

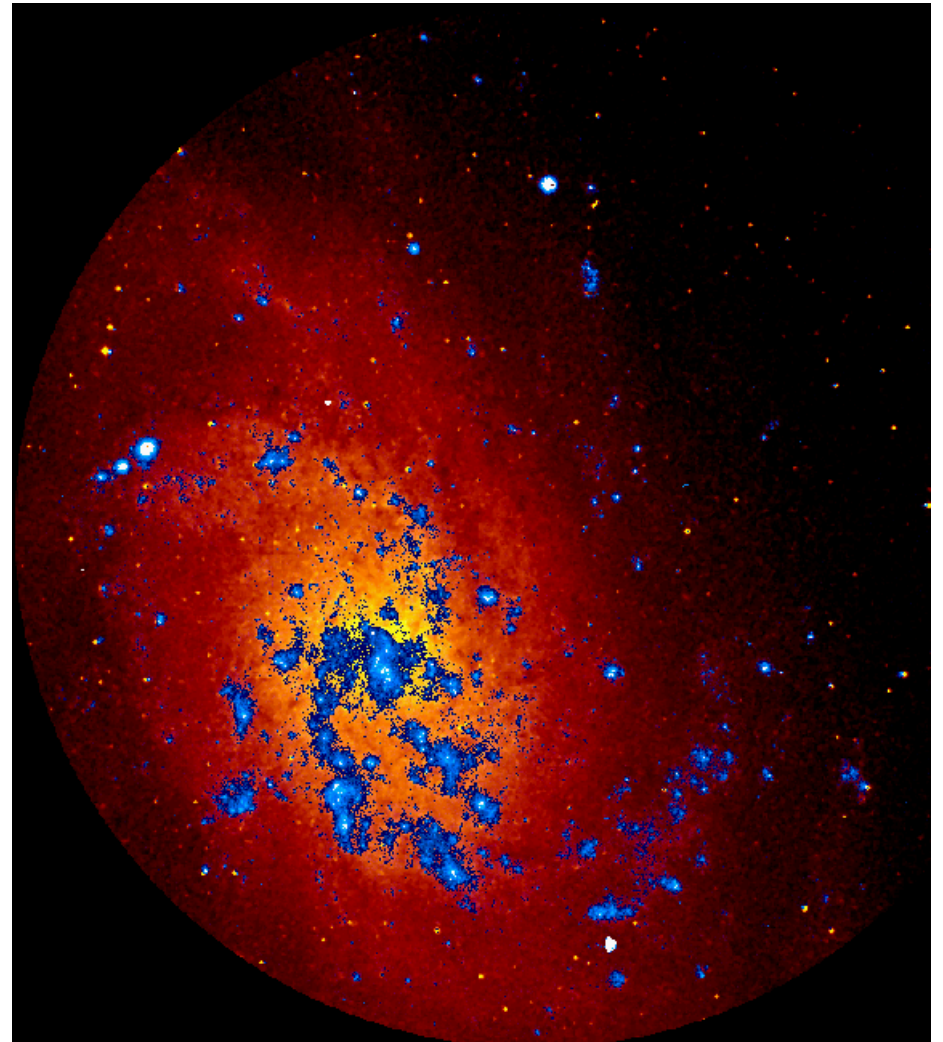
# The outer disk and halo

*F. Combes, Paris Observatory*

→ 1- Generic slide: state of the art

→ 2- Star forming history,  
possible formation scenarios

→ 3- OQs on formation/evolution



# Status, and main issues

→ Spectacular break in the disk at 8kpc ( $4.5R_e$ )

Origin? Inside-out formation? Accretion?

Resonant diffusion due to bar/spiral?

→ Prolonged by a strong warp

Physics of the gas different from the inner parts

Interaction with M31? Cold gas accretion from cosmic filaments?

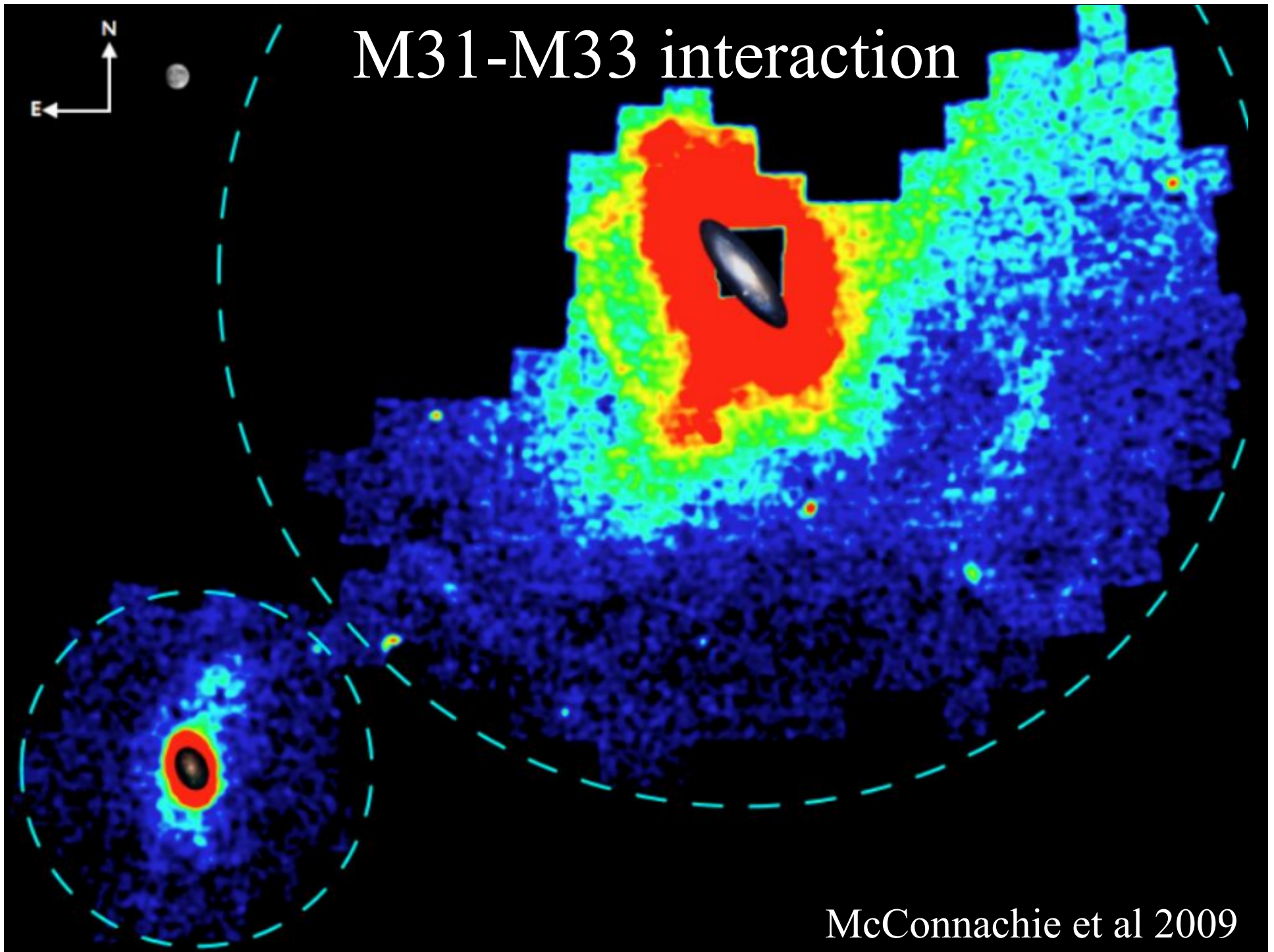
→ Gradients of age and metallicity

Scenarios of star formation, Radial mixing?

→ Metallicity of halo, streams?

