



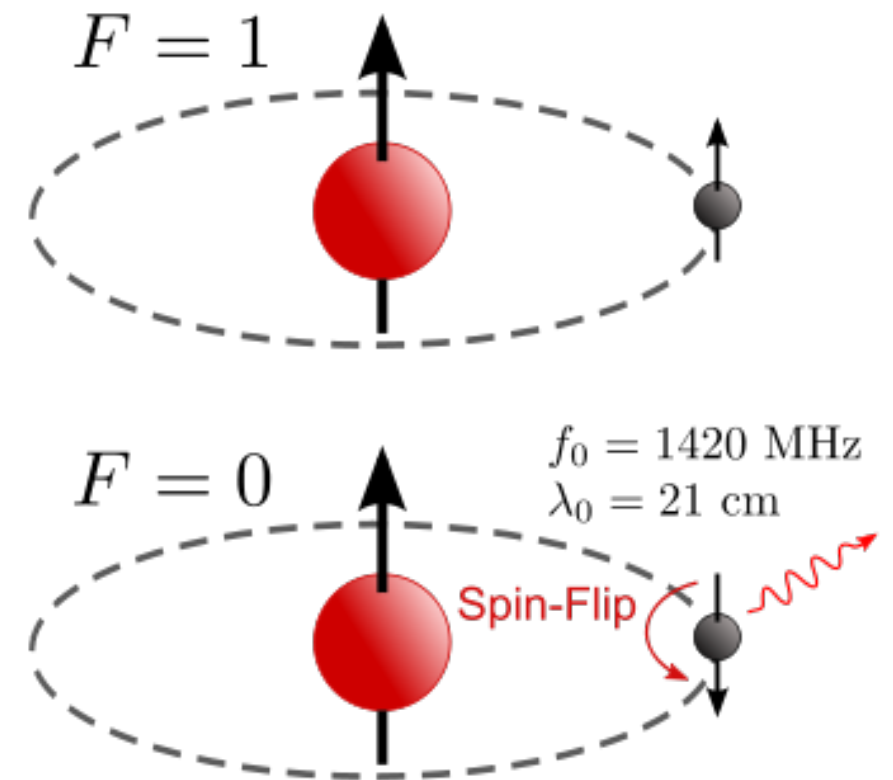
HELGA DÉNES

HI IN GALAXIES

ASTRON 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



**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

$$\Theta = \lambda / D$$

Θ – resolution

λ – wavelength

D – diameter/baseline

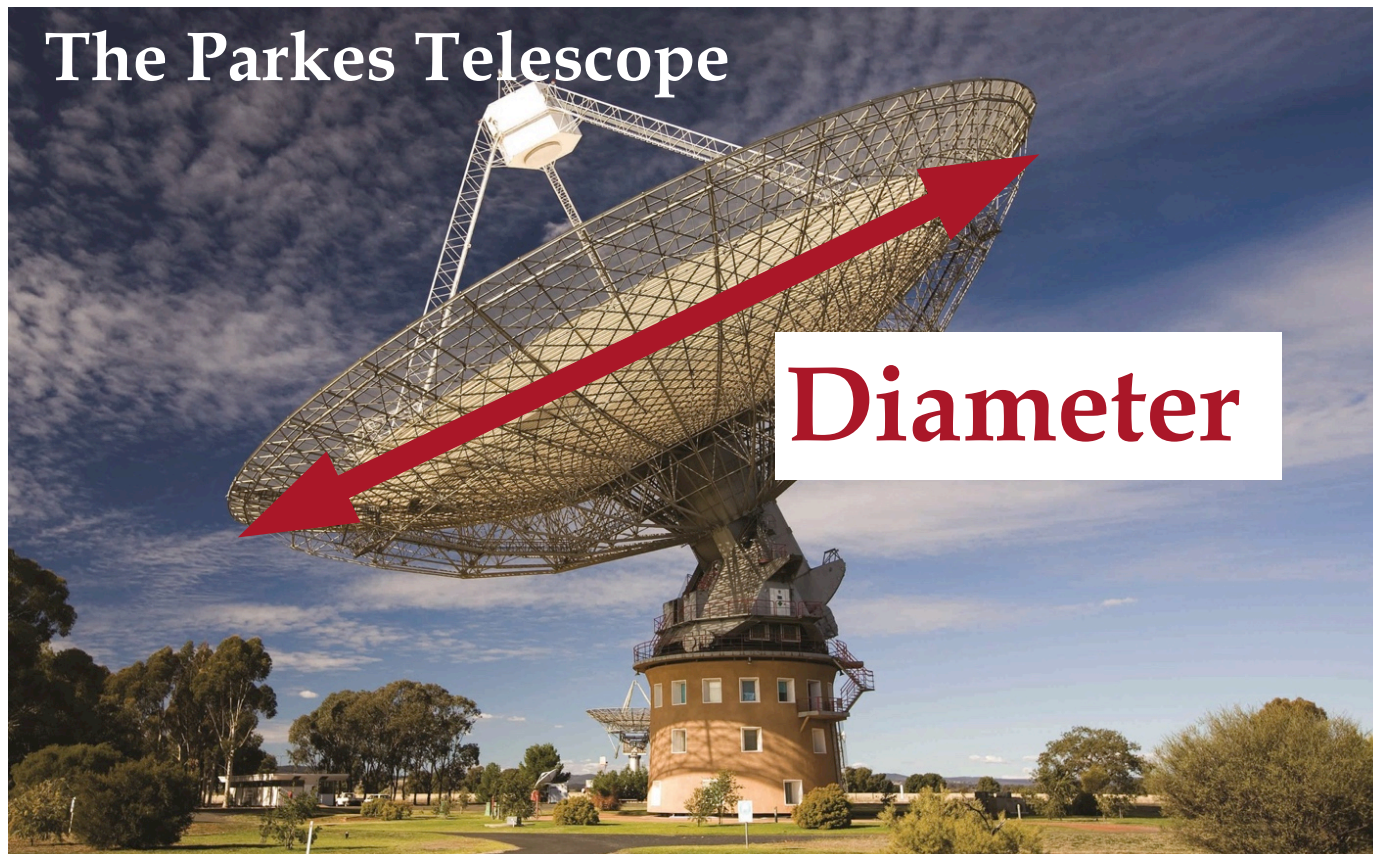
Singel dish telescopes:

Resolution: ~ Diameter

Interferometers:

