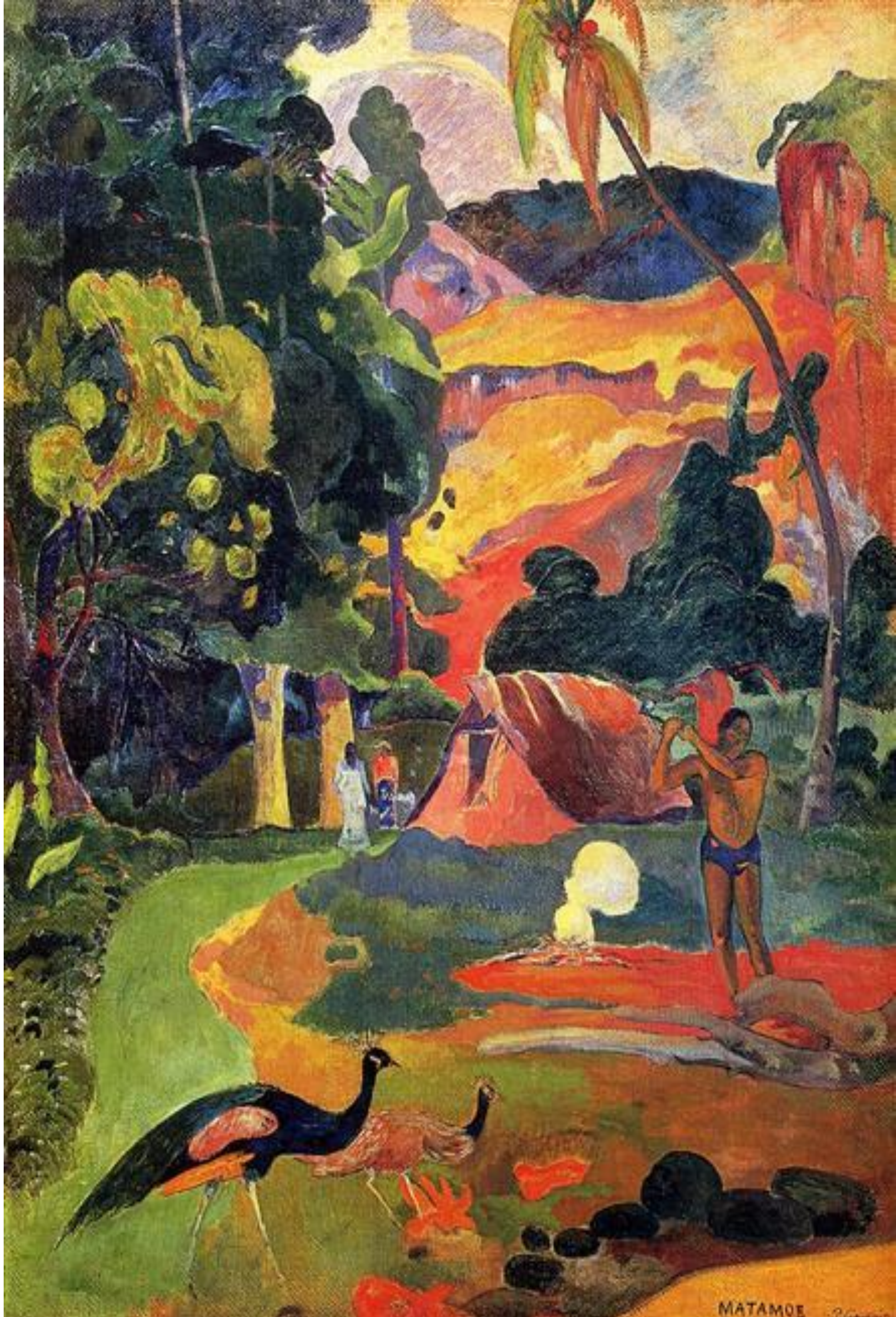
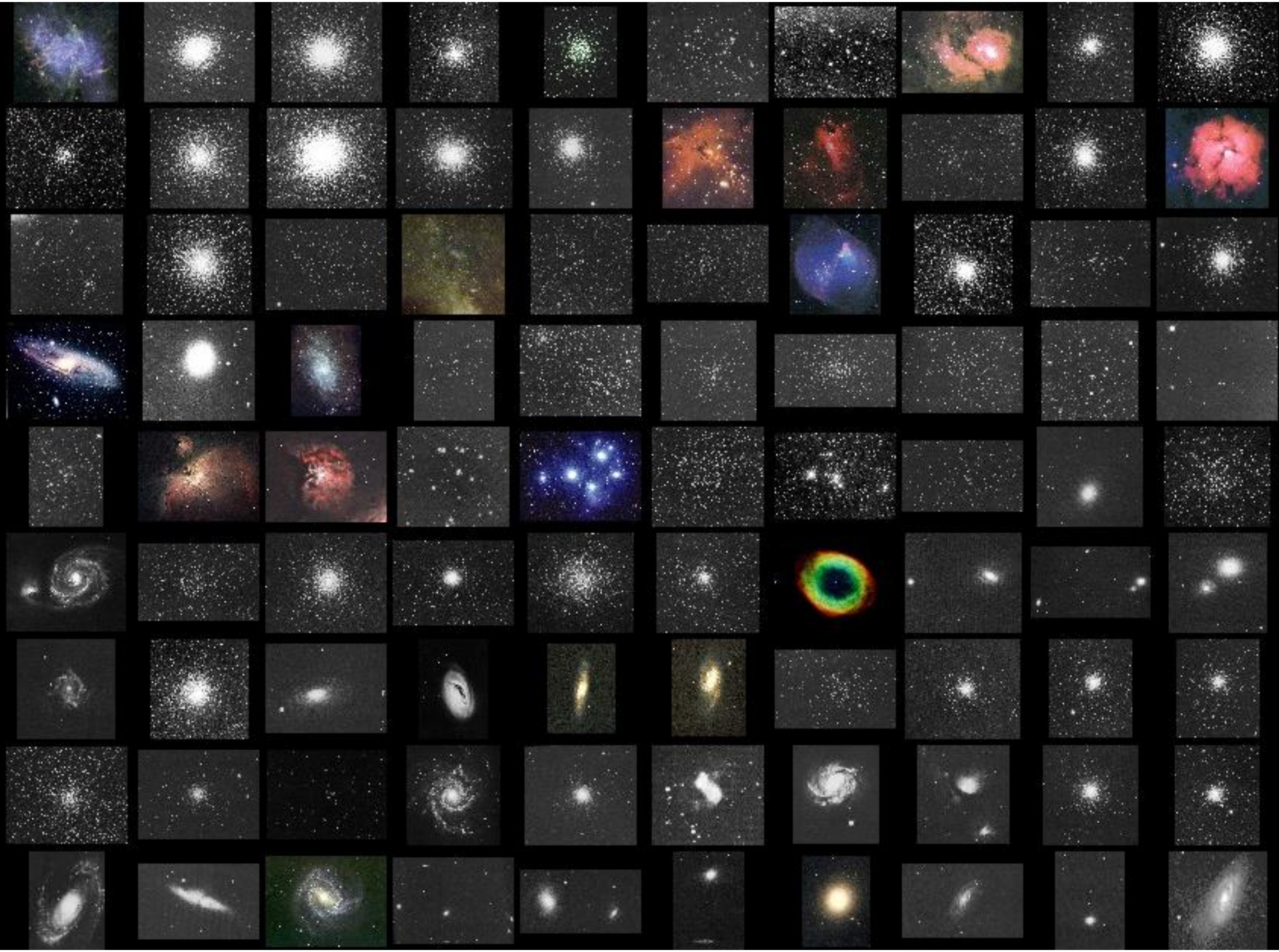
An Introduction to Astronomy
Presentation III
Fall 2018
Physics Department –SUT
Shant Baghram



Landscape with peacocks by Paul Gauguin (1892)



History of Galactic (& Extragalactic) Astronomy

- 1610 - Galileo discovered the Milky Way is comprised of many stars

- 1755 - Immanuel Kant theorized that the galaxy has a planar structure, some nebulae might actually be entire other galaxies or *island universes*

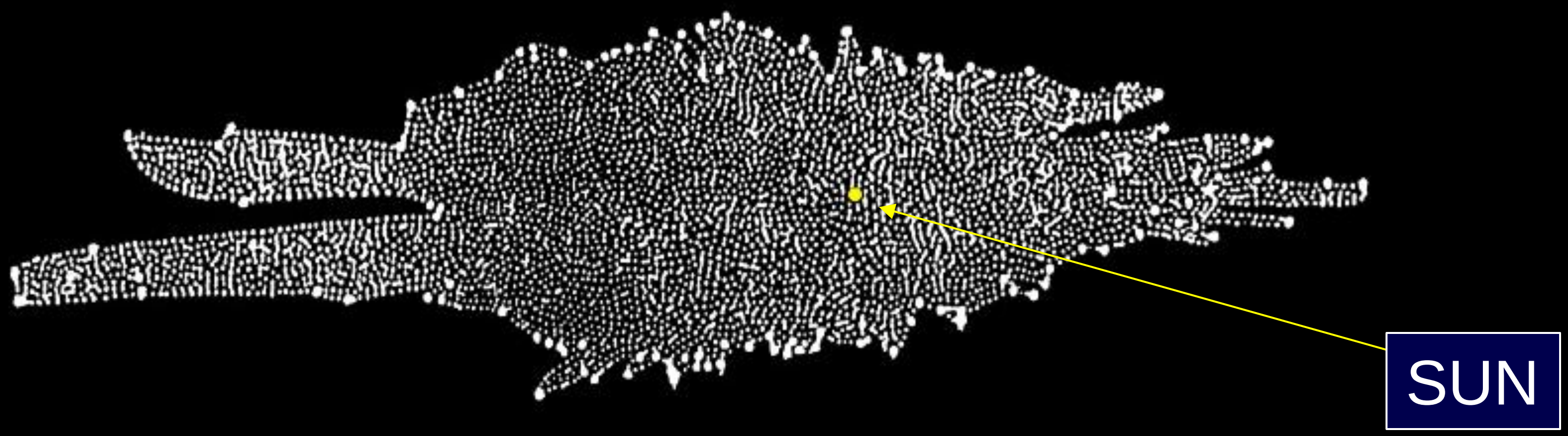
- 1774 -1781 - Messier catalog compiled including Andromeda galaxy as M31

- 1781-1802 - William and Caroline Herschel conducted first “all-sky survey” and cataloged 5000 nebulae, resolving some into their individual stars

- 1845 - William Parsons (Lord Rosse), using a 72-inch telescope, classified the nebulae into featureless *ellipticals* and whirlpool-like *spiral nebulae*

History of Galactic (& Extragalactic) Astronomy

- 1785 - Herschel attempted to determine the shape and size of Galaxy
  Assumptions:
    - All stars have same intrinsic brightness
    - Star are arranged uniformly throughout the MW
    - He could see to the edge of the MW



Herschel could not account well for the effects of dust.

More dust along the disk causes the distribution of stars to drop-off artificially – objects more than a few kpc from the Sun are obscured by dust.

History of Galactic (& Extragalactic) Astronomy

- Kapteyn (early 1900s) used stellar parallax to estimate the true size of the Galaxy → Kapteyn Universe

    - 10kpc diameter and 2kpc thick with the Sun less than a kpc from the center (rather heliocentric)

    - Tried to estimate scattering due to ISM gas but determined it to be insignificant (most obscuration is due to *dust absorption* which has a smaller wavelength dependence)

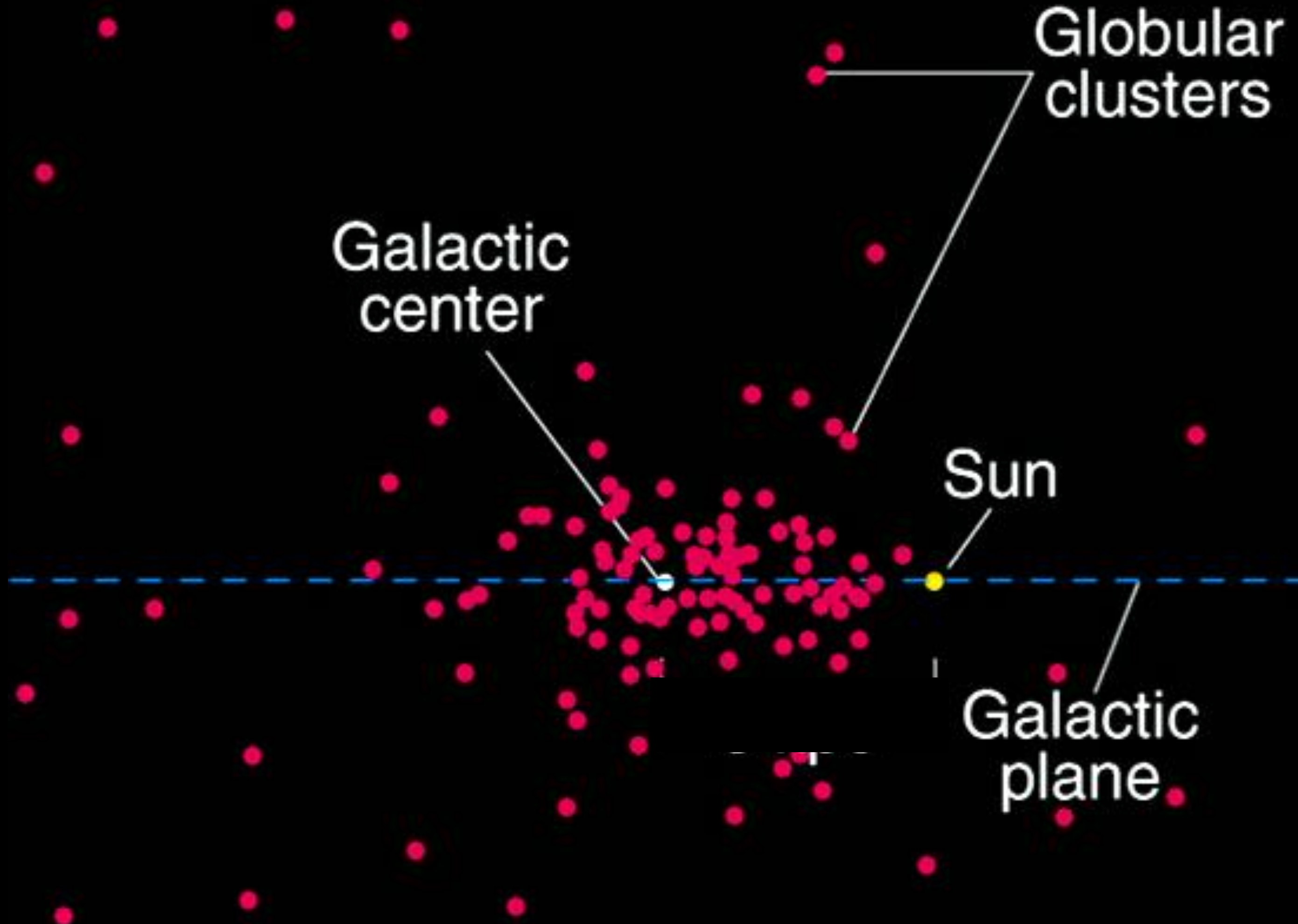
- Shapley (1919) observed that *globular clusters* are distributed asymmetrically in the sky and that if one assumes they are distributed about the center of the galaxy, this implies the Sun in not near the center of the Galaxy

