HELGA DÉNES

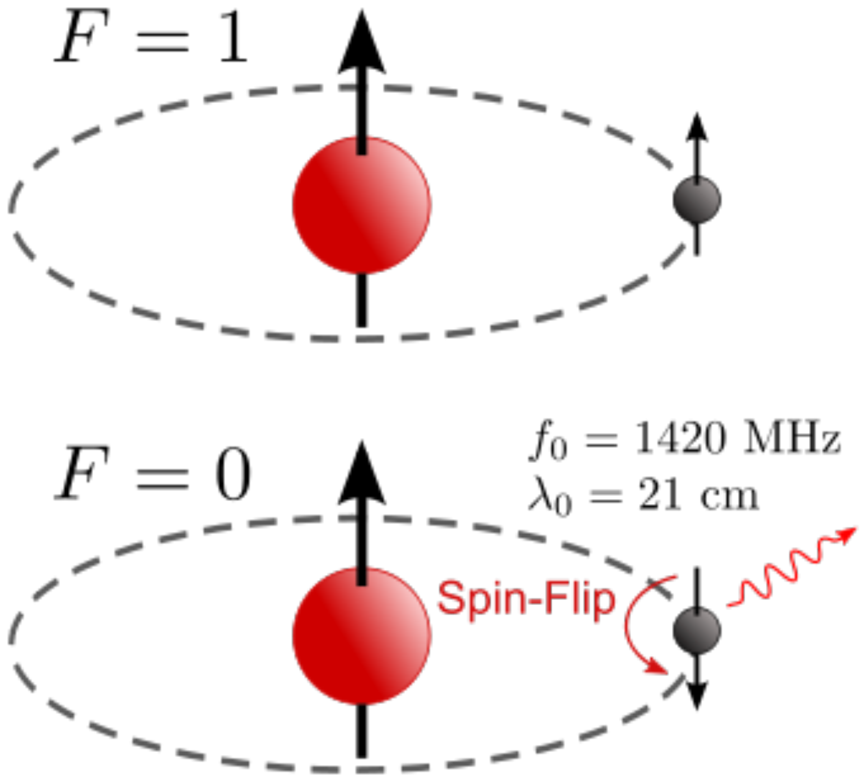
HI IN GALAXIES

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.

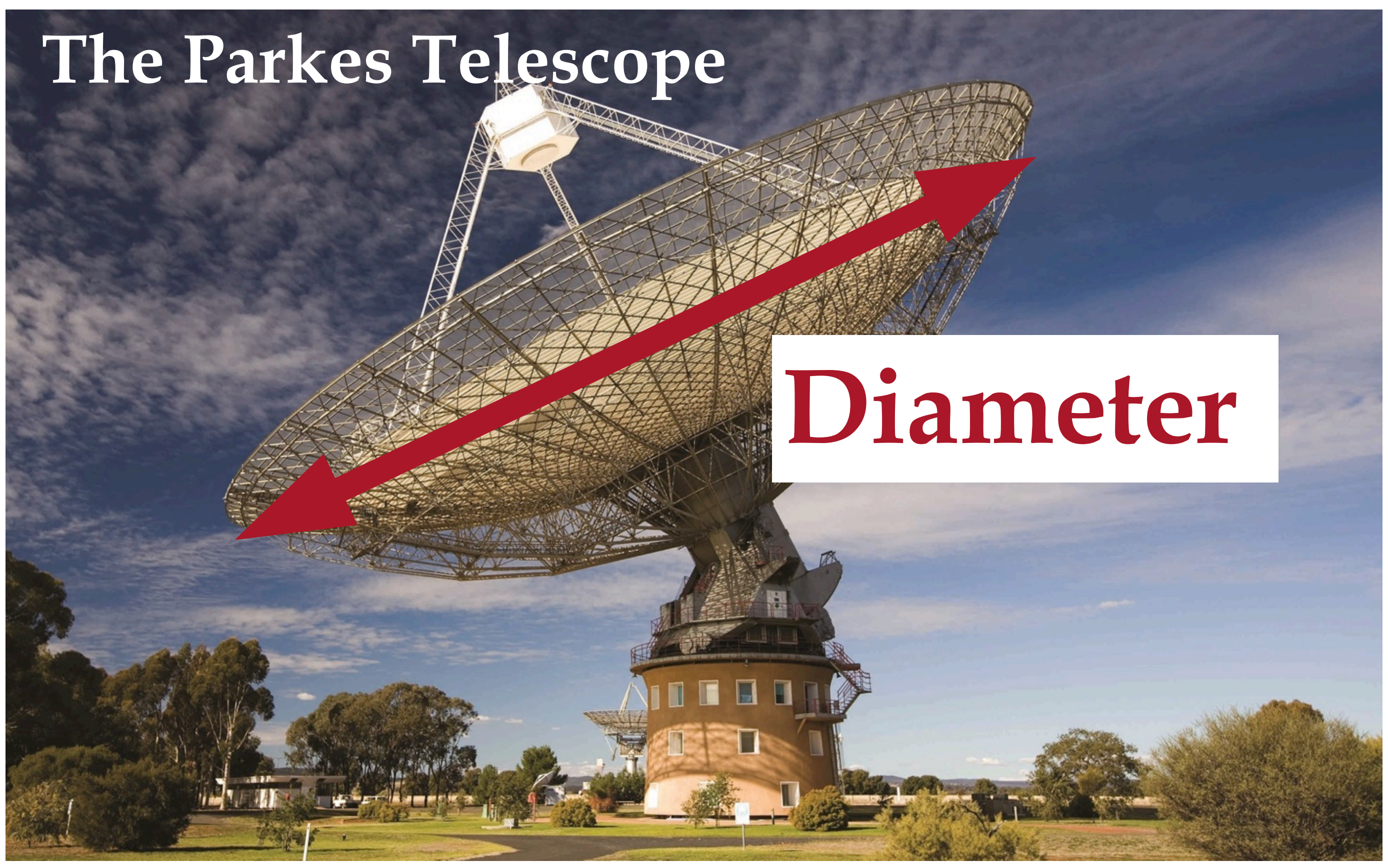
- This is good for short wavelengths, like UV or optical telescopes
- But unfortunate for radio telescopes

$$\Theta = \lambda / D$$

Θ – resolution
λ – wavelength
D – diameter/baseline

Singel dish telescopes:

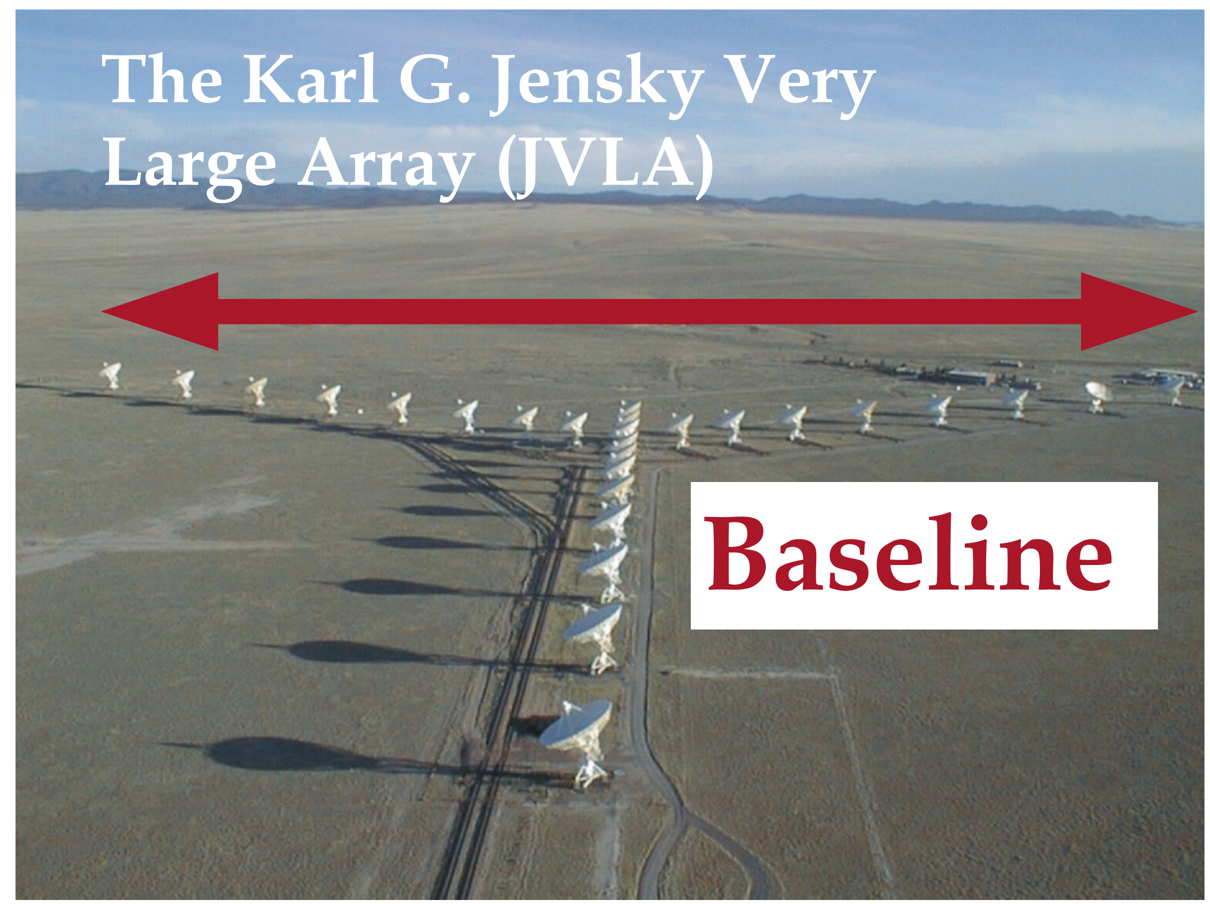
Resolution: ~ Diameter



www.csiro.au

Interferometers:

Resolution: ~ distance between telescopes



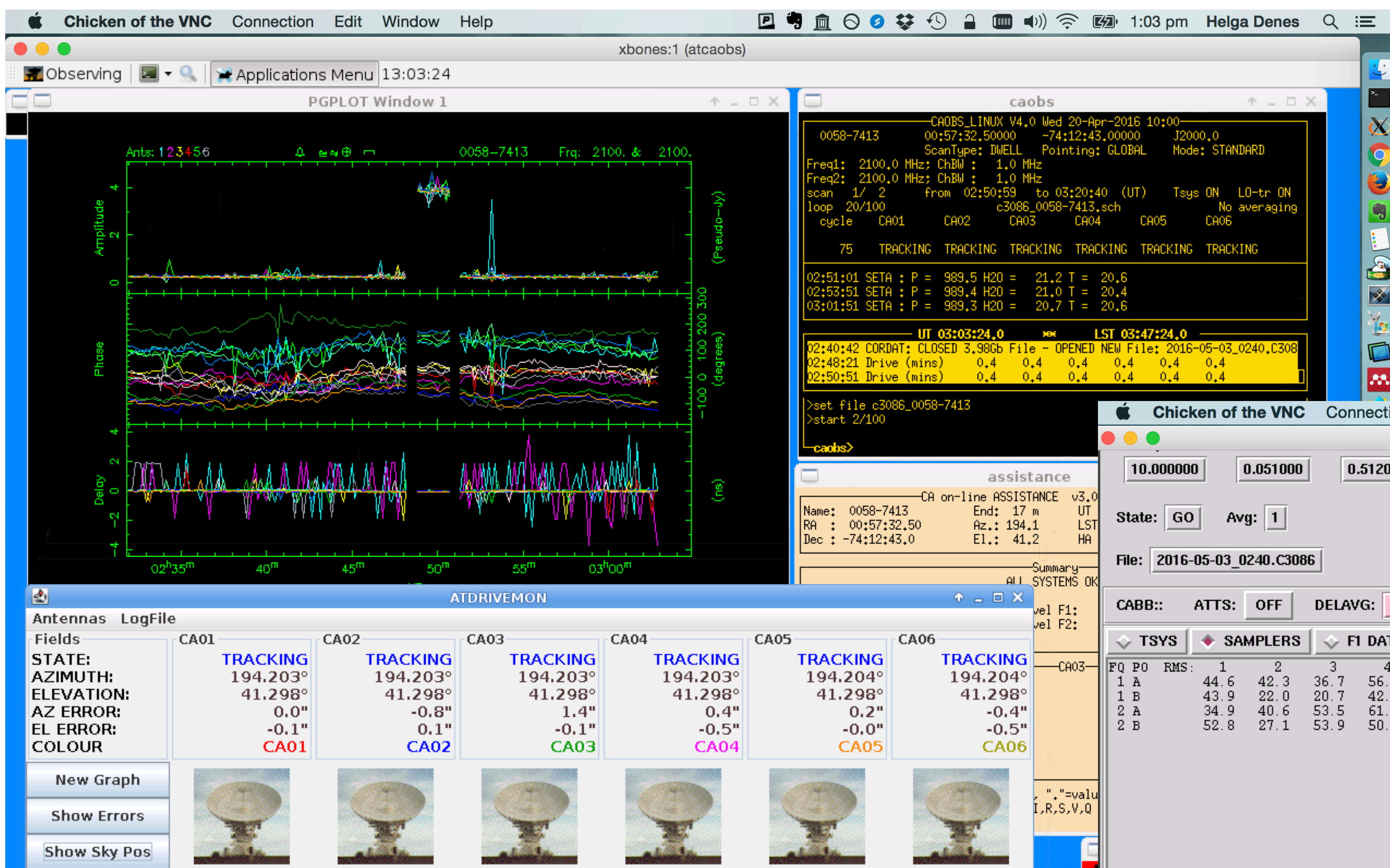
http://images.nrao.edu

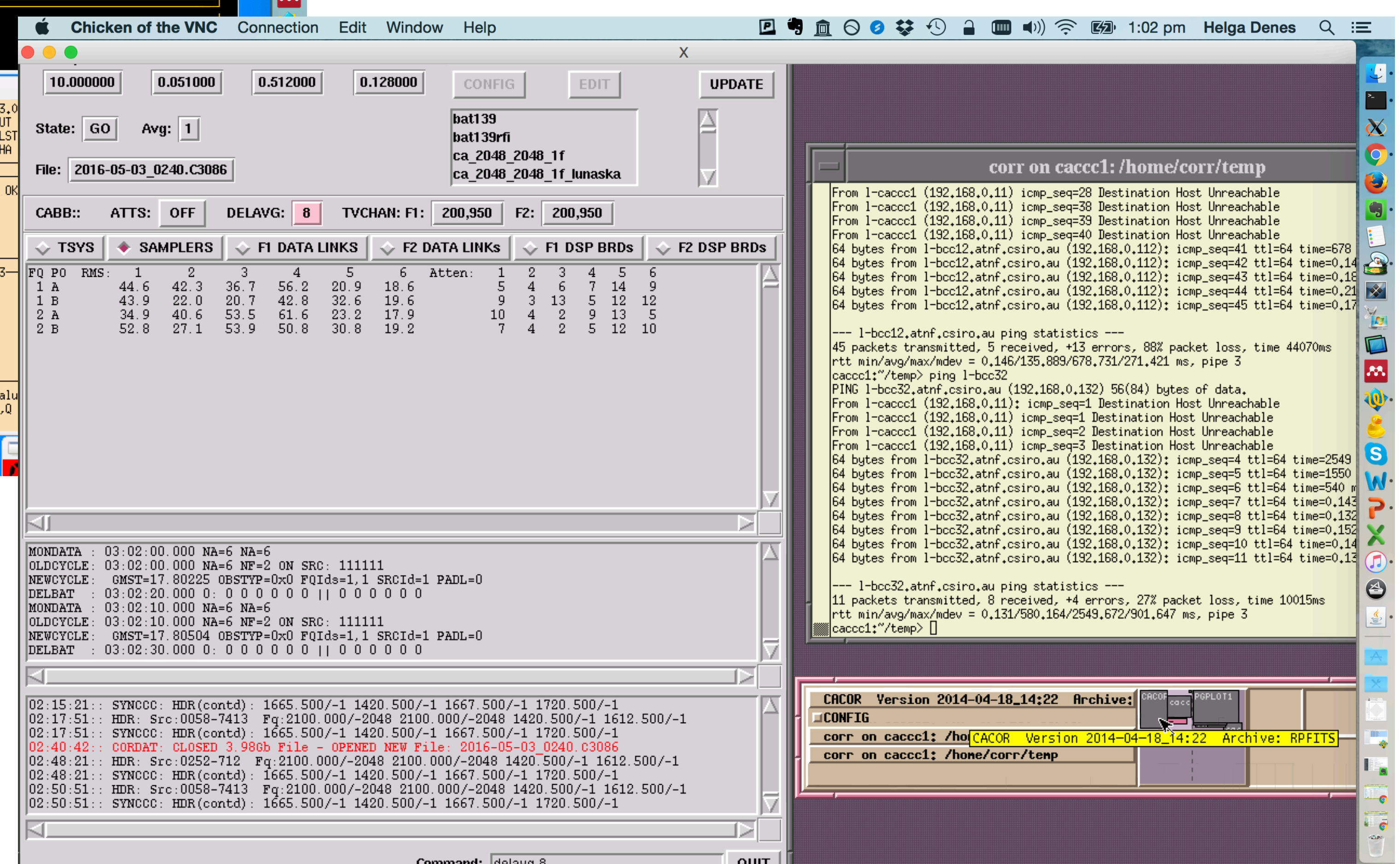
OBSERVING WITH ATCA

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.



