010, 2011, MNRAS

Galactic fountain model



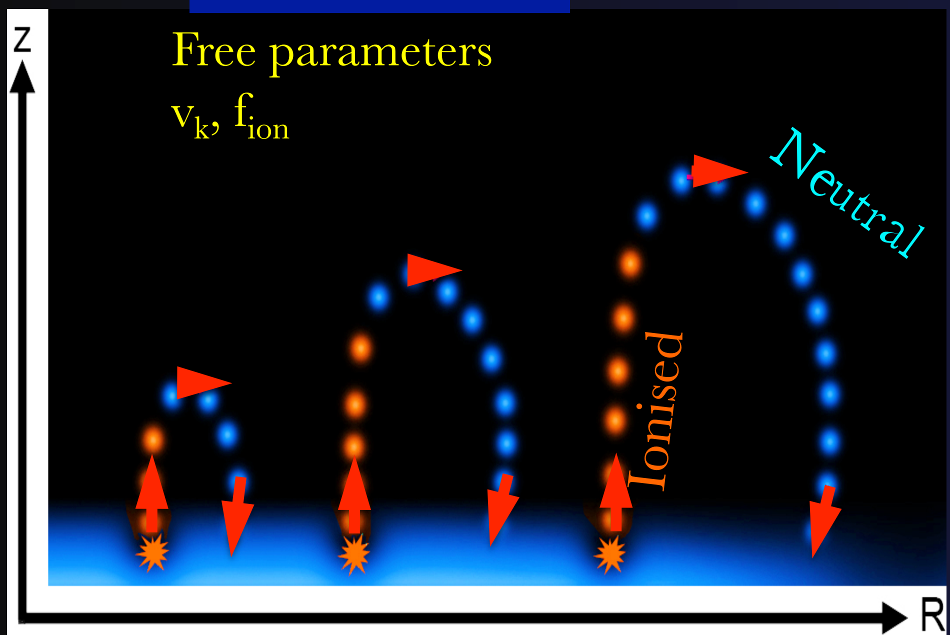
Building of several model cubes -> minimization residuals with LAB

We fit:

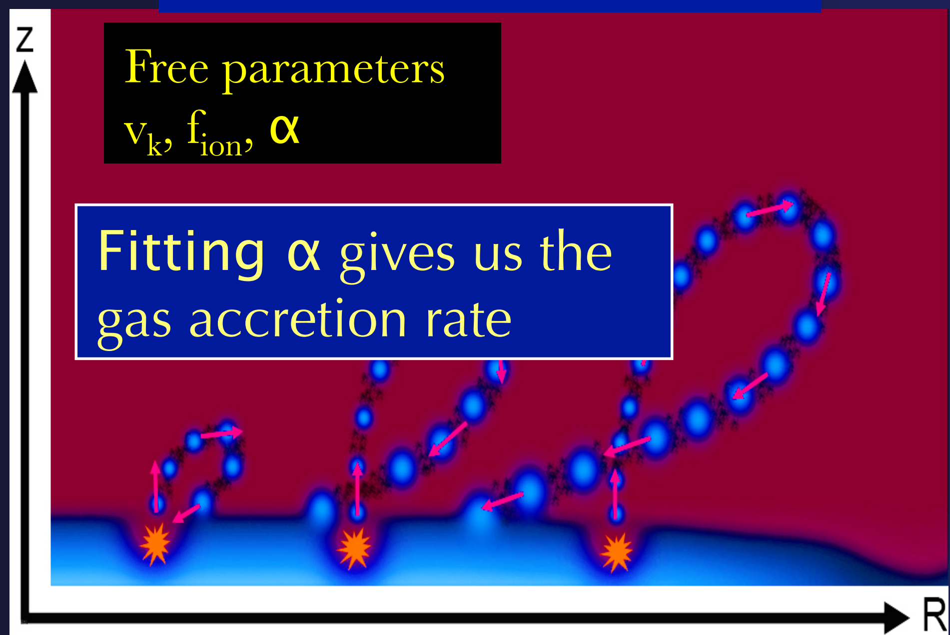
1. kick velocities (v_k) ⟹ scaleheight
2. Ionised fraction (f_{ion}) ⟹ vertical motions
3. Accretion coefficient (α) ⟹ radial motions