    - Estimated distances to globular clusters using variable stars and P-M relationship

    - Concluded size to be 100kpc with Sun 15kpc from center

    Still wrong…didn't account for dust absorption which makes things look further away

History of Galactic (& Extragalactic) Astronomy



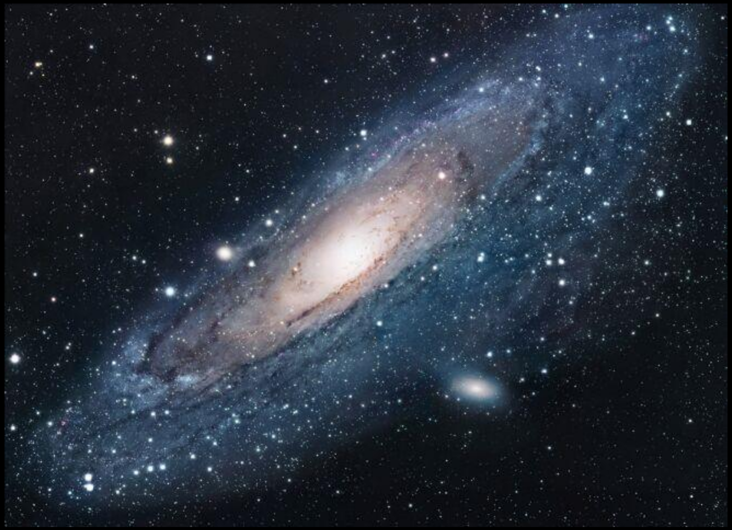
Shapley realized that the globular clusters are all orbiting the center of our Galaxy and map out the true extent of the Galaxy.

History of Galactic (& Extragalactic) Astronomy

In 1920, the National Academy of Science hosted the *Great Debate* concerning the nature of the Spiral Nebulae: were they island universes outside of the Milky Way?

- Shapley had MW size too big and therefore argued "NO", they are part of the Milky Way

- Others at that time believed the Kapteyn model of a much smaller MW and argued "YES", they are separate galaxies.



In 1922-1924 Edwin Hubble resolved the controversy using the superior 100-inch telescope at Mount Wilson. He observed Cepheid variables in Andromeda and, using the P-M relation (distance method), determined its distance to be 300kpc -- well outside of the MW (still off by a factor of 2 due to poor Cepheid calibrations)

Morphology of our Galaxy

Also in the early 1900's, the first kinematic studies of the MW revealed the velocities of those globular clusters were ~250 km/s, much higher than the mass of the smaller Kapteyn galaxy model would require. So the galaxy must contain more stars (and mass) than Kapteyn originally thought in order to keep the star clusters from flying off.

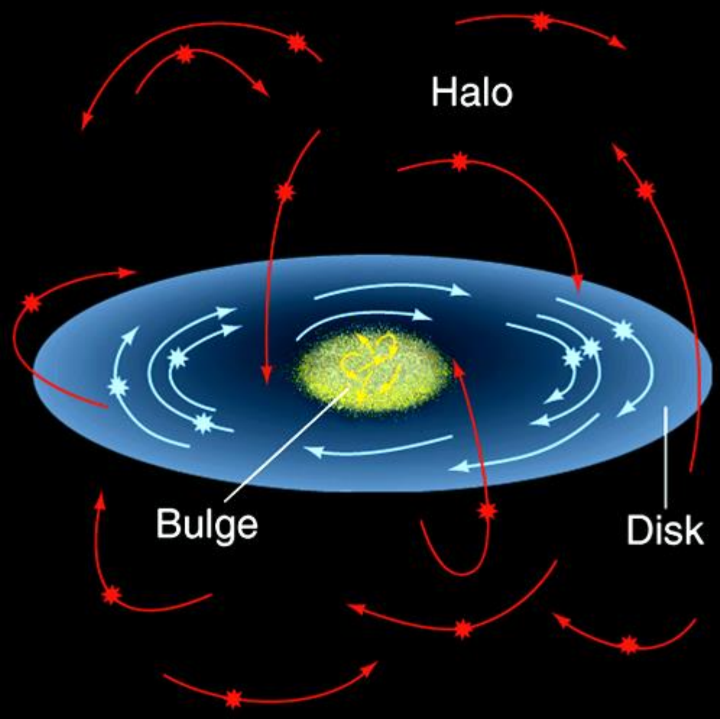
First detailed kinematic model (Lindblad 1927) revealed

•A spherical component with random motions (~250 km/s) → HALO

•A flattened component with rotational motion measured at 200 to 300 km/s near the Sun – DISK

•A third component, also spherical, exists in the center of the galaxy – BULGE

Stars here also move on mostly random orbits

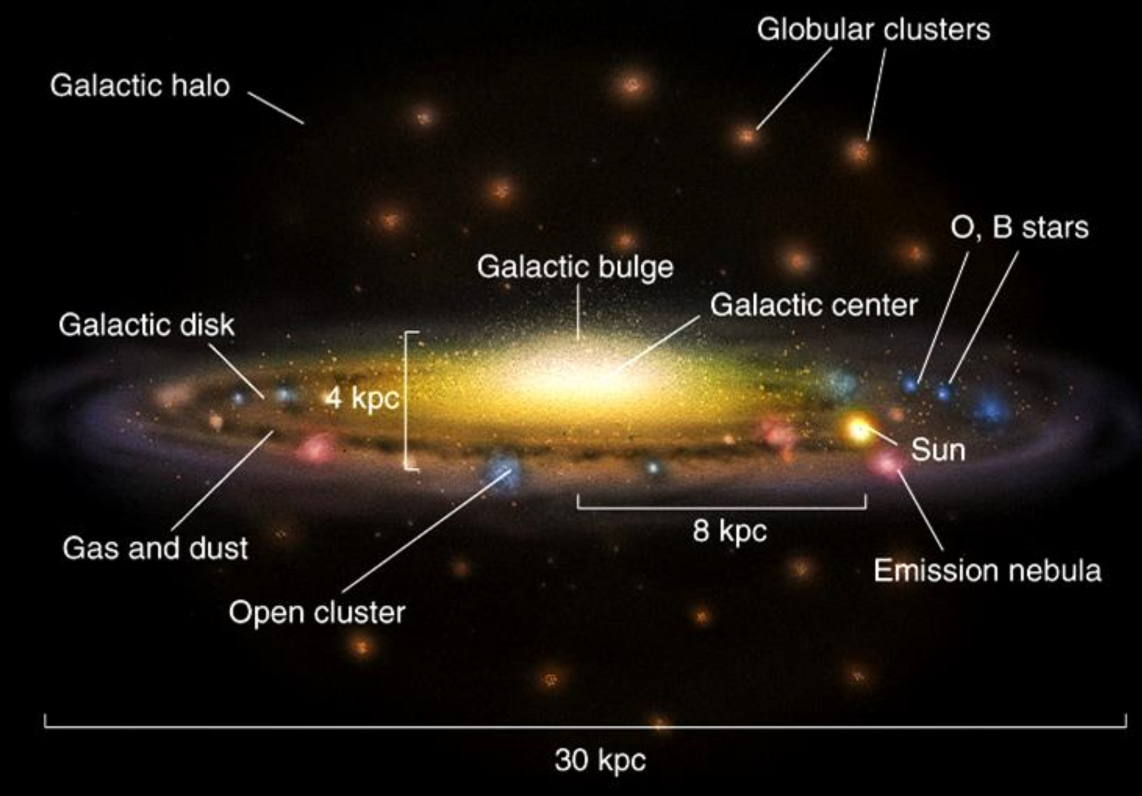


Morphology of our Galaxy

The three components of our galaxy (disk, halo and bulge) also differ in the mix of the types of stars they contain

- **Population I**: Hot, blue stars and young open clusters accompanied by gas and dust are primarily found in the disk of the Milky Way

- **Population II**: red stars and older globular clusters are found in the halo of the Milky Way



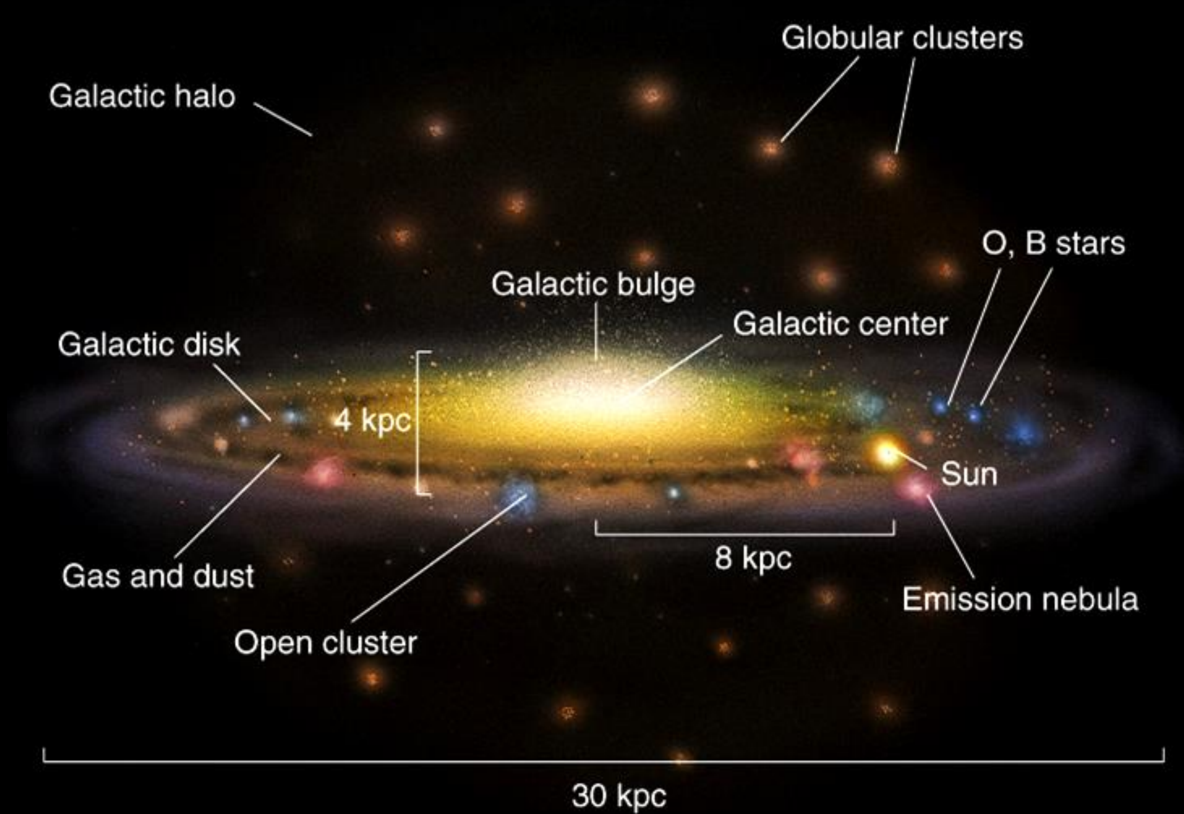
Morphology of our Galaxy

Plotting stars on HR diagrams showed that the populations differed in *age and metallicity (enrichment of elements heavier than Helium):*

Pop I young and metal rich
Pop II old and metal poor

Disk – mainly Pop I
Halo – mainly Pop II
Bulge – mix of Pop I and II

- Disk: $L_B = 19 \times 10^9 L_\odot$
- Bulge: $L_B = 2 \times 10^9 L_\odot$
- Halo: $L_B = 2 \times 10^9 L_\odot$
- Grand Total: $L_B = 23 \times 10^9 L_\odot$



Since most stars are smaller than the sun, the Milky Way actually contains far more than 23 billion stars – more like 200 billion

