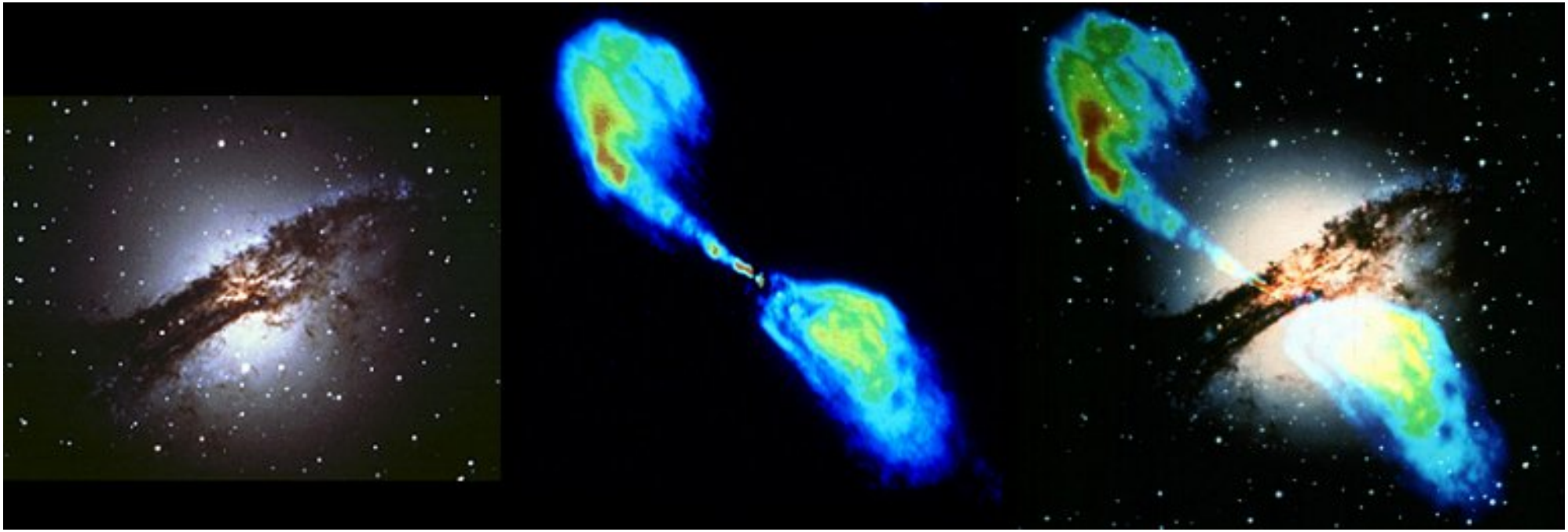
Aktivne galaksije



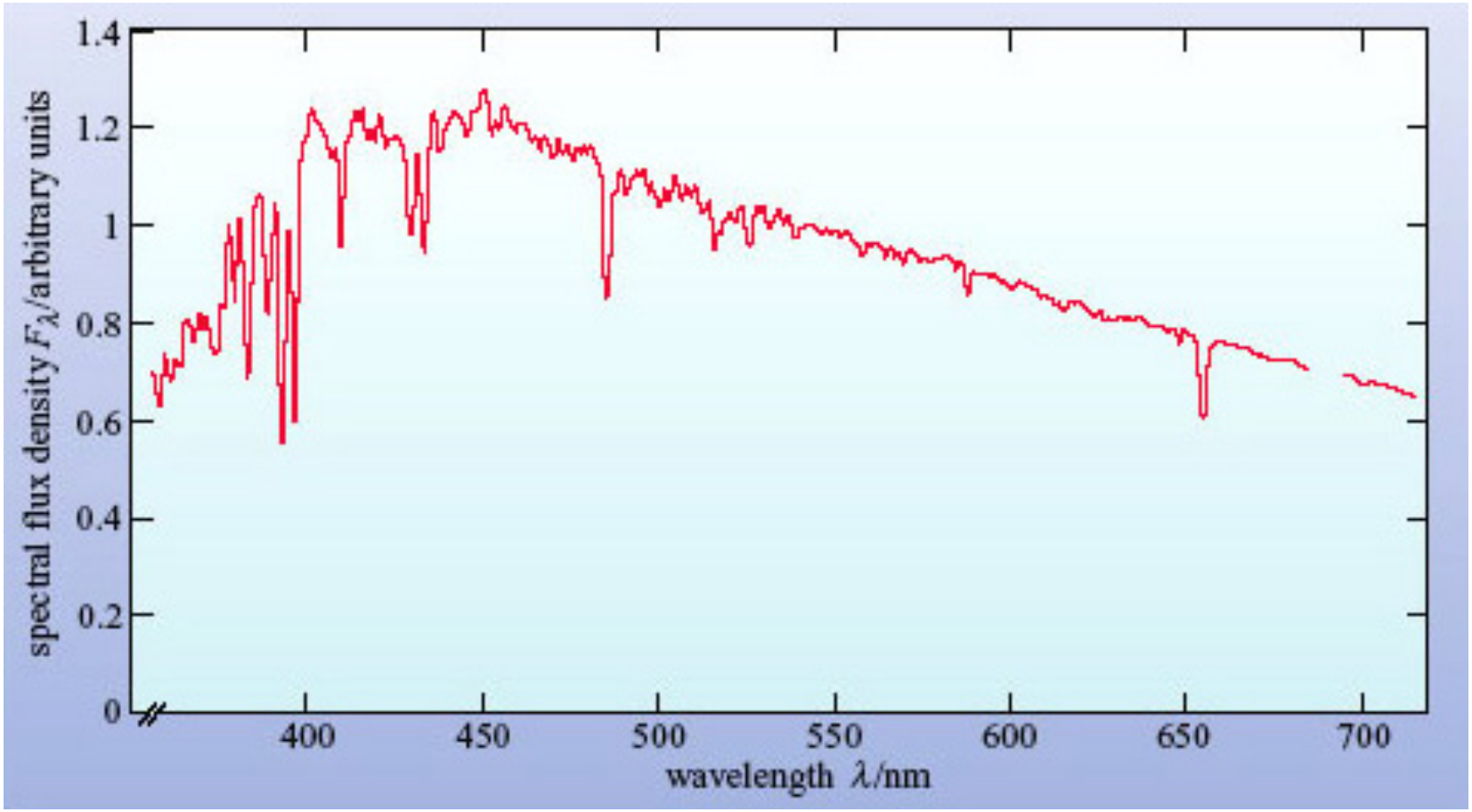
galaksije sestavljajo:

- temna snov
- zvezde
- plin
- prah

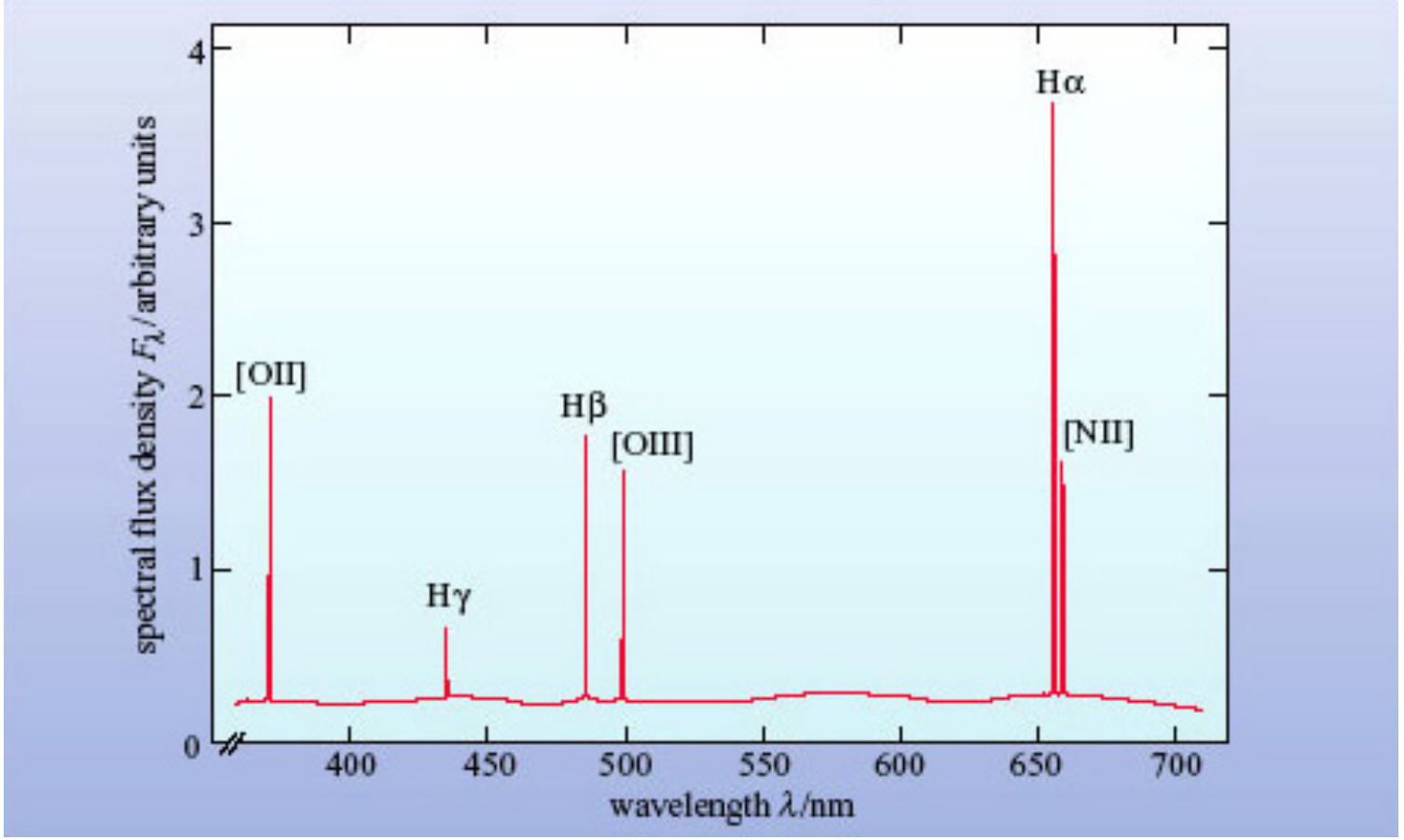
Kaj prispeva k spektru galaksije?

- temna snov ne
- zvezde
- plin
- prah - absorbira v vidni svetlobi, emitira v daljni IR