$$\dot{m} = \alpha m$$

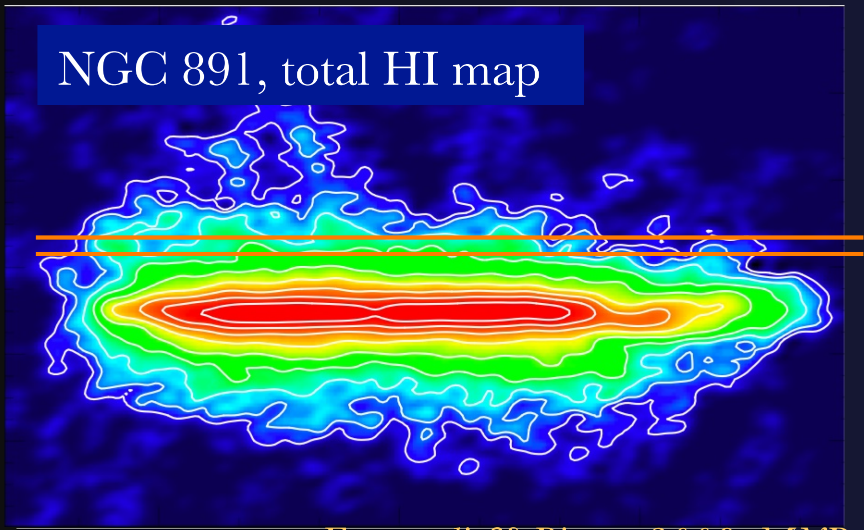
Pure fountain



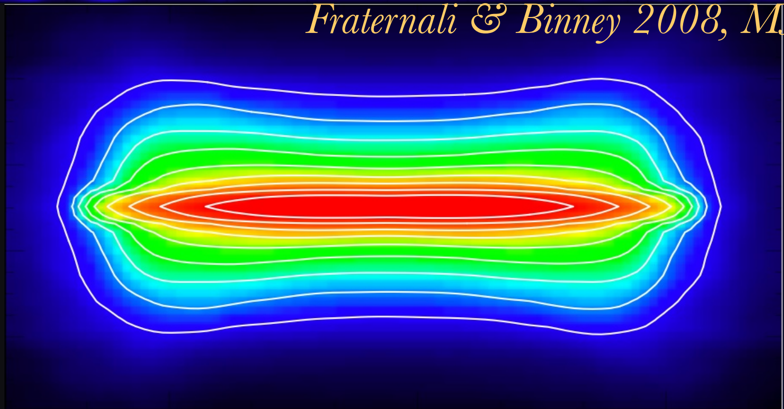
Fountain + accretion

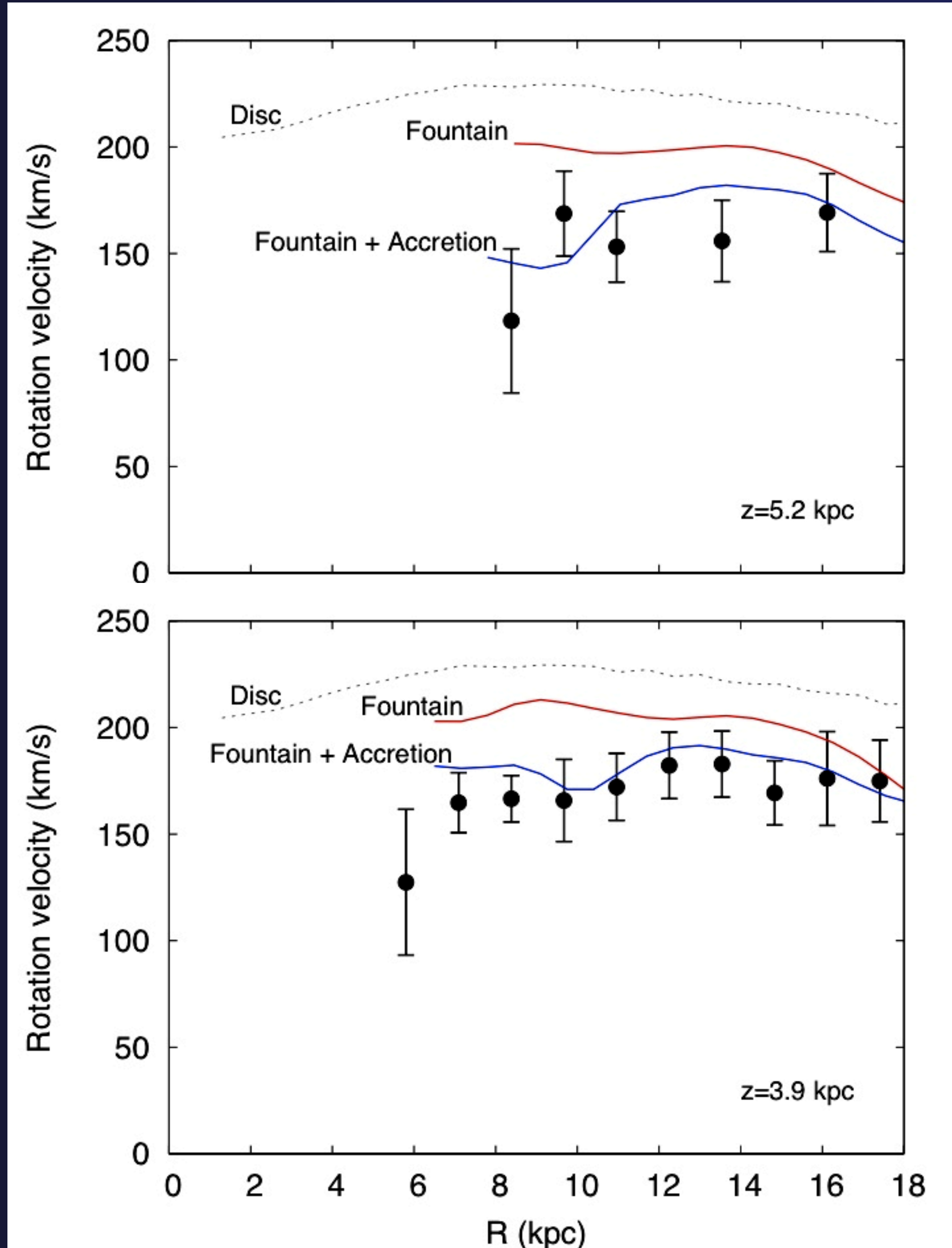