دوران مشاهده ساختارهای بزرگ مقیاس کیهانی

- ✓ مساحی بزرگ مقیاس

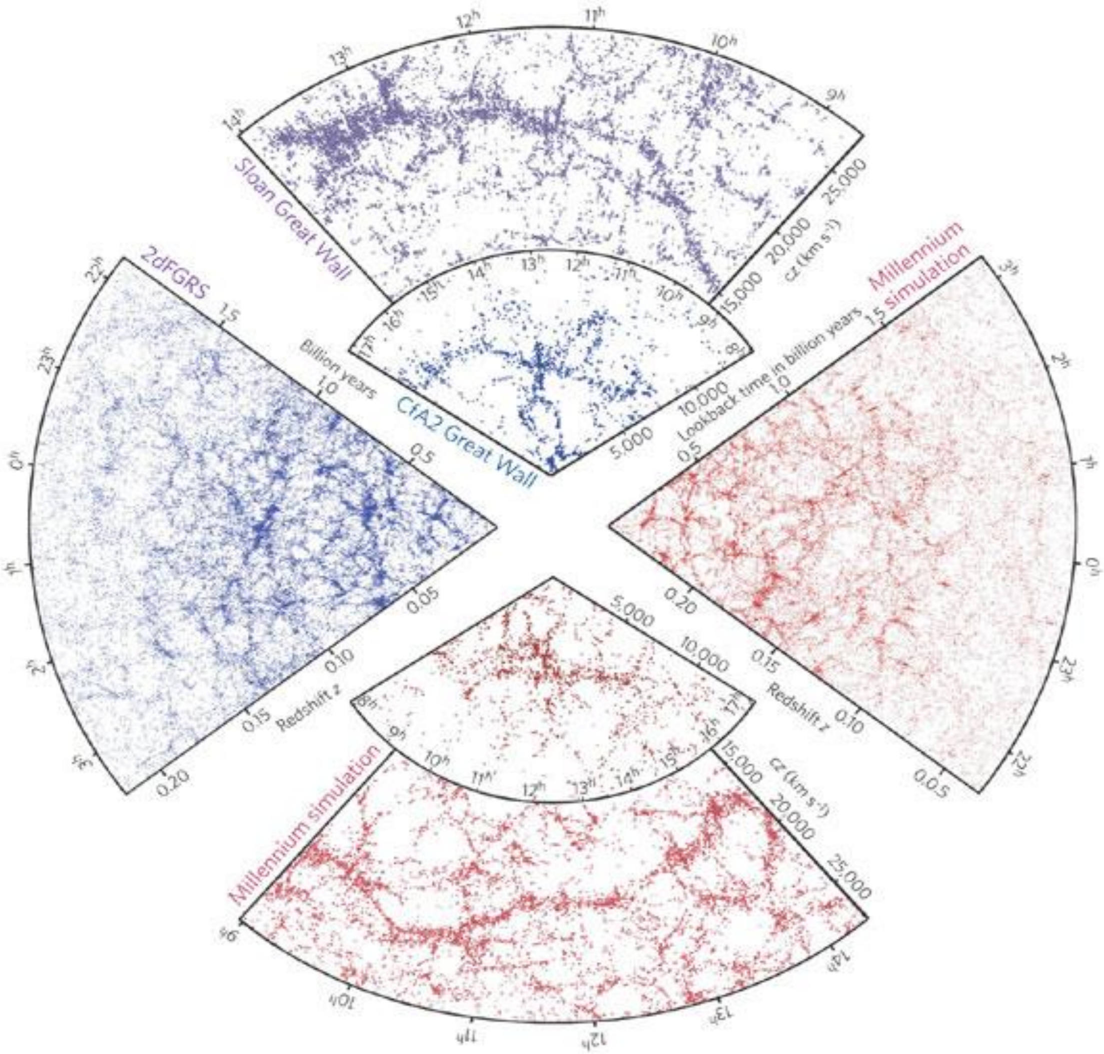
۱۴۵۵۵ درجه مربع پوشش آسمان

۹۳۲۸۹۱۱۳۳ طیف کهکشان

۲۲۸۴۶۸ طیف کوازار

2.5-m wide-angle optical telescope at Apache Point Observatory in New Mexico (2000-)

اصل کیهان شناخت: کیهان همگن و همسانگرد



Volker Springel, Carlos S. Frenk & Simon D. M. White، Nature 440, 1137-1144 (27 April 2006)

تحول کهکشان ها

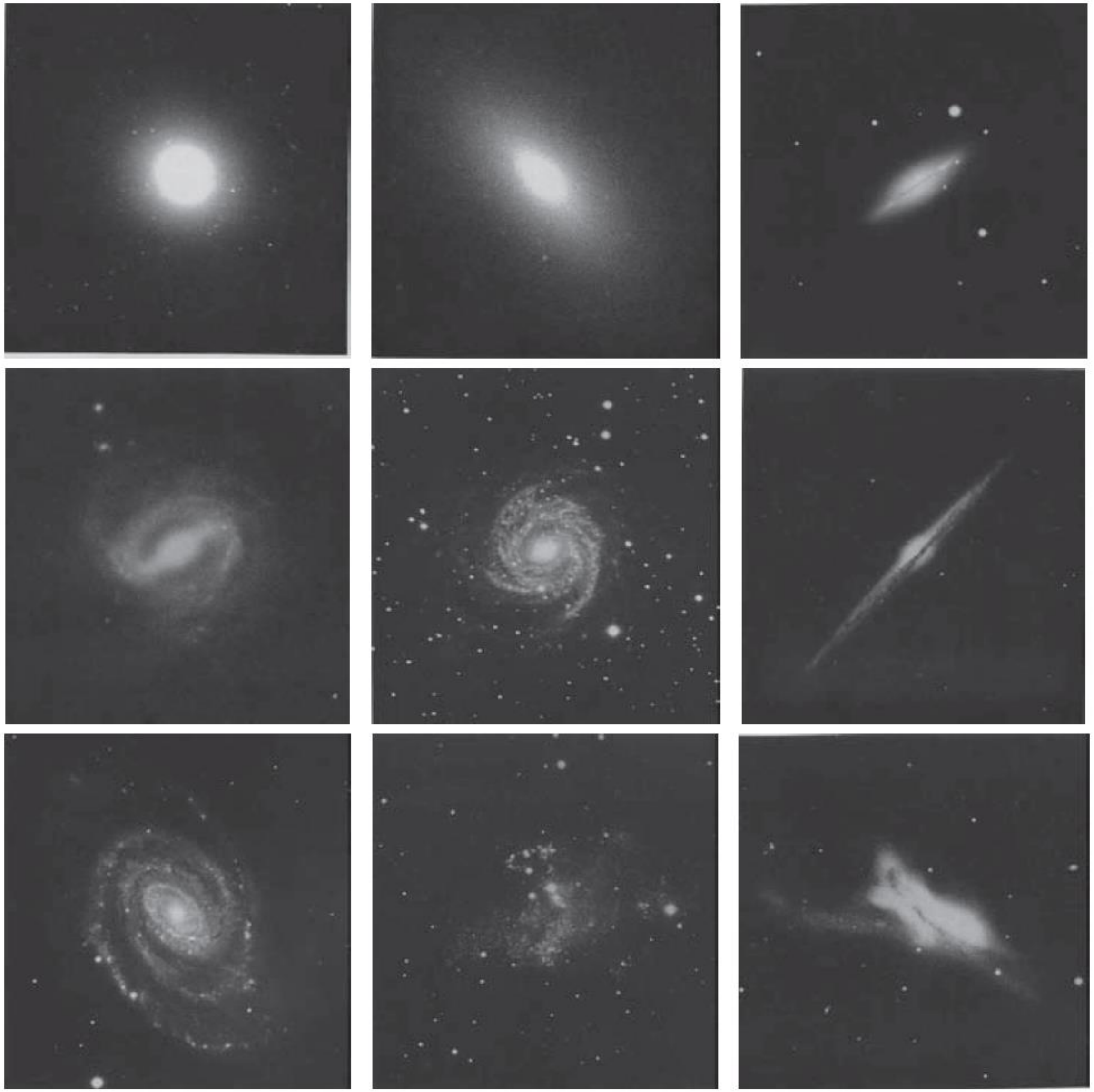
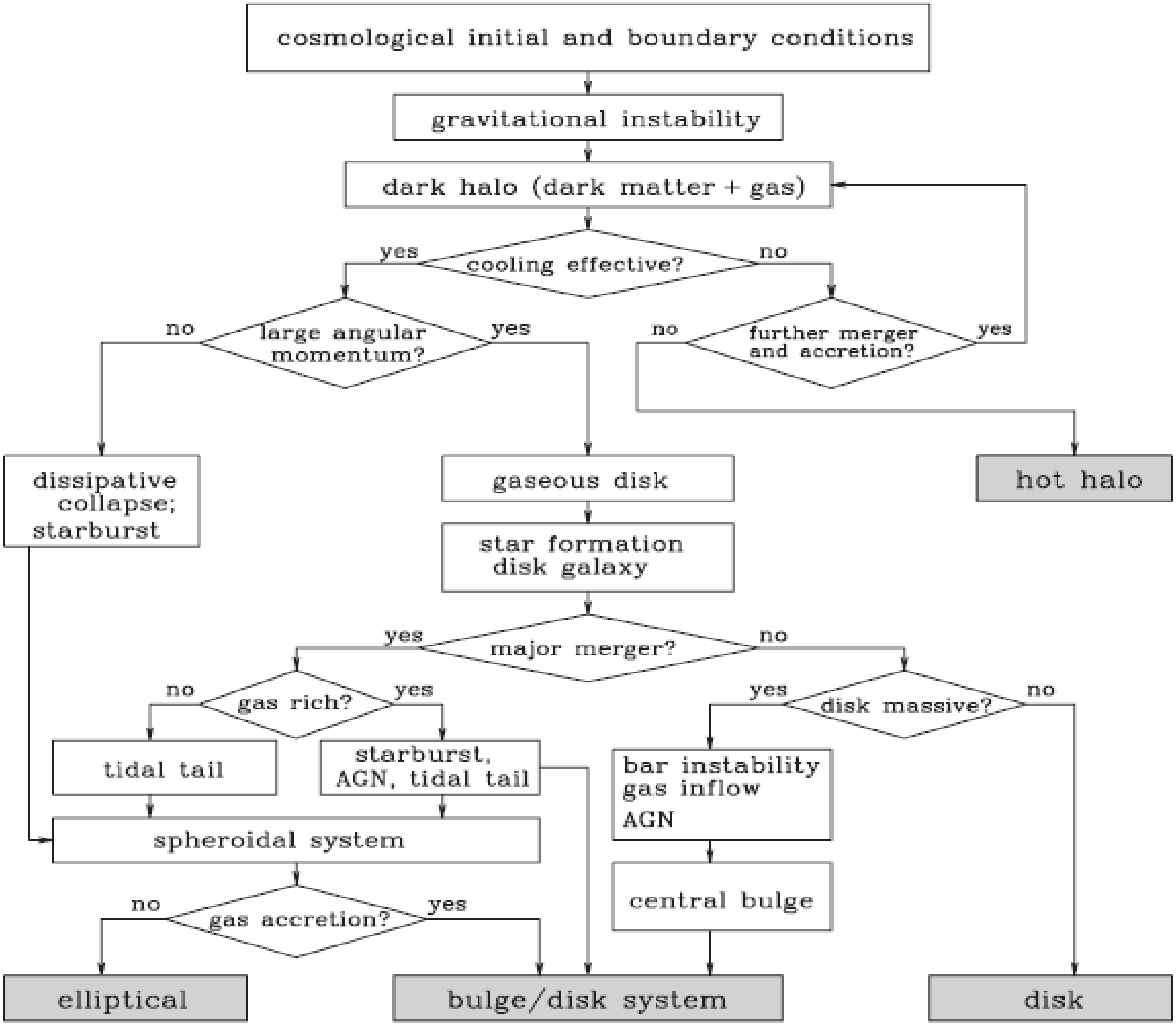
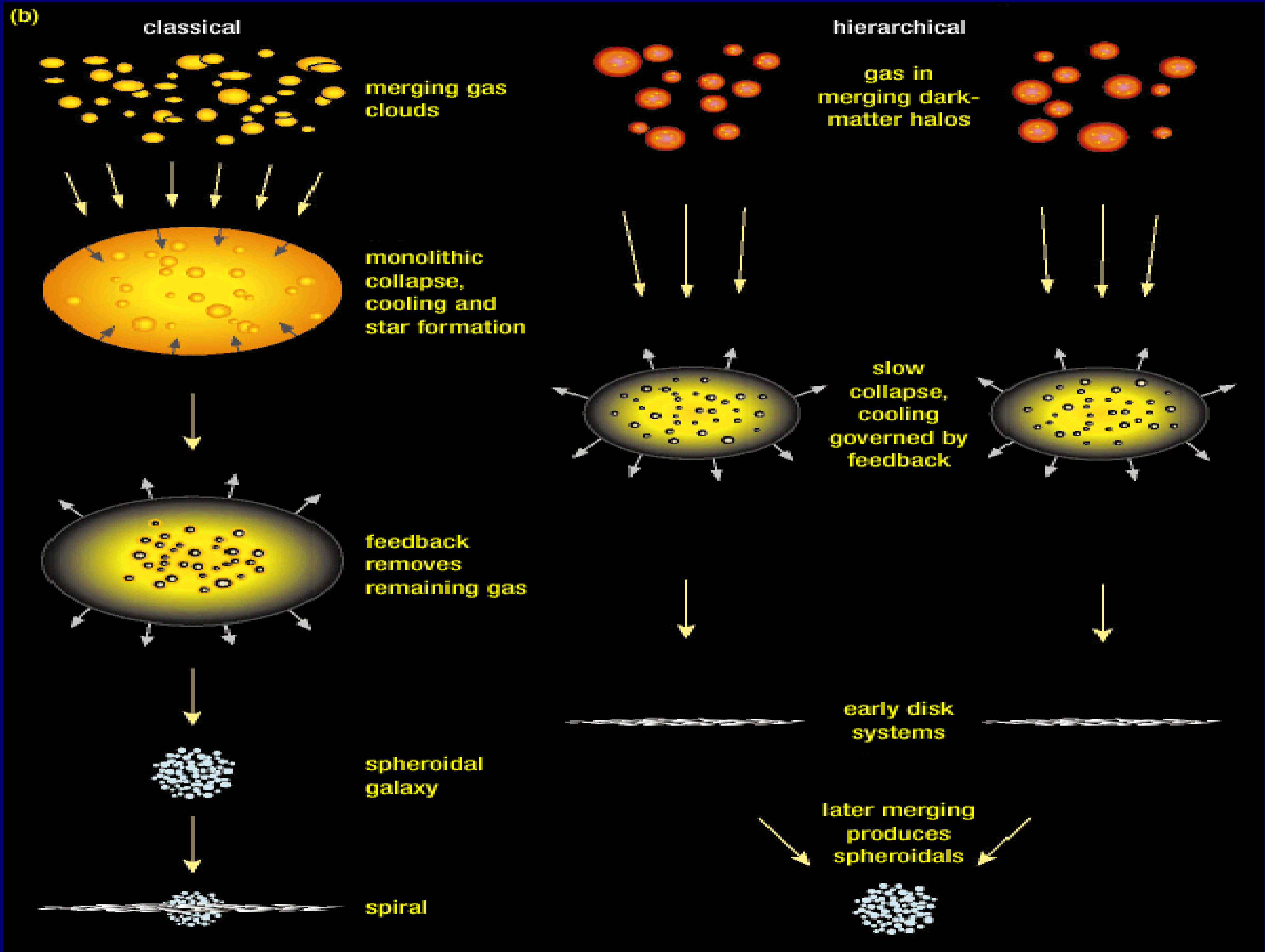