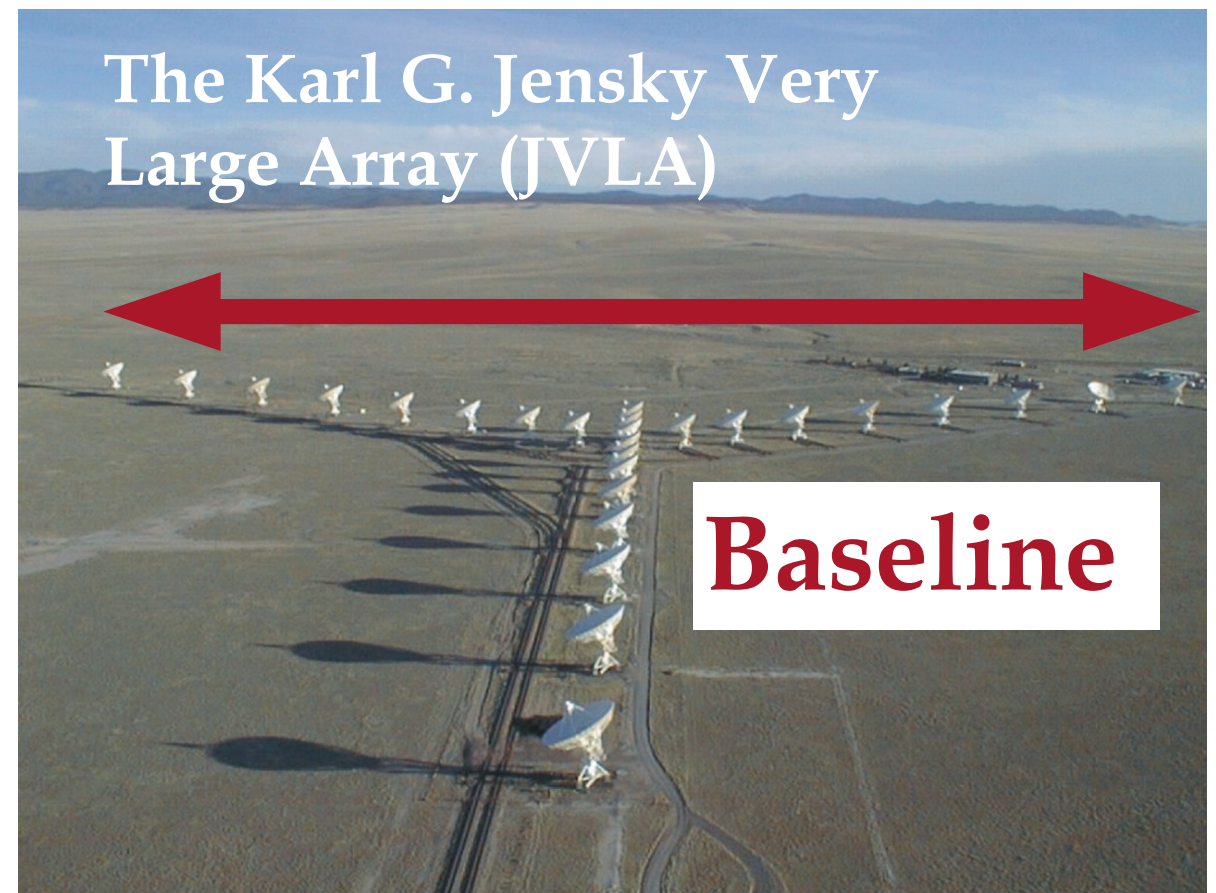
Resolution: ~ distance between telescopes

The Parkes Telescope



Diameter

The Karl G. Jansky Very Large Array (JVLA)



Baseline

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 screenshot displays the ATCA observation software interface, which is running on a VNC session. The interface is divided into several windows:

- PGPLOT Window 1:** Shows three vertically stacked plots. The top plot is Amplitude (Pseudo- μ), the middle is Phase (degrees), and the bottom is Delay (ns). The x-axis represents frequency from 2100.0 MHz to 2100.0 MHz. The y-axis represents Amplitude, Phase, and Delay.
- caobs:** A terminal window showing observation parameters and logs. It includes fields for Frequency (2100.0 MHz), Scan Type (DMELL), Pointing (GLOBAL), and Mode (STANDARD). It also shows tracking status for antennas CA01 through CA06.
- assistance:** A window showing antenna status and coordinates. It lists the name (0058-7413), RA (00:57:32.50), Dec (-74:12:43.0), and other parameters.
- Antennas LogFile:** A table showing the status of six antennas (CA01 to CA06). All are in a "TRACKING" state. The table includes columns for Azimuth, Elevation, Azimuth Error, and Elevation Error.
- System Logs:** A large window at the bottom right showing system logs, including CABB status, TVCHAN settings, and various error messages and ping statistics.

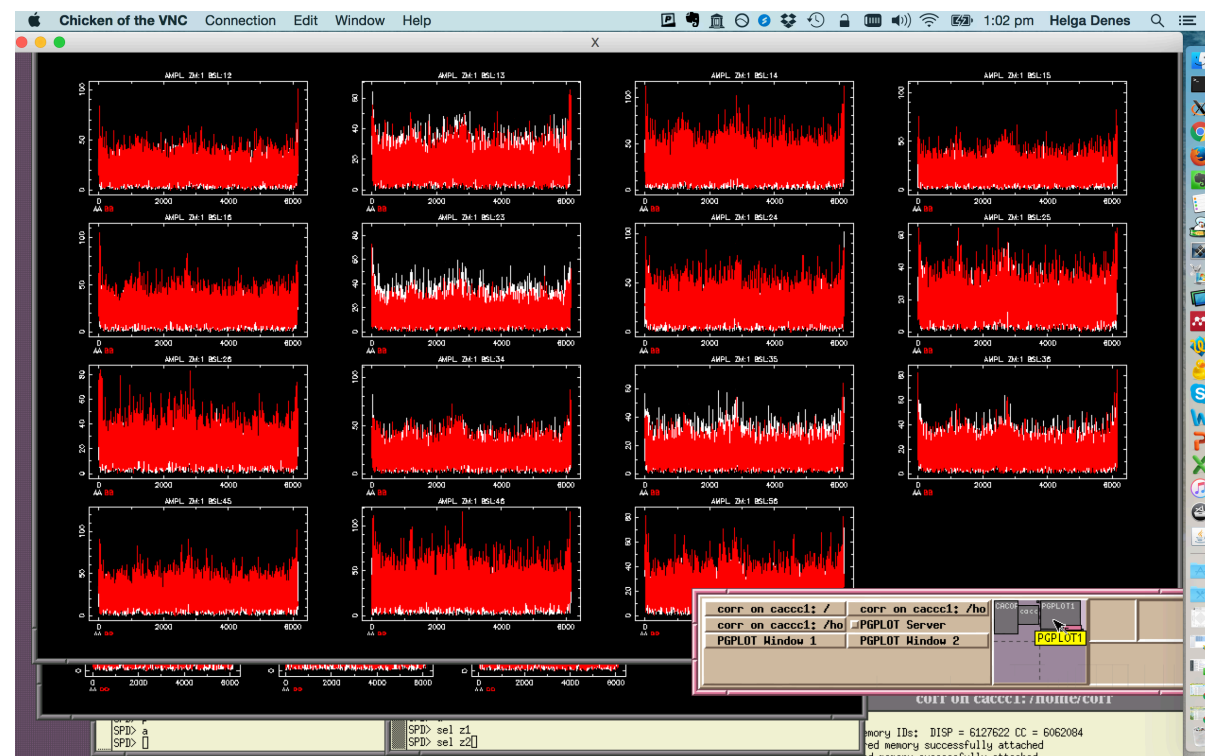
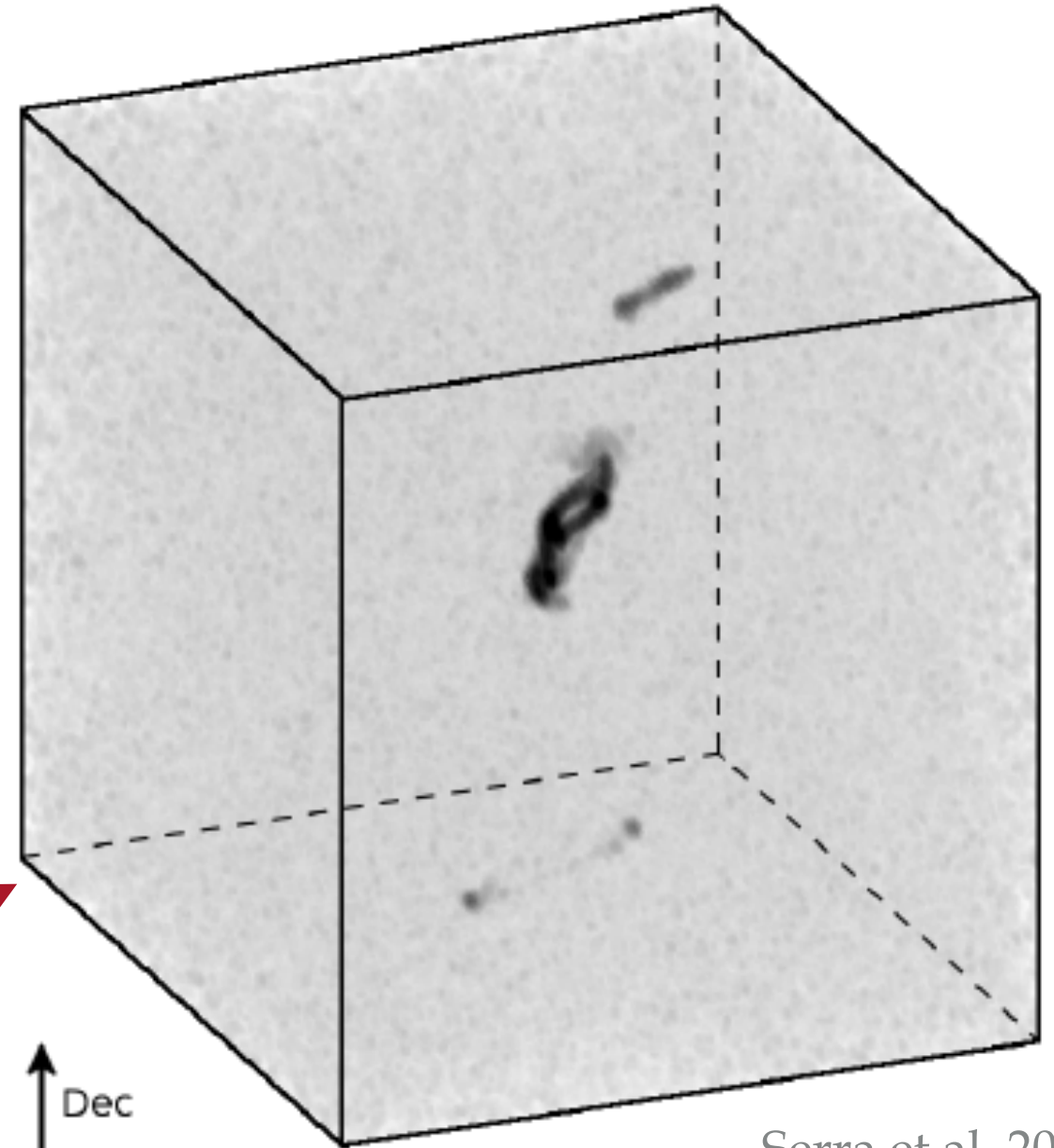
In the bottom left corner, there is a photograph of the ATCA telescopes, showing several large white parabolic dishes in an open field under a cloudy sky.