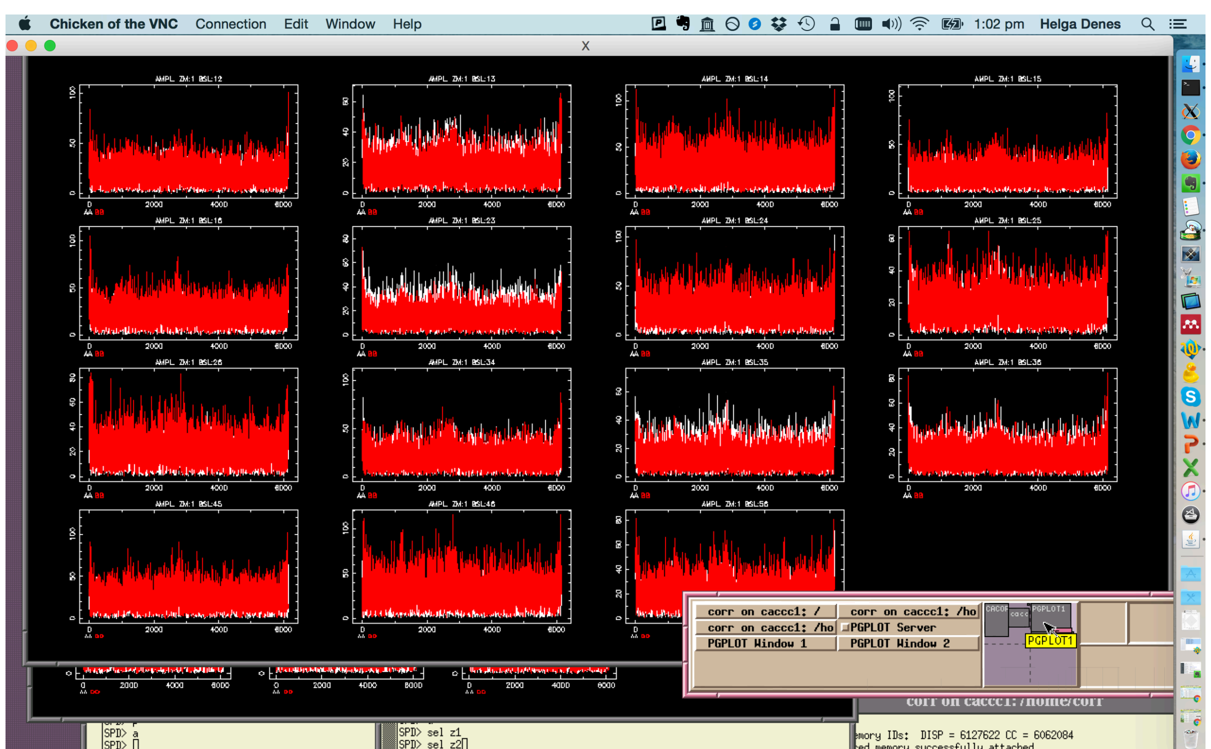


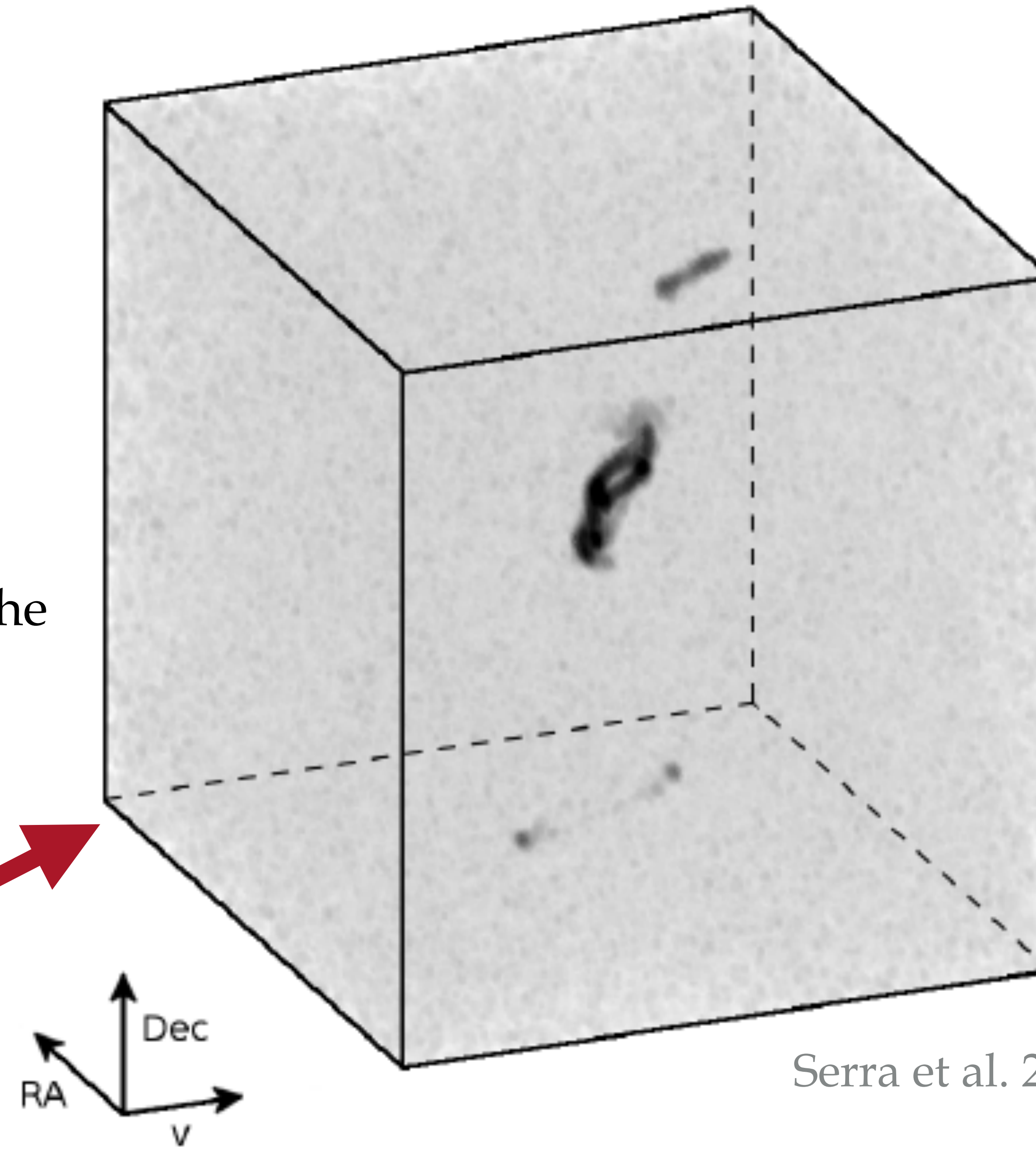
CALIBRATING THE DATA

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.

