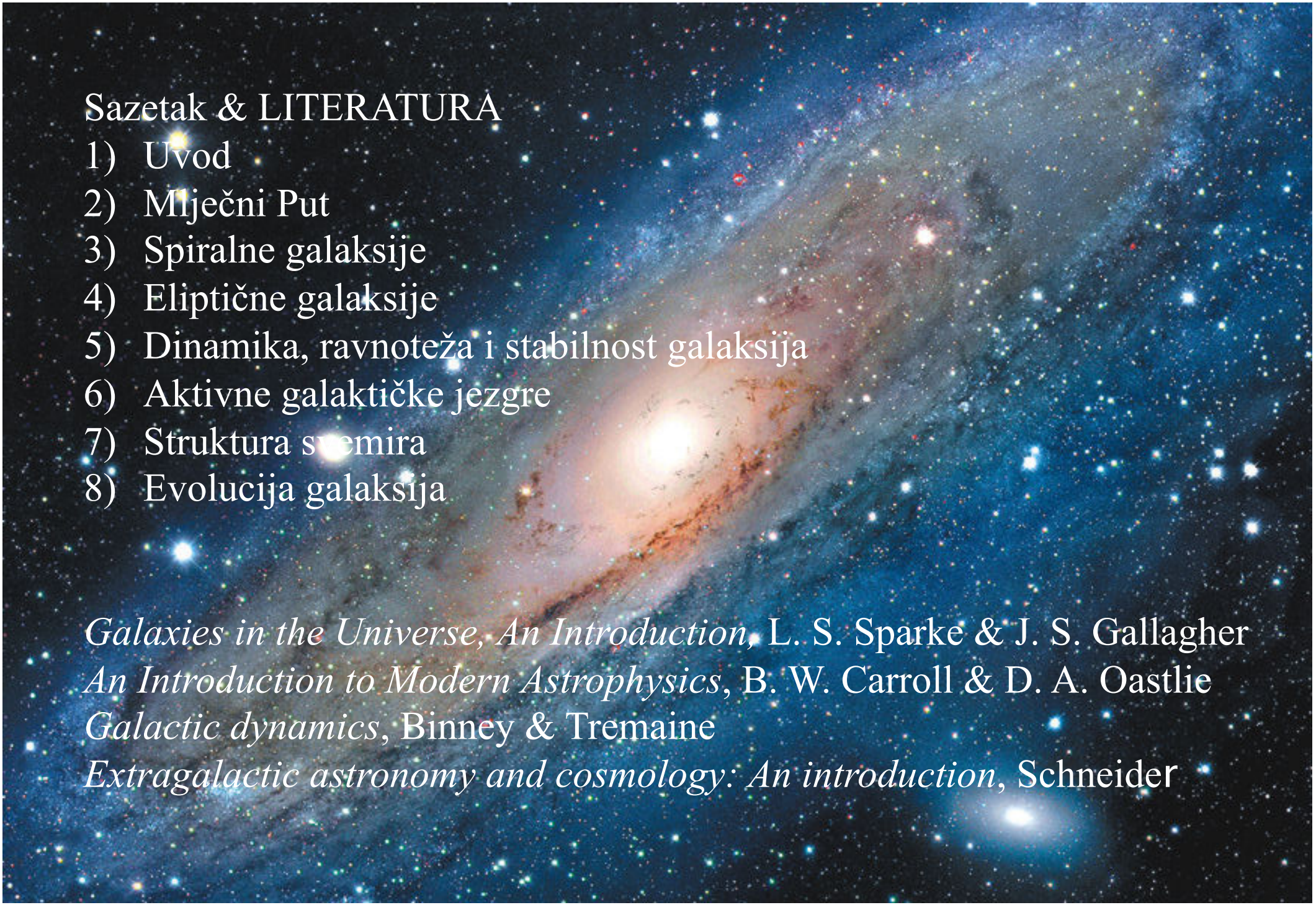
Galaksije



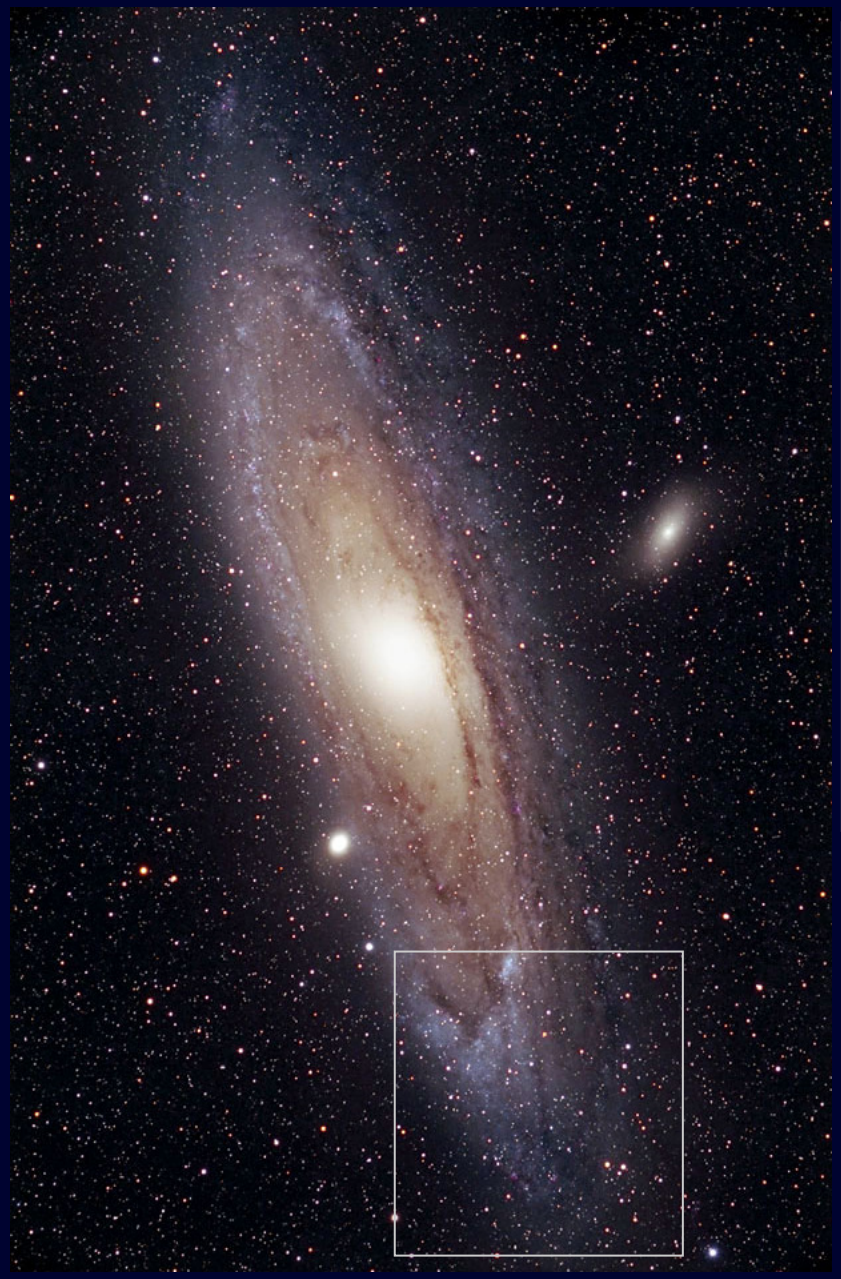
Sazetak & LITERATURA

1) Uvod
2) Mliječni Put
3) Spiralne galaksije
4) Eliptične galaksije
5) Dinamika, ravnoteža i stabilnost galaksija
6) Aktivne galaktičke jezgre
7) Struktura svemira
8) Evolucija galaksija

Galaxies in the Universe, An Introduction, L. S. Sparke & J. S. Gallagher
An Introduction to Modern Astrophysics, B. W. Carroll & D. A. Oastlie
Galactic dynamics, Binney & Tremaine
Extragalactic astronomy and cosmology: An introduction, Schneider

Vazno

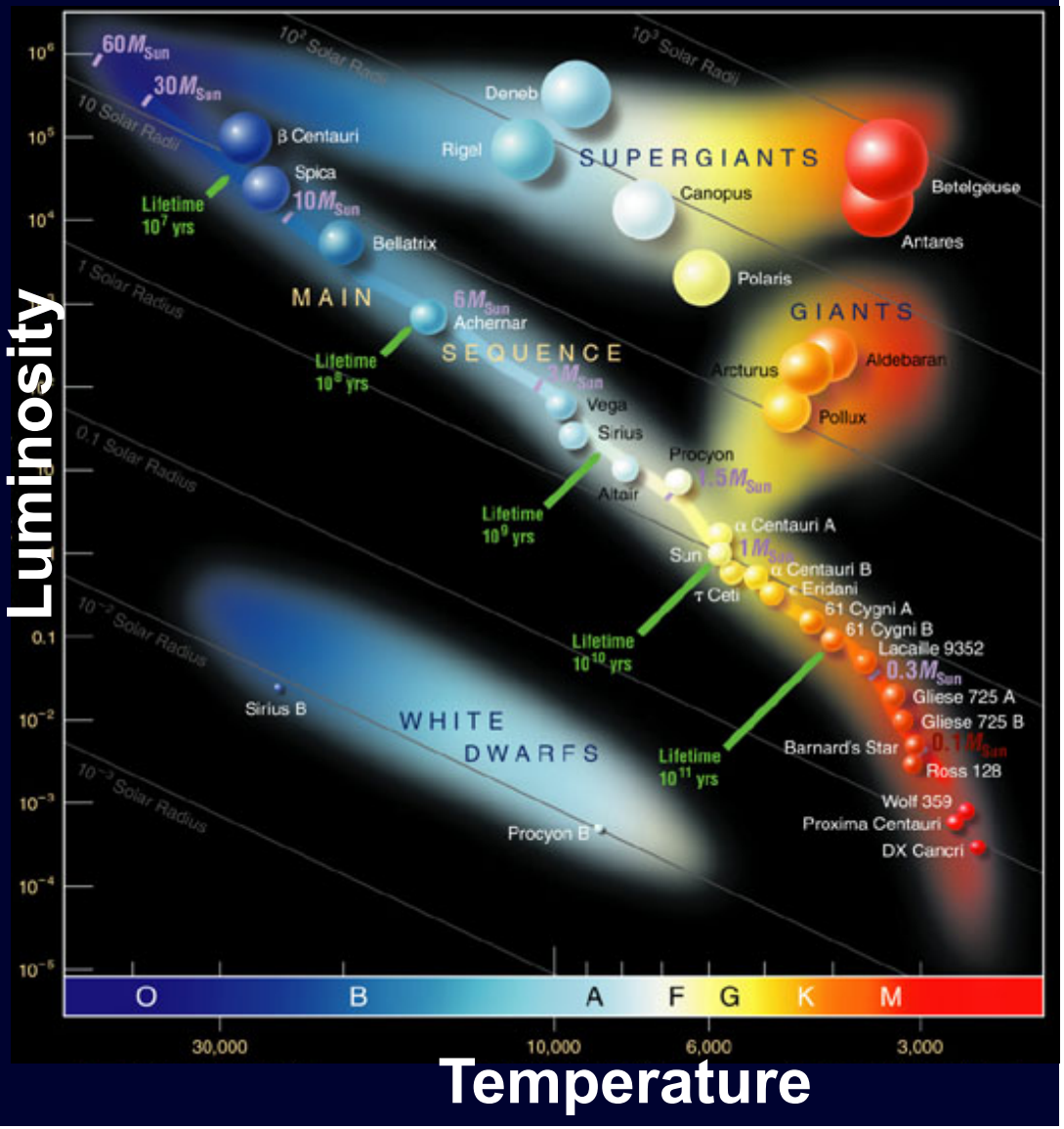
- http://www.phy.pmf.unizg.hr/~vs/Galaksije/
- Uvjeti za polaganje kolegija
  - predati 50 rjesenih zadataka vezanih uz temu klegija
  - pismeni seminar vezan uz maleno istrazivanje
  - usmeni seminar (u trajanju od otprilike pola sata) vezan uz zadanu literatura
  - Polozen zavrsni (pismeni) ispit