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.

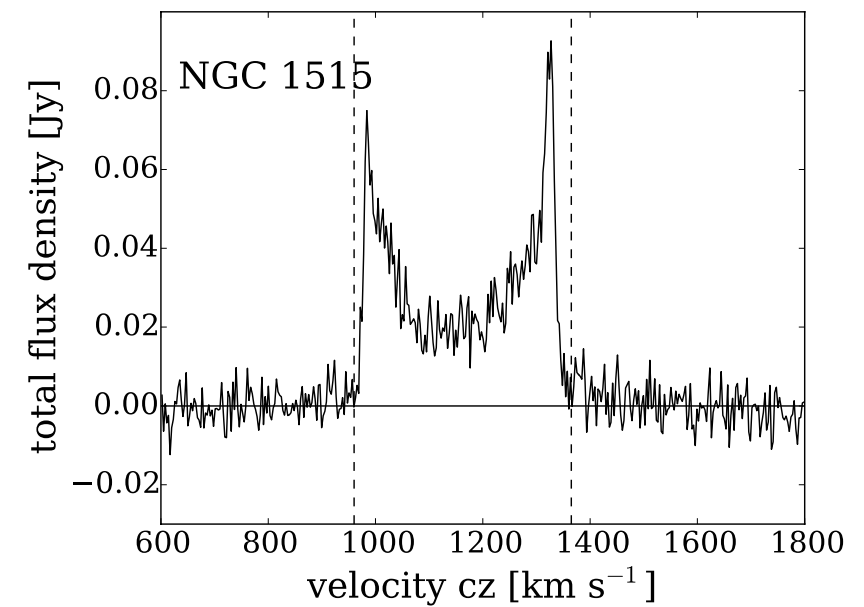
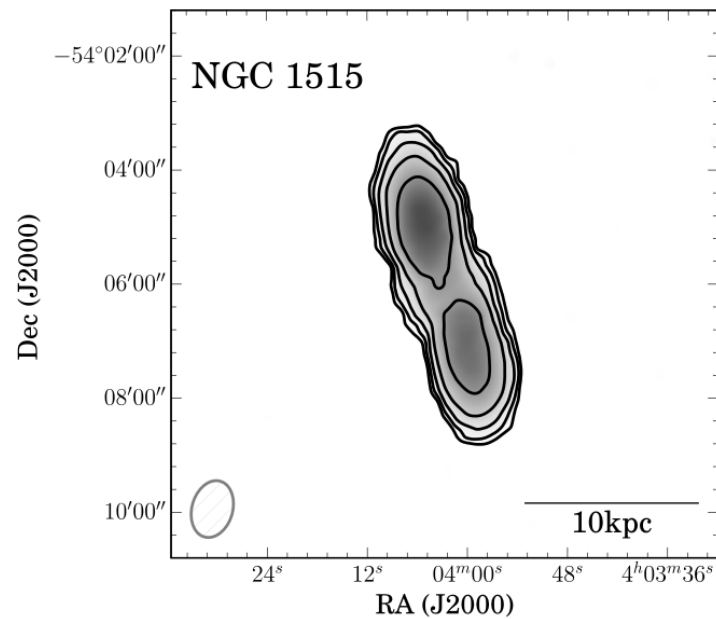