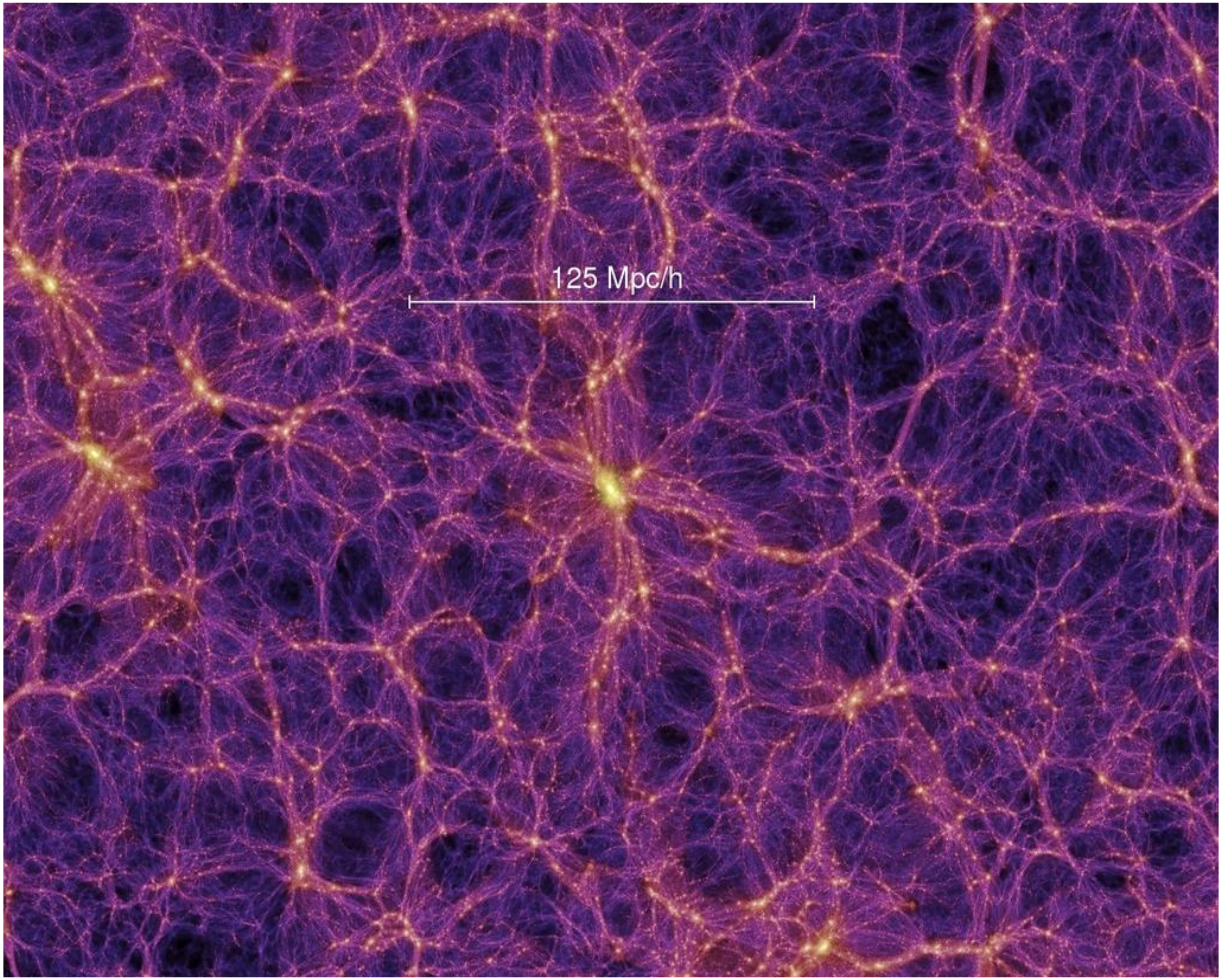
Fig. 2.7. Examples of different types of galaxies. From left to right and top to bottom, NGC 4278 (E1), NGC 3377 (E6), NGC 5866 (SO), NGC 175 (SBa), NGC 6814 (Sb), NGC 4565 (Sb, edge on), NGC 5364 (Sc), Ho II (Irr I), NGC 520 (Irr II). [All images are obtained from the NASA/IPAC Extragalactic Database (NED) which is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration]



cosmological initial and boundary conditions
gravitational instability
dark halo (dark matter + gas)
cooling effective?
yes
no
large angular momentum?
no
yes
further merger and accretion?
no
yes
dissipative collapse; starburst
gaseous disk
hot halo
star formation disk galaxy
major merger?
yes
no
gas rich?
no
yes
disk massive?
yes
no
tidal tail
starburst, AGN, tidal tail
bar instability gas inflow AGN
spheroidal system
central bulge
gas accretion?
no
yes
elliptical
bulge/disk system
disk

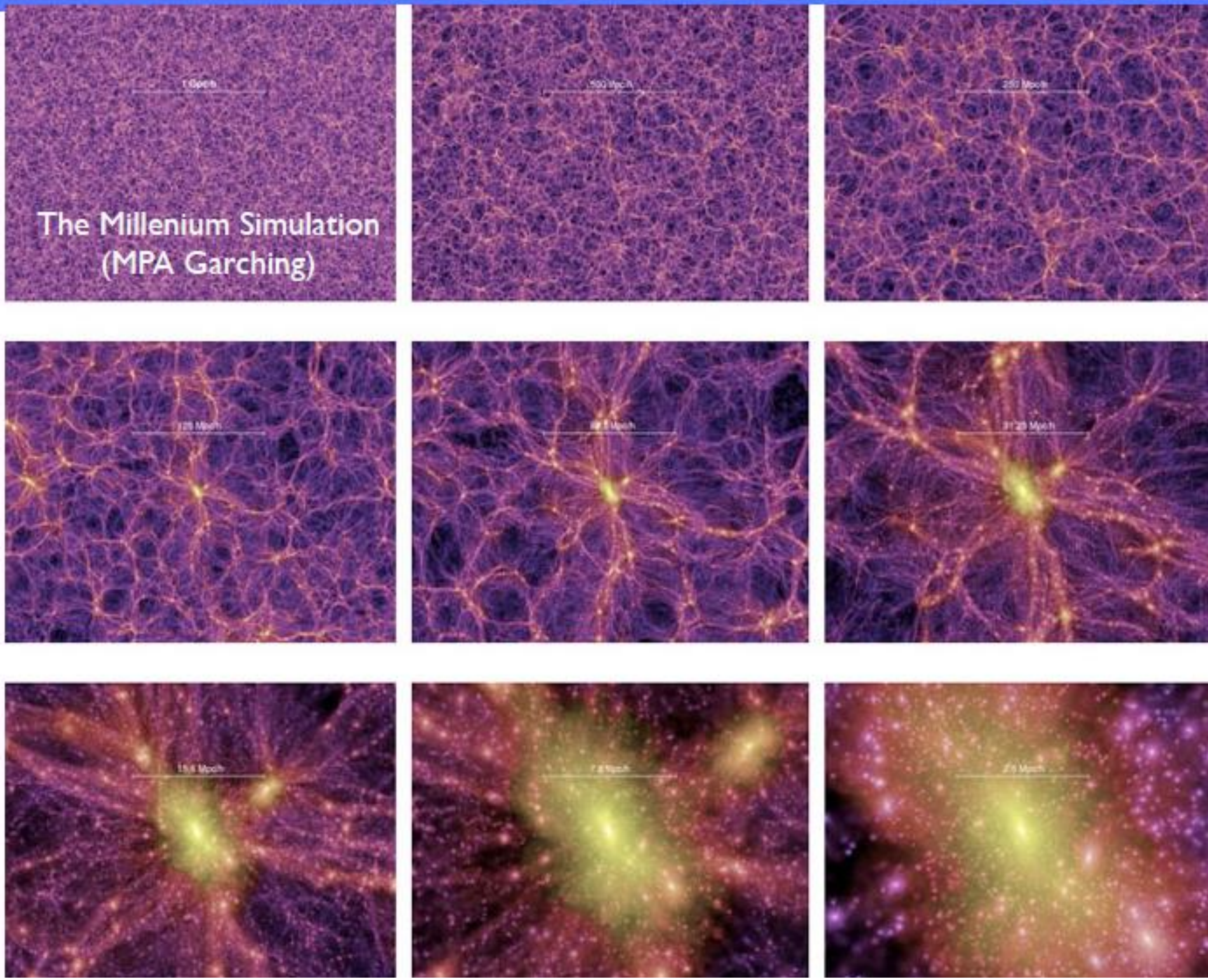

(b)
classical
hierarchical
merging gas clouds
monolithic collapse, cooling and star formation
feedback removes remaining gas
spheroidal galaxy
spiral
gas in merging dark-matter halos
slow collapse, cooling governed by feedback
early disk systems
later merging produces spheroidals

شبیه سازی

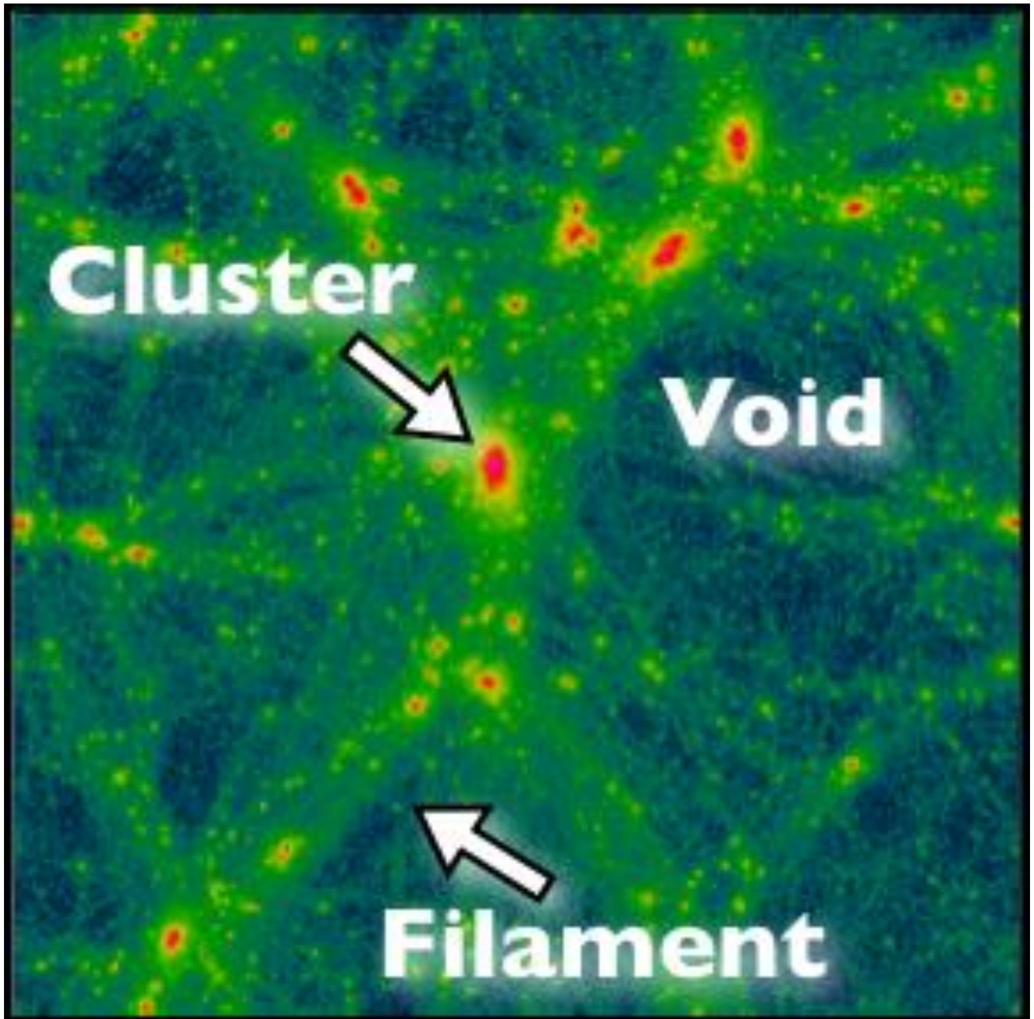


The Cosmic Web of dark matter

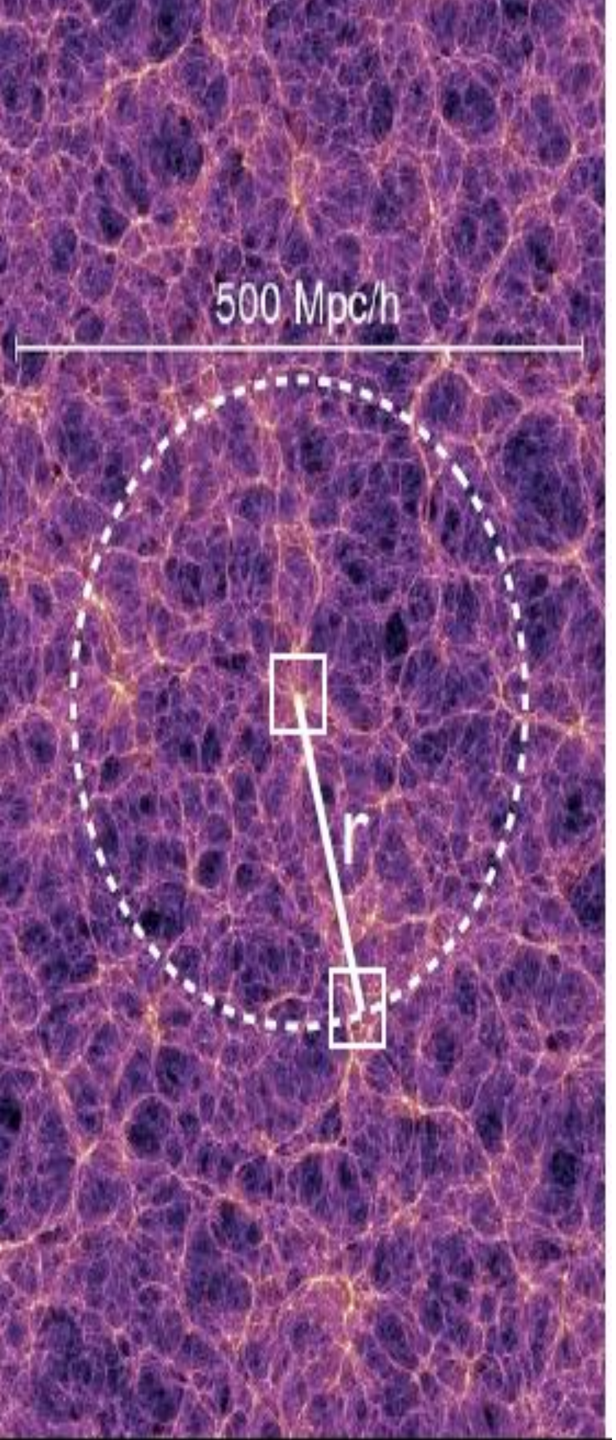
شبیه سازی ها



ساختارهای بزرگ مقیاس کیهانی



- کهکشان ها
- گروه های کهکشانی
- خوشه های کهکشانی
- تهی جاها
- شبکه کیهانی



کیهان با اختلالات

برای بررسی آماری احتیاج به محاسبه تابع دو نقطه ای داریم.