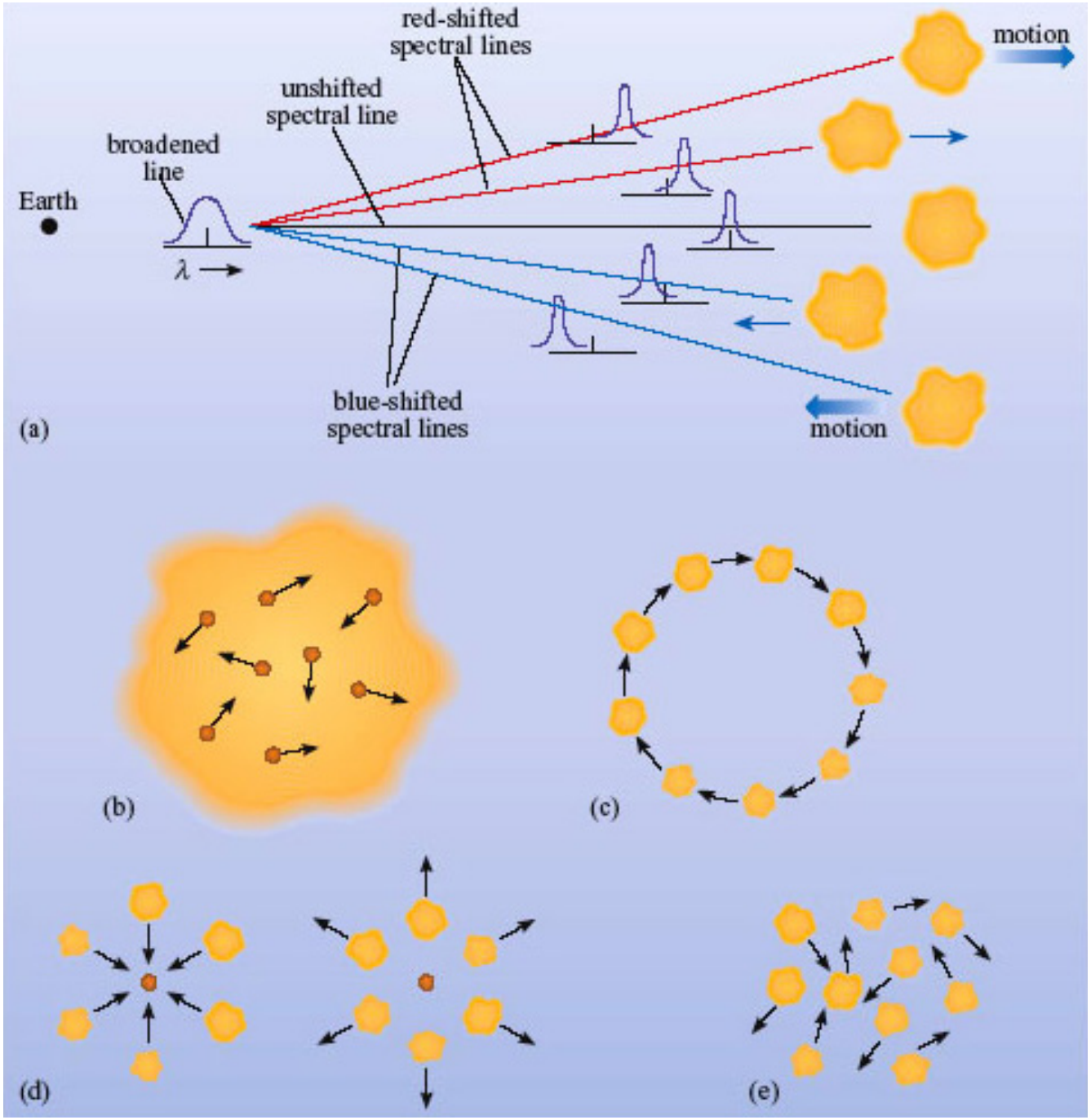
zvezde - optičnem delu spektra



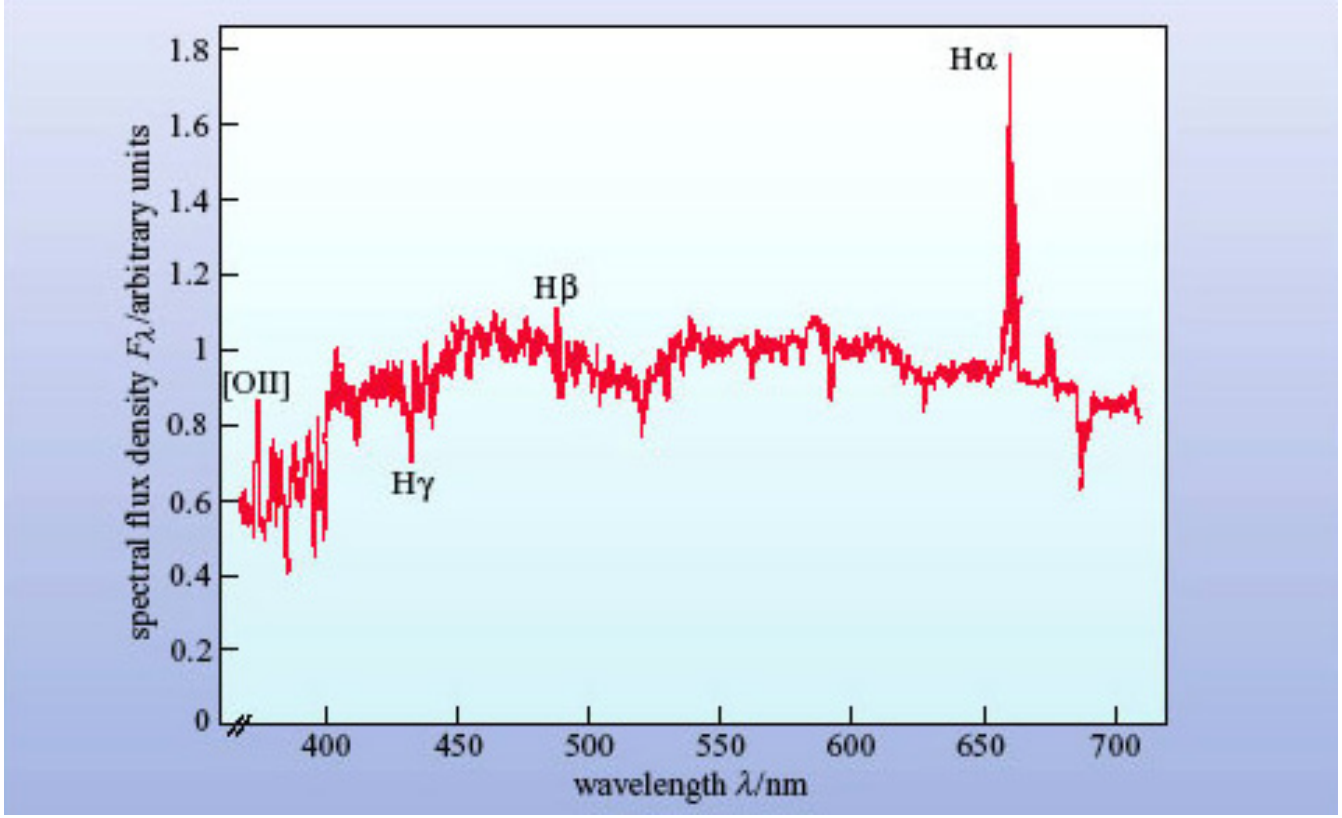
območja HII – v optičnem delu spektra



- spekter galaksije = vsota spektrov zvezd in plina (ter prahu)
- črte so manj izrazite
- premaknjene zaradi kozmološkega rdečega premika: $z = \frac{\Delta\lambda}{\lambda_{em}}$
- premaknjene zaradi gibanja galaksije: $\frac{v}{c} = \frac{\Delta\lambda}{\lambda_{em}}$
- razširjene zaradi gibanja zvezd, oblakov: $\frac{\Delta v}{c} = \frac{\Delta\lambda}{\lambda_{em}}$
- namesto Δλ govorimo pogosto o hitrosti (v km/s)

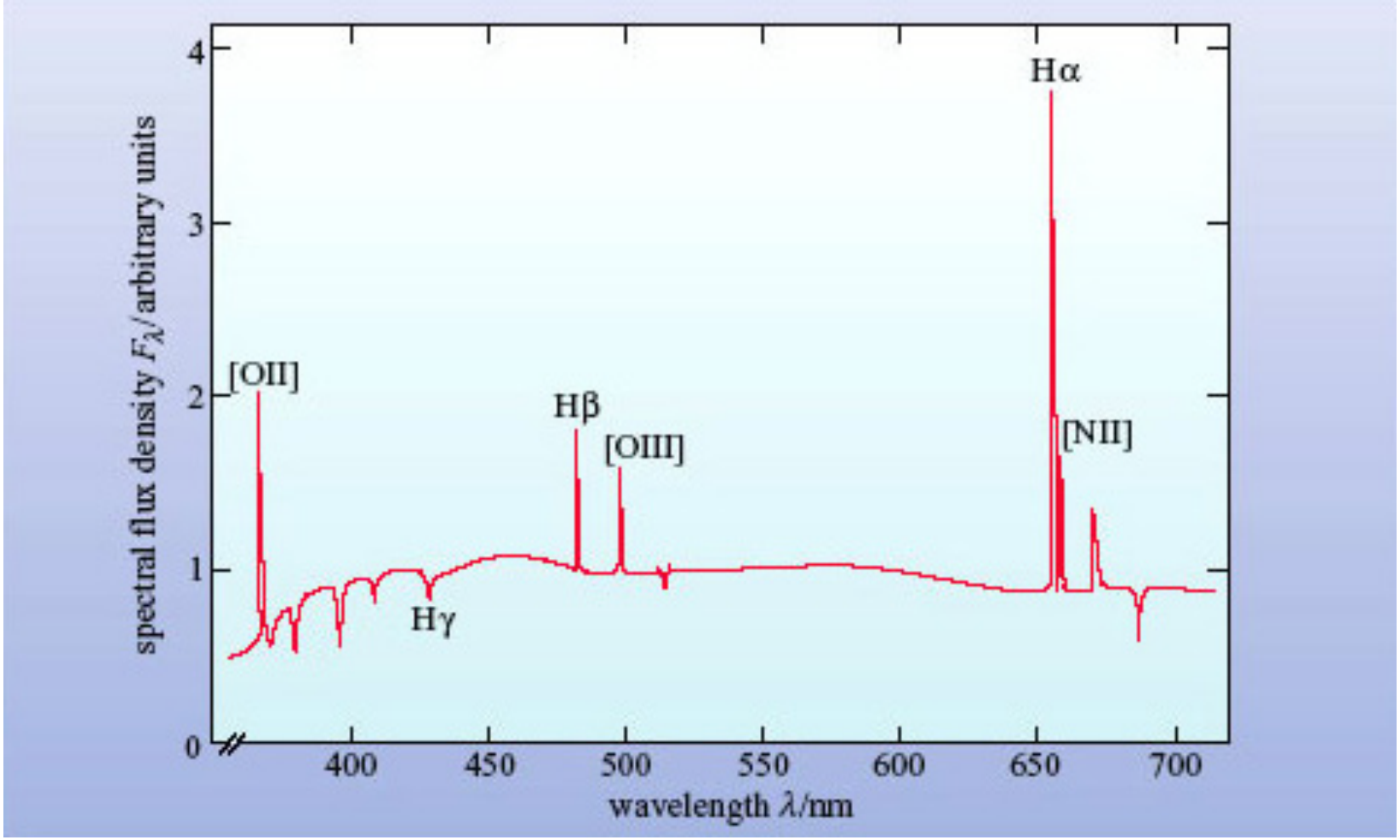

red-shifted
spectral lines
motion
unshifted
spectral line
broadened
line
Earth
λ
blue-shifted
spectral lines
motion
(a)
(b)
(c)
(d)
(e)

spekter normalne galaksije



splošno pravilo:
optične absorbcijske črte – od zvezd, optične emisijske črte – od vročega plina

kakšna galaksija je to?



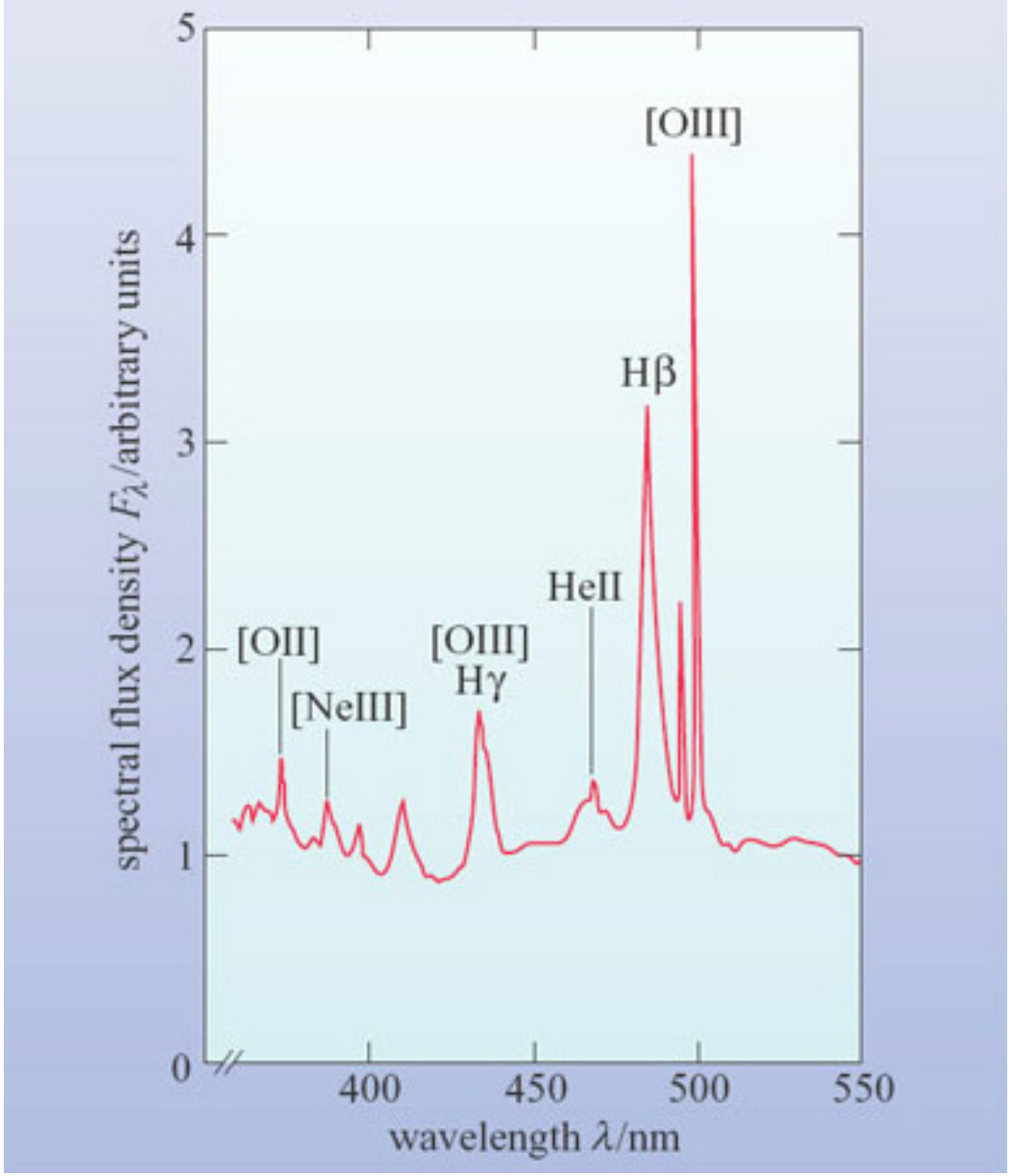
starburst galaxy – galaksija z močnim nastajanjem zvezd

spekter aktivne galaksije

- optični spekter
- široke črte:

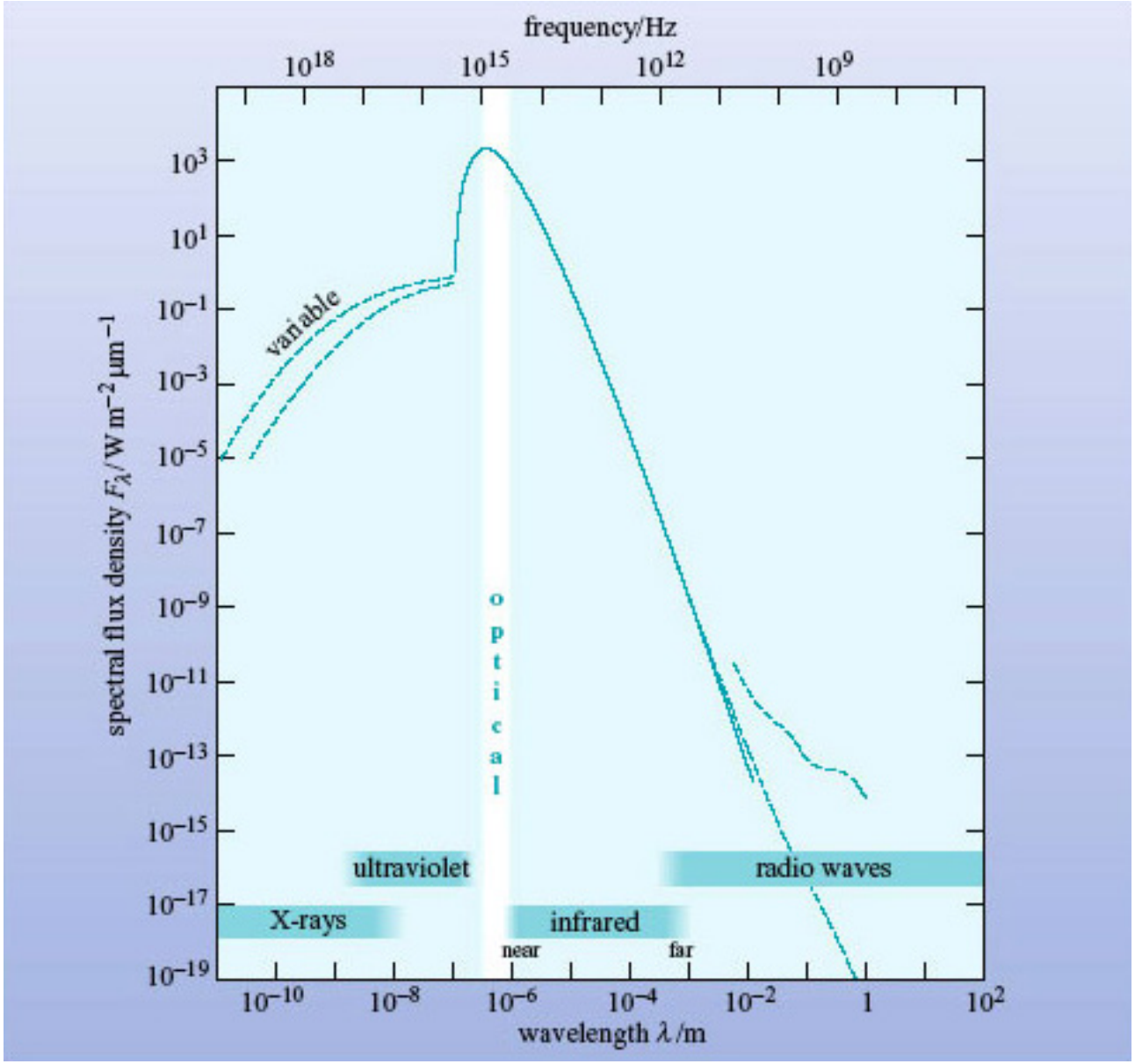
ali $T \approx 10^6$ K (ne gre)

