



HELGA DÉNES

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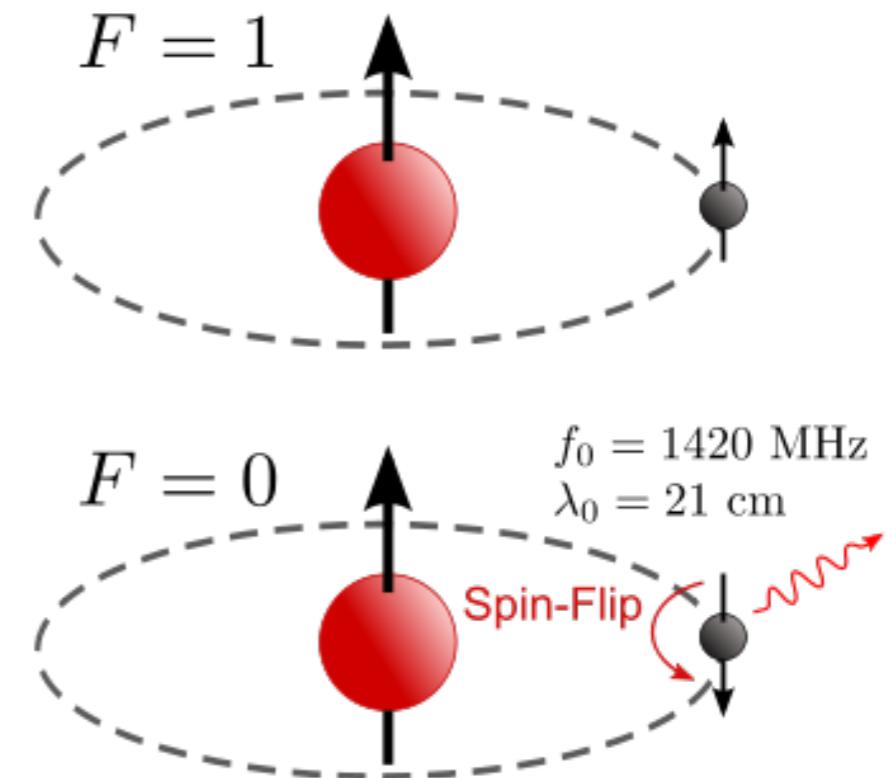
HI IN GALAXIES

AST(R)ON

EPIC 2, 13 OCTOBER 2022

# HI IN GALAXIES

- ▶ Hydrogen is the most common element
- ▶ HI is the **fuel for potential star formation**
- ▶ Late-type star forming galaxies usually have a significant amount of HI
- ▶ HI is a **good tracer of galaxy evolution** - loosely bound at the edges of the disk



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RADIO OBSERVATIONS,  
NOT THE SAME AS OPTICAL

# 2 TYPES OF RADIO TELESCOPES

The resolution of a telescope depends on its size and the wavelength of light that is getting observed.

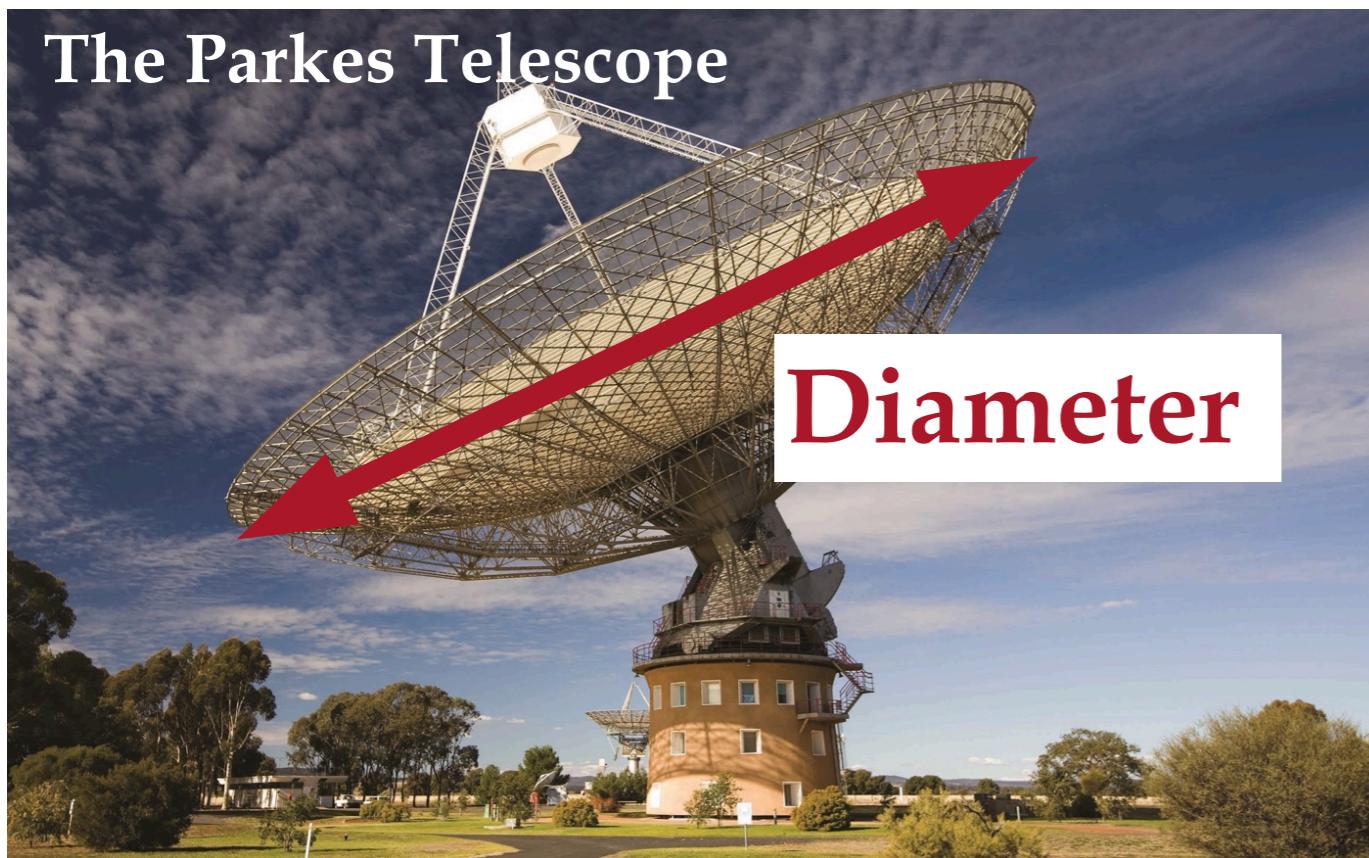
- ▶ This is good for short wavelengths, like UV or optical telescopes
- ▶ But unfortunate for radio telescopes

$$\Theta = \lambda / D$$

$\Theta$  - resolution  
 $\lambda$  - wavelength  
D - diameter/baseline

## Singel dish telescopes:

Resolution: ~ Diameter



## Interferometers:

Resolution: ~ distance between telescopes



# OBSERVING WITH ATCA

## ATCA - Australia Telescope Compact Array

The telescope observes voltages as a function of frequency, which gets digitalised.

For an interferometer the digital data from the individual telescopes gets correlated in a computer cluster.

The image shows a desktop environment with several open windows:

- PGPLOT Window 1:** Displays three panels of data: Amplitude (top), Phase (middle), and Delay (bottom). The x-axis represents frequency in MHz (2000 to 2100) and the y-axis represents amplitude or phase in dB. The title bar indicates "Ants: 123456" and "Freq: 2100, & 2100".
- caobs:** A terminal window showing the CAOBS Linux V4.0 interface. It displays a log of observations for project 0058-7413, including frequencies (2100.0 MHz), channel bandwidths (1.0 MHz), and scan times (from 02:50:59 to 03:20:40 UT). It also shows the status of tracking (75 tracking cycles) and various parameters like SETA and Drive times.
- assistance:** A window showing CA online assistance version 3.0. It lists parameters such as Name (0058-7413), End (17 m), UT, RA (00:57:32.50), Dec (-74:12:43.0), Az (194.1), El (41.2), and LST.
- ATDRIVEMON:** A window showing the status of six antennas (CA01 to CA06). All are listed as "TRACKING". It includes fields for STATE, AZIMUTH, ELEVATION, AZ ERROR, EL ERROR, and COLOUR. Below the table are small images of each antenna.
- DELAGV:** A window titled "DELAGV: F1: 200,950 F2: 200,950". It contains tables for TSYS, SAMPLERS, F1 DATA LINKS, F2 DATA LINKS, F1 DSP BRDs, and F2 DSP BRDs. The TSYS table shows values for various frequency bands (F0 to F6).
- MONDATA:** A window displaying log messages for MONDATA, OLDTCYCLE, NEWTCYCLE, and DELBAT. These messages include details about observation parameters like SRCID, PADL, and HDR.
- caccc1:** A terminal window showing network statistics for the interface "caccc1:/home/corr/temp". It includes ping statistics to various hosts (l-bcc12, l-bcc32, etc.) and error counts.
- CACOR:** A window titled "CACOR Version 2014-04-18\_14:22 Archive: RPFITS". It shows a configuration table with entries for "corr on caccc1: /home/corr/temp" and "corr on caccc1: /home/corr/temp".

