
Chapter 7

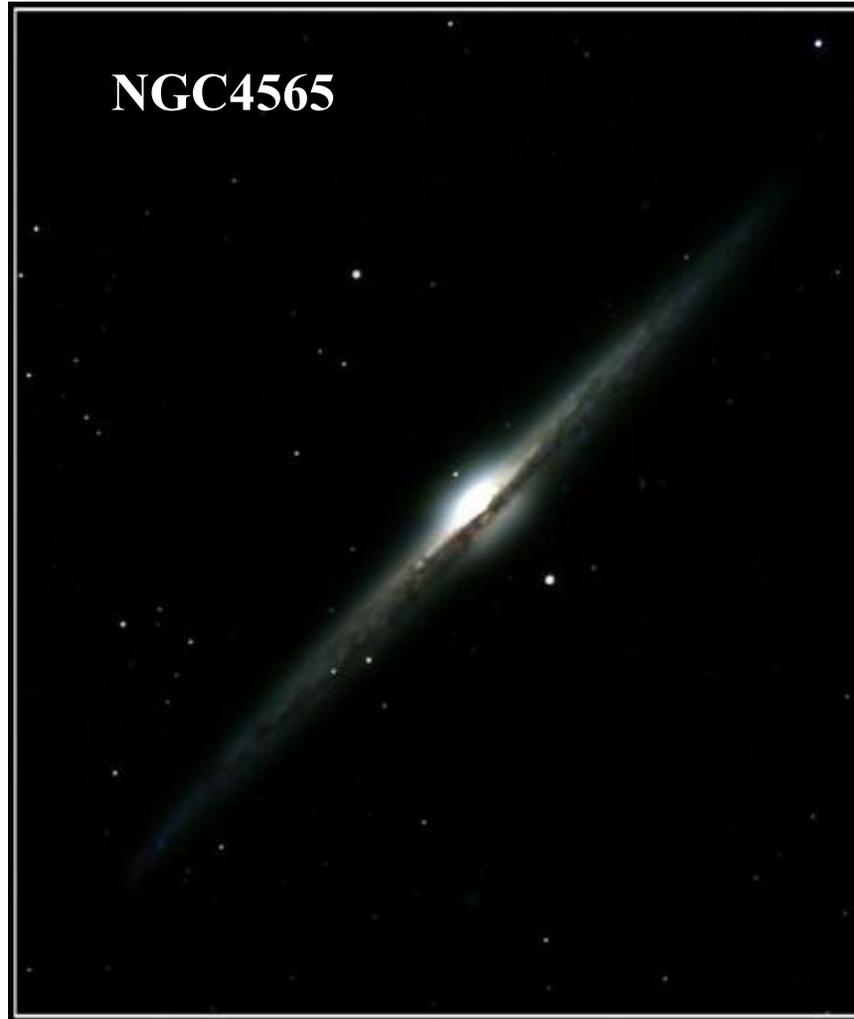
Dark Matter

Galaxies: face-on view



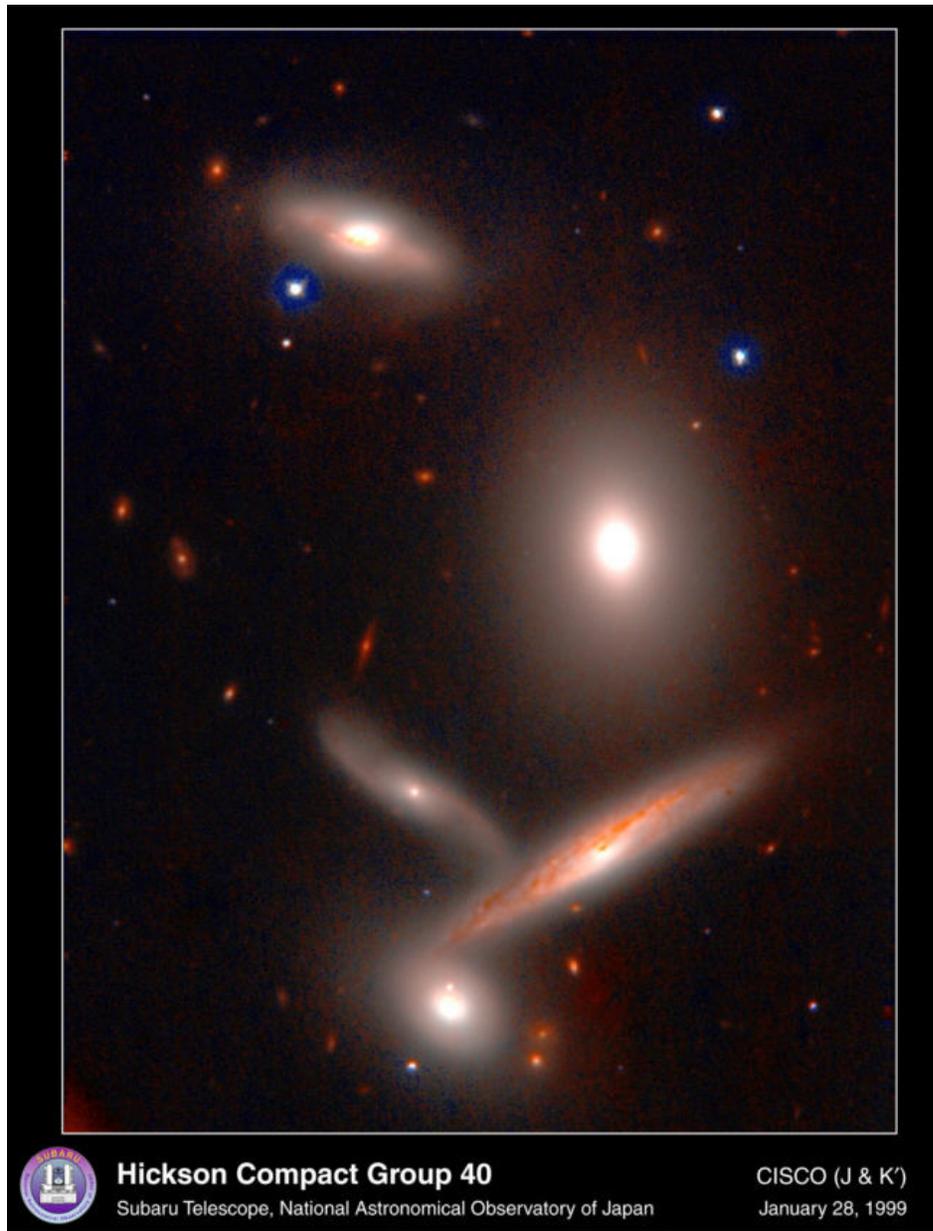
a galaxy like our Milky Way: 10^{11} stars, ~ 50 kpc diameter

Galaxies: edge-on view



central stellar bulge, stellar disk, interstellar medium (gas and dust)