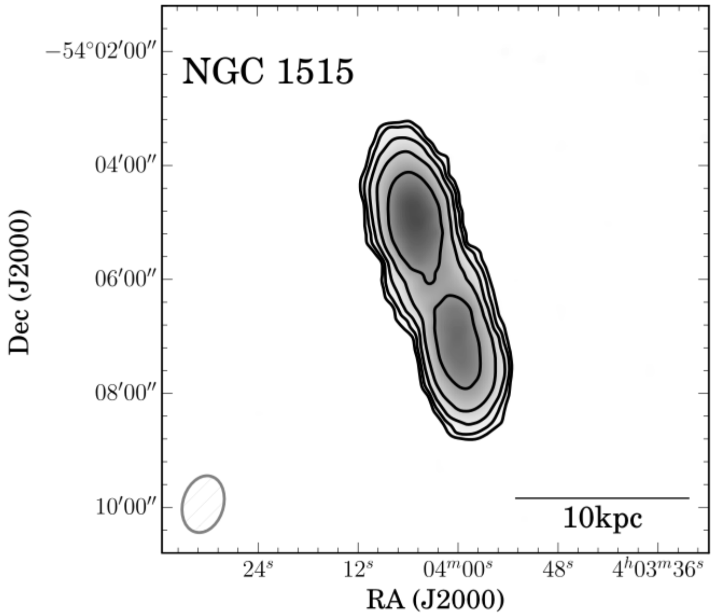




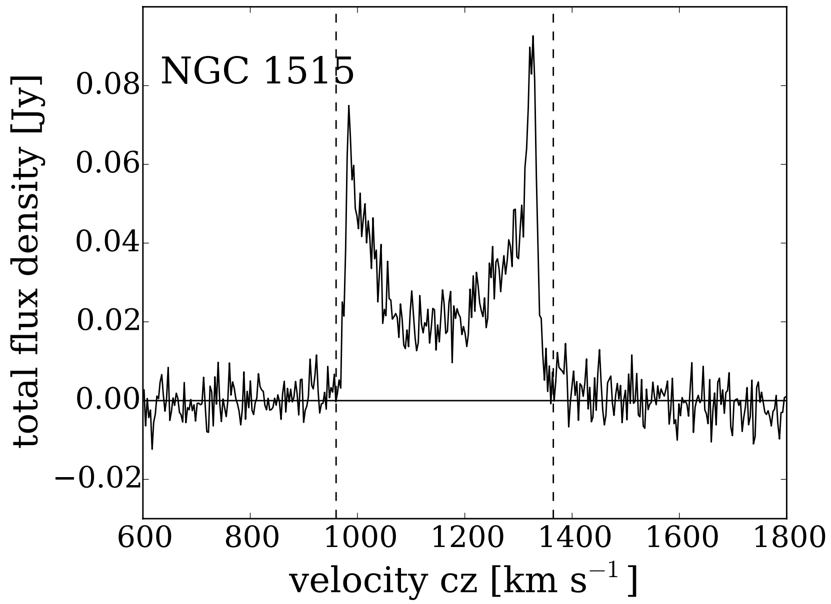
Serra et al. 2015

THE FINISHED DATA

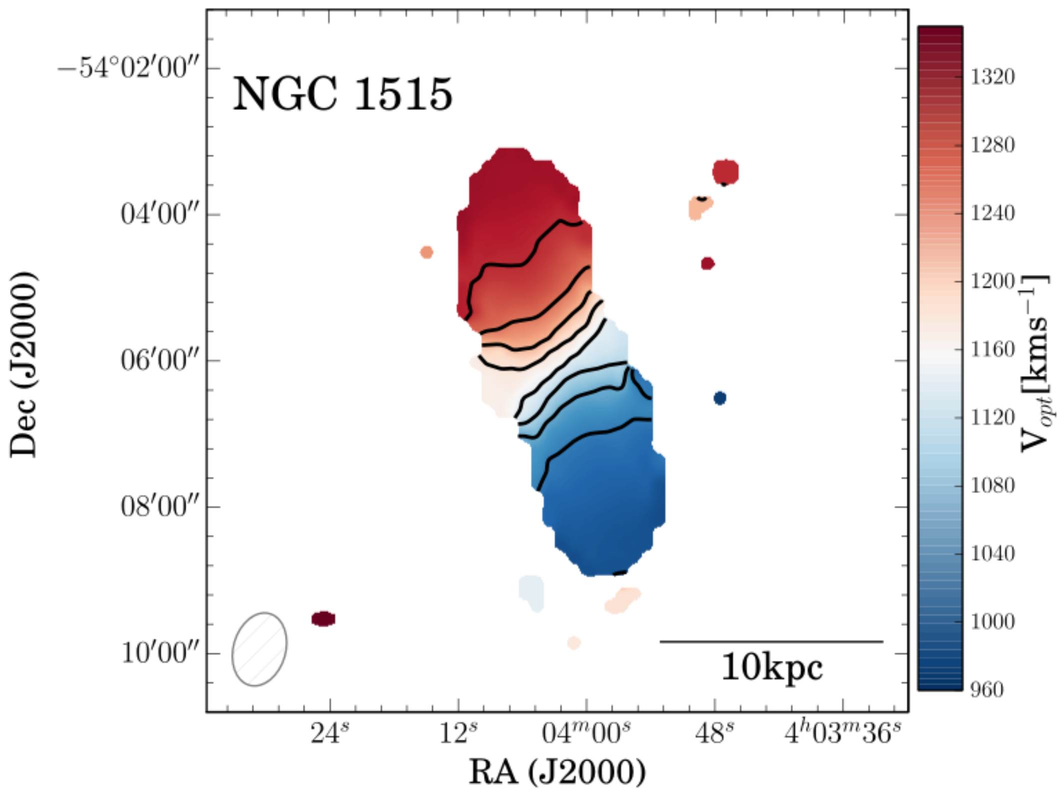
HI intensity



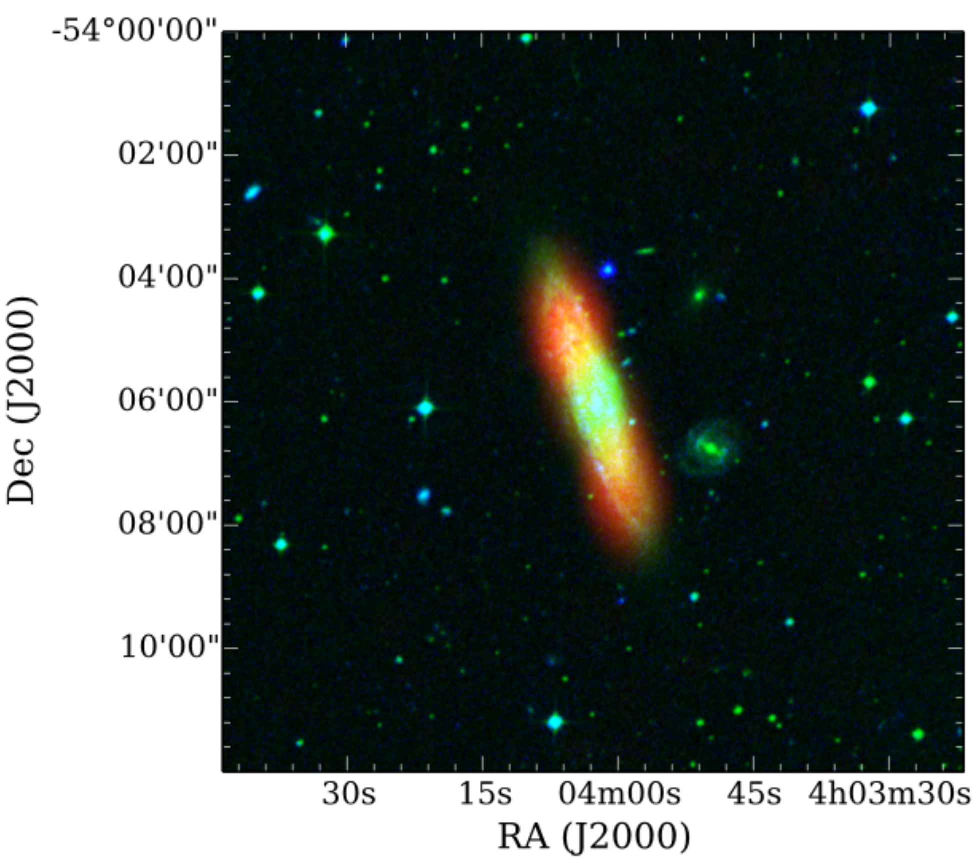
HI line profile



HI velocity field

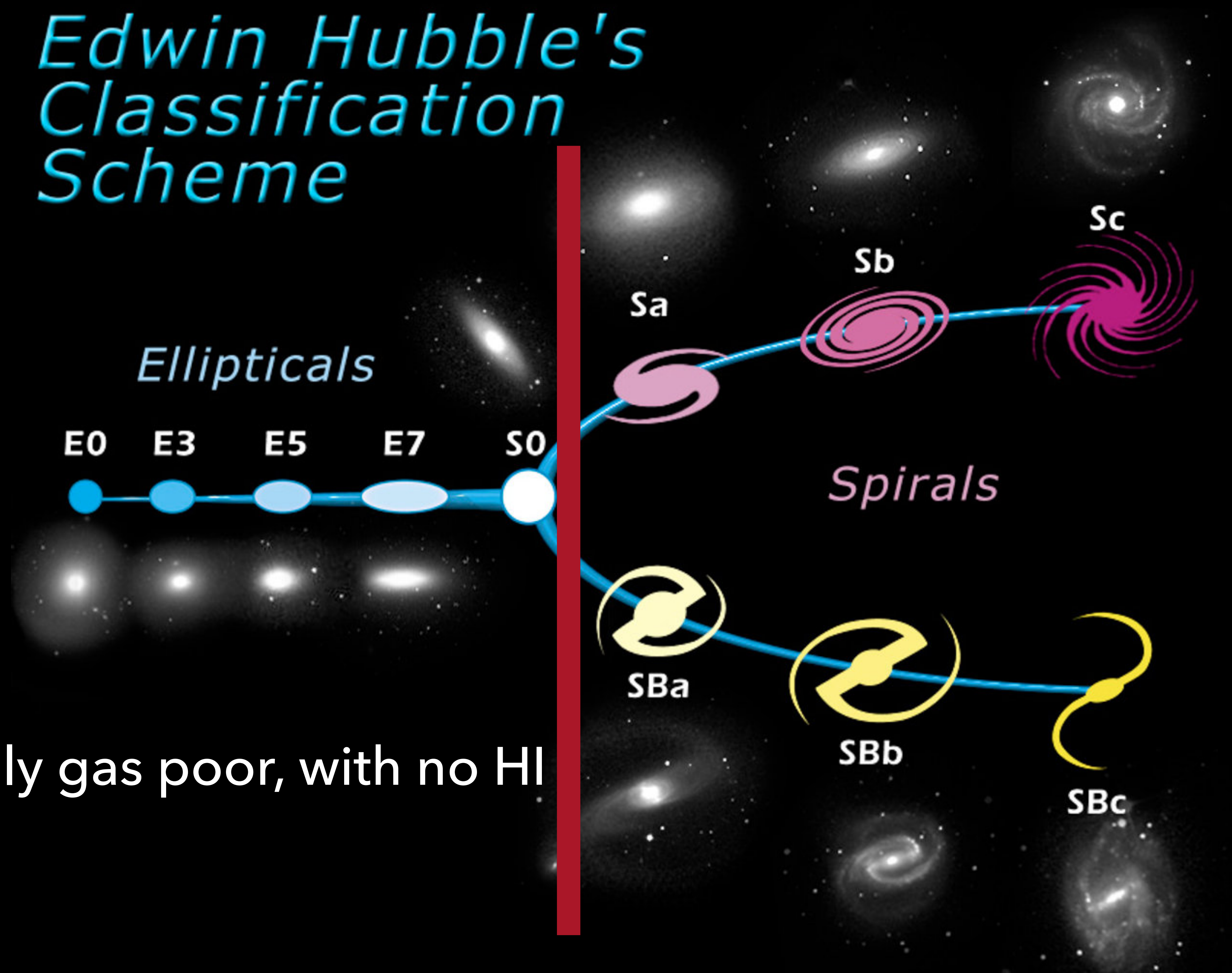


HI, optical and UV data



GALAXY TYPES

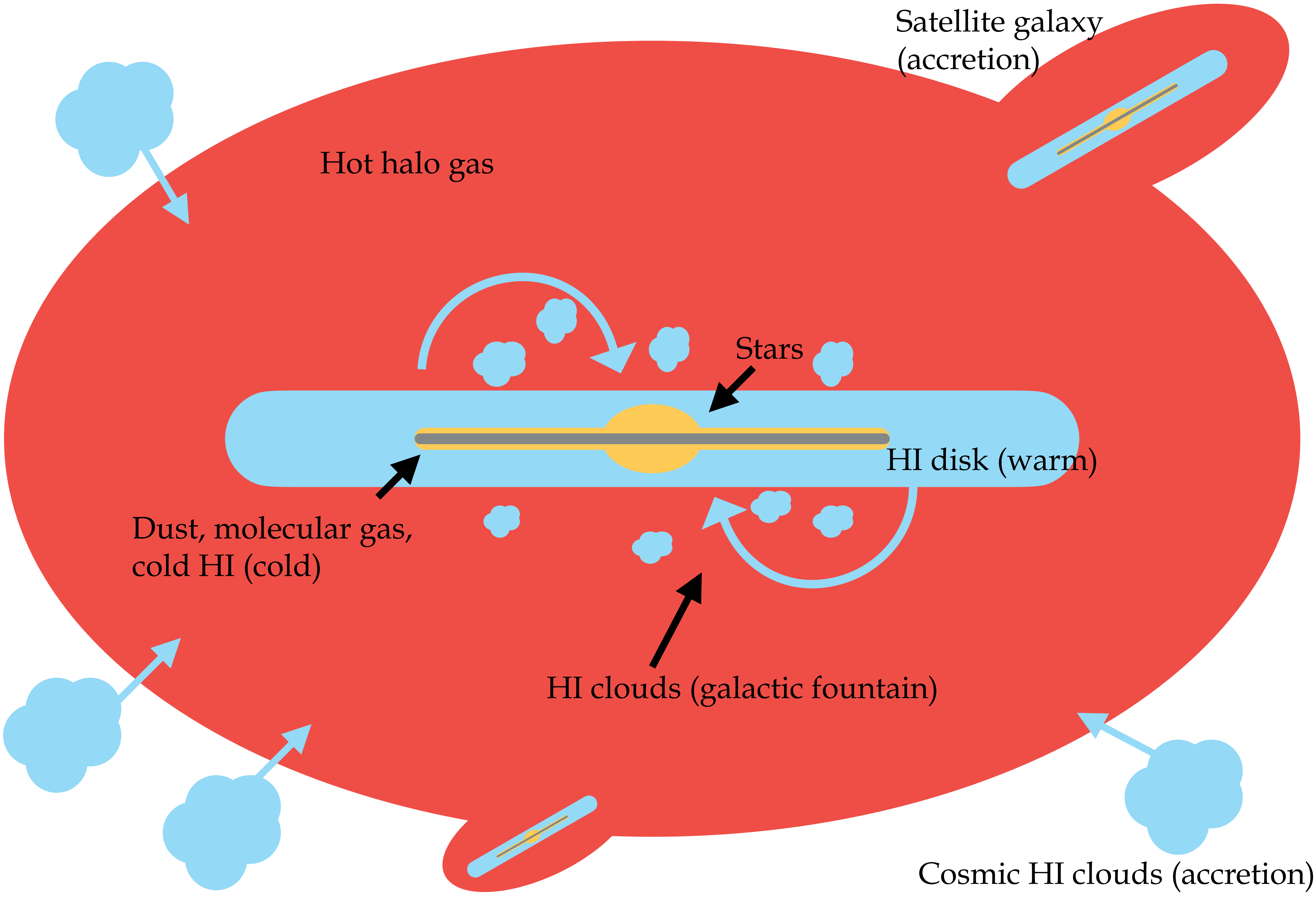
Typically gas rich, with HI