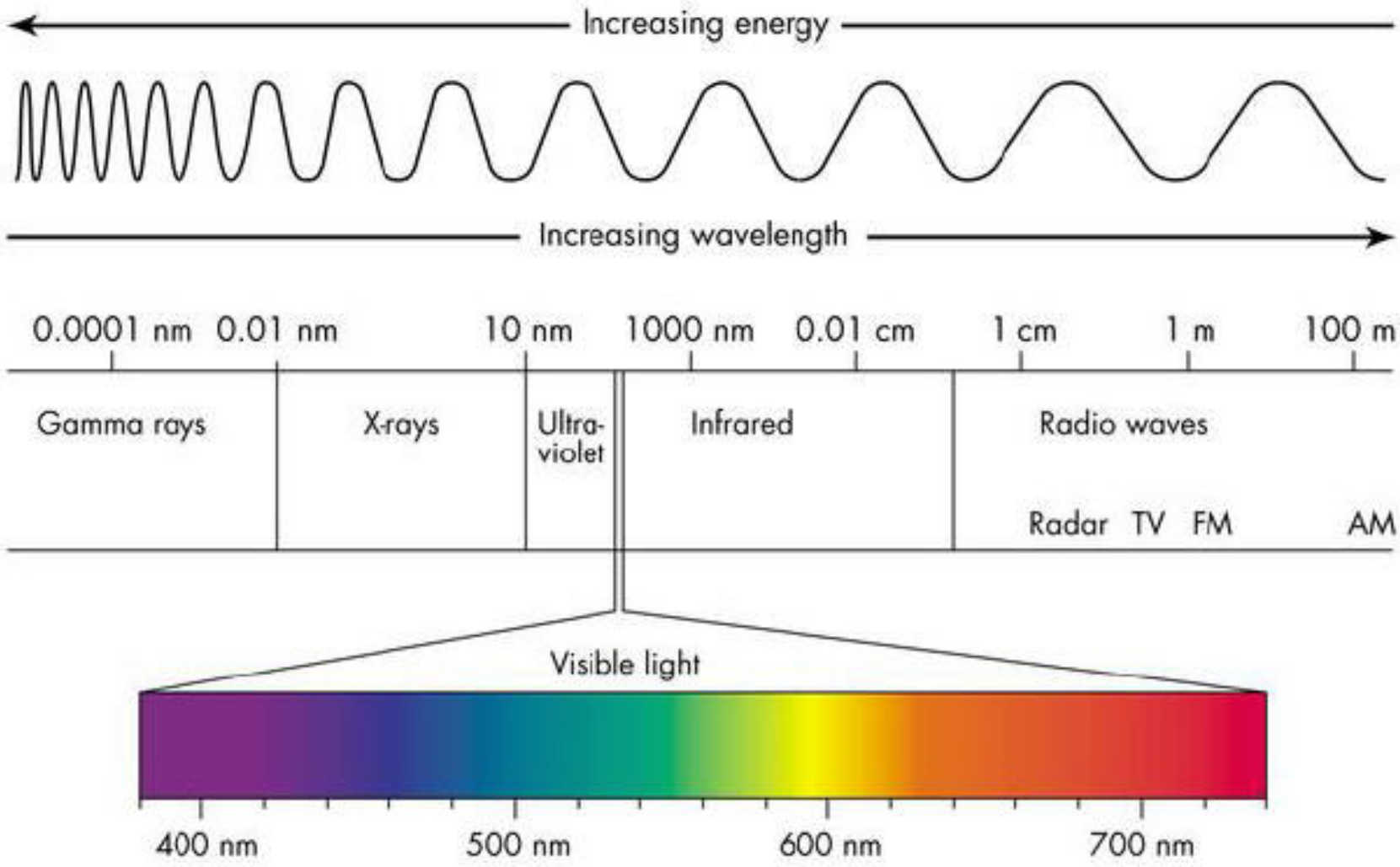
ali $v \approx 1000$ km/s



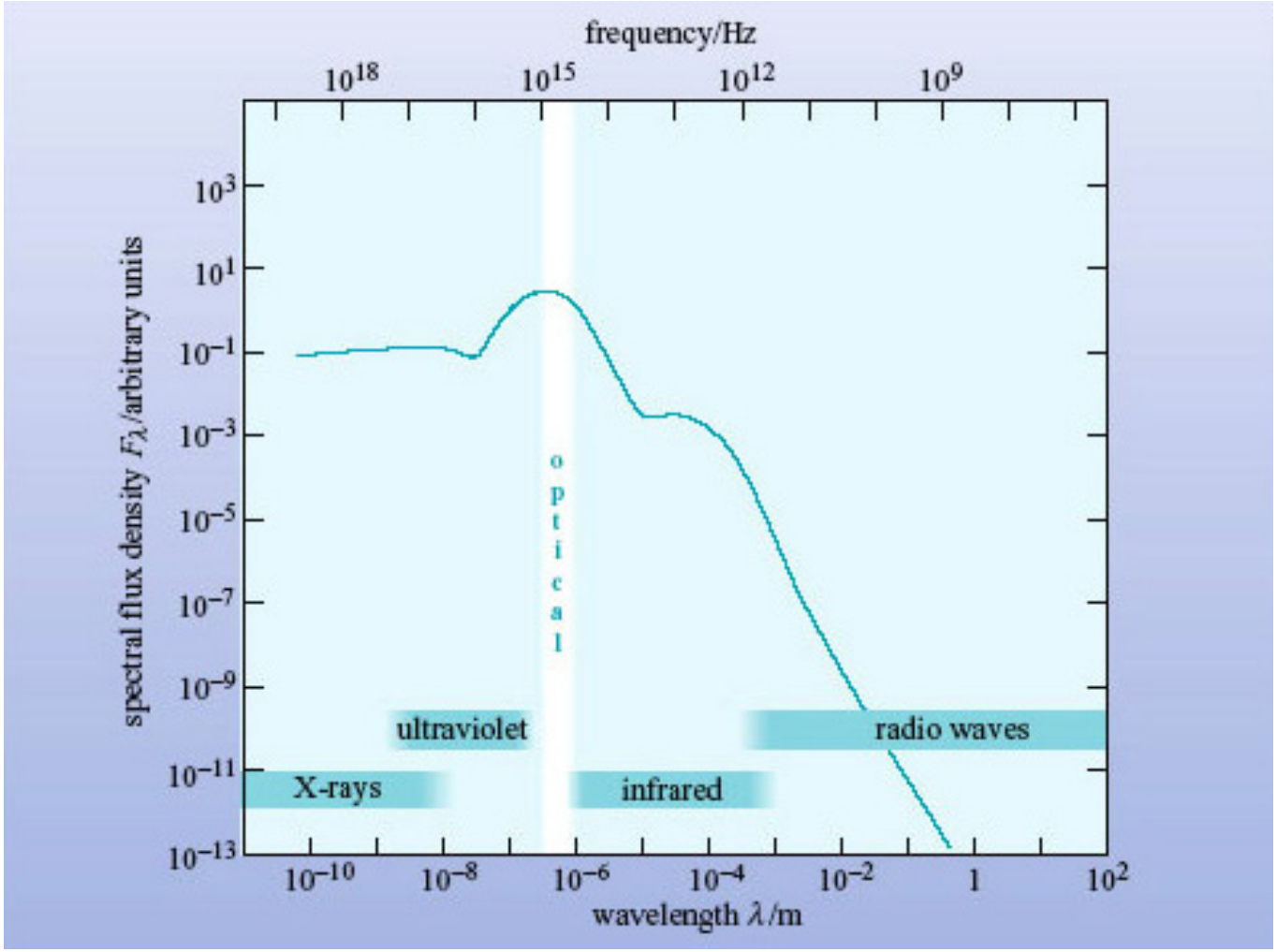
širokopasovni spektri

- Sonce
- log-log




Increasing energy
Increasing wavelength
0.0001 nm
0.01 nm
10 nm
1000 nm
0.01 cm
1 cm
1 m
100 m
Gamma rays
X-rays
Ultra-violet
Infrared
Radio waves
Radar
TV
FM
AM
Visible light
400 nm
500 nm
600 nm
700 nm

- normalna galaksija



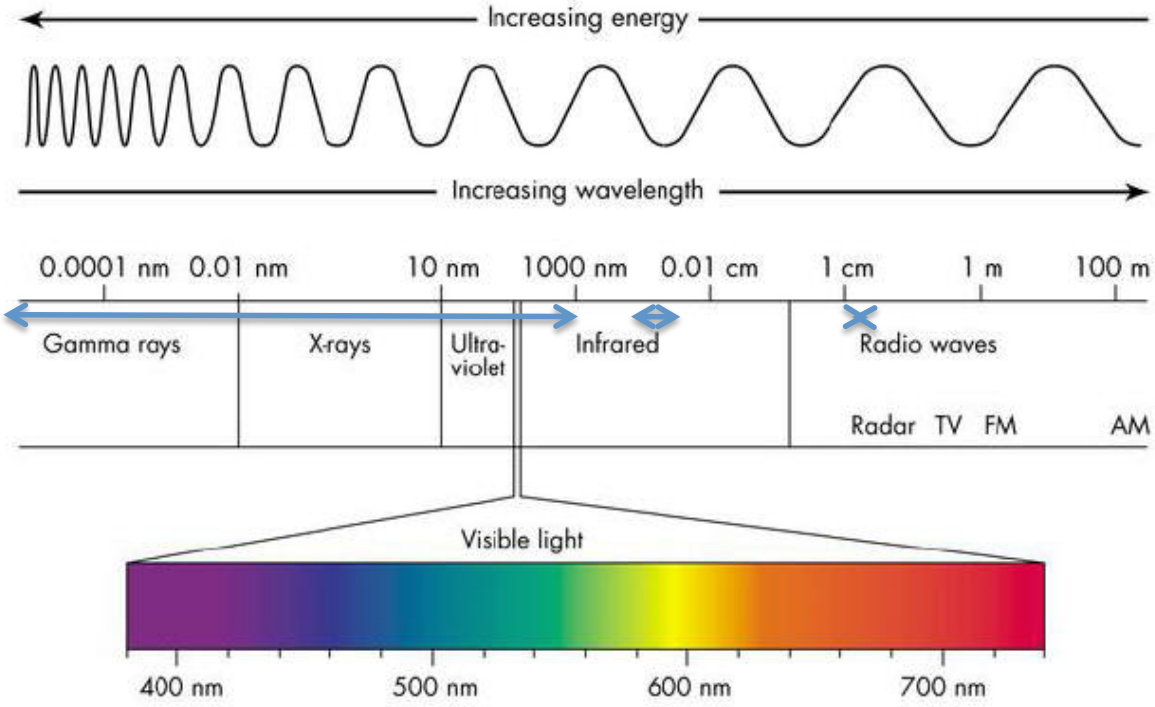
- kje je vrh?
- a je res svetlejša v X kot v IR?

y os: F_λ oz. j_λ

$$j_\lambda = \frac{dE}{dt \cdot dS \cdot d\lambda} \qquad \text{enota:} \qquad \frac{W}{m^2 \mu m}$$

(ali $j_\nu = F_\nu = \frac{dE}{dt \cdot dS \cdot d\nu}$ enota: $\frac{W}{m^2 Hz}$)

pretirano v X,
premalo v IR, radio



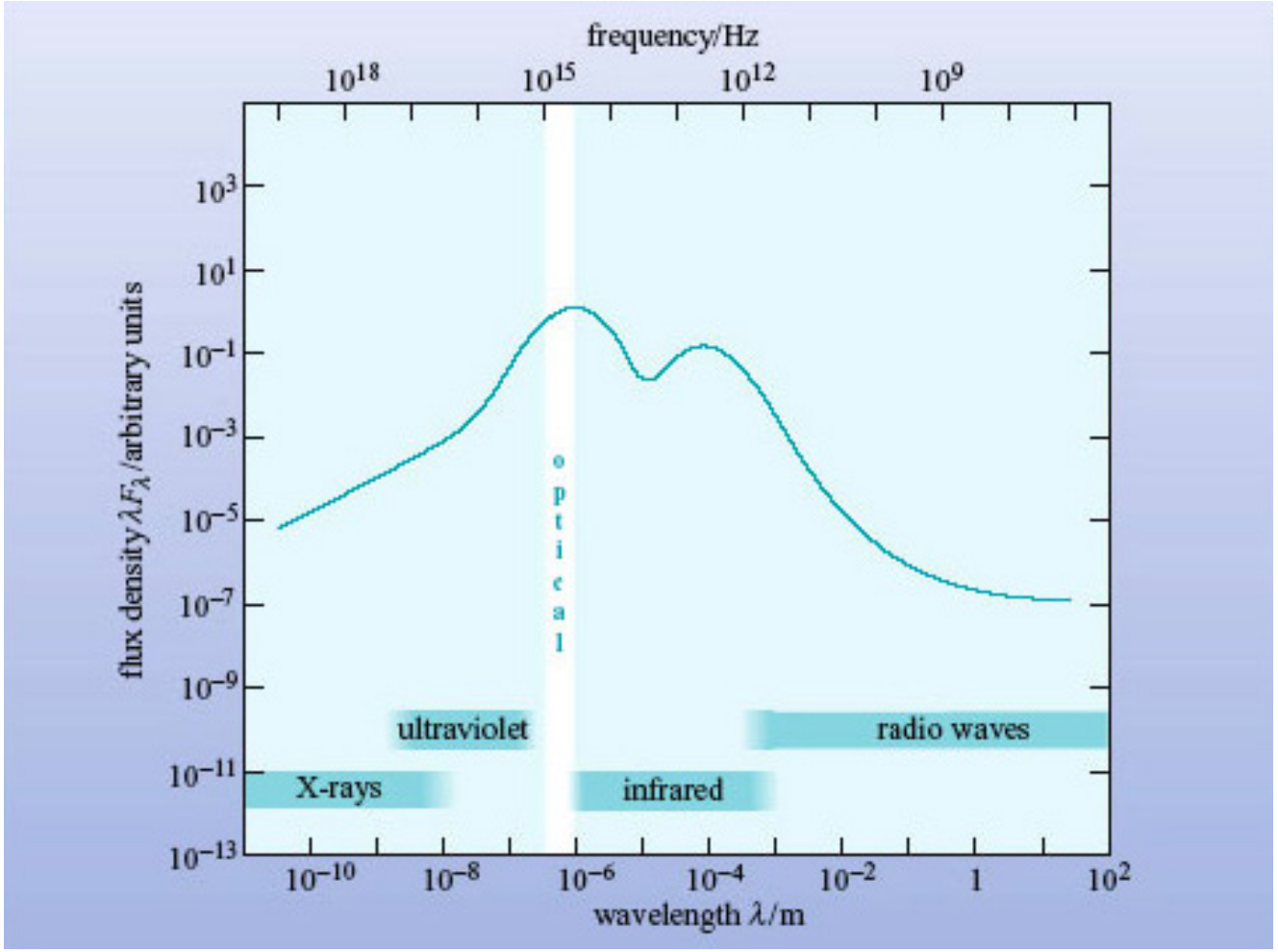
λF_λ oz. νF_ν

- enota: W/m^2
- vrh grafa (log-log) kaže območje, v katerem največ oddaja
- SED:

  Spectral

  Energy

  Distribution



primer

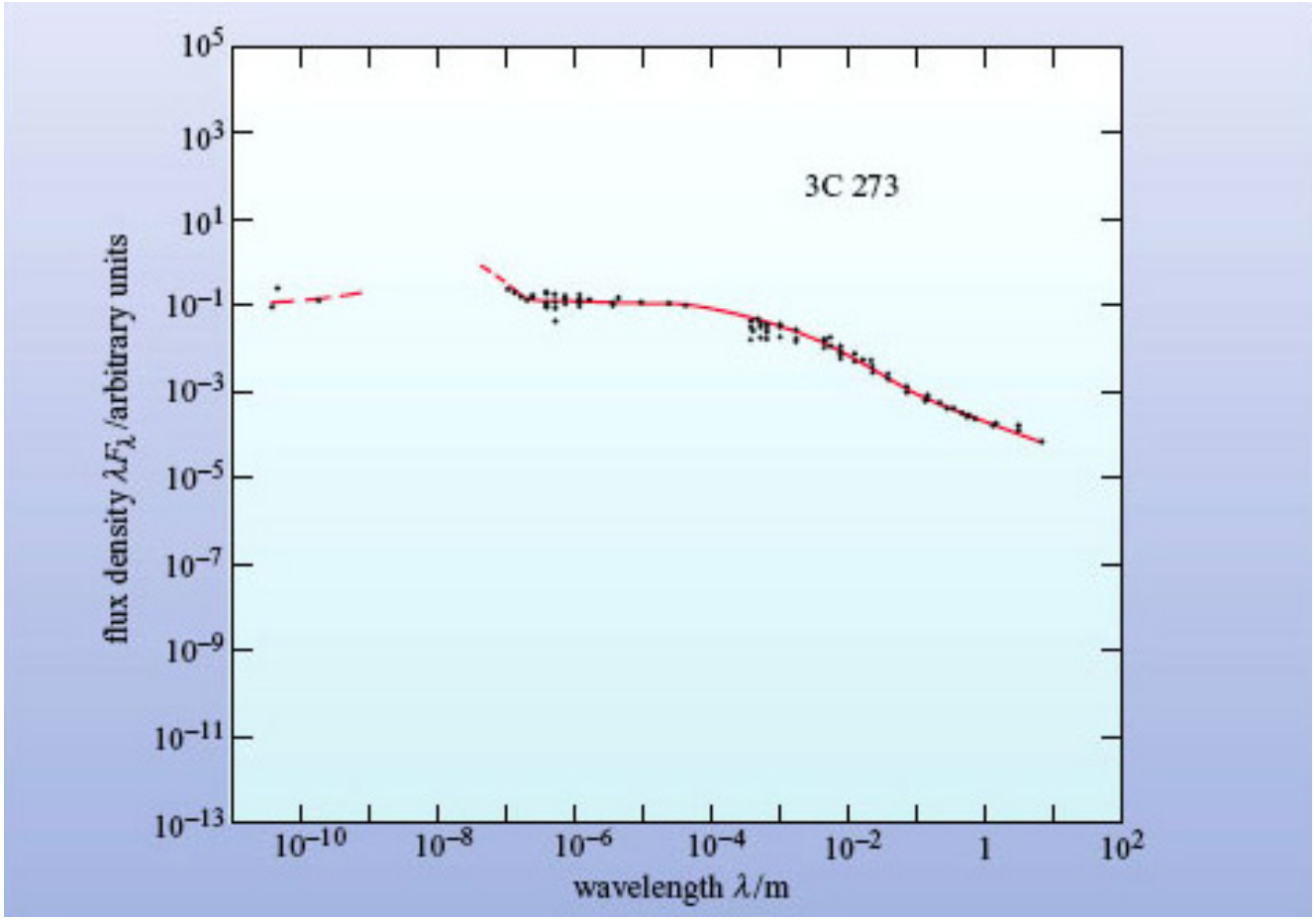
- galaksija A: pri λ=500 nm ima $F_\lambda=10^{-29}$ W/m^2/μm
  pri λ=100 μm ima zgornjo mejo $F_\lambda<10^{-32}$ W/m^2/μm
- galaksija B: pri λ=500 nm ima $F_\lambda=10^{-30}$ W/m^2/μm
  pri λ=100 μm ima $F_\lambda=10^{-30}$ W/m^2/μm
- Katera je svetlejša (odda več energije)?

- galaksija A: pri λ=500 nm ima $\lambda F_\lambda=0.5 \times 10^{-29}$ W/m^2
  pri λ=100 μm ima zgornjo mejo $\lambda F_\lambda<10^{-30}$ W/m^2
- galaksija B: pri λ=500 nm ima $\lambda F_\lambda=0.5x10^{-30}$ W/m^2
  pri λ=100 μm ima $\lambda F_\lambda=10^{-28}$ W/m^2

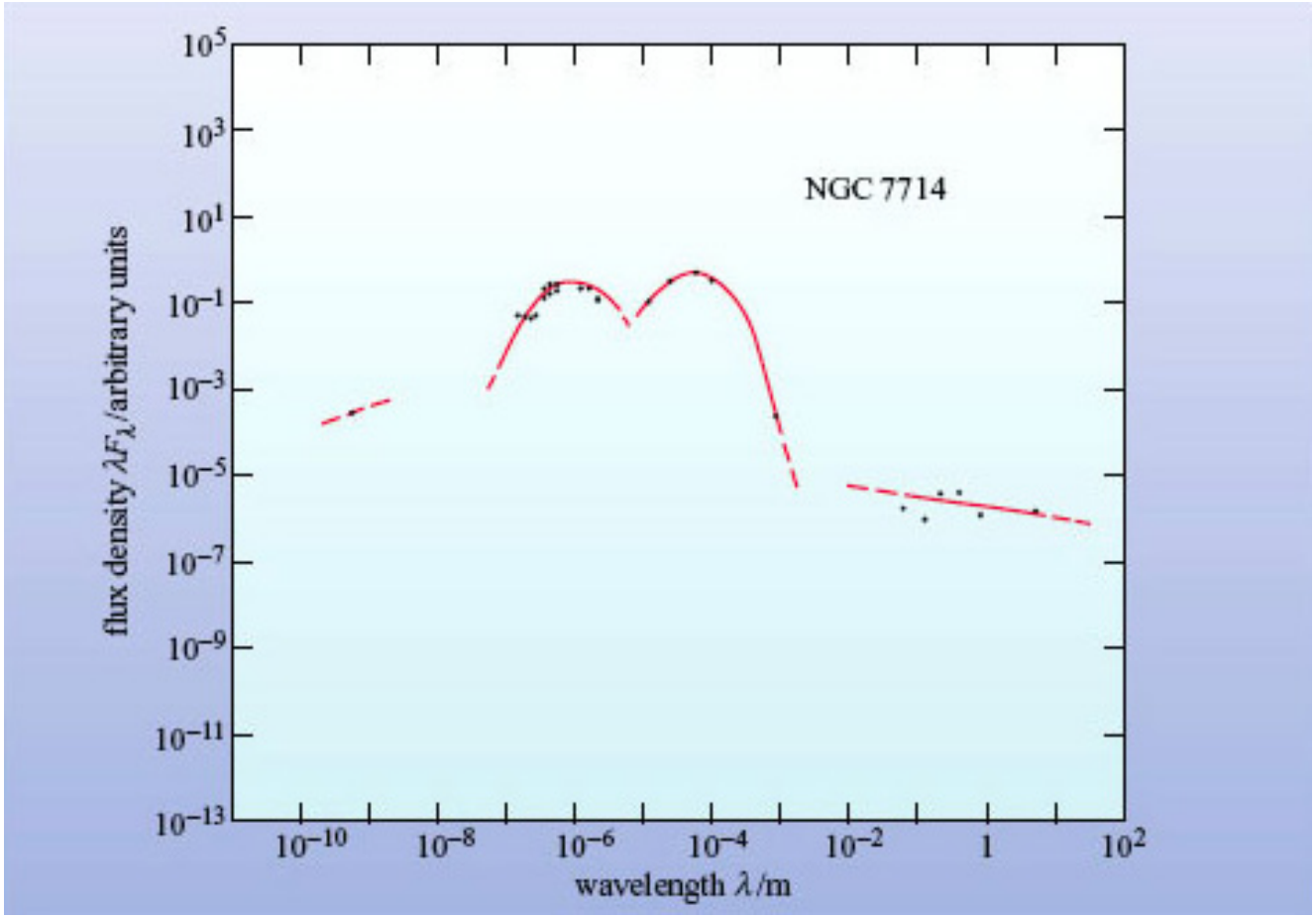
galaksija B je svetlejša od A!

SED aktivne galaksije

- spectral excess
- več energije
- npr. big blue bump



kakšna galaksija je to?