Clues to mass assembly history

# M31-M33 interaction

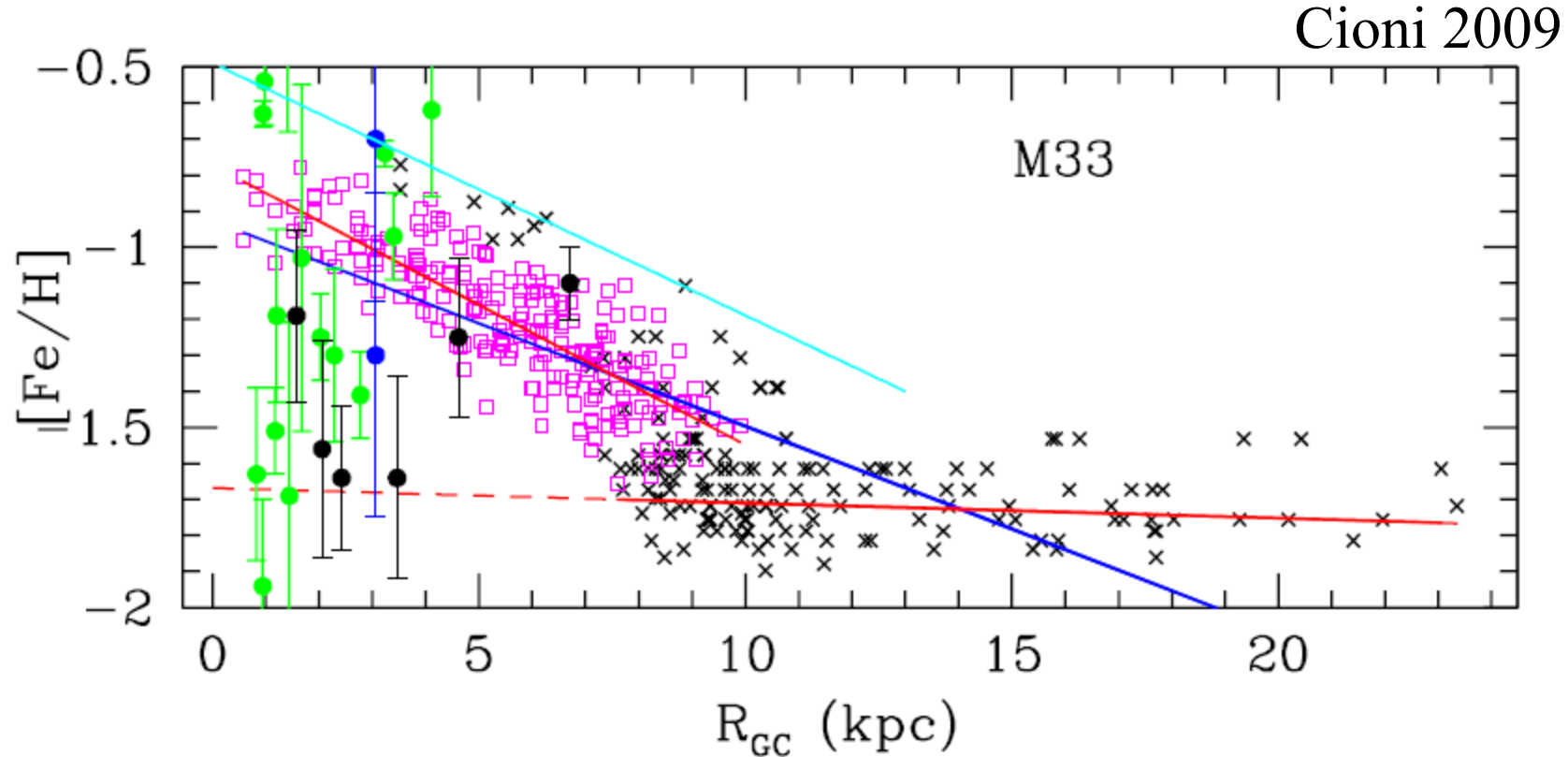


McConnachie et al 2009

# Evidence of inside out formation

Abundances obtained by comparison between AGB- C and M-types

→ "inside-out" disc formation via accretion of metal poor gas



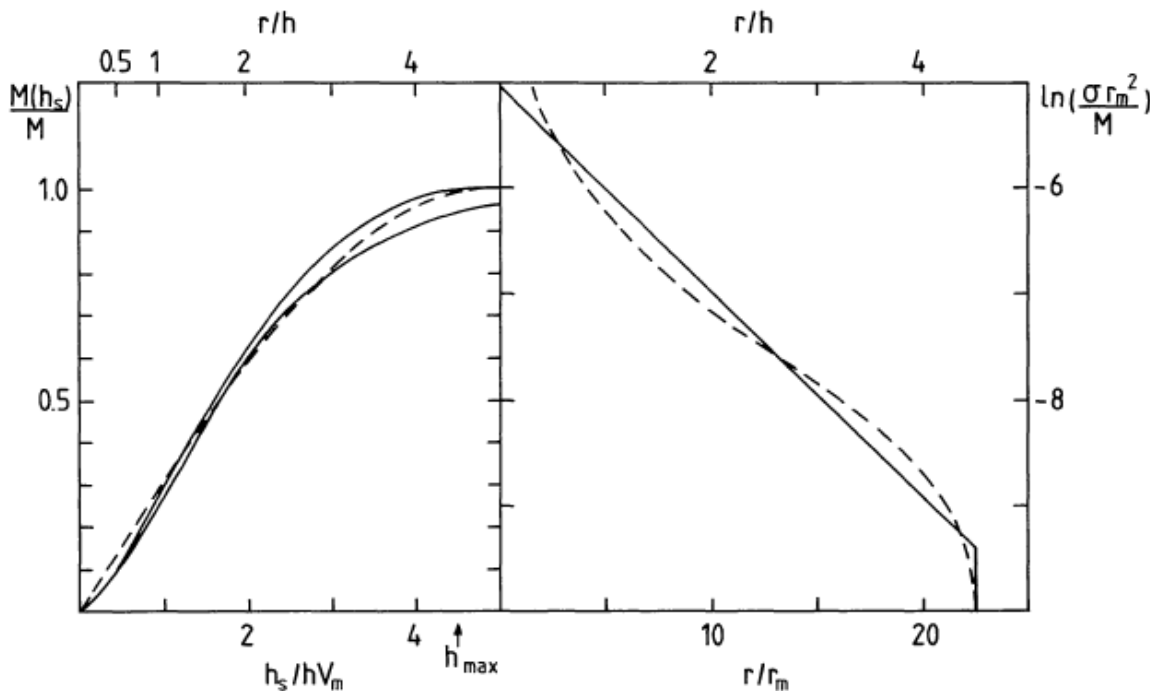
# Possible scenarios

1- Fall & Efstathiou (1980), van der Kruit (1987)

AM conservation during the collapse of a uniformly rotating uniform sphere ( $r_m = 0.2h$ )

→ produces an exponential disk, with a cut-off at  $4.5h$

HI extensions accreted later??



The baryons cannot lose AM, since it is barely sufficient

→ Disks too concentrated

Van der Kruit 1987

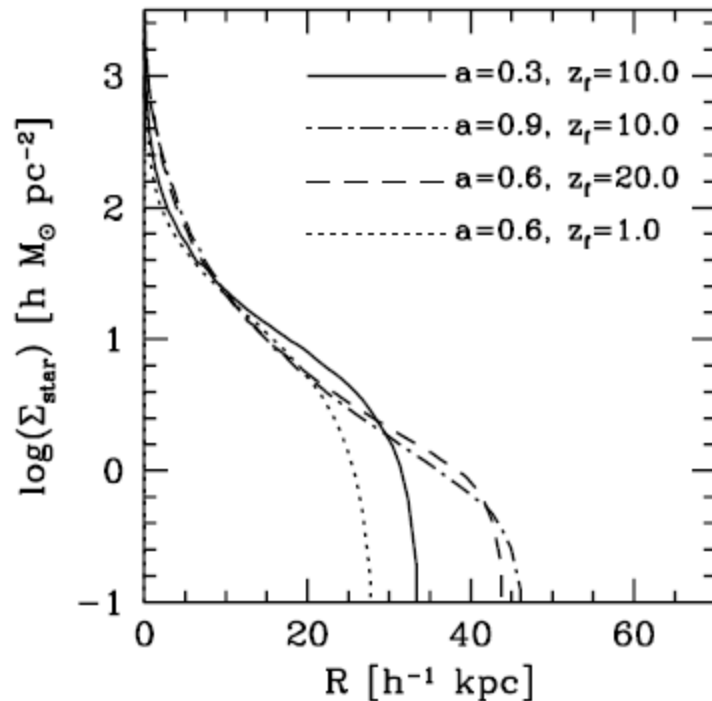
# Possible scenarios (2)

2- Star formation threshold, for the stellar exp disk (Kennicutt 1989)

But extended UV disks: 2 SF prescriptions?