Early model: application to NGC891



Fraternali & Binney 2008, MNRAS

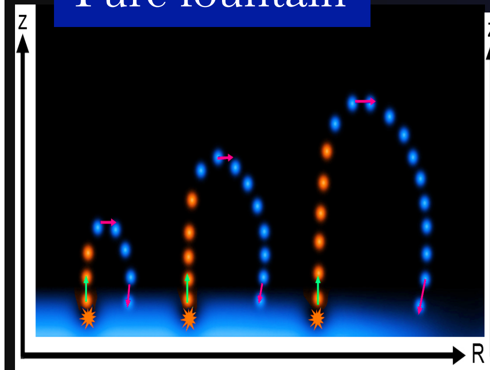




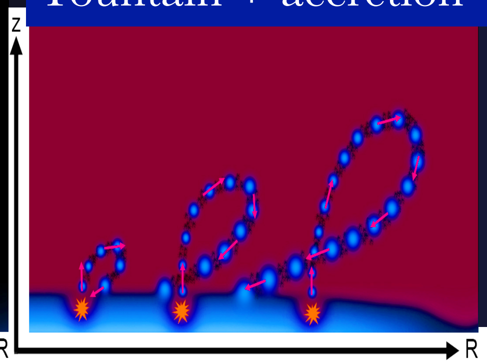
Best-fit Accretion Rate ~ $3\ M_{\odot} yr^{-1}$