Typically gas poor, with no HI

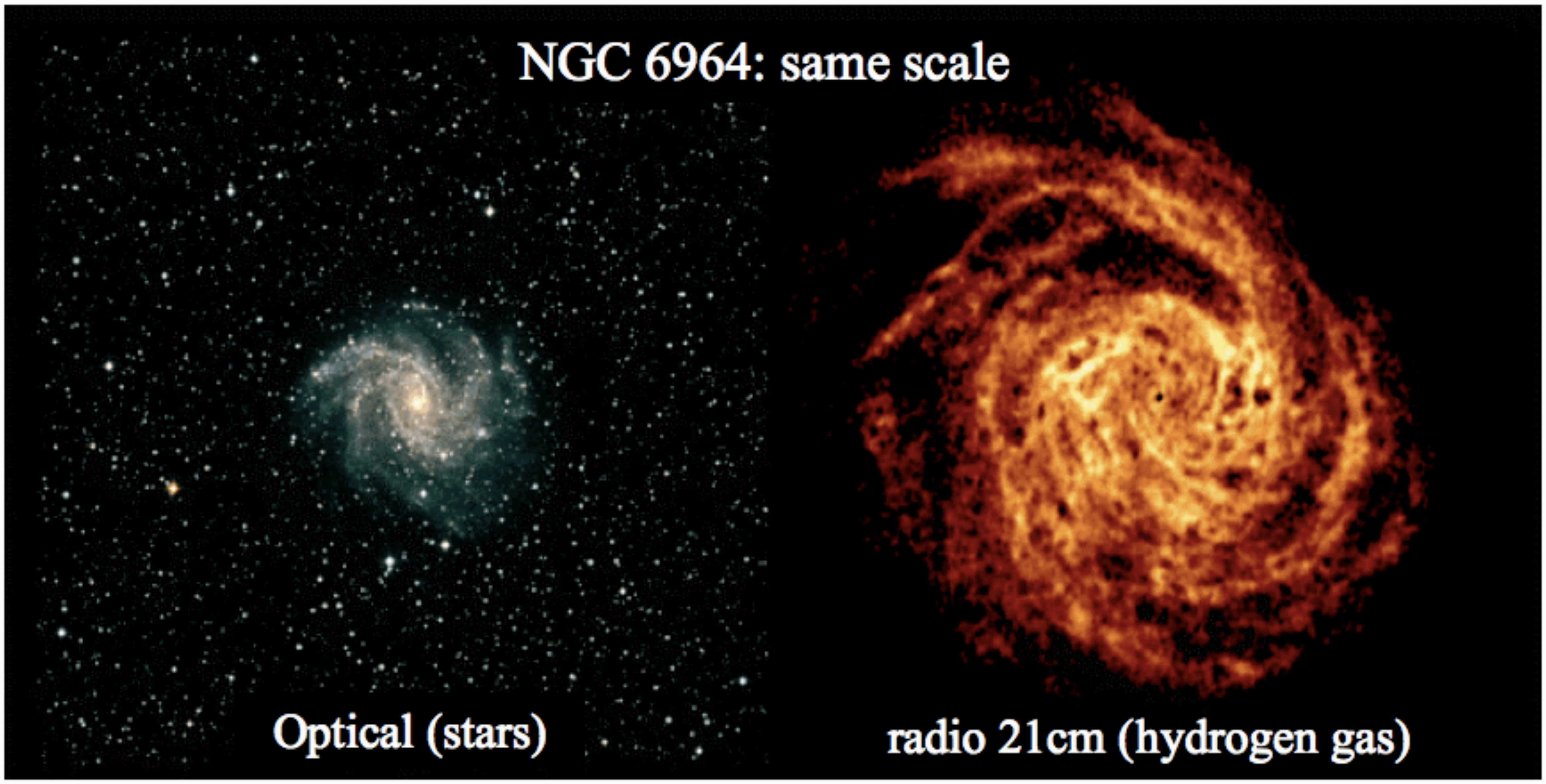
https://www.spacetelescope.org/images/heic9902o/

A TYPICAL LATE-TYPE/SPIRAL GALAXY



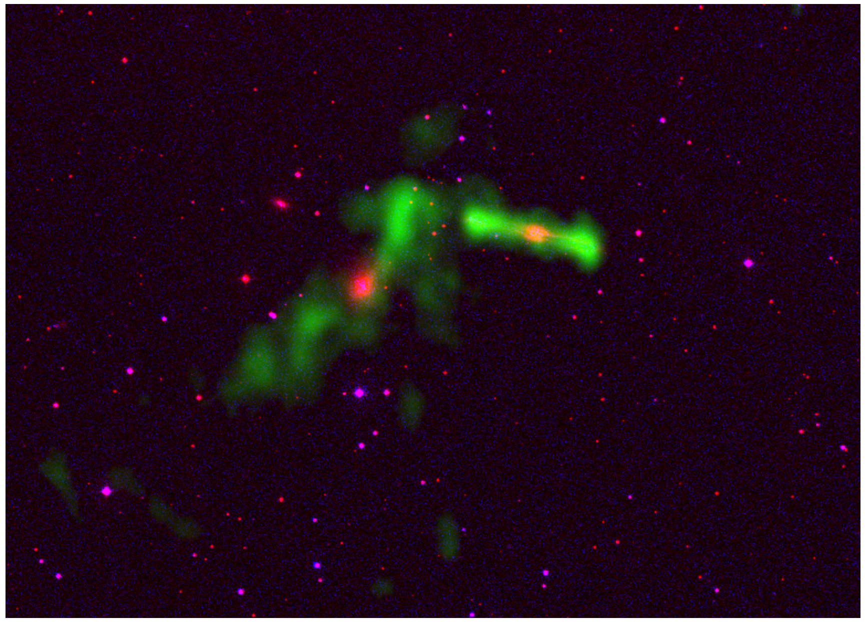
HI IN LATE TYPE GALAXIES

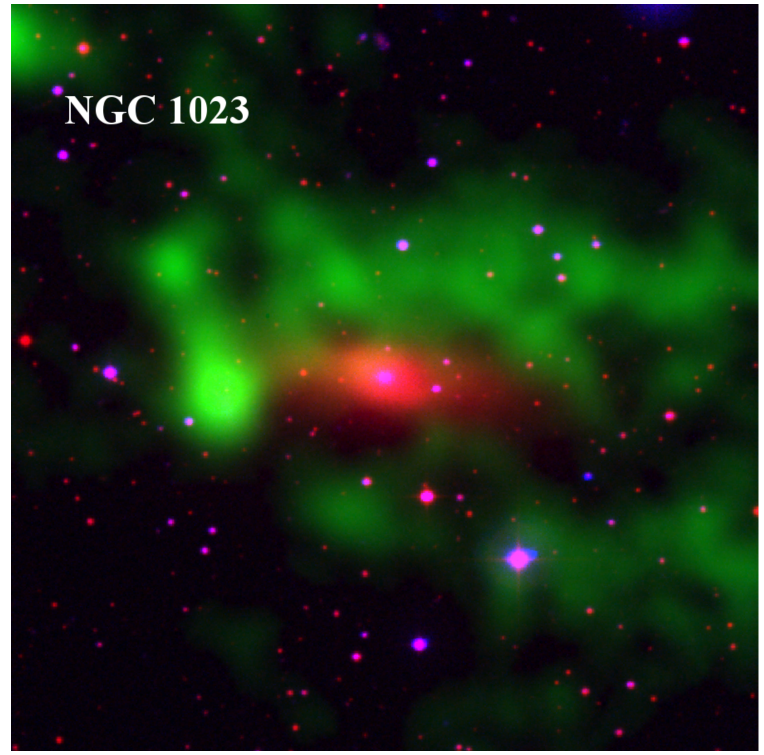
- Star forming **late-type galaxies** have usually significant amounts of HI
- Morphology is usually a **regular disk approximately 2-3 times the stellar diameter**

