HELGA DÉNES

# HI IN GALAXIES

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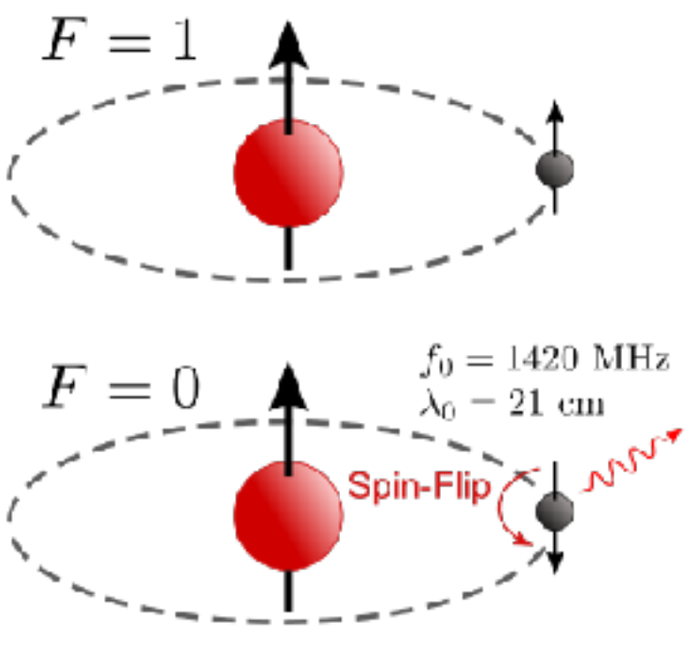
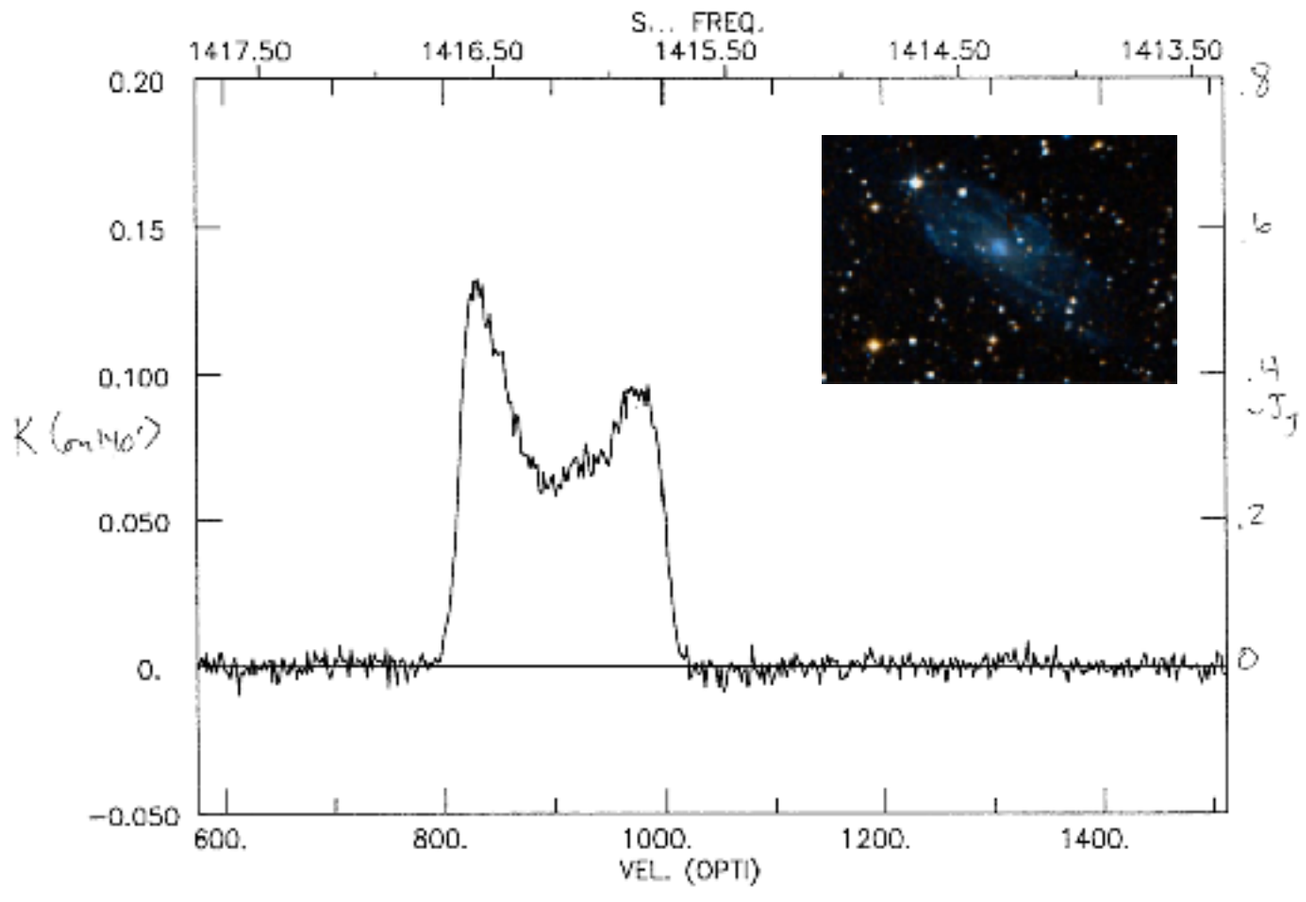
- Hydrogen is the most common element
- HI is the **fuel for potential star formation**
- Late-type star forming galaxies usually have a significant amount of HI
- HI is a **good tracer of galaxy evolution** - loosely bound at the edges of the disk




HI profile of UGC 11707
https://www.cv.nrao.edu/course/astr534/HILine.html

# HI IN LATE TYPE GALAXIES

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

$$\left(\frac{M_{\rm H}}{M_\odot}\right) \approx 2.36\times10^5\left(\frac{d}{\rm Mpc}\right)^2 \int\left[\frac{S(v)}{\rm Jy}\right]\left(\frac{dv}{\rm km\ \ s^{-1}}\right)$$

Distance to the galaxy

Integral of the HI line

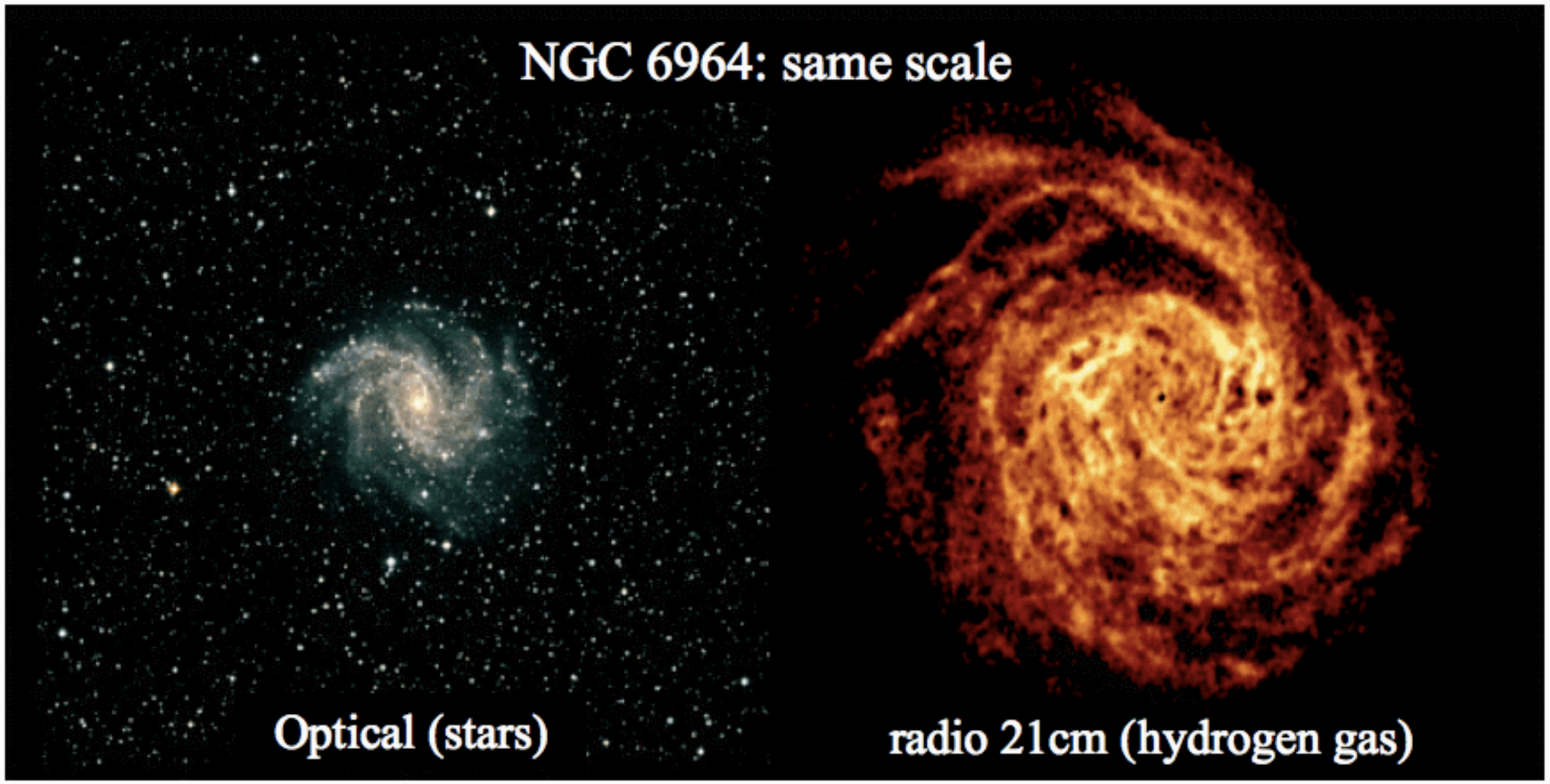
$$d \approx \frac{v_r\,(\text{optical})}{H_0}$$