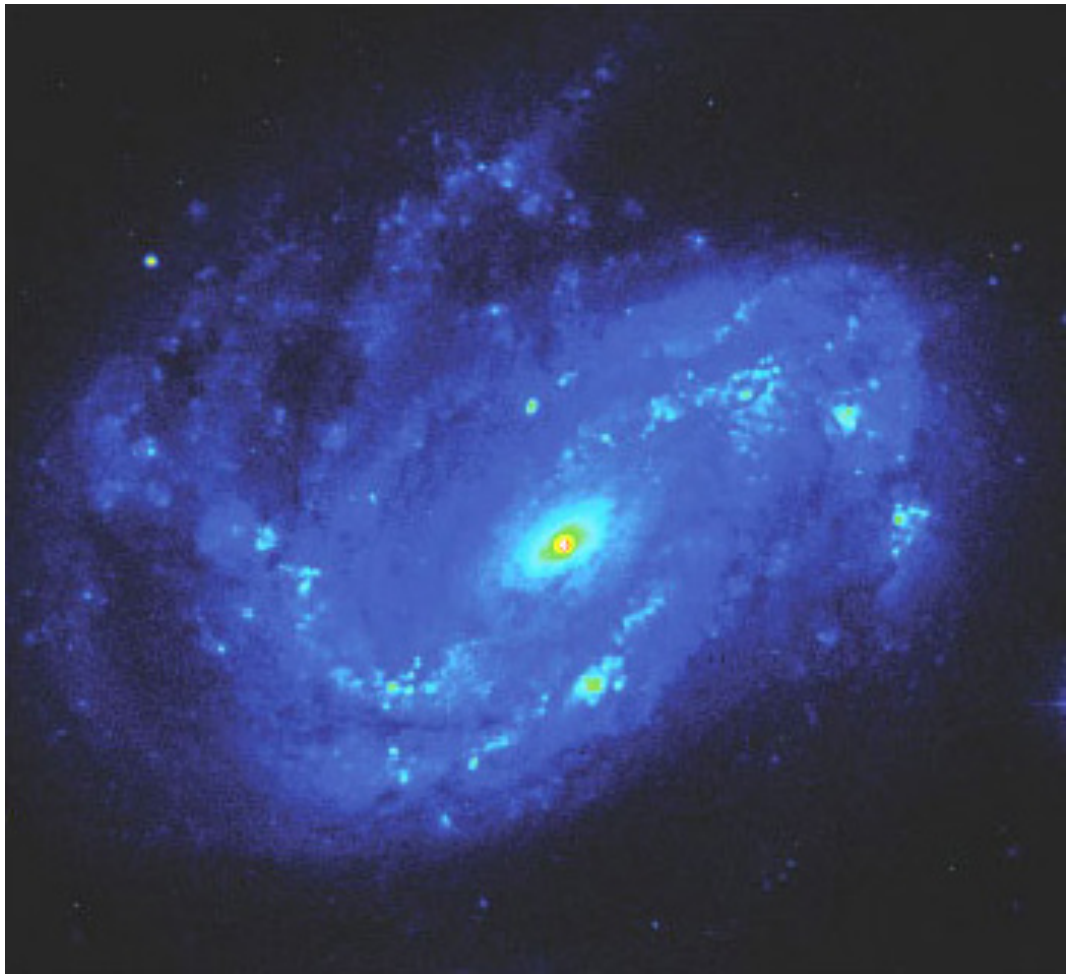


starburst galaxy – galaksija z močnim nastajanjem zvezd

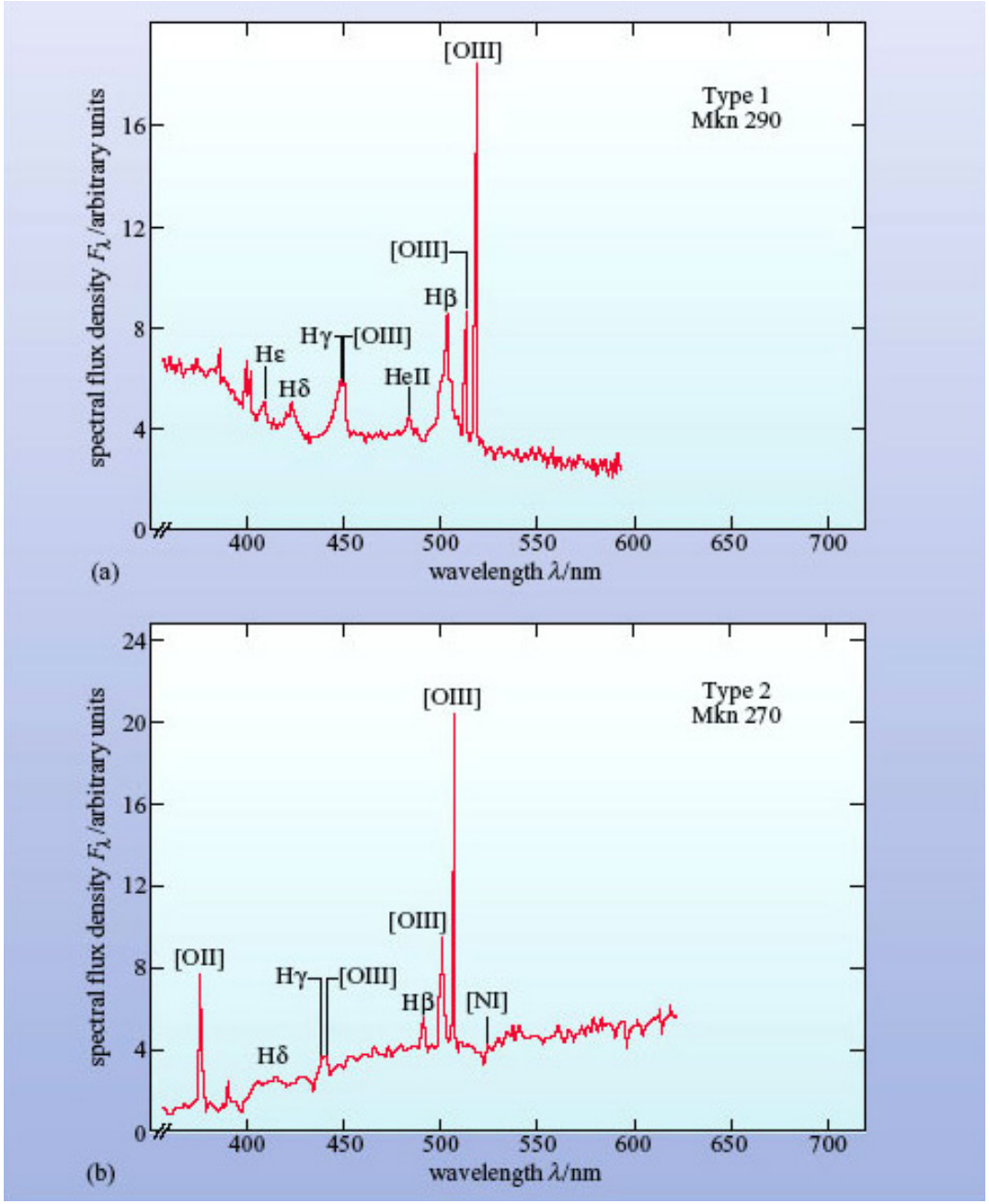
Vrste aktivnih galaksij

- Seyfertove g.
- 1908: Fath
- 1926: Hubble
- 1943: Seyfert

g. z zelo svetlim jedrom,
široke emisijske črte

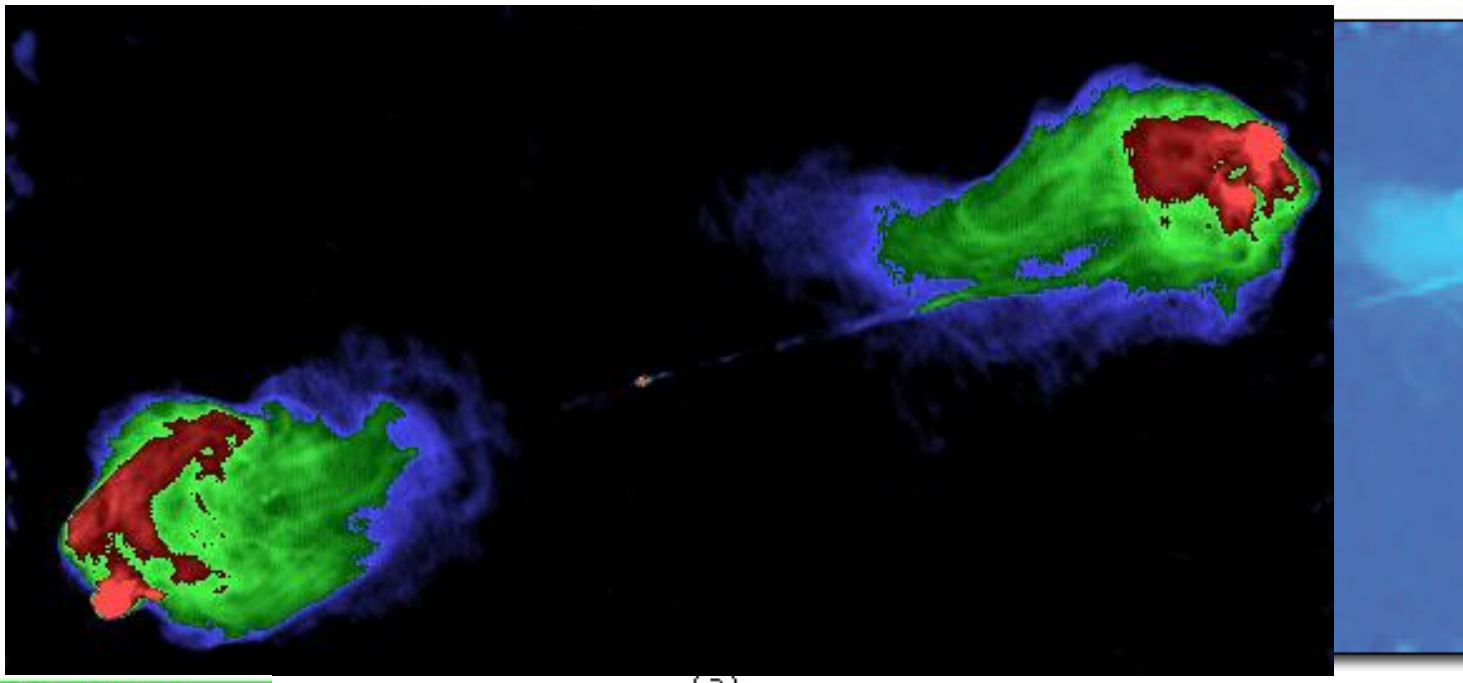


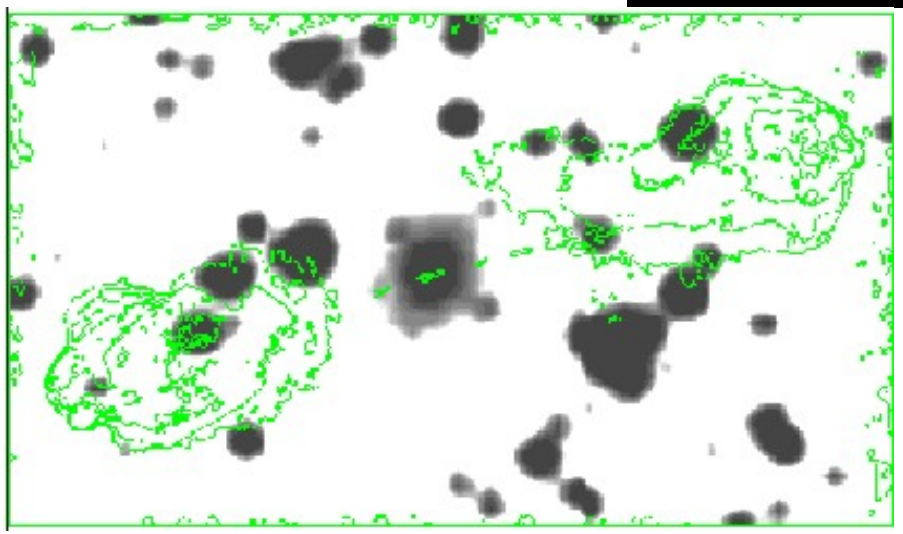
- 2 podvrsti:

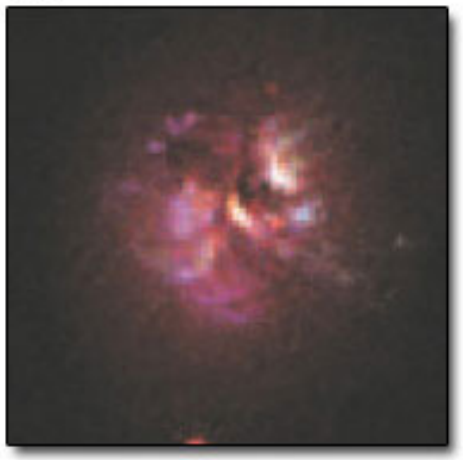

[OIII]
Type 1
Mkn 290
spectral flux density F_λ /arbitrary units
16
12
8
4
0
[OIII]
Hβ
Hγ
[OIII]
Hε
Hδ
HeII
400
450
500
550
600
650
700
wavelength λ/nm
(a)
24
20
16
12
8
4
0
[OIII]
Type 2
Mkn 270
[OII]
[OIII]
Hγ
[OIII]
Hβ
[NI]
Hδ
(b)

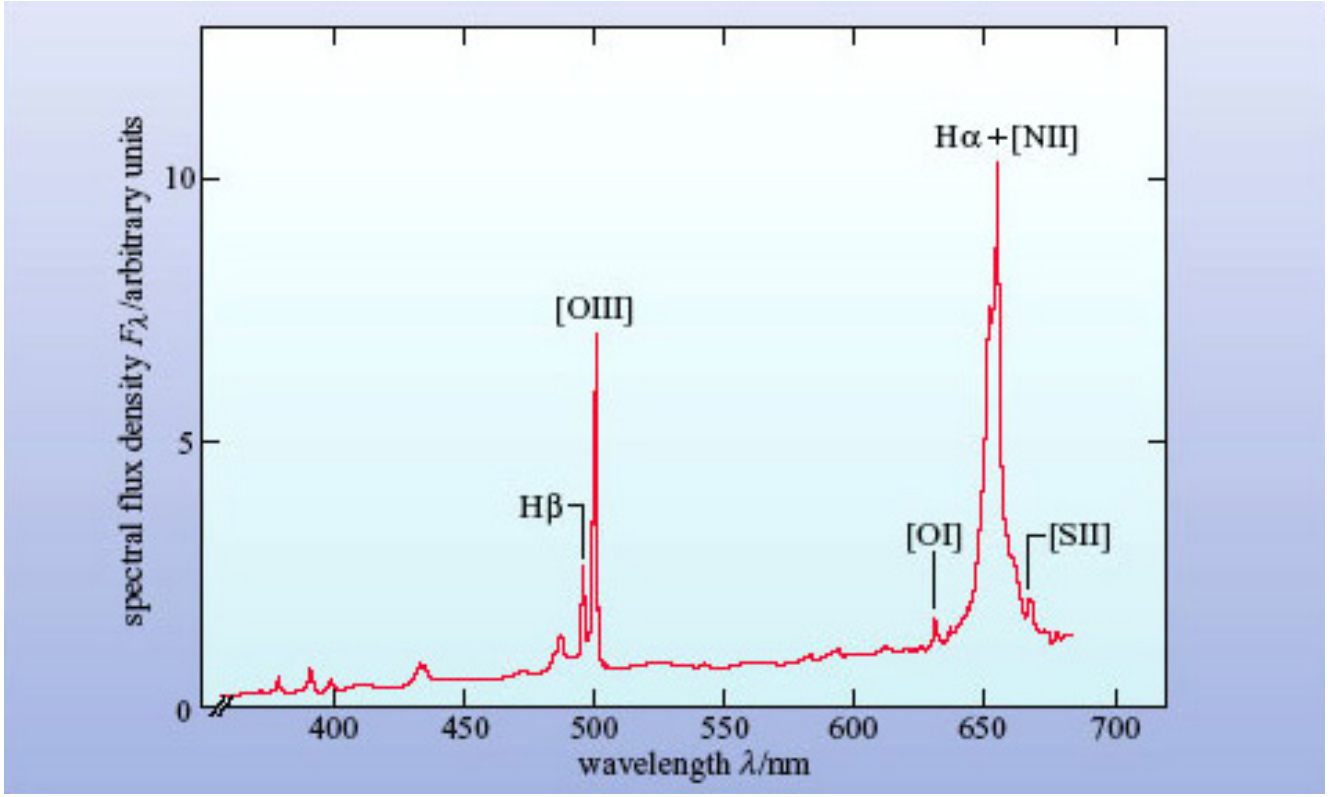
radijske g.