- ✓ مفهوم تباین:

$$\delta(x)=\frac{\rho(x)-\rho_b}{\rho_b}$$

$$\delta_g(R)=\frac{n_g(R)-\bar{n}_g}{\bar{n}_g}$$

- ✓ تابع همبستگی دو نقطه ای:

$$\xi(\vec{r})=\left\langle \delta(\vec{x})\delta(\vec{x}+\vec{r})\right\rangle$$

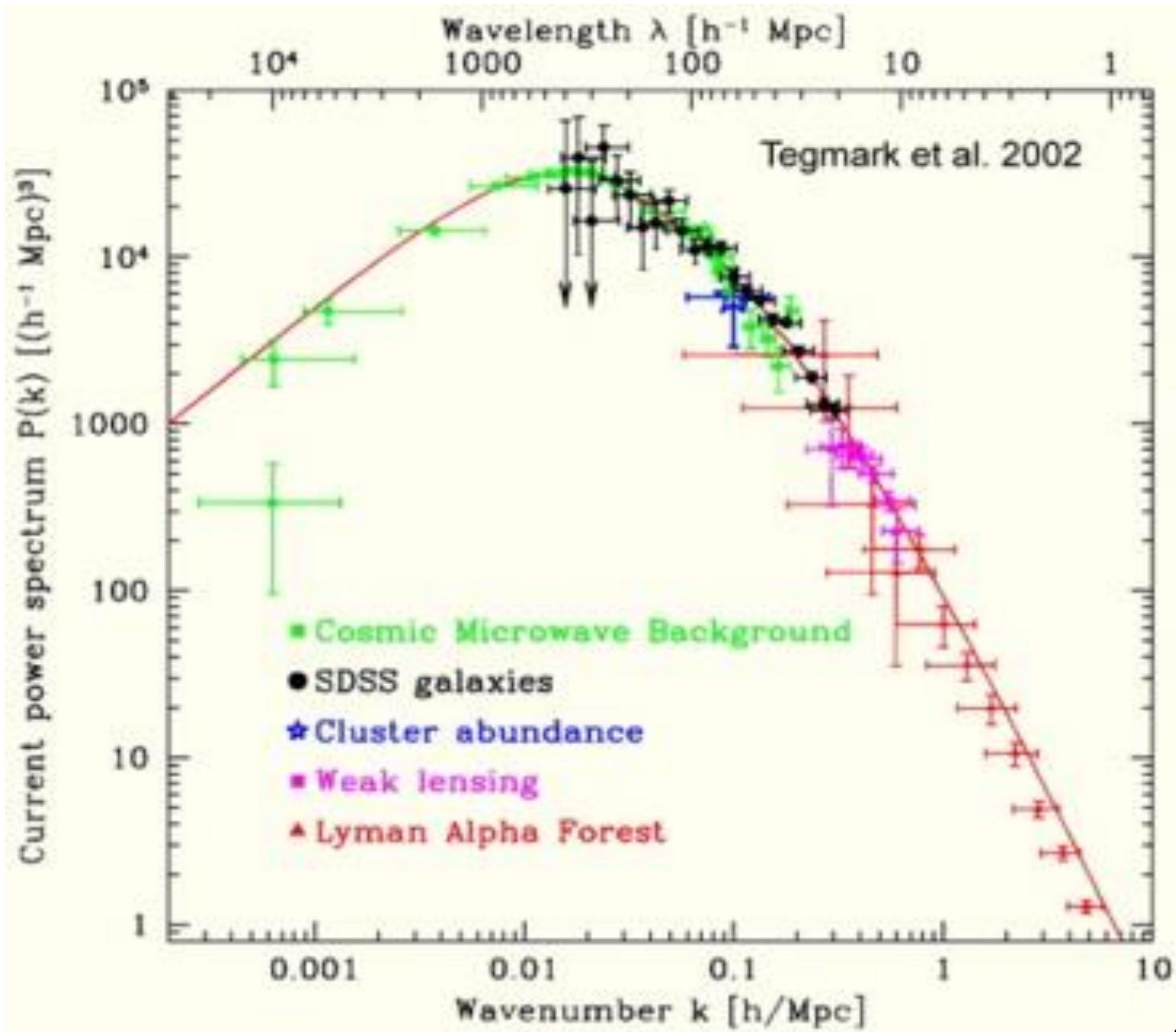
- ✓ طیف توان:

$$\left\langle \delta(\vec{k})\delta(\vec{k}')\right\rangle=(2\pi)^3P(k)\delta^D(\vec{k}+\vec{k}')$$

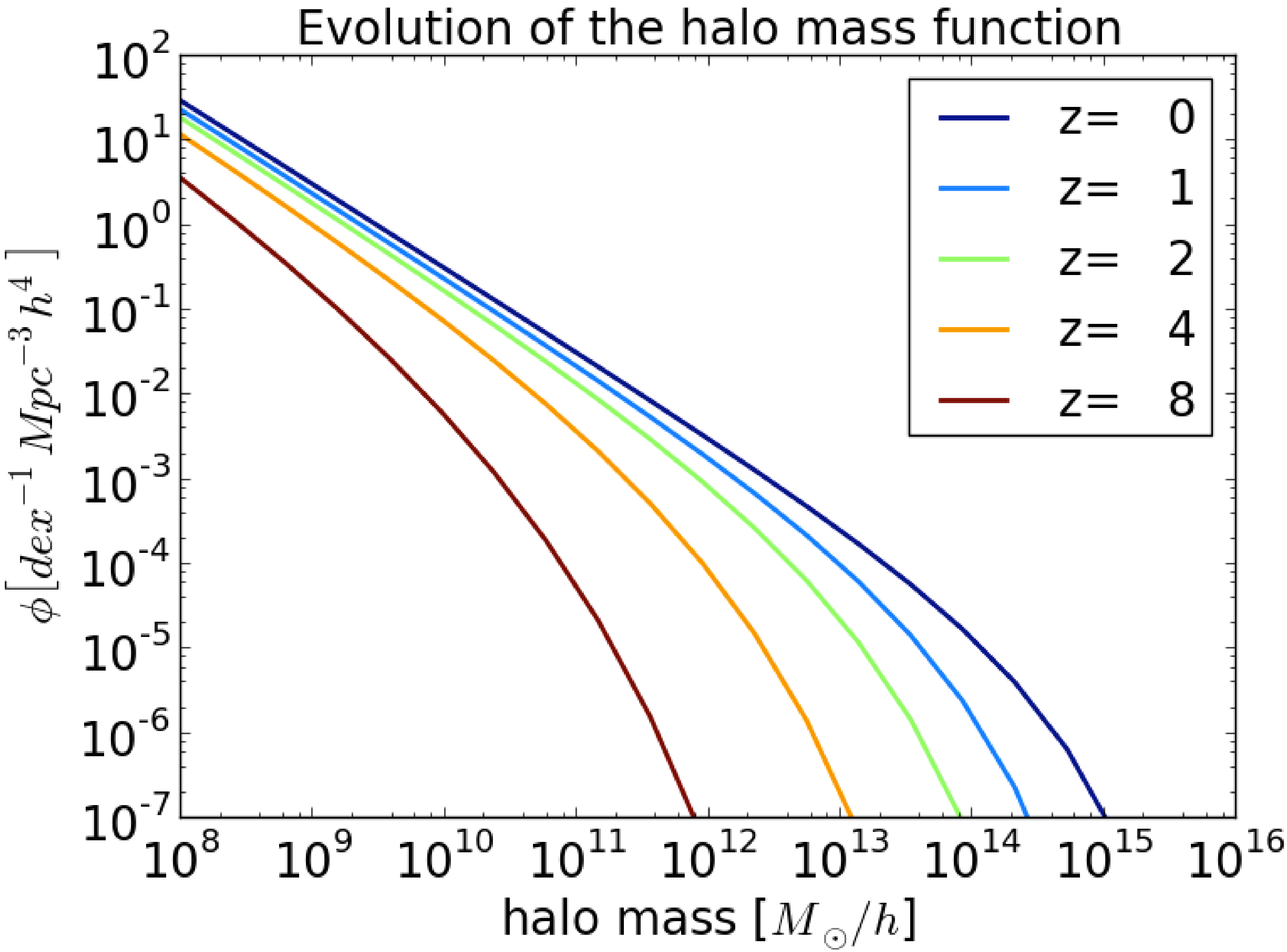
Millennium Simulation Project - Max-Planck-Institut für Astrophysik

طیف توان ساختارها در کیهان : پیروزی کیهان شناسی

طیف توان

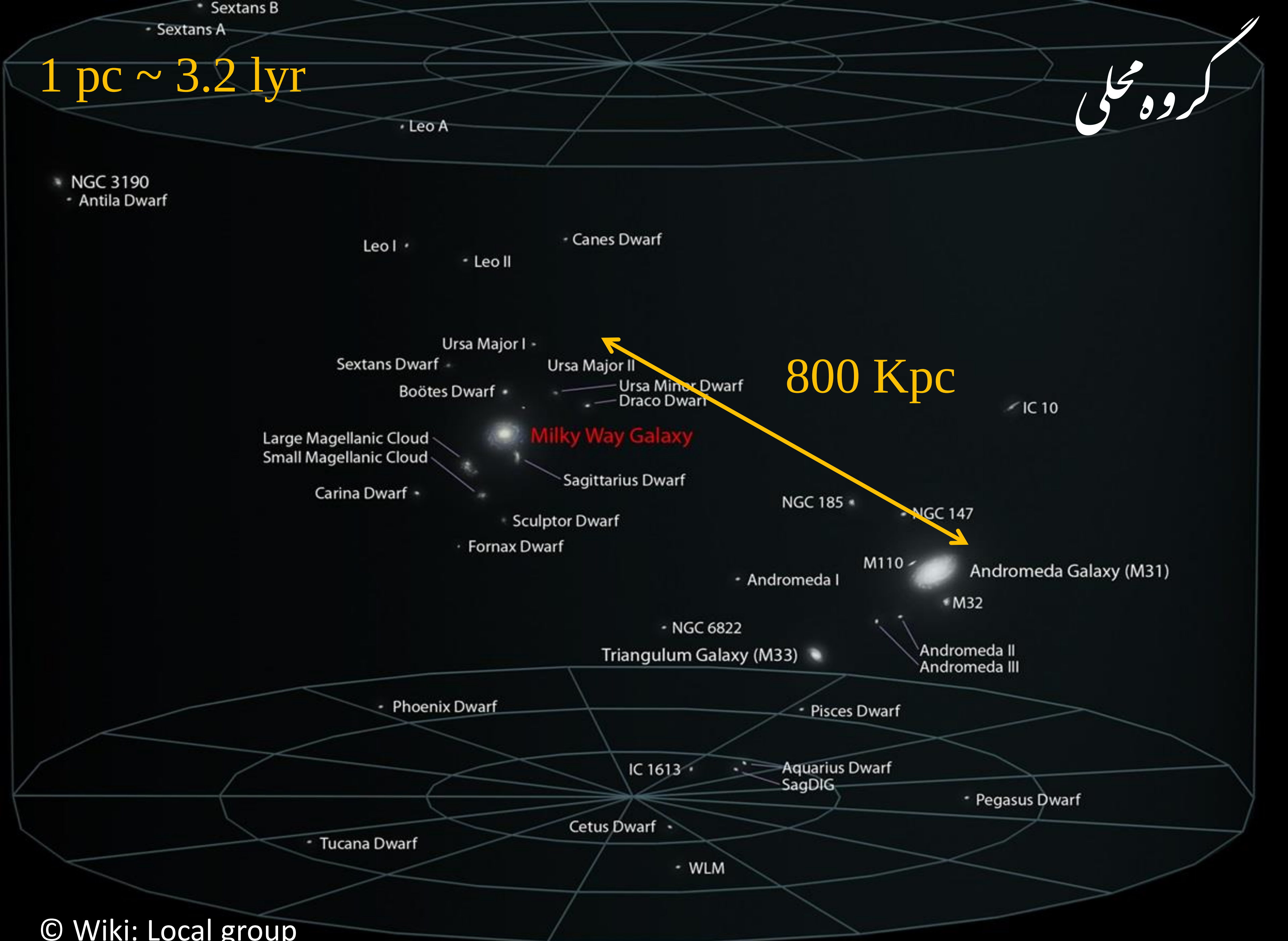


مقیاس



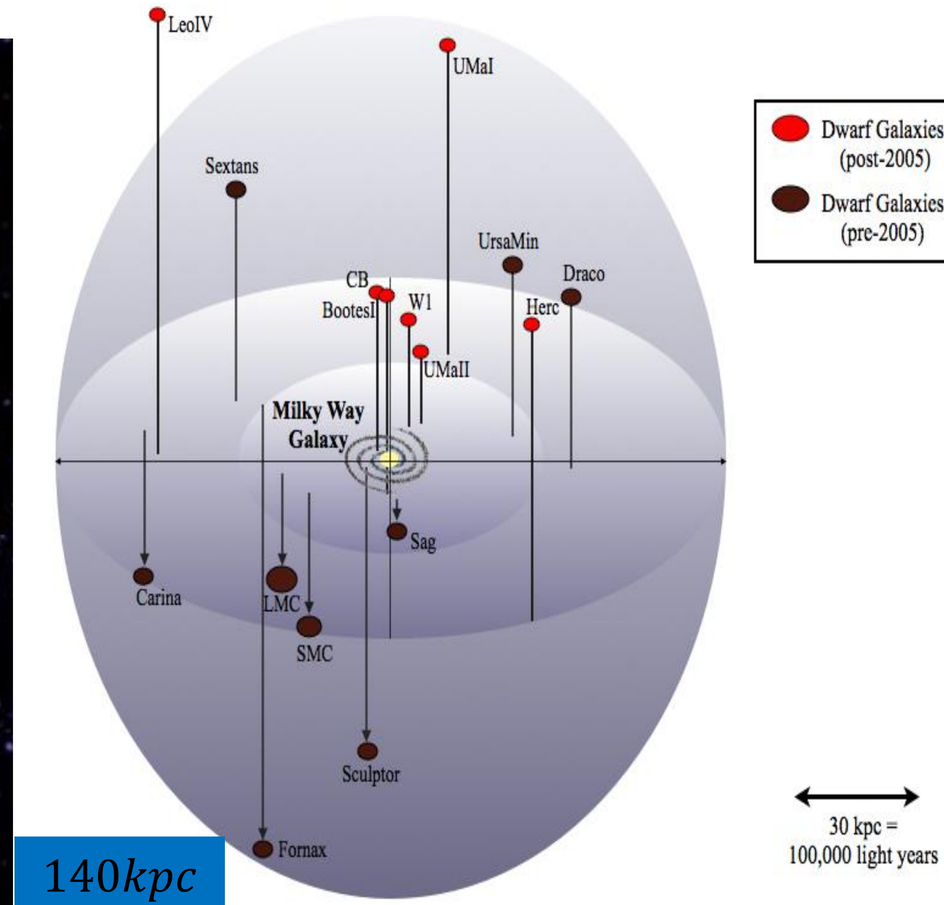
Evolution of the halo mass function
$\phi\,[dex^{-1}\,Mpc^{-3}\,h^{4}]$
halo mass $[M_\odot/h]$
z= 0
z= 1
z= 2
z= 4
z= 8
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{8}
10^{9}
10^{10}
10^{11}
10^{12}
10^{13}
10^{14}
10^{15}
10^{16}