Galaxy groups



a few up to ~ 100 galaxies

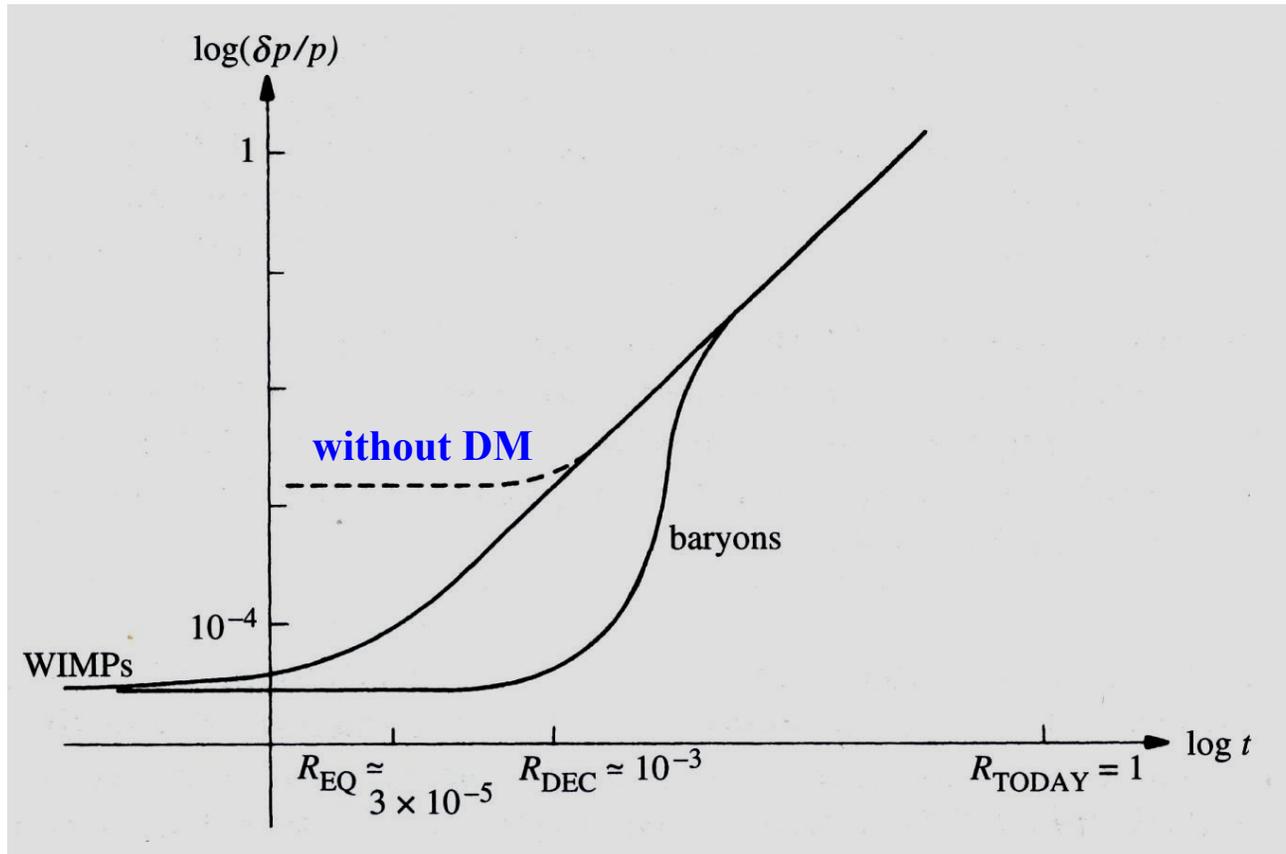
Galaxy clusters



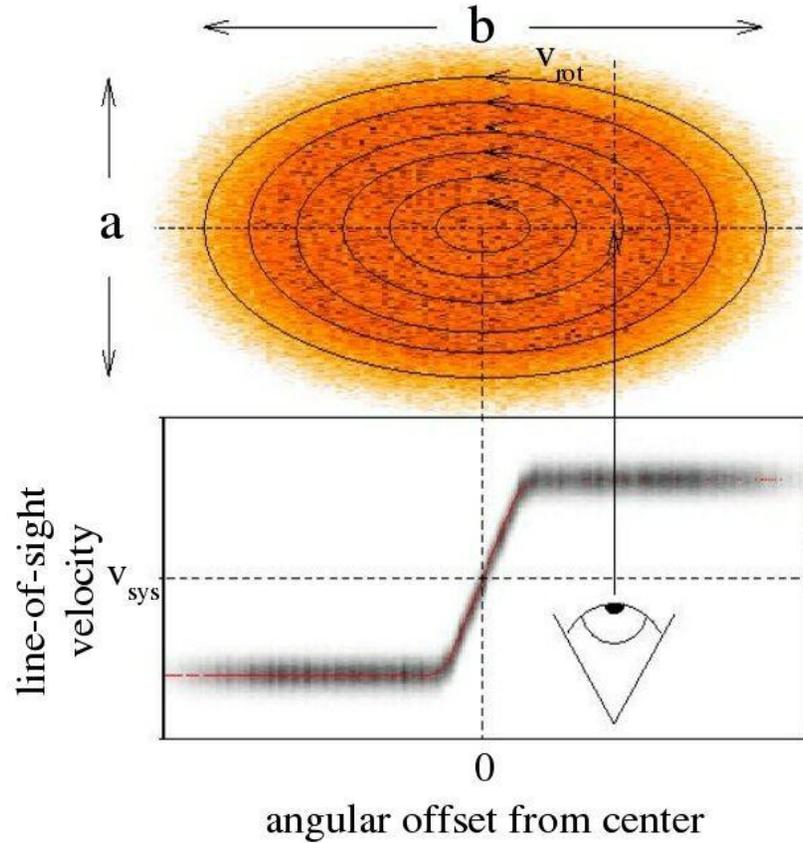
up to a few 1000 galaxies

a few Mpc total size

Density fluctuations



Rotation curves of galaxies

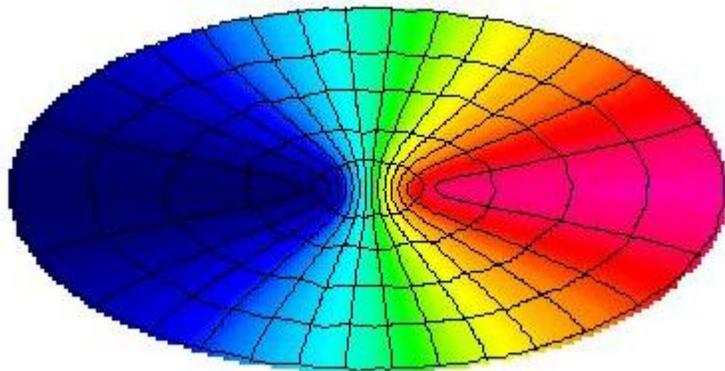


rotating gaseous disk (HI)

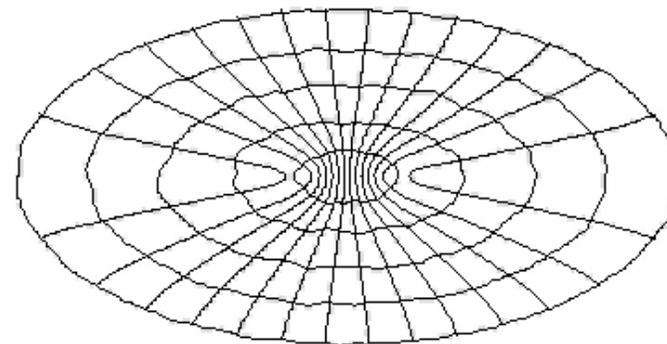
rotation velocity $v(r)$ from Doppler shift

$$V_{rot} = \frac{|V_{l.o.s.} - V_{sys}|}{\sin i}, \quad i = \arccos\left(\frac{a}{b}\right)$$

