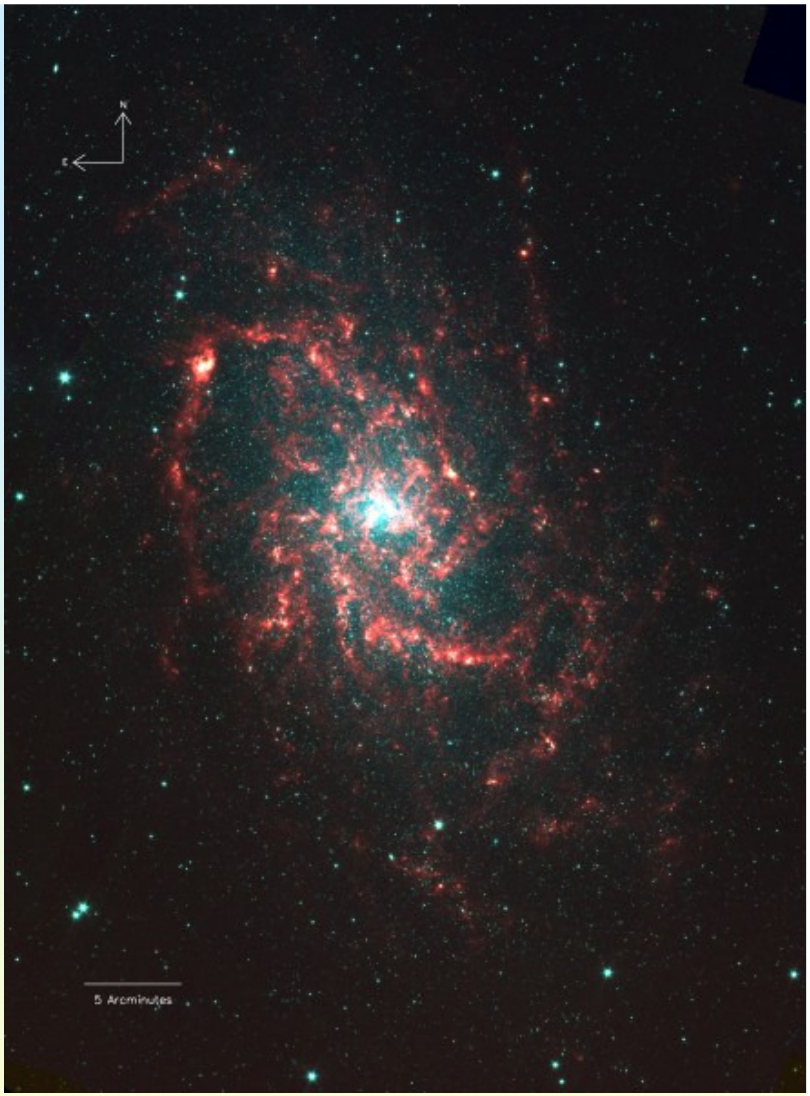
l'Observatoire de Paris
LERMA
Laboratoire d'Étude du Rayonnement et de la Matière en Astrophysique

Baryons and dark matter in outer disks



M33, Gehrz et al 07

Spineto June 2007

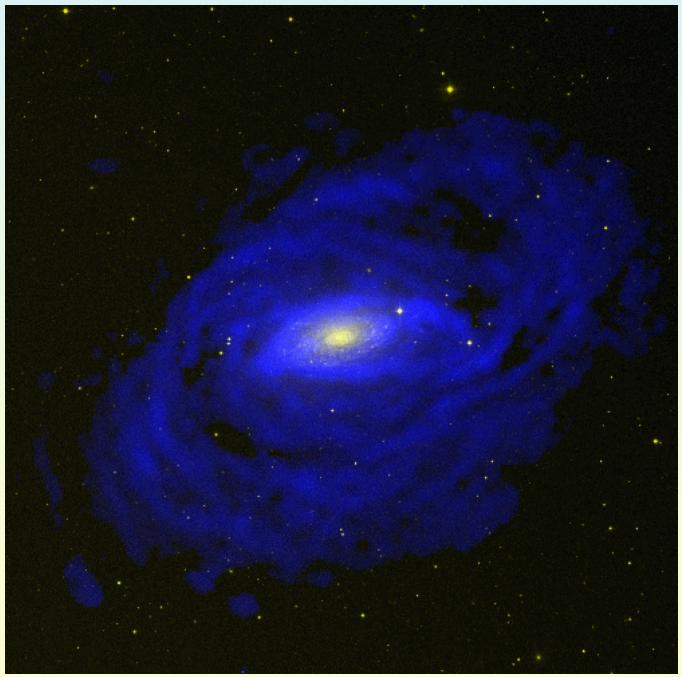
Françoise COMBES

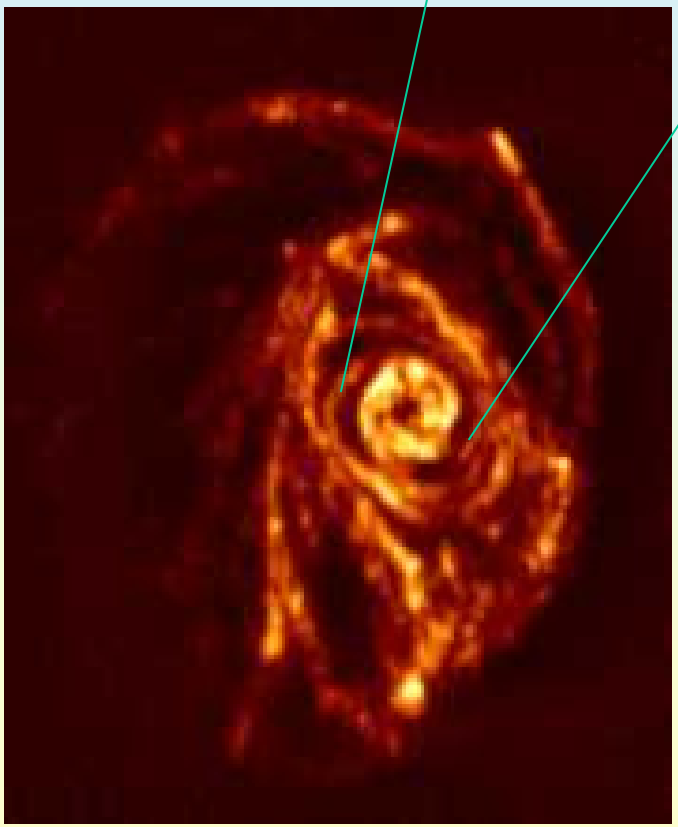
HI extension of galaxies

M83: optical

➔ Dark halo exploration

HI





NGC 5055 Sbc

Milky Way-like spiral (10^9 $M_\odot$ of HI): M83

HI appears as a tracer of DM

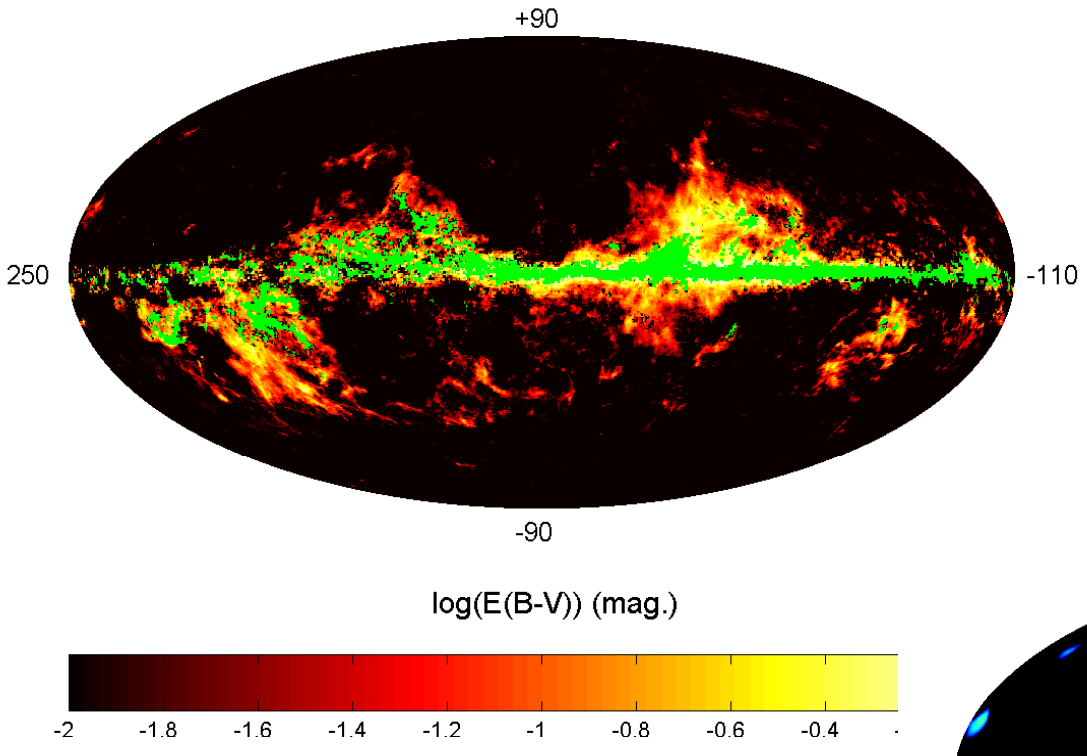
Surface densities ~1/r : Correlation σ_{DM}/σ_{HI}
(Bosma 1981, Freeman 1994, Carignan 1997, Hoekstra et al 2001)

The observed ratio σ_{DM}/σ_{HI} ~10 for spiral galaxies, varies slightly with morphological type, decreases for dwarfs and LSB

➔Is there some baryonic DM?
Could be in the form of clumpy cold H2 gas

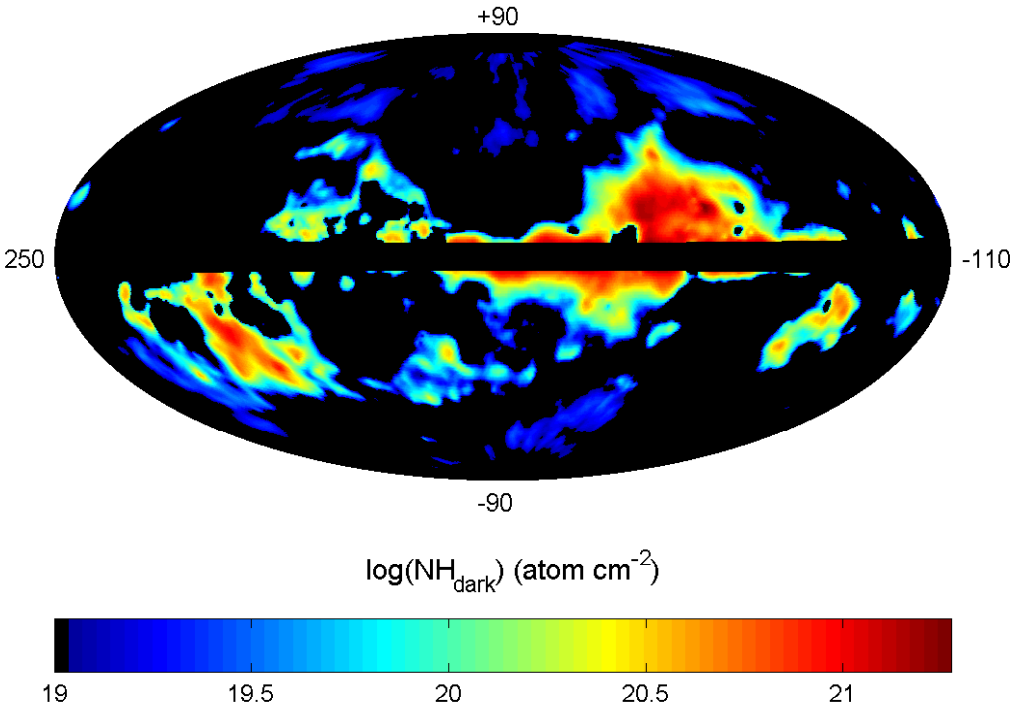
HI gas is the interface with the extragalactic radiation field
Beyond the HI disk, the interface **is ionized**