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

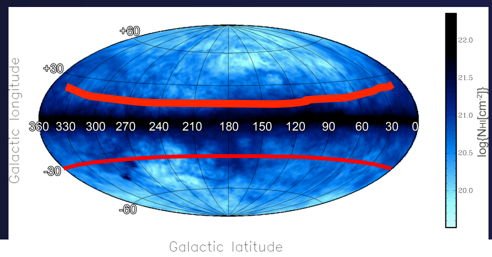
Pure fountain



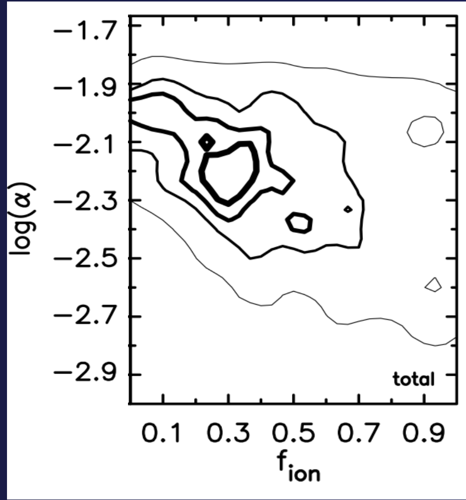
Fountain + accretion

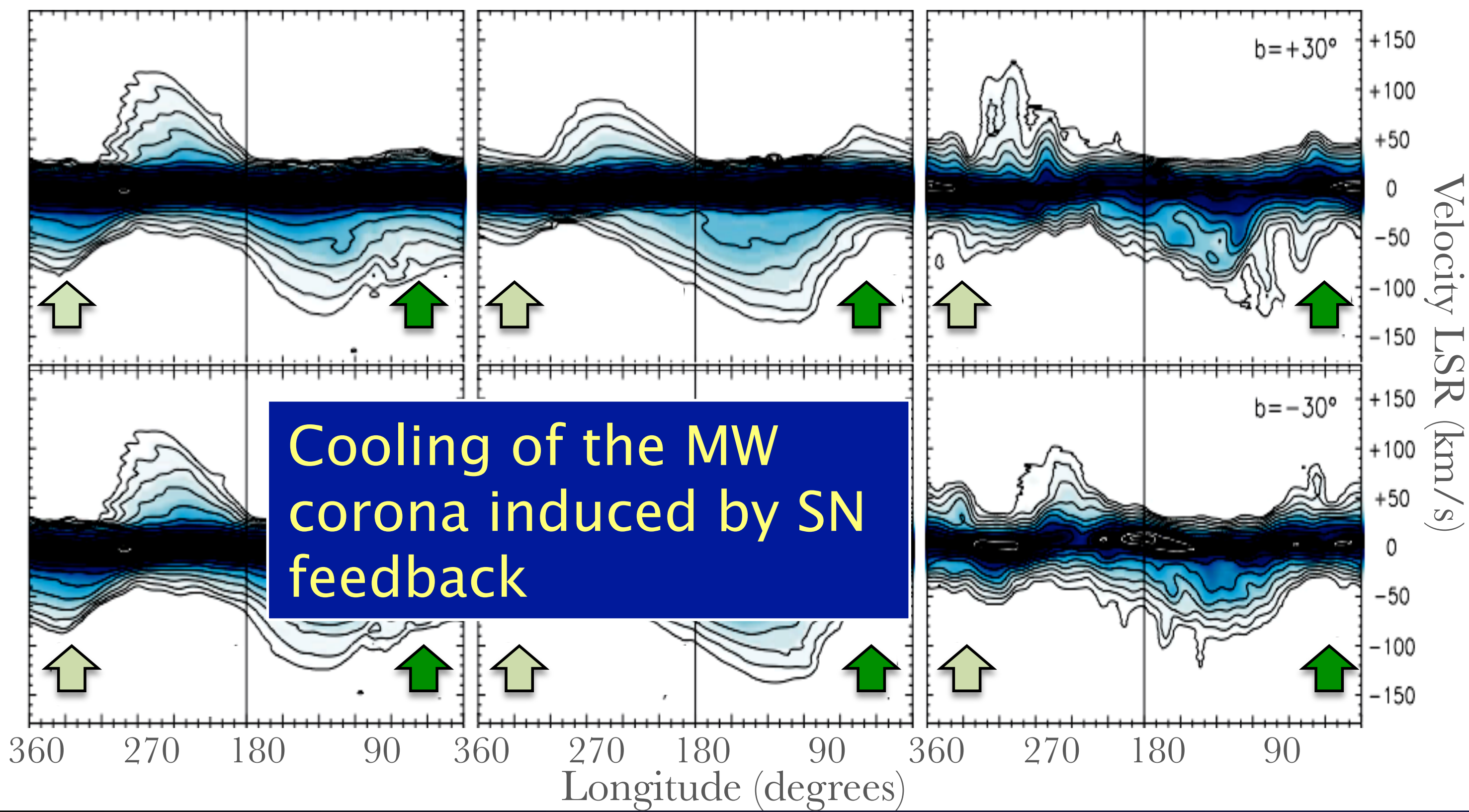


HI data



Best fit





Cooling of the MW corona induced by SN feedback

$v_k = 75$ km/s

$f_{ion} = 0.3$

$\dot{M}_{cor} \sim 2\ M_\odot/yr$

Halo HI:

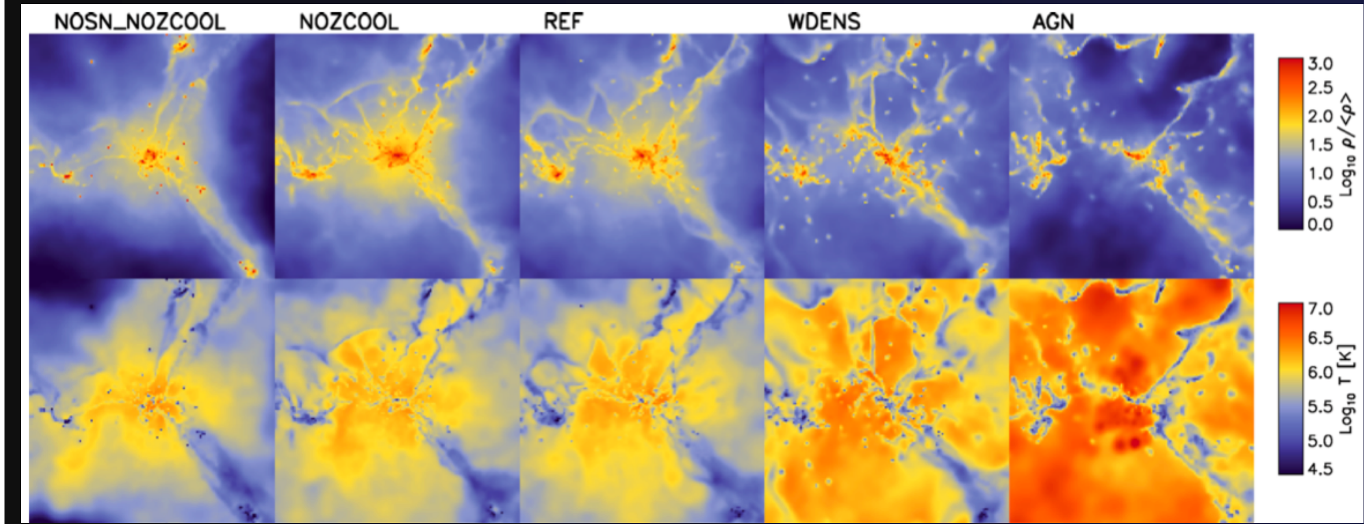
~90% from fountain

~10% from corona

Marasco, Fraternali & Binney 2012

What about other simulations?