3- Maximum AM of the cooled gas (van den Bosch 2001)

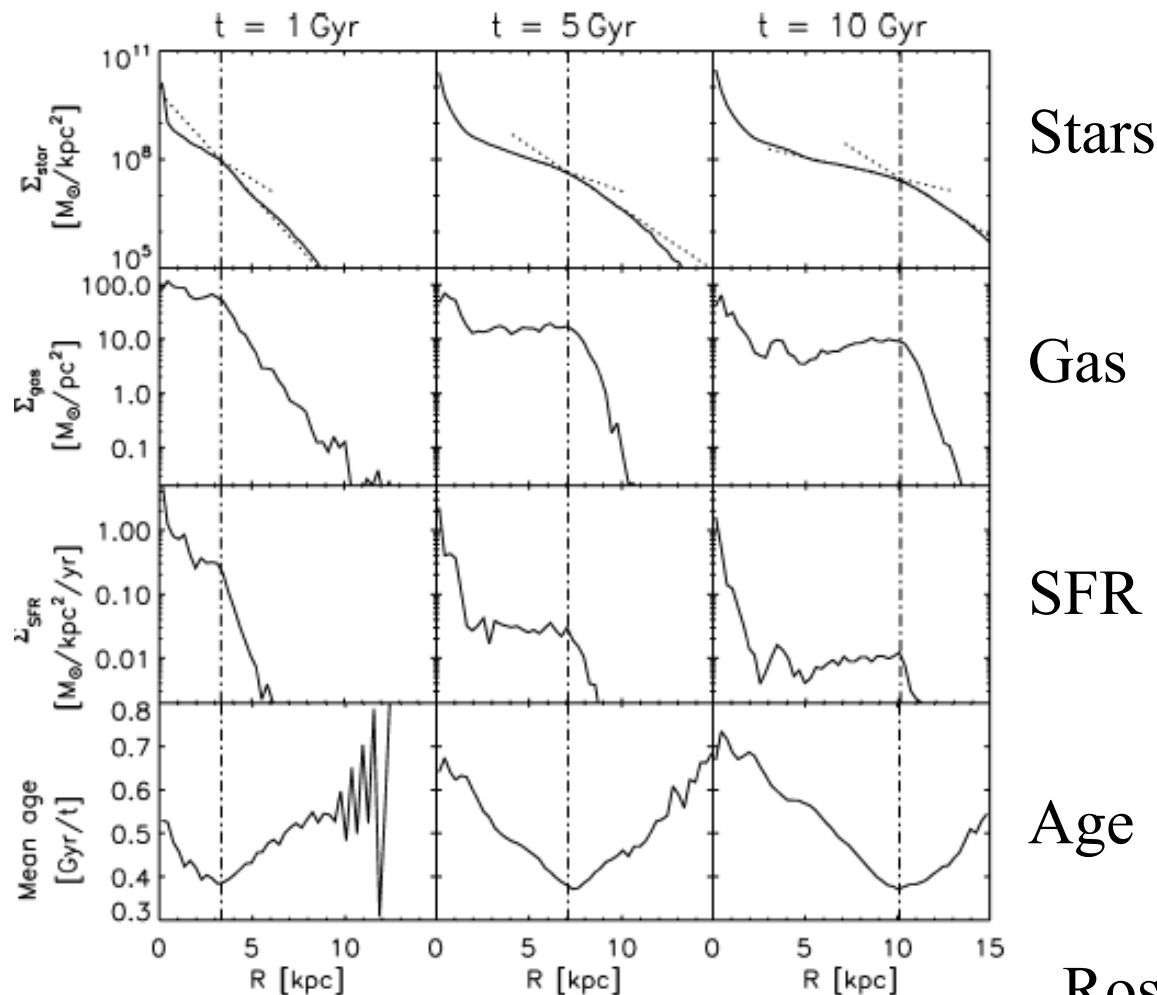
→ But again, large central concentration



$Z_f$  begin to accrete  
with a speed  $\sim a$

# Break moves radially outwards

TreeSPH simulation of collapse: break moves due to gas break and Toomre Q increase

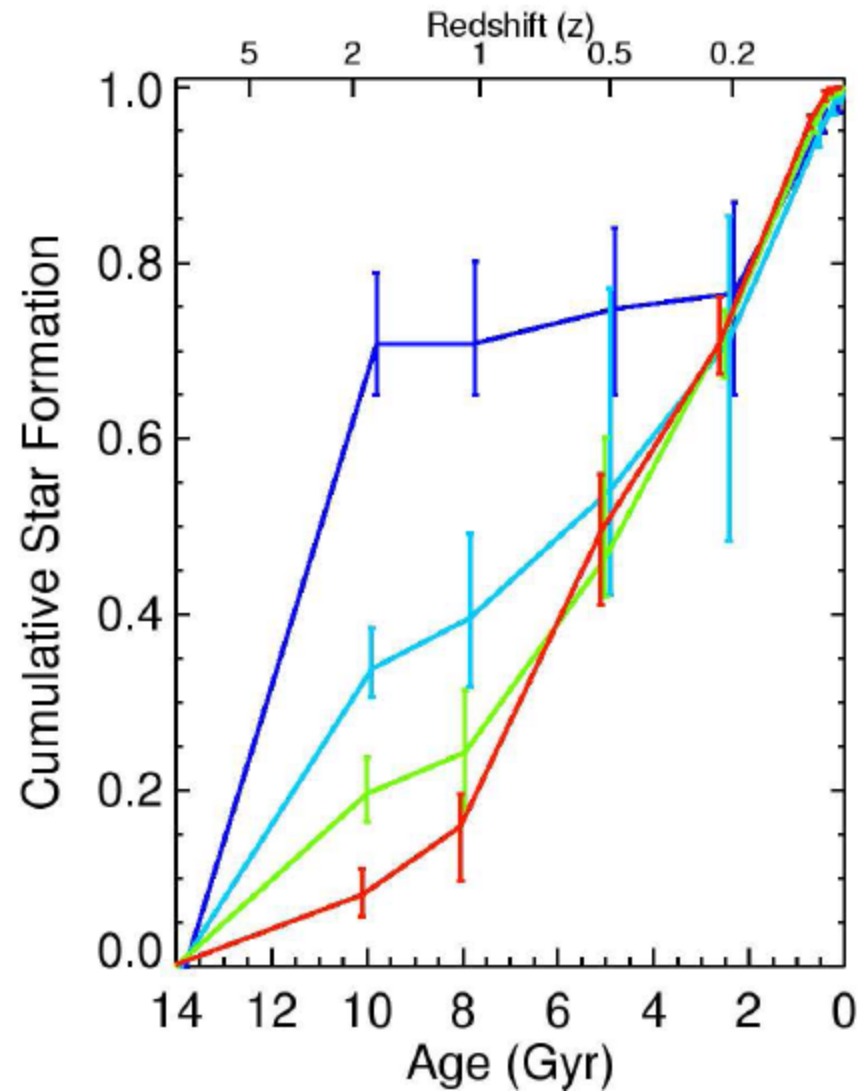
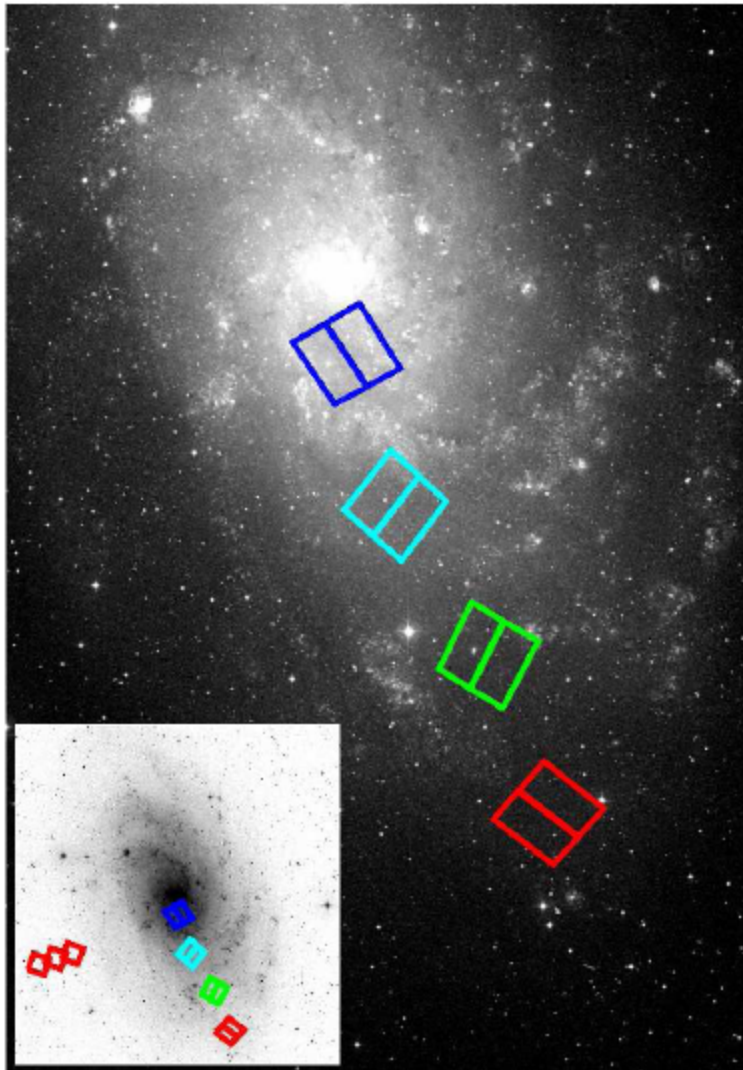