Dark gas in the solar neighborhood



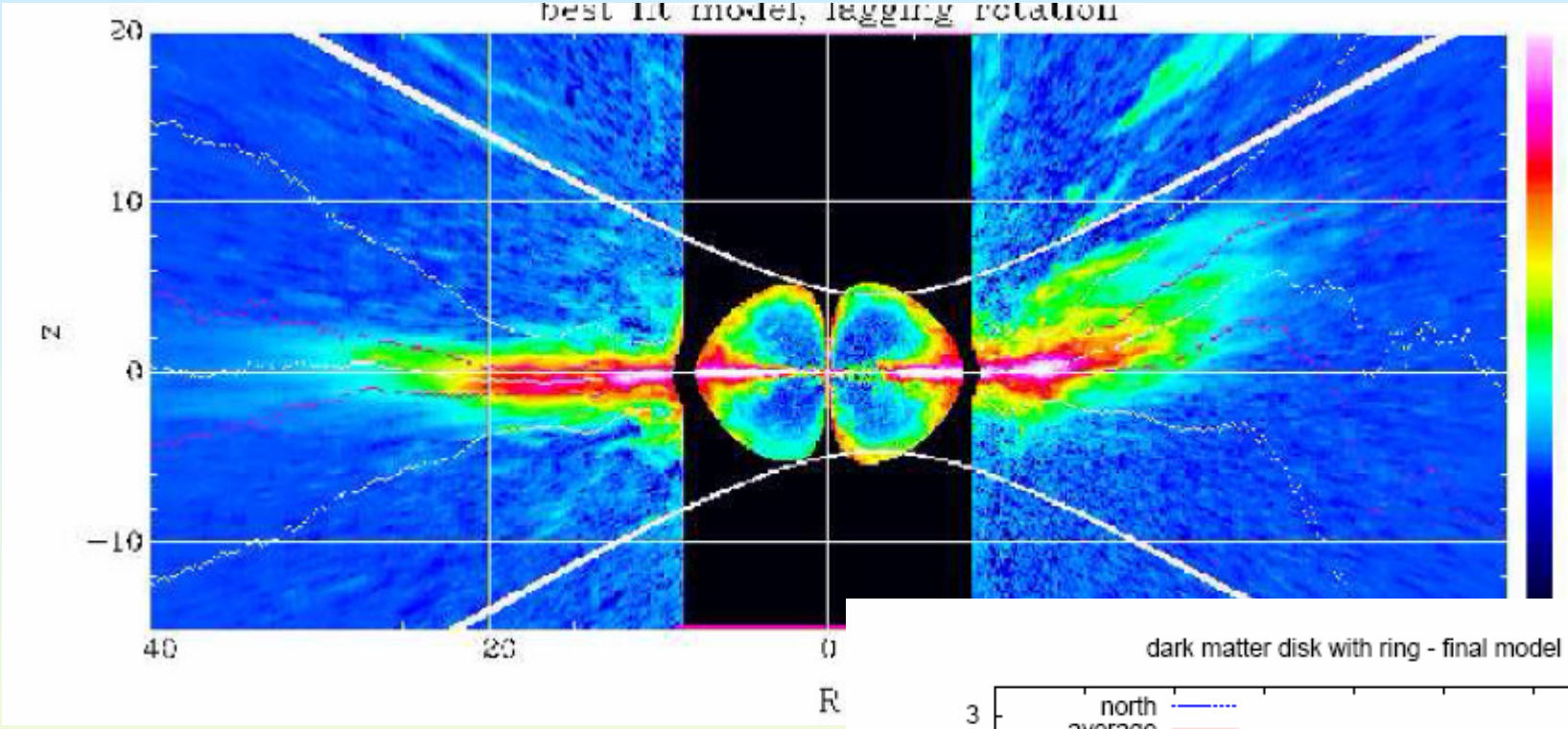
Dust detected in B-V
(by extinction)
and in emission at 3mm

Emission in Gamma associated to the dark gas



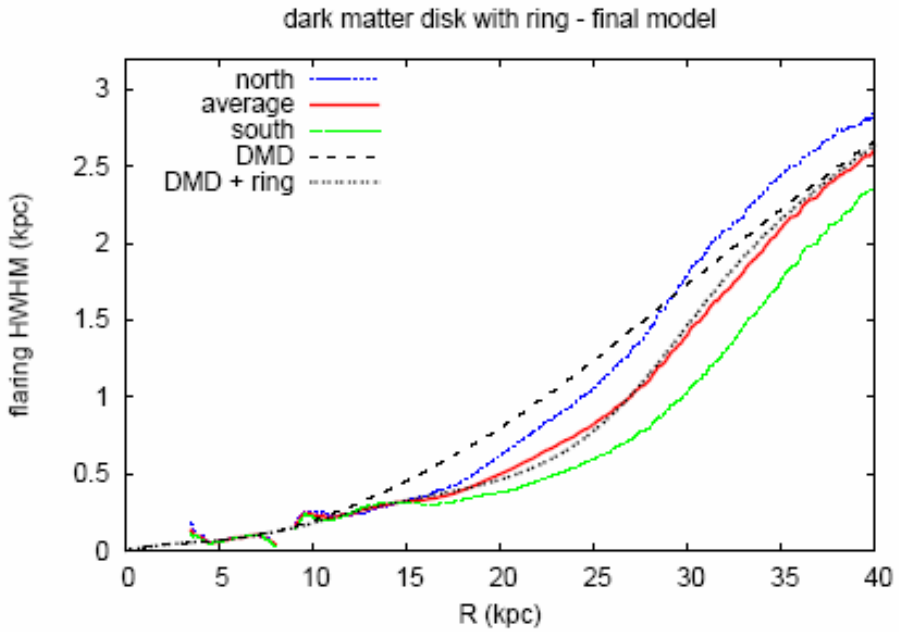
By a factor 2 (or more)
Grenier et al (2005)

Dark matter in the MW disk: HI flaring



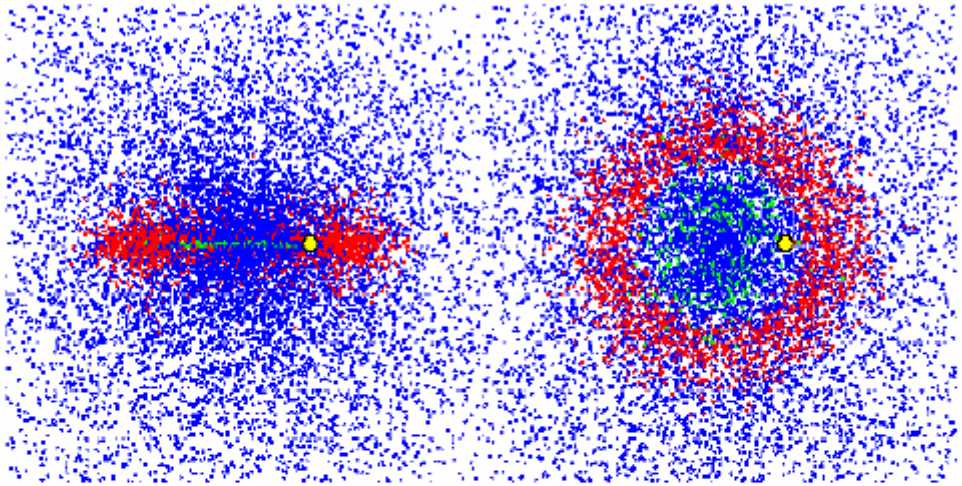
Kalberla et al 2007

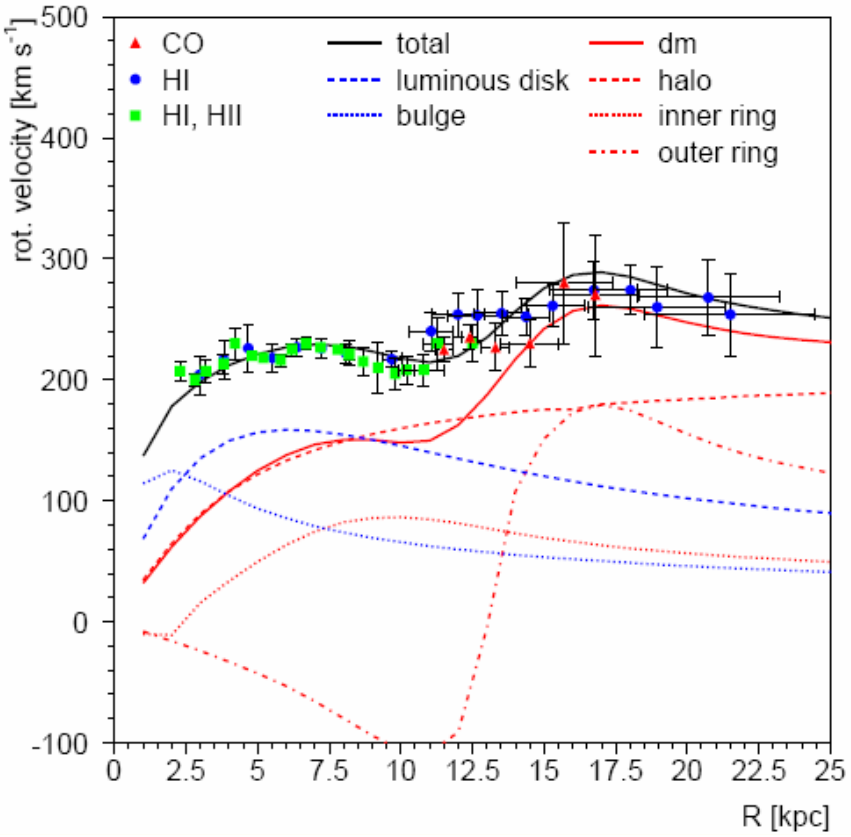
➔The best fit model to account for the HI flaring is dark matter in the disk + DM ring (15-17kpc)
M ~3 10^{10}Mo

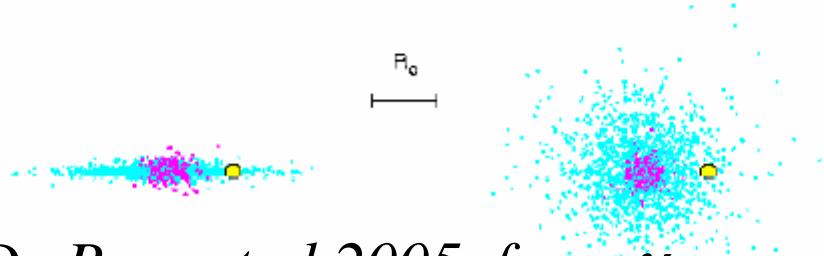


Dark matter rings?

DMA?
(dark matter annhihilation)
Or baryons?