Positive feedback in other sims

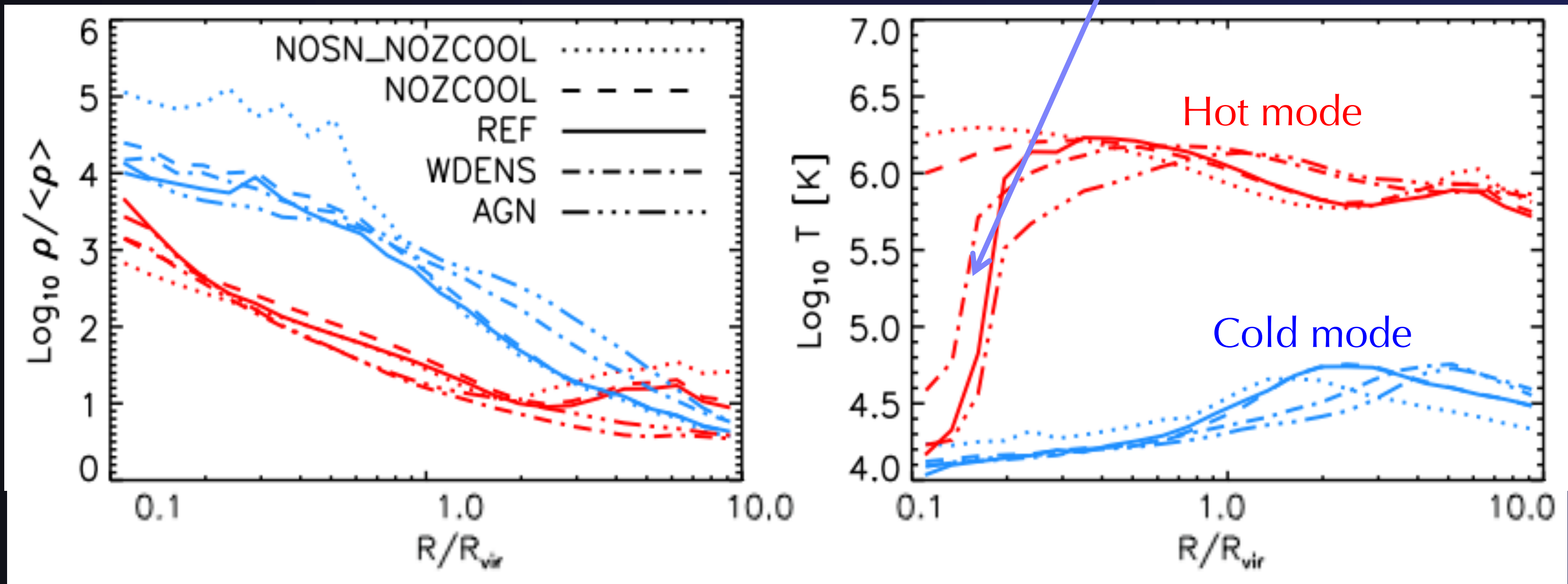


z=2

Cooling induced close to galaxies by metals ejected by feedback

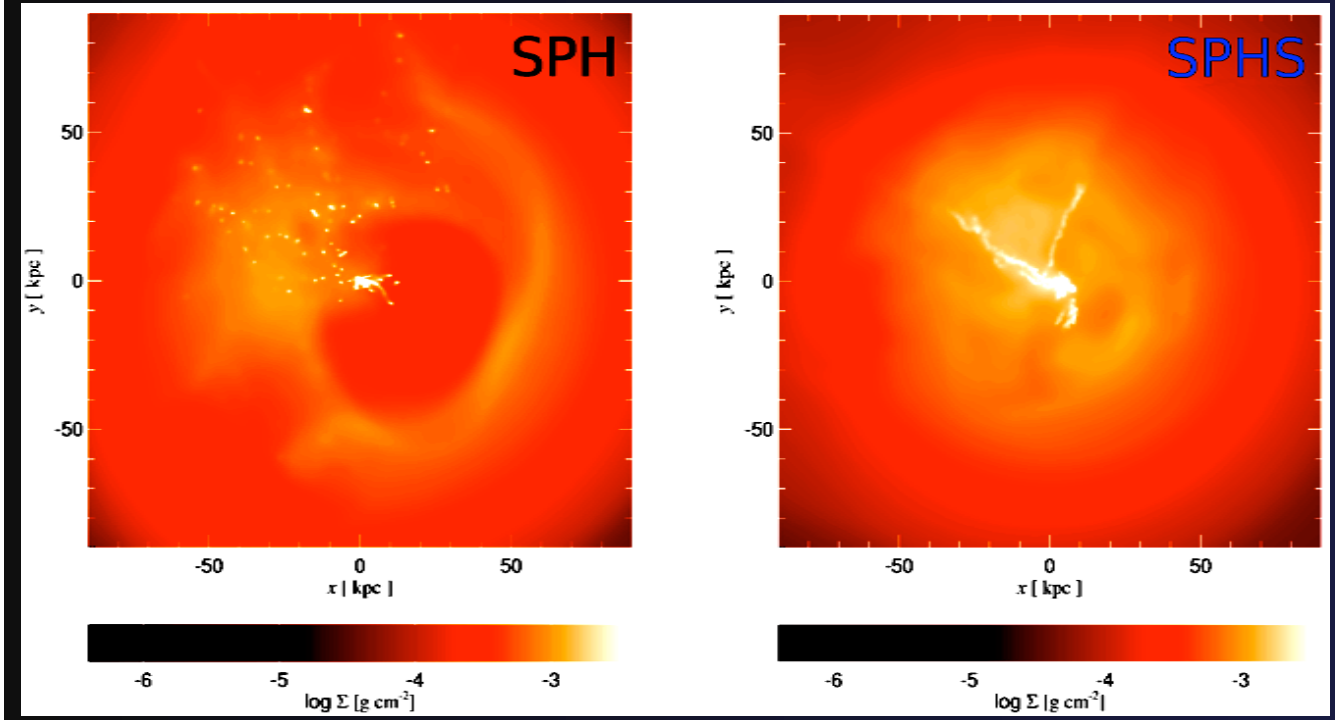
OWLS

GADGET-3



van de Voort & Schaye 2012

SN-driven accretion in other sims



Modified SPH

No formation of clumps

"Cold gas condenses from the halo at the intersection of supernovae-driven bubbles. This positive feedback feeds cold gas to the galactic disc directly, fuelling SF.