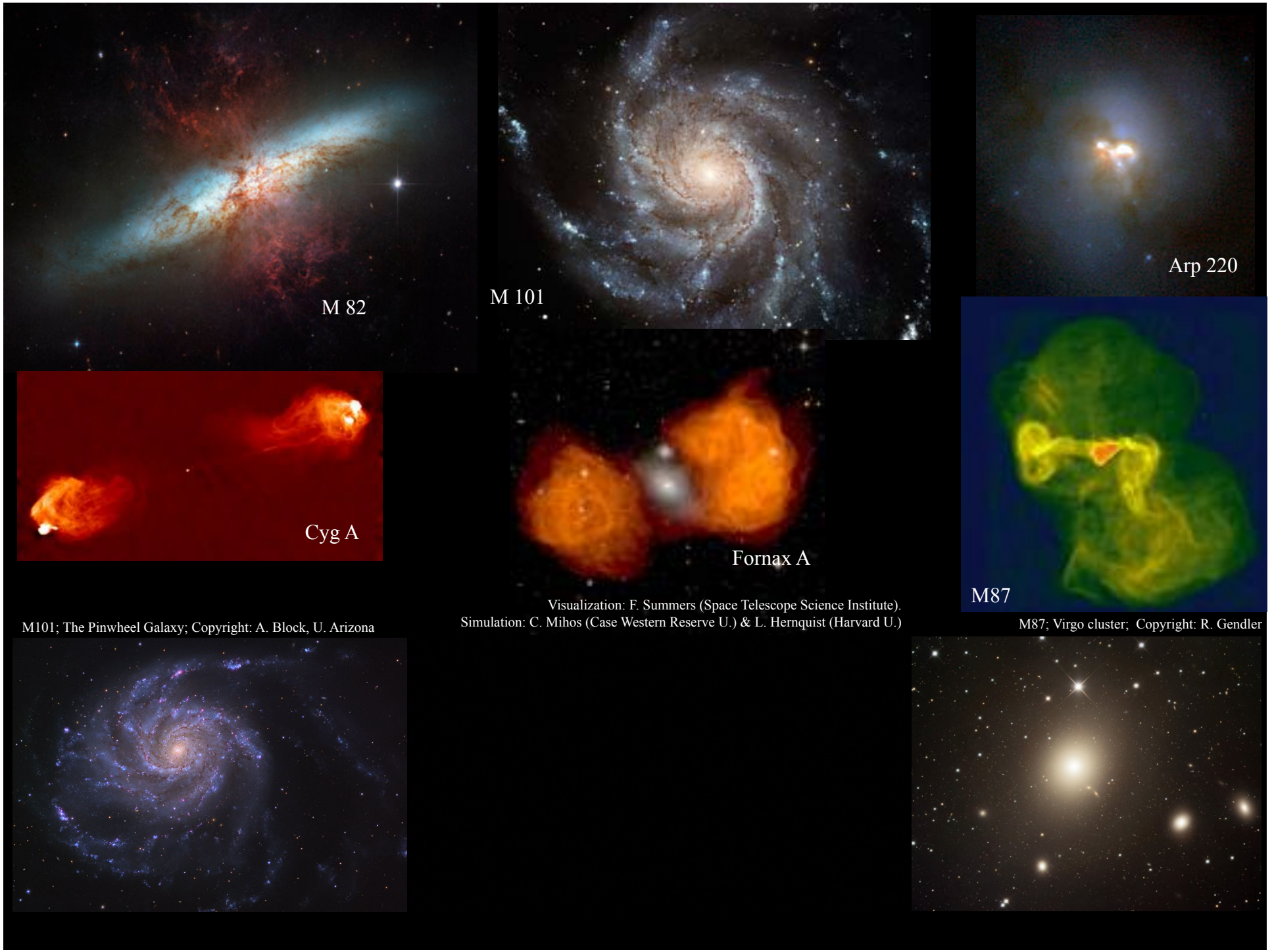


Galaksije su gravitacijski vezani sustavi koji se sastoje od:

- ✓ Zvijezda
- ✓ Medjuzvjedanog plina i prasine
- ✓ Tamne tvari

- Spektar galaksije je kompozit spektara zvijezda razlicitih temperatura
- Prasina u medjuzvjezdanom prostoru utjece na svjetlost zvijezda (apsorpcija + rasprsenje)
- Skoro sva svjetlost galaksija dolazi od zvijezda





M101; The Pinwheel Galaxy; Copyright: A. Block, U. Arizona

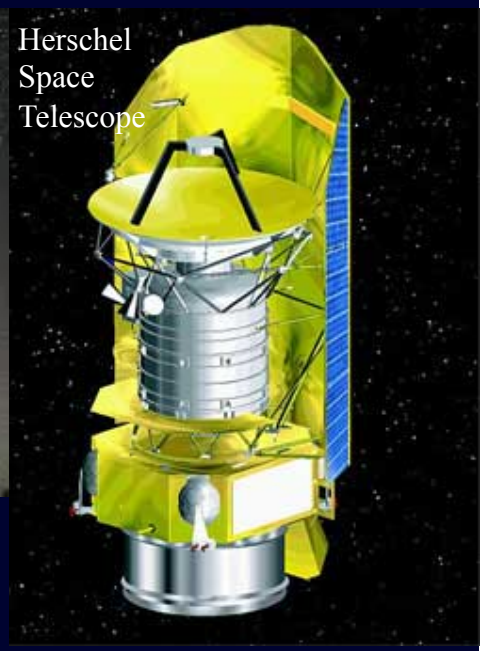
Visualization: F. Summers (Space Telescope Science Institute).
Simulation: C. Mihos (Case Western Reserve U.) & L. Hernquist (Harvard U.)

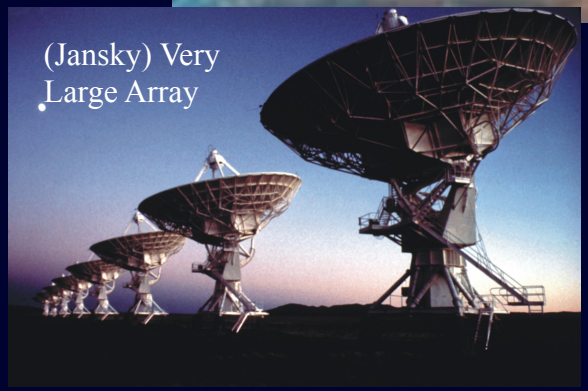
M87; Virgo cluster; Copyright: R. Gendler

Kako opazamo galaksije?


Hubble Space Telescope


Very Large Telescope

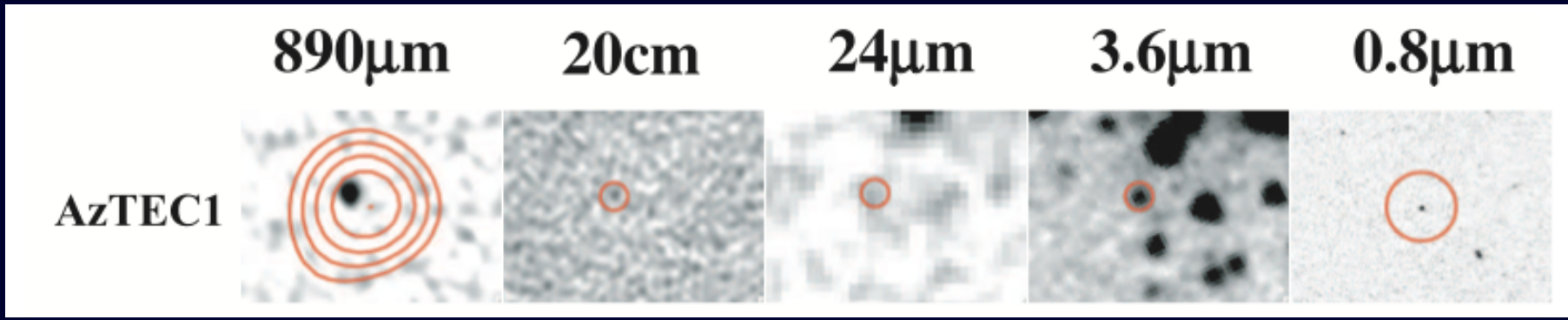

Herschel Space Telescope


(Jansky) Very Large Array


Atacama Large Millimeter/ Submillimeter Array

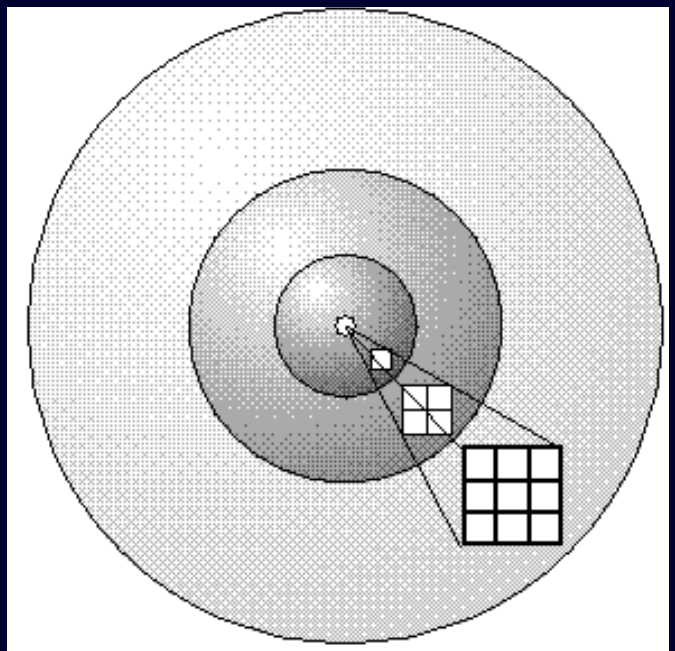
Opazanja galaksija

- Detaljna, duboka opazanja pojedinih galaksija
- (Duboka) opazanja velike povrsine na nebu: milijuni galaksija (SDSS, COSMOS)