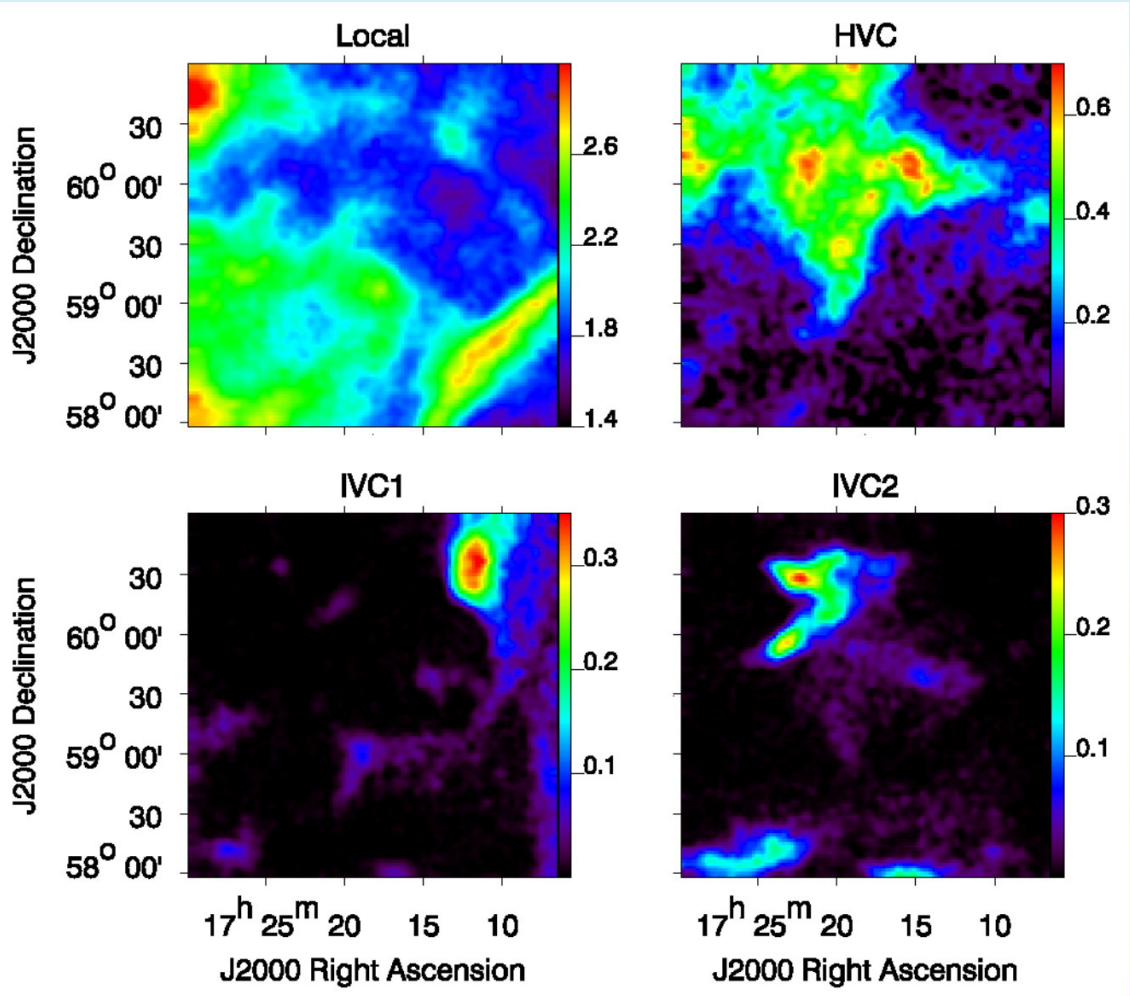


De Boer et al 2005, from γ-rays

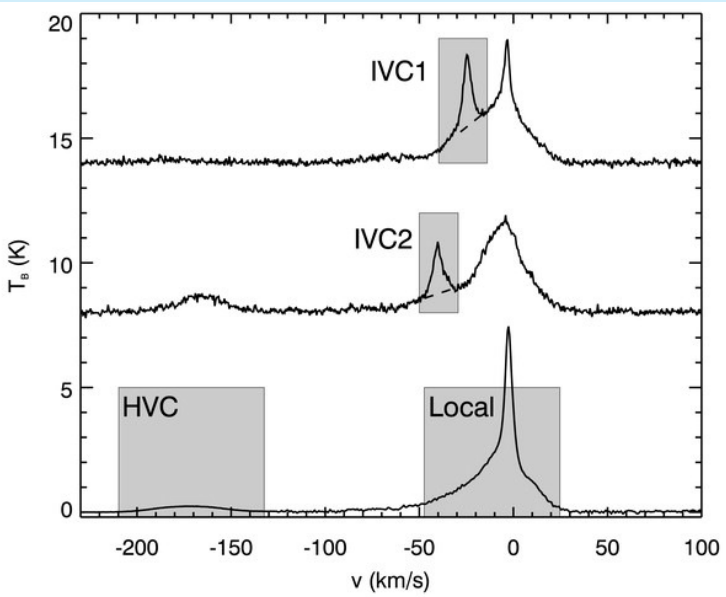
Disrupted dwarf satellites
Since they possess DM,
the DM could also follow streams

High Velocity Clouds infalling onto the Galaxy

HI Maps



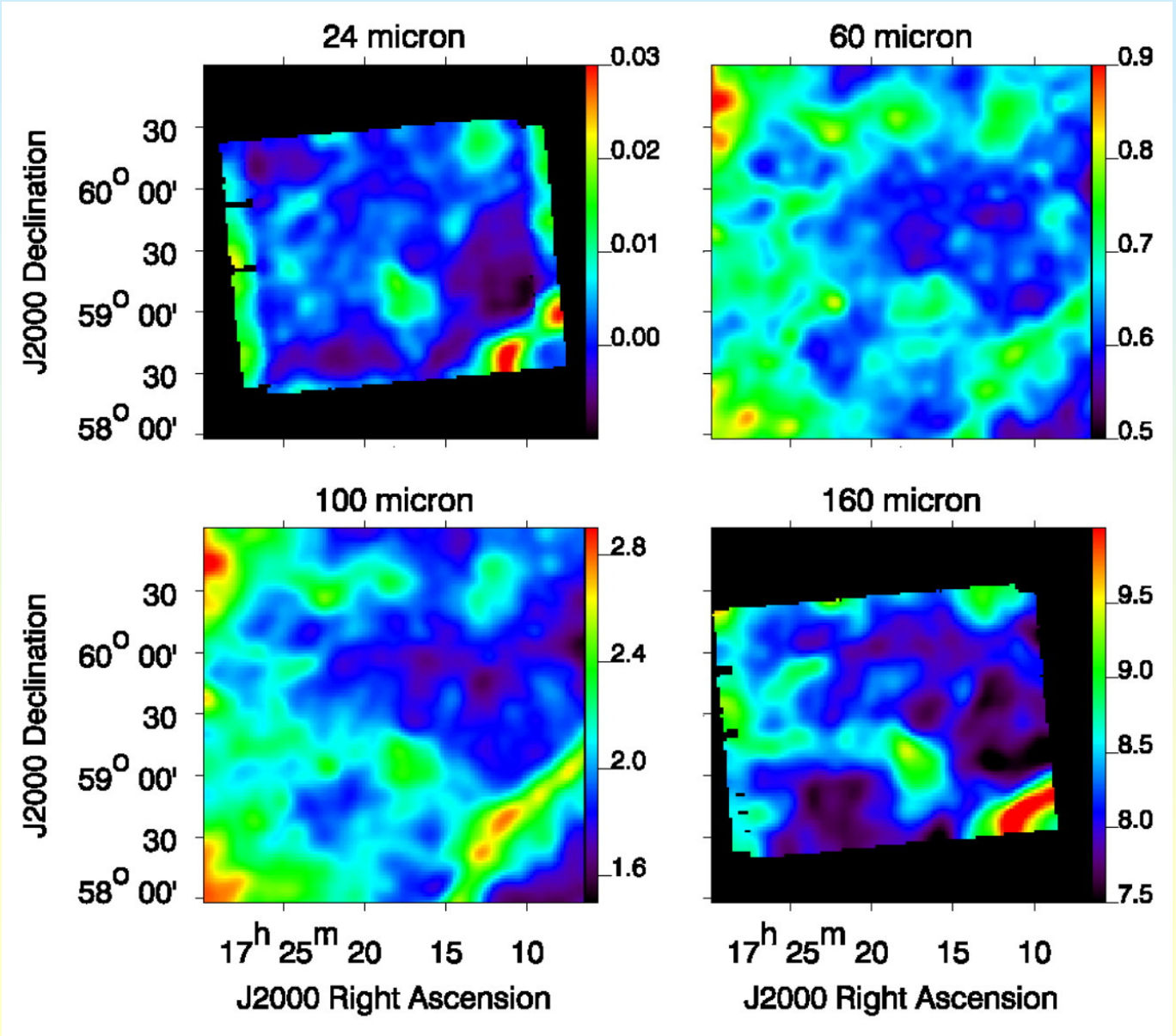
HI Spectra



Lockman and Condon 2005

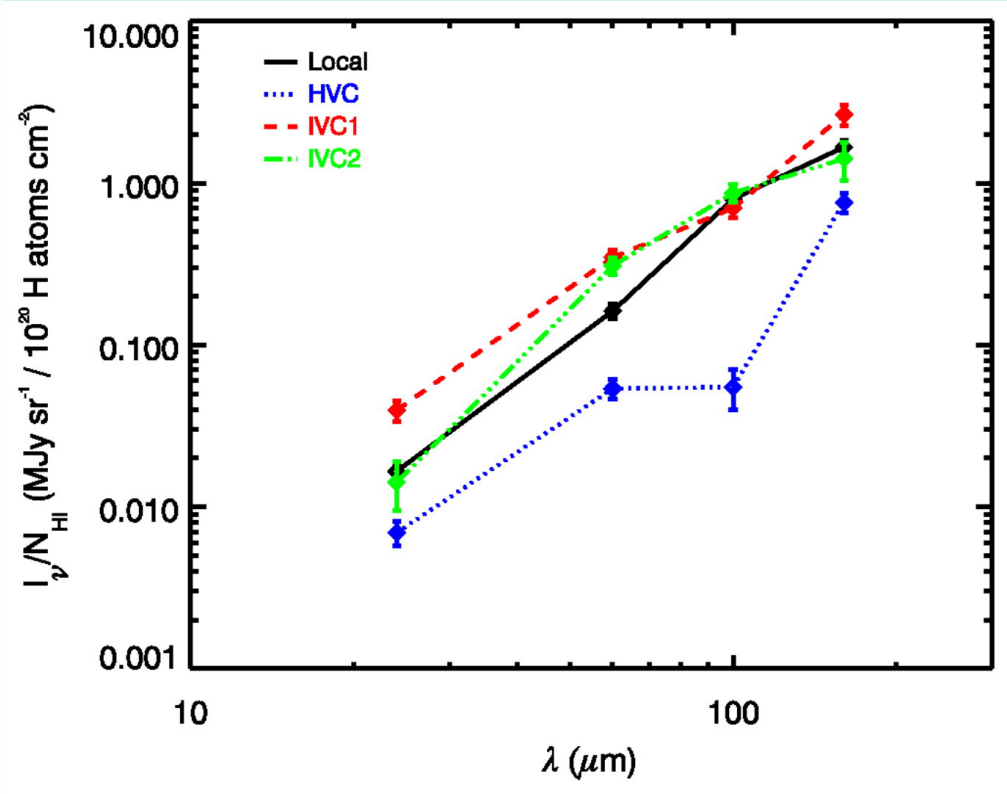
GBT Observations

Spitzer and IRAS Images



Infrared-HI correlation

$$I_\nu(x,y) = \Sigma_i \alpha_\nu^i N_{HI}^i(x,y) + C_\nu(x,y)$$



- Multivariate regression to estimate the infrared emissivity of each HI component.