Galaxy kinematics



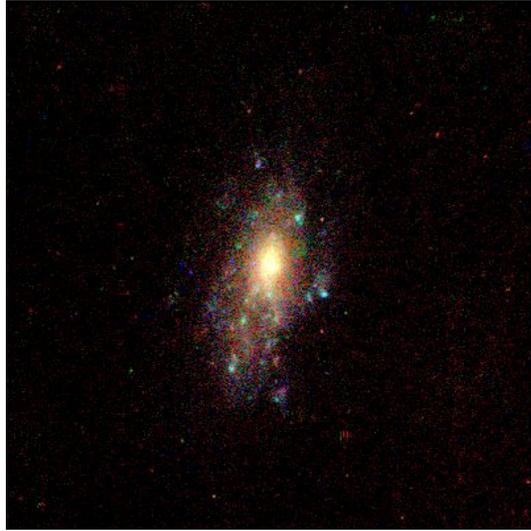
Isovelocity contours



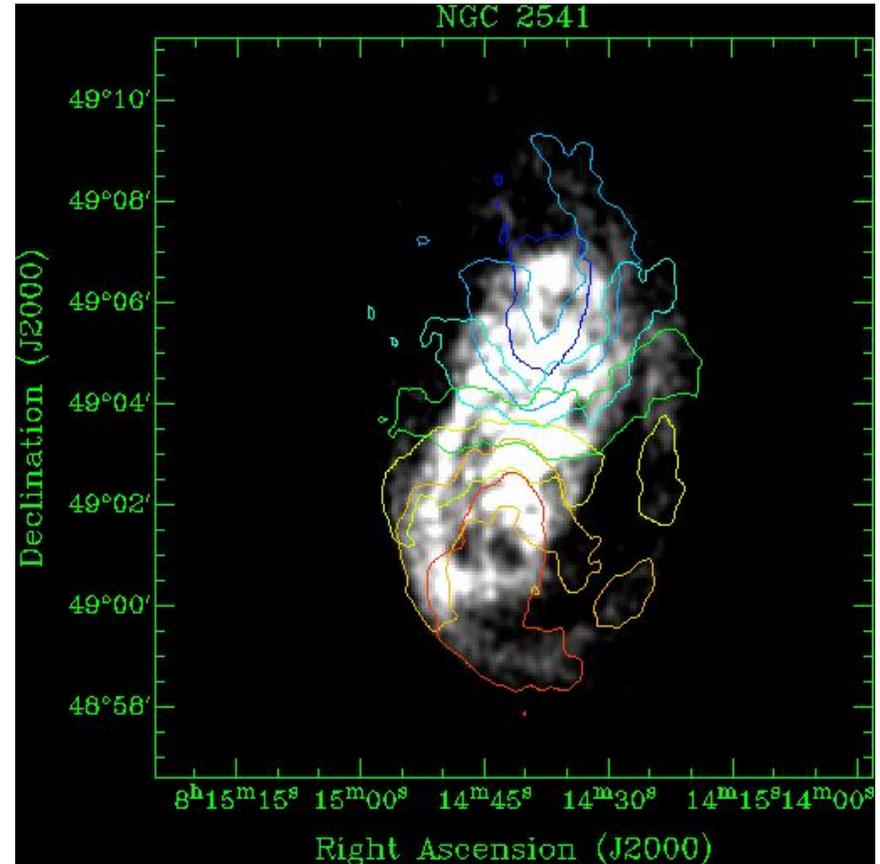
$v(x,y)$

movie

Galaxy kinematics

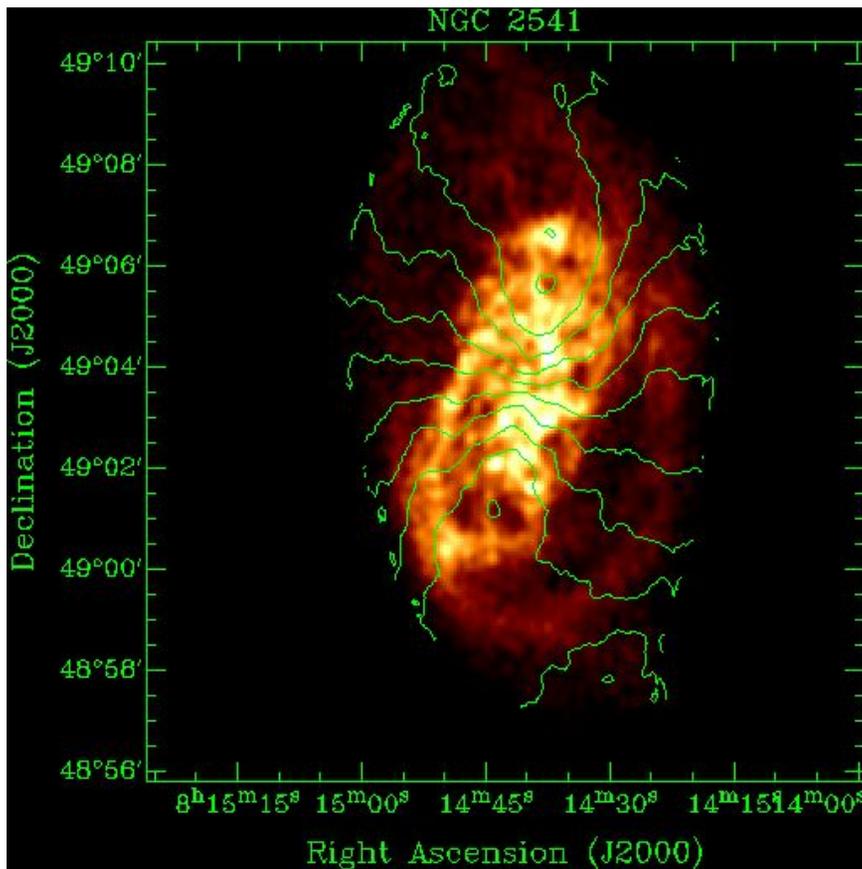


a real galaxy (NGC2541)
optical image

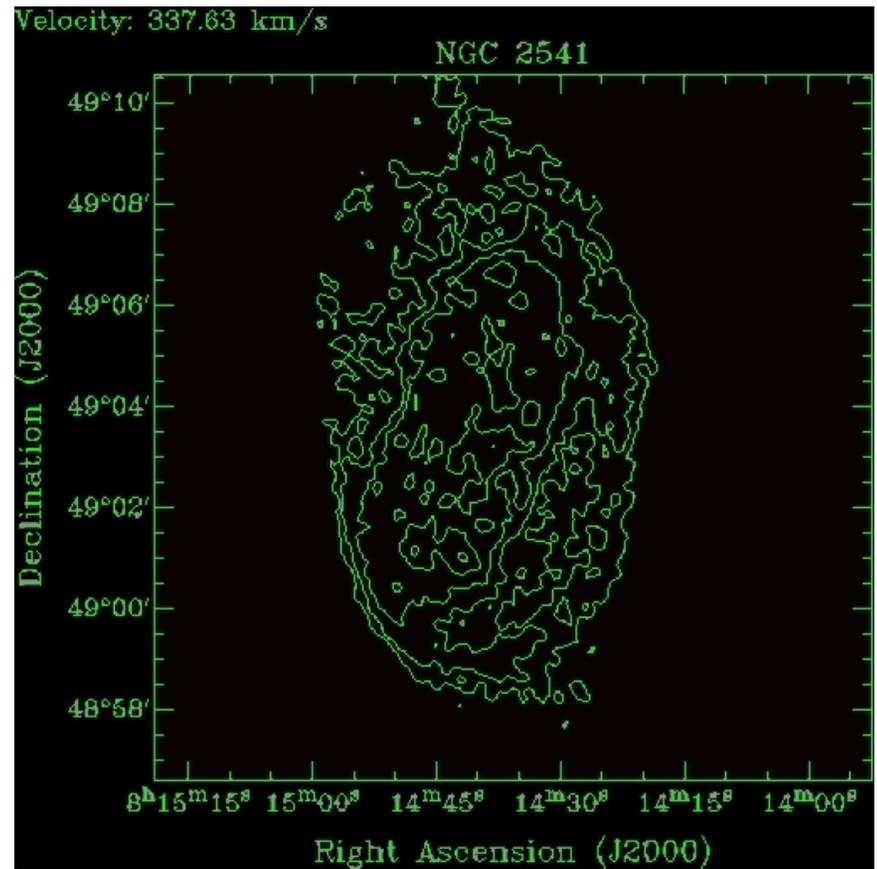


column density of neutral hydrogen
(grey/white) and isovelocity contours

A movie of $v(x,y)$

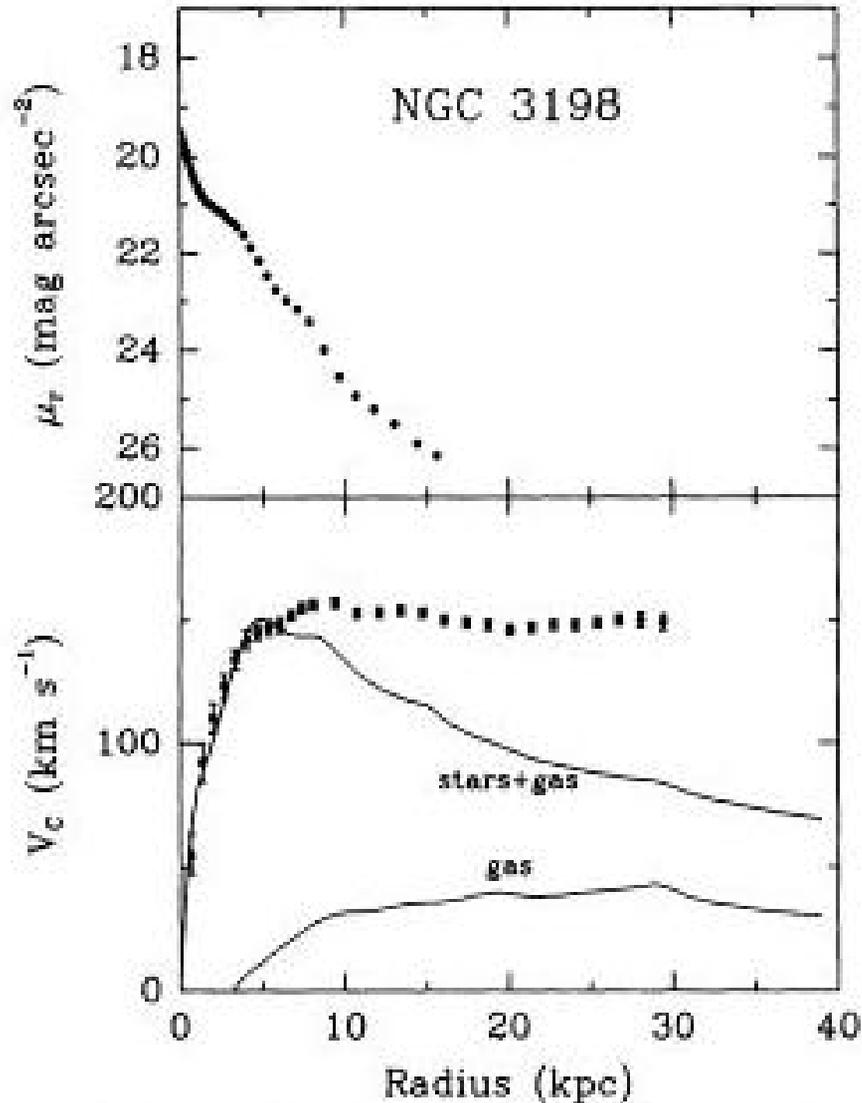


model galaxy



real galaxy (NGC2541)