Systemic velocity of the galaxy

Hubble constant

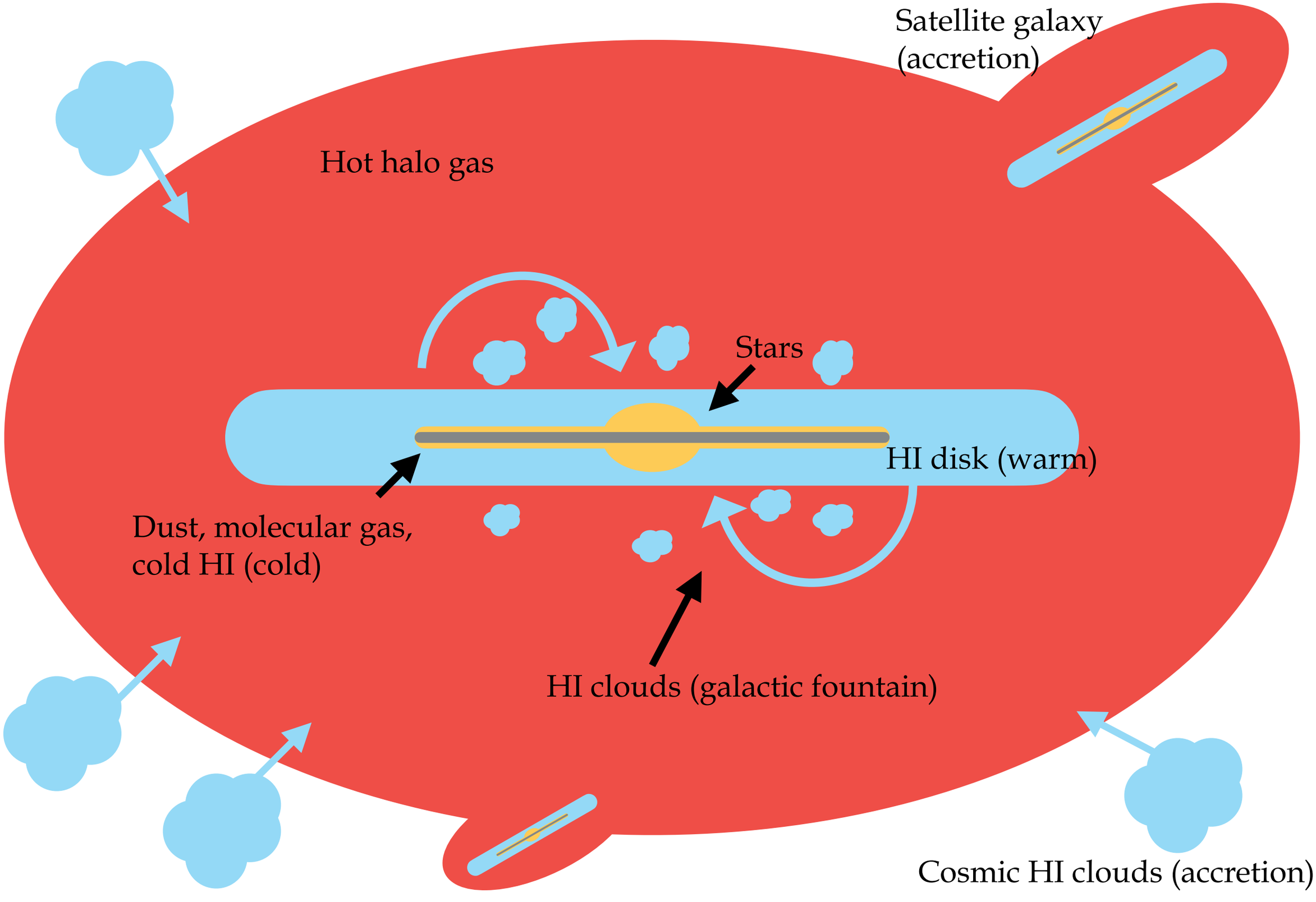
# HI IN LATE TYPE GALAXIES

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



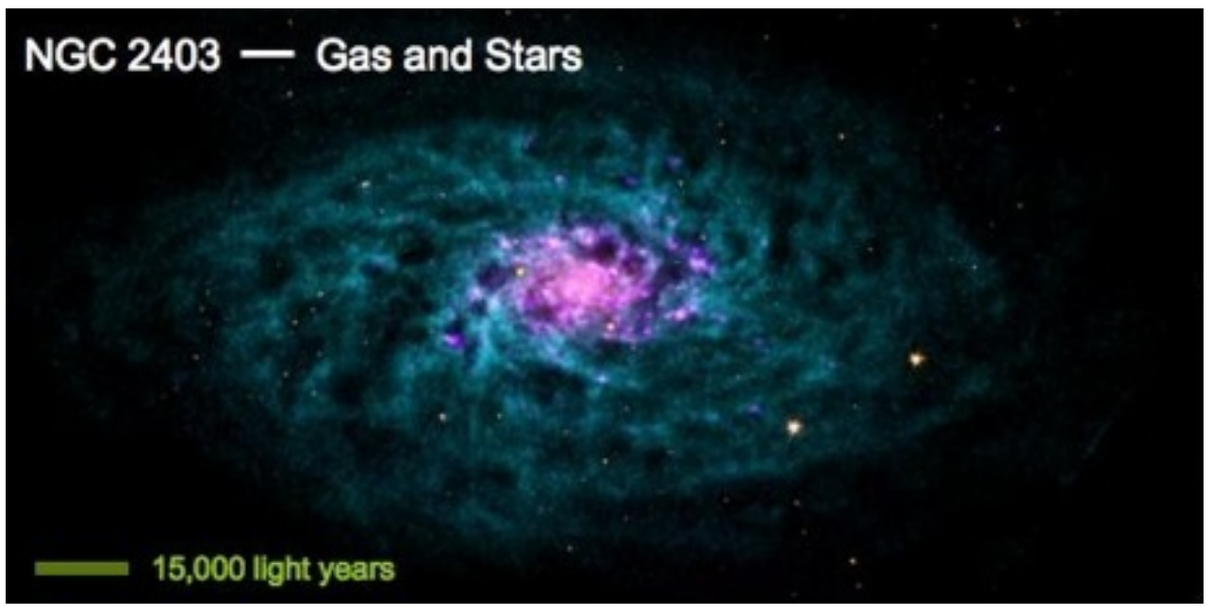

Credit: T. Oosterloo

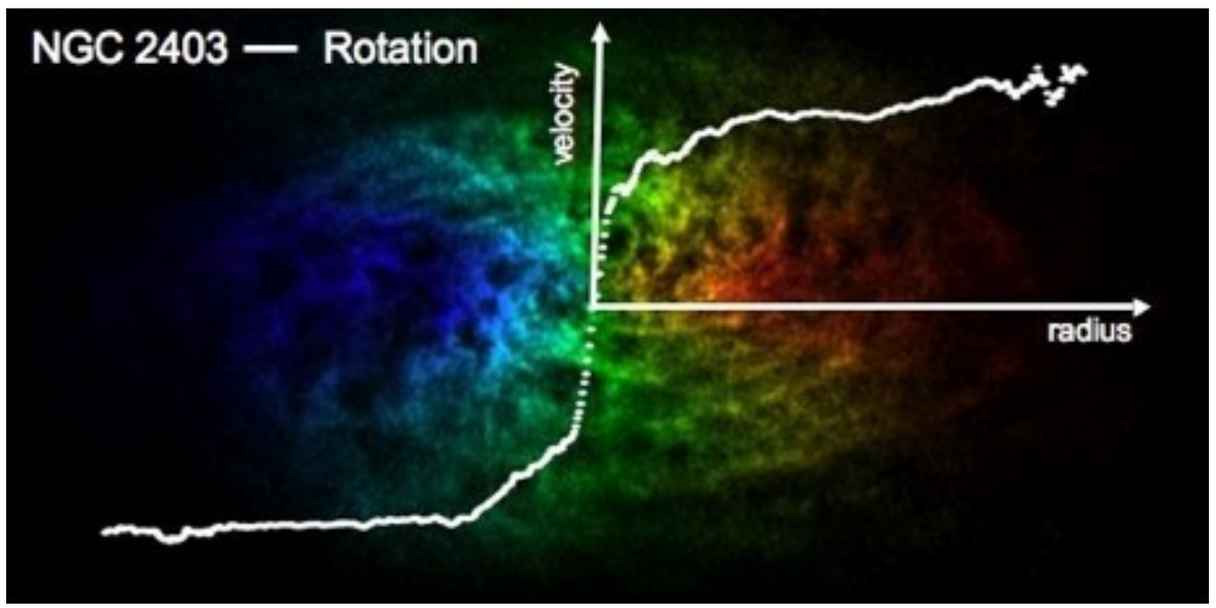
# A TYPICAL LATE-TYPE GALAXY



# 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)

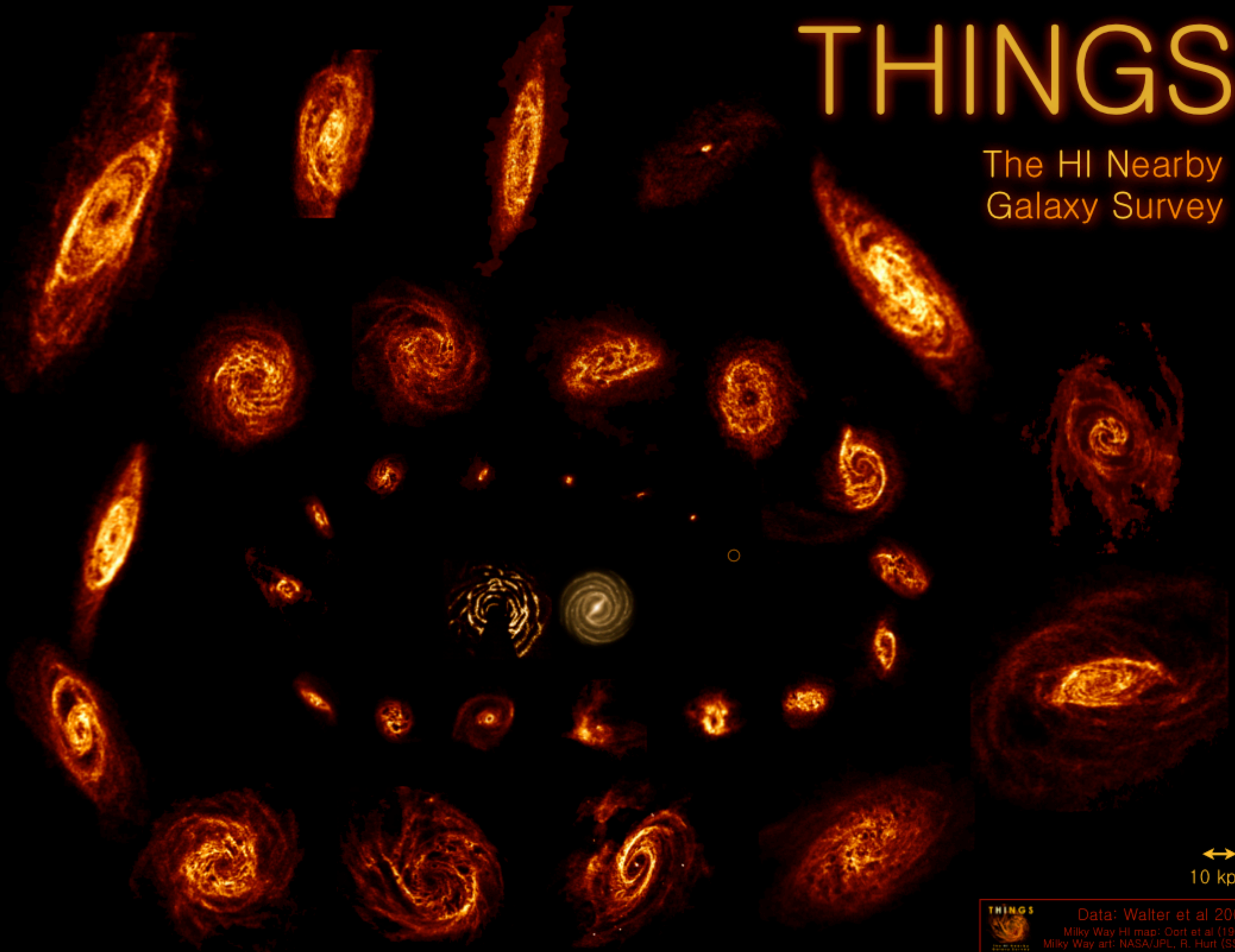



THINGS survey, Walter et al. 2008

# THINGS

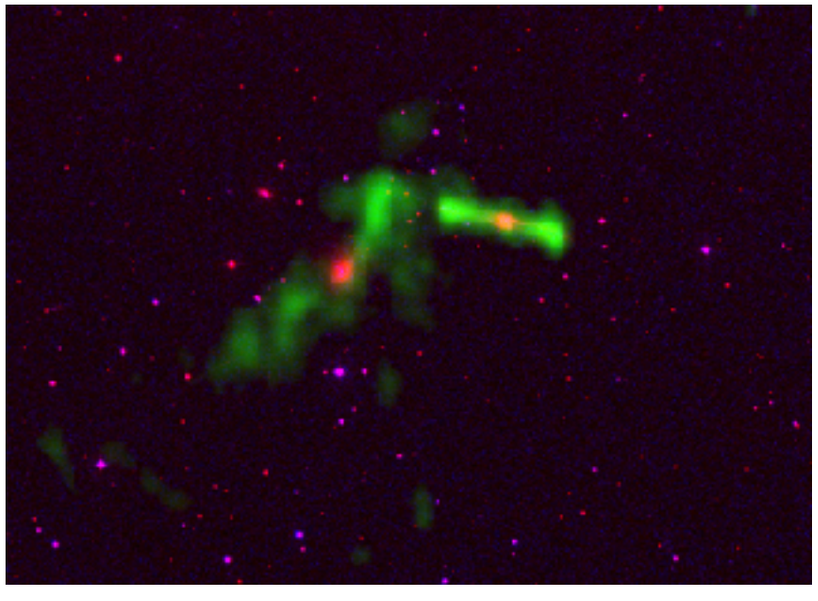