Serra et al. 2015

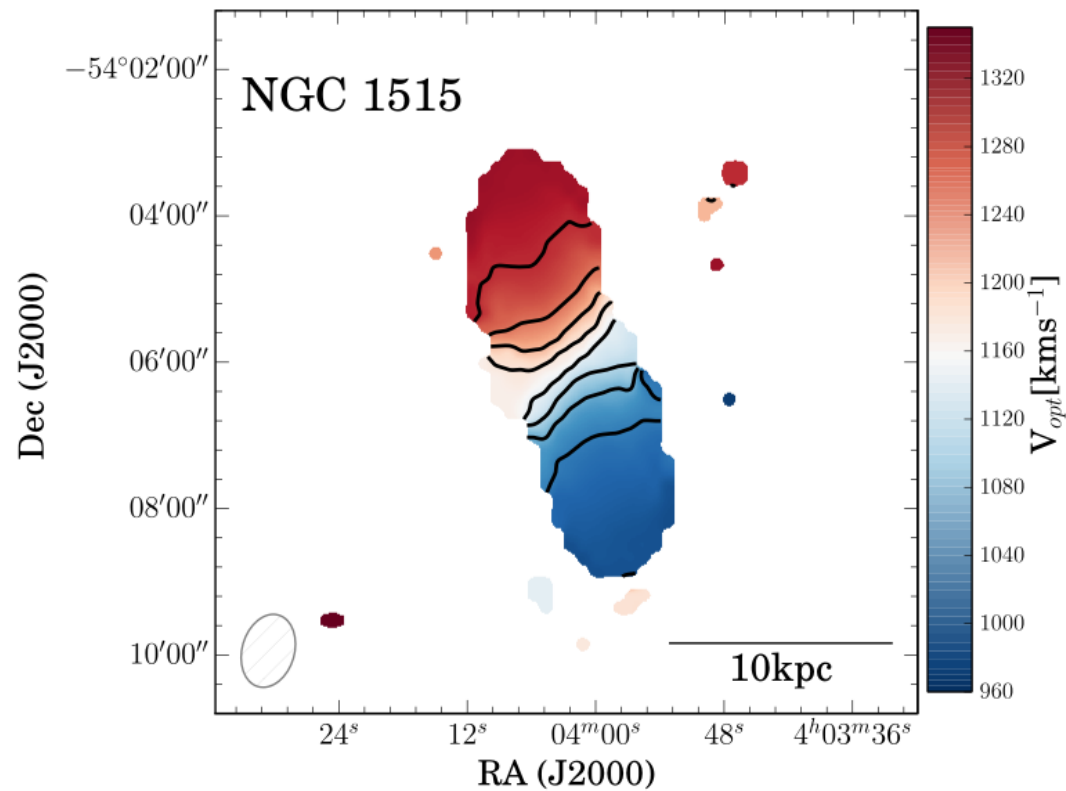
THE FINISHED DATA

HI line profile

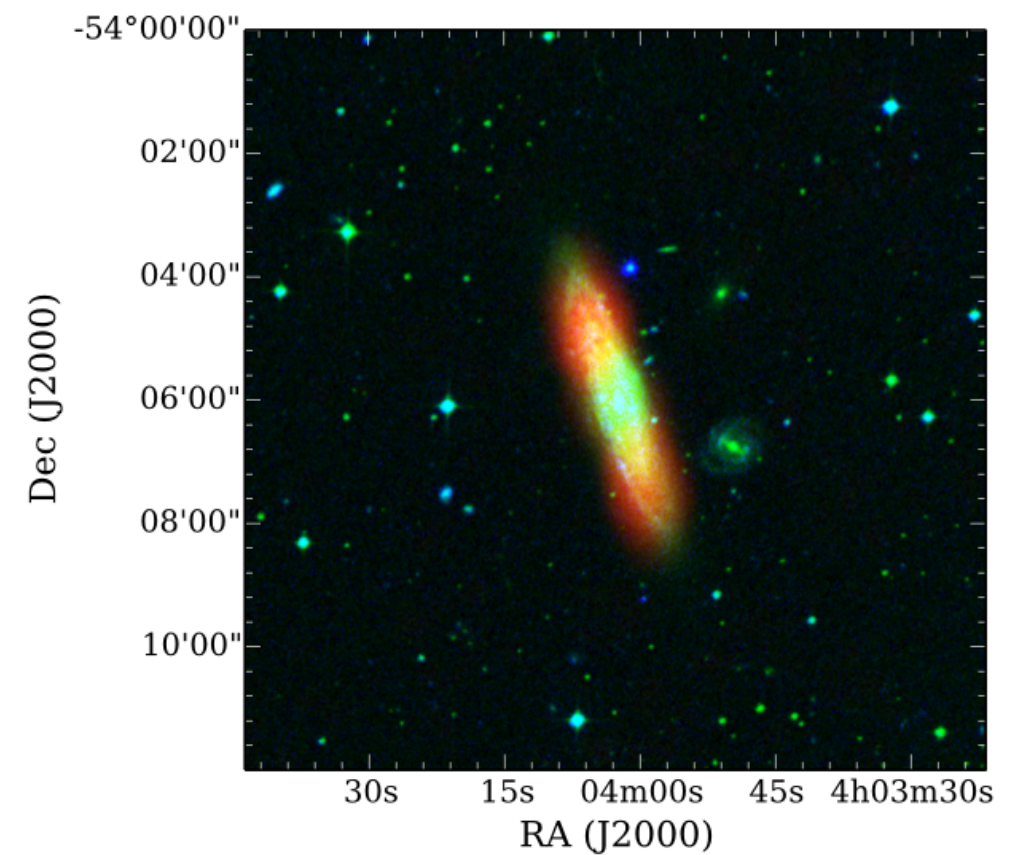
HI intensity



HI velocity field



HI, optical and UV data



GALAXY TYPES

Typically gas rich, with HI

Edwin Hubble's Classification Scheme

Ellipticals

E0 E3 E5 E7 S0



Sa



Sb



Sc



Spirals