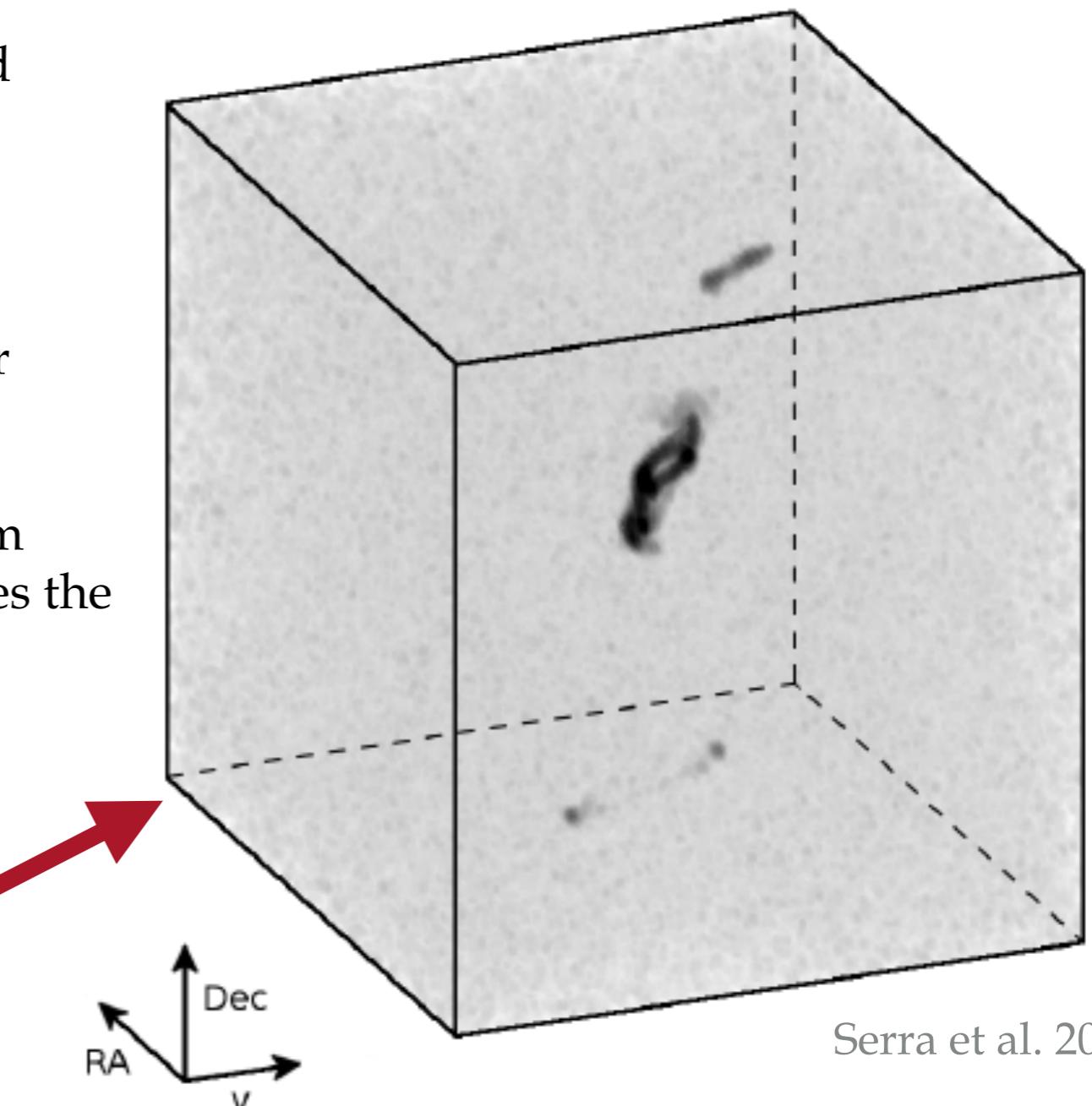
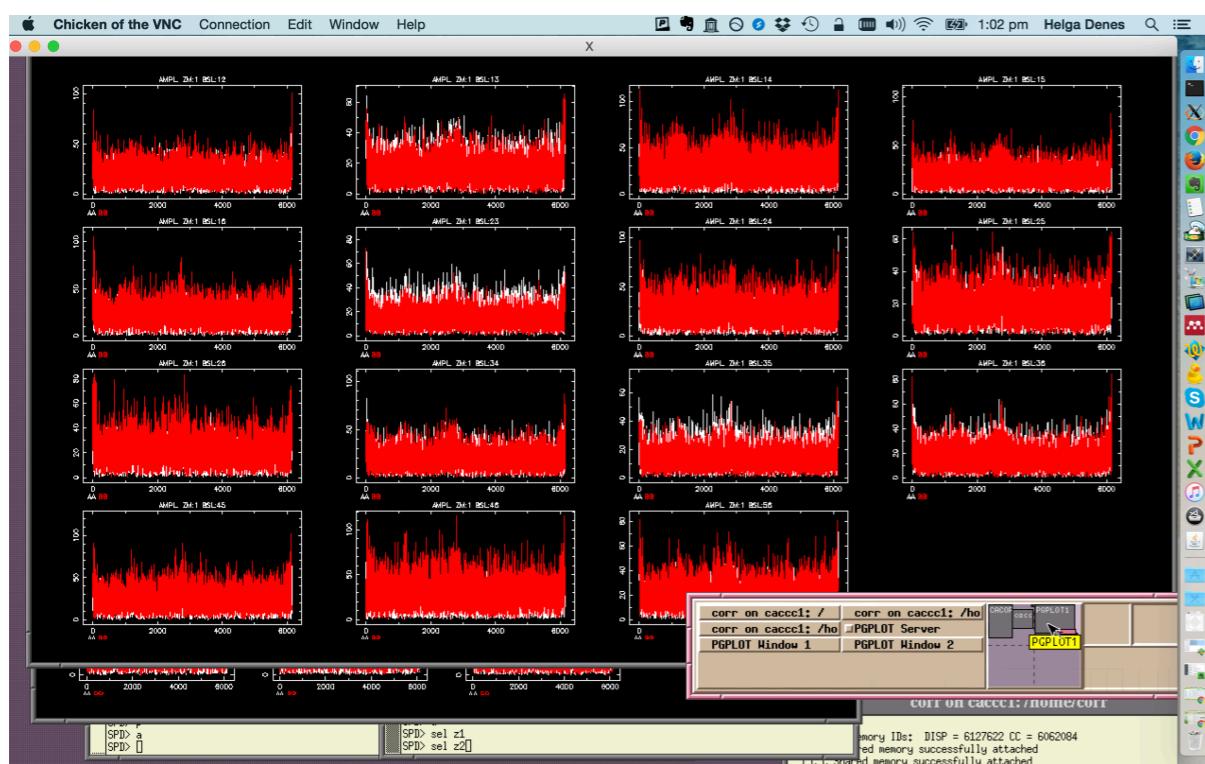
At the bottom of the image, there is a photograph of the Australia Telescope Compact Array (ATCA) in a field under a cloudy sky.

# CALIBRATING THE DATA

The raw data needs to be cleaned from RFI and calibrated to the instrument response and to a standard flux scale.

Then data from different angles in the sky is gridded into an image. This is a type of Fourier transformation to produce a raw data cube.

After this the data is cleaned, with an algorithm that iteratively models the signal and minimises the noise.