The HI Nearby Galaxy Survey

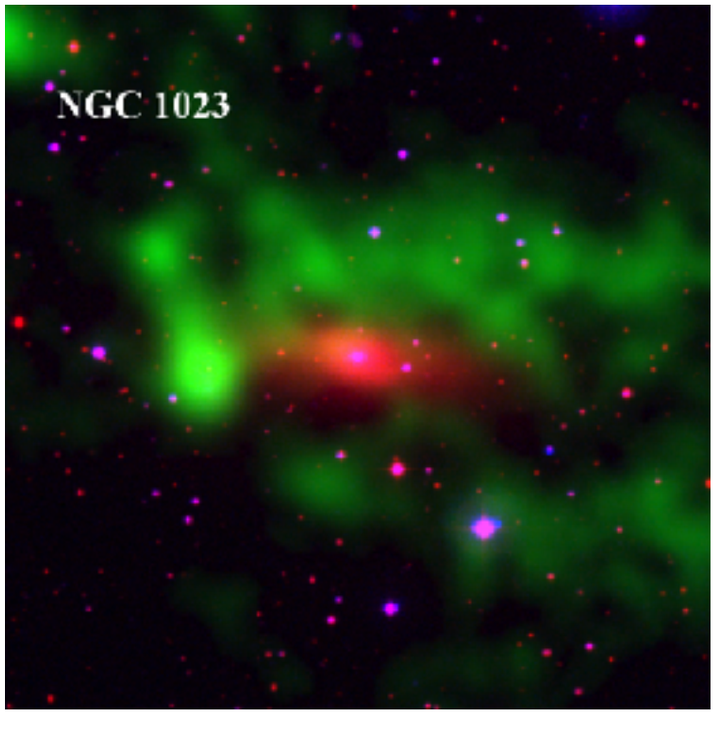


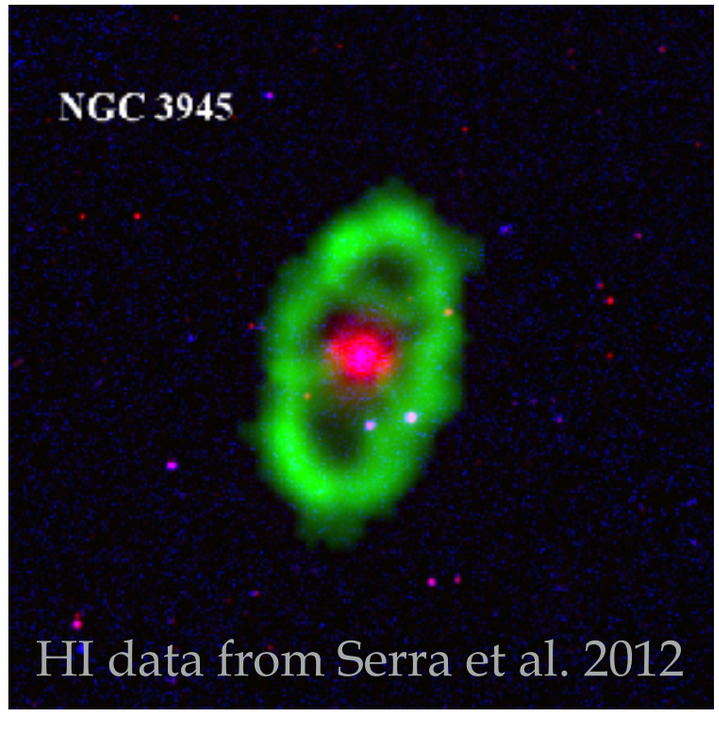
10 kpc

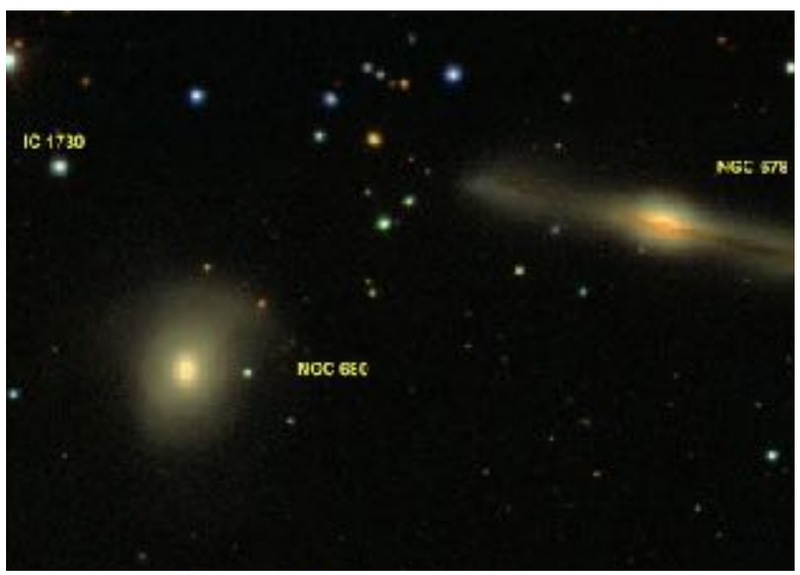
Data: Walter et al 2008
Milky Way HI map: Oort et al (1958)
Milky Way art: NASA/JPL, R. Hurt (SSC)

# HI IN ELLIPTICAL/LATE-TYPE GALAXIES





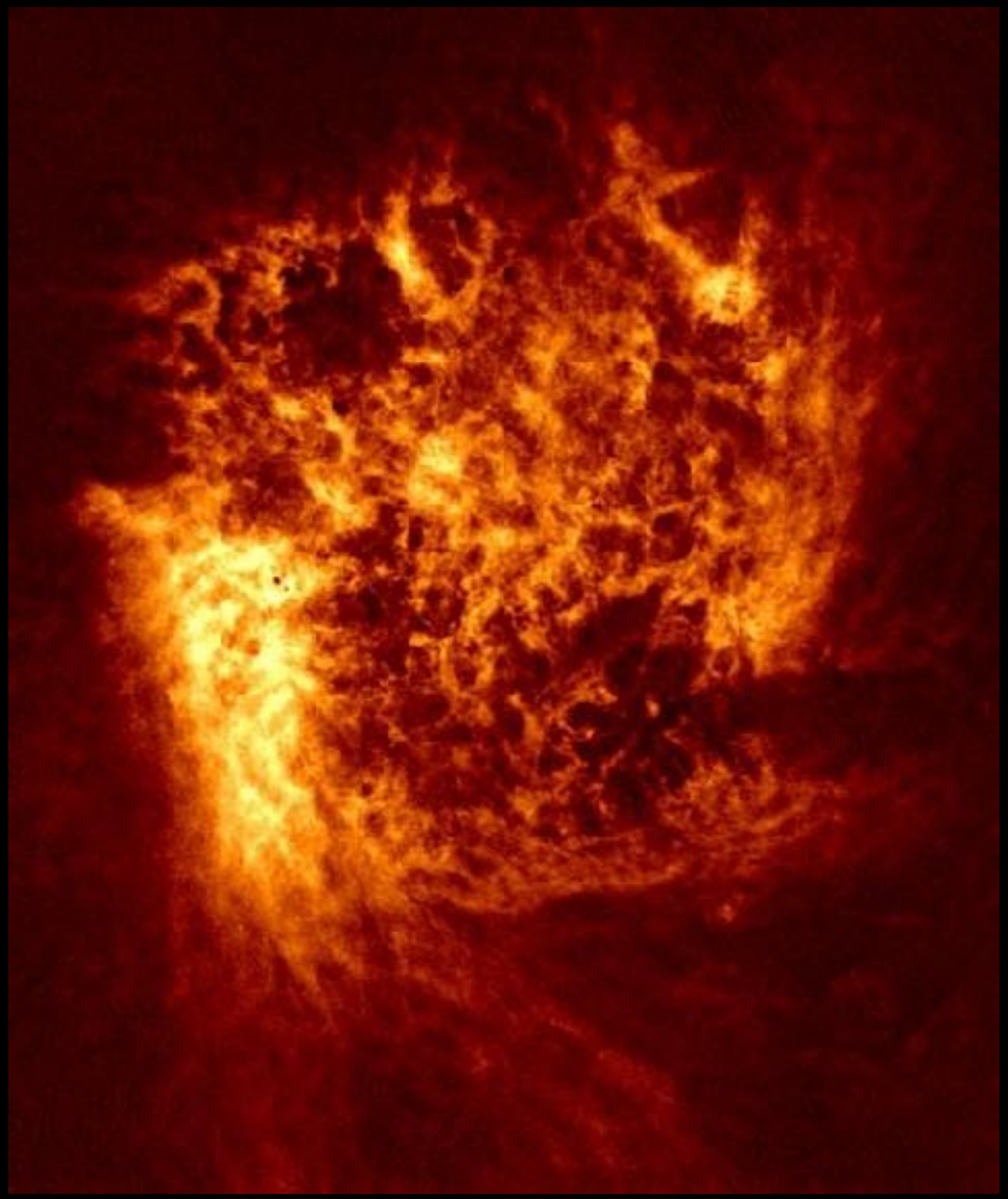

red: optical, DSS2 B;
green: HI, blue: UV, GALEX

- **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)