SBa



SBb

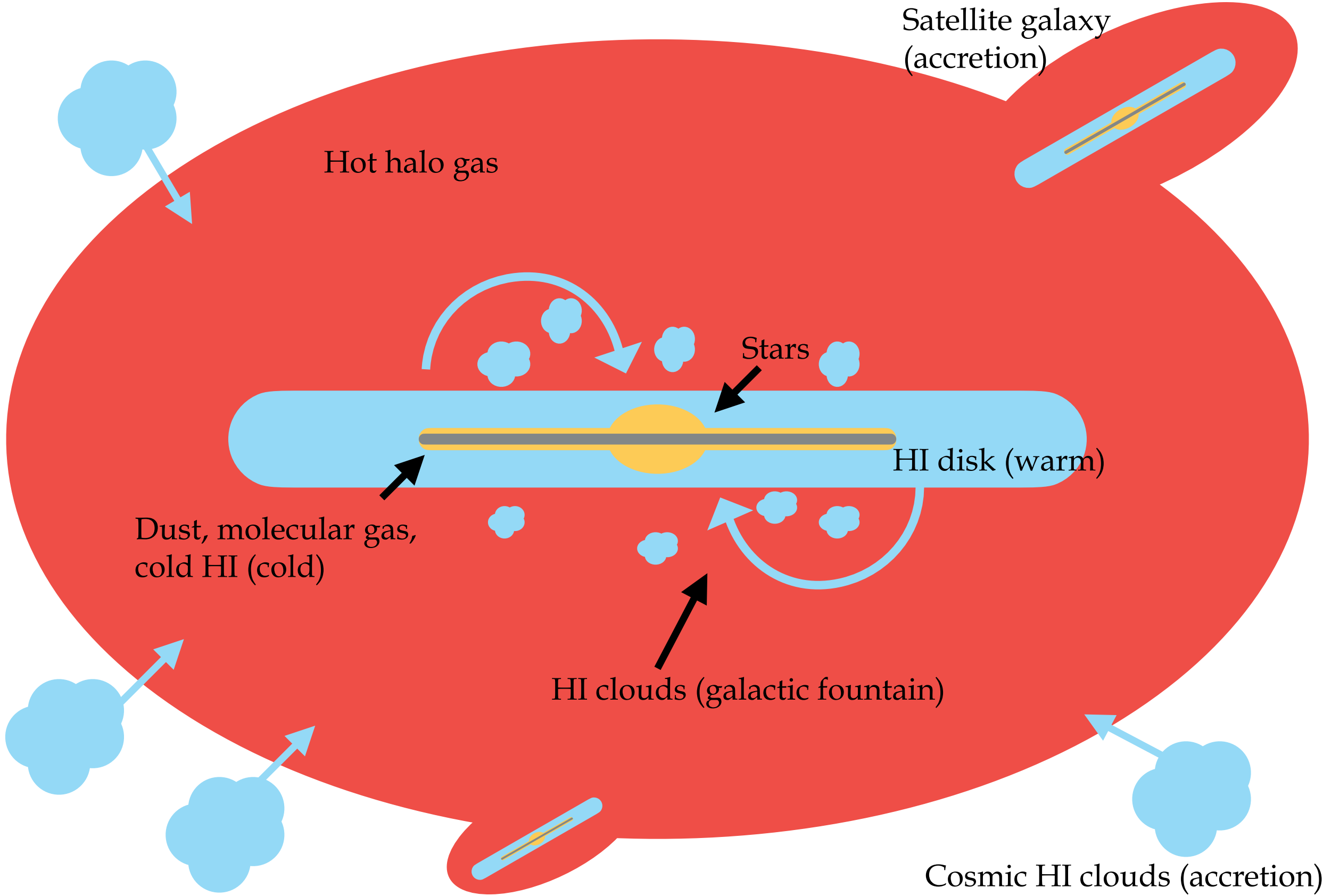


SBc



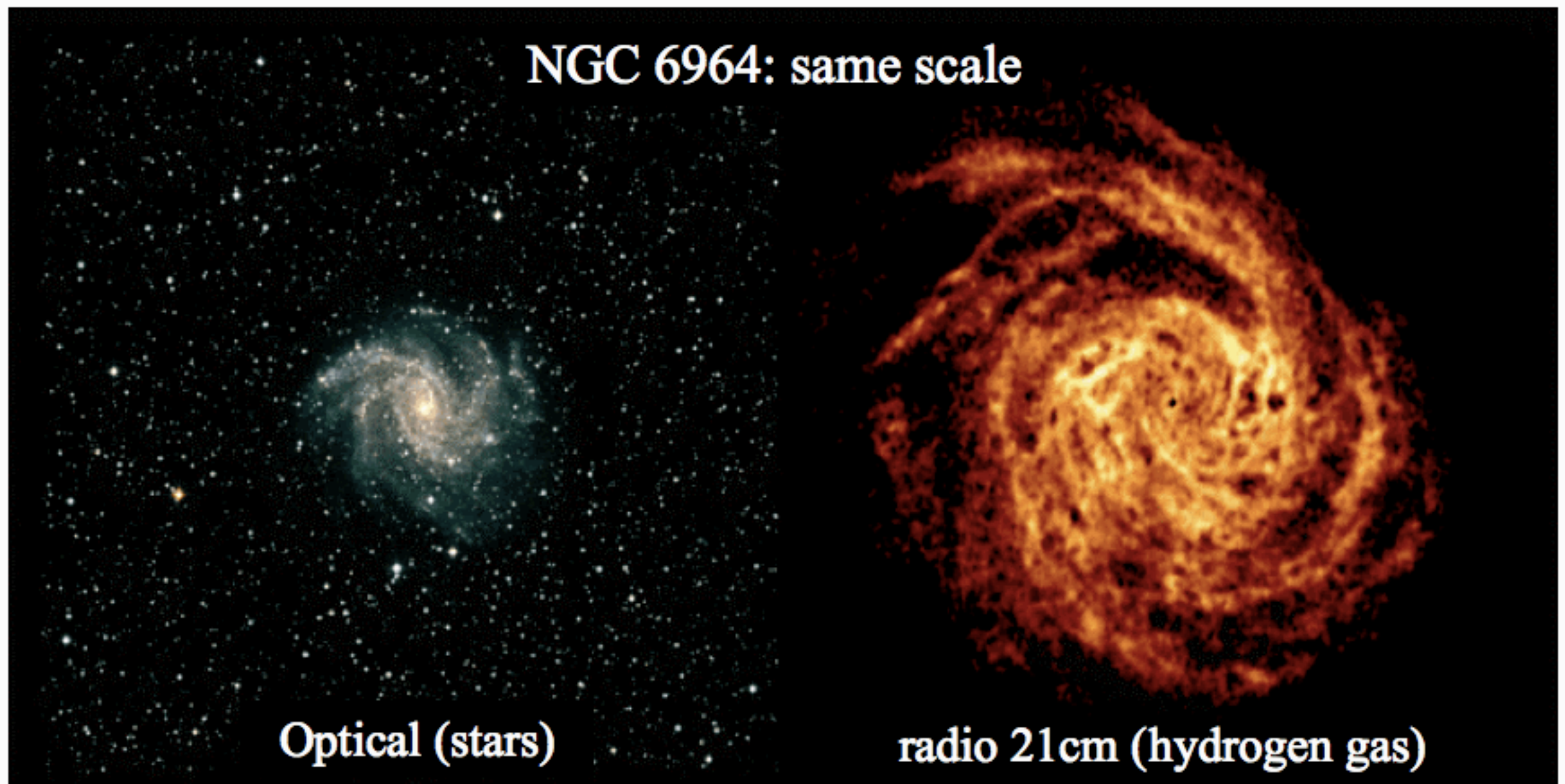
Typically gas poor, with no HI

A TYPICAL LATE-TYPE/SPIRAL GALAXY

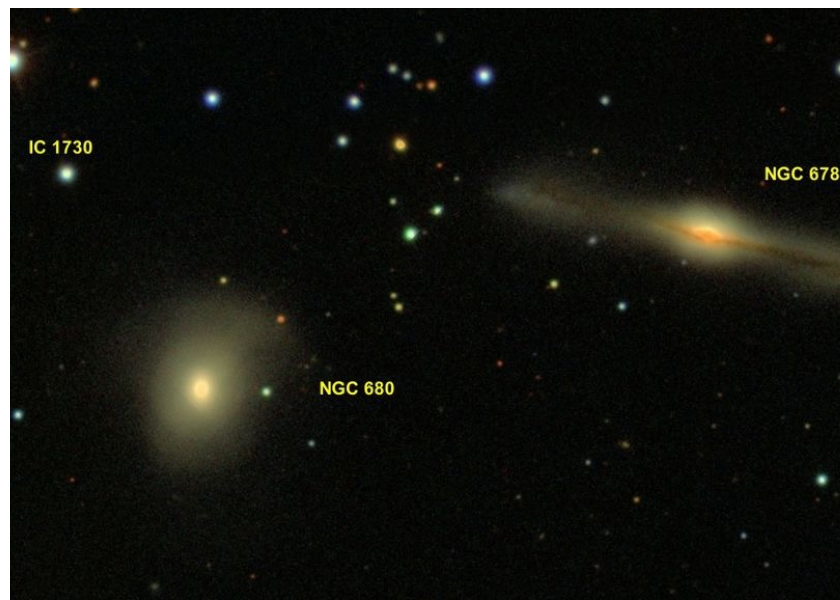
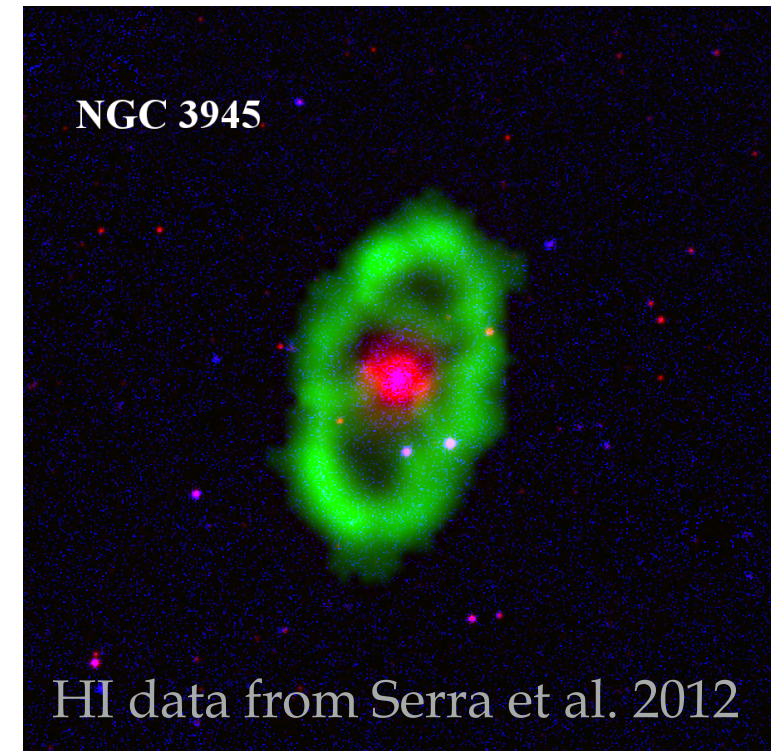
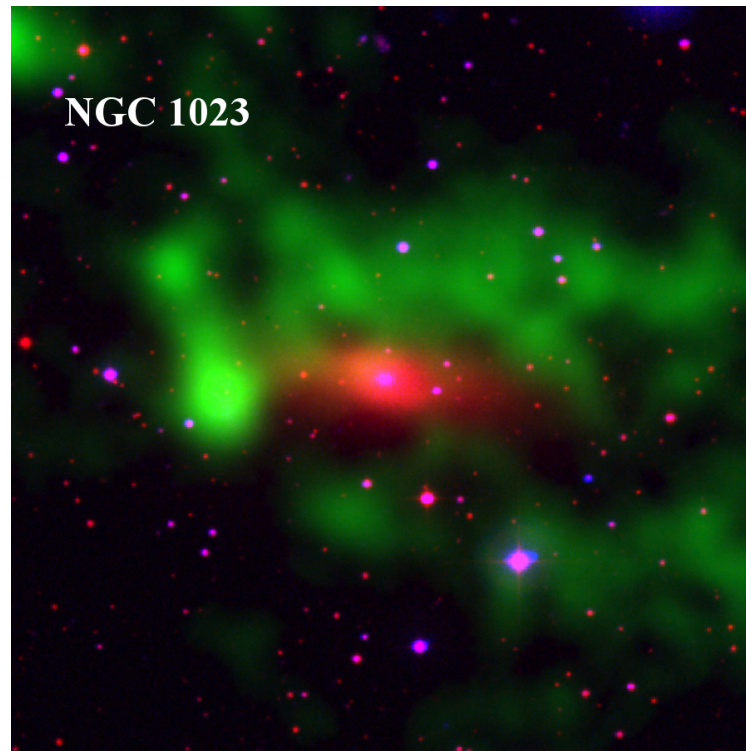
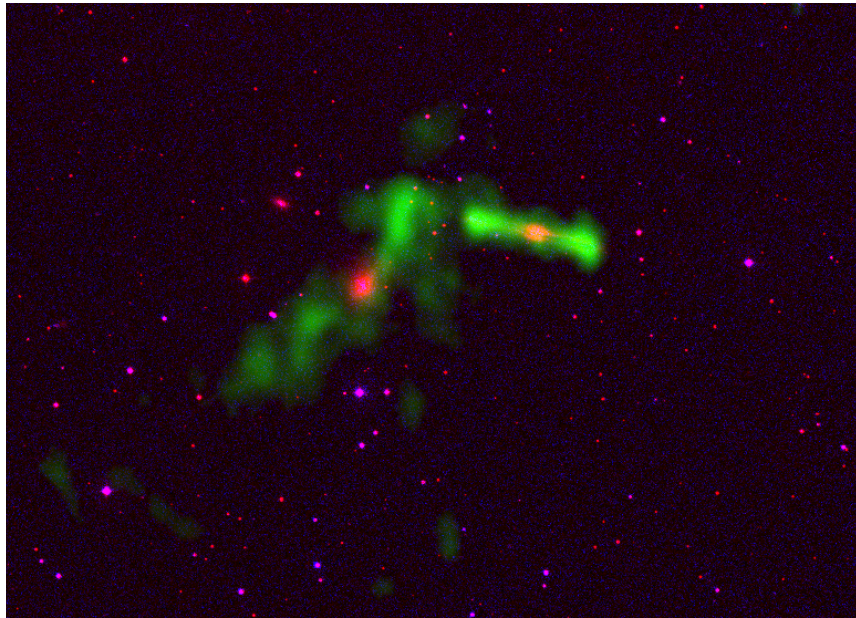