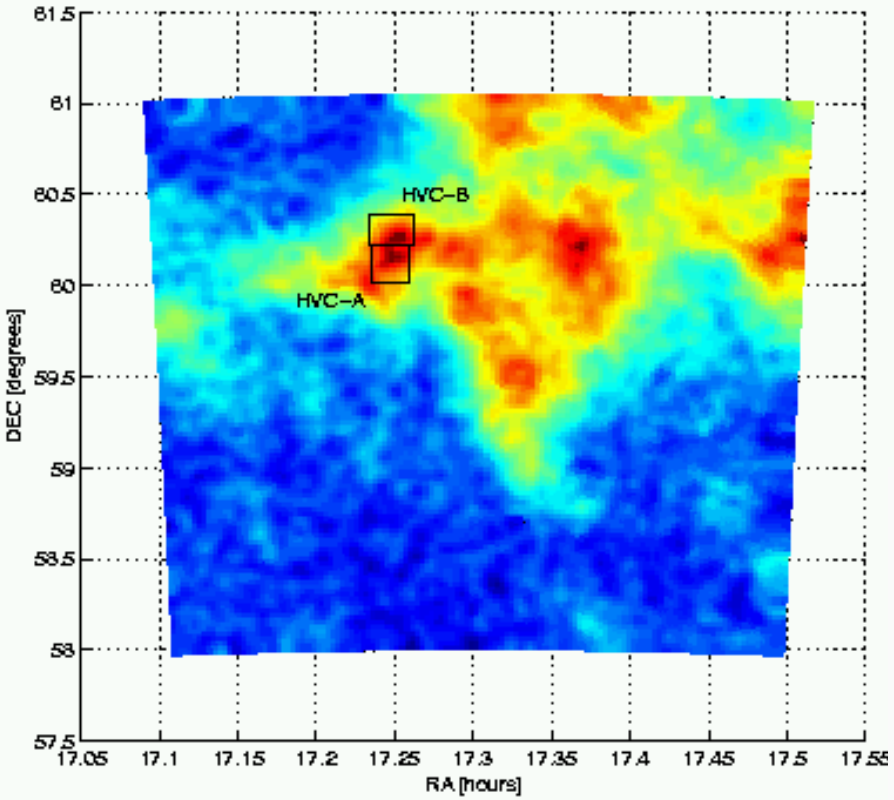
→ First detection of dust emission in the HVC

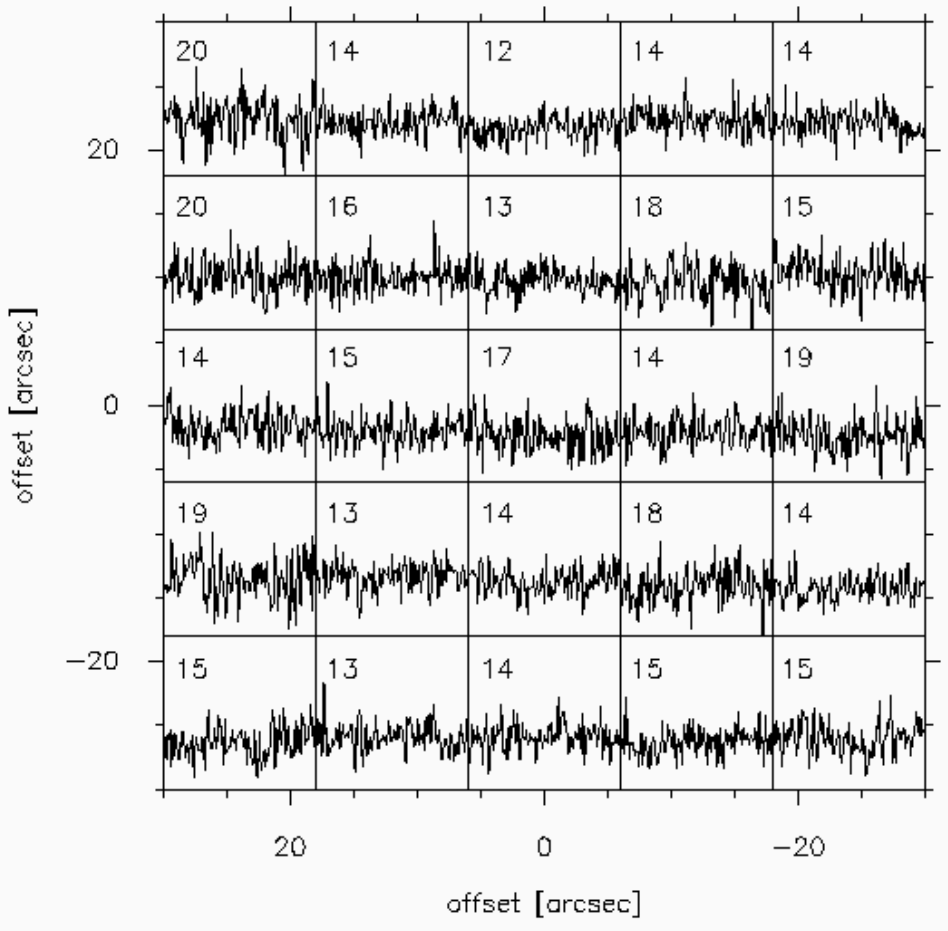
  - HVC Emissivity at **100 μm ~ 10 times smaller** than local gas, but **only a factor 2 smaller** at **160 μ**

  ➔ **Colder dust**

Miville-Deschênes et al 2005

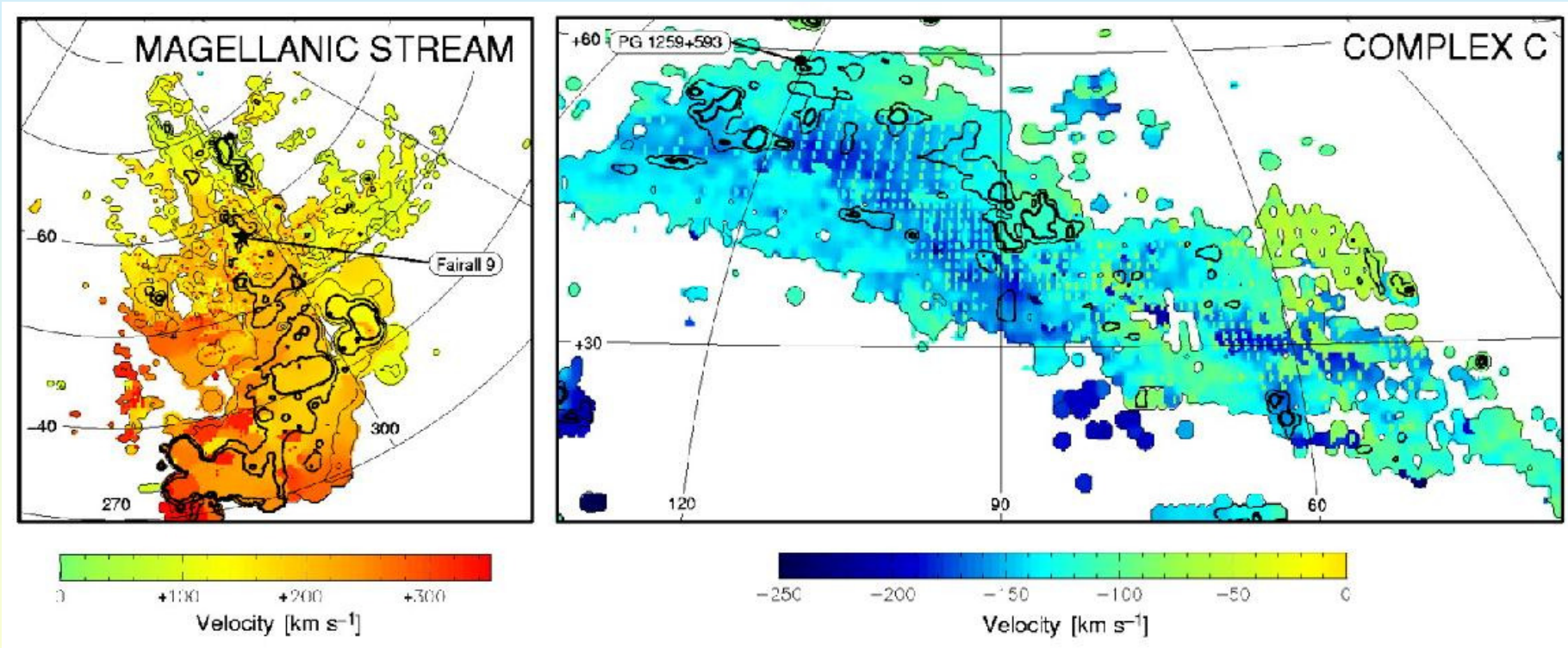
IRAM-30m observations





Dessauges-Zavadsky, Combes, Pfenniger 07

UV H_2 absorption lines with FUSE
16/35 IVCs detected, while 1/19 HVC detected in H_2
Wakker et al 2006

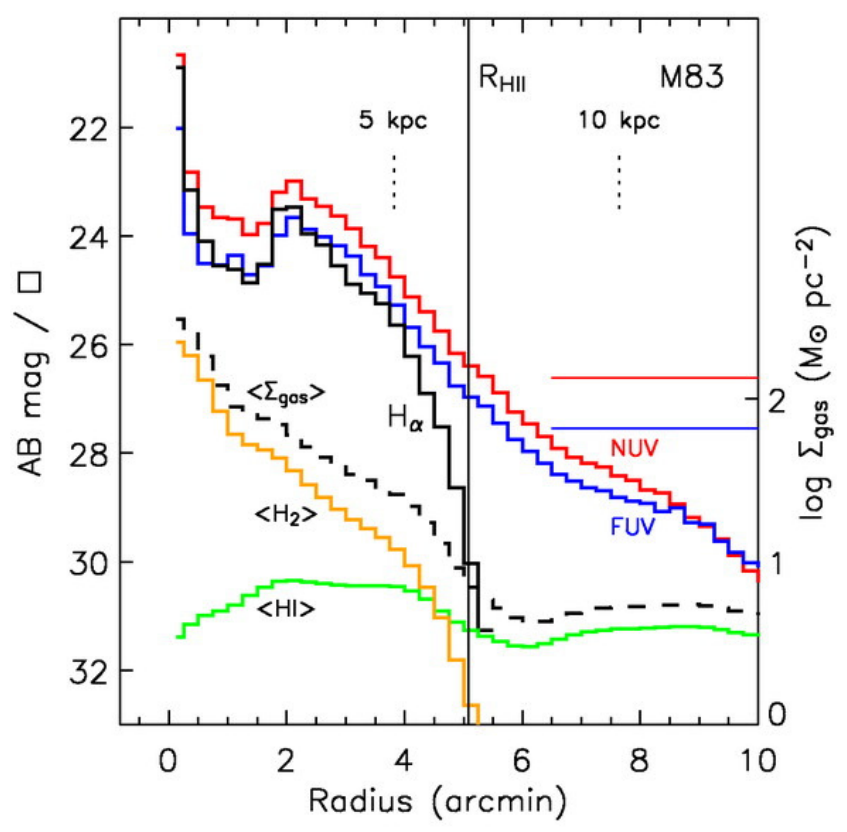


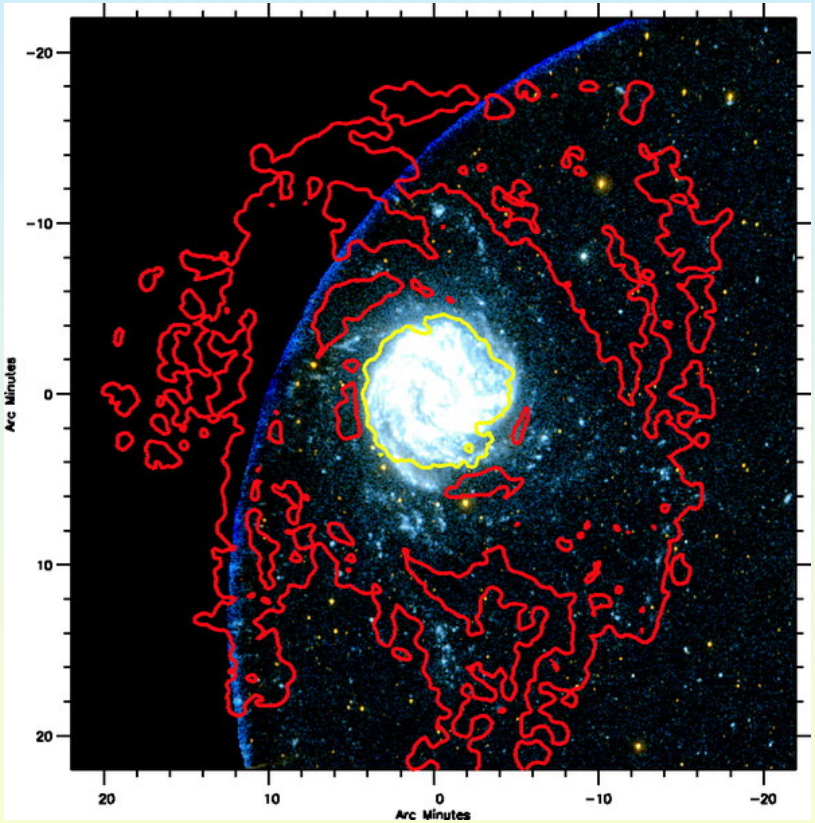
Detection of H_2 in absorption by FUSE in HVCs