890μm
20cm
24μm
3.6μm
0.8μm
AzTEC1

Mjere

- *Luminozitet* (zvijezde/ galaksije): kolicina energije emitirana po sekundi: W, erg/s
- Prividni sjaj ili *fluks*: ukupna energija primljena po sekundi po (c)m^2 primatelja (teleskop/oko): W/m^2, $erg/s/cm^2$



$$F = \frac{L}{4\pi d^2}$$

- Fluks se obicno mjeri u nekom valnom (frekvencijskom) rasponu => fluks po jedinici valne duljine, $F_\lambda(\lambda)\, d\lambda$, je energija svjetlosti primljene u rasponu od λ do $\lambda+d\lambda$: W/m^2/Å, erg/s/cm^2/Å (1Å=10^{-10}m)
- Energija primljena u rasponu frekvencije od v do $v+dv$ je $F_v(v)\, dv$ & $F_\lambda=(v^2/c)F_v$
- F_v se cesto mjeri u jedinicama “Jansky”: 1Jy=10^{-26} W/m^2/Hz

- Prividna magnituda: m_1-m_2=$-2.5log(F_1/F_2)$
  - Normalizacija (i.e. nul-tocka): zvijezda Vega (A0), AB magnituda $m = -2.5\ log(\ F\ /\ 3631Jy\ )$
  - Ovisi o odzivu filtera (T_{BP}) u odredjenom valnom pojasu (BP=bandpass):

$$F_{BP} = \int_0^\infty T_{BP}(\lambda) F_\lambda(\lambda) d\lambda \approx F_\lambda\left(\lambda_{eff}\right)\Delta\lambda$$

- Apsolutna magnituda, ekvivalentna luminozitetu, je prividna magnituda koju bi zvijezda/galaksija imala na udaljenosti 10pc: $M = m - 5log(d/10pc) = m - DM$ ("distance modulus")
- Boja je razlika dviju magnituda, npr. U-B, u-r

Ucestali valni pojasevi

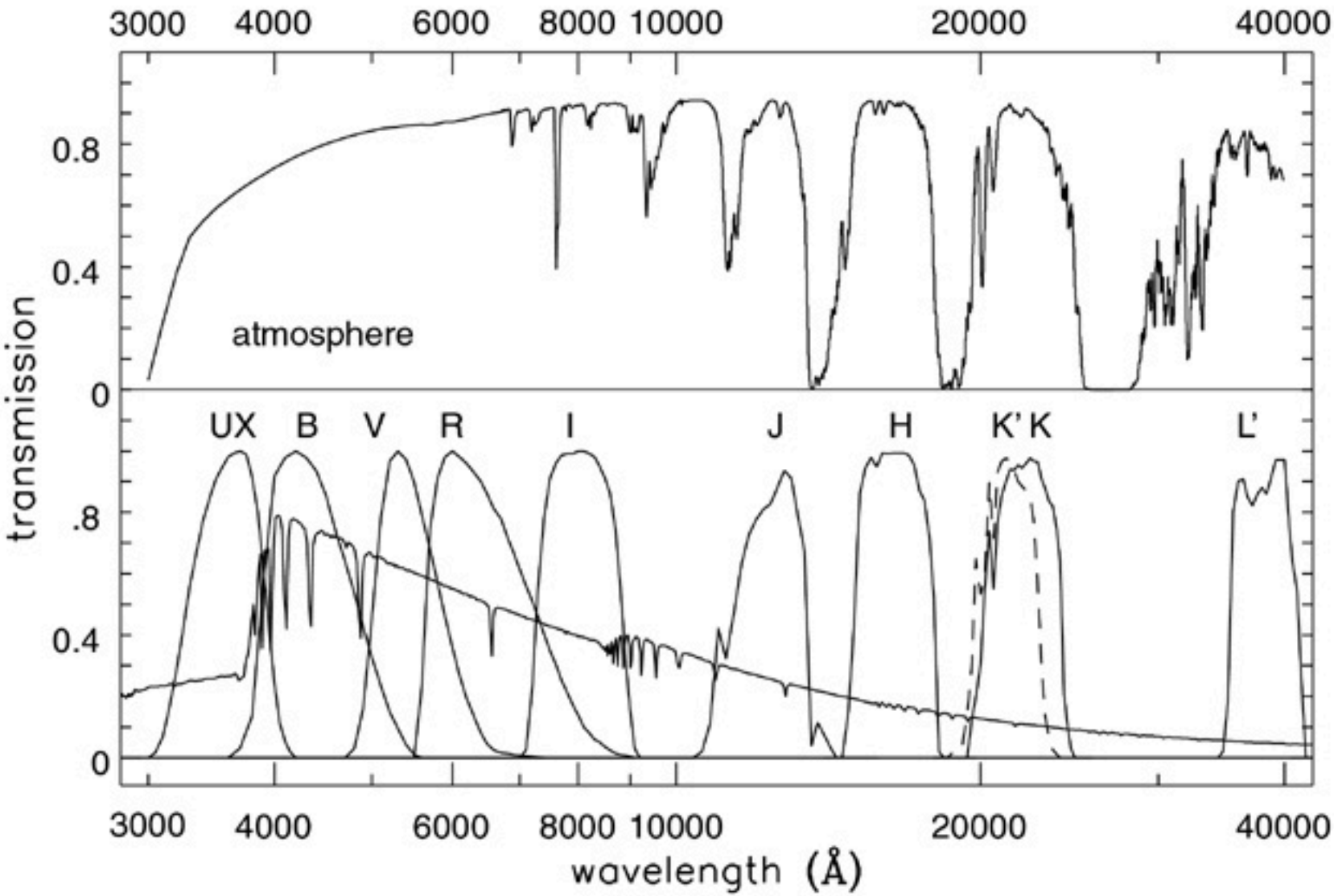
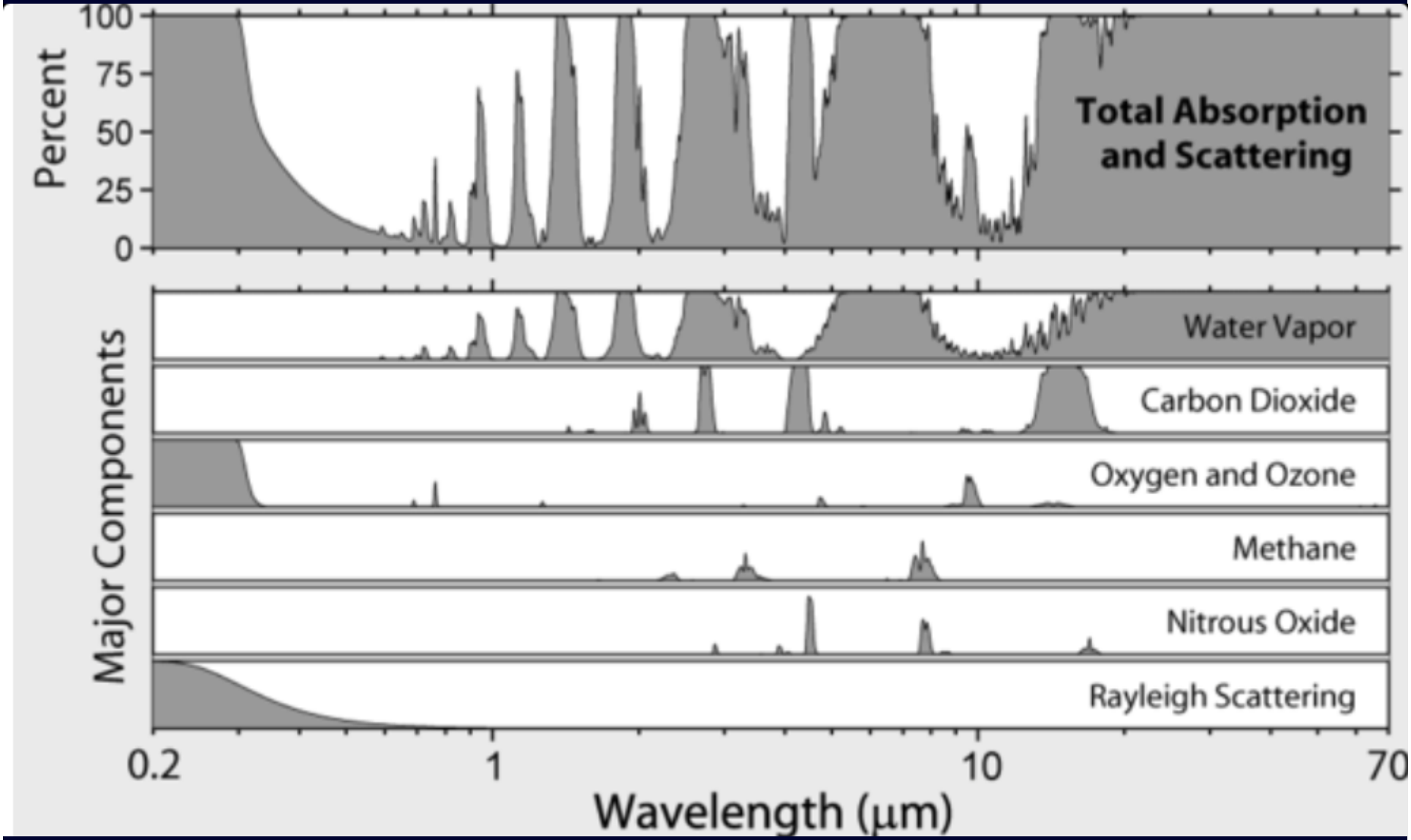
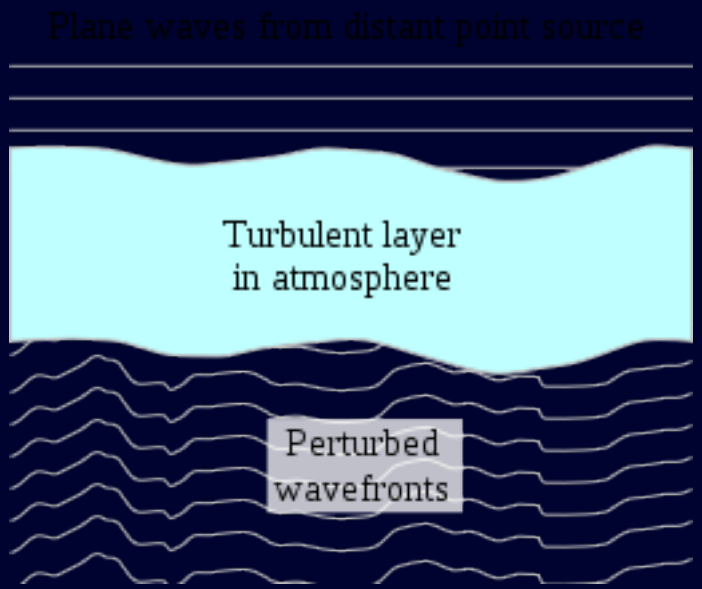