HI IN LATE TYPE GALAXIES

- ▶ 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

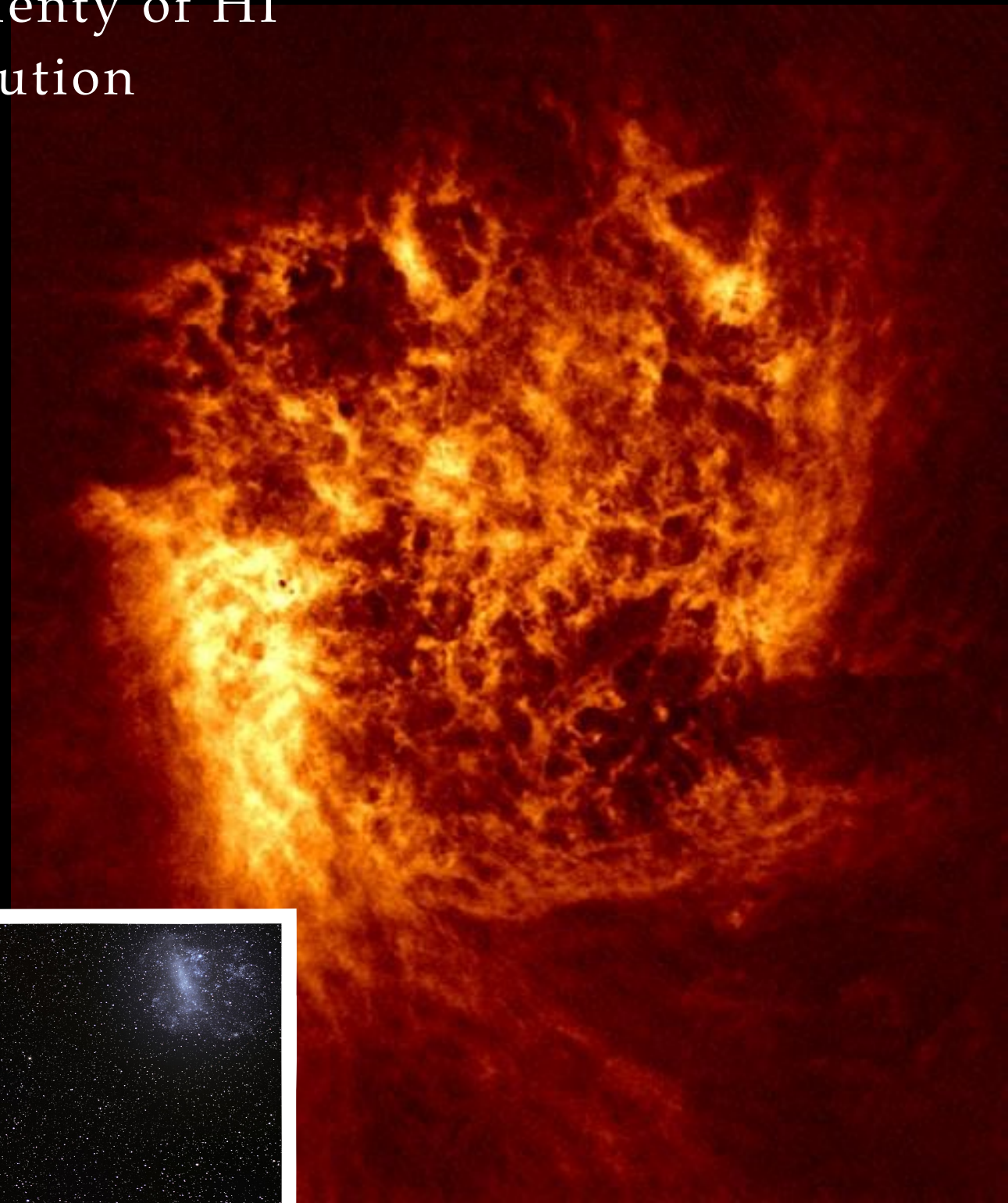


- ▶ **Early-type galaxies** can have various HI morphologies from regular disks to rings and unsettled clouds.
- ▶ This gas is usually acquired from another galaxy (e.g. gas rich merger or tidal interaction)