- Labod A

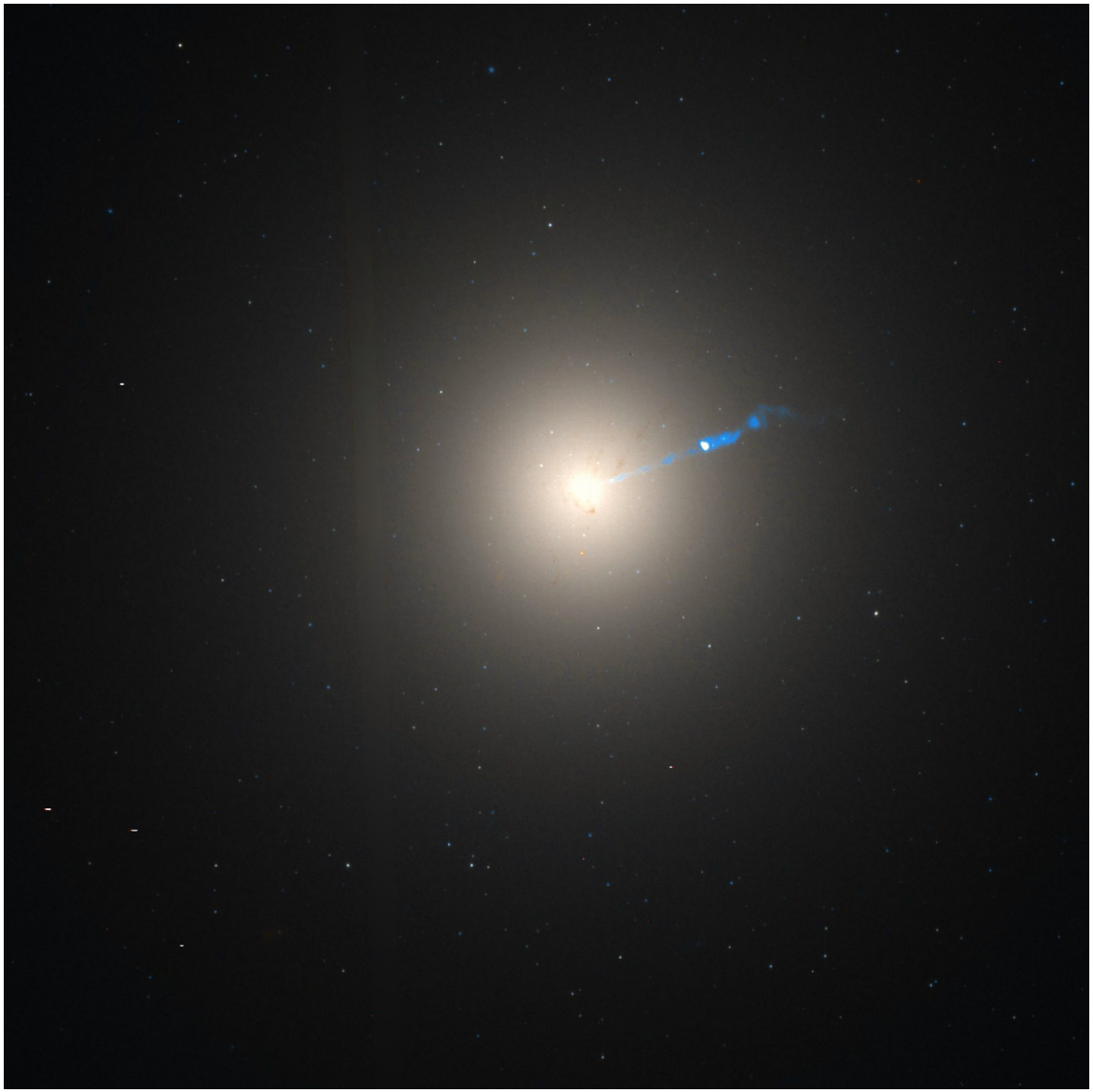


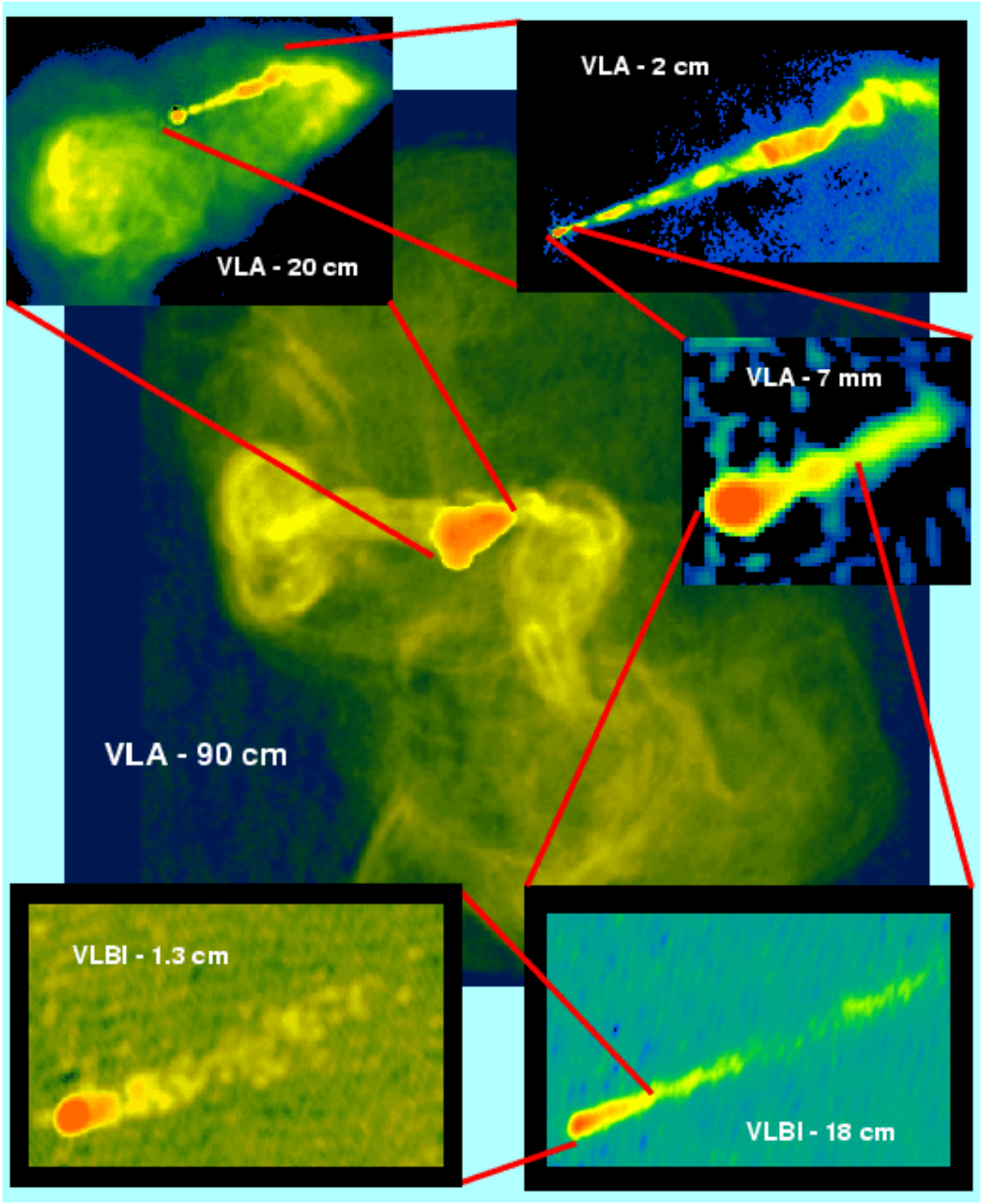




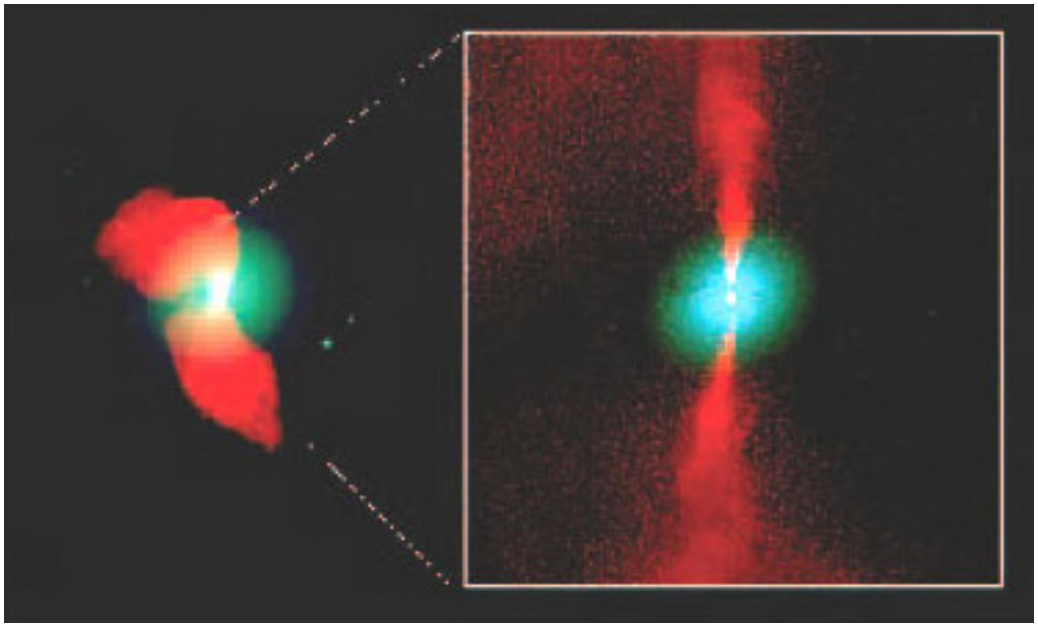

spectral flux density F_λ/arbitrary units
10
5
0
400
450
500
550
600
650
700
wavelength λ/nm
Hα+[NII]
[OIII]
Hβ
[OI]
[SII]

M 87

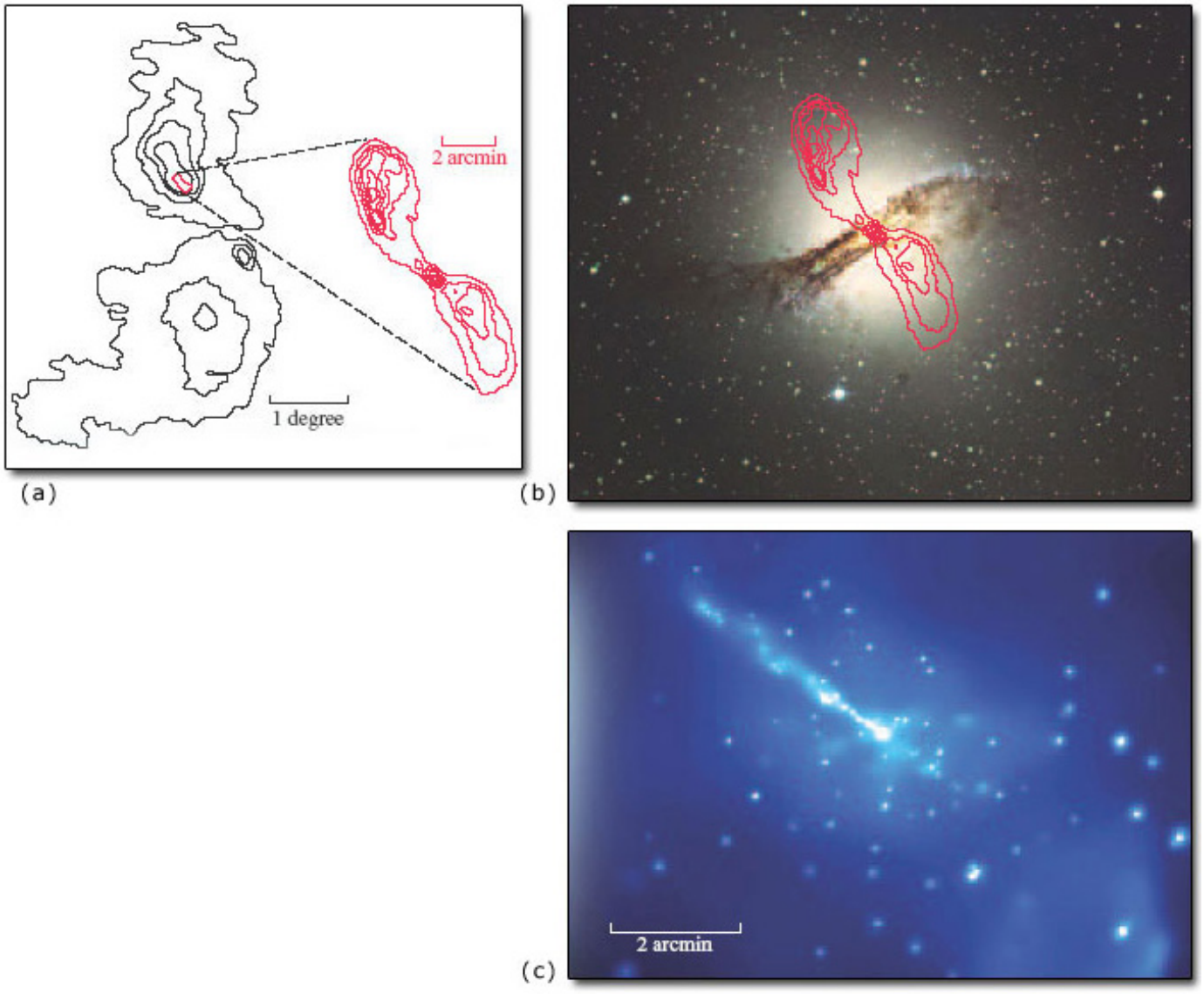



VLA - 2 cm
VLA - 20 cm
VLA - 7 mm
VLA - 90 cm
VLBI - 1.3 cm
VLBI - 18 cm

M 84



Kentaver A

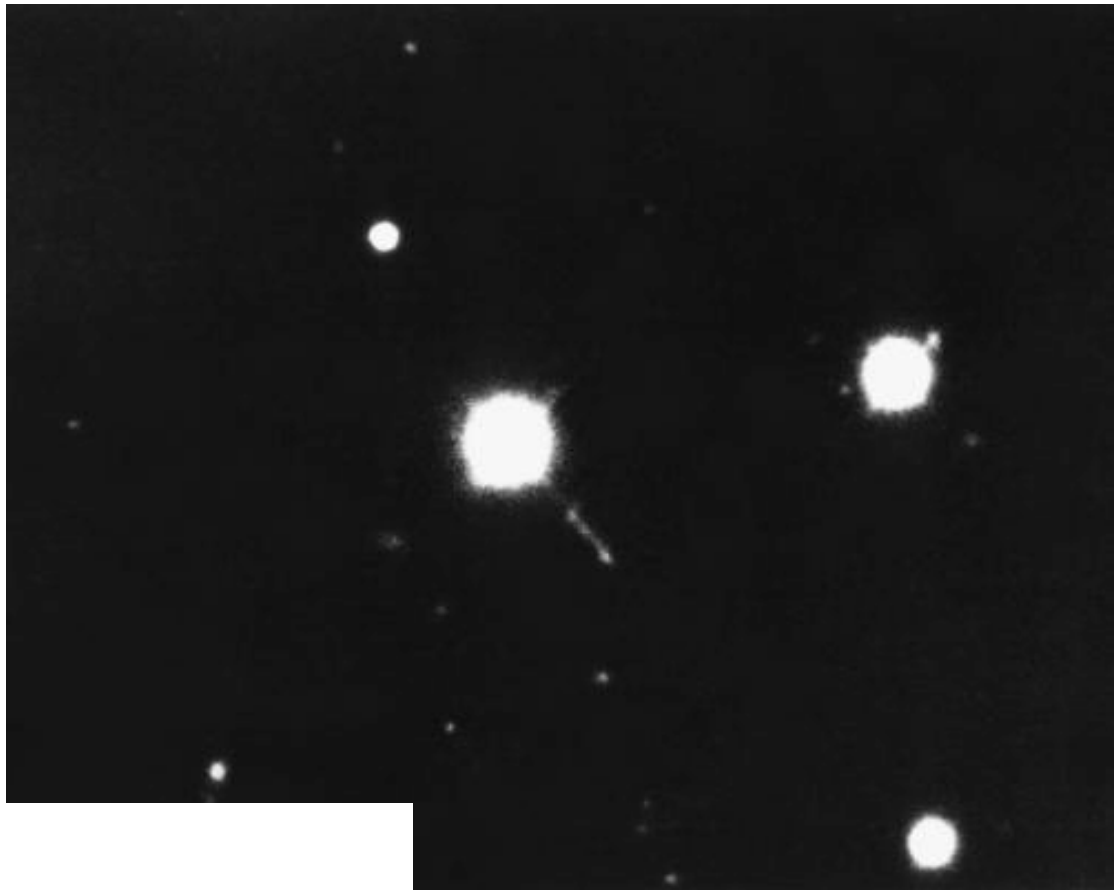


kvazarji

quasar –

‘quasi-stellar radio source’ (QSR)

ali ‘quasi-stellar object’ (QSO)