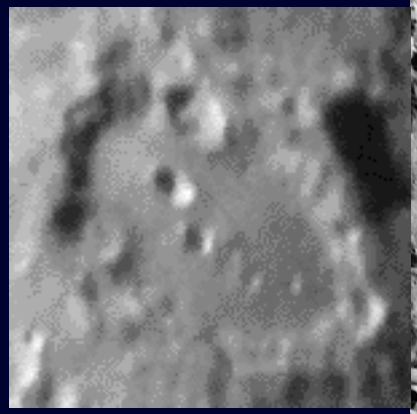
Fig 1.7 (M. Bessell) 'Galaxies in the Universe' Sparke/Gallagher CUP 2007

Zracenje atmosfere

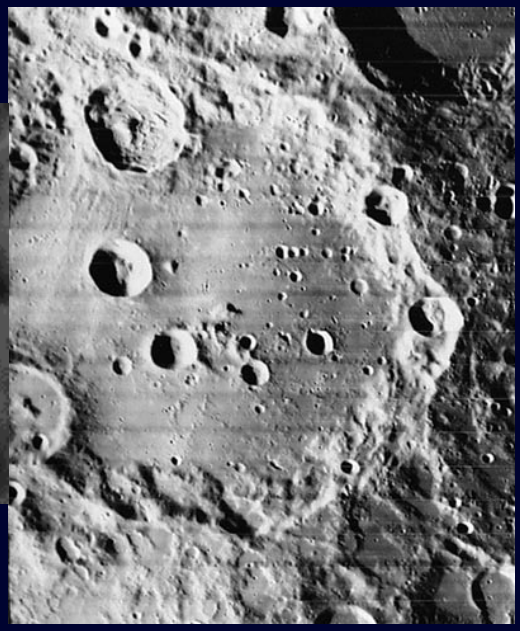


Atmosfera: “Seeing”





Mjesec kroz teleskop na Zemlji: efekt seeinga

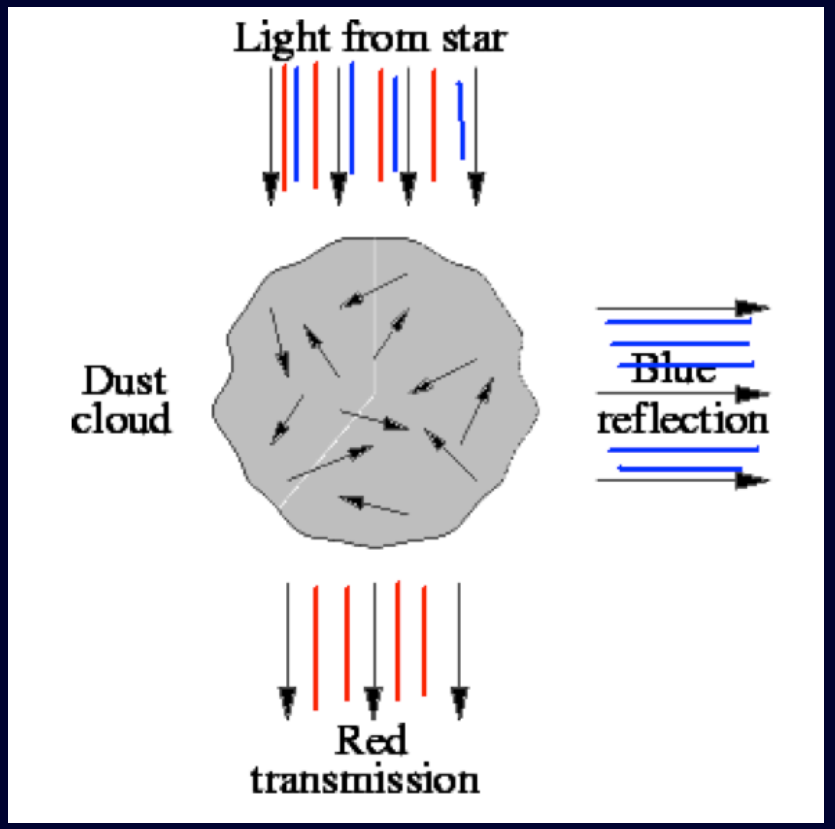


Satelitska slika Mjeseca

Problem prasine

- ~1% mase ISMa se sastoji od prasine
  - silikati i oblici ugljika, $r < 1\mu m$
  - Apsorpcija i rasprsenje zracenja $\lambda<r$
- Nepropusnost (*opacity,* κ): rata apsopcije svjetlosti

Ekstinkcija = apsorpcija + rasprsenje



Problem prasine

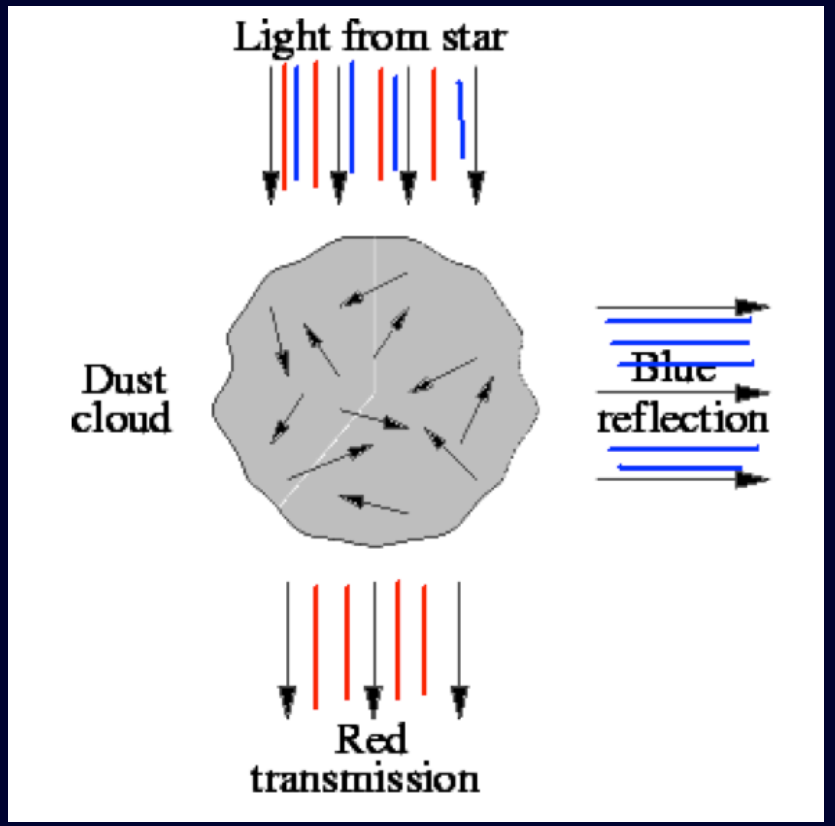
- Ekstinkcija zatamnjuje sjaj:
  $m_\lambda = M_\lambda + 5\log(d/10pc) + A_\lambda$
- A_λ povezana s optickom dubinom *(optical depth)*

$$F_\lambda = F_{\lambda,0} e^{-\tau_\lambda} \rightarrow$$

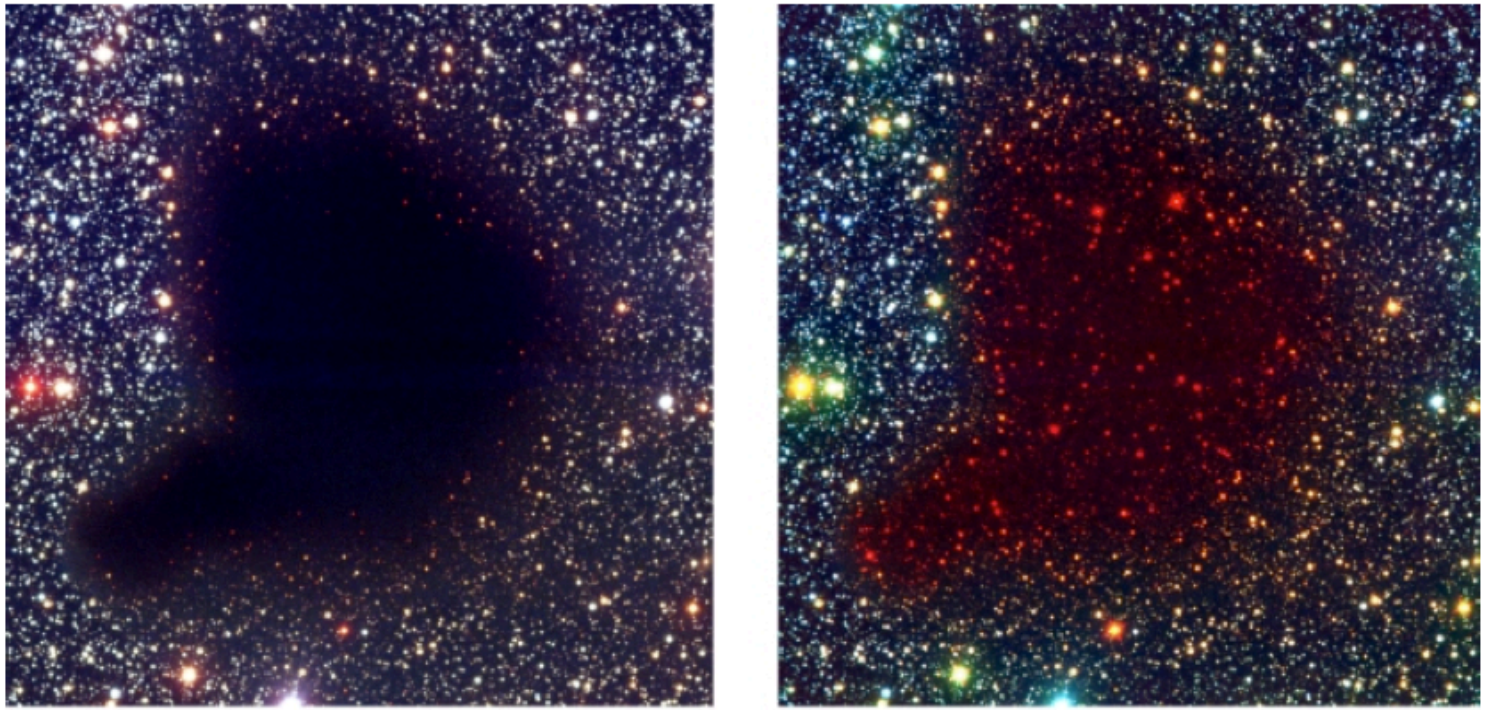
$$A_\lambda = m_\lambda - m_{\lambda,0} = 1.086\tau_\lambda$$