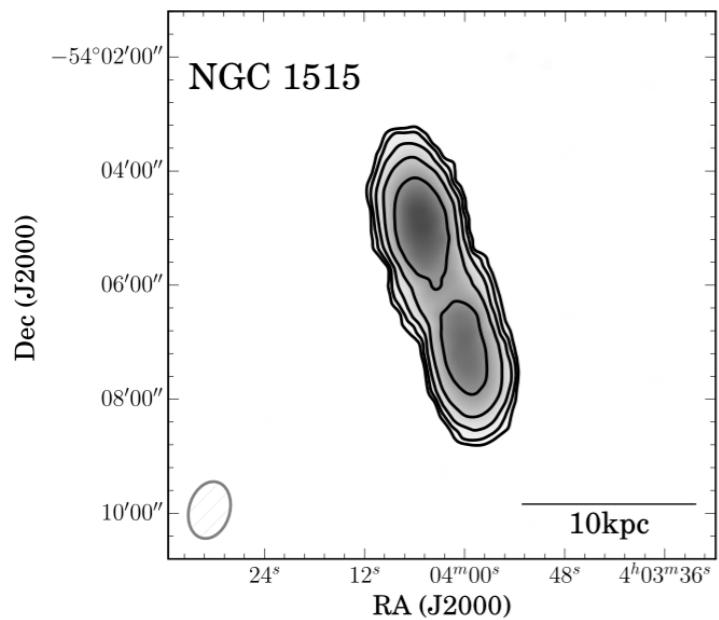


Serra et al. 2015

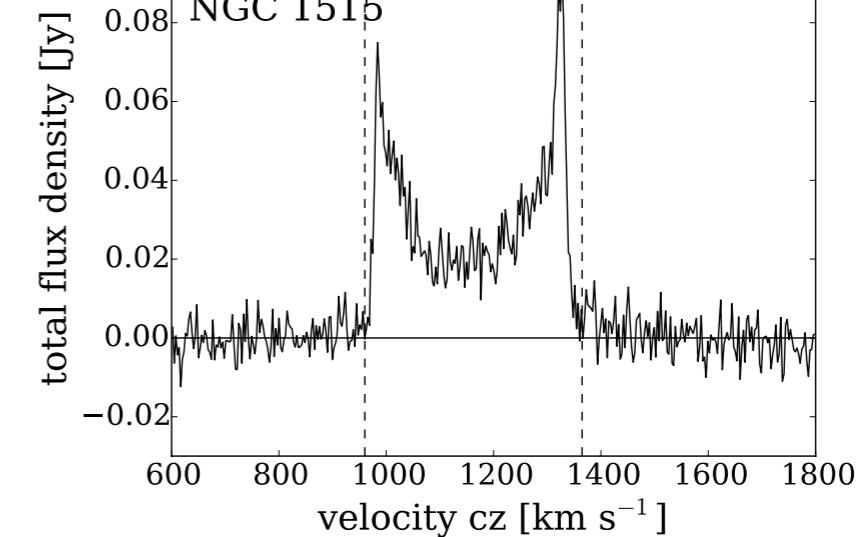
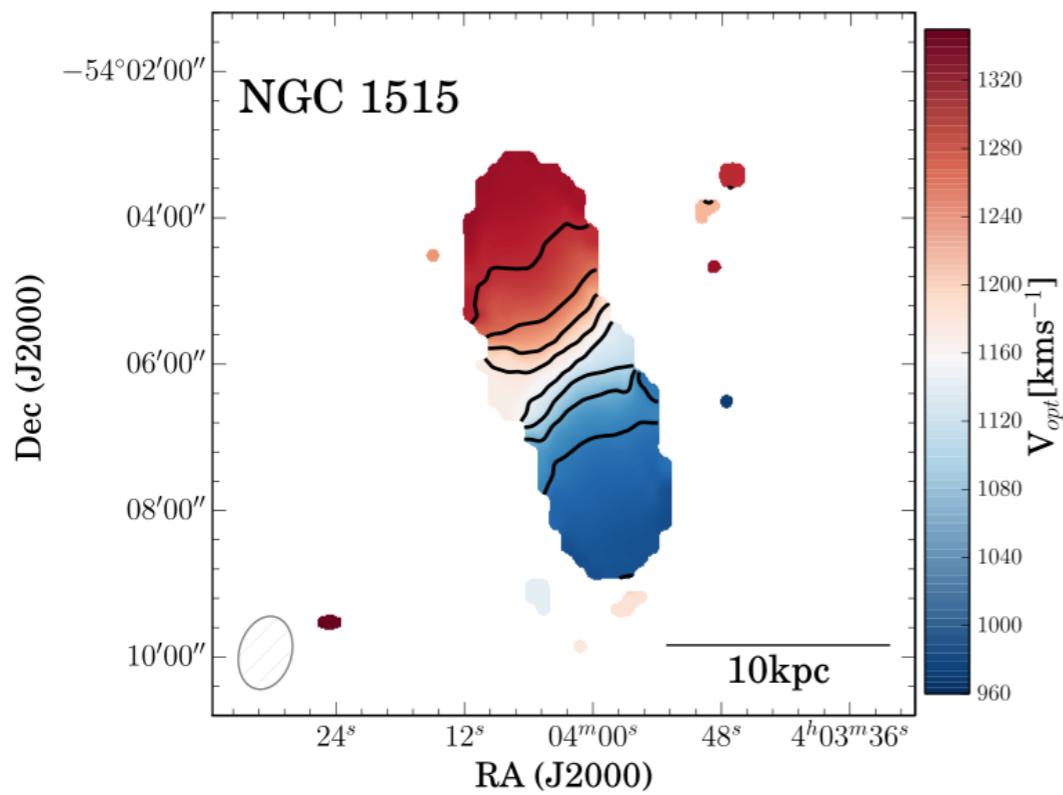
# THE FINISHED DATA

## HI line profile

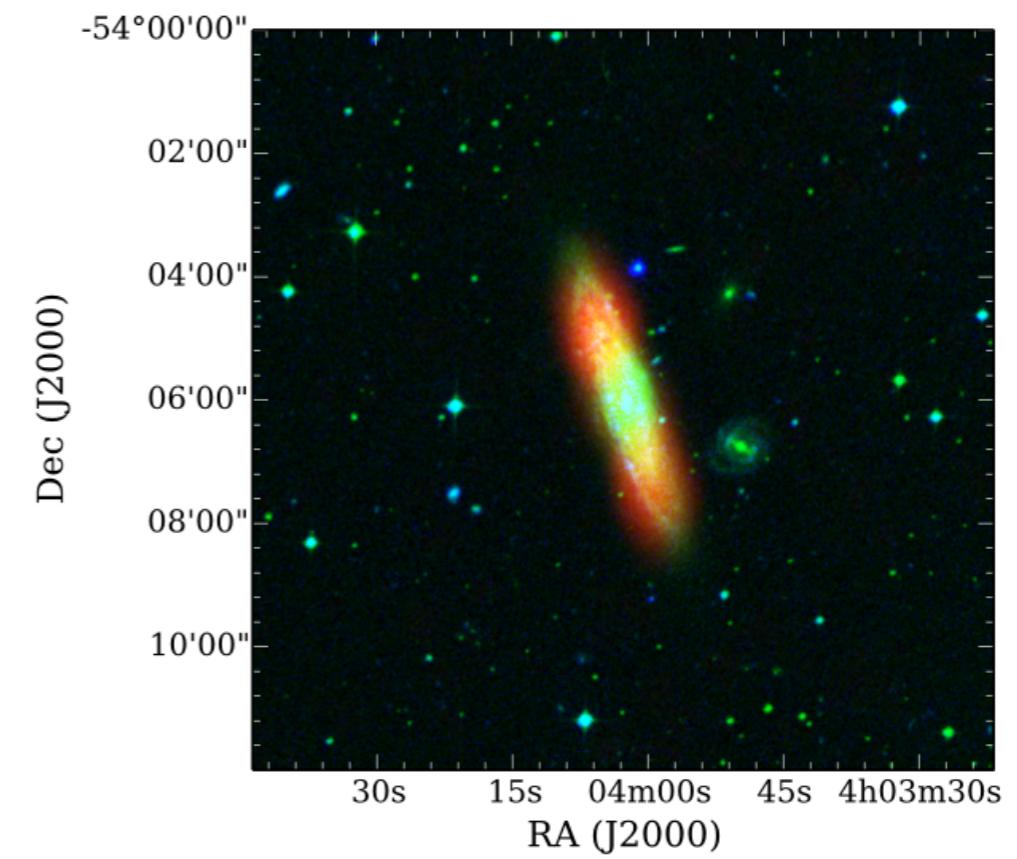
**HI intensity**



**HI velocity field**



**HI, optical and UV data**



# GALAXY TYPES

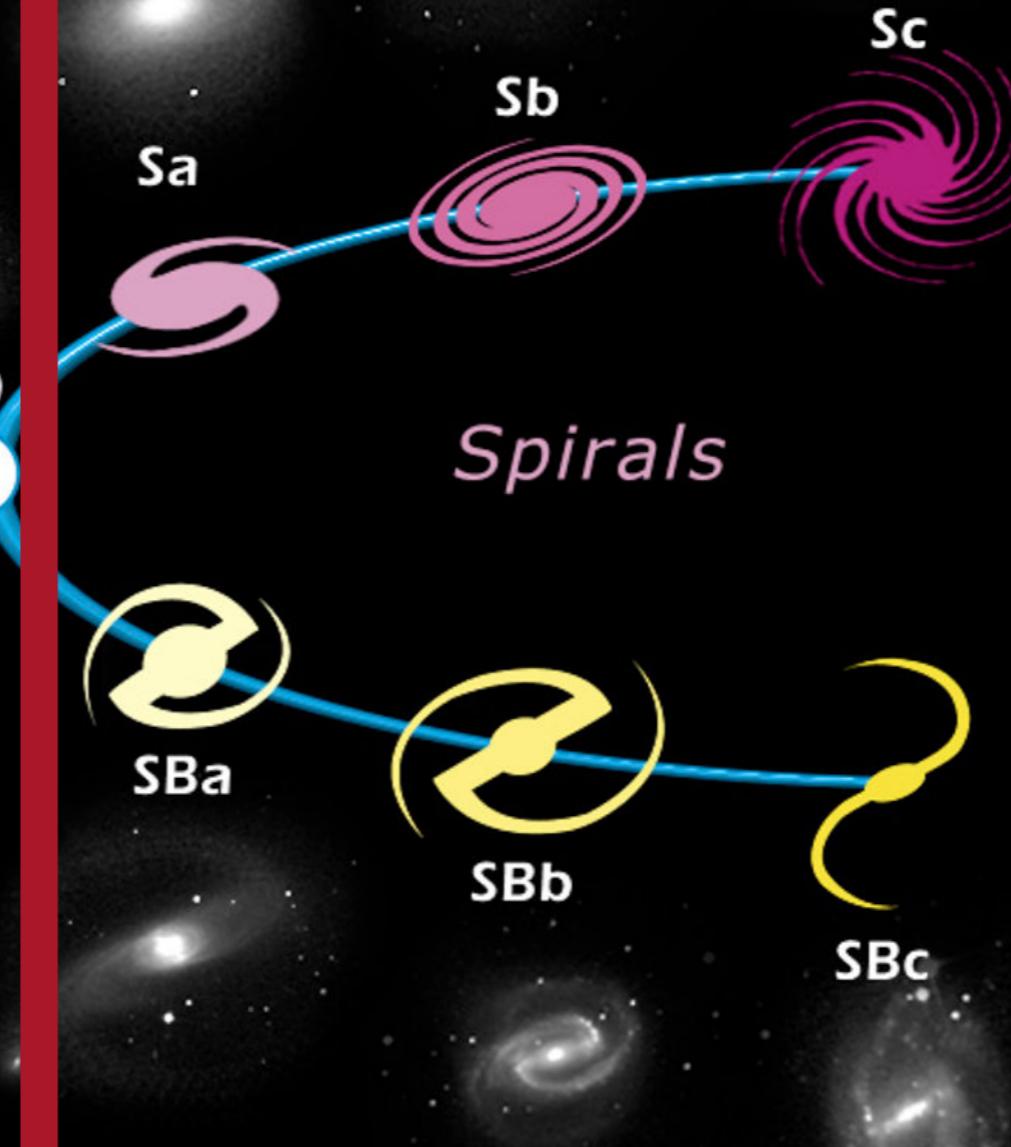
## *Edwin Hubble's Classification Scheme*