Murphy et al (2000), Sembach et al 2001

$N(H_2) = 10^{14} – 10^{20}$ cm^{-2}

Extension in UV (GALEX)
XUV disks, M83 and others



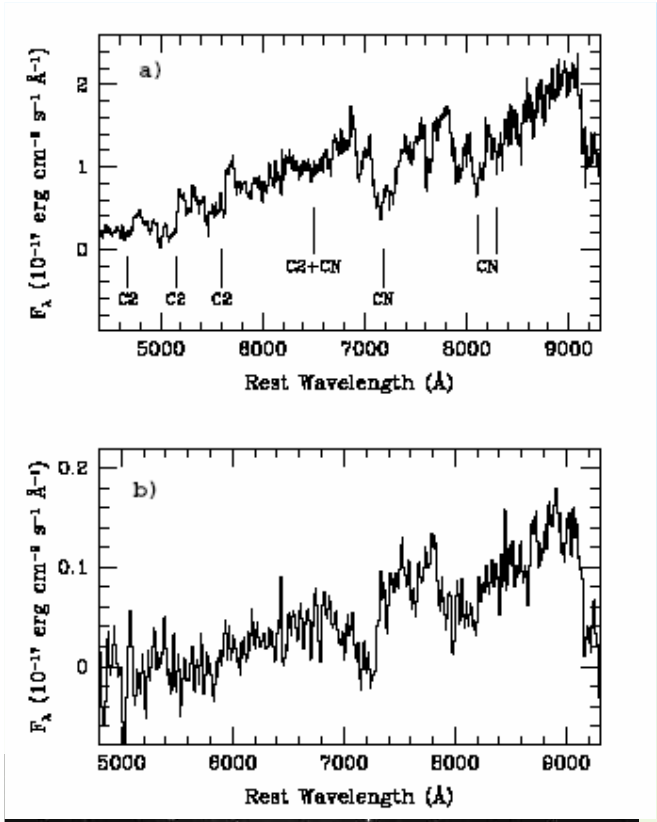


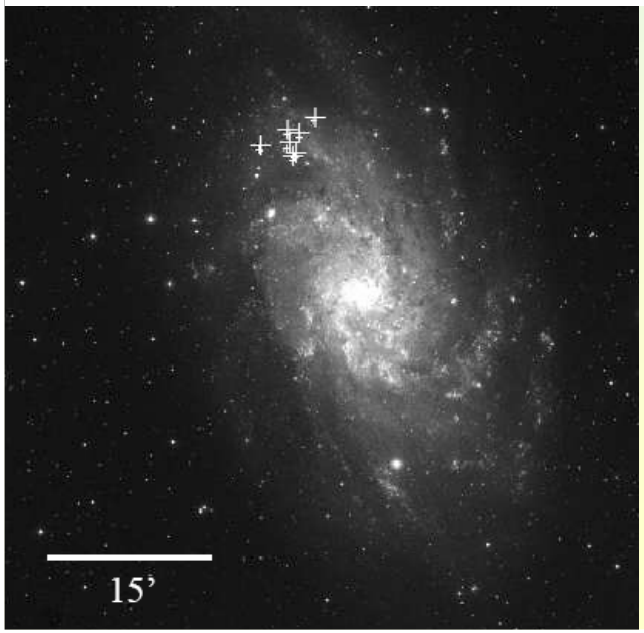
Bluer regions outside
Younger SF + scattered light

M83, Galex, +HI contours (red)
Thilker et al 2005
Yellow line RH_{II}, $10M_o/pc^2$ in HI

AGB Carbon Stars in M33

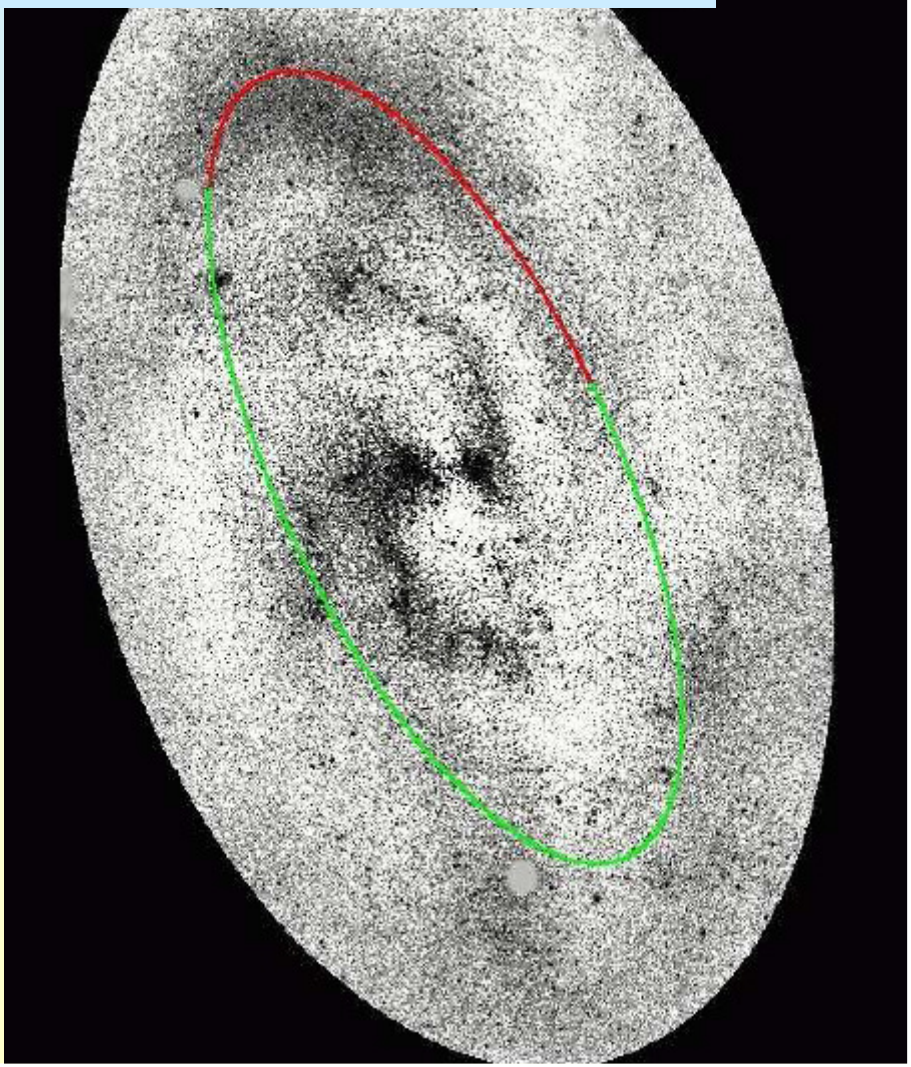
intermediate age (0.6 Gyr - 2 Gyr)

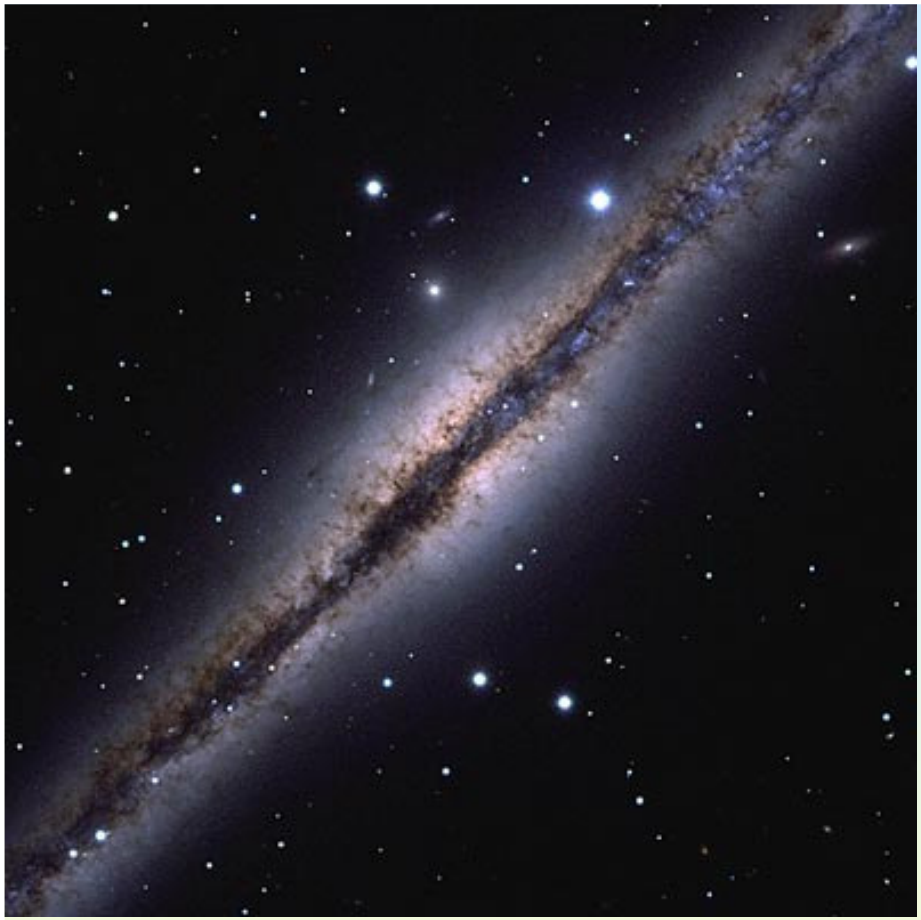


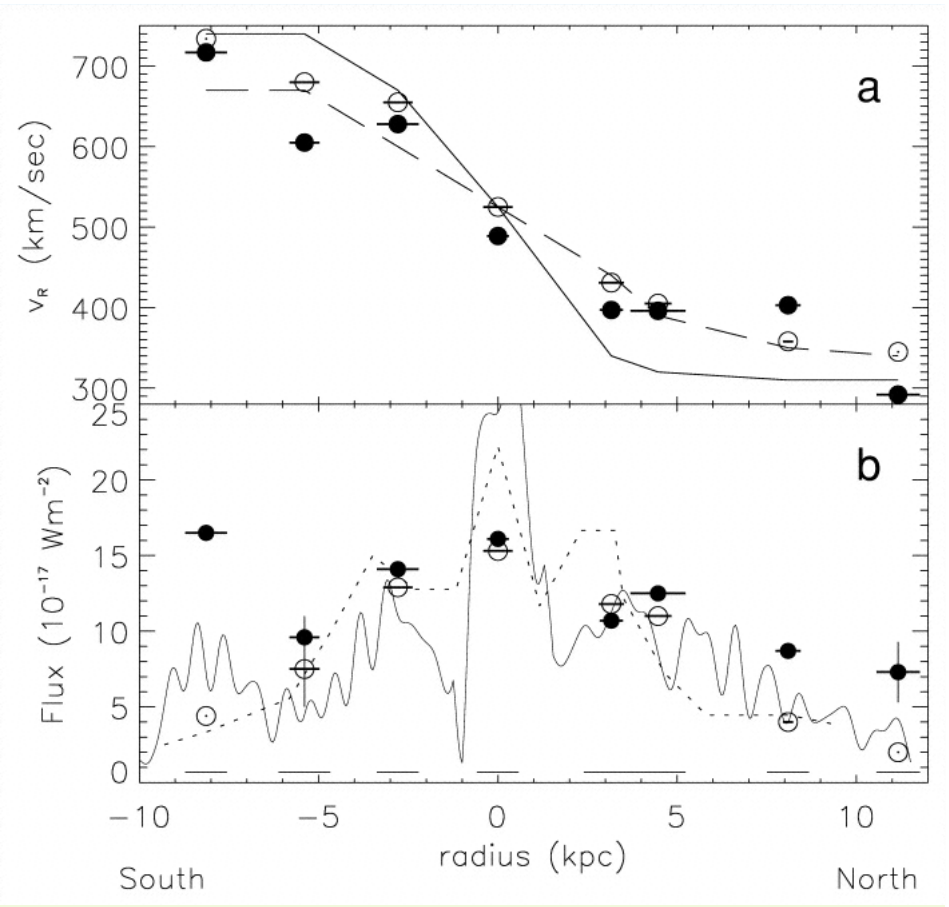


Block et al 2007

➔ Recent accretion of gas







Pure rotation lines of H_2

H_2 distribution in NGC891 (Valentijn, van der Werf 1999)