- Promjena u magnitudi zbog ekstinkcije je ~jednaka optickoj dubini uzduz smjera promatranja

Ekstinkcija = apsorpcija + rasprsenje



Primjer apsorpcije



B, V, I

B, I, K

Pre-Collapse Black Cloud B68 (comparison)
(VLT ANTU + FORS 1 - NTT + SOFI)

ESO PR Photo 02c/01 (10 January 2001)

Primjer rasprsenja

Galaksije u svemiru koji se siri: Hubblov zakon

- Svemir se siri, sto je galaksija udaljenija, brzina uzmicanja (*recession speed*) je veca

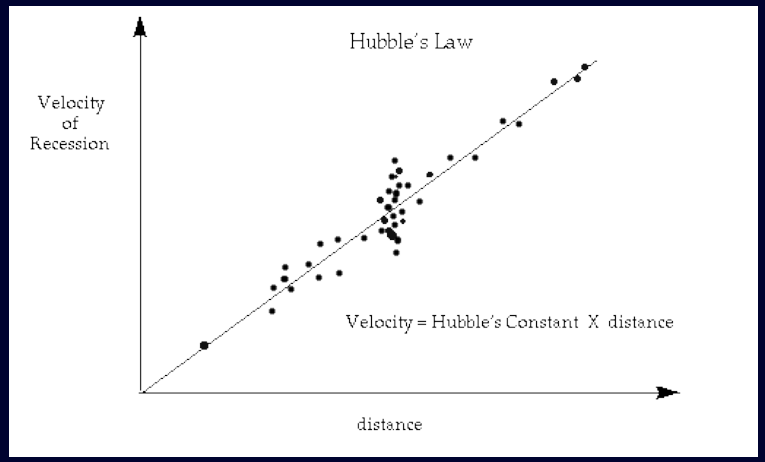
  $v_r \approx H_0\, d$

  H_0 = *Hubblova cte. = 60-75km/s/Mpc*

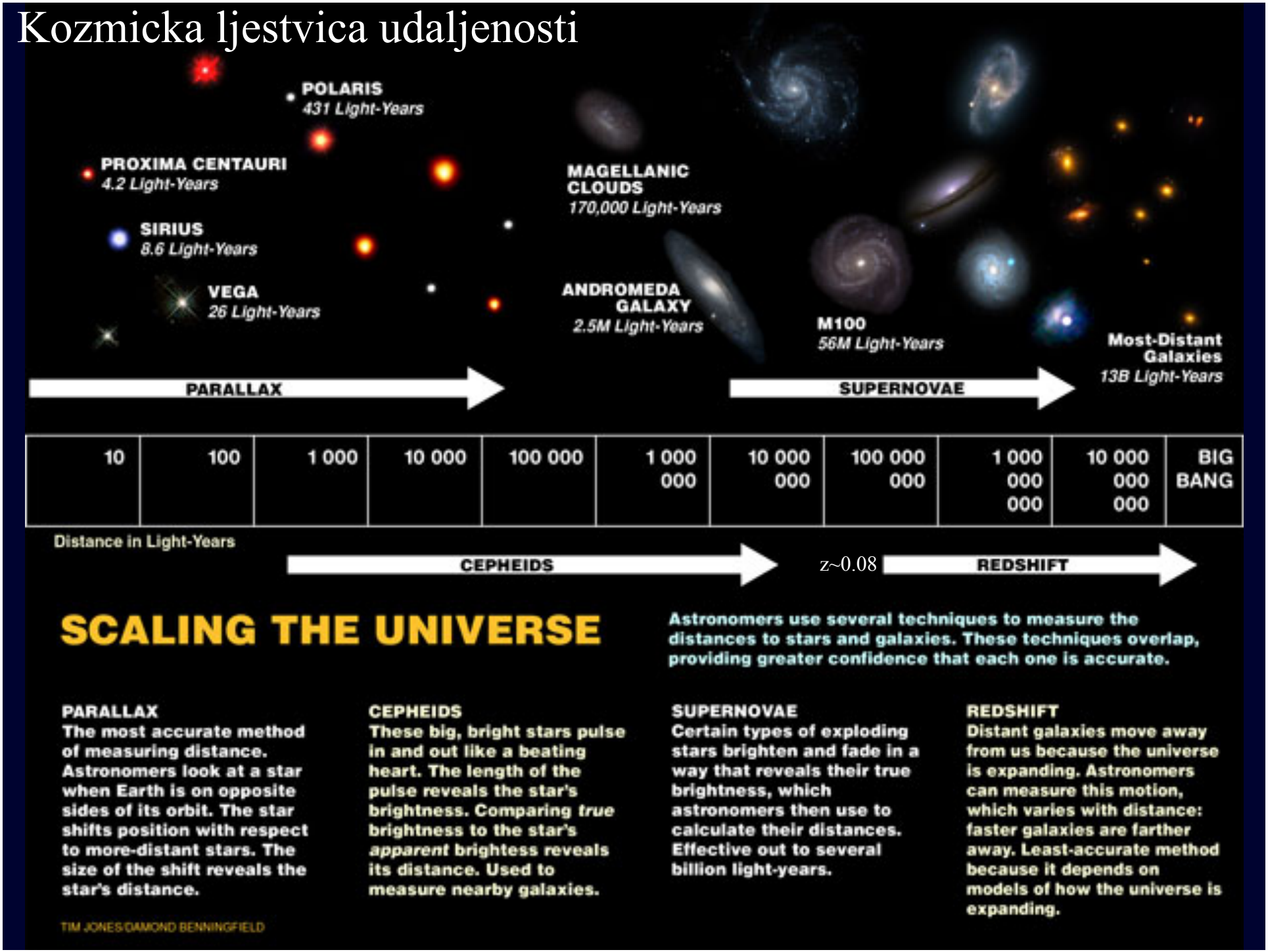
- Dopplerov pomak ➔ pomak prema crvenom (*z, redshift*), ekvivalent udaljenosti:

  $z = (\lambda_{obs} - \lambda_{em}) / \lambda_{em}$

  $1 + z \approx v_r/c$



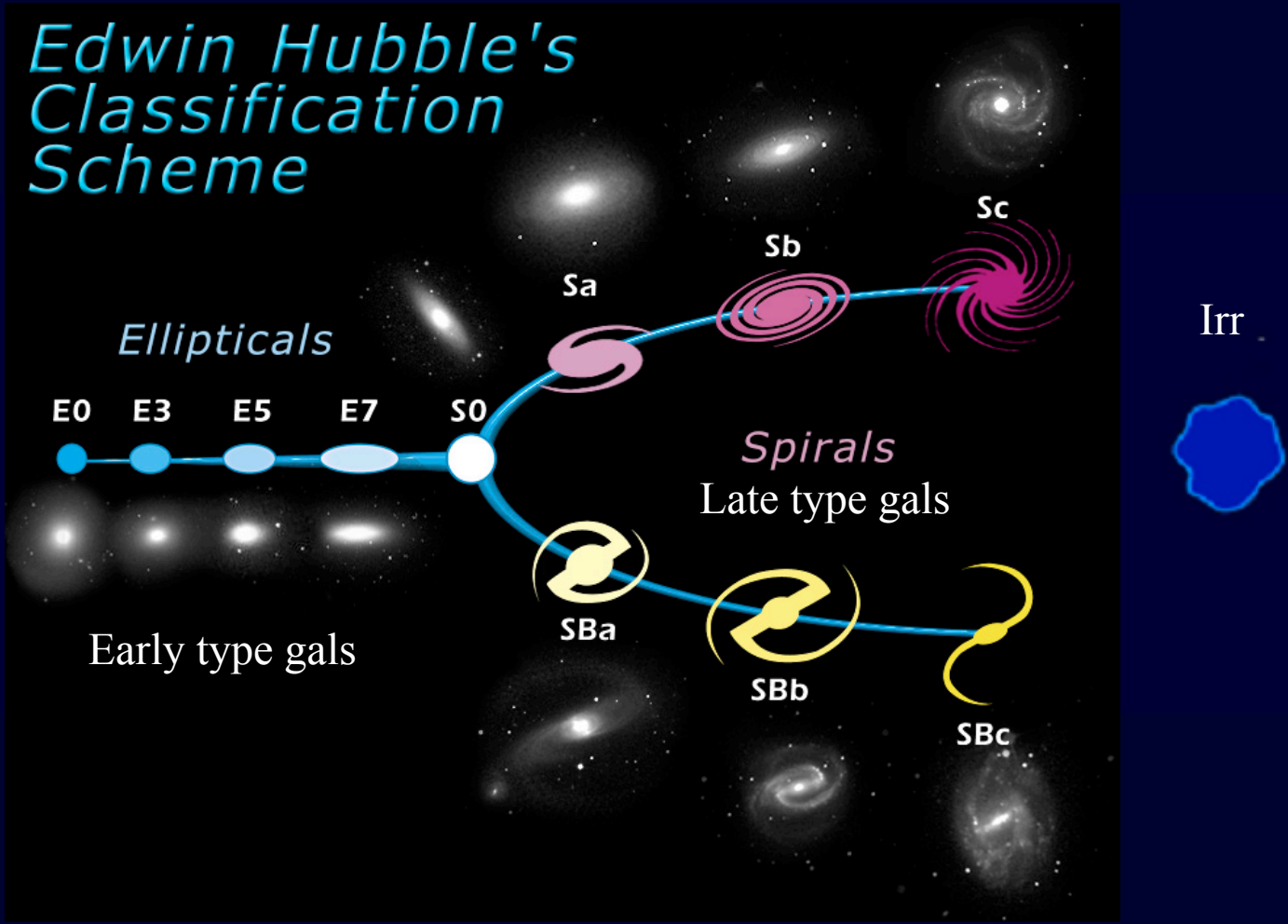
Kozmicka ljestvica udaljenosti



Podjela galaksija

Podjela galaksija

eliptične spiralne nepravilne

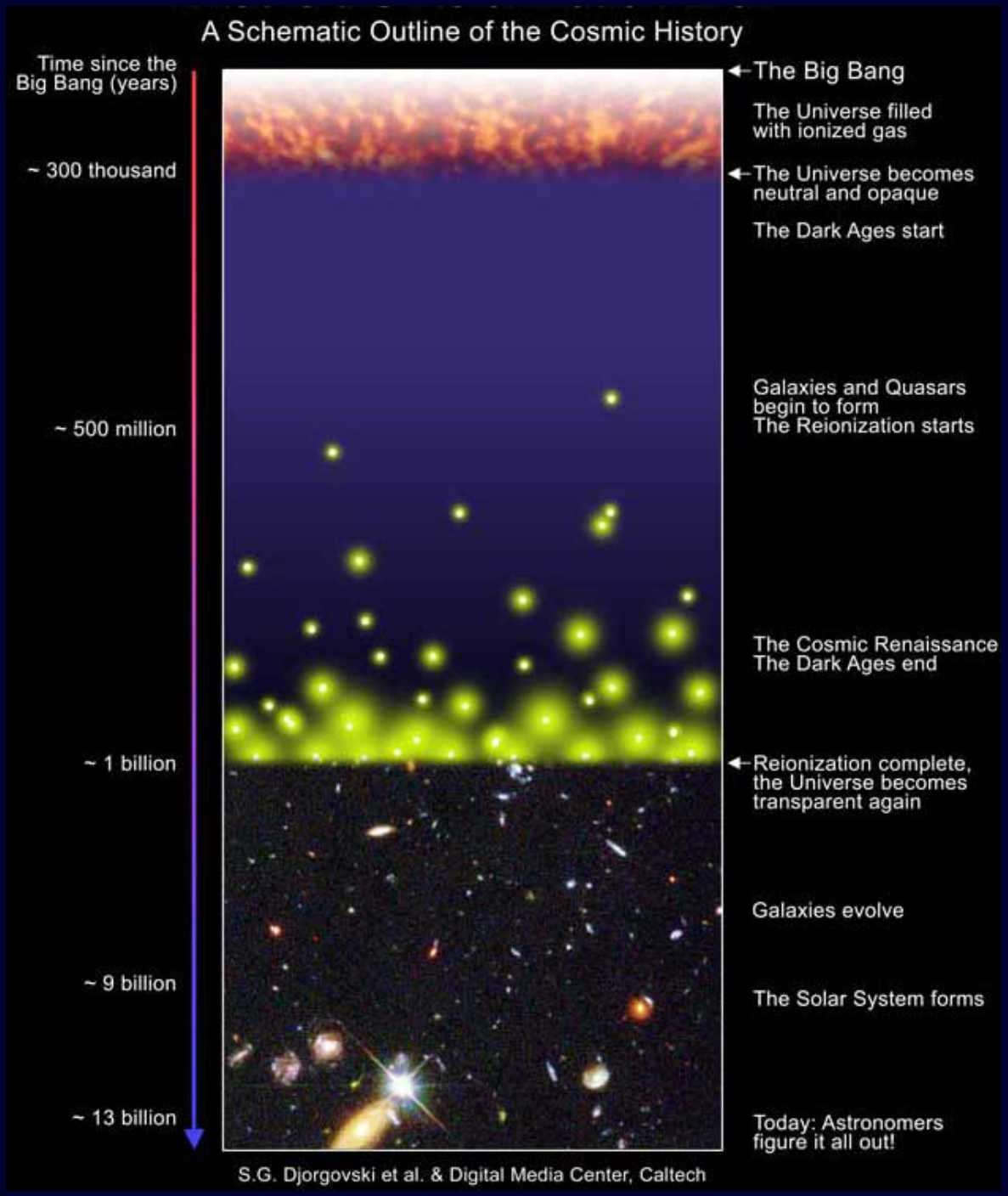


> 60% < 30% < 15%


Local Galaxies
E
S0
S0
S0
Sa
Sa
Sb
Sc
Sc
Sd
Sd
Pec
Pec
SBb
SBb
SBb
SBb
SBc
SBd
SBd
Distant Galaxies
E
S0
S0
S0
Sa
Sc
Sd
SBb
SBc
SBd
Pec
Pec
Pec
Pec
Pec
Pec
Pec
Pec
Pec

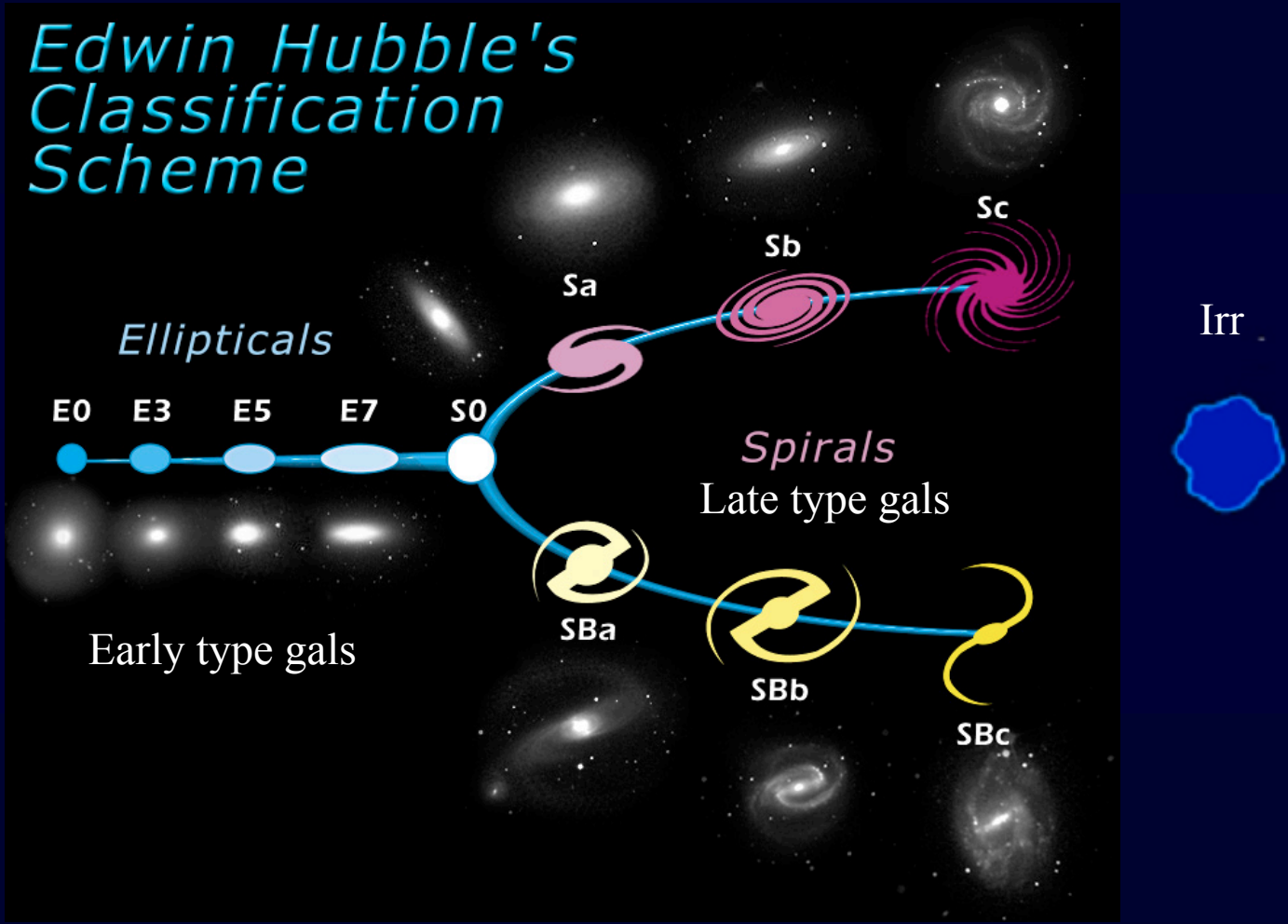
Panoramska NIR slika neba + nasa Galaksija

Credit: *Thomas Jarrett, IPAC/Caltech*


A Schematic Outline of the Cosmic History
Time since the Big Bang (years)
~ 300 thousand
~ 500 million
~ 1 billion
~ 9 billion
~ 13 billion
The Big Bang
The Universe filled with ionized gas
The Universe becomes neutral and opaque
The Dark Ages start
Galaxies and Quasars begin to form
The Reionization starts
The Cosmic Renaissance
The Dark Ages end
Reionization complete, the Universe becomes transparent again
Galaxies evolve
The Solar System forms
Today: Astronomers figure it all out!
S.G. Djorgovski et al. & Digital Media Center, Caltech

Podjela galaksija

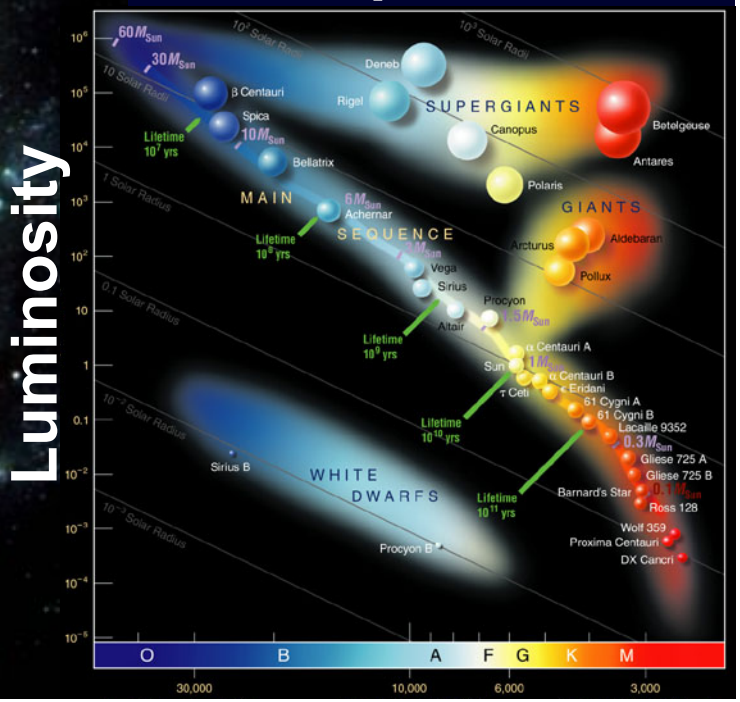
eliptične spiralne nepravilne



> 60% < 30% < 15%

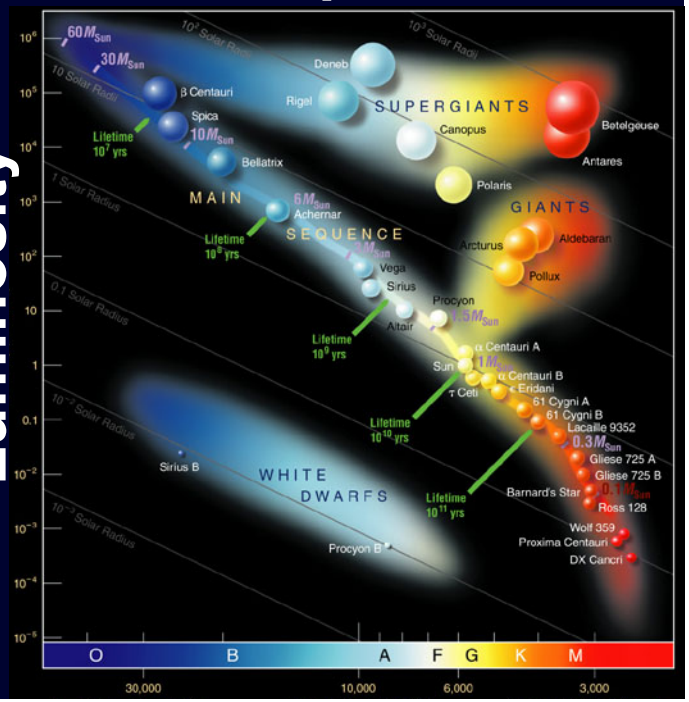
Spiralne Galaksije

- Boja?
- Oblik?