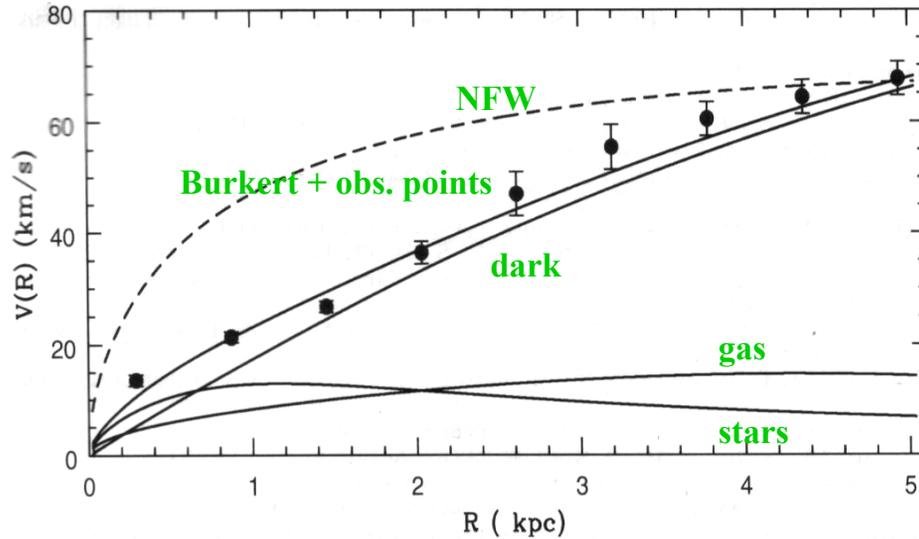
Measured rotation curve



radial distribution of stellar light

rotation curve with stellar and gaseous contribution

NFW profile vs. observation

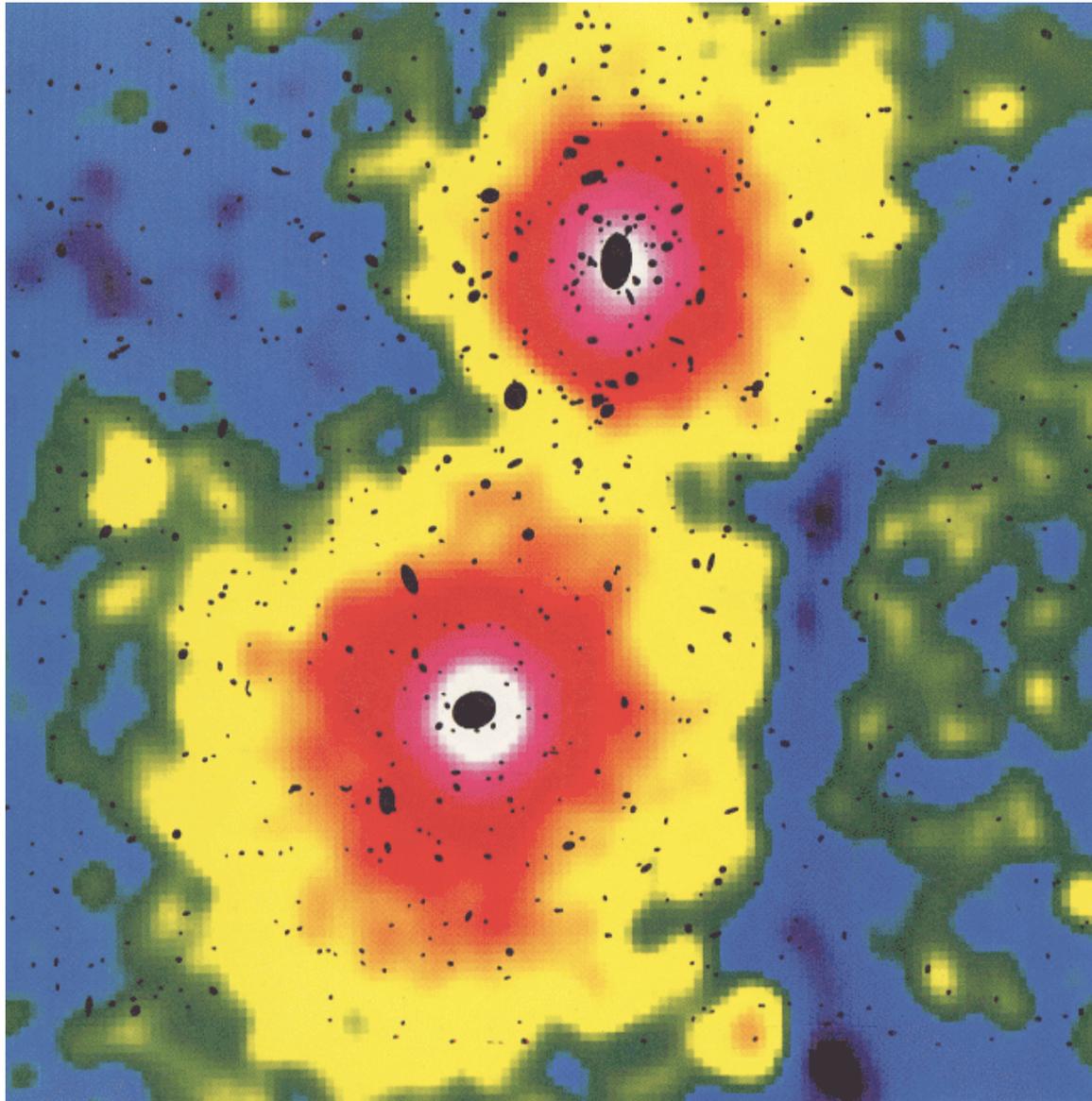


An extreme case: dwarf galaxy
DDO 47 with mass $M \approx 10^{10} M_{\odot}$

NFW overpredicts central
velocities

⇒ “cusp problem”