S(0) filled; S(1) open – CO profile (full line)

Derived $N(H_2)/N(HI) = 20$ ➔ **Dark Matter**

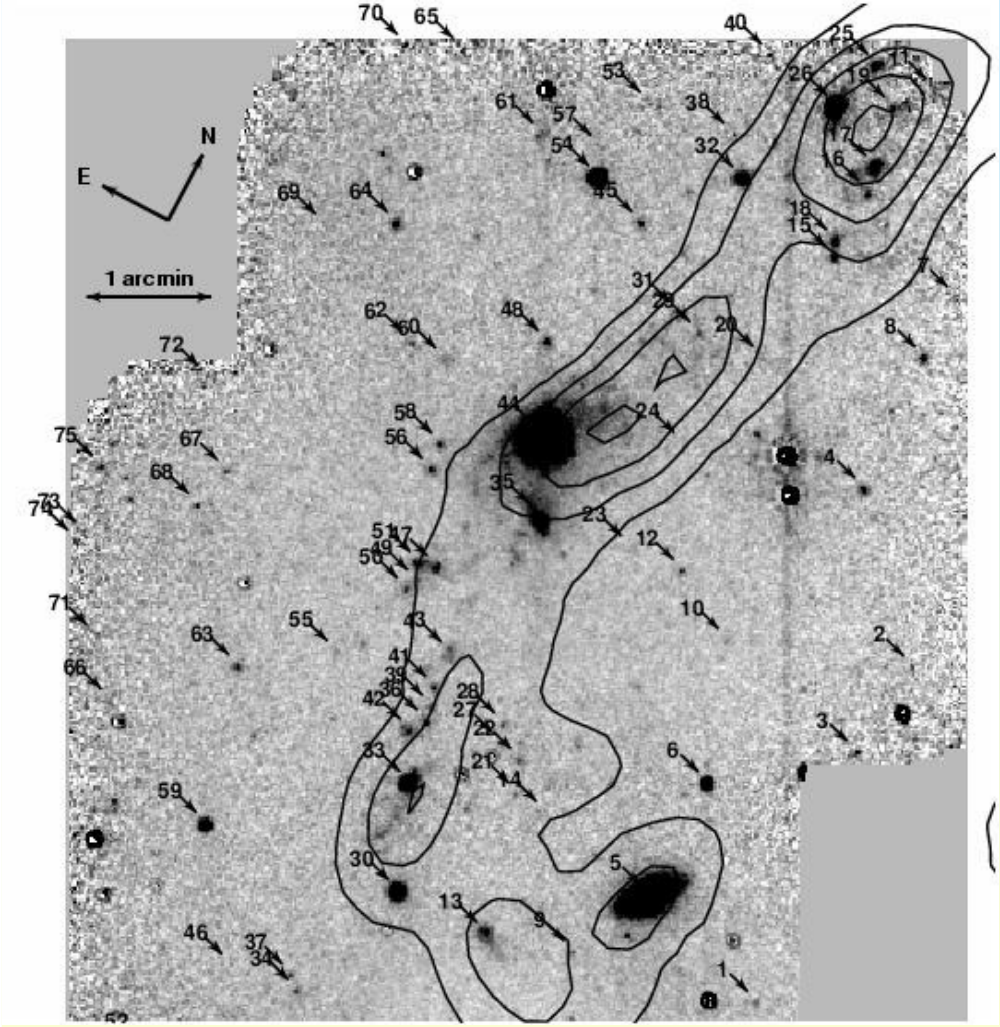
H_2 line detection in Tidal Dwarf Galaxy (TDG)

S. Higdon et al (2006)
two tidal dwarfs: NGC5291 N/S
H_2 detected, 0.1% of H_2 inferred from CO
14 mins = 840 s exposures

S(0) 28.22μ	$<1.7 \quad 10^{-22}$ Wcm^{-2}	< 1.7
S(1) 17.03μ	$1.1\pm0.4\ 10^{-22}$ Wcm^{-2}	1.3 ± 0.3
S(2) 12.28μ	$1.9\pm0.8\ 10^{-22}$ Wcm^{-2}	0.9 ± 0.4
S(3) 9.66μ	$2.2\pm0.9\ 10^{-22}$ Wcm^{-2}	1.6 ± 0.5

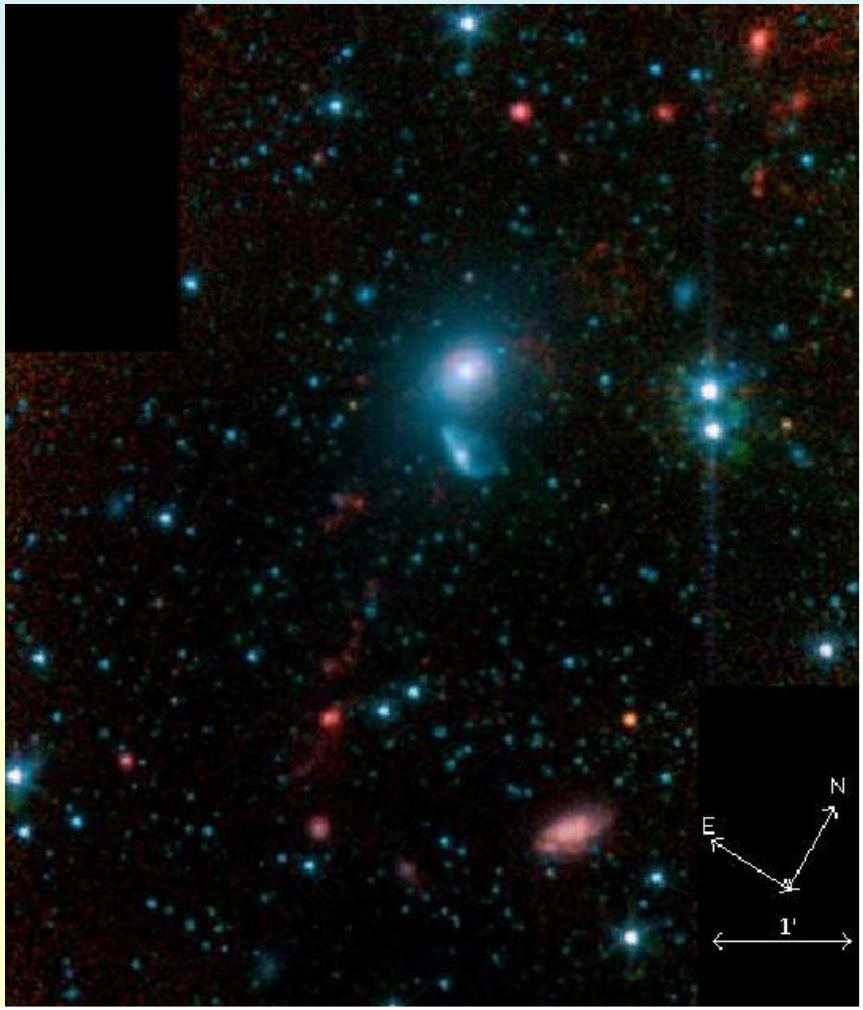
NGC5291 N/S: 460, 400 K
MH_2warm =1-1.5$10^5$ Mo; if colder (150 K): 10^6 Mo