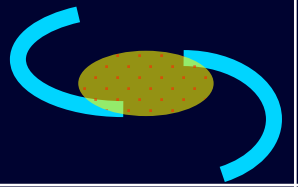
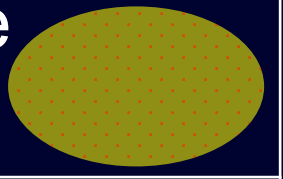


Eliptične Galaksije

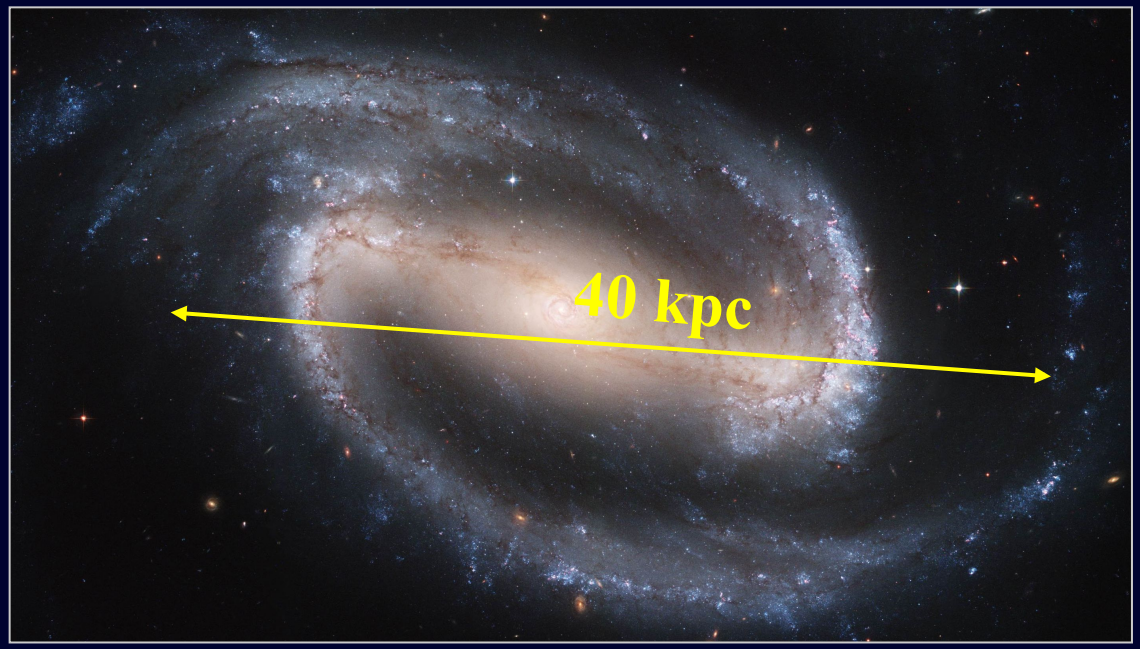
- Boja?
- Oblik?



Svojstva galaksija

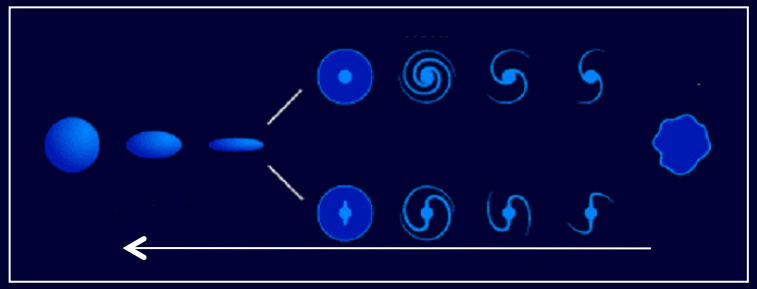
	Spiralne 	Ellipticne 
Znacajke	disk, zadebljanje (bulge)	elipticne
boja	plava (mlade, masivne zvijezde)	Crvena (divovi)
Plin, prasina	U disku	Malo ili uopce ne
Smjestaj	Grupe, prazniji djelovi	Skupovi galaksija

1 Mpc = $3.08568*10^{24}$ cm



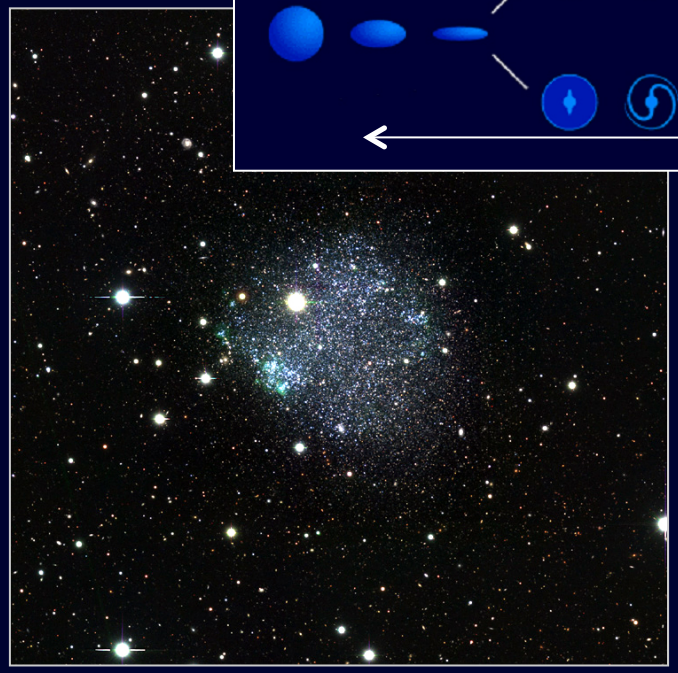
Veličina [kpc]

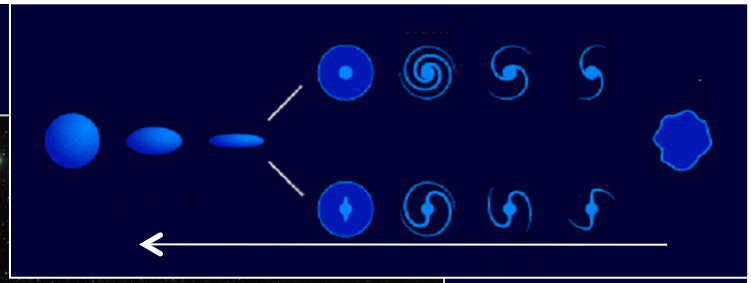
Patuljaste eliptične dE	0.5 - 1
Nepravilne	1 - 10
Spiralne, Lećaste S, S0	10 - 50
Eliptične E, gE	10 - 100



Luminozitet [W]

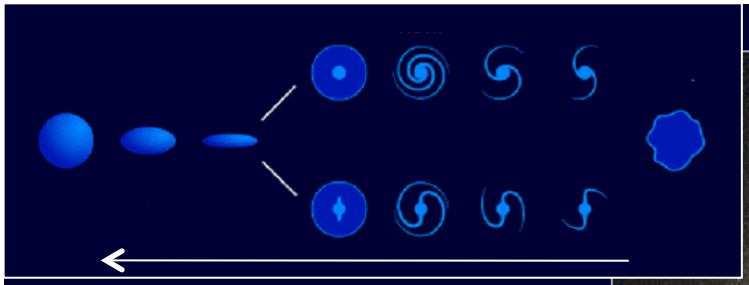
dE	10^{31}
Irr	$2\ 10^{35} - 2\ 10^{36}$
S	$10^{36} - 3\ 10^{37}$
gE	10^{38} $(\sim 10^{12}\ L_S)$

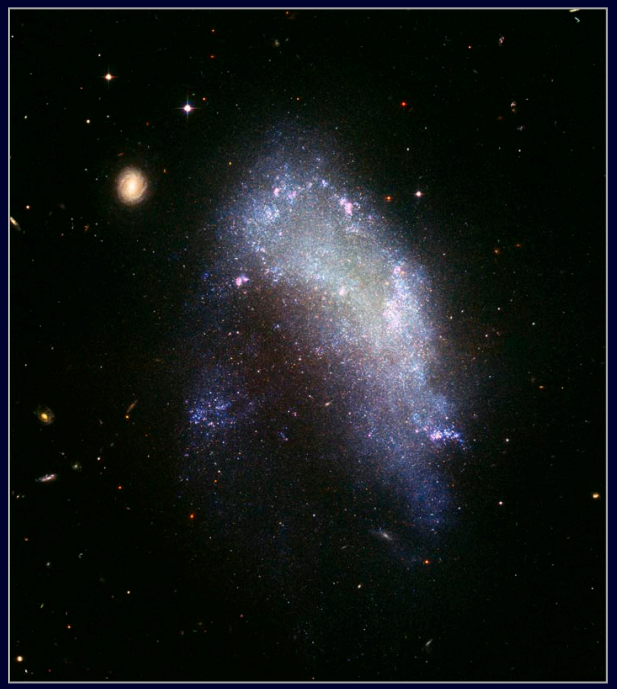




Masa [M_{Sun}]

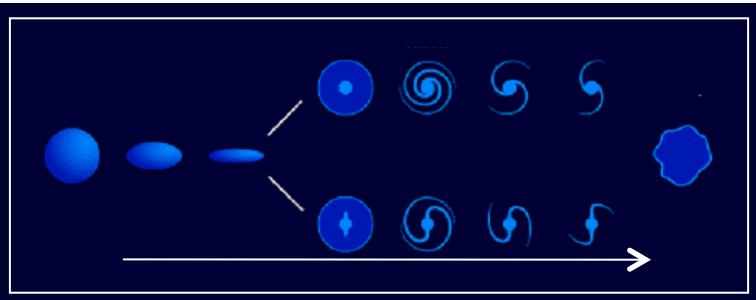
Patuljaste eliptične dE	10^6
Nepravilne Irr	$10^6 – 10^{10}$
Spiralne, Lećaste S, S0	$10^{10} – 3\ 10^{11}$
Eliptične E, gE	10^{12}