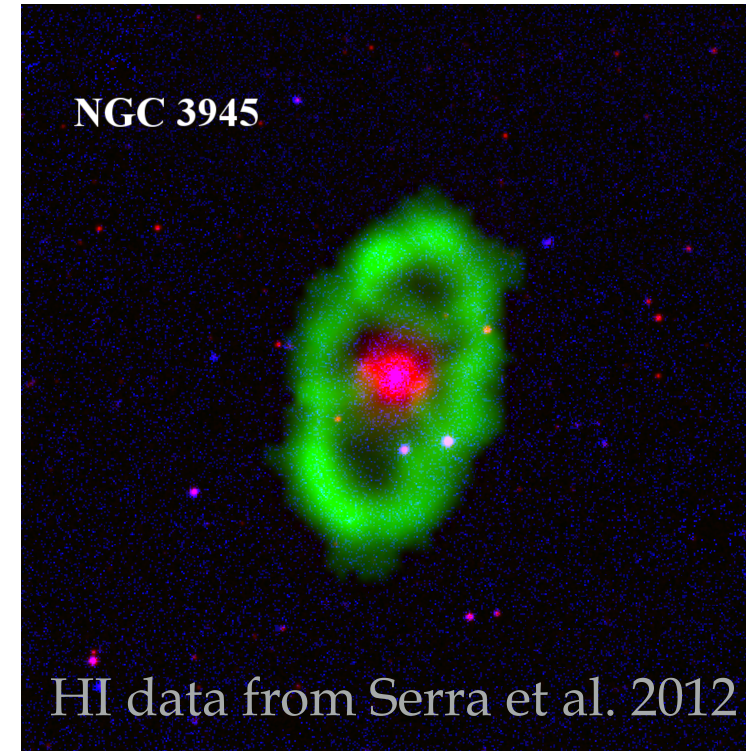


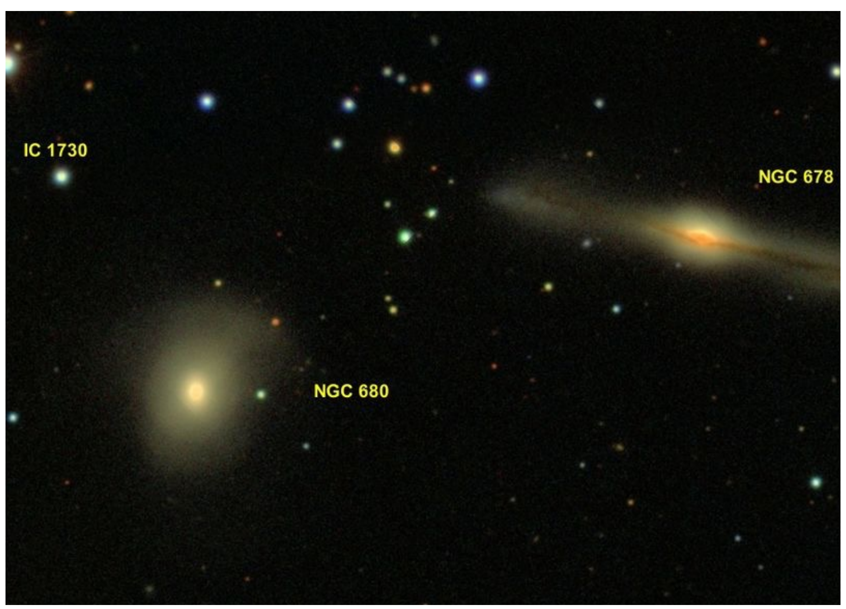
Credit: T. Oosterloo

HI IN ELLIPTICAL/LATE-TYPE GALAXIES









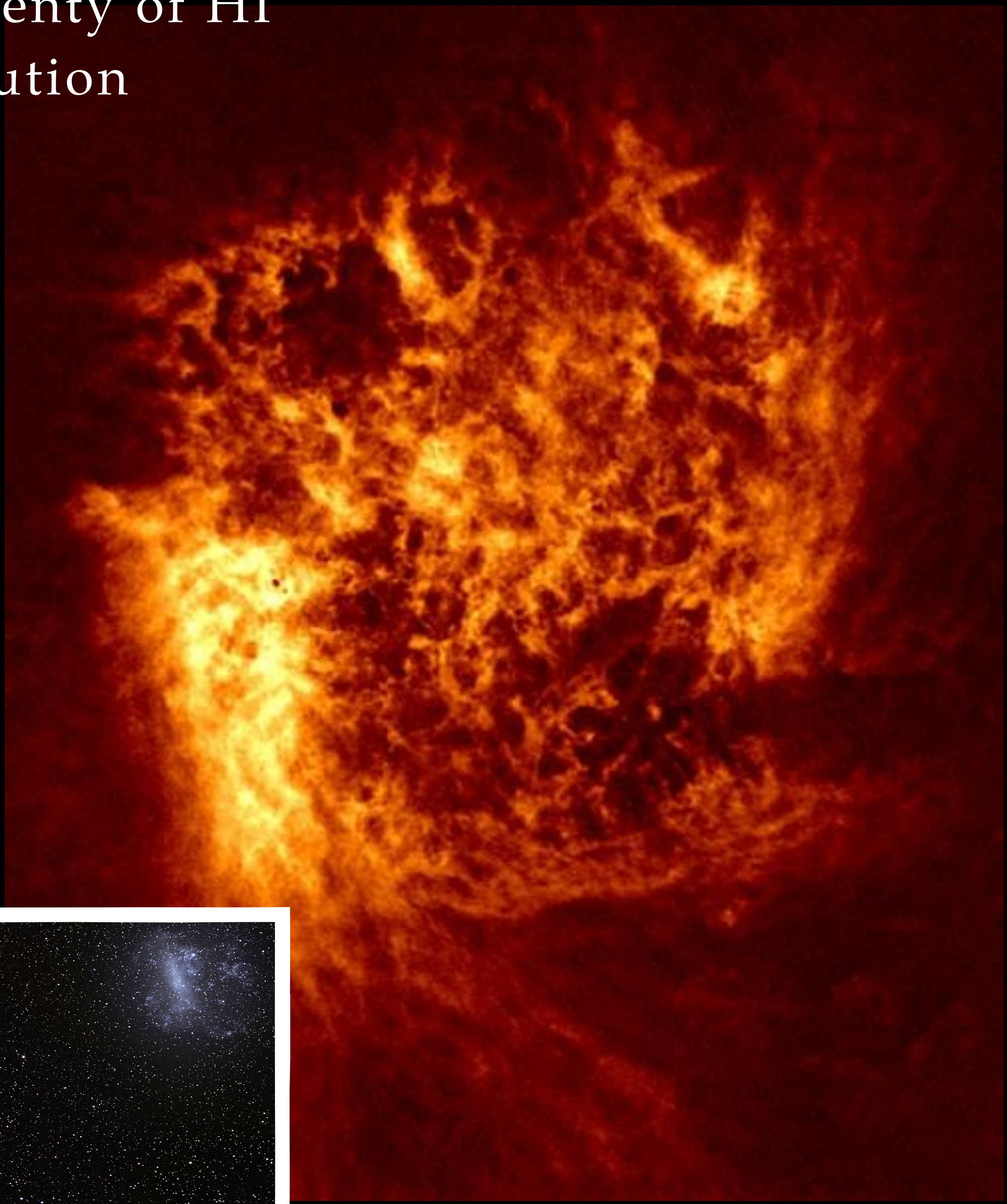
- **Early-type galaxies** can have various HI morphologies from regular disks to rings and unsettled clouds.
- This gas is usually acquired from another galaxy (e.g. gas rich merger or tidal interaction)

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?

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

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

Distance to the galaxy

Integral of the HI line

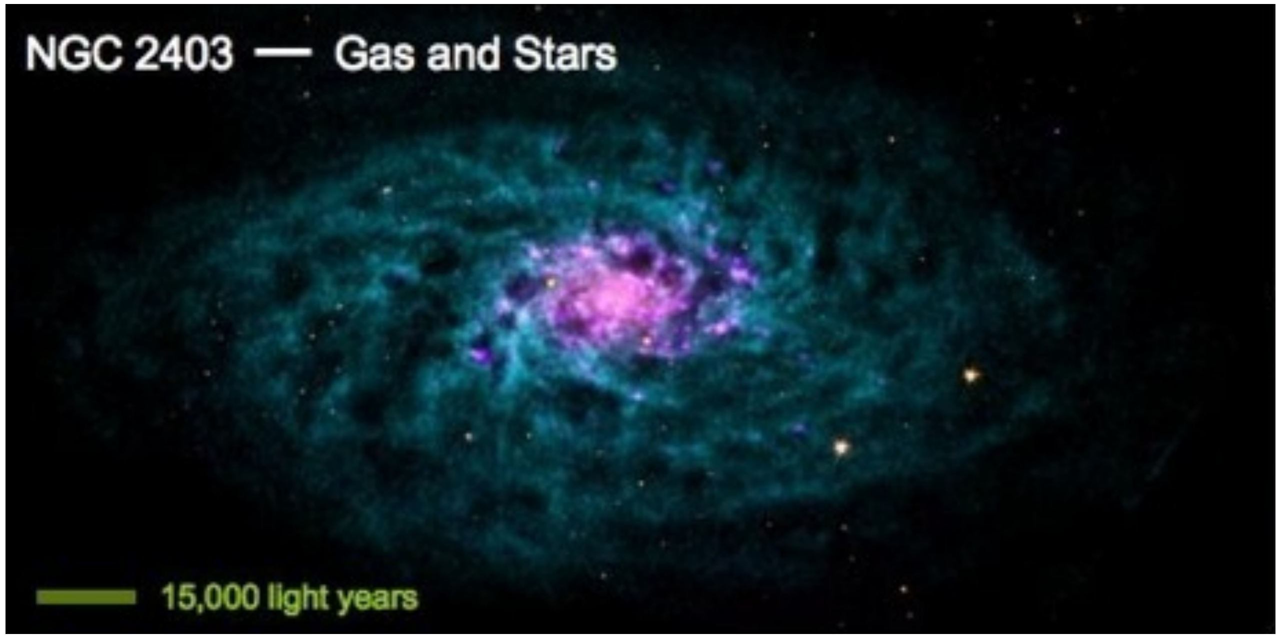
$$d \approx \frac{v_r\,(\mathrm{optical})}{H_0}$$