گروه محلی


1 pc ~ 3.2 lyr
800 Kpc
Sextans B
Sextans A
Leo A
NGC 3190
Antila Dwarf
Leo I
Leo II
Canes Dwarf
Ursa Major I
Sextans Dwarf
Ursa Major II
Ursa Minor Dwarf
Draco Dwarf
Boötes Dwarf
Milky Way Galaxy
Large Magellanic Cloud
Small Magellanic Cloud
Sagittarius Dwarf
Carina Dwarf
Sculptor Dwarf
Fornax Dwarf
IC 10
NGC 185
NGC 147
M110
Andromeda Galaxy (M31)
Andromeda I
M32
NGC 6822
Triangulum Galaxy (M33)
Andromeda II
Andromeda III
Phoenix Dwarf
Pisces Dwarf
IC 1613
Aquarius Dwarf
SagDIG
Pegasus Dwarf
Cetus Dwarf
Tucana Dwarf
WLM

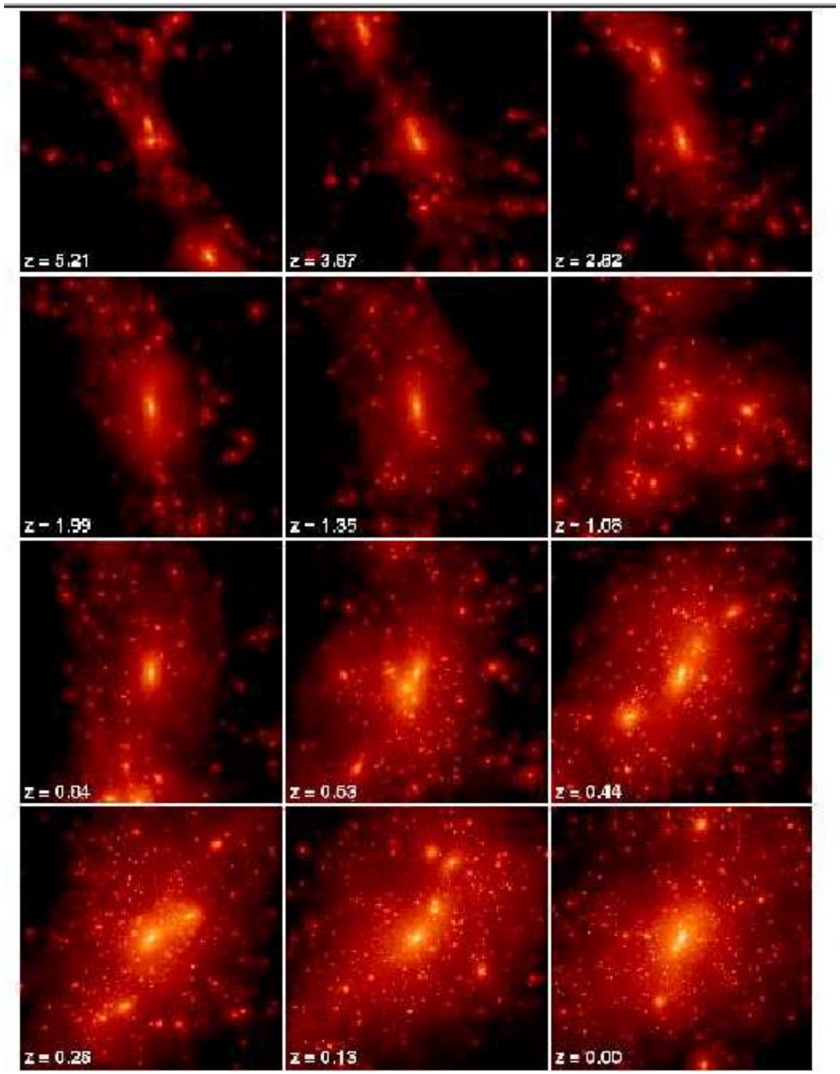
ماده تاریک و چالش های آن در مقیاس کهکشانی- مقیاس ناوردایی طیف

Strigari et al. , Nature 454:1096-1097, 2008



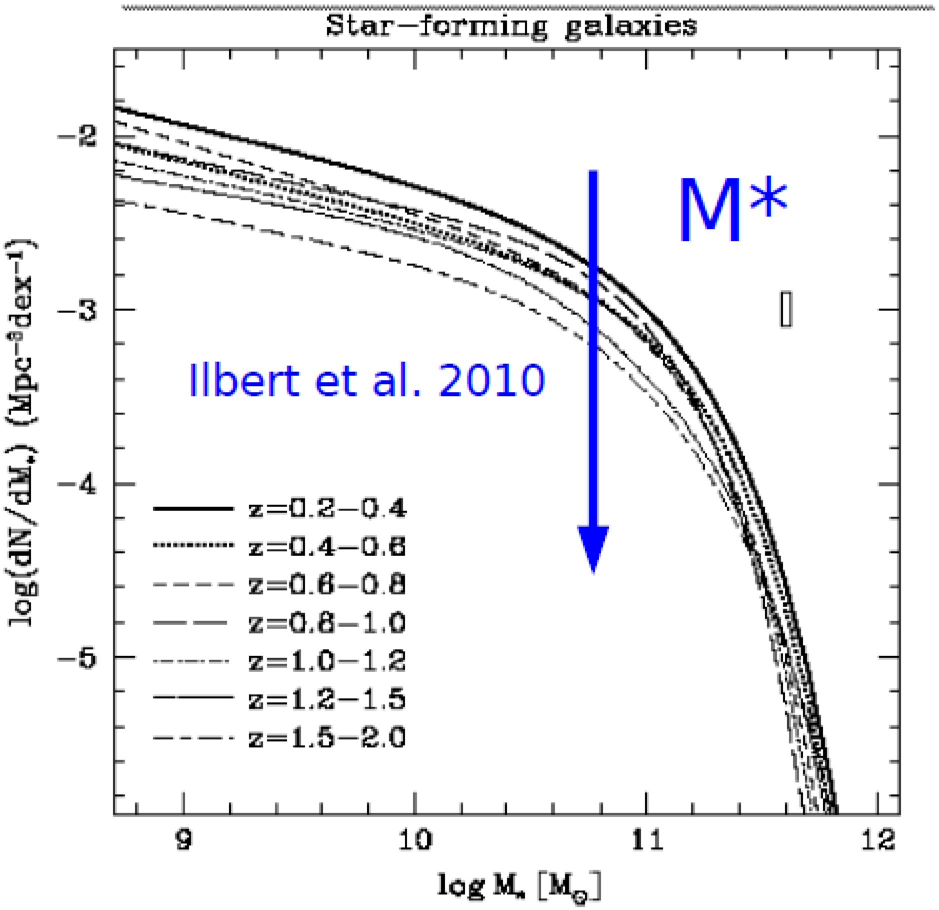
.(A. Boyarsky, O. Ruchayskiy, and M. Shaposhnikov, Annual Review of Nuclear and Particle Science 59, 2009

CDM - Hierarchical scenario



Helmi, White & Springel (2002, astro-ph/0201289) **rescaled** of a factor **10** the Springel's simulation in order to study the evolution of CMD galactic halo and investigate the kinematics of CMD streams in the solar neighborhood.
* Note: baryonic - CDM interactions (e.g. central bar) have been neglected.

2) In spite of making stars at very high rate, the mass function of SF galaxies is almost unevolving

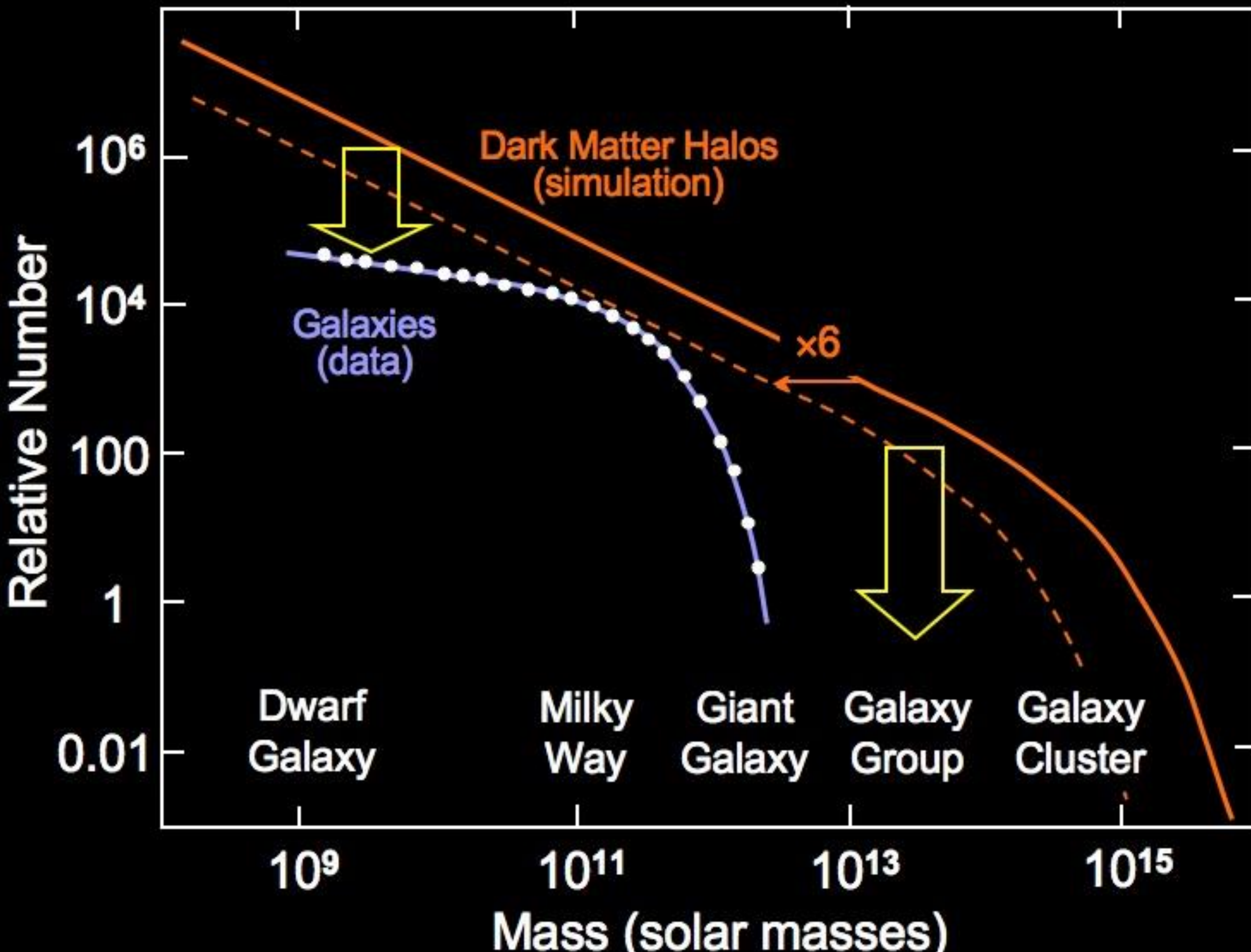


Faint end slope α
and
characteristic mass
M^*
appear to remain constant since at least
Z~2