X-ray halos of galaxy clusters

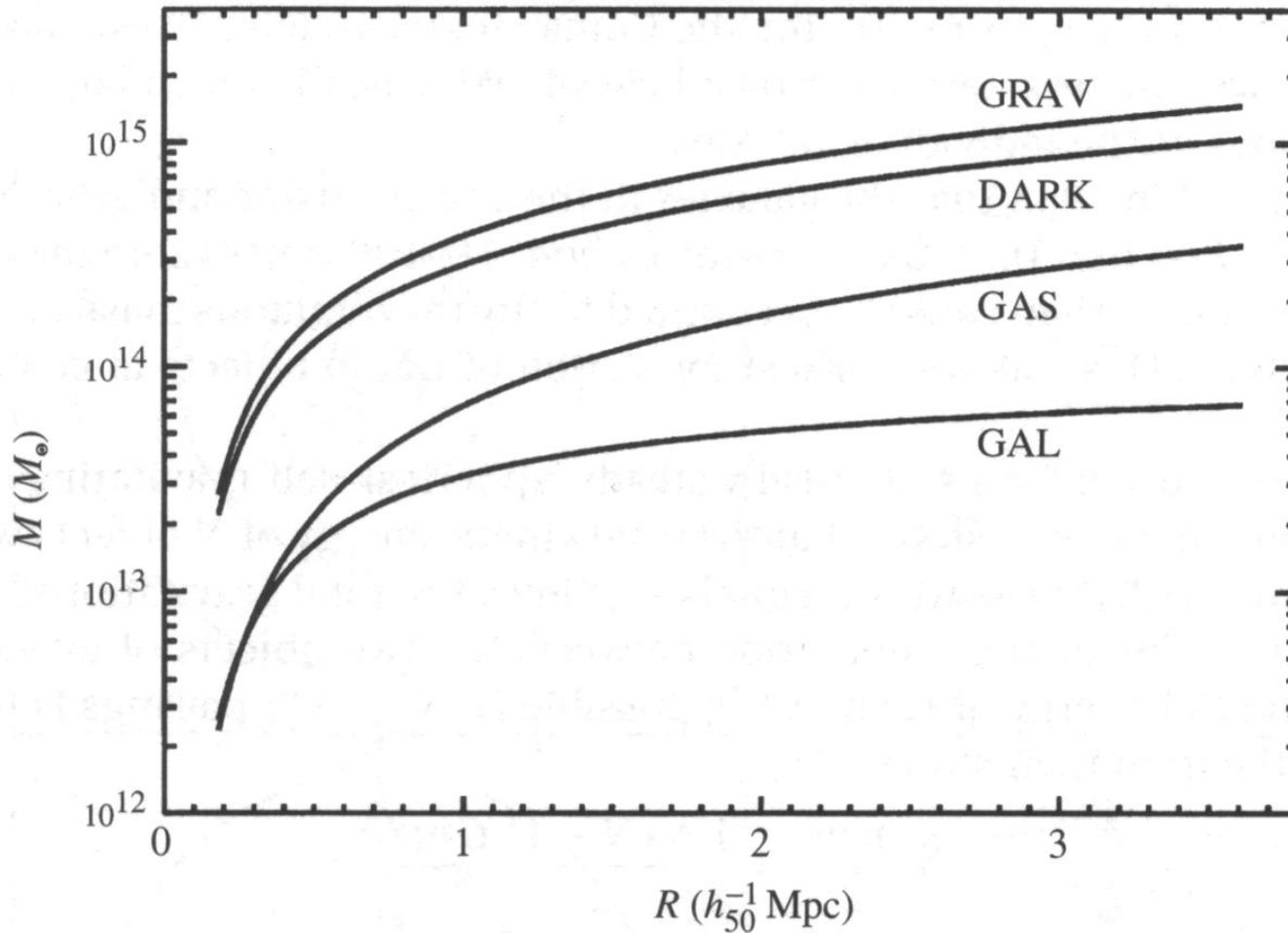


Cluster A3528

black ellipses: optically visible galaxies

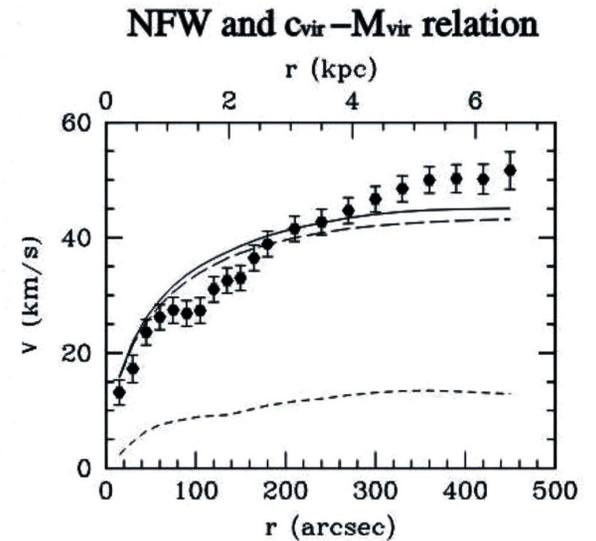
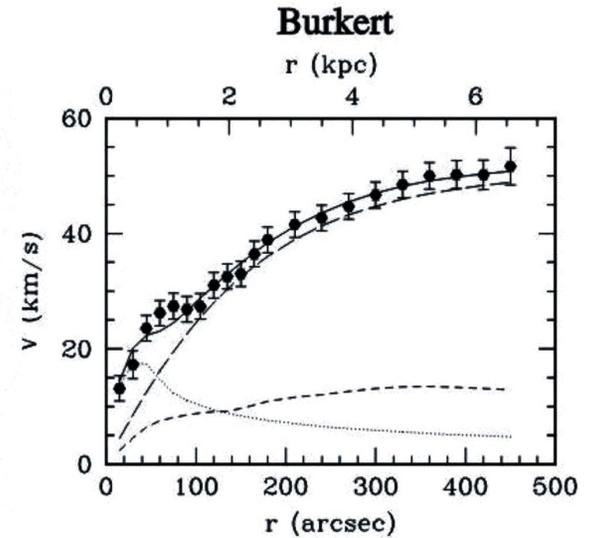
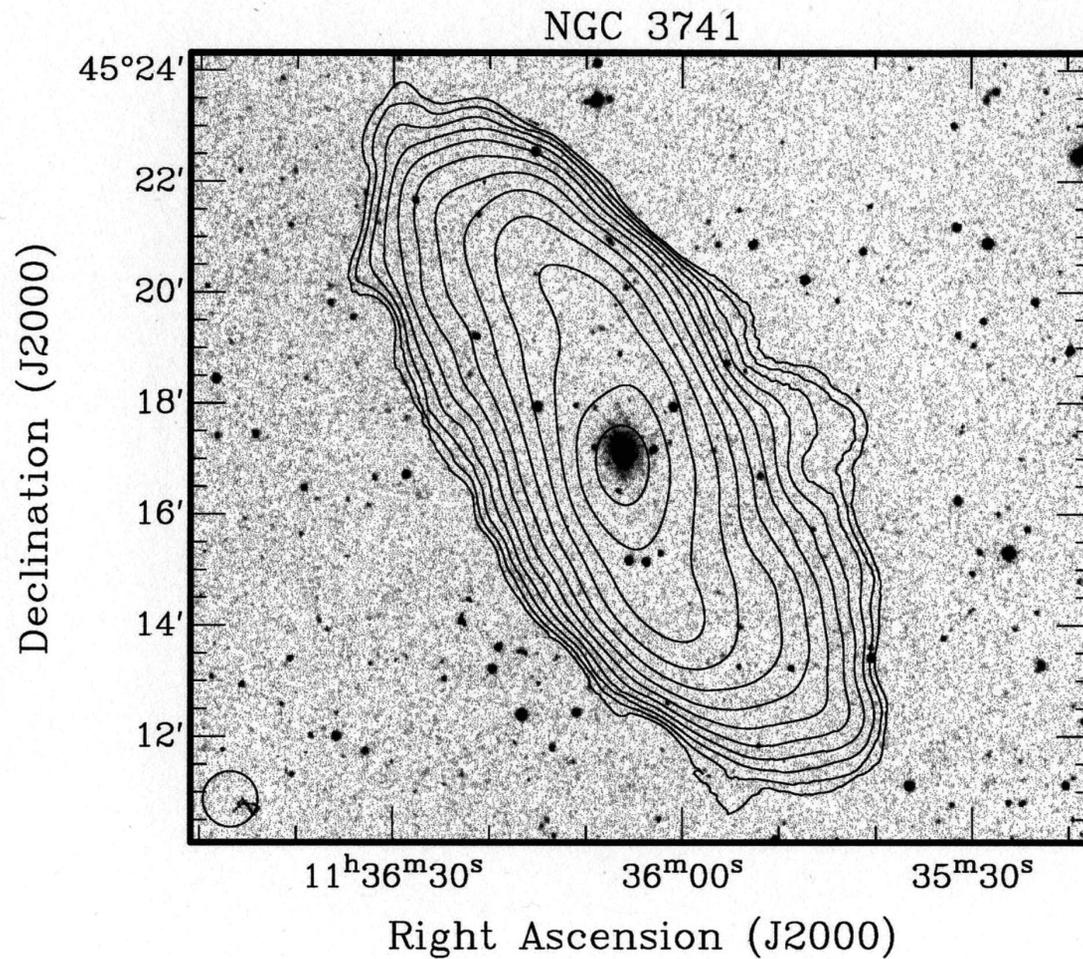
colour: X-ray emission

Total mass in galaxy clusters



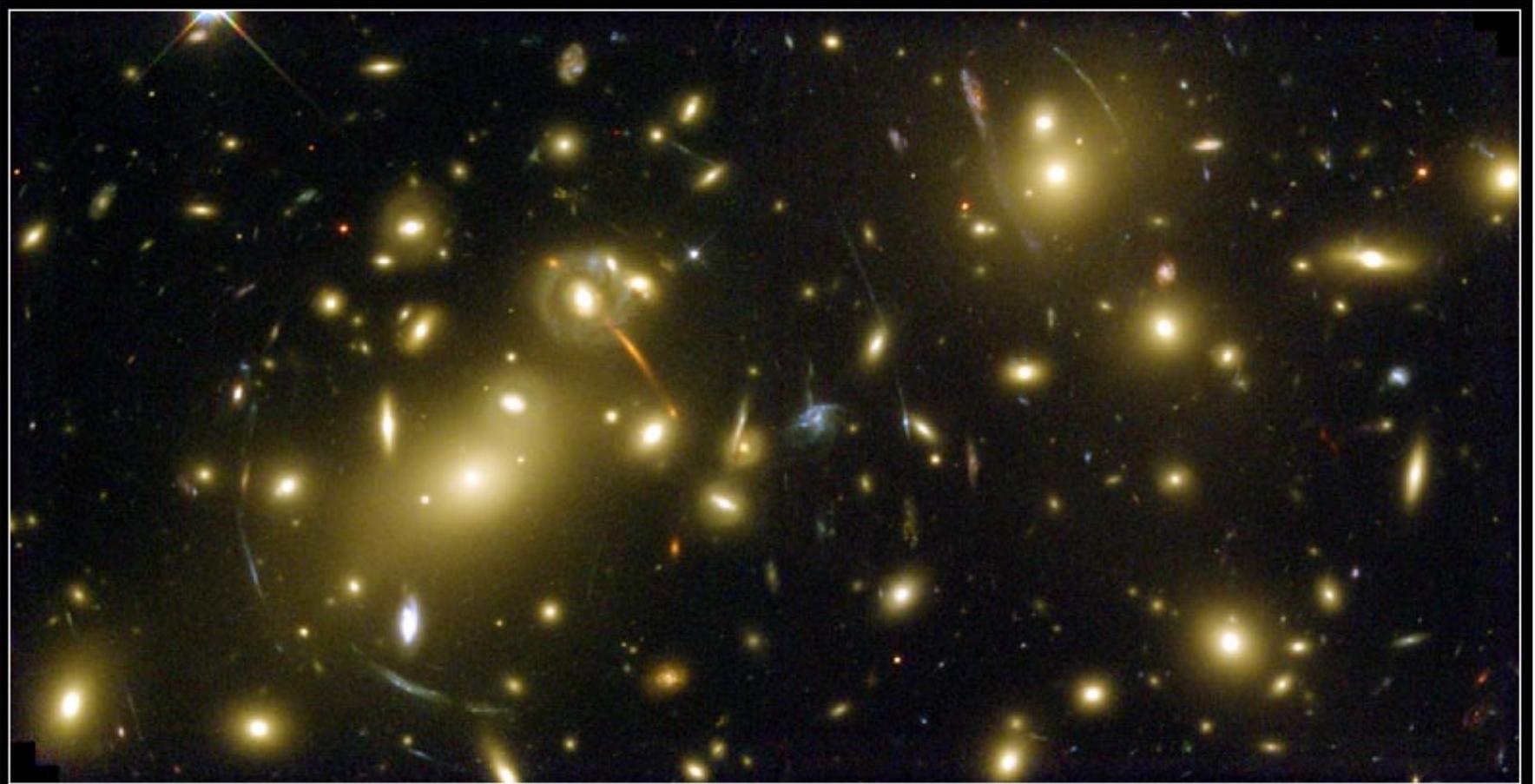
distribution of mass in a galaxy clusters