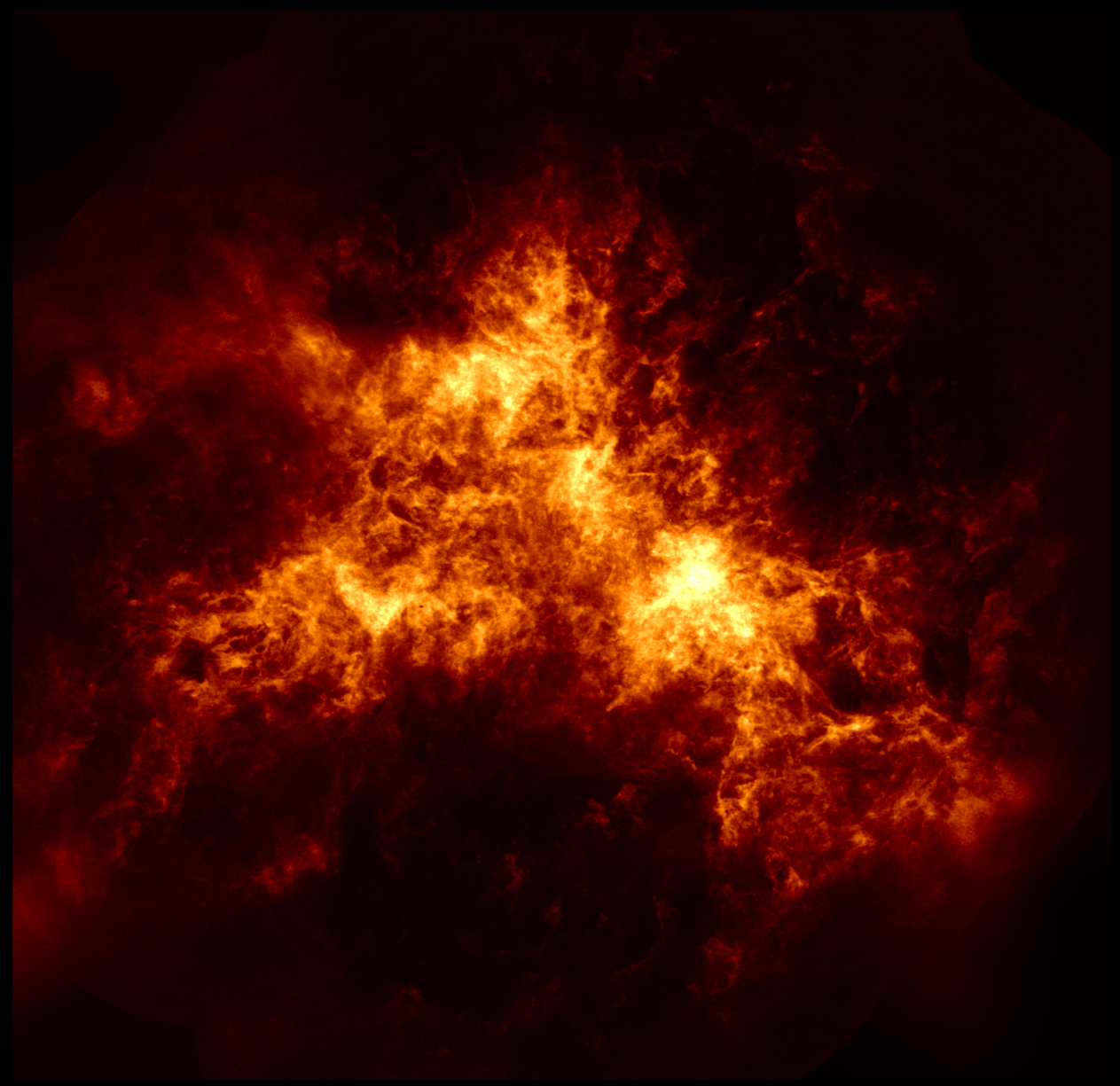
# HI IN DWARF GALAXIES

- Star forming dwarfs generally have plenty of HI
- HI is usually in a disk
- Still, plenty to explore

# HI IN DWARF GALAXIES - MAGELLANIC CLOUDS



LMC - ATCA+Parkes



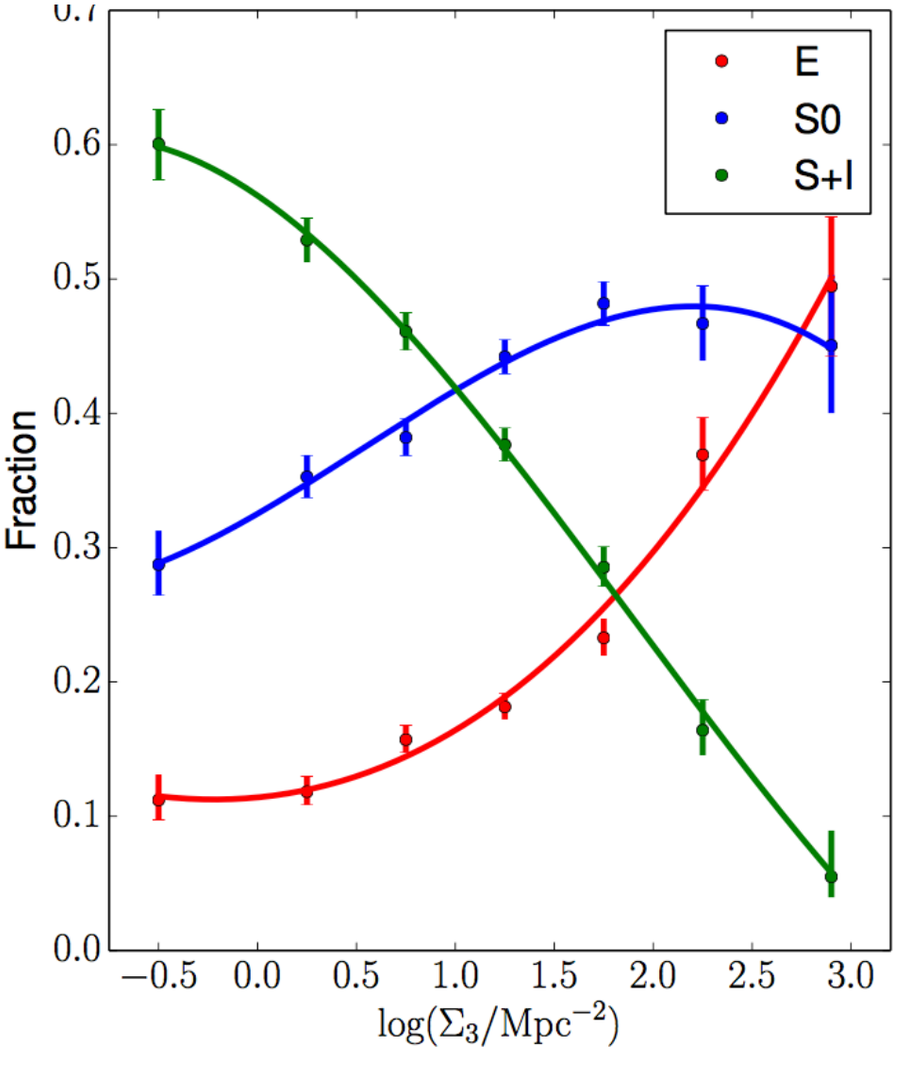
SMC - ASKAP+Parkes

# TRACING THE ENVIRONMENT

# ENVIRONMENT

- Galaxies reside in different environments
  - Field, groups and clusters

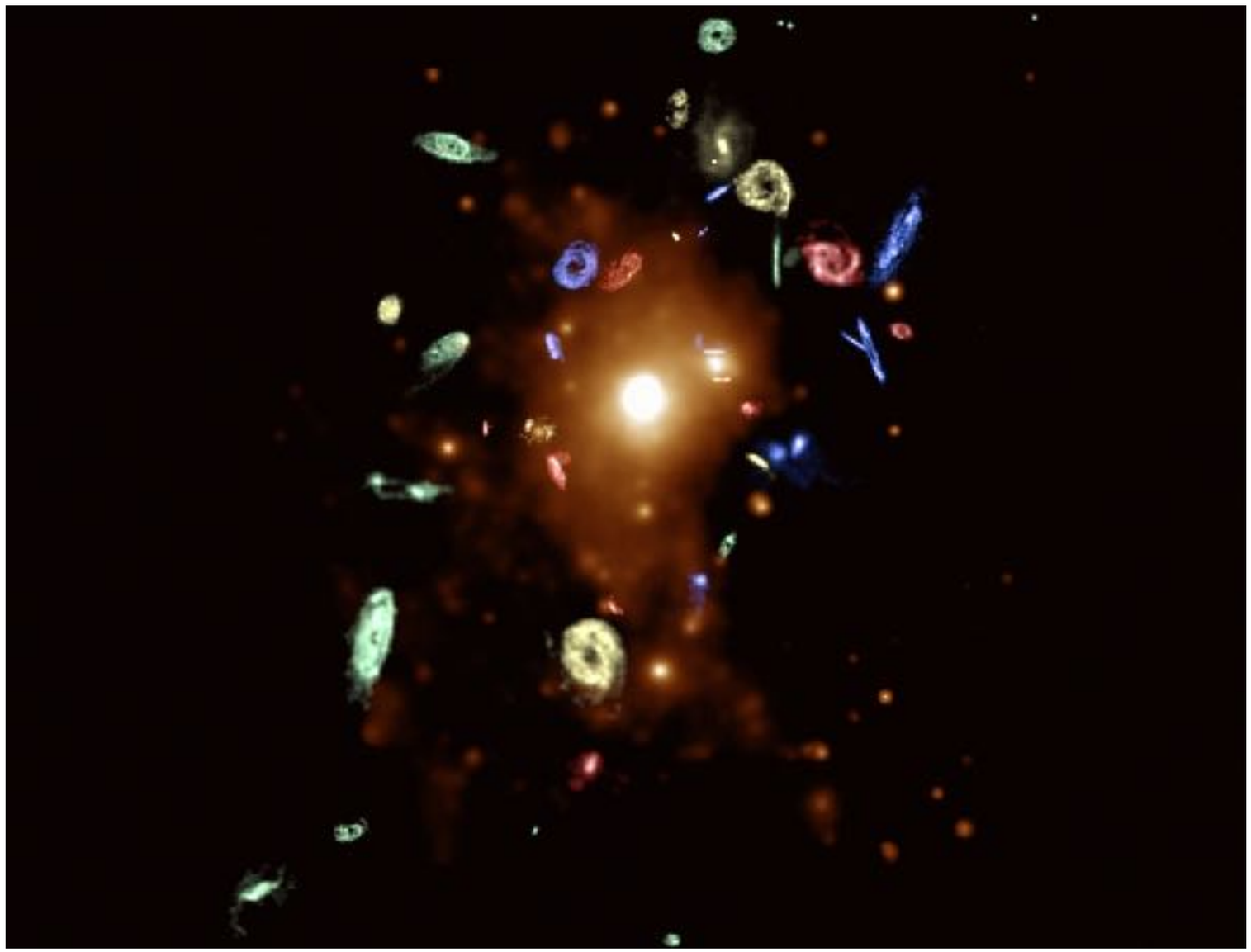
- Dressler (1980) – 'morphology-density relation'
- Star formation – density relation (Lewis et al. 2002, Gómez et al. 2003)

# ENVIRONMENTAL EFFECTS ON THE HI CONTENT

- Late-type galaxies in high density environments tend to have less HI (e.g. Haynes & Giovanelli 1985, Solanes et al., 2001)
- Is this also true for intermediate densities, e.g. galaxy groups?