→ Spiral and bar transfer inner stars to the outer parts

Roskar et al 2008

# Age gradient reverses after 8kpc

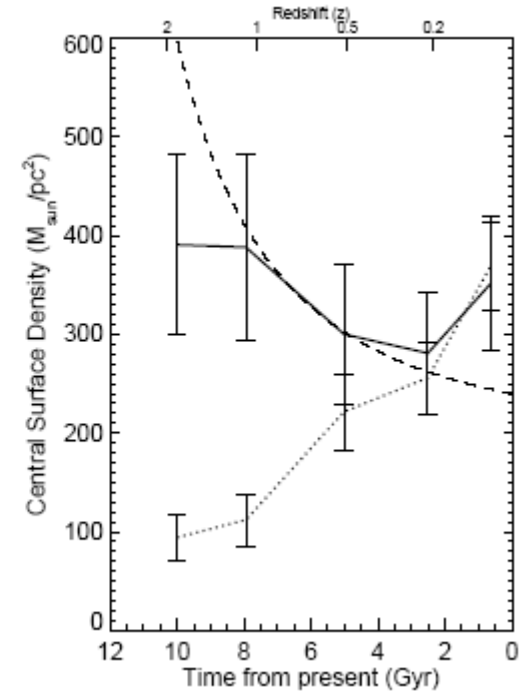
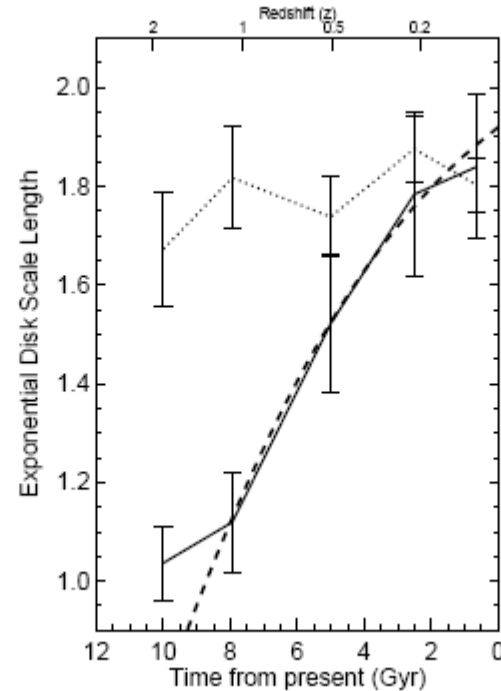
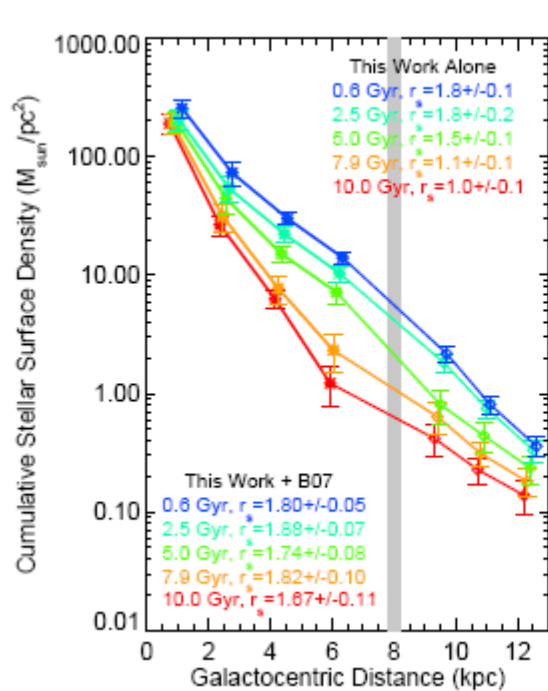
Williams et al 2009





# Increase of the disk scale

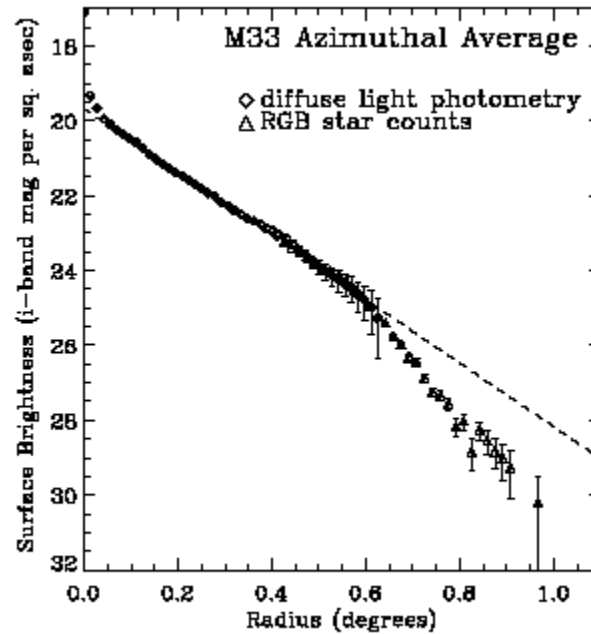
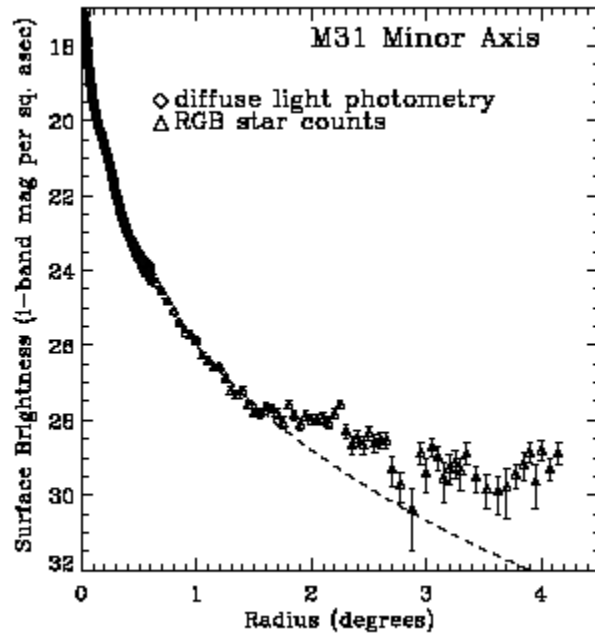
CMD diagrams from  
HST/ACS (Williams et al 2009)