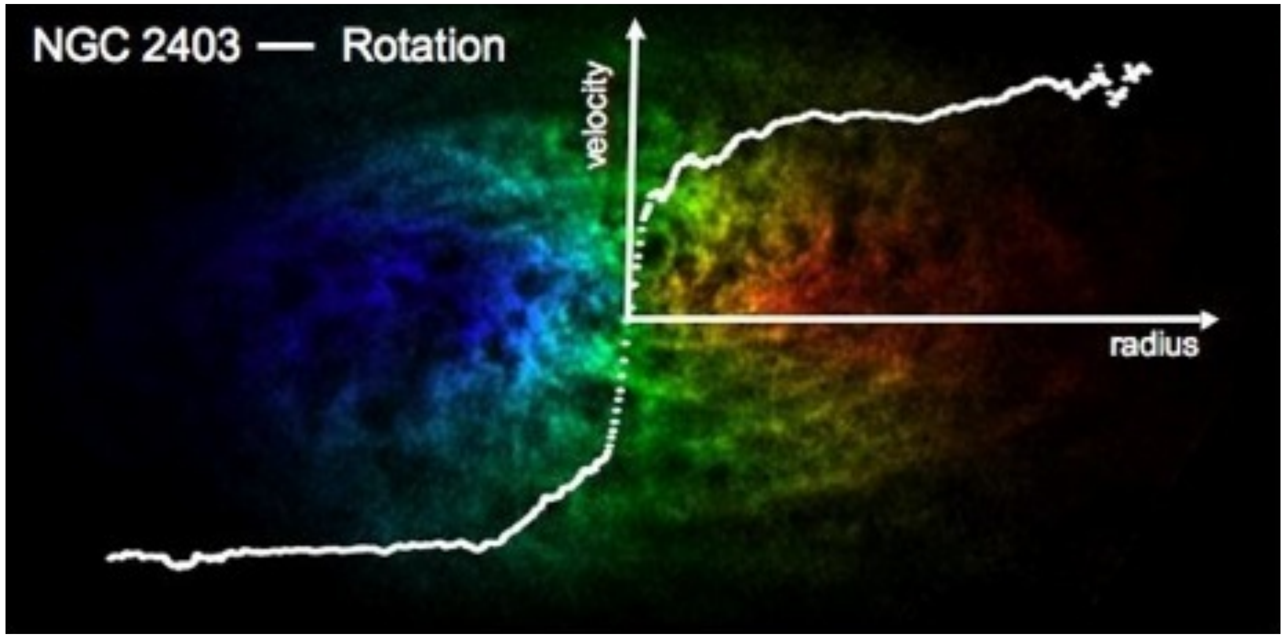
Systemic velocity of the galaxy

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)



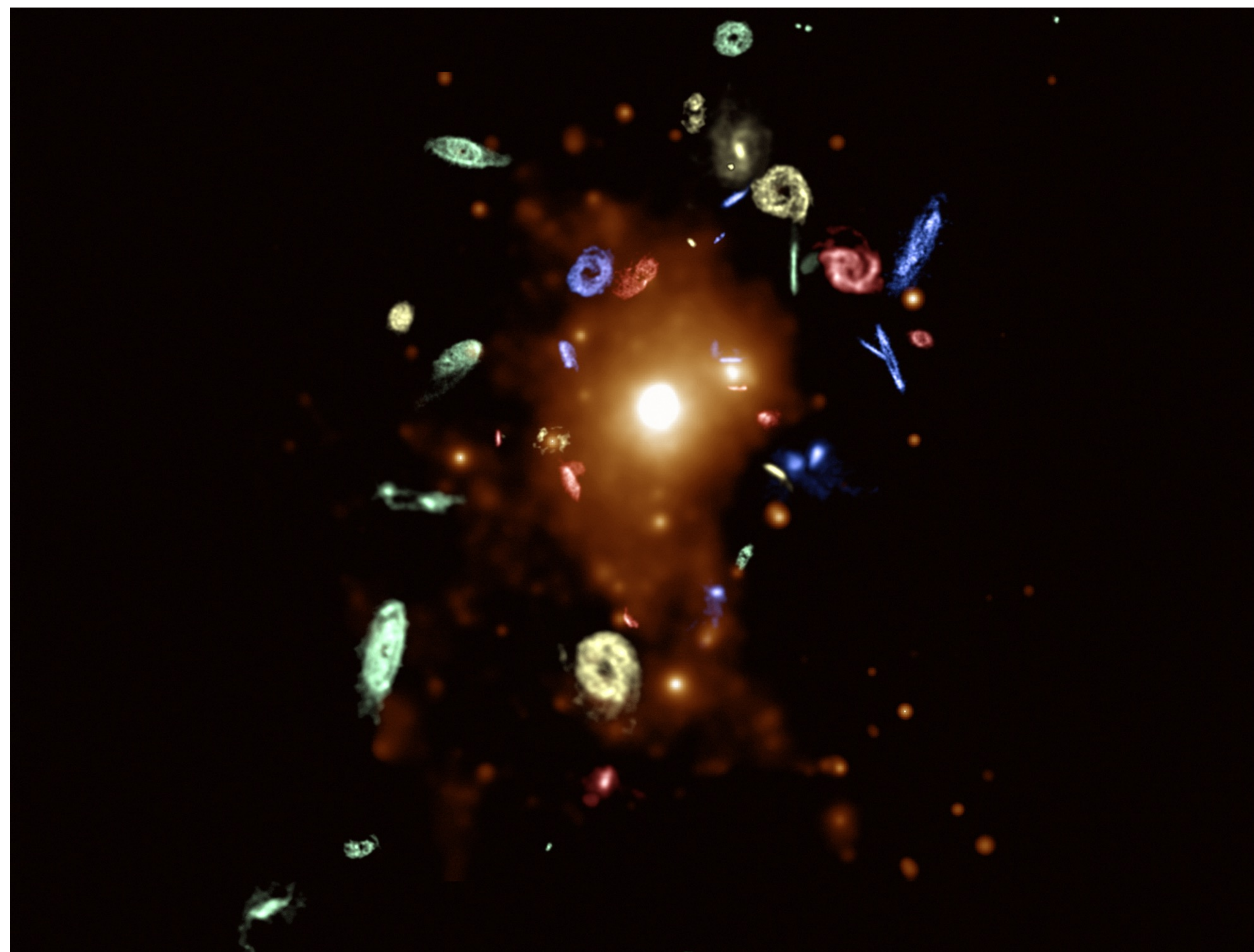


THINGS survey, Walter et al. 2008

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

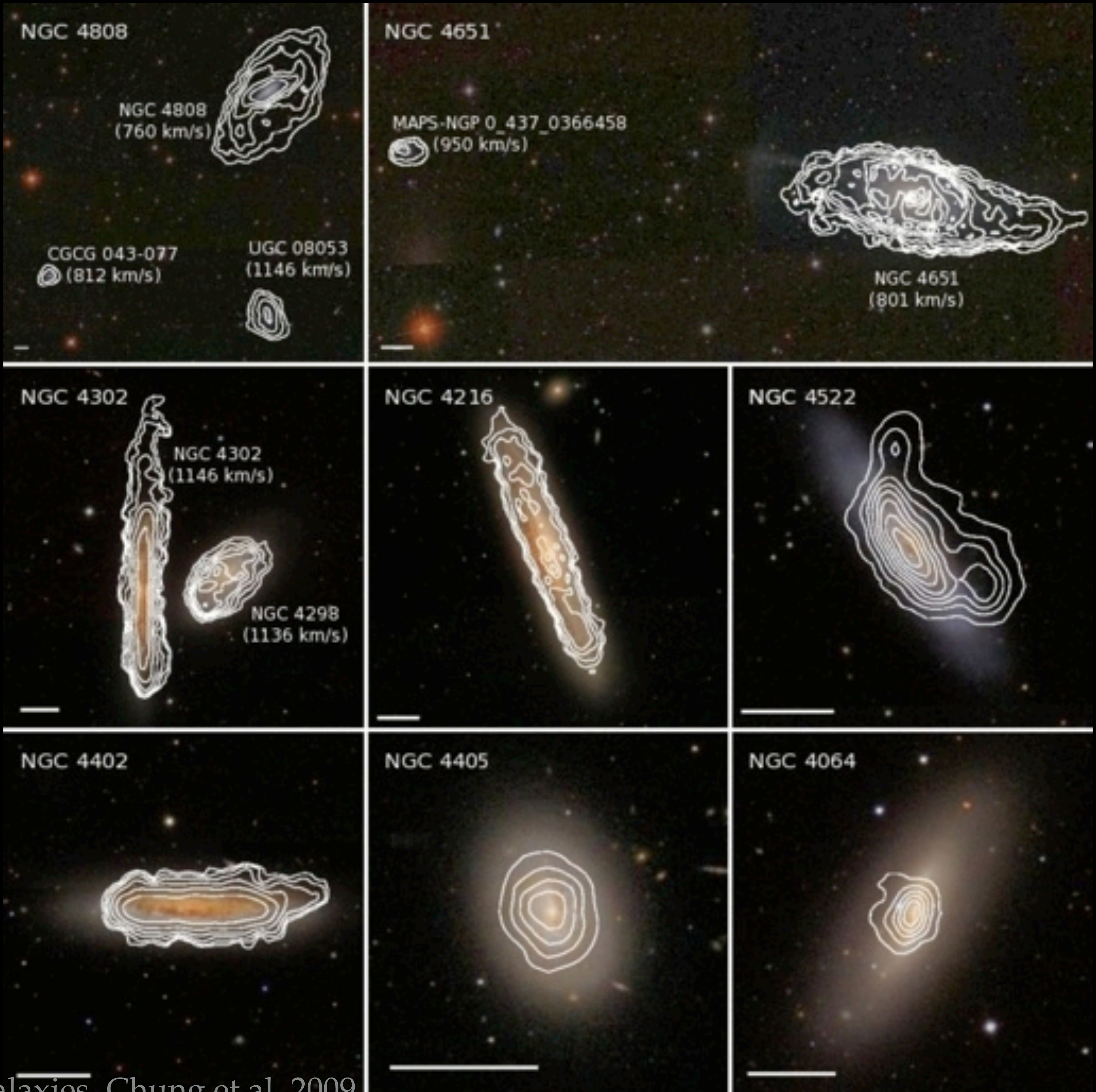
- **Environmental processes:**
  - tidal interactions
  - mergers
  - ICM interactions
  - starvation