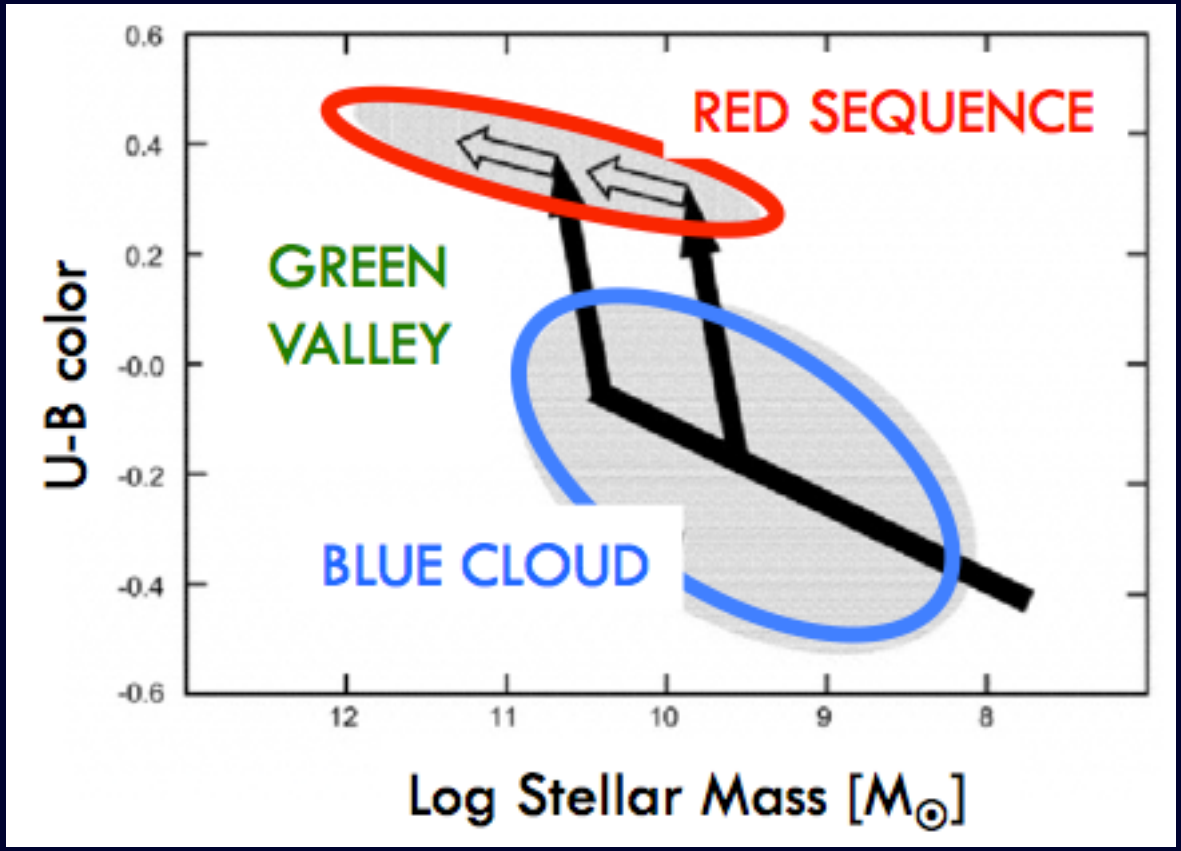
Omjer masa-luminozitet

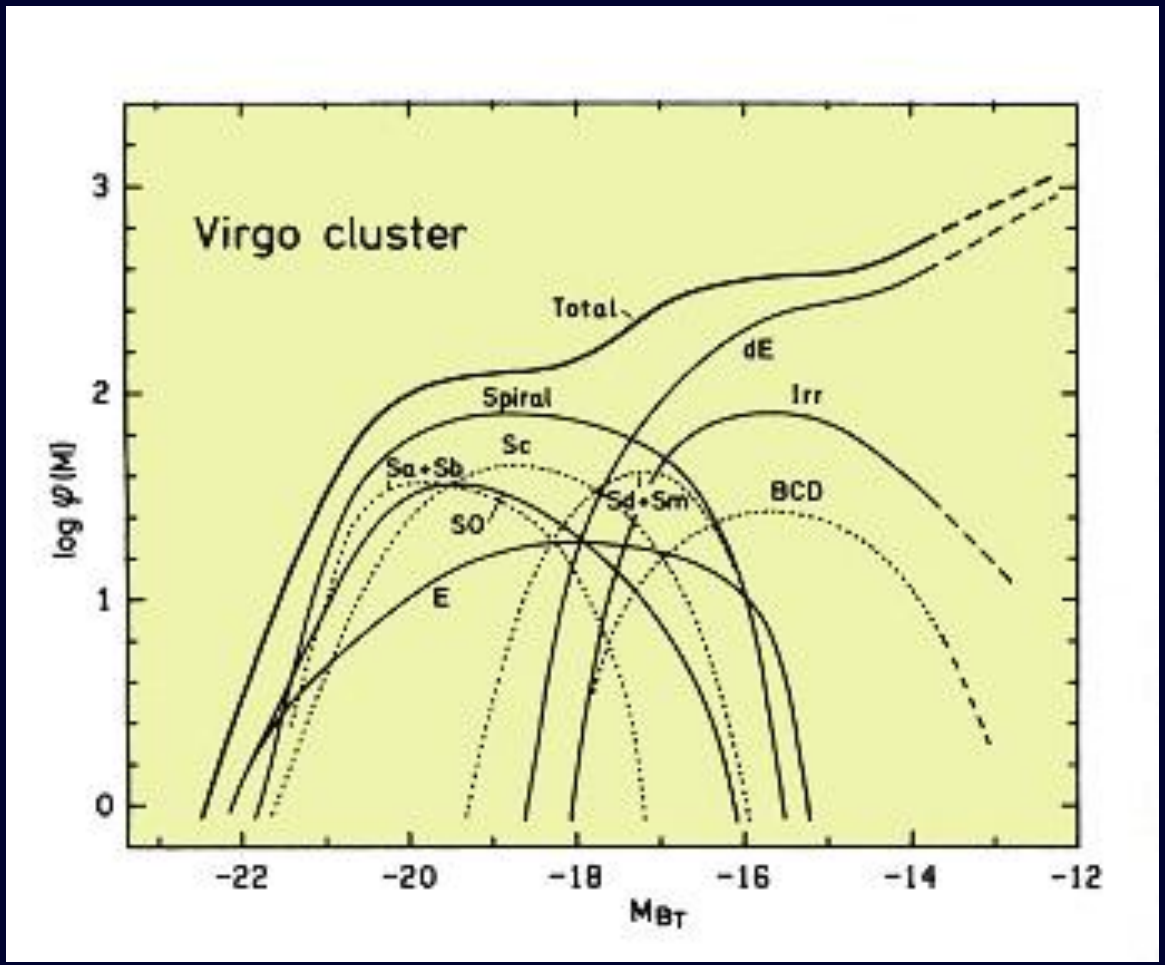
E	20 - 40
S0	10
Sa	10
Sb	10
Sc	< 10
Irr	< 10



Udio plina u masi
[u postocima]

E	~0
S0	0.5
Sa	3
Sb	5
Sc	7
Irr	20


RED SEQUENCE
GREEN VALLEY
BLUE CLOUD
U-B color
0.6
0.4
0.2
-0.0
-0.2
-0.4
-0.6
12
11
10
9
8
Log Stellar Mass [M⊙]



Nema malih spiralnih galaksija!

Nema velikih nepravilnih galaksija!

Funkcija luminoziteta galaksija

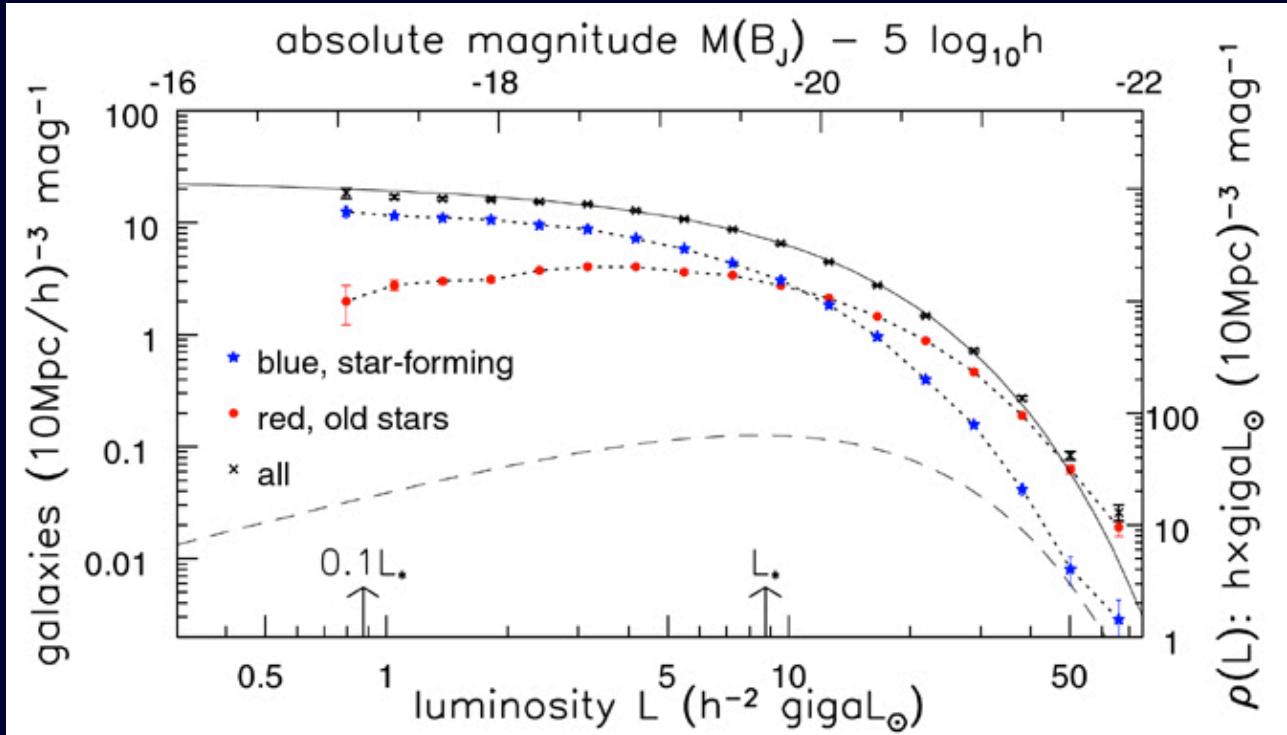


Fig 1.16 'Galaxies in the Universe' Sparke/Gallagher CUP 2007

Schechterova jednadzba: $$\Phi(L)\Delta L = n_*\left(\frac{L}{L_*}\right)^{\alpha}\exp\left(-\frac{L}{L_*}\right)\frac{\Delta L}{L_*}$$