*Ellipticals*

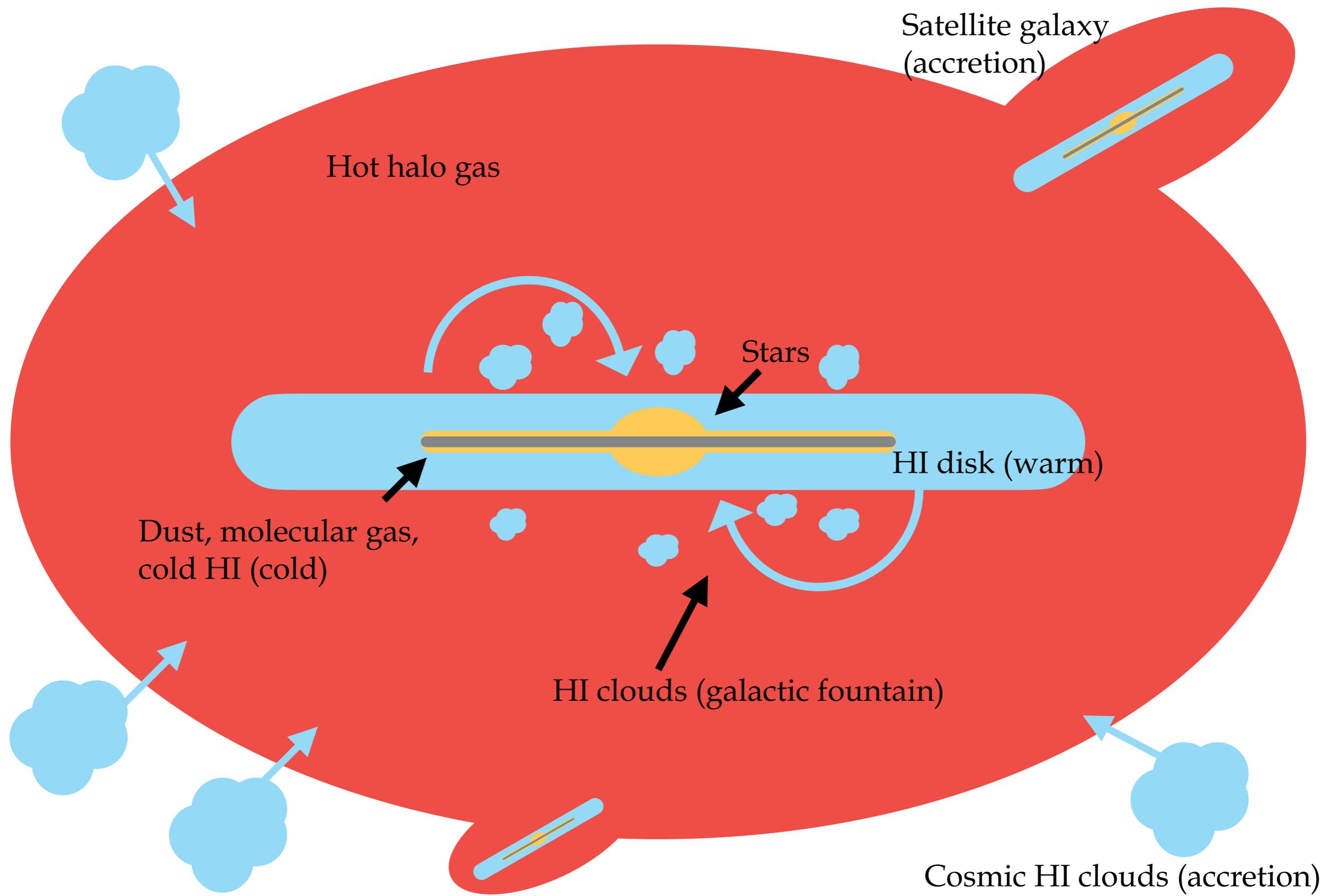
E0    E3    E5    E7    S0

Typically gas poor, with no HI

Typically gas rich, with HI



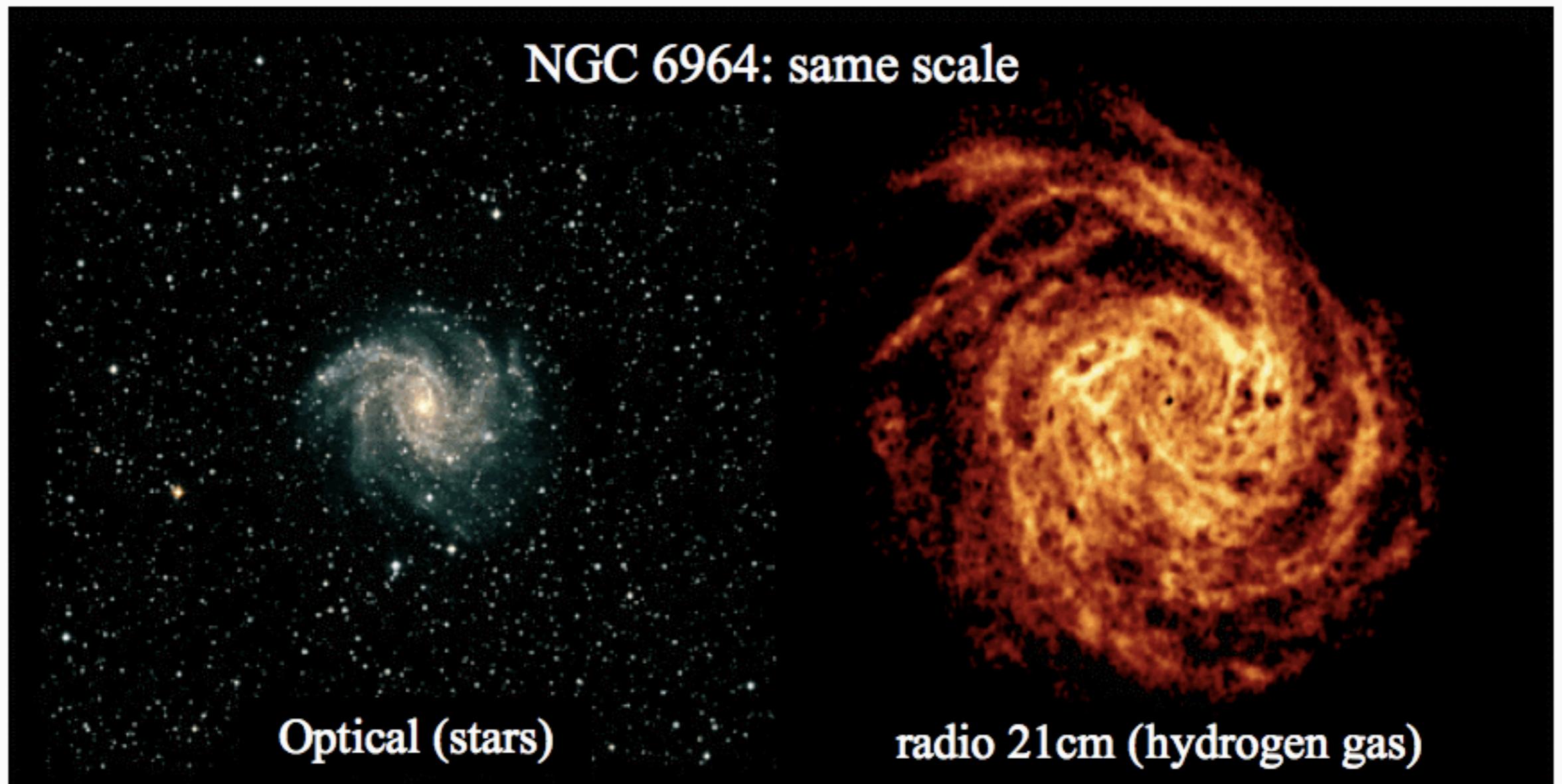
# A TYPICAL LATE-TYPE/SPIRAL GALAXY



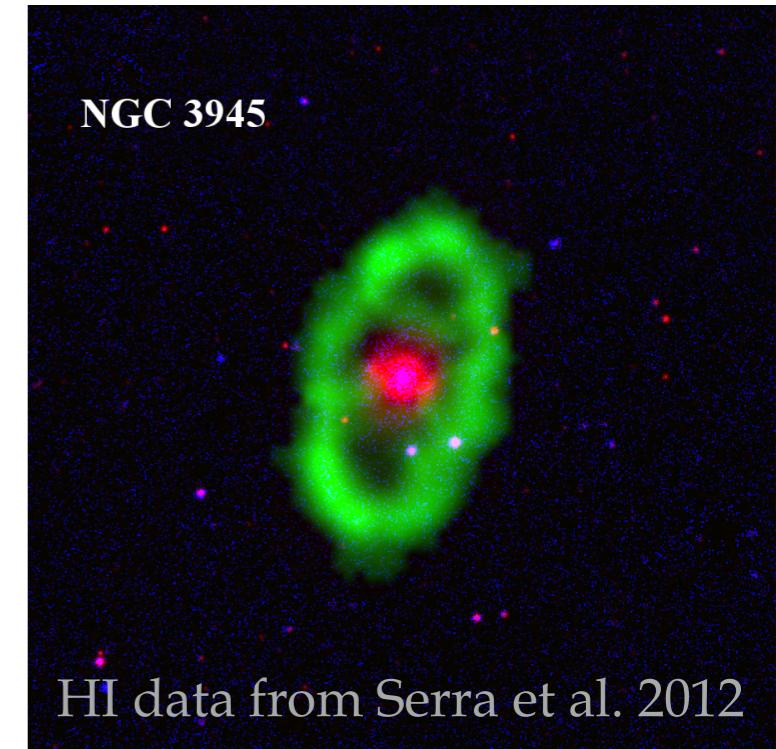
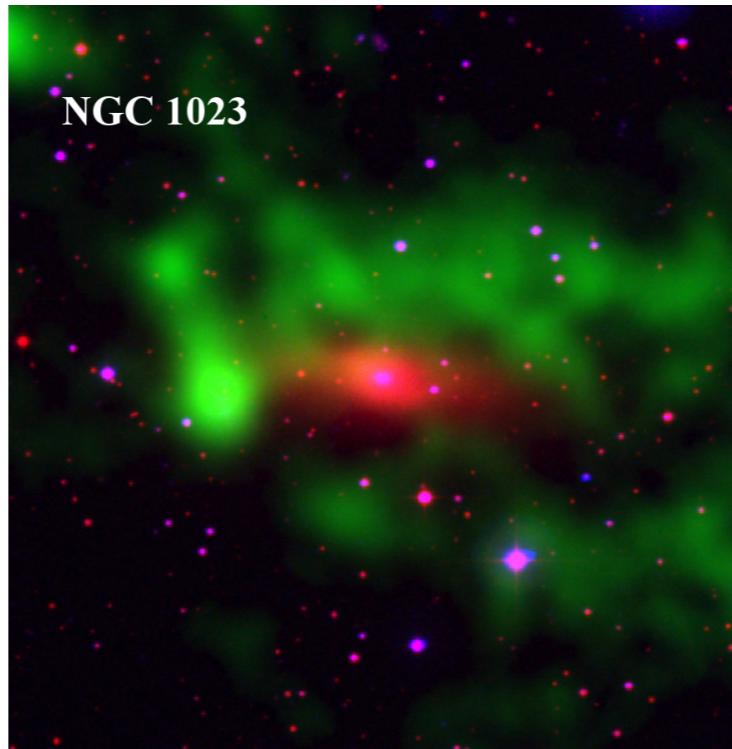
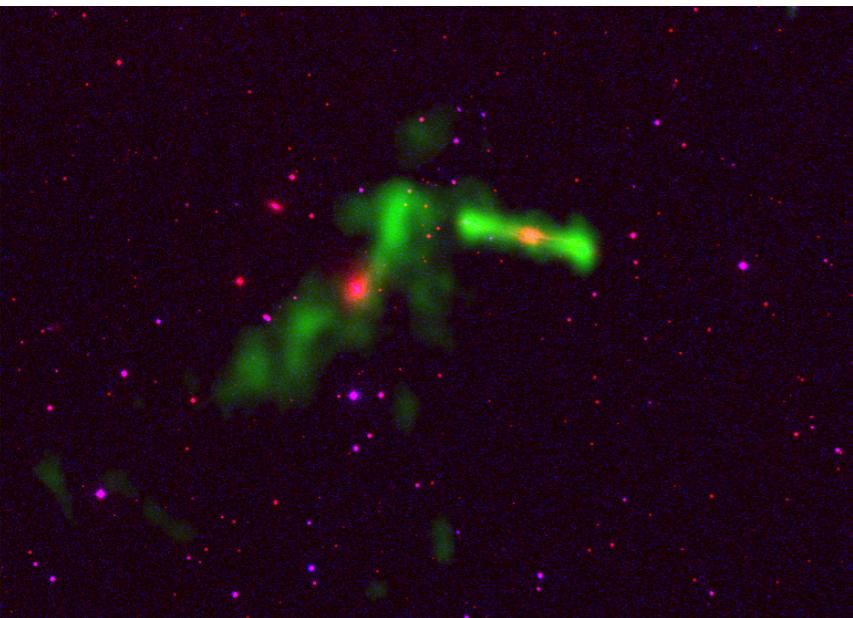