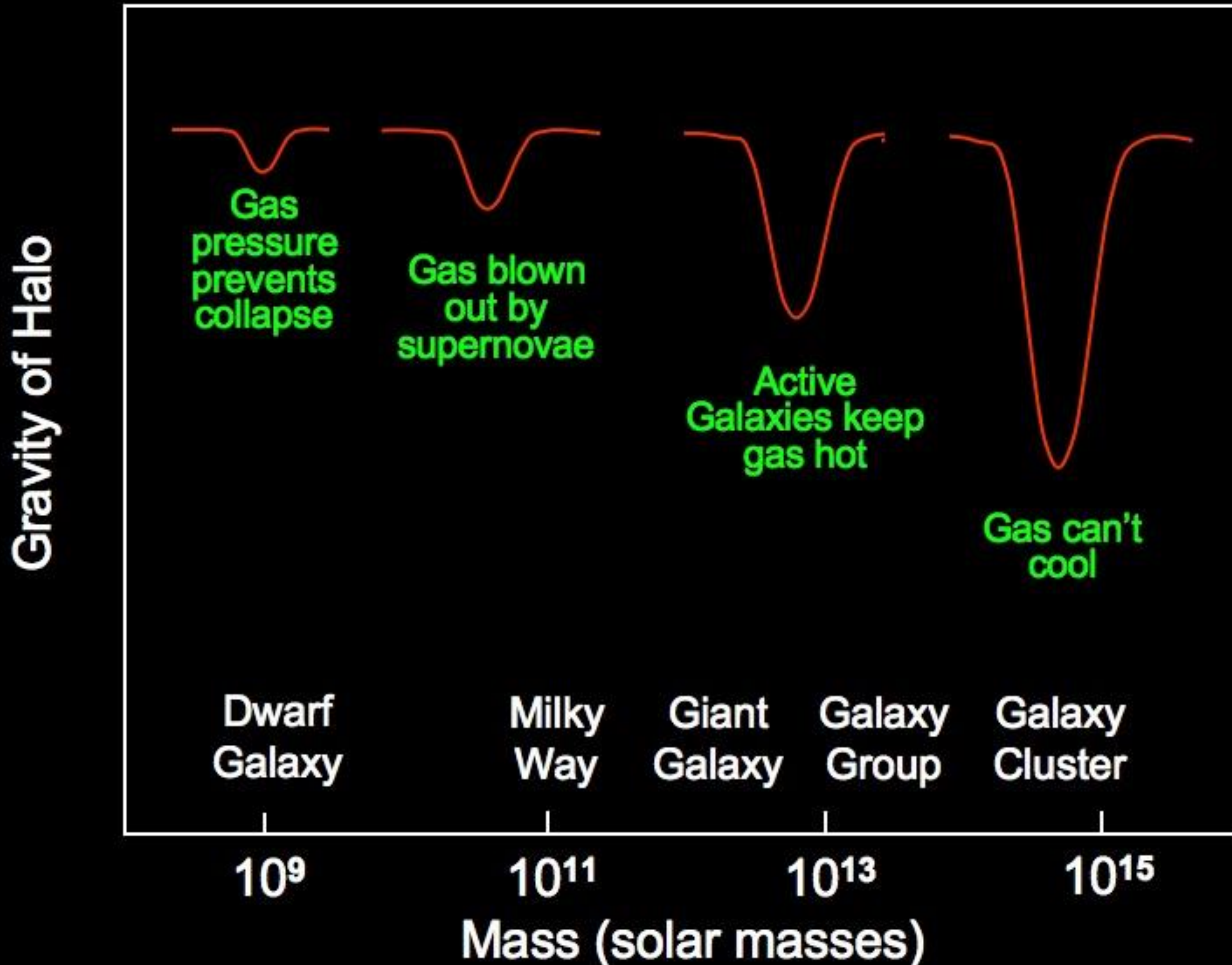
The "Schechter" MF

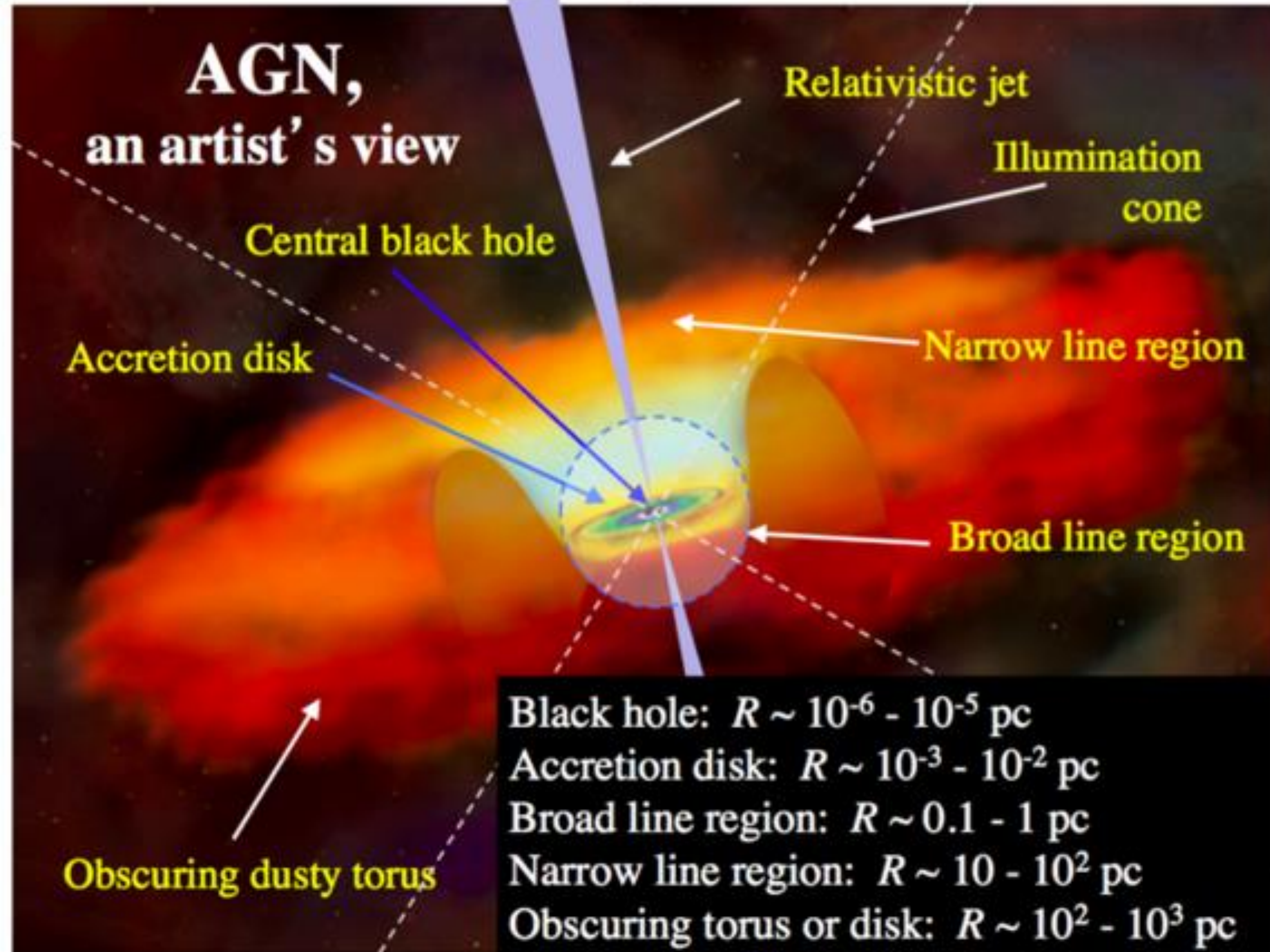
$$\phi(M_\star)dM_\star = \phi^* \left(\frac{M_\star}{M_\star^*}\right)^\alpha \mathrm{e}^{-M_\star/M_\star^*} dM_\star,$$

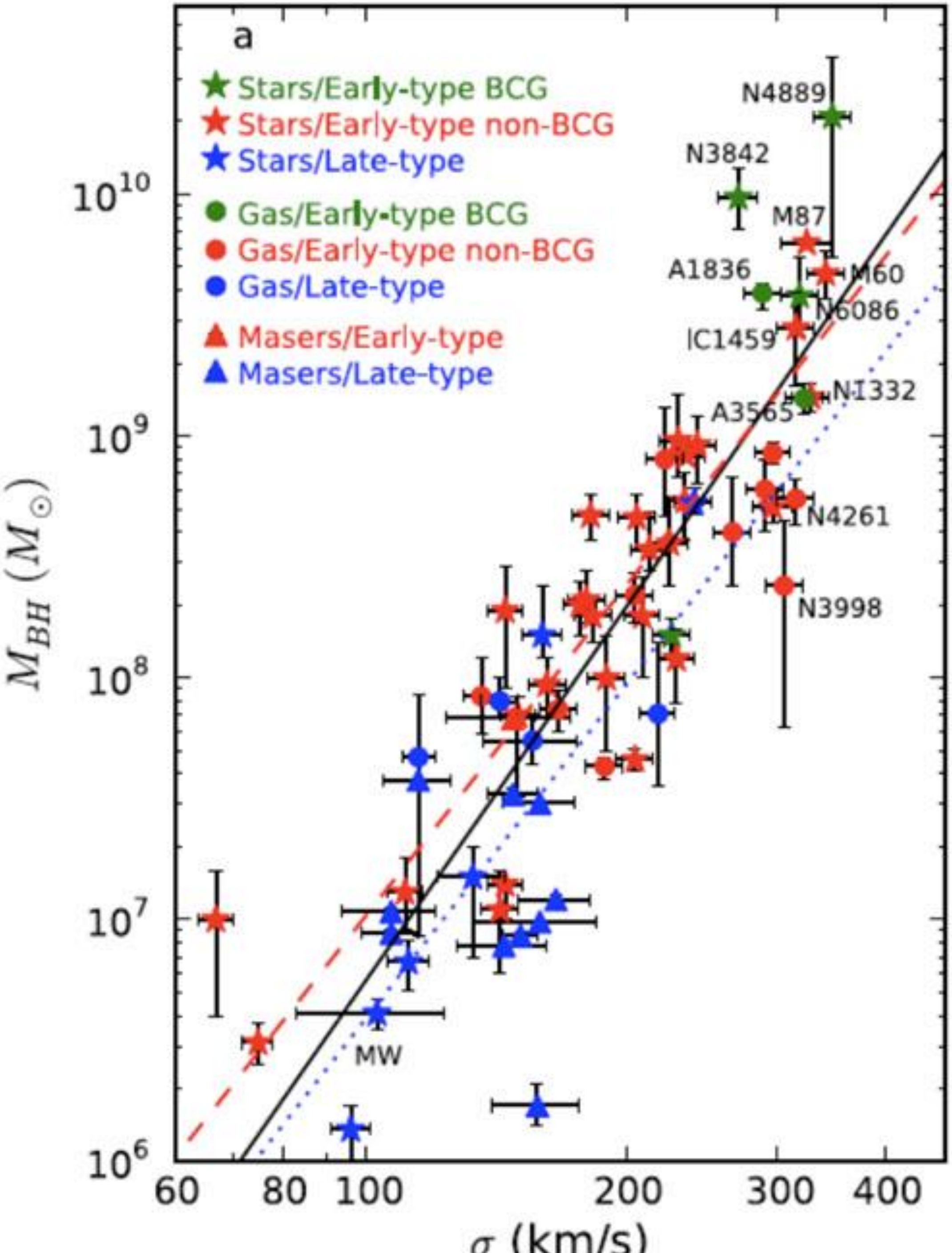
Halo and Galaxy Mass Distributions



Halo Gravity and Suppression of Galaxy Formation

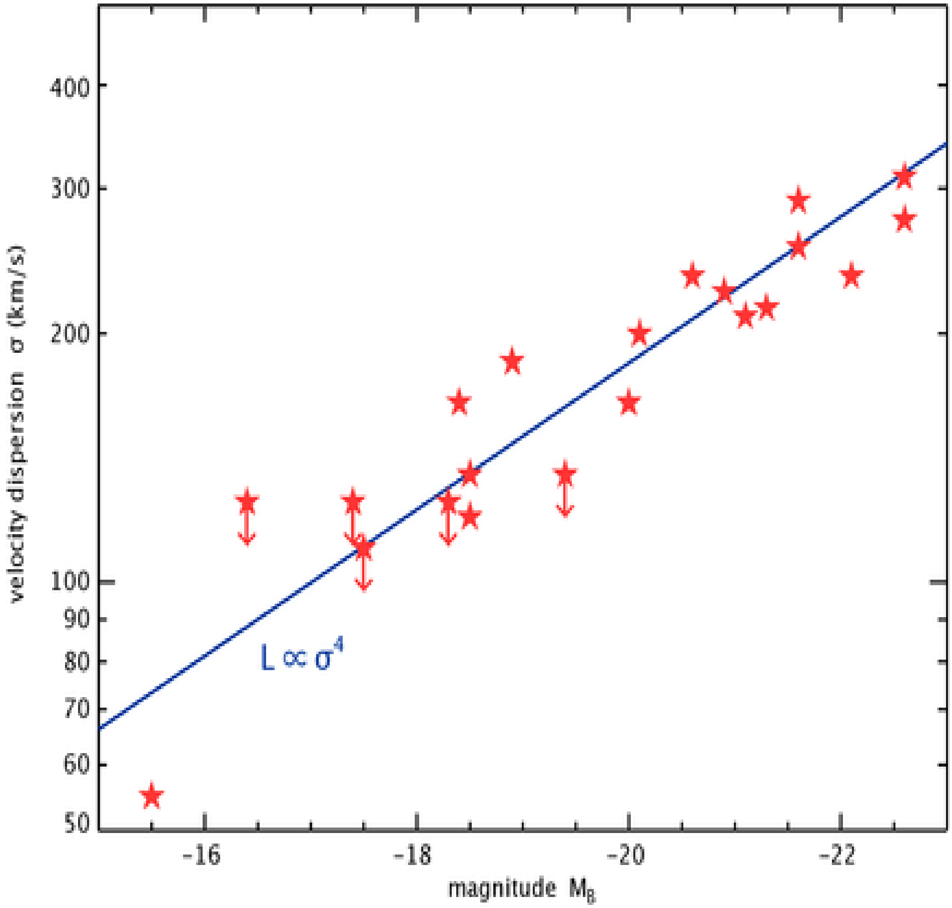


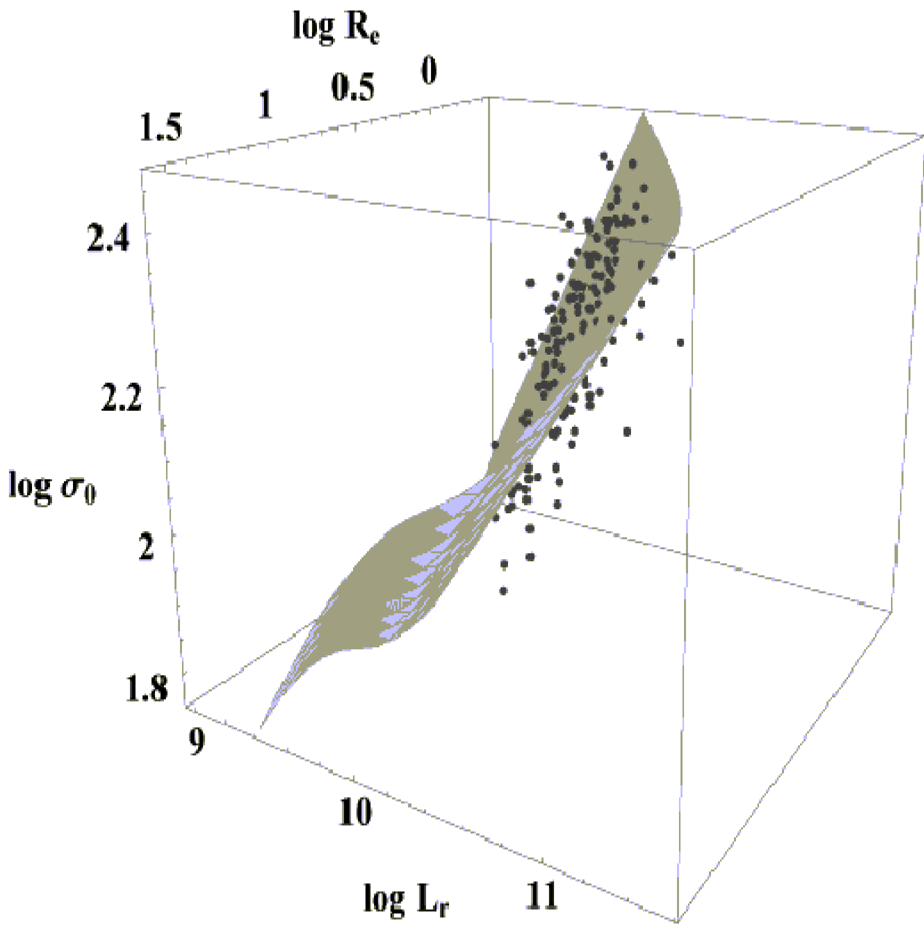

AGN,
an artist's view
Relativistic jet
Illumination cone
Central black hole
Accretion disk
Narrow line region
Broad line region
Obscuring dusty torus
Black hole: R ~ 10^-6 - 10^-5 pc
Accretion disk: R ~ 10^-3 - 10^-2 pc
Broad line region: R ~ 0.1 - 1 pc
Narrow line region: R ~ 10 - 10^2 pc
Obscuring torus or disk: R ~ 10^2 - 10^3 pc