Hobbs et al. 2013, MNRAS

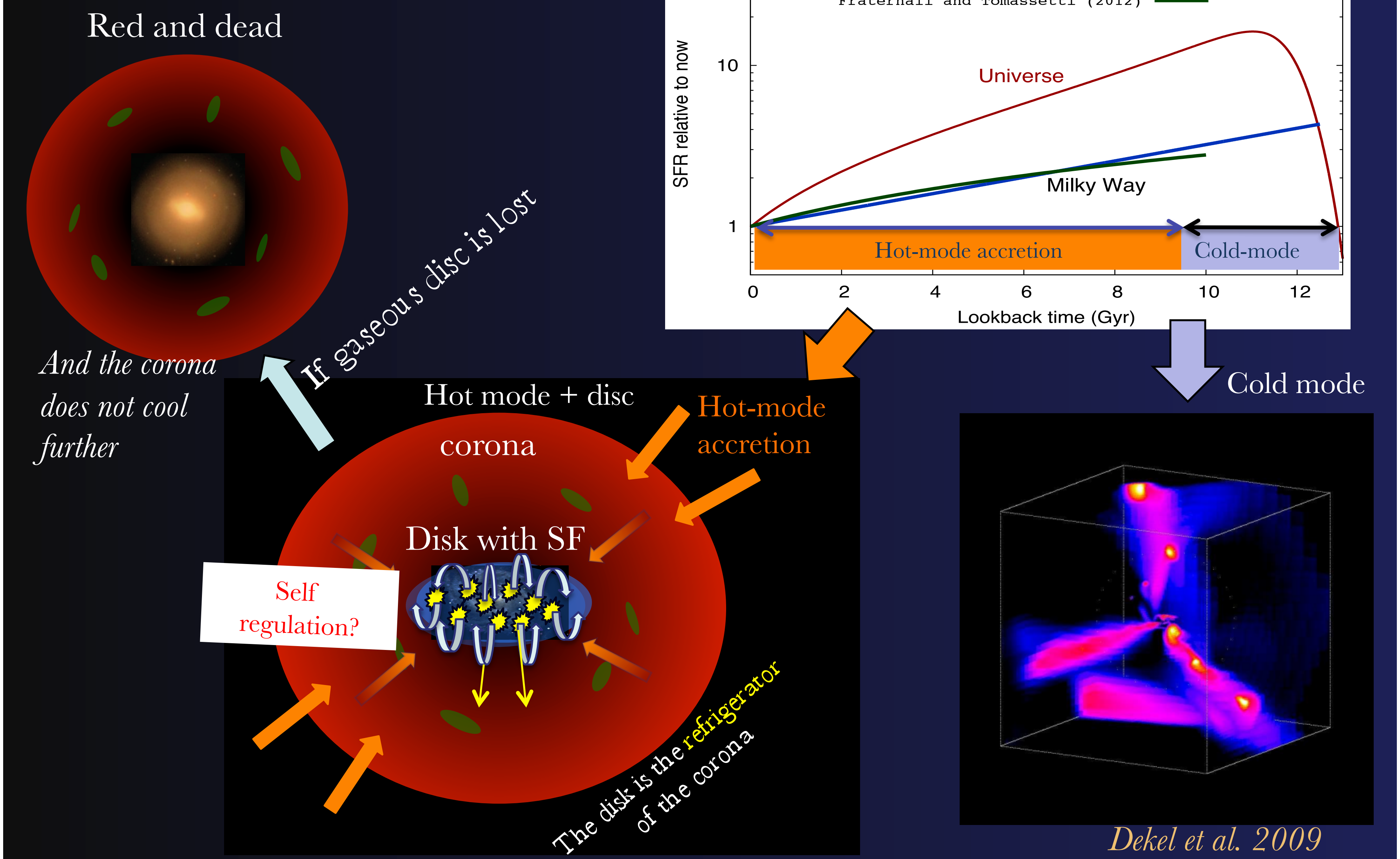
MaGICC - GASOLINE

Halos enriched by galactic fountain

Gas in the fountain cycle comes back to the disk more metal poor!

Brook+12, Brook+13

Evolution of discs



Conclusions

- Minor mergers and HI HVCs cannot feed star formation

- The circumgalactic medium is multiphase and extended

- Supernova feedback cools the corona in star-forming galaxies
  - Very good fits: HI in the MW and external galaxies, ionized absorbers in the MW

- Both positive and negative feedbacks play important roles in galaxy evolution