# HI IN LATE TYPE GALAXIES

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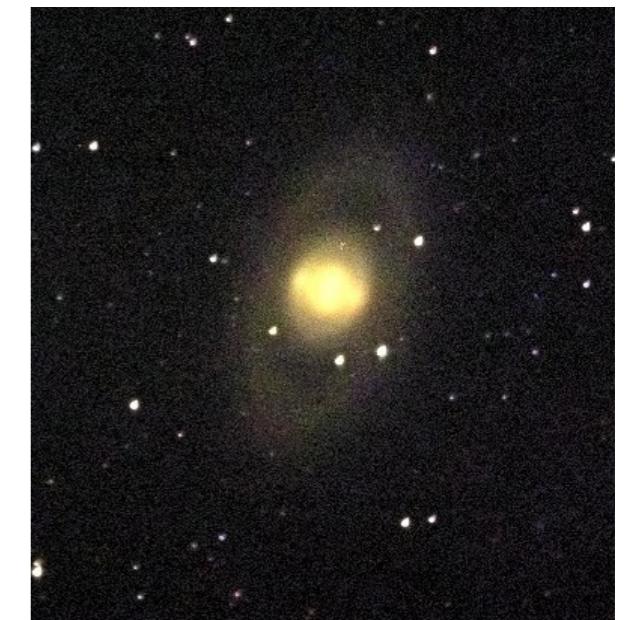
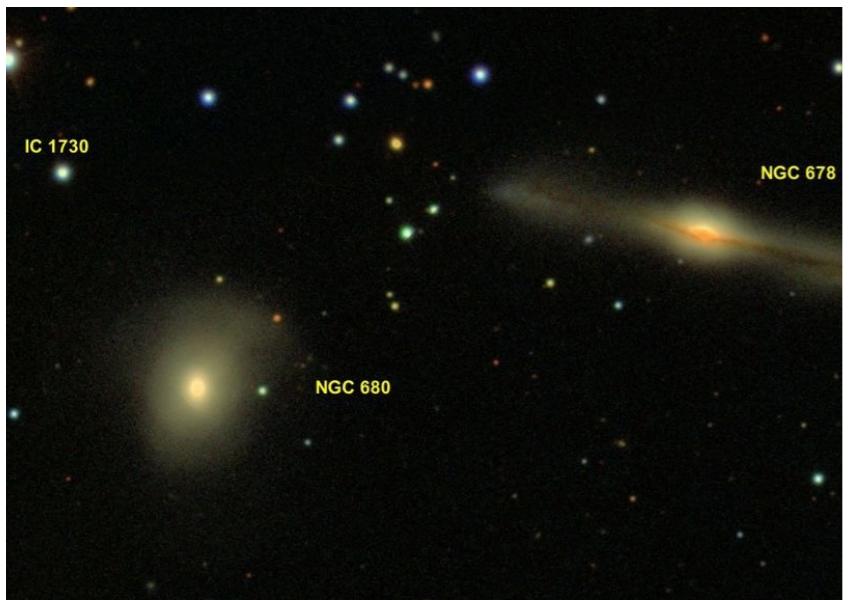
- ▶ Star forming **late-type galaxies** have usually significant amounts of HI
- ▶ Morphology is usually a **regular disk approximately 2-3 times the stellar diameter**