--- Mo et al 1998, ... all radii      — inside 8kpc

# Metallicity of halo/disk stars

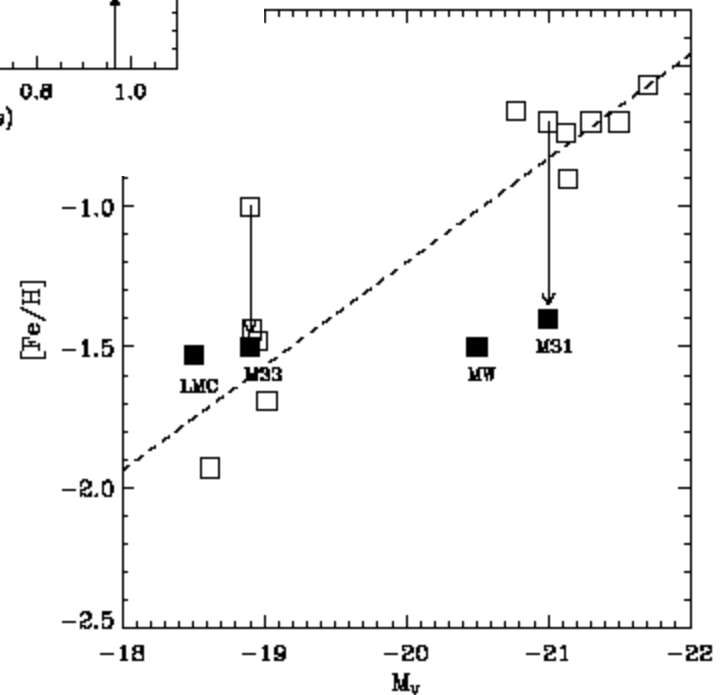
Truncation of the Radial profile



Ferguson et al 2007

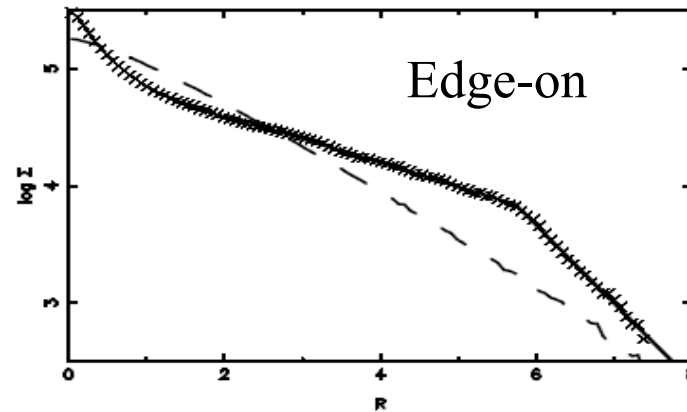
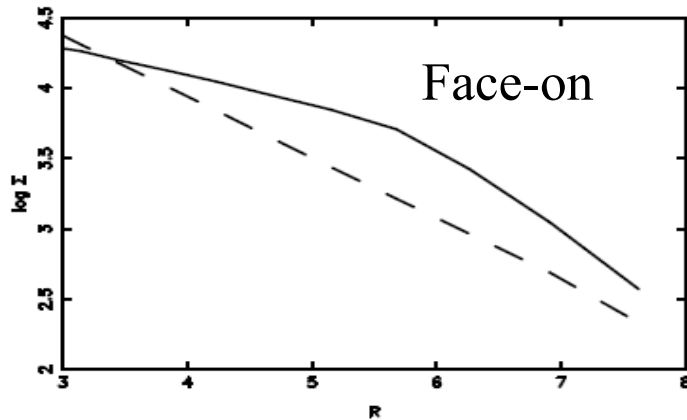
Revised metallicity in the halo  
from Mouhcine et al (2005)