Total mass in galaxy clusters



rotation curve of a dwarf galaxy

Gravitational lensing by galaxy clusters

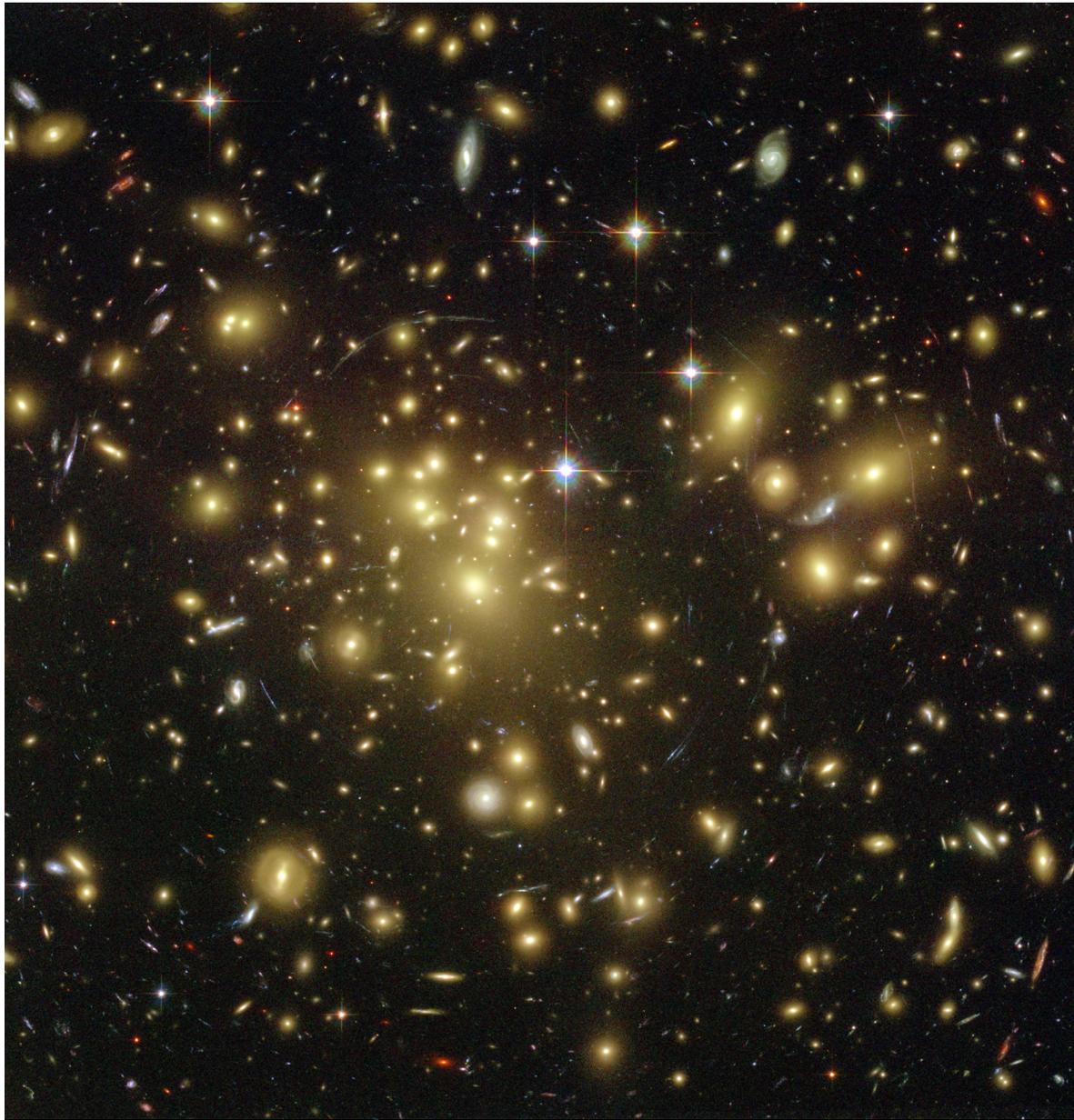


Galaxy Cluster Abell 2218

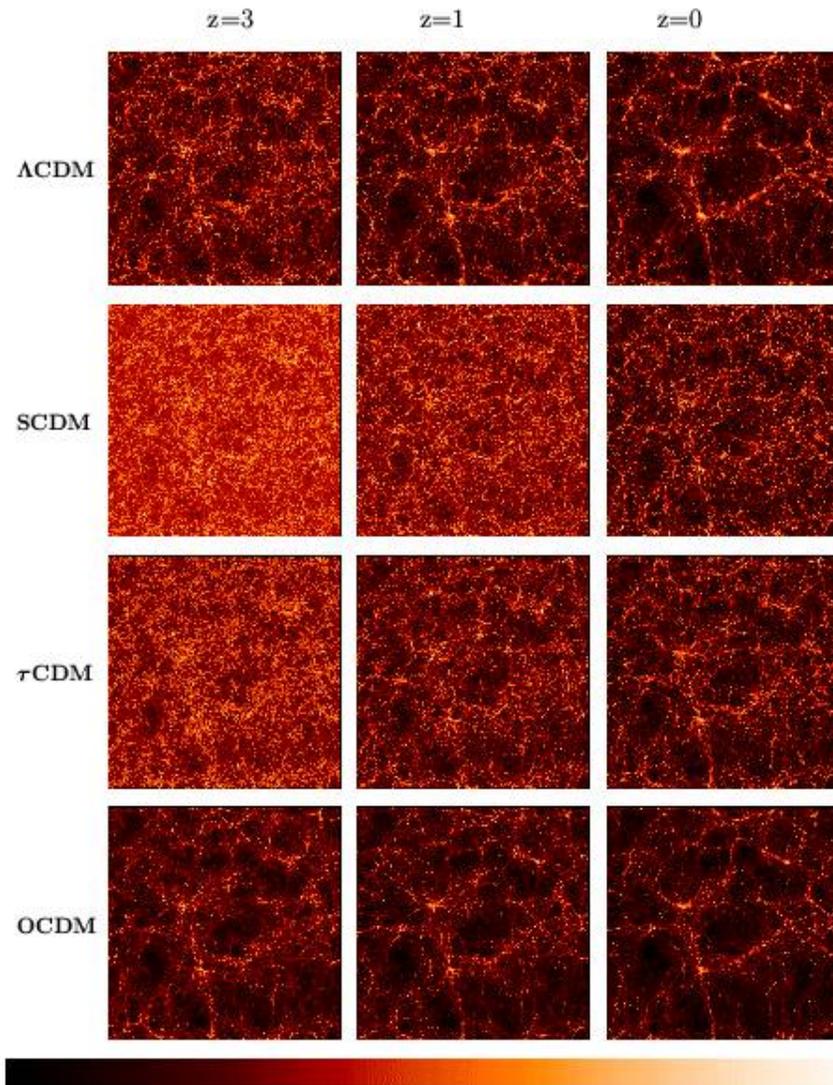
HST • WFPC2

NASA, A. Fruchter and the ERO Team (STScI, ST-ECF) • STScI-PRC00-08

Gravitational lensing by galaxy clusters



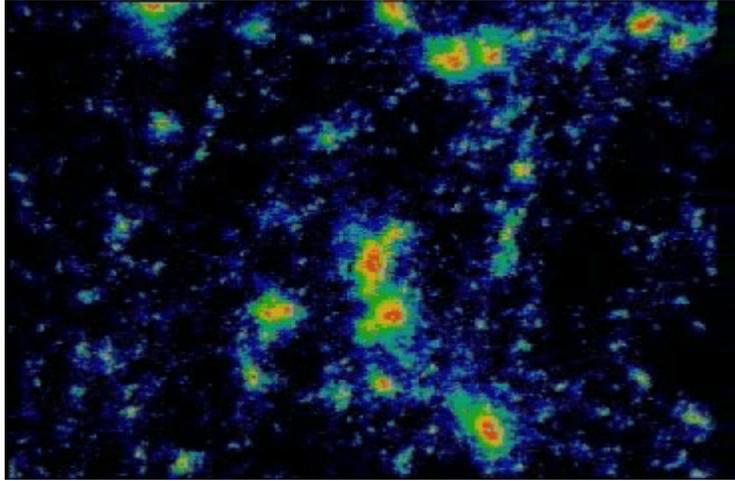
Numerical Λ CDM simulations



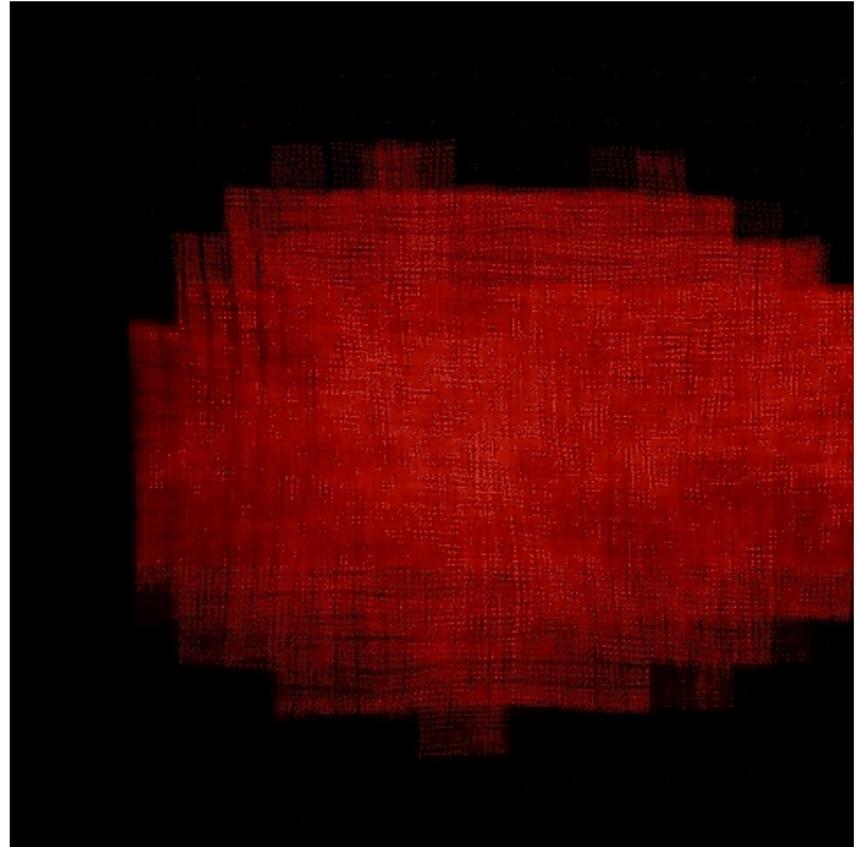
Simulated large-scale structure for different cosmologies