# HI IN ELLIPTICAL/LATE-TYPE GALAXIES



HI data from Serra et al. 2012

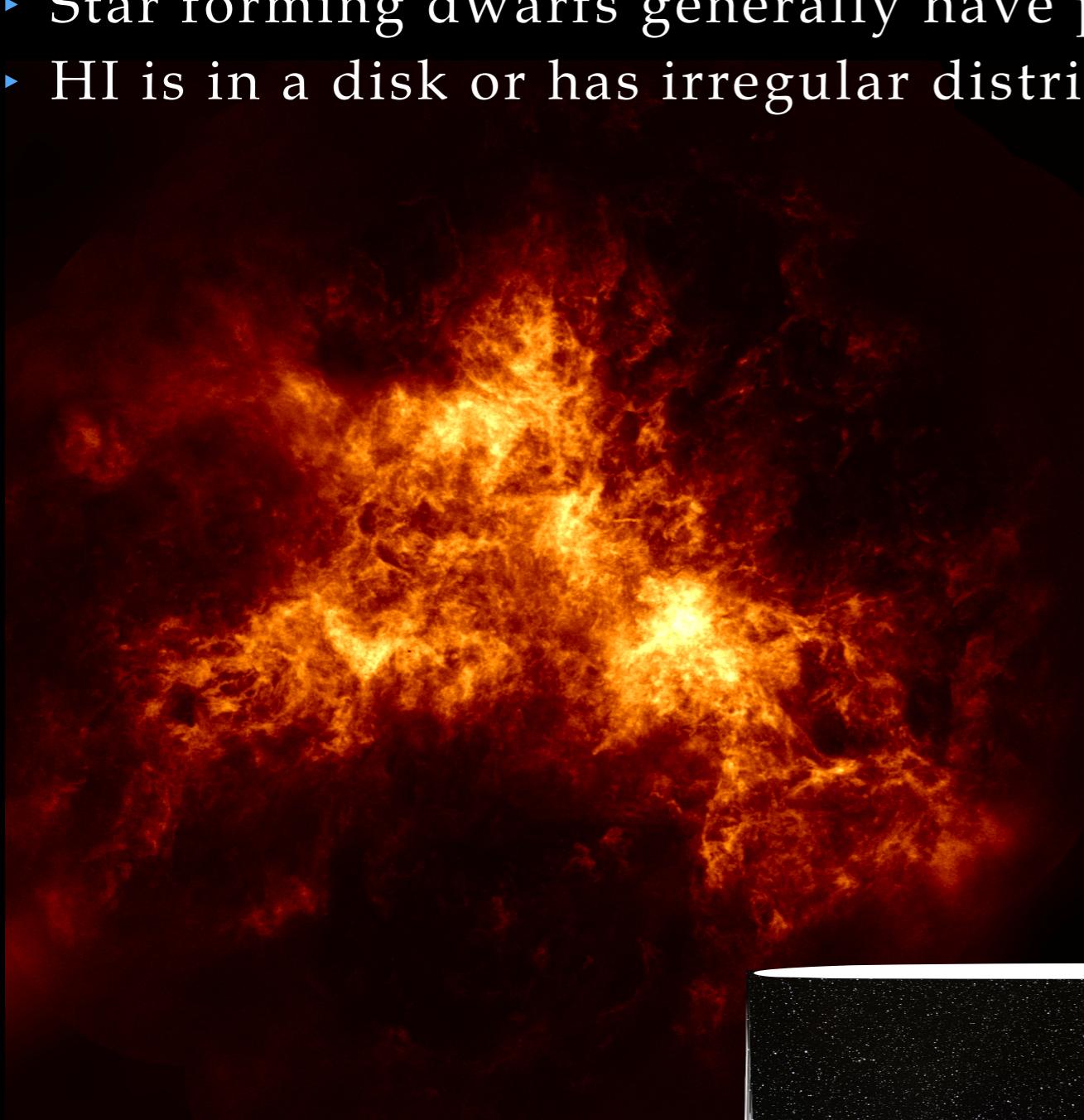


- ▶ **Early-type galaxies** can have various HI morphologies from regular disks to rings and unsettled clouds.
- ▶ This gas is usually acquired from another galaxy (e.g. gas rich merger or tidal interaction)

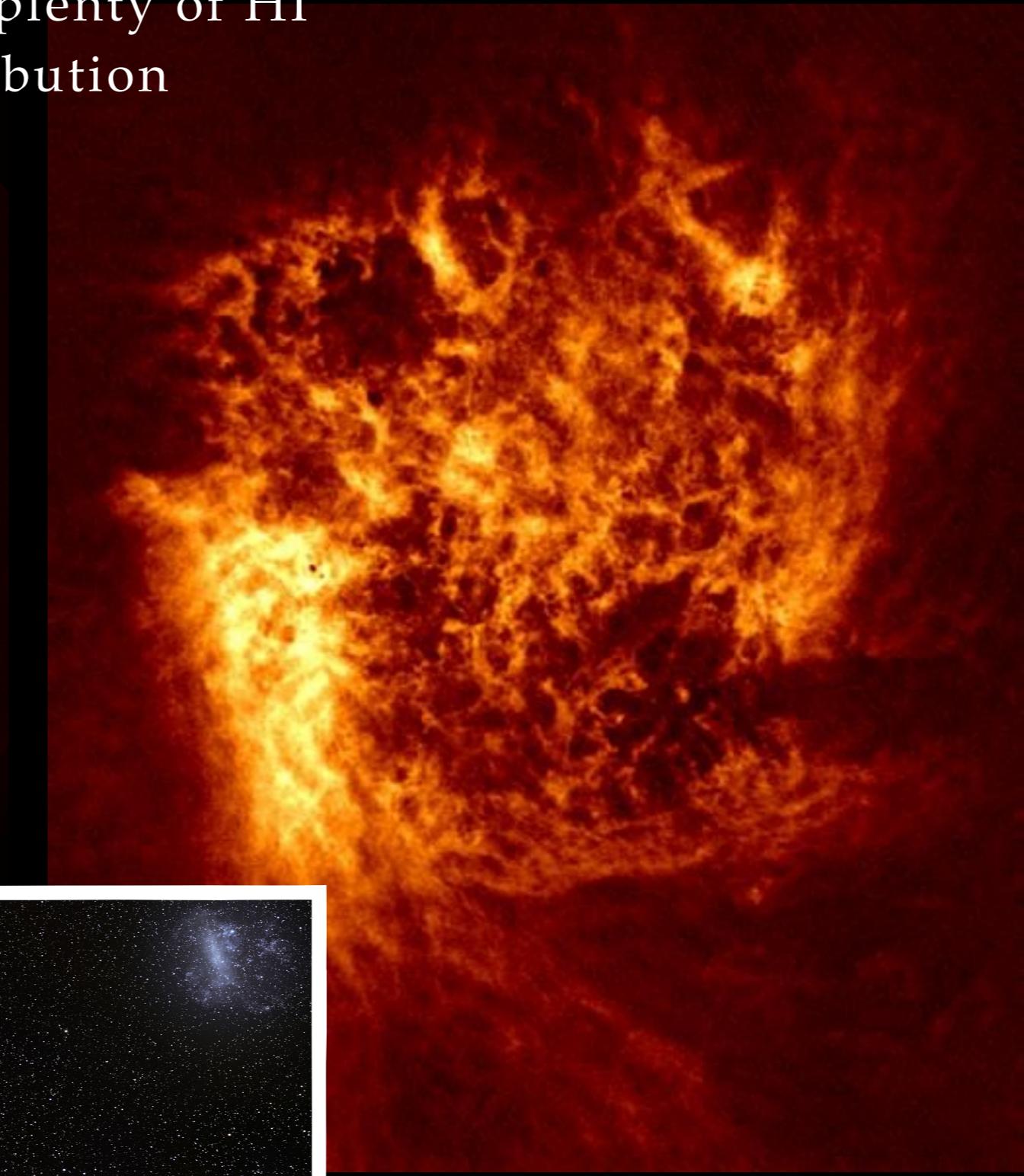
red: optical, DSS2 B;  
green: HI, blue: UV, GALEX

# HI IN DWARF GALAXIES - MAGELLANIC CLOUDS

- Star forming dwarfs generally have plenty of HI
- HI is in a disk or has irregular distribution



SMC - ASKAP+Parkes



LMC - ATCA+Parkes

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# WHAT CAN WE LEARN FROM THE HI DATA?