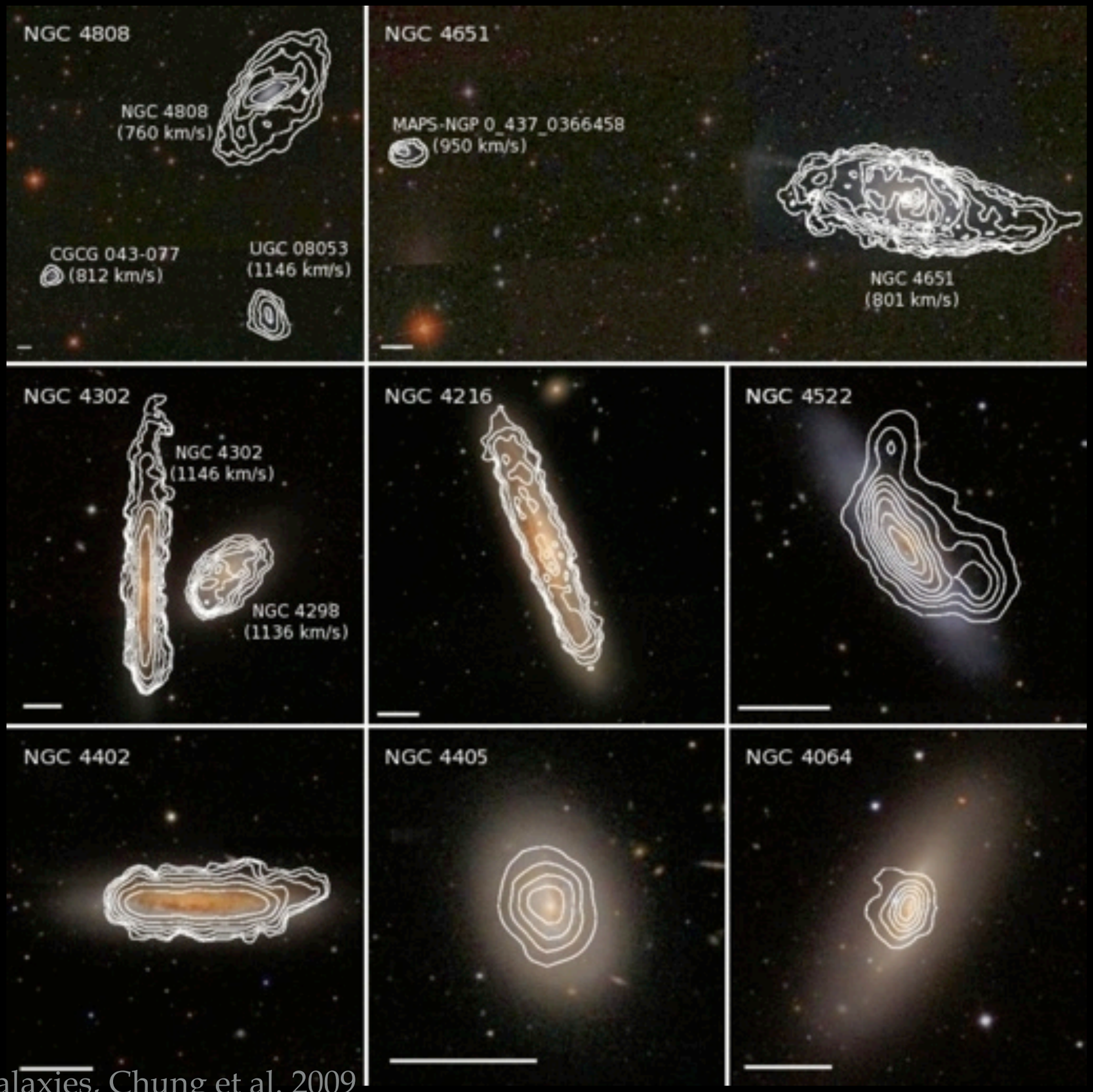
- **Environmental processes:**
  - tidal interactions
  - mergers
  - ICM interactions
  - starvation