The VIRGO Collaboration 1996

Numerical Λ CDM simulations



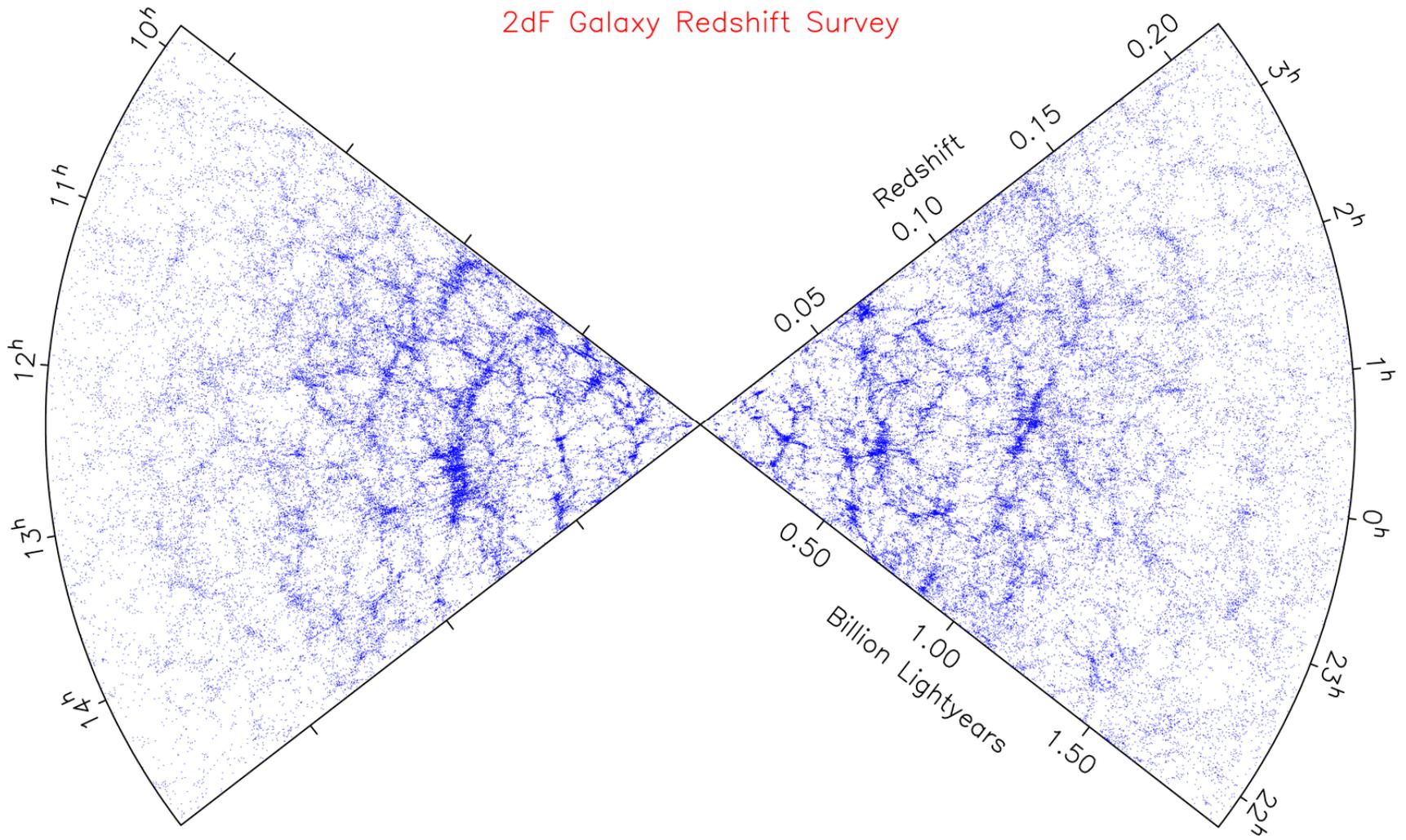
cluster



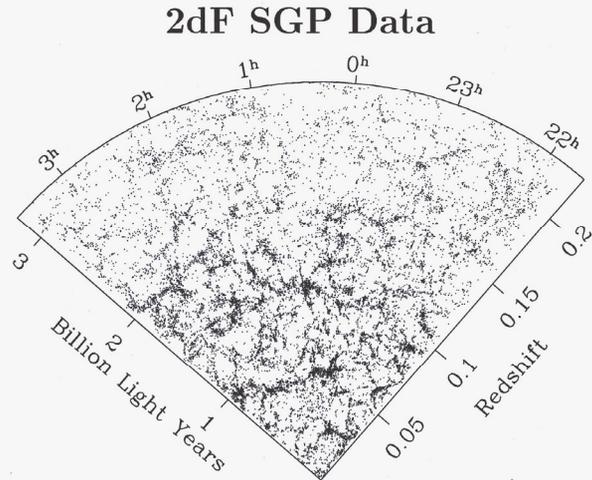
large galaxy

Observations

2dF Galaxy Redshift Survey



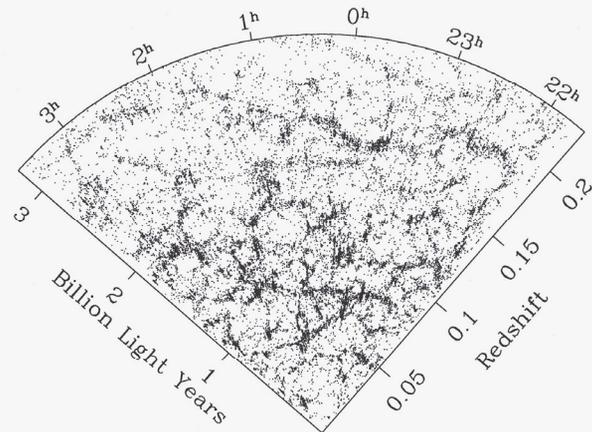
Simulations and observations



2dF Galaxy Redshift Survey: May 2000

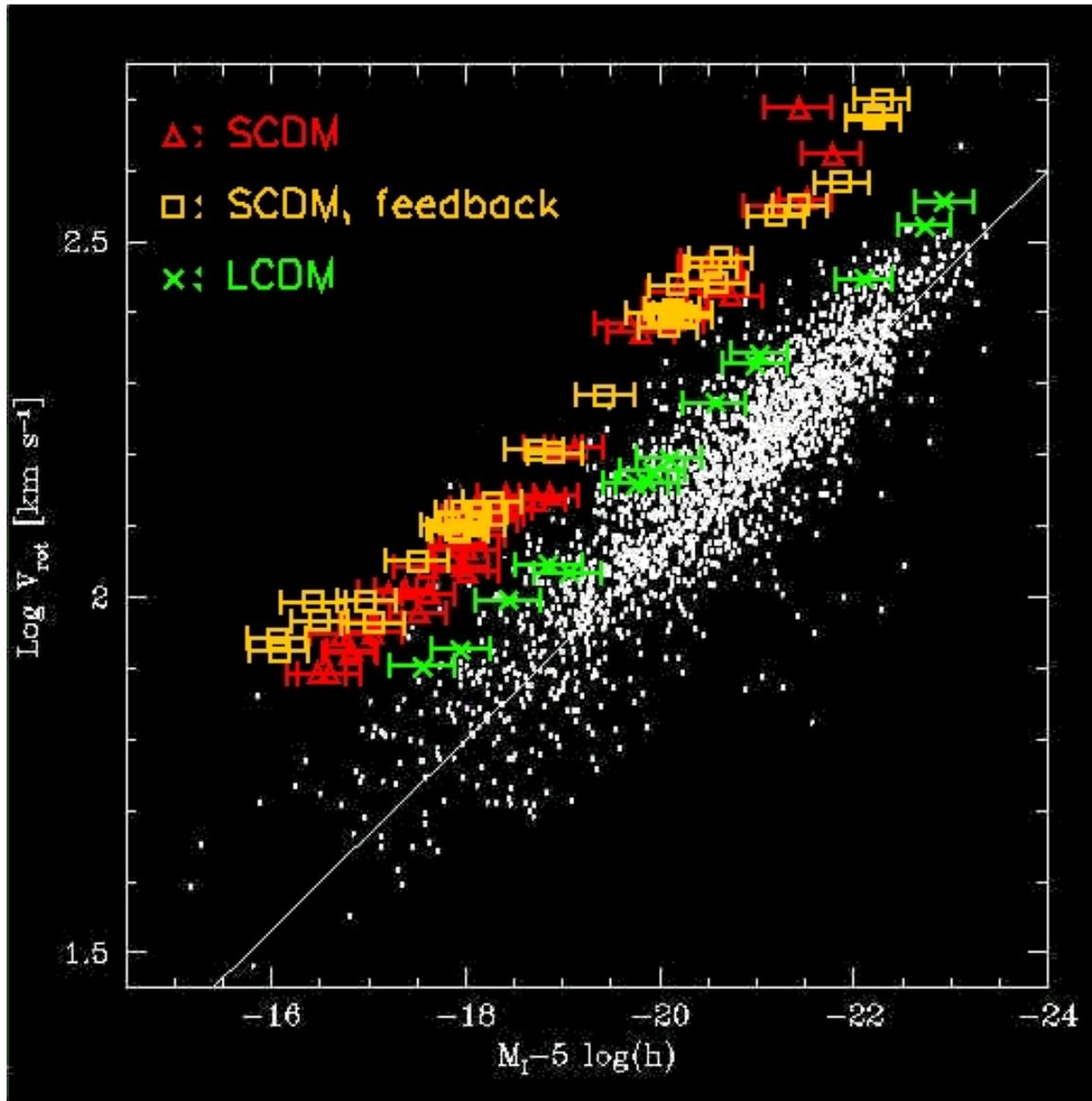
24,542 Galaxies (3° wide slice in dec)