X-ray and HI composite of the Virgo cluster

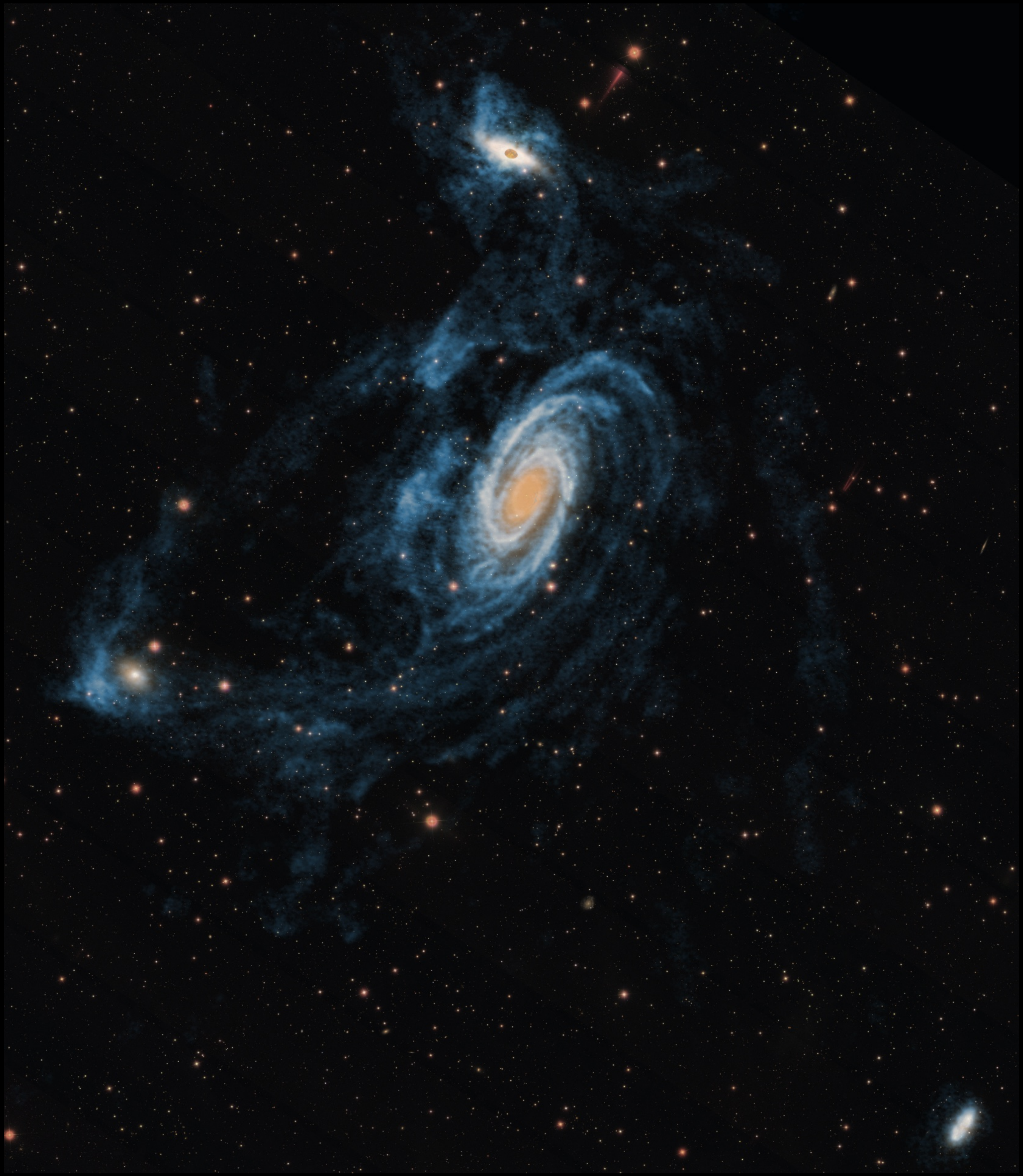
Chung et al. 2009

VIRGO CLUSTER GALAXIES



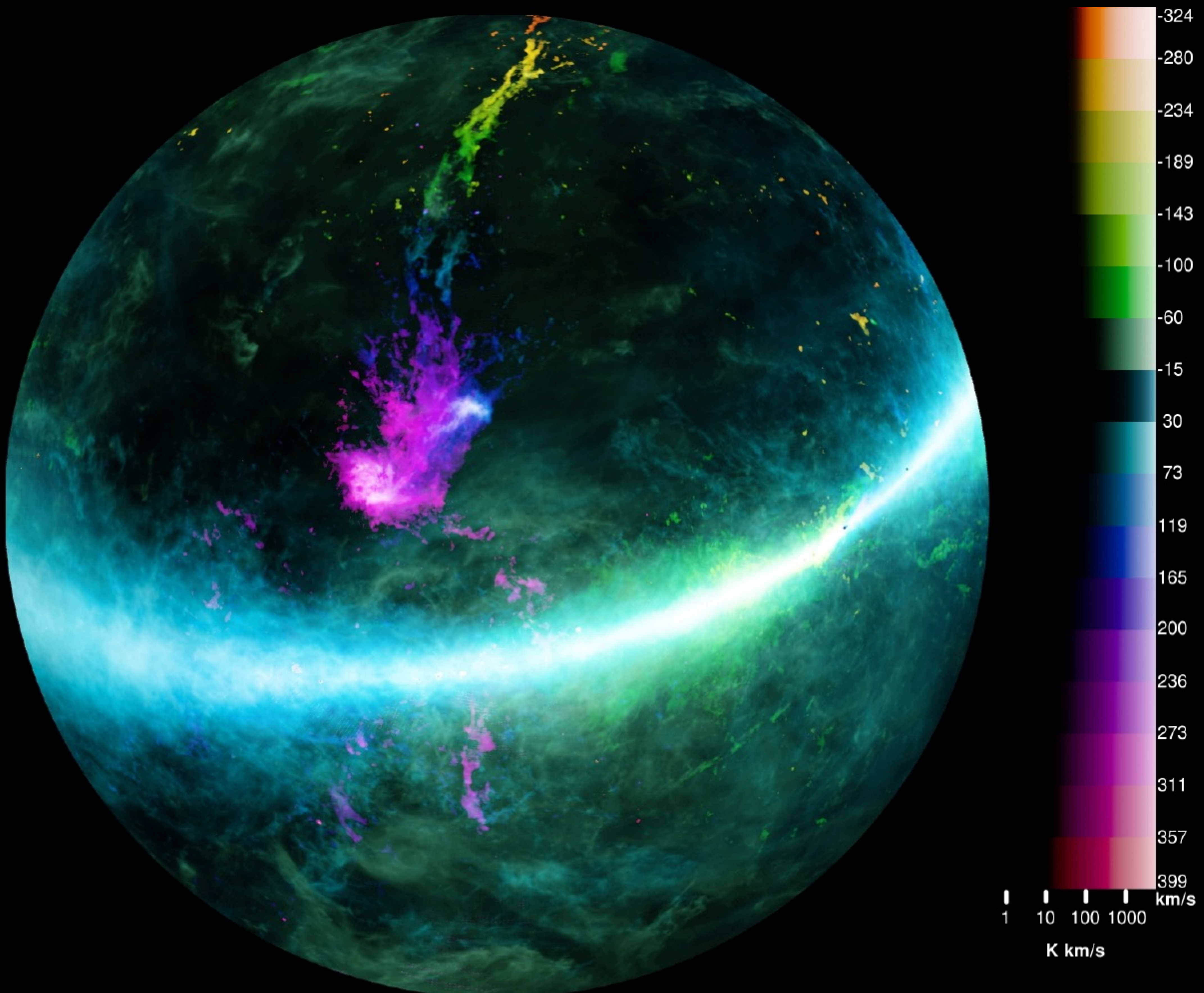
HI maps of Virgo galaxies, Chung et al. 2009

THE M81 GROUP



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

THE MAGELLANIC SYSTEM



THANK YOU!