X-ray and HI composite of the Virgo cluster

Chung et al. 2009

# VIRGO CLUSTER GALAXIES

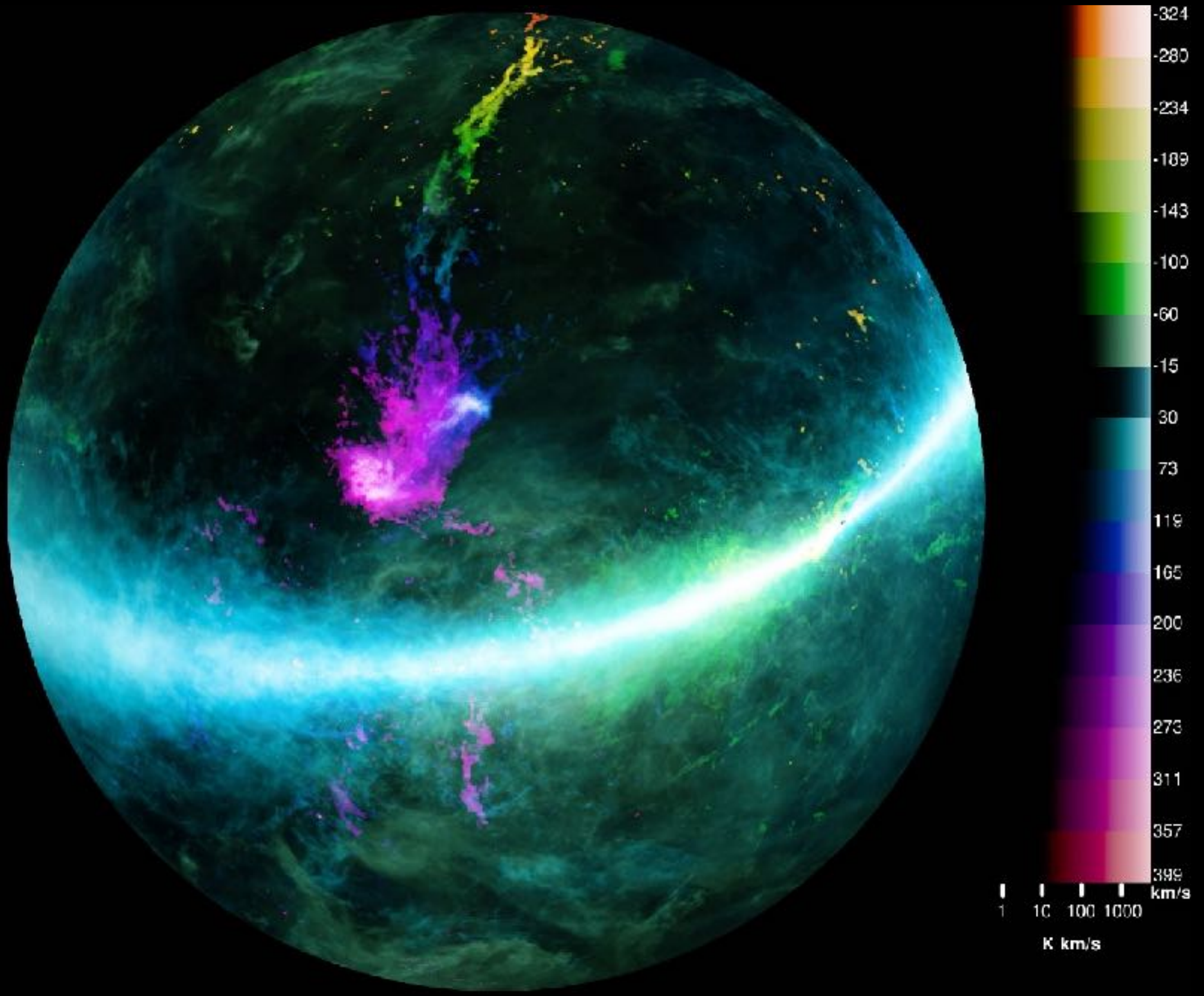



HI maps of Virgo galaxies, Chung et al. 2009

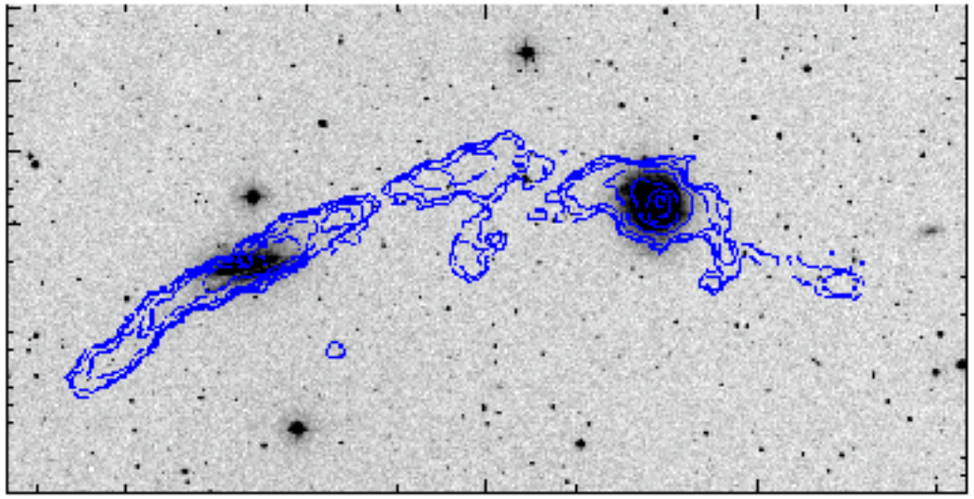
# THE M81 GROUP

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

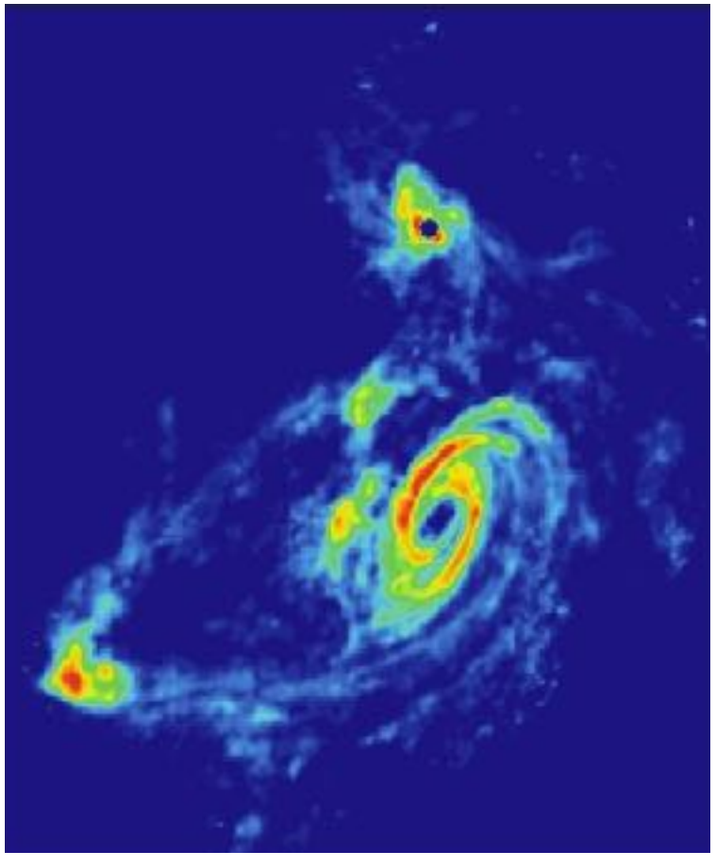