# CALCULATEING THE HI MASS OF A GALAXY

- We can calculate the HI mass of a galaxy the following way
  - Here we assume that the HI is optically thin

$$\left(\frac{M_{\text{H}}}{M_{\odot}}\right) \approx 2.36 \times 10^5 \left(\frac{d}{\text{Mpc}}\right)^2 \int \left[\frac{S(v)}{\text{Jy}}\right] \left(\frac{dv}{\text{km s}^{-1}}\right)$$

Distance to the galaxy

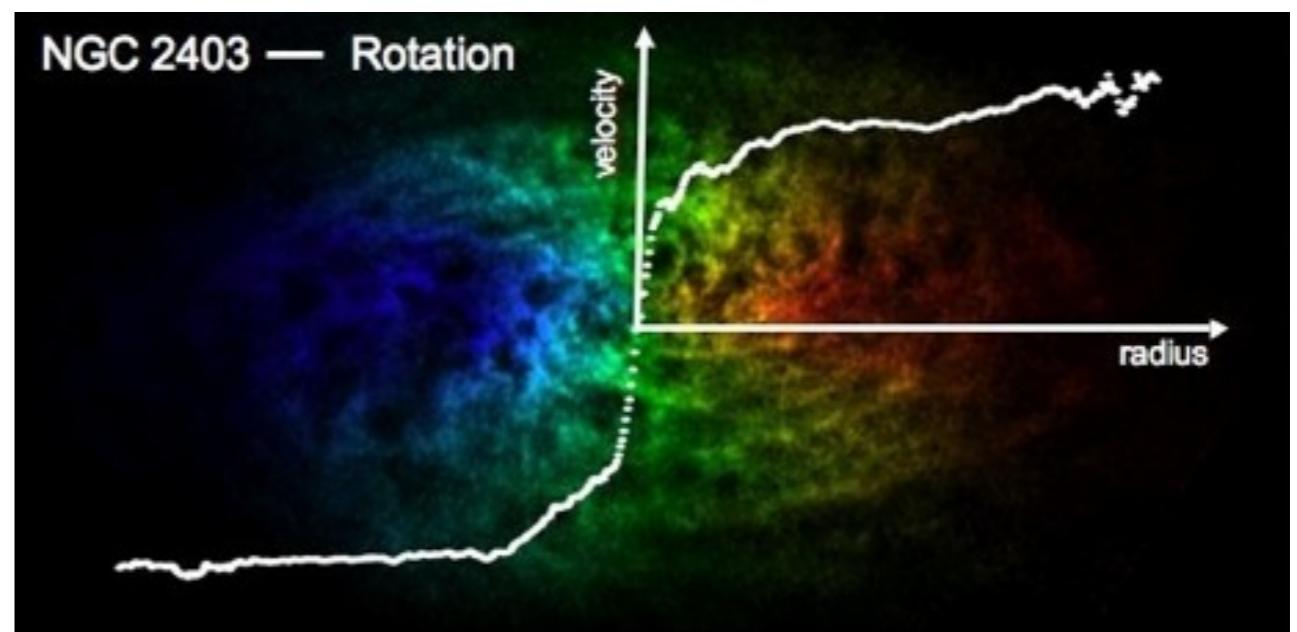
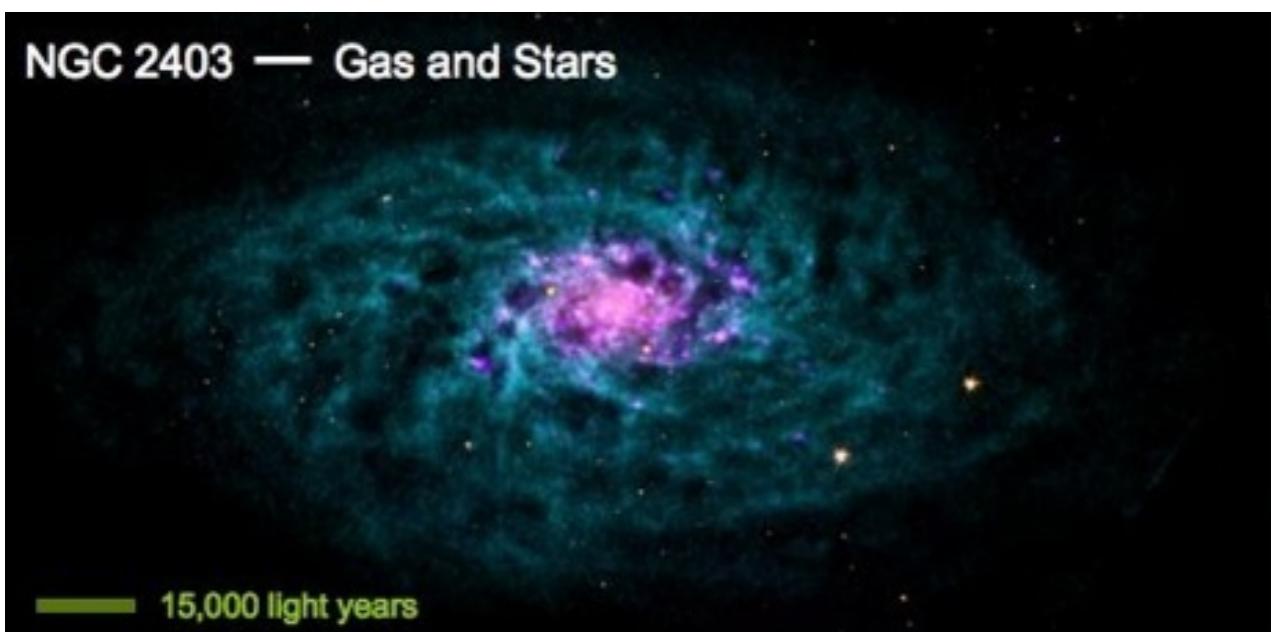
Integral of the HI line

$$d \approx \frac{v_r (\text{optical})}{H_0}$$

Systemic velocity of the galaxy  
Hubble constant

# TRACING VELOCITY FIELDS

- ▶ HI extends much further out than the stellar light.
- ▶ Because we measure the HI line, we also get velocity information on the gas.
  - ▶ The velocity information can be used for **distance measurement**.
  - ▶ Velocity fields can be used to derive **rotation curves** and to trace the total mass distribution of a galaxy far outside the stellar disk.
  - ▶ In most galaxies, the HI rotation curve is flat at large radii, implying the existence of large quantities of **dark matter**.
  - ▶ The velocity information can be used to trace various **galaxy evolution** processes (e.g. interaction with another galaxy)