→ No longer any relation with host mass



# Surface density breaks

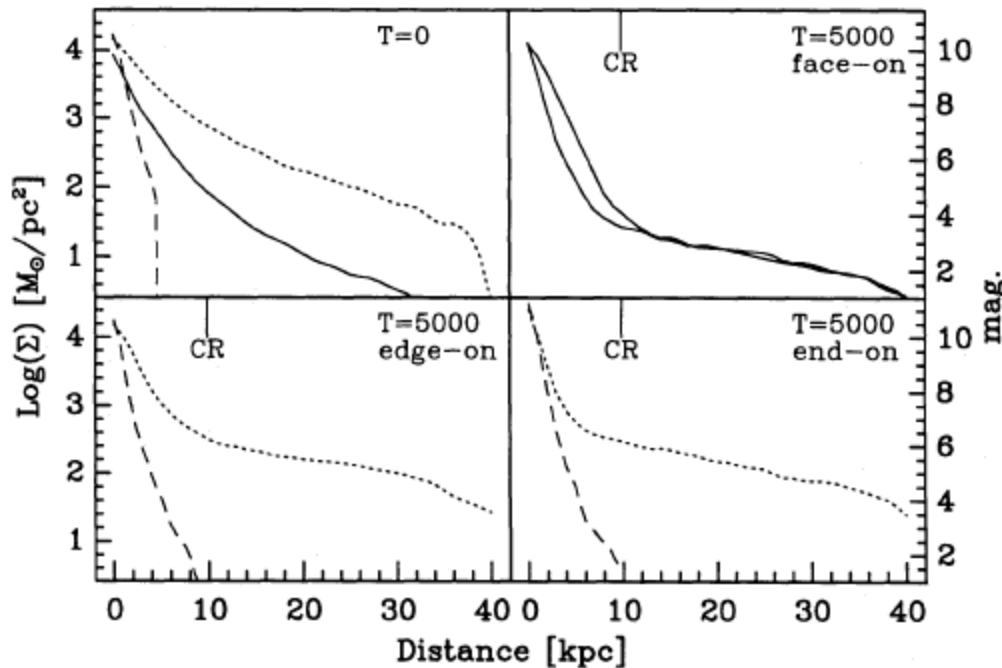
*Debattista et al 2006*



Consequence of AM exchange

Outer and inner disks breaks

$R_{\text{break}} \sim R_{\text{OLR}}$

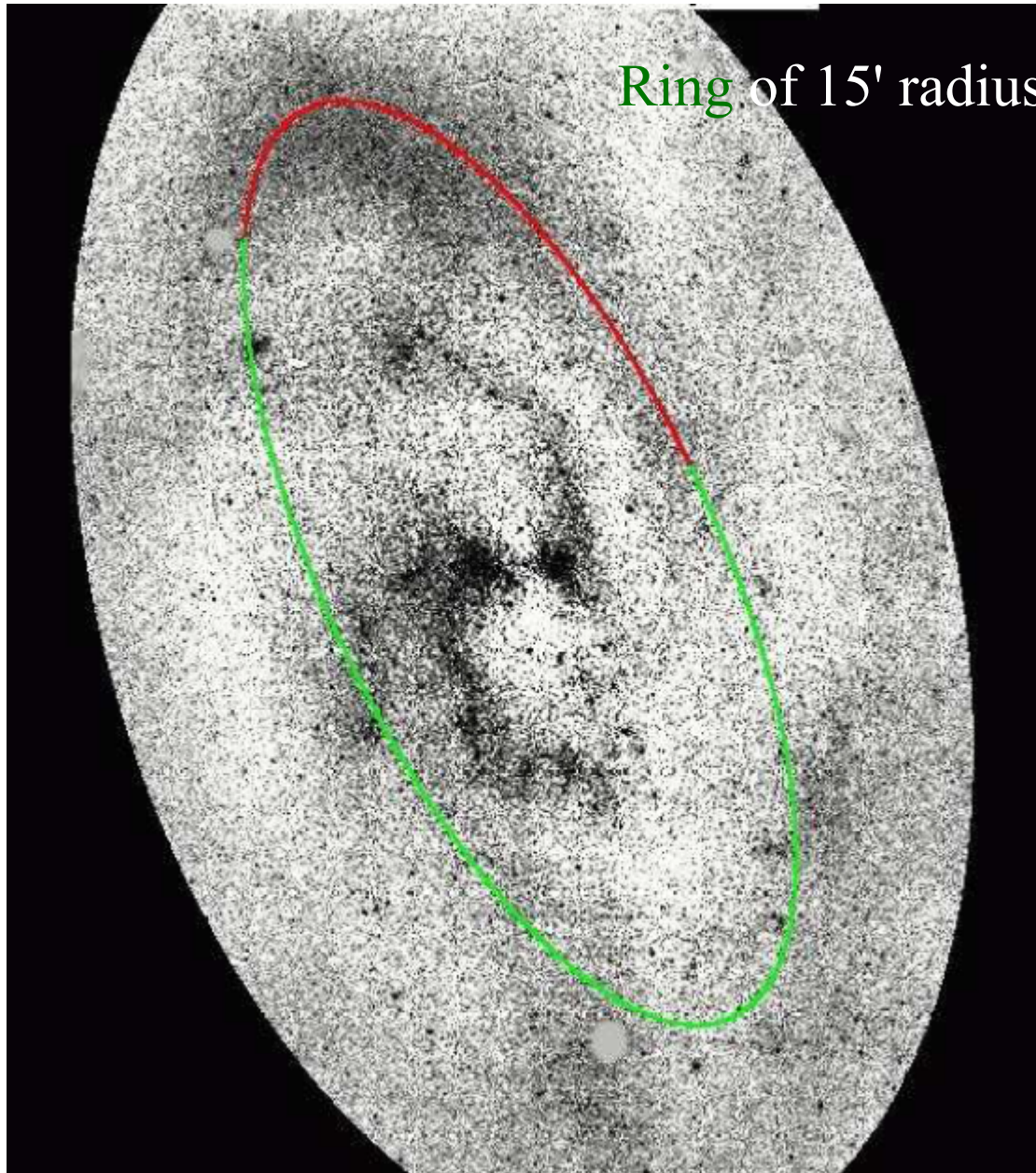


Could be a stellar processus (Pfenniger & Friedli 1991)

Or a gas process, with SF threshold

Roskar et al 2008

# Second structure in the inner/ outer disk



Block et al 2004, 2007

Detection of Carbon stars  
In the outer disk  
AGB stars

Redder color in the outer parts  
Due to the AGB carbon stars  
(+ Keck spectroscopy)

Recent star formation,  
Fueled by the HI gas reservoir  
From the accreted warped  
disk

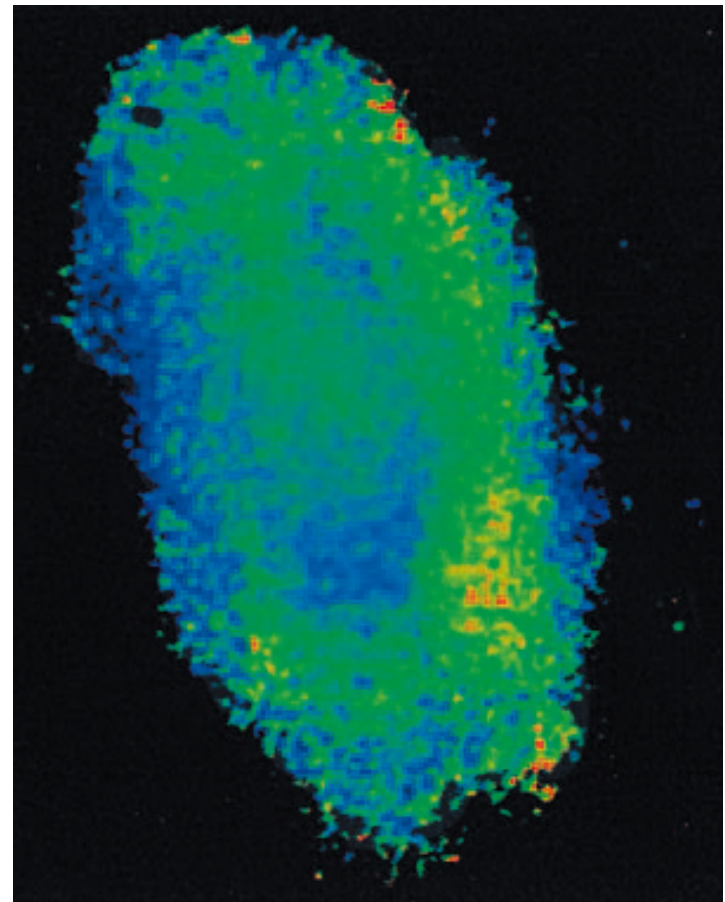
# Red outer parts

Carbon stars (0.6-2 Gyr)  
Dominate the red luminosity

Young stellar populations of  
Red giants

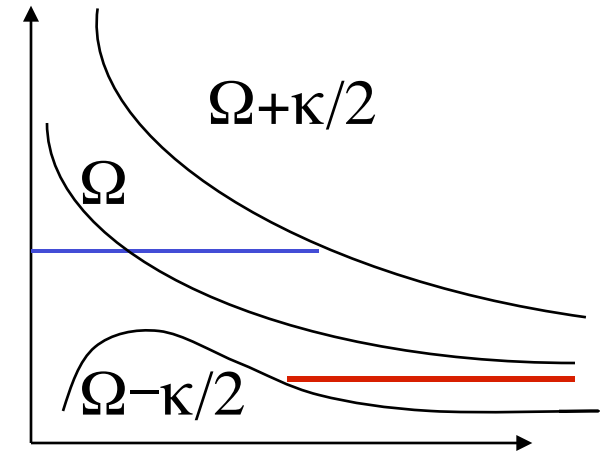
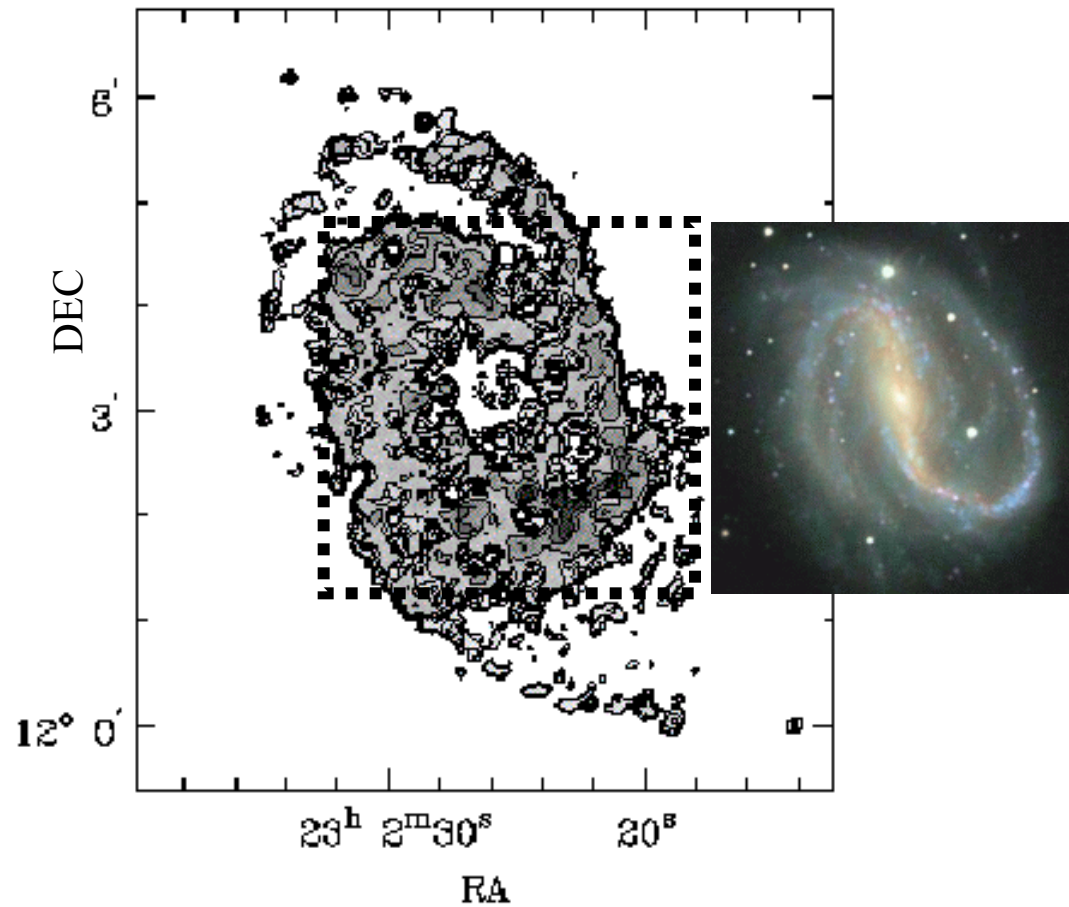
Period of 240 Myr at the ring