N5291 TDG N and S

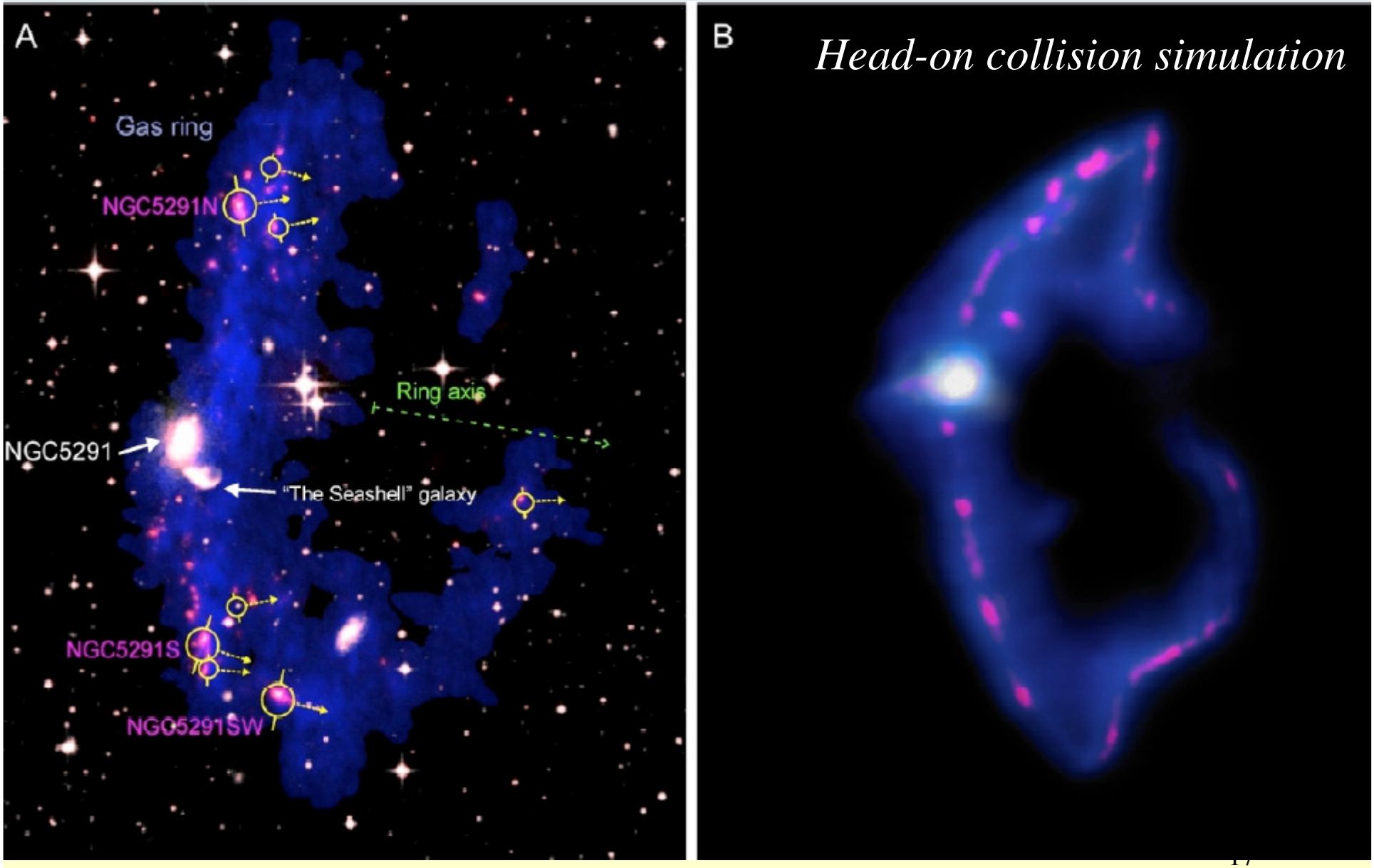


HI VLA contours

IRAC color image
Red: PAH

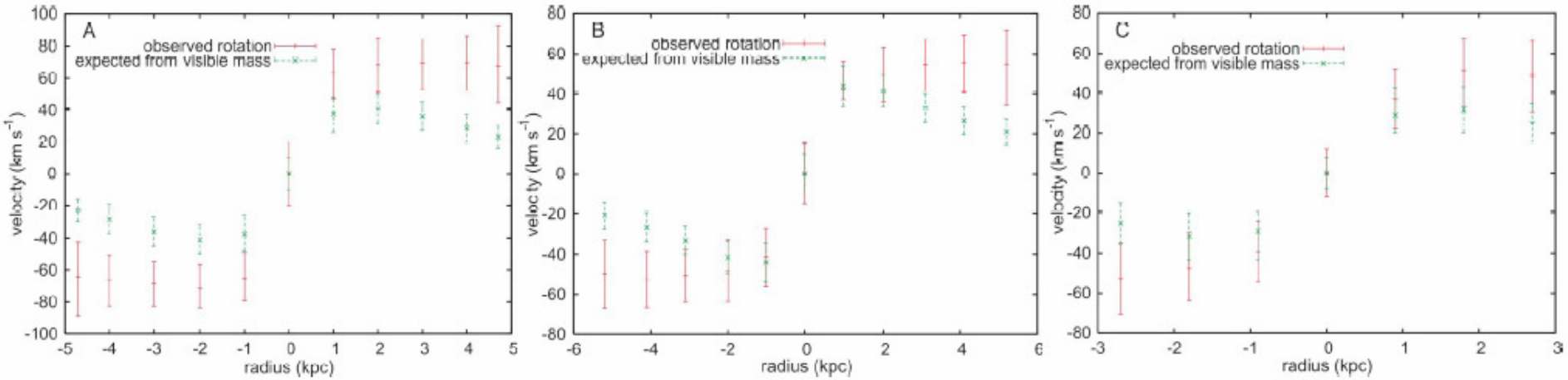


TDG in N5291 HI ring

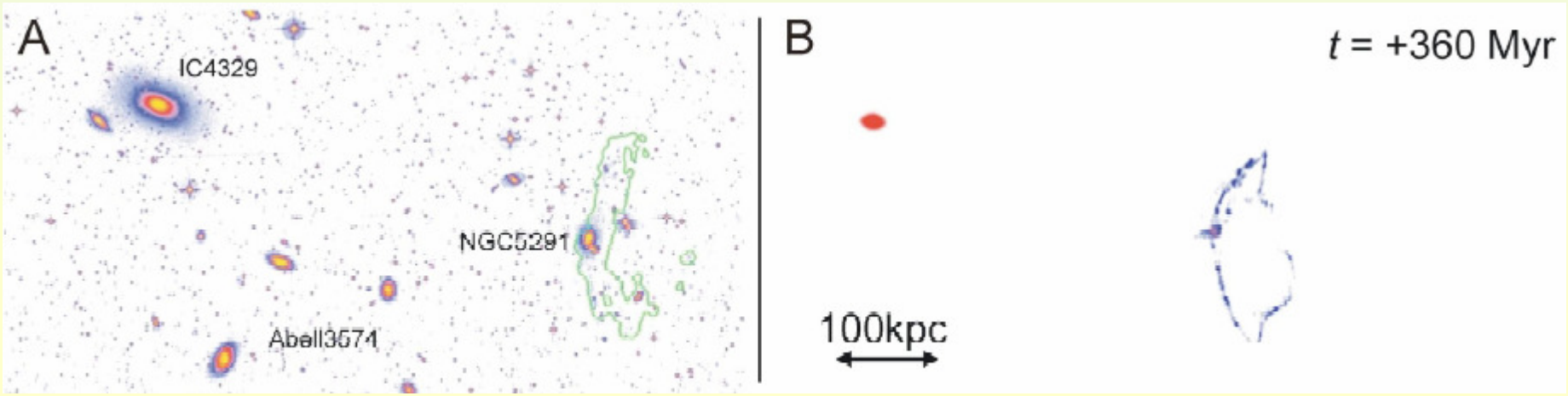


Bournaud et al 2007

Dynamics of the TDGs



All inclinations assumed to be 45°, from simulations (Bournaud et al 07)

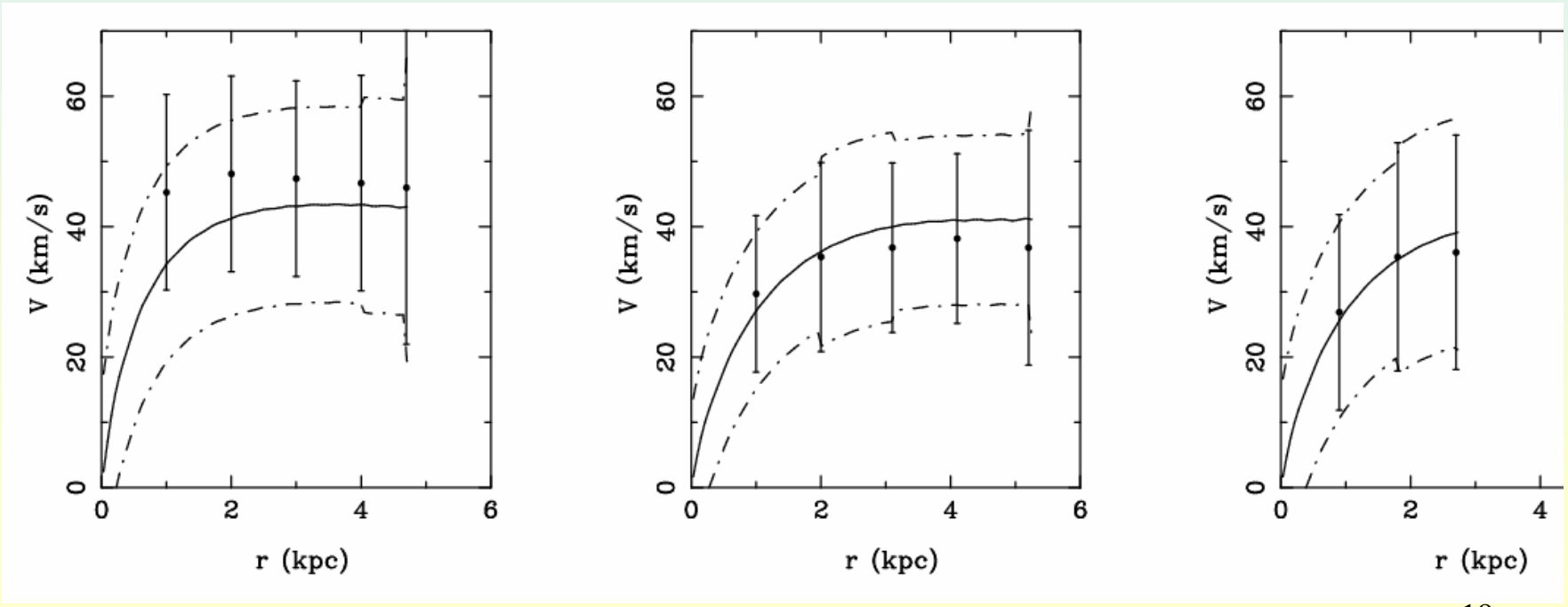


Compatible also with no DM

➔In fact, the inclination could be more edge-on (65-90°)

➔The radial HI distribution is unknown

➔ If 45°, either cold H2, or MOND can explain *(Milgrom 07)*



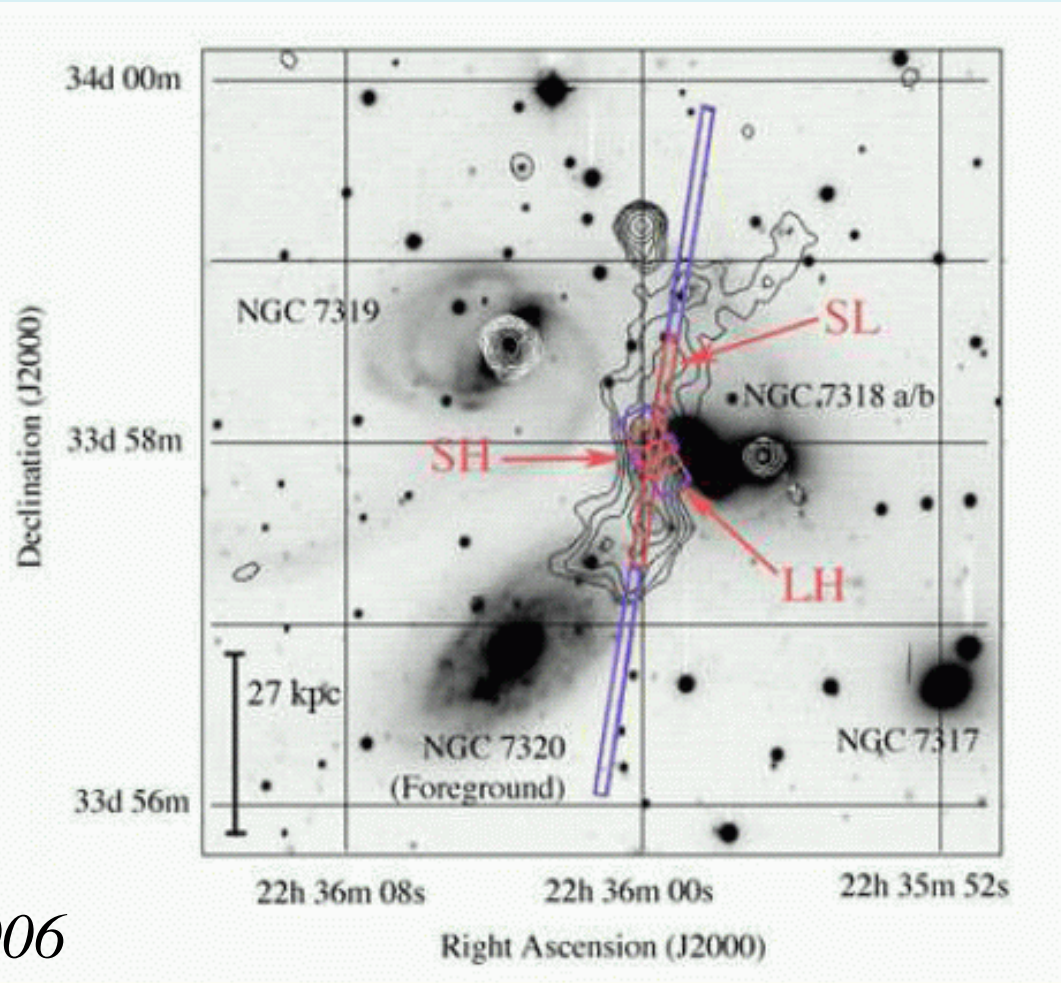
TDG rotation curves accounted for without any DM