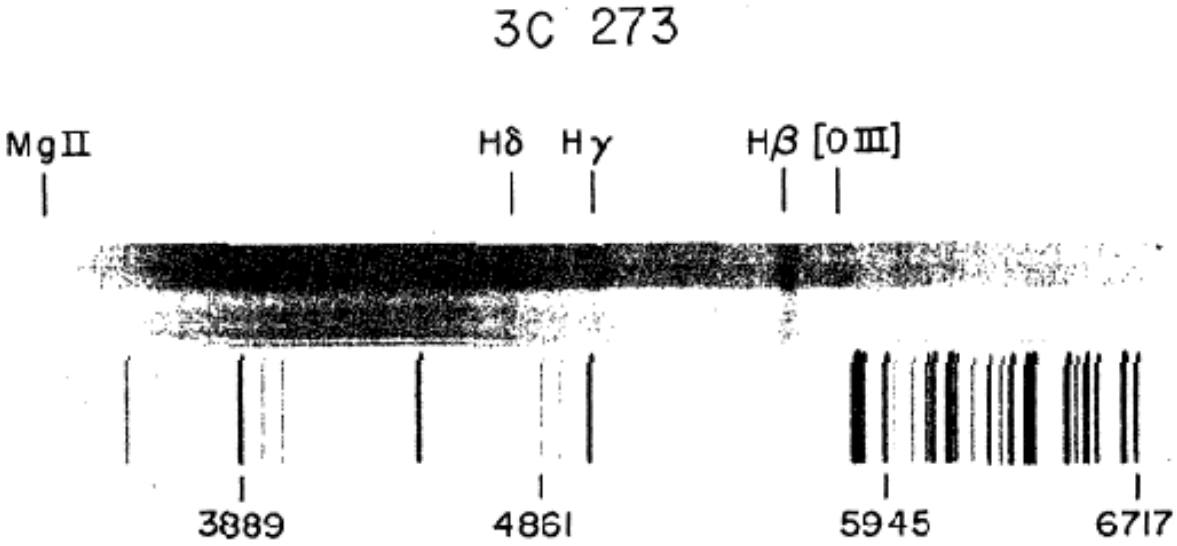
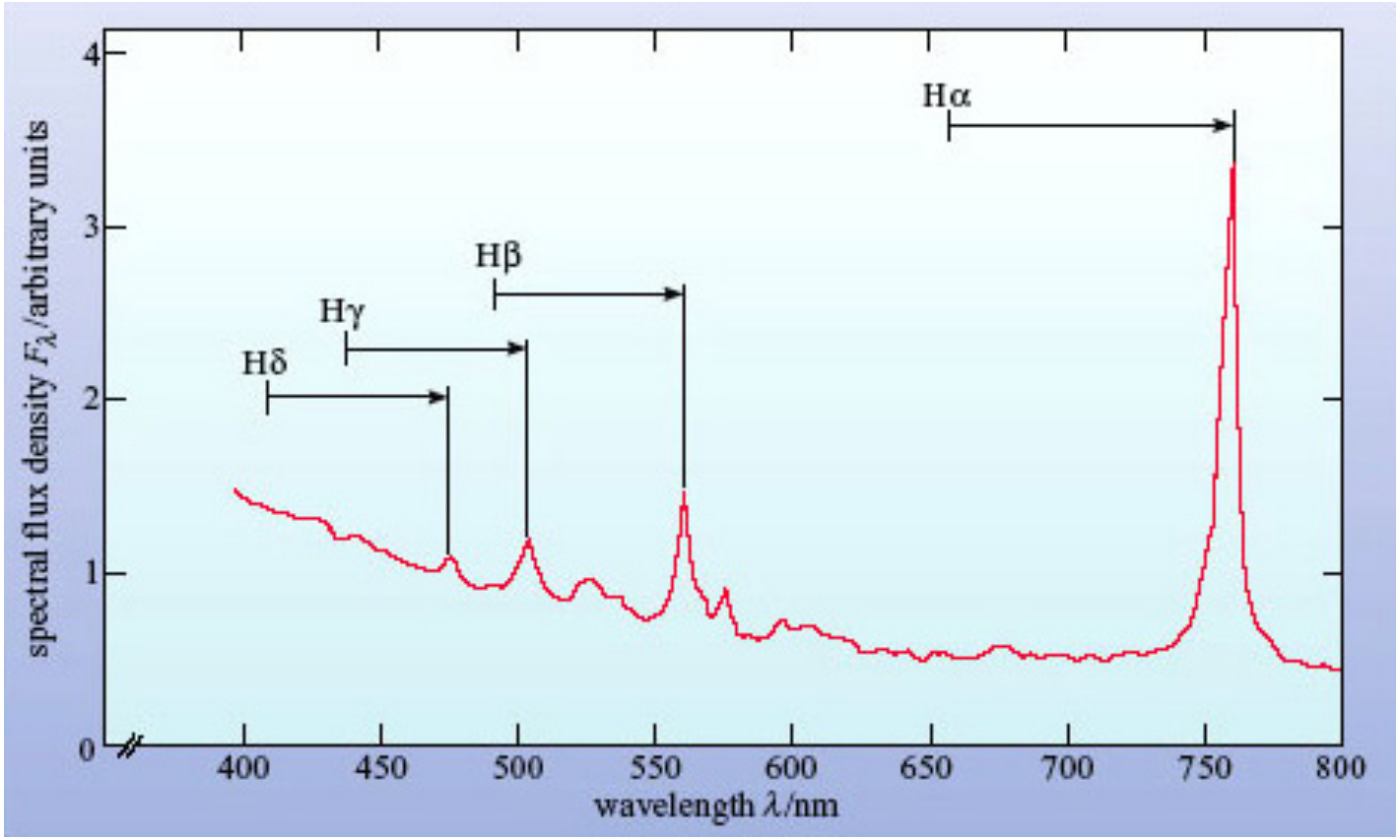
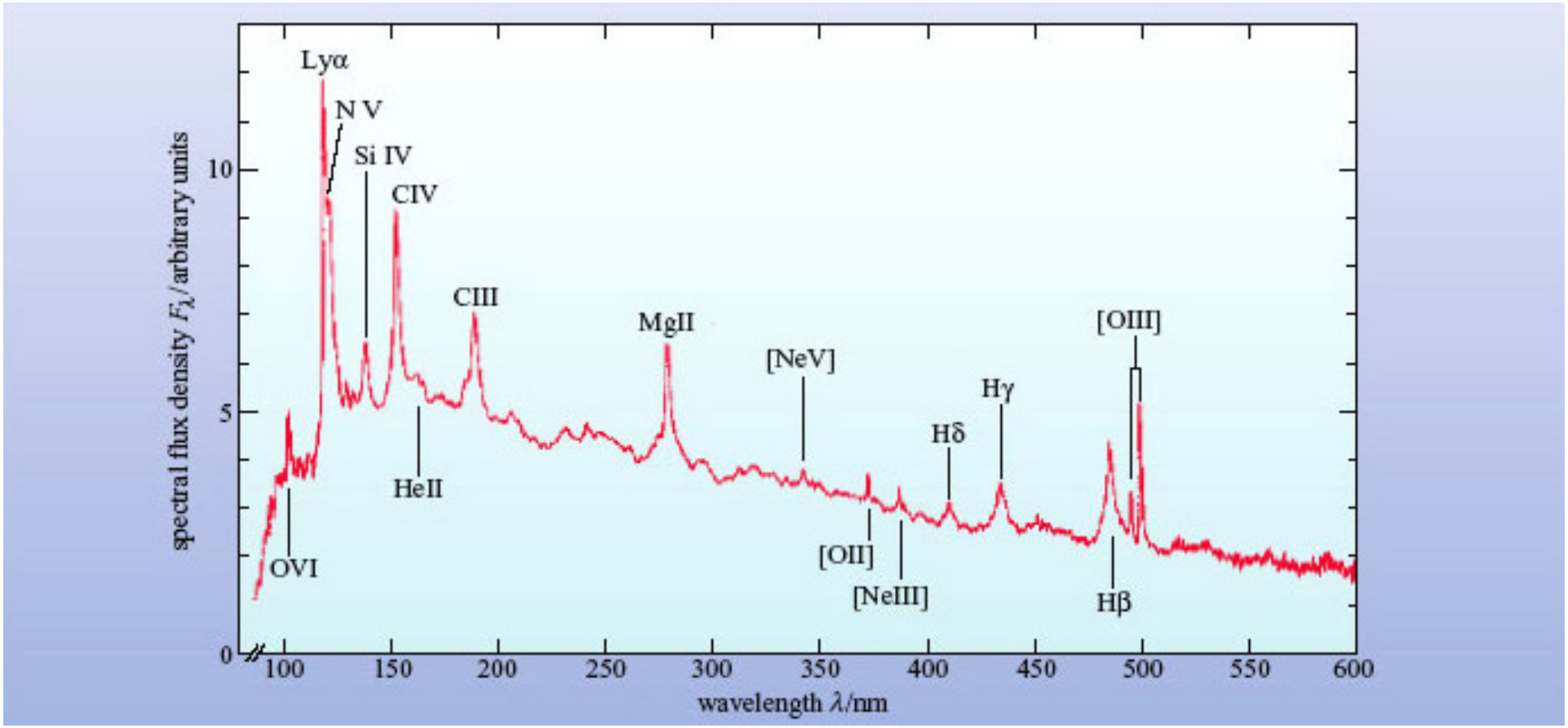
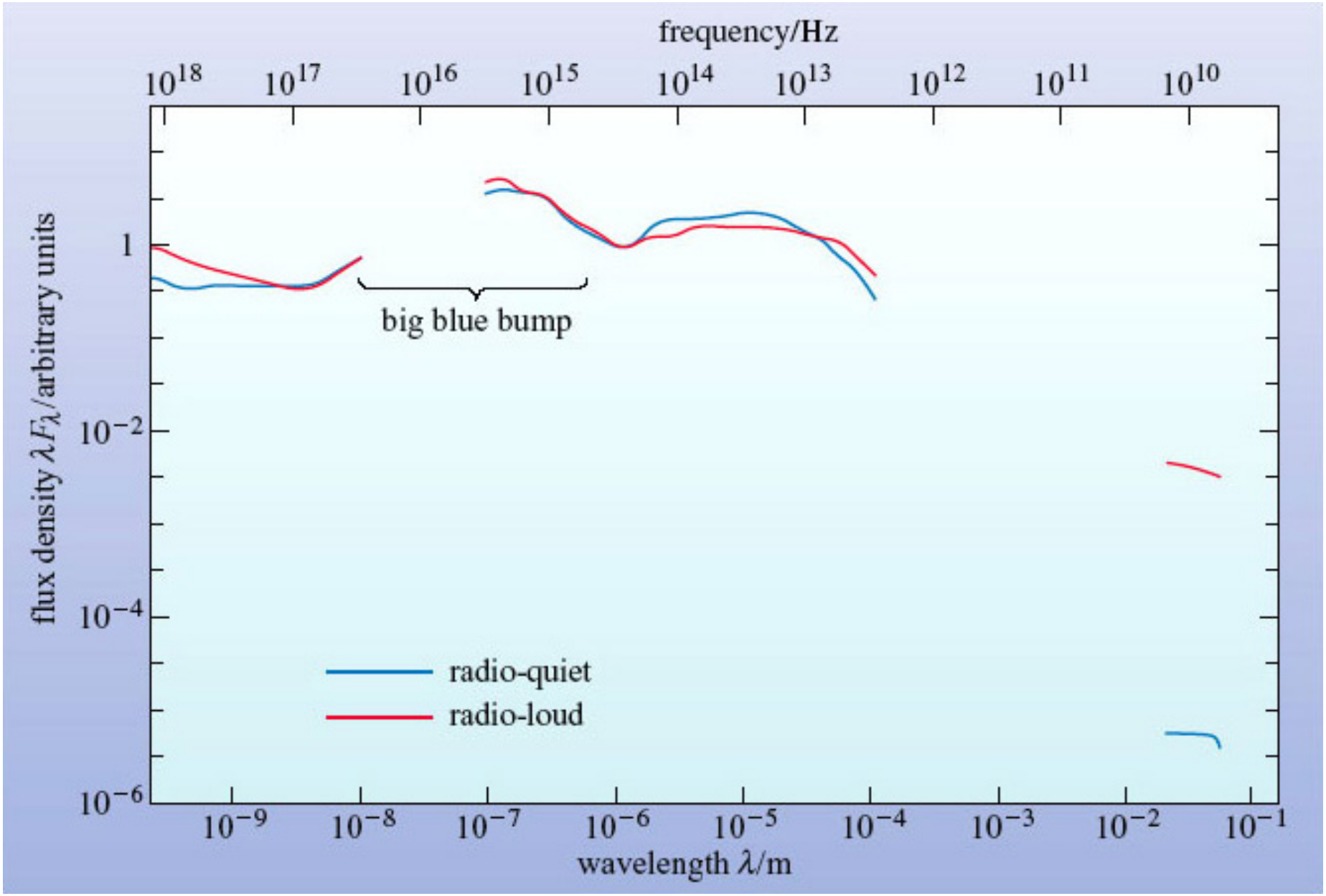


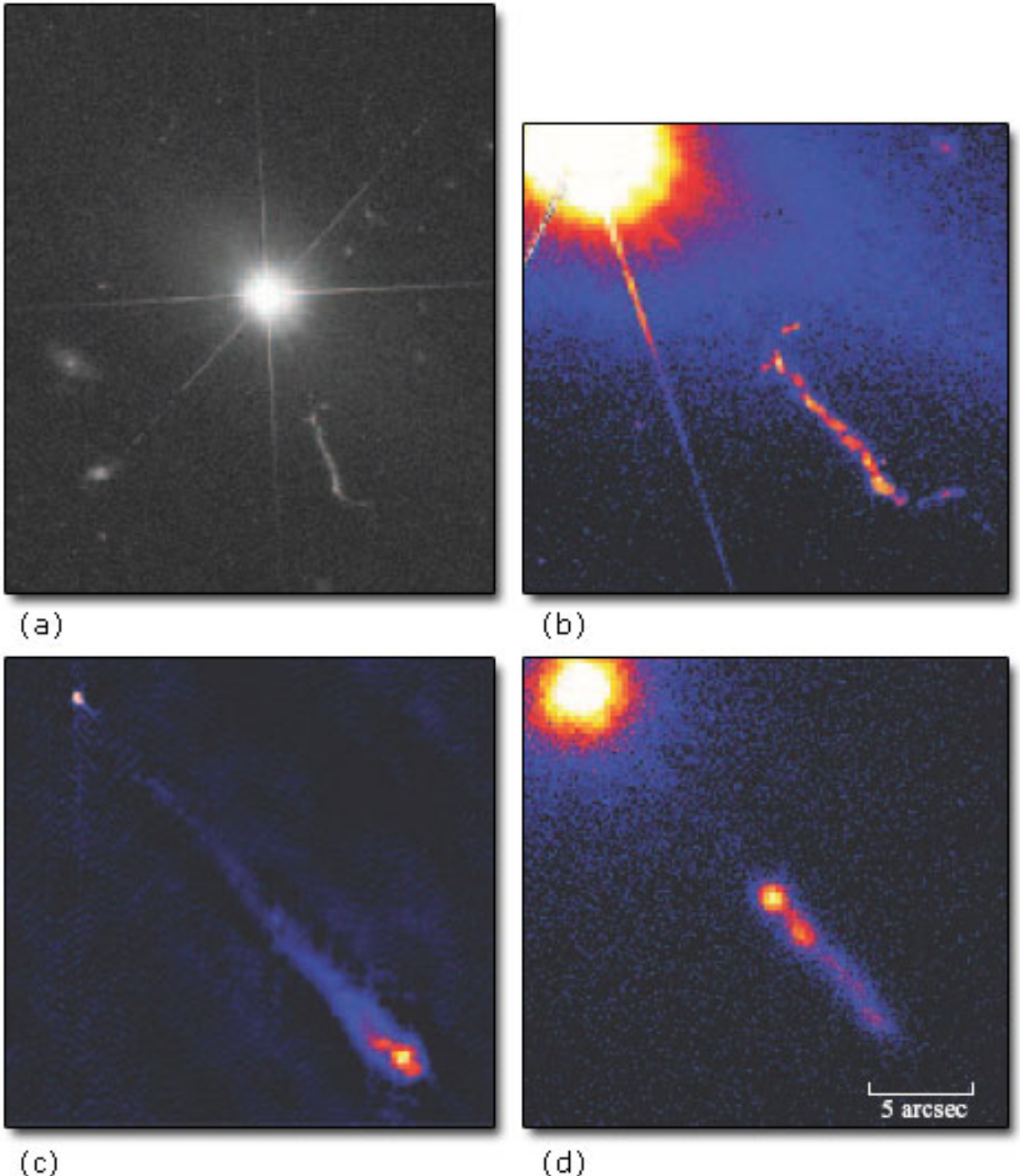
FIG. 2.—Spectrum of the quasi-stellar object 3C 273B, 400 Å/mm original, 103a-F, January 23, 1963. The comparison spectrum is H + He — Ne. Exposure over the upper half of slit was three times that over the lower half. Redshifted emission lines of H and [O III] are indicated; also the barely visible line of Mg II, confirmed on denser exposures.


Hα
Hβ
Hγ
Hδ
spectral flux density F_λ/arbitrary units
wavelength λ/nm
0
1
2
3
4
400
450
500
550
600
650
700
750
800

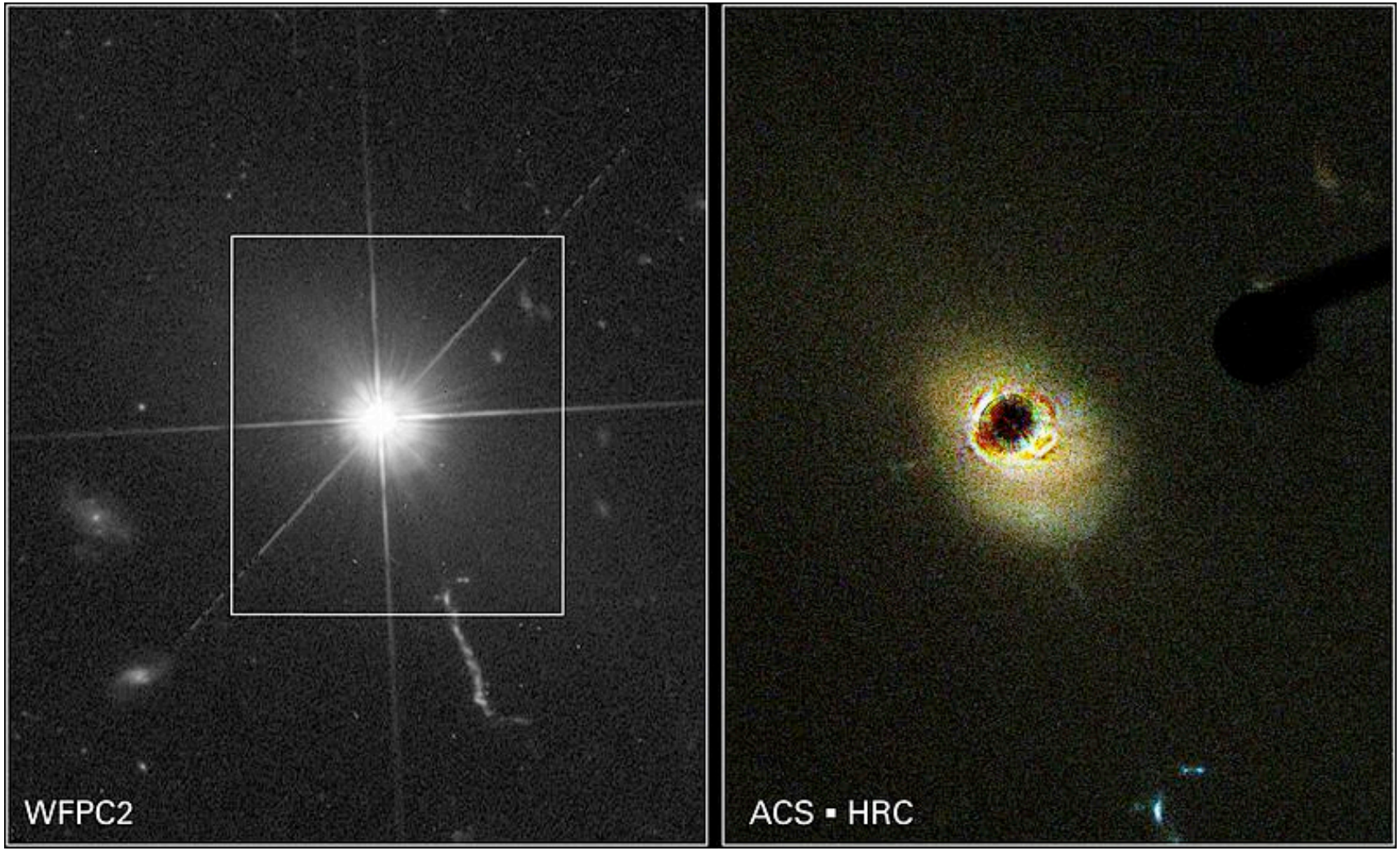

Lyα
N V
Si IV
CIV
CIII
MgII
[NeV]
[OIII]
Hγ
Hδ
HeII
OVI
[OII]
[NeIII]
Hβ
spectral flux density F_λ/arbitrary units
0
5
10
100
150
200
250
300
350
400
450
500
550
600
wavelength λ/nm