J-K image



Block et al 2004

# Gas at large scale?



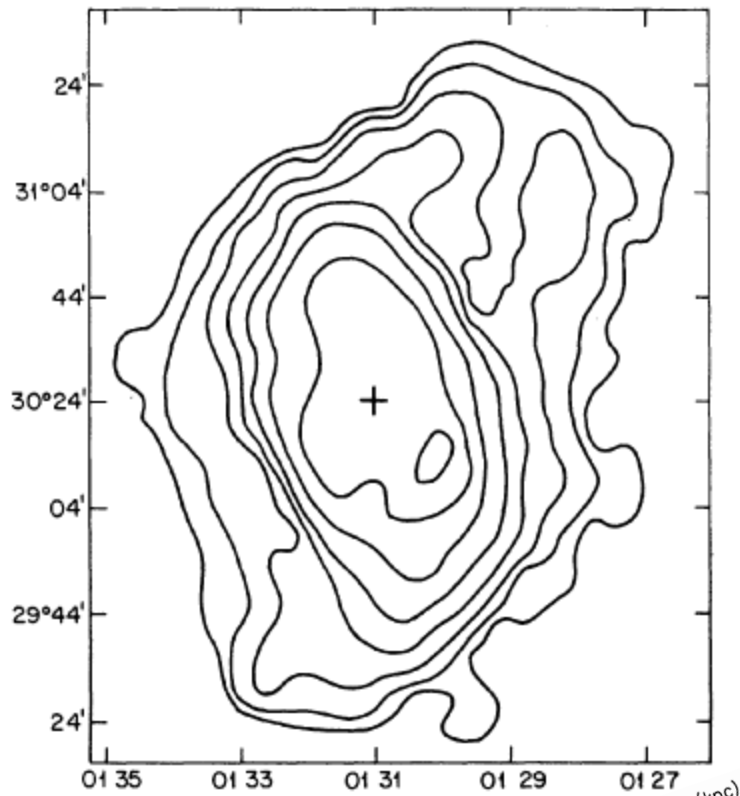
2 patterns

OLR of the 1st =

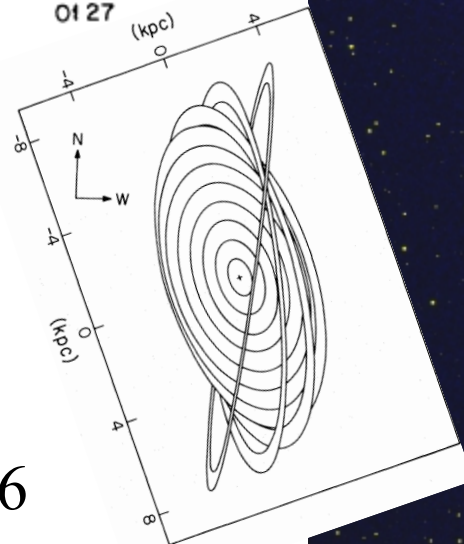
ILR of the 2nd

# HI gas

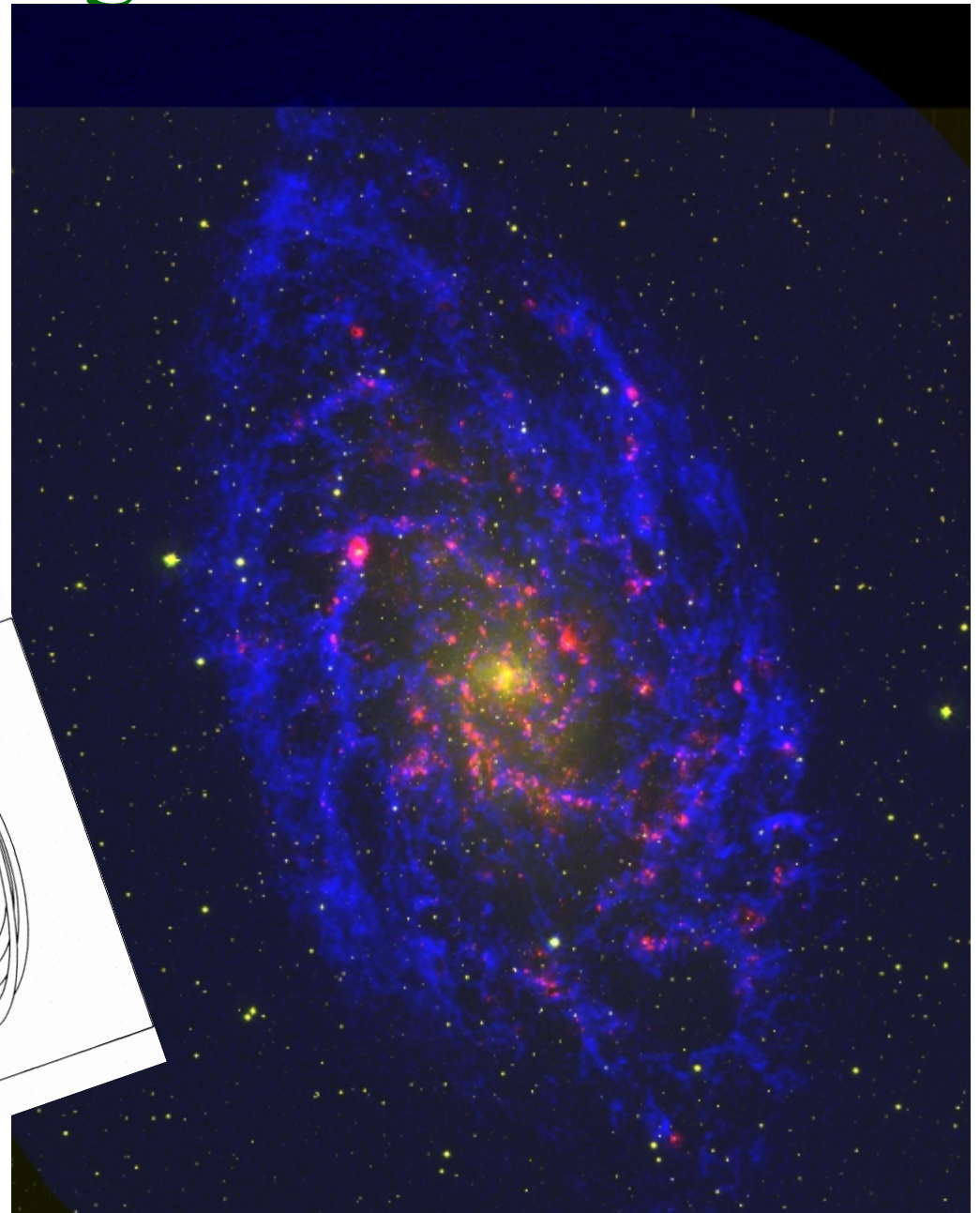
Thilker et al VLA



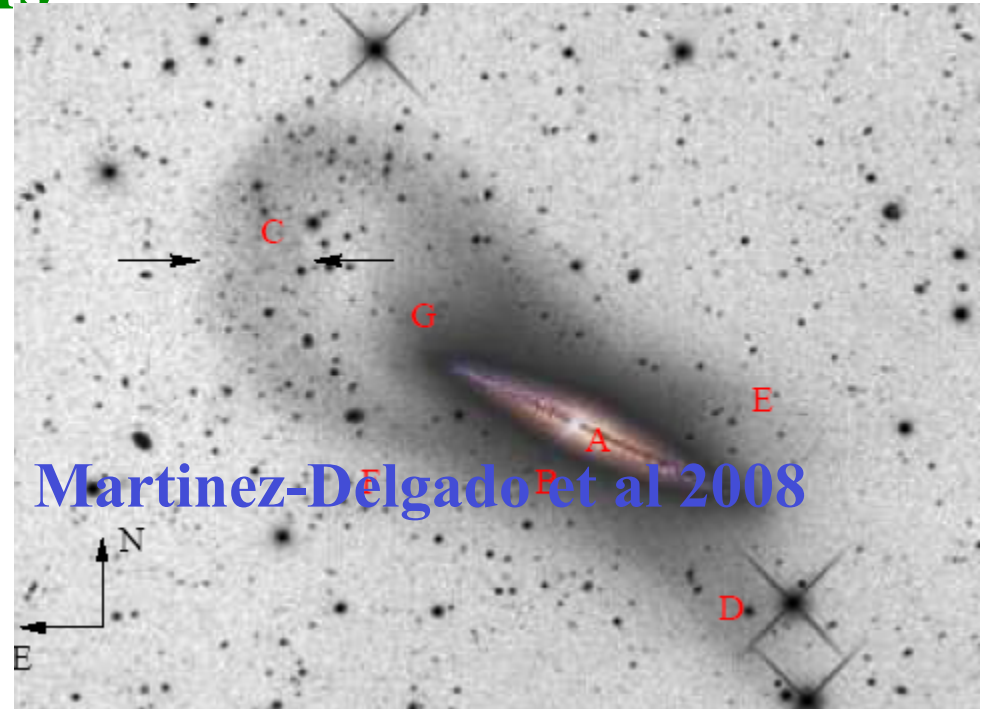
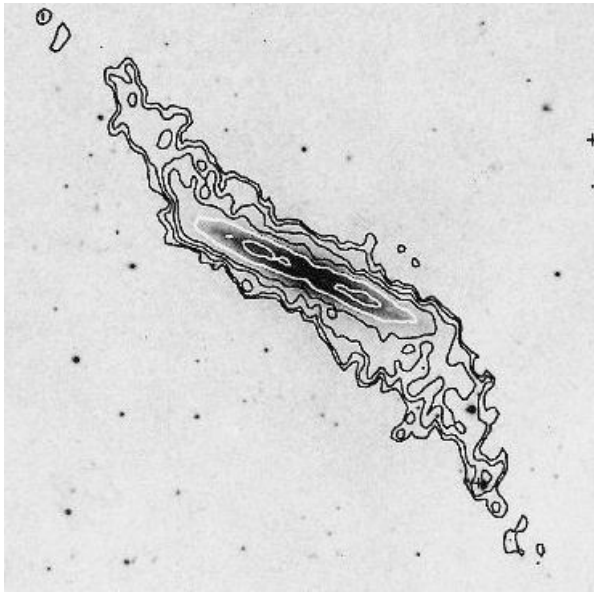
Corbelli et al 1989,  
Arecibo



Warp, Rogstad et al 76