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

**WHAT CAN WE LEARN FROM
THE HI DATA?**

CALCULATING 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

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

Distance to the galaxy

Integral of the HI line

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



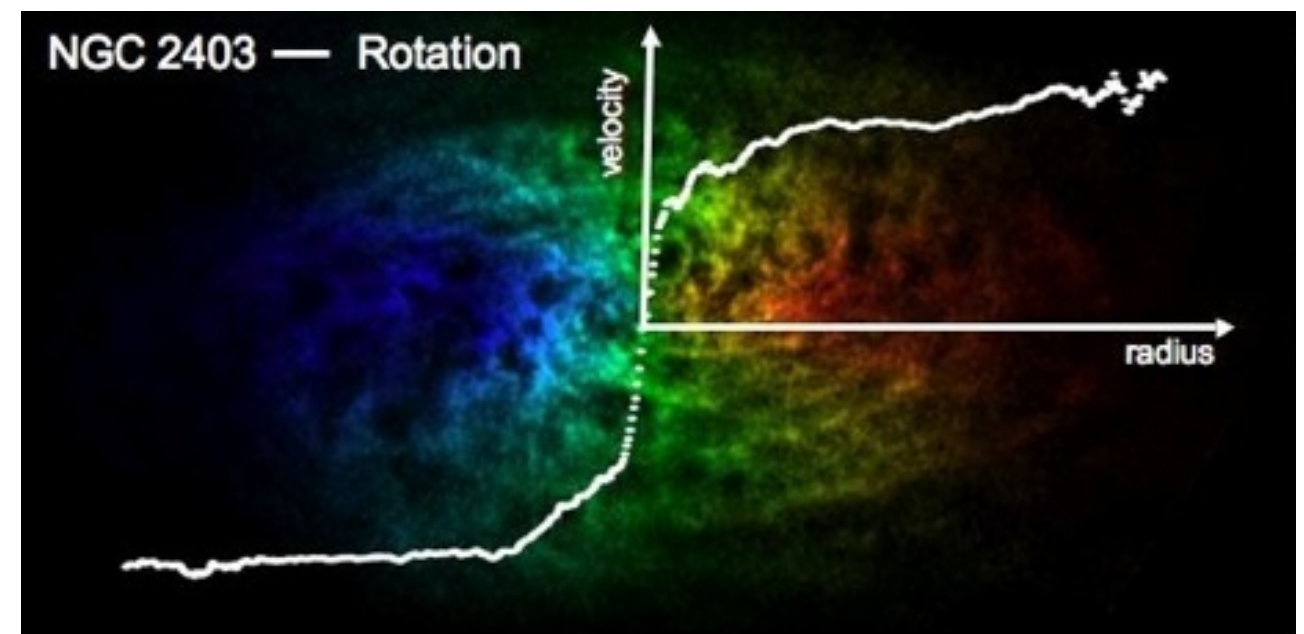
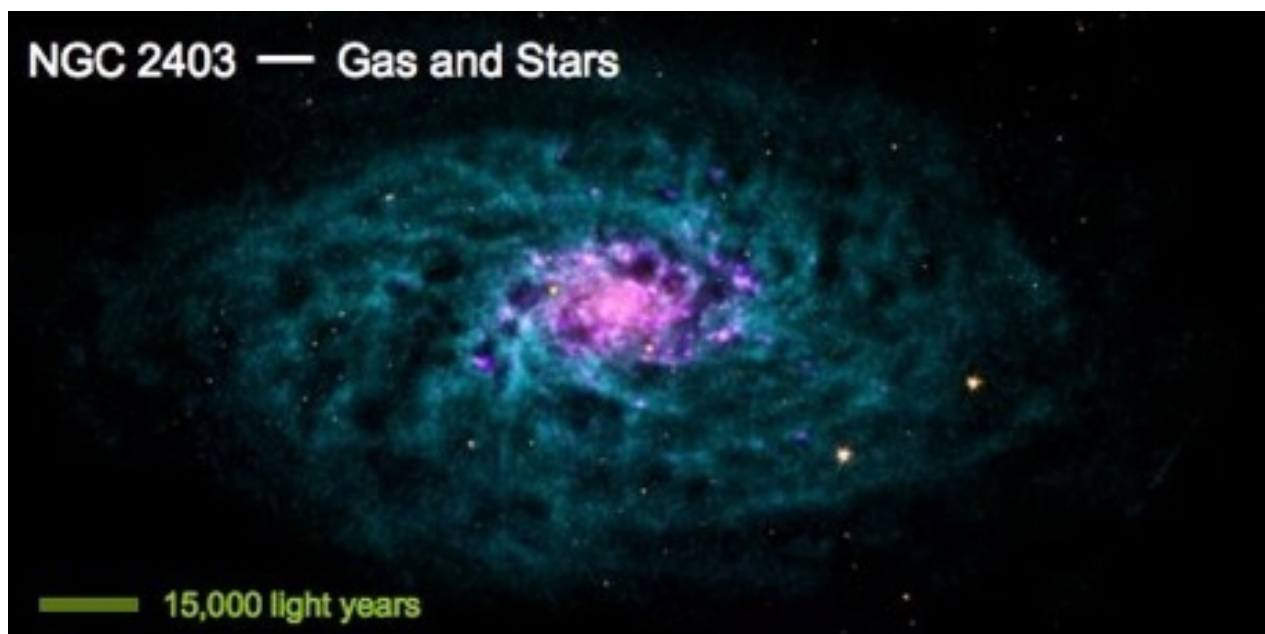
Systemic velocity of the galaxy



Hubble constant

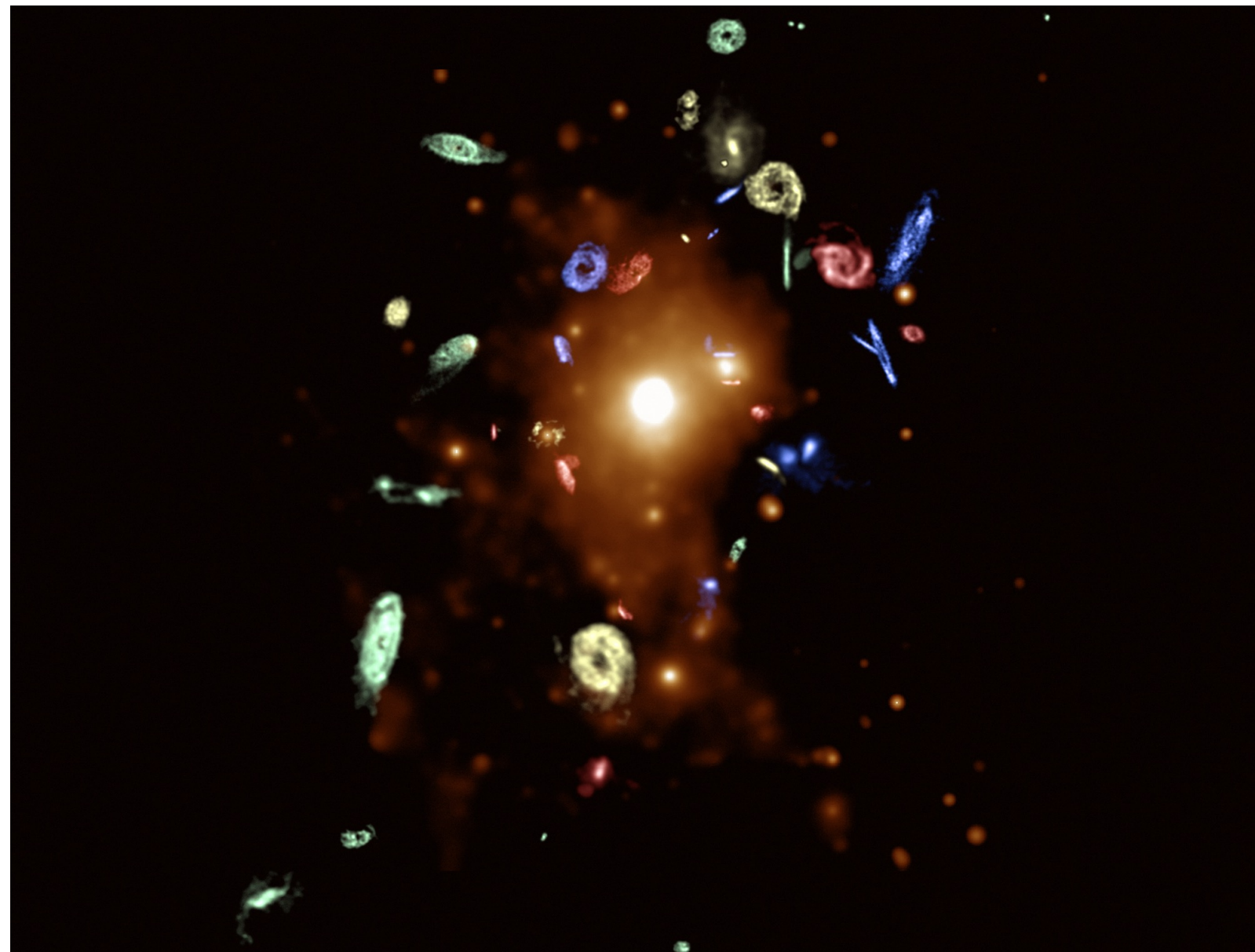
TRACING VELOCITY FIELDS

- ▶ 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)