Λ CDM Mock Catalogue

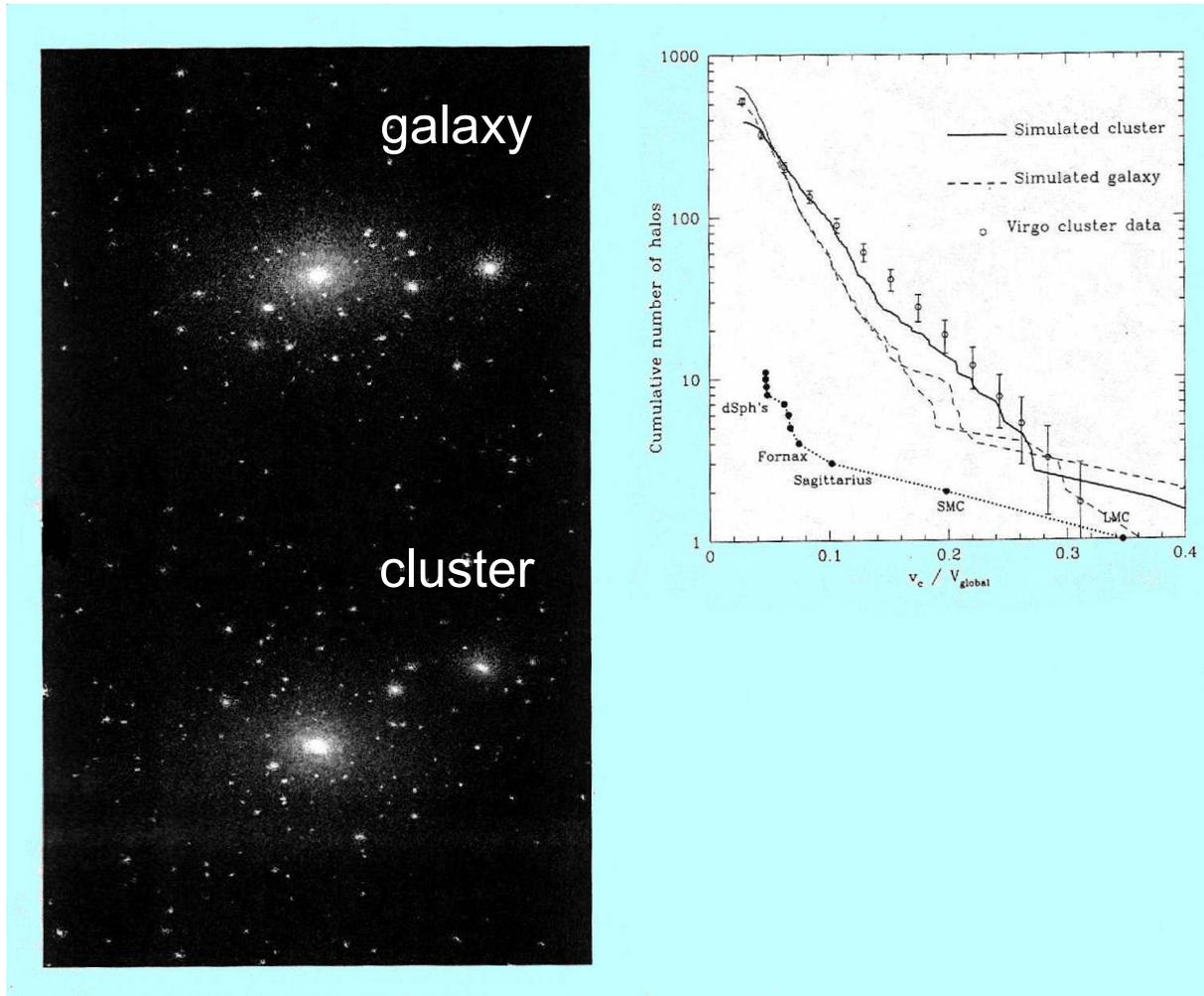


**simulations and observations
agree on large scales**

Tully-Fisher relation



'Missing satellites'



Virgo Cluster : agreement
Milky Way : large discrepancy

Web sites for numerical simulations

<http://www.mpa-garching.mpg.de/~volker/gadget/index.html>

<http://www.aip.de/People/MSteinmetz/Movies.html>

WIMP search