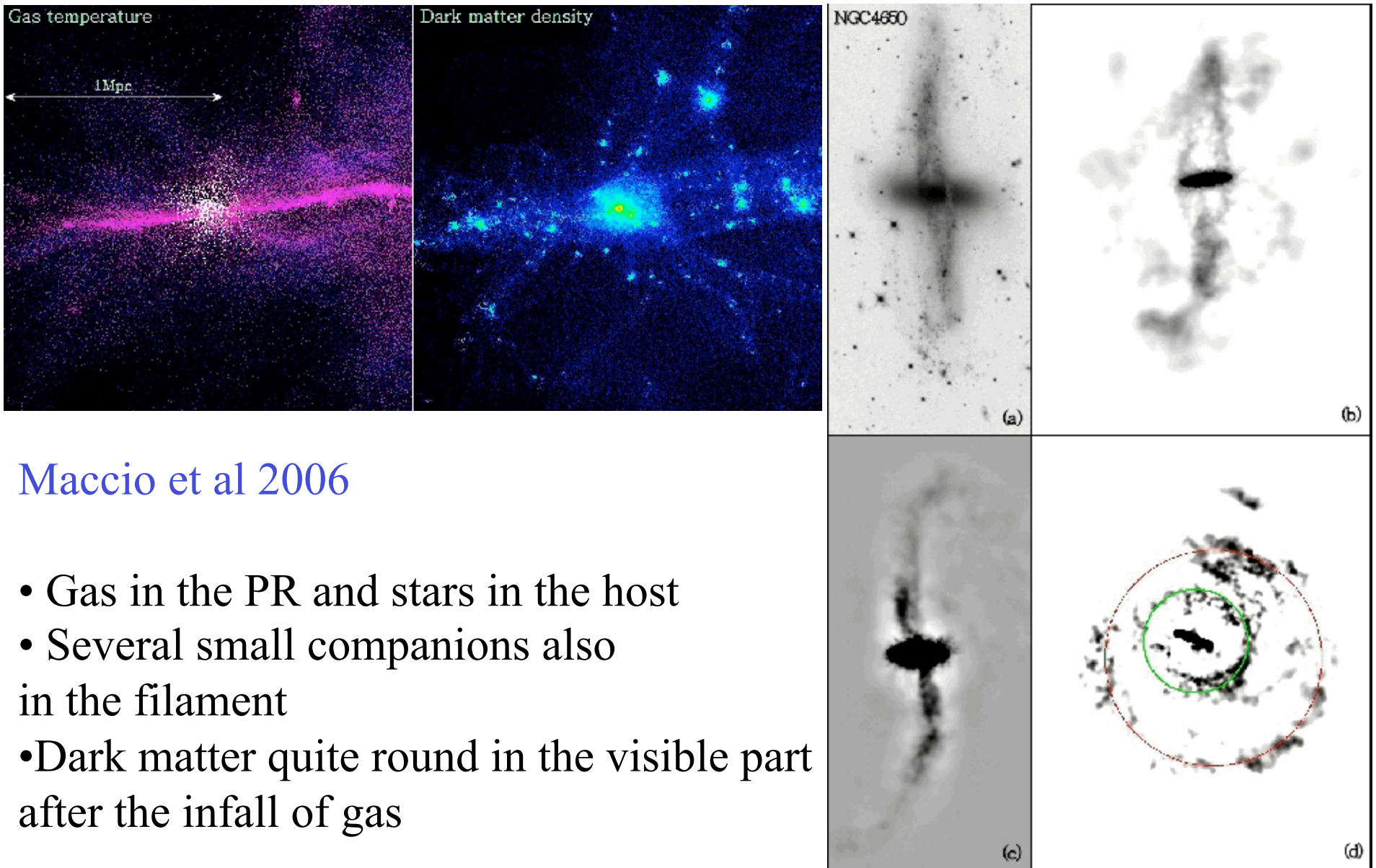
# Warped disks: isolated or due to companions



NGC 4013  
Bottema 1996



# Cold accretion from cosmic filaments



# Open Questions

- 1- Role of inside out formation, & resonant diffusion of stars?  
*which bar, waves? Destroyed bar?*
- 2- Dark Matter, truncation or not? (*inside a gas filament*)
- 3- Satellites around M33? Interaction with M31?