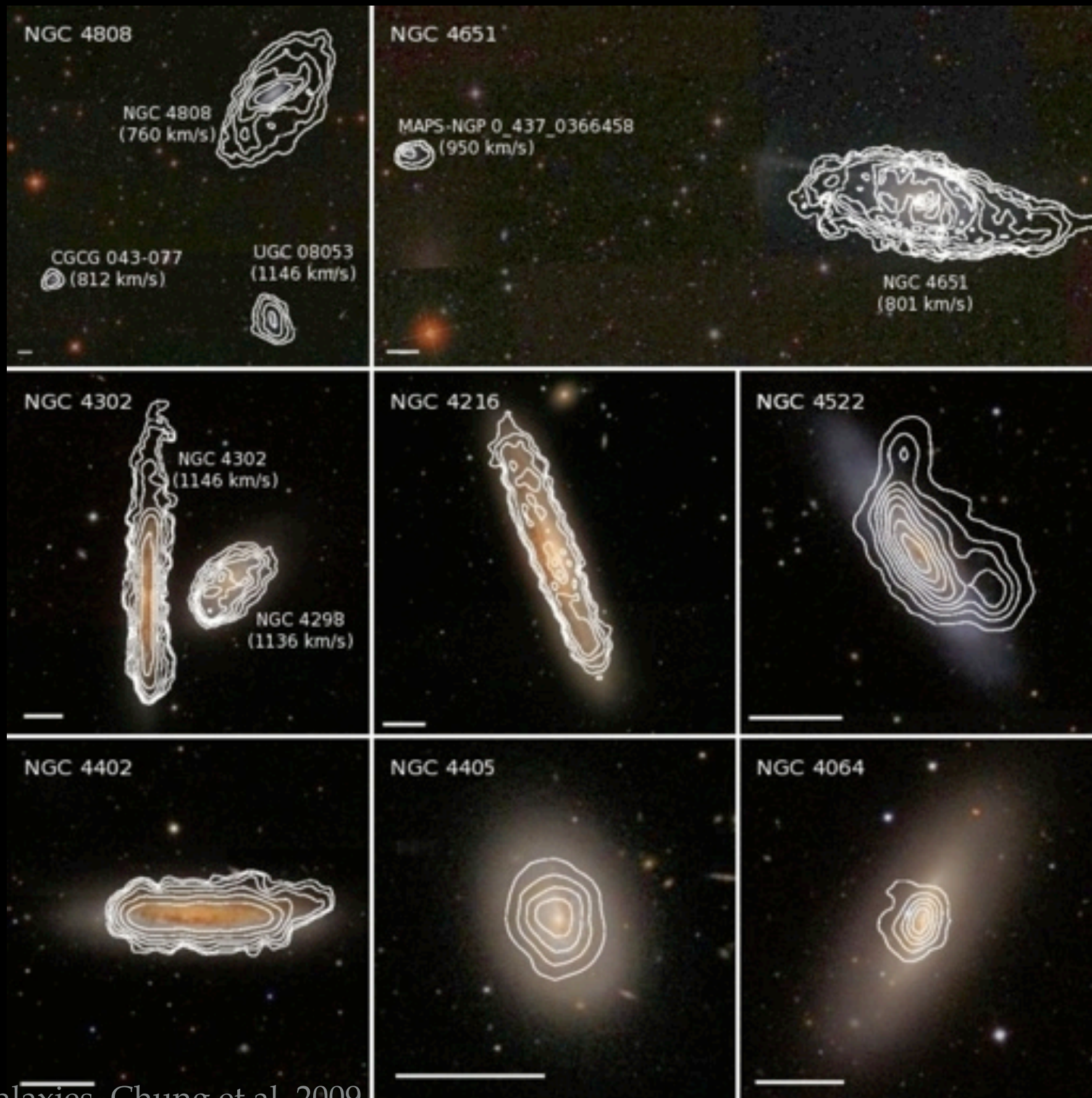
ENVIRONMENTAL EFFECTS ON THE HI CONTENT

- ▶ 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

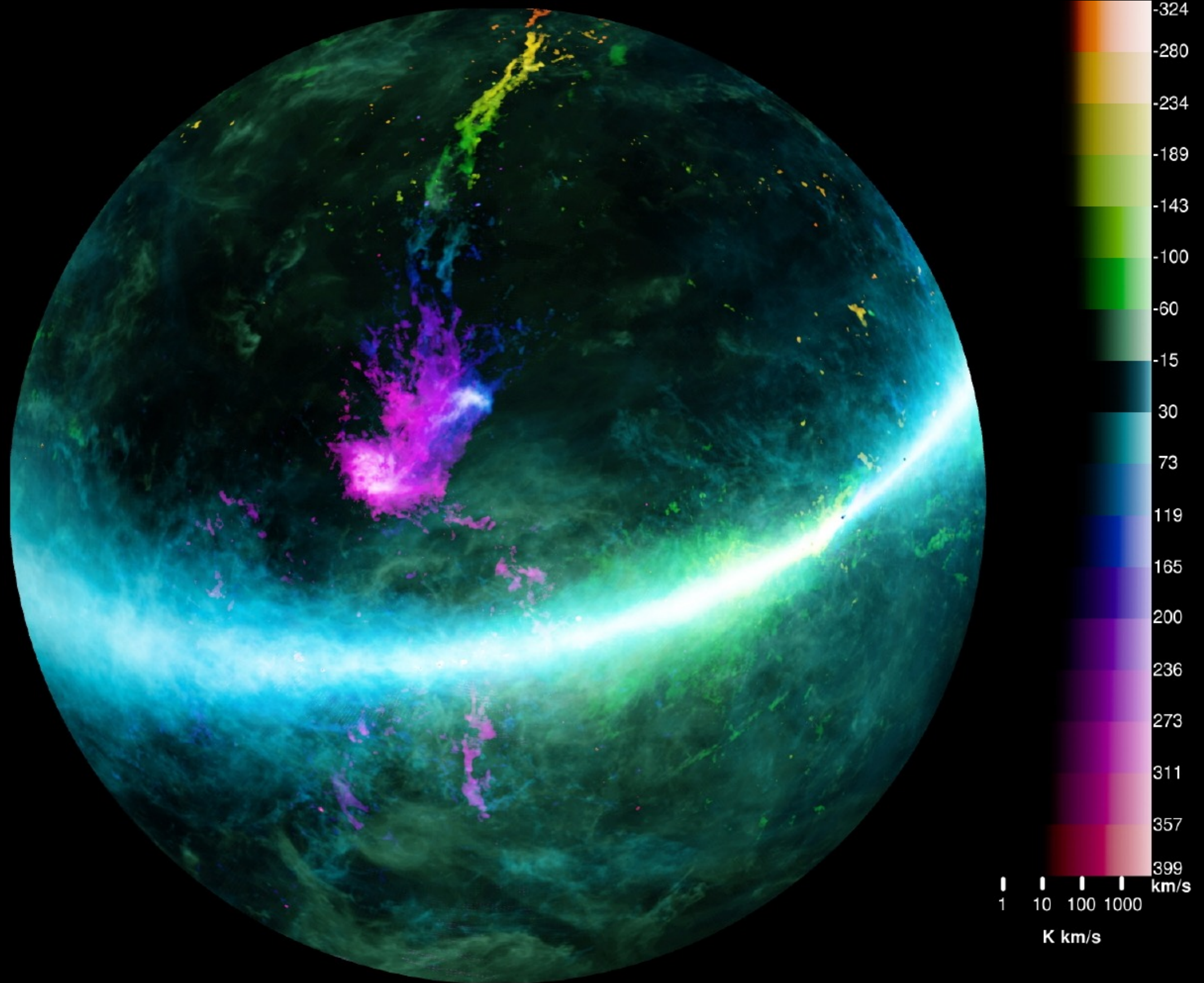
VIRGO CLUSTER GALAXIES



THE M81 GROUP



THE MAGELLANIC SYSTEM





THANK YOU!