H_2 in Stephan's quintet

Stephan's quintet: broad (870 km/s) bright H_2
probably group-wide shock wave
fluxes ~10^{-21} W cm^{-2};

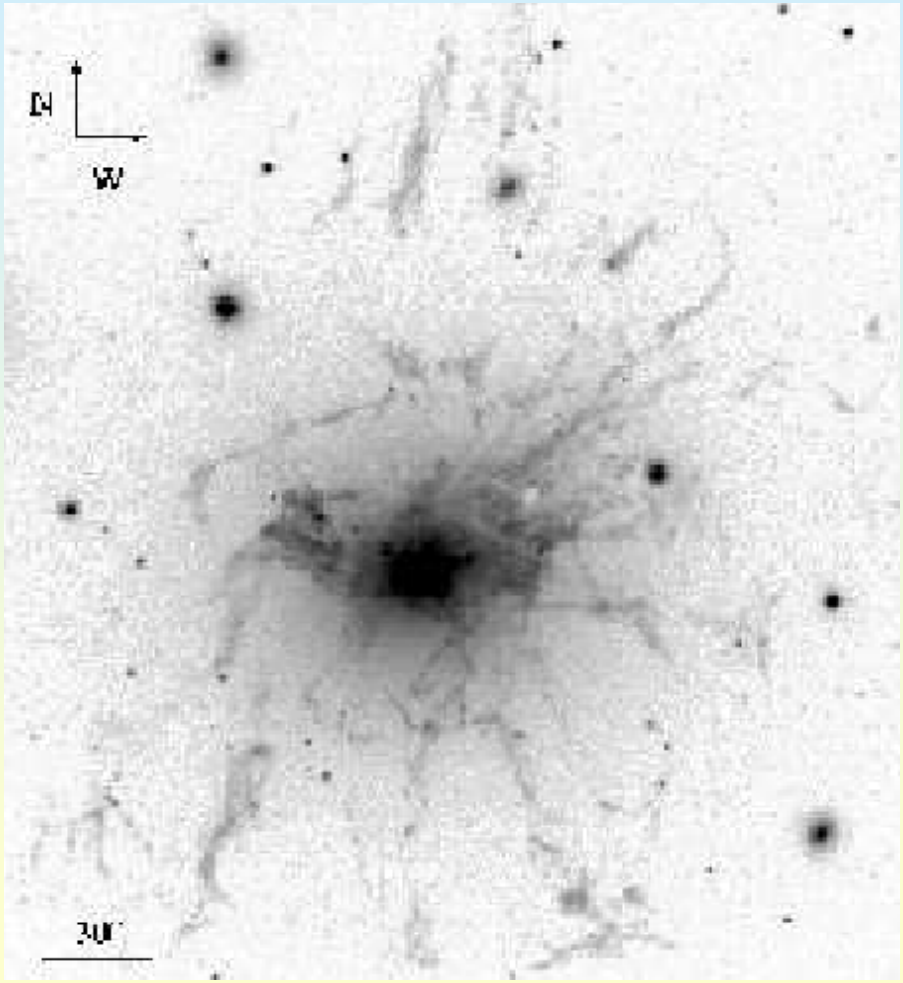
No PAH features,
very low excitation
ionized gas

Shocks when
the high-V intruder
collides with gas filaments
in the group

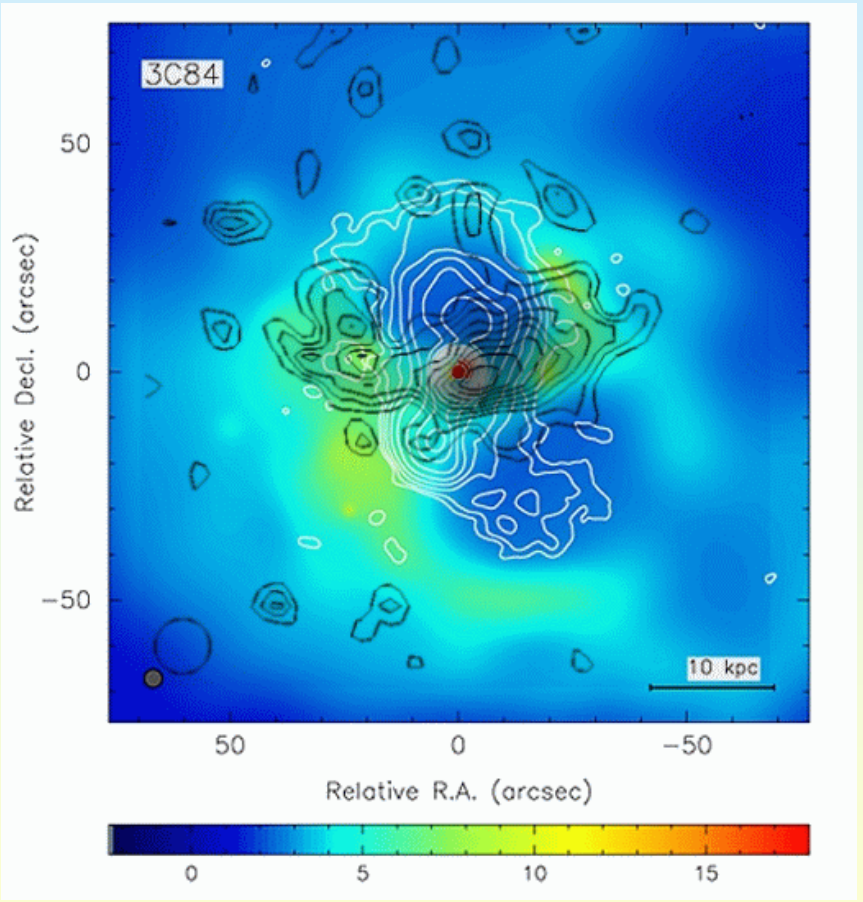


Appleton et al 2006

NGC 1275 Hα (WIYN) and CO (IRAM)

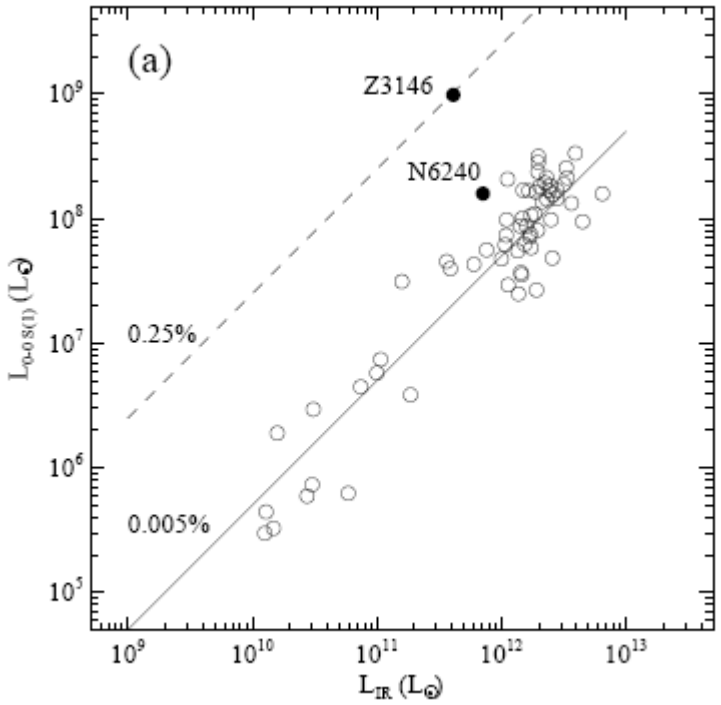


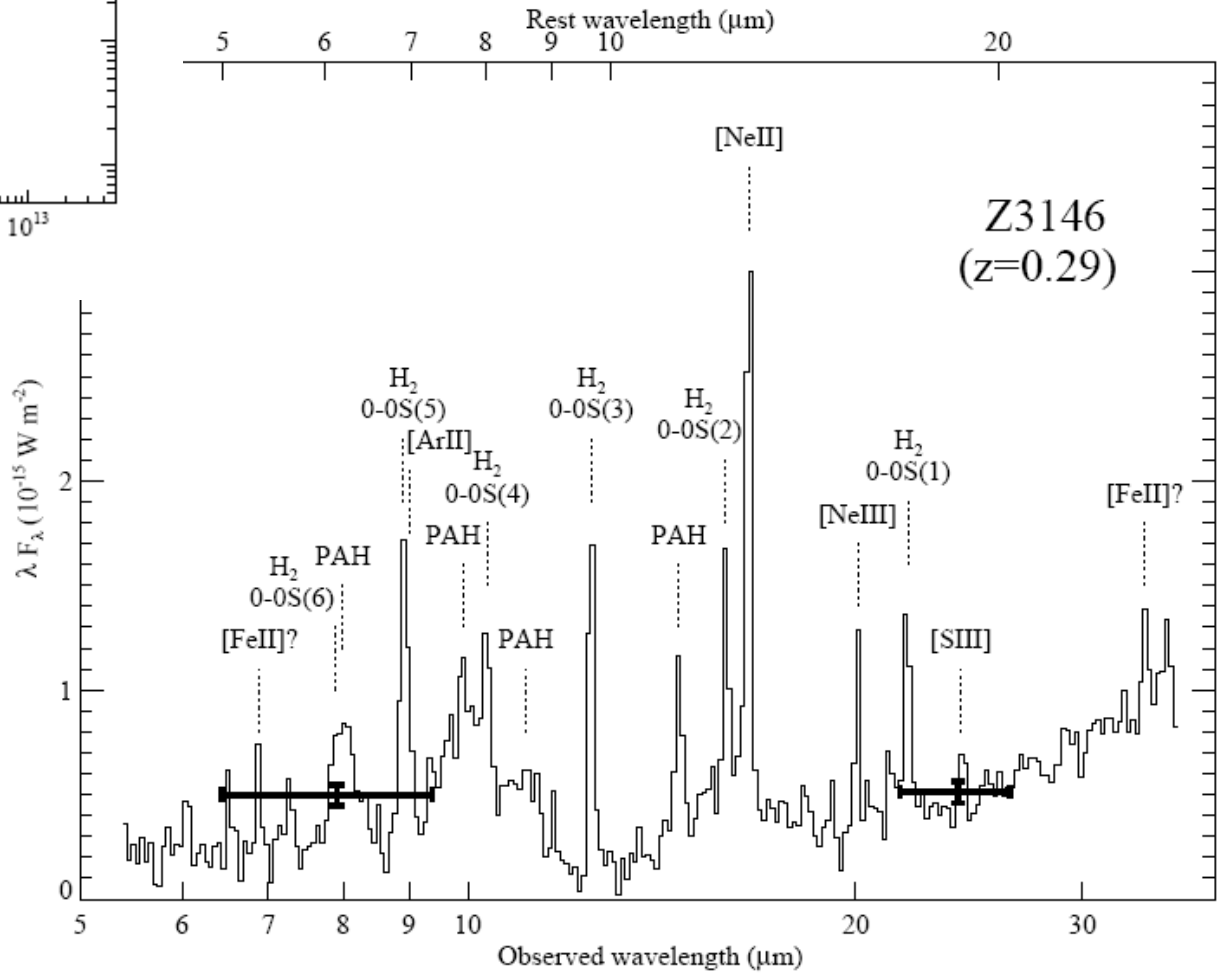
Hα, Conselice 01



CO: Salome, Combes, Edge et al 05
H2 lines : Johnstone et al 2007

H2 in cooling flow clusters





Egami et al 2006

Summary

Baryons and dark matter association in outer disks
Rotation curve wiggles ➔ DM in the disk?

What is the fraction of cold H2 gas?

HVC: too cold or clumpy to be detected?

H2 rotational lines detected in TDG, compact clusters, cooling flows

The H2EX mission: will search for H2 in many environements

H_2* can be considered a tracer of the bulk of molecular gas
In the main disk CO is a tracer, but it fails in the outer parts