# THE MAGELLANIC SYSTEM



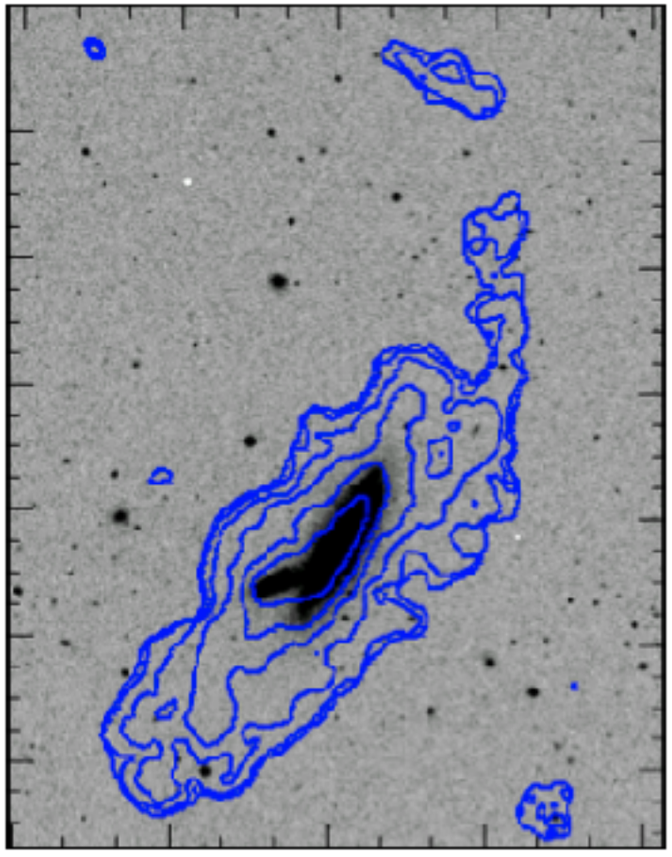
# TIDAL INTERACTIONS - MERGERS



NGC 5713/5719
Langston & Teuben, ASP Conf. Ser. 240, Gas & Galaxy Evolution, p. 861.

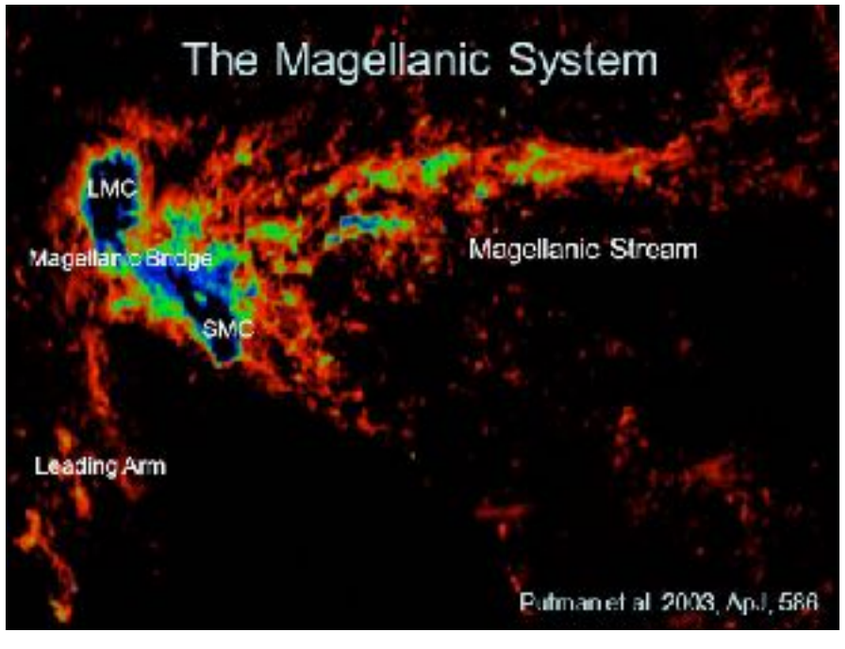


M81 - Yun et al. 1994

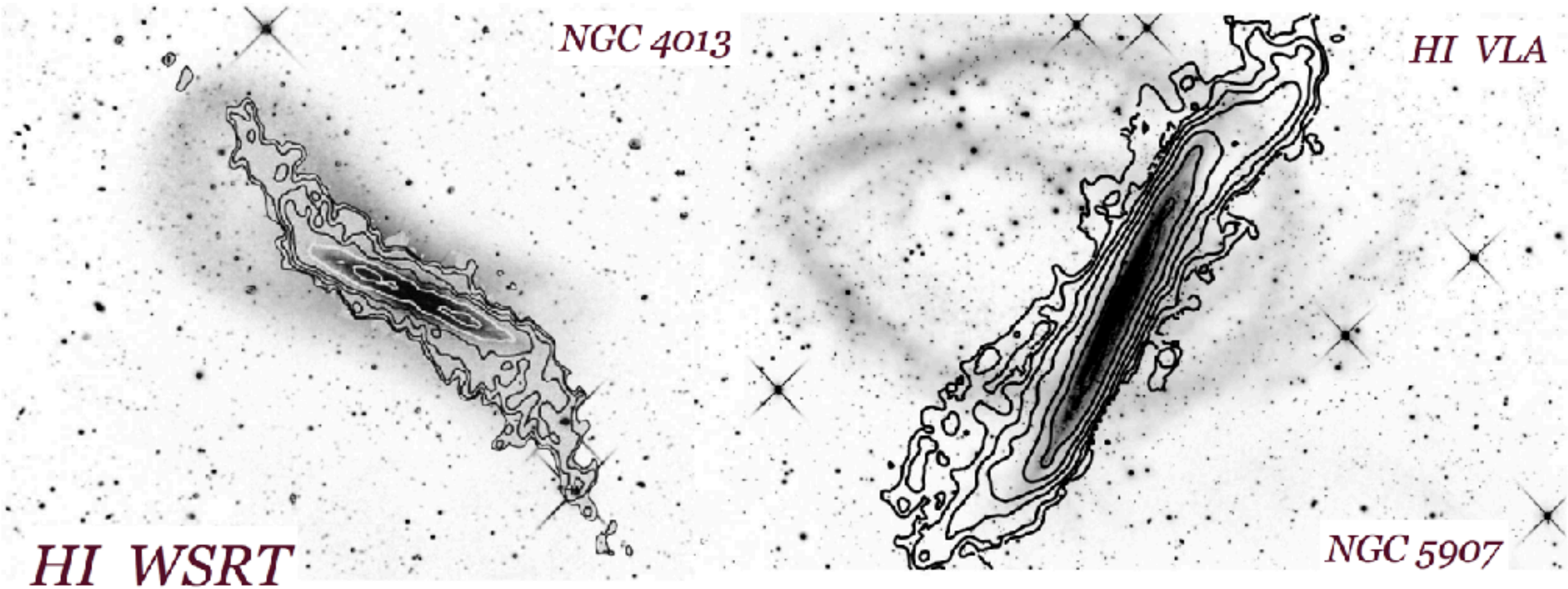


Apr 280 system
Clemens, M. S., 1998, Ph.D. Thesis, Cambridge University.