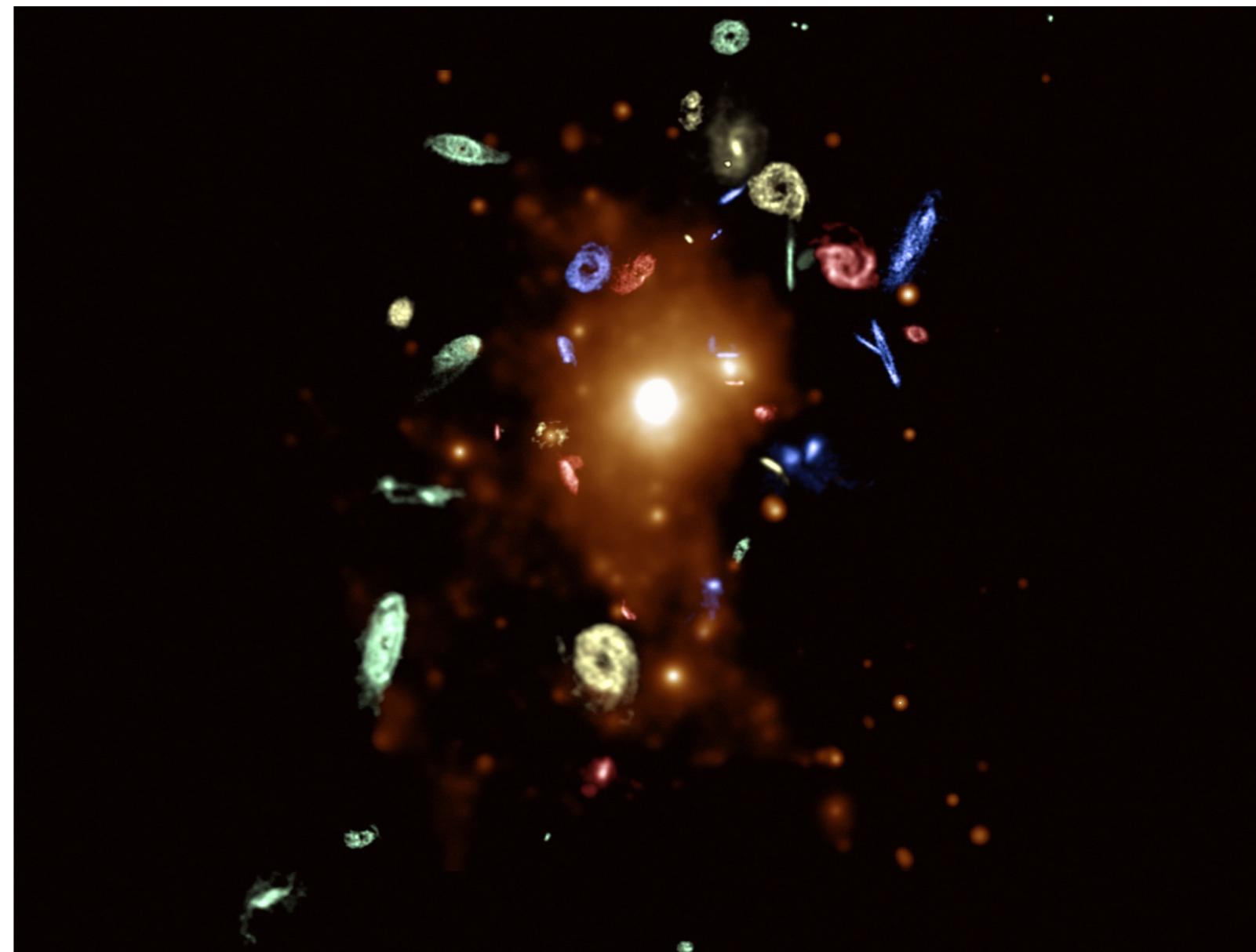


# ENVIRONMENTAL EFFECTS ON THE HI CONTENT

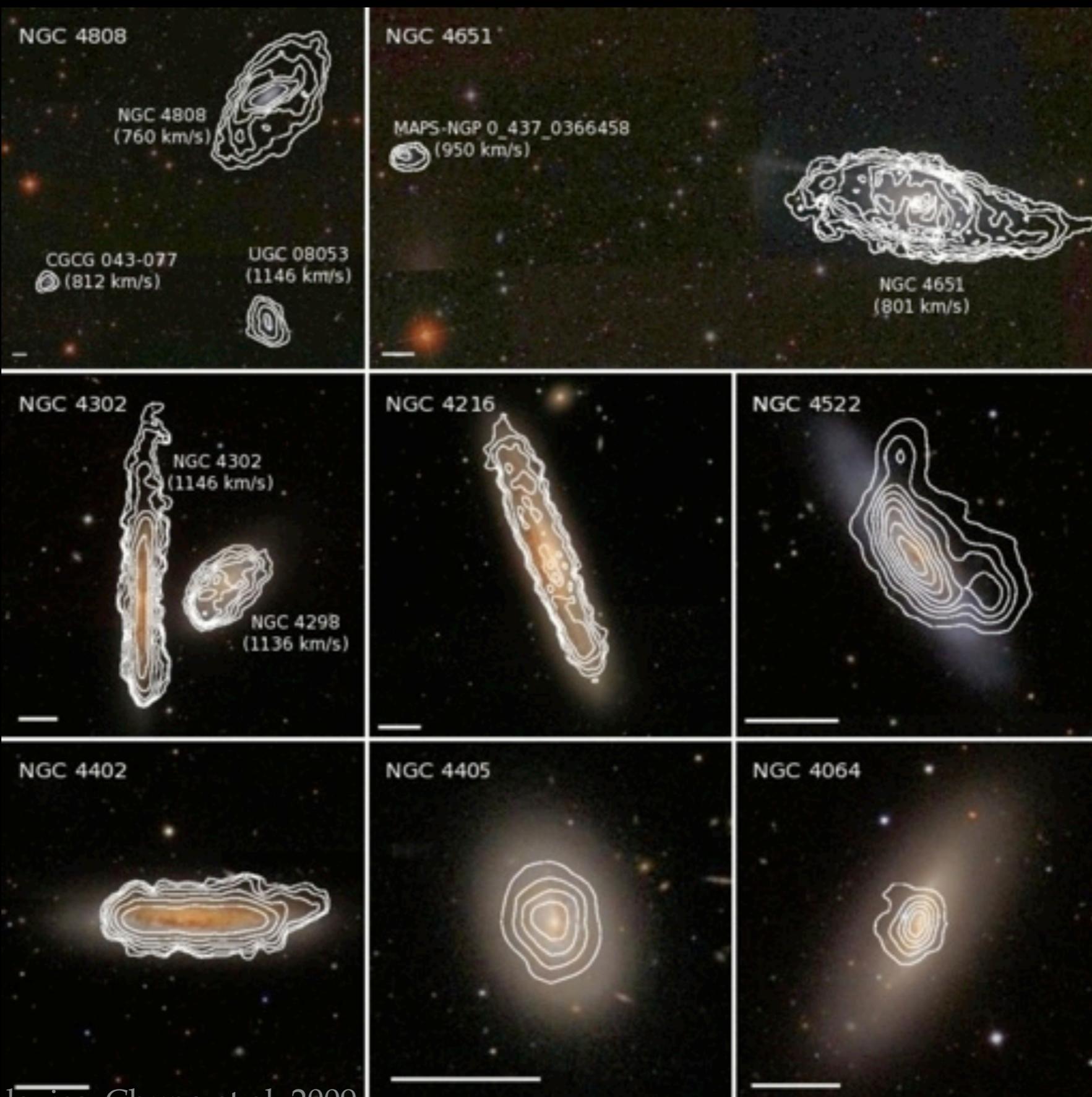
- ▶ Galaxies reside in different environments
  - ▶ Field, groups and clusters
- ▶ morphology-density relation
- ▶ Star formation – density relation
- ▶ Late-type galaxies in high density environments tend to have less HI
  
- ▶ **Environmental processes:**
  - ▶ tidal interactions
  - ▶ mergers
  - ▶ ICM interactions
  - ▶ starvation

X-ray and HI composite of the Virgo cluster

Chung et al. 2009



# VIRGO CLUSTER GALAXIES



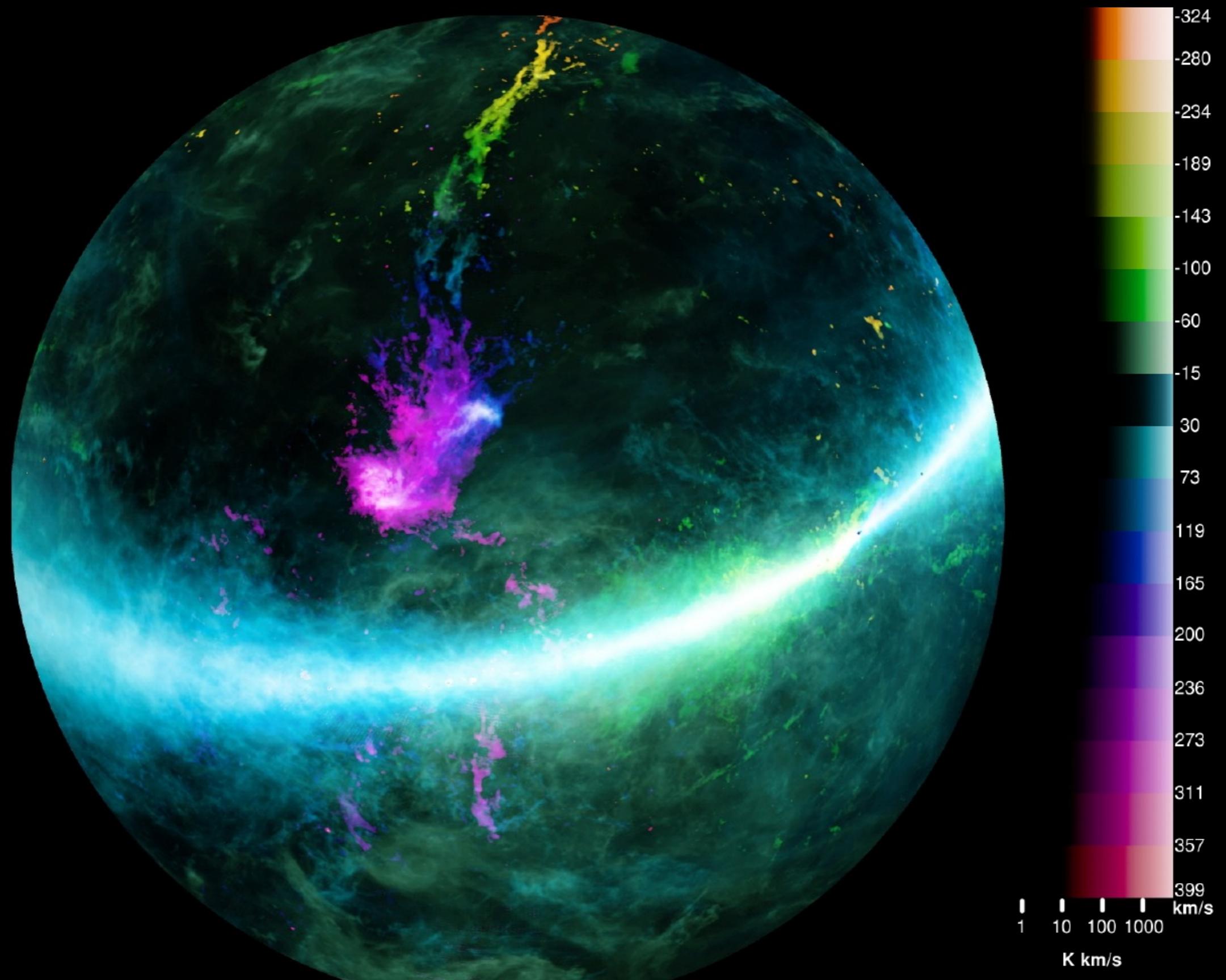
# THE M81 GROUP

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de Blok et al. 2018, SDSS image + HI (blue)

# THE MAGELLANIC SYSTEM





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# THANK YOU!