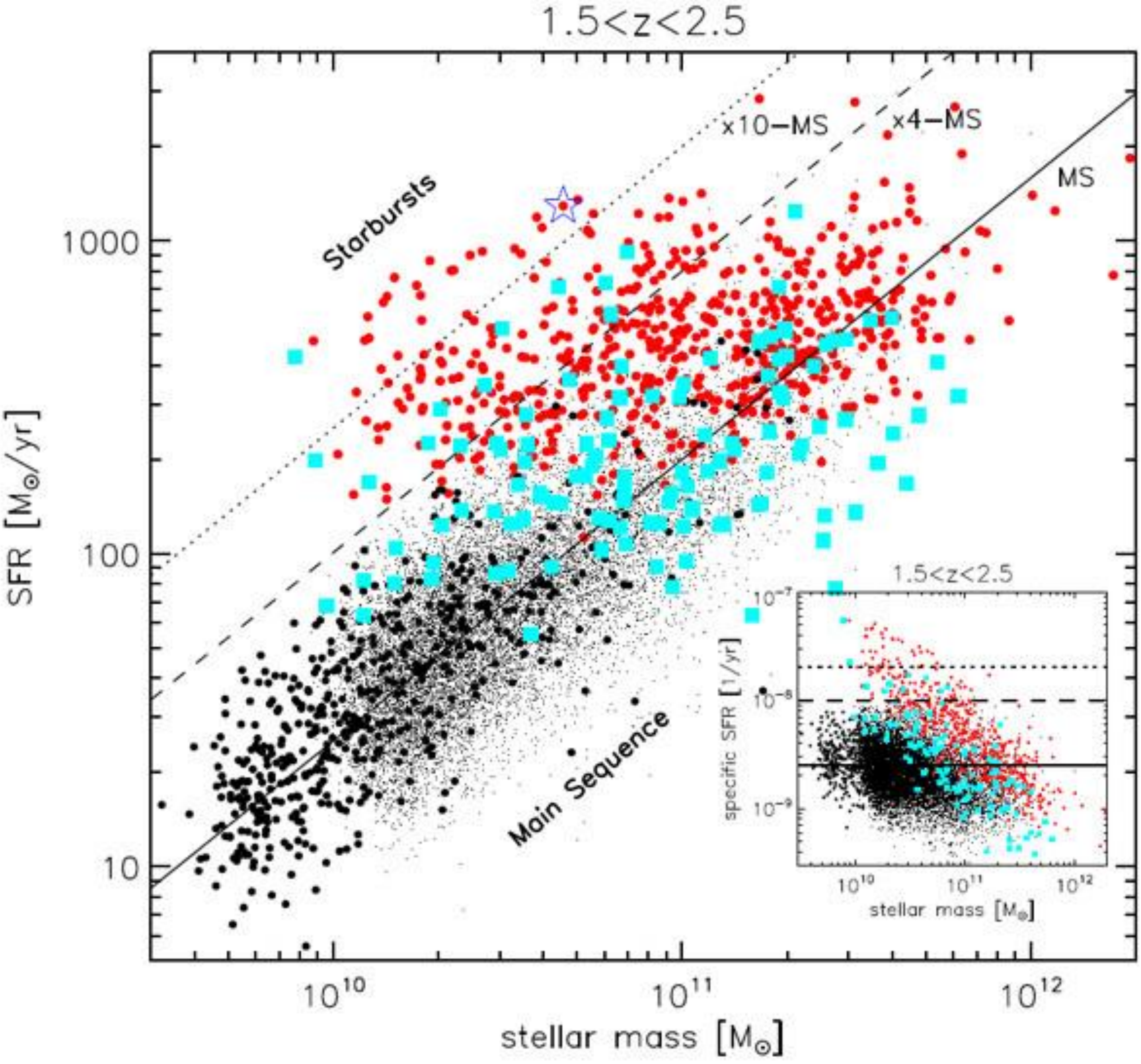


McConnell N. J., Ma C.-P., Gebhardt K., Wright S. A., Murphy J. D., Lauer T. R., Graham J. R. Richstone D. O., [Nature 480 (2011) 215](#).

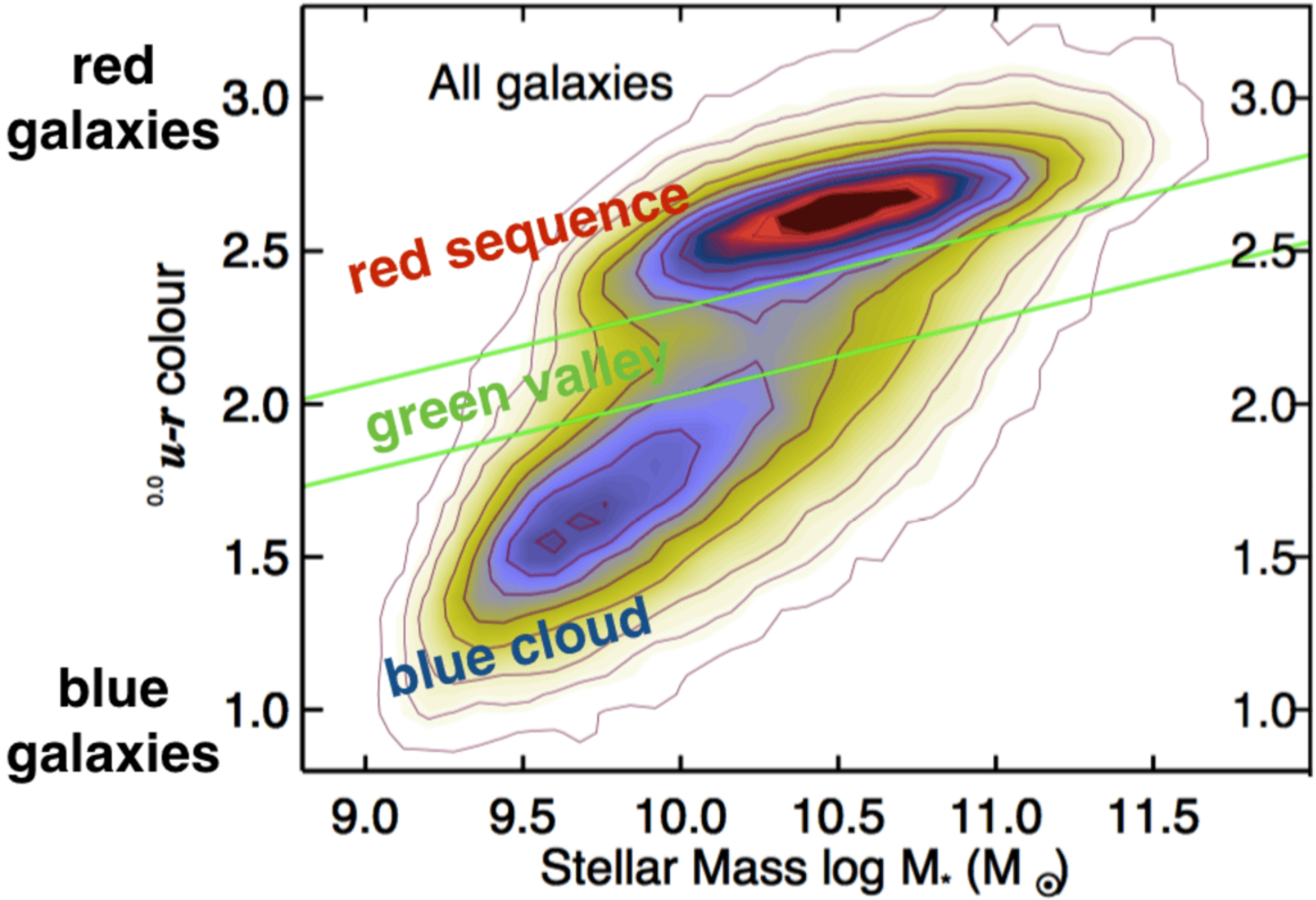
Faber-Jackson and Fundamental plane relation

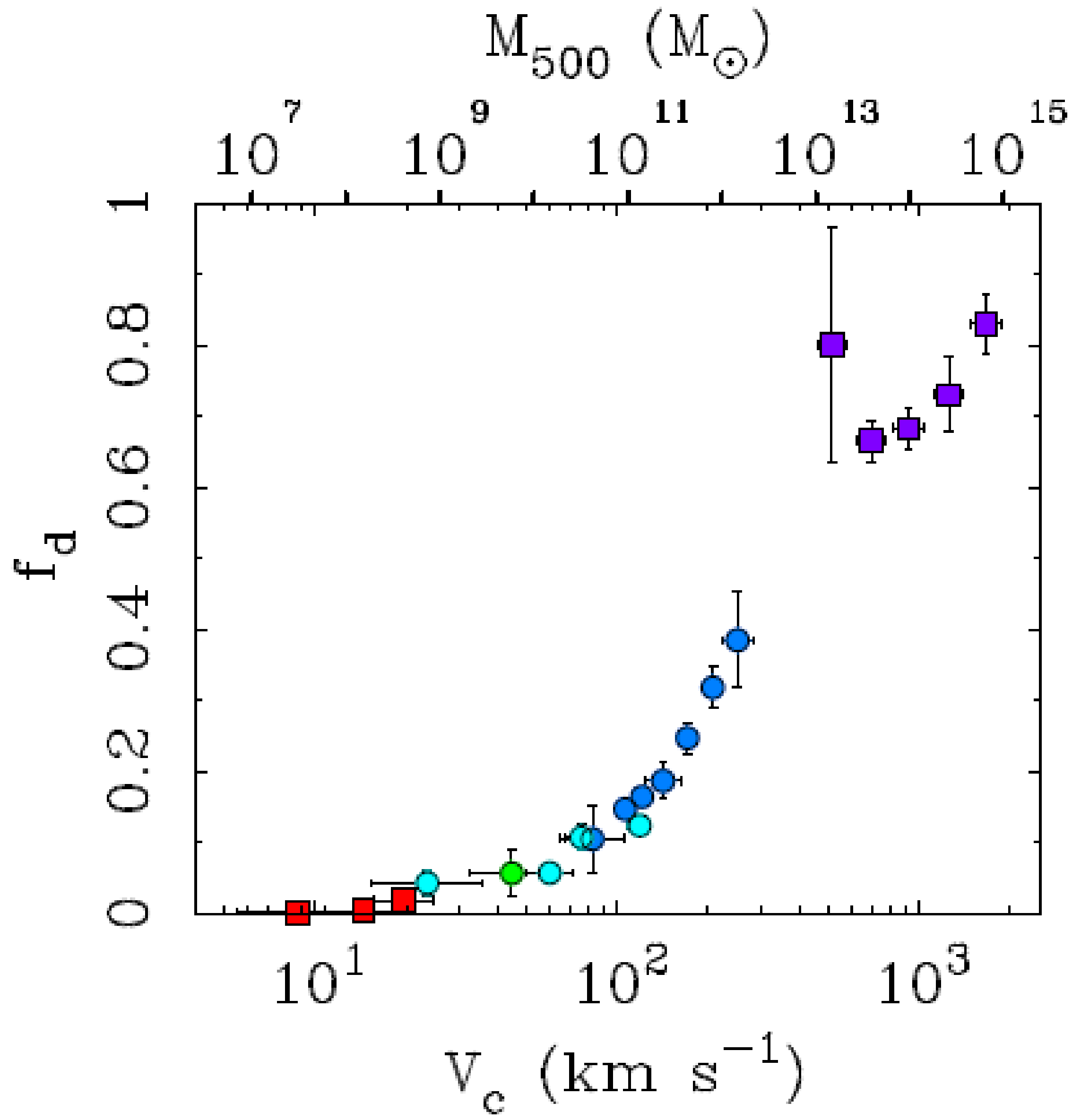






1.5<z<2.5
x10−MS
x4−MS
MS
Starbursts
Main Sequence
1000
100
10
SFR [M⊙/yr]
10^10
10^11
10^12
stellar mass [M⊙]
1.5<z<2.5
specific SFR [1/yr]
10^-7
10^-8
10^-9
stellar mass [M⊙]


red galaxies
blue galaxies
All galaxies
red sequence
green valley
blue cloud
3.0
2.5
2.0
1.5
1.0
$^{0.0}u$-r colour
9.0
9.5
10.0
10.5
11.0
11.5
Stellar Mass log M$_*$ (M$_\odot$)



M_{500} ($M_\odot$)
10^7
10^9
10^{11}
10^{13}
10^{15}
f_d
0
0.2
0.4
0.6
0.8
1
10^1
10^2
10^3
V_c (km s^{-1})