- Both HI and optical observational signatures:
  - HI arms and bridges
  - Optical tidal arms
  - Disturbed HI/optical disk
  - Warps



# WARPS IN THE HI DISK - MINOR MERGERS

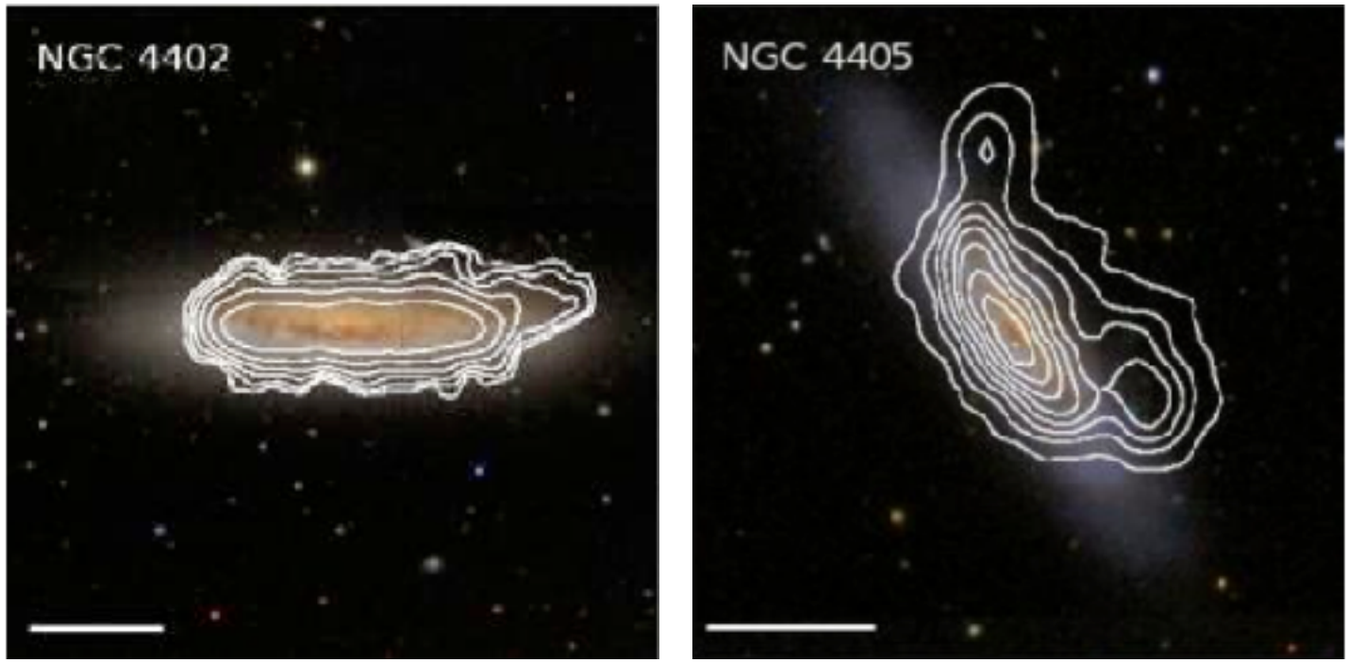


# RAM PRESSURE STRIPPING

$$\rho_{\rm ICM} v^2 \gtrsim 2\pi G \sigma_\star(r) \sigma_{\rm g}(r)$$

ram pressure

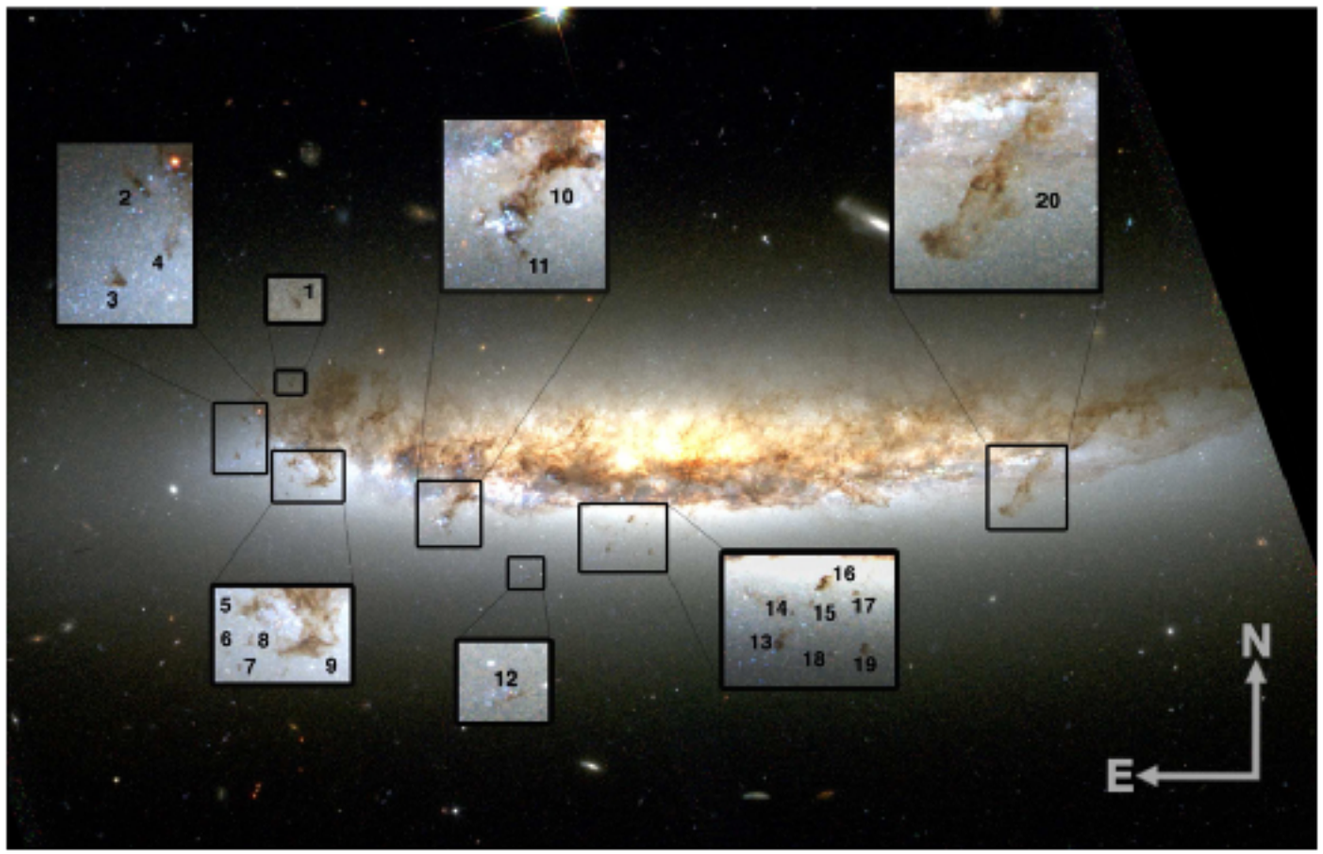
disk's gravitational potential




Virgo galaxies
(SDSS images overlaid with VLA contours)
Chung et al., 2009

- **Observational signatures:**
  - Truncated HI disk
  - Undisturbed stellar disk
  - One sided gas 'tail'

- **Extreme cases:**
  - Stripping of dust and CO as well




HST image of NGC 4402
Abramson et al., 2014

# STARVATION

The external gas supply of the galaxy gets cut of
(e.g. no accretion from the cosmic web, the hot halo of the galaxy, or other galaxies)

- Observational signatures:
  - Undisturbed stellar disk
  - Low HI surface brightness
  - Truncated HI disk


NGC 4216 in Virgo
(SDSS images overlaid with VLA contours)
Chung et al., 2009

# THANK YOU!