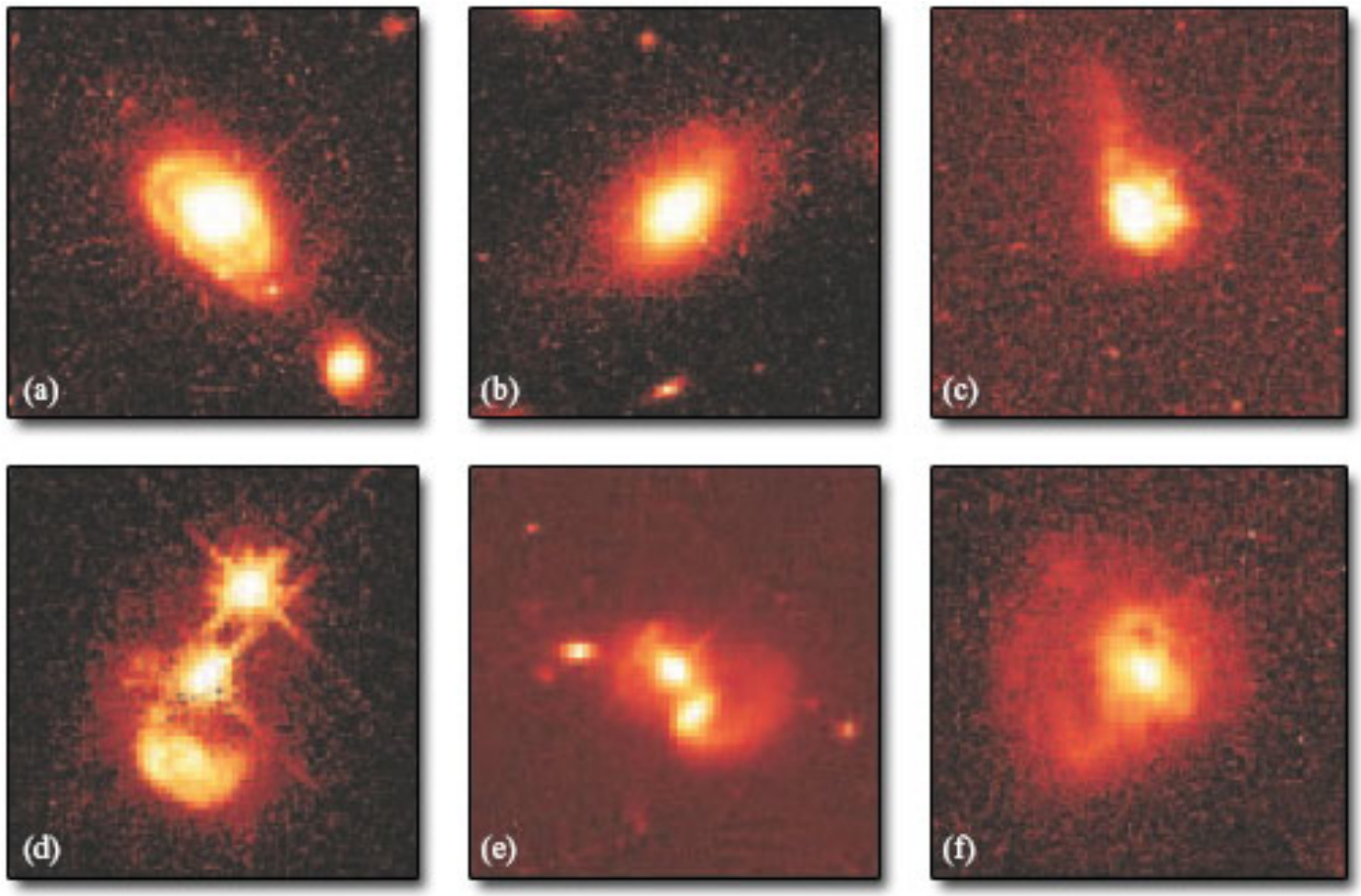

frequency/Hz
10^{18}
10^{17}
10^{16}
10^{15}
10^{14}
10^{13}
10^{12}
10^{11}
10^{10}
flux density λF_λ/arbitrary units
1
10^{-2}
10^{-4}
10^{-6}
big blue bump
radio-quiet
radio-loud
10^{-9}
10^{-8}
10^{-7}
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
wavelength λ/m

jeti

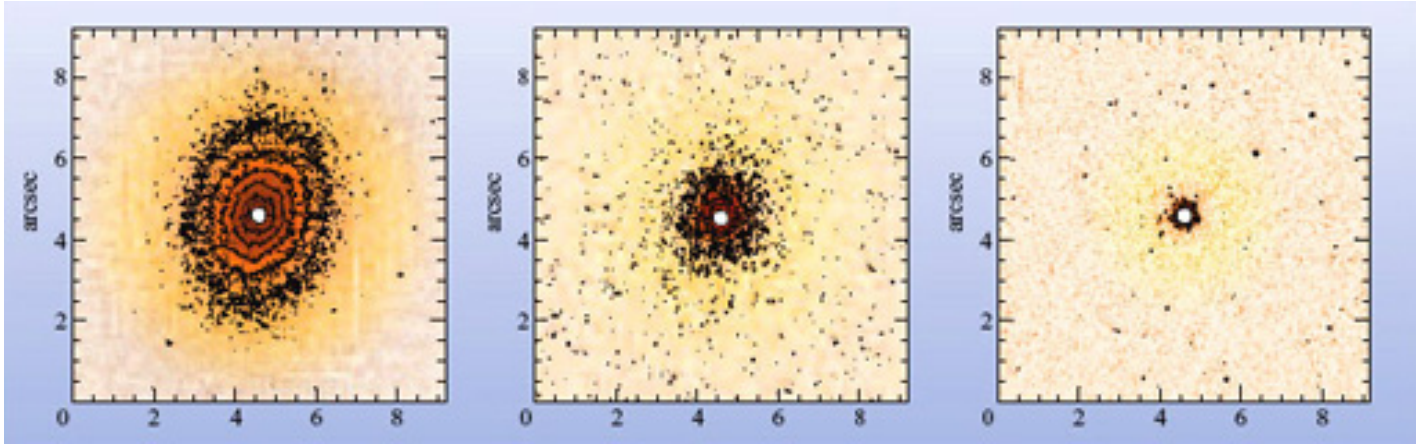


3C 273




(a)
(b)
(c)
(d)
(e)
(f)

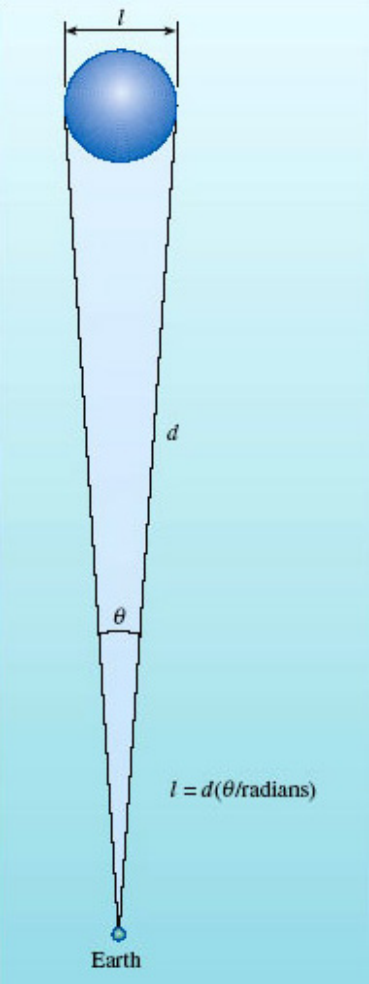
blazarji



Characteristic	**Active galaxies**				
	Normal	**Seyfert**	**Quasar**	**Radio galaxy**	**Blazar**
Narrow emission lines	weak	yes	yes	yes	no
Broad emission lines	no	some cases	yes	some cases	some cases
X-rays	weak	some cases	some cases	some cases	yes
UV excess	no	some cases	yes	some cases	yes
Far-infrared excess	no	yes	yes	yes	no
Strong radio emission	no	no	some cases	yes	some cases
Jets and lobes	no	no	some cases	yes	no
Variability	no	yes	yes	yes	yes

skupno: velik izsev iz jedra in spremenljivost

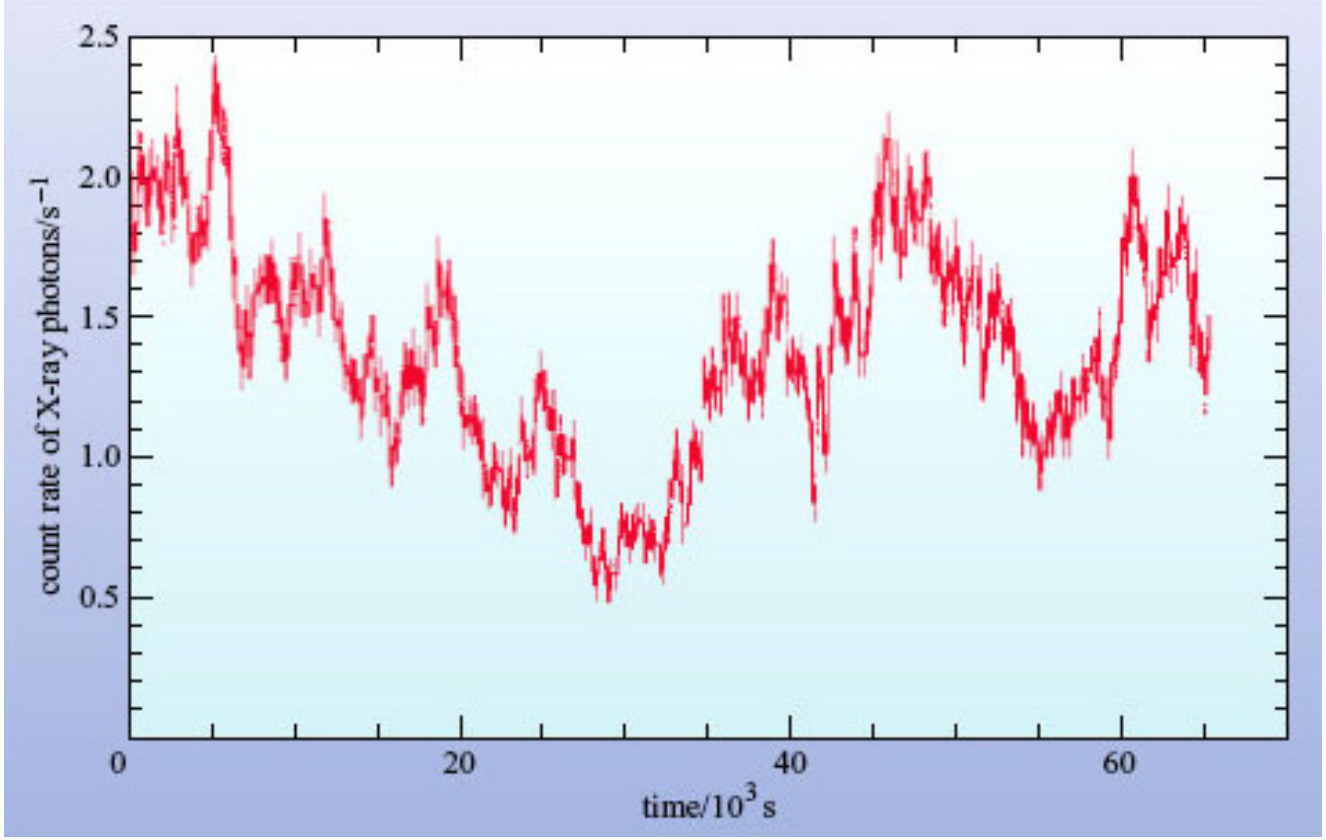
velikost AGJ



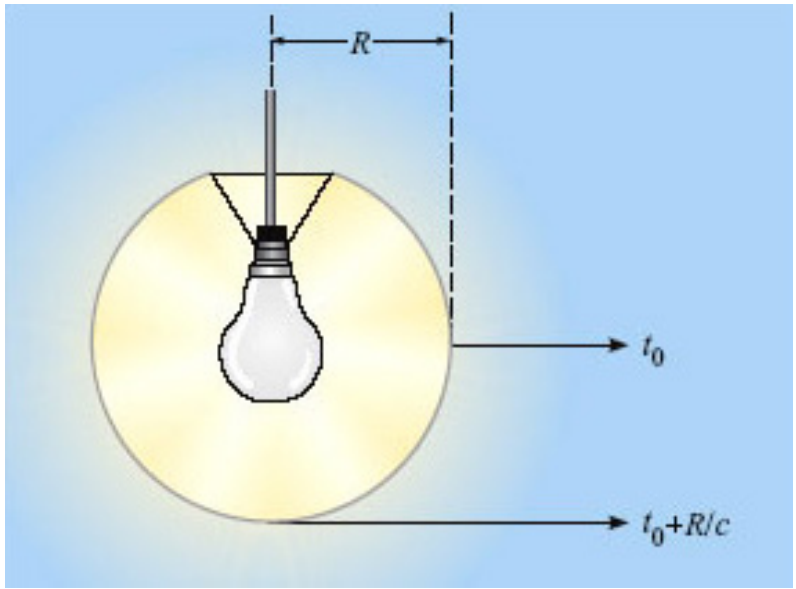
ne razločimo niti z najboljšimi teleskopi
zgornja meja: $l = d \times \Theta < 1$ pc

spremenljivost

Seyfertova galaksija MCG–6–30–15



$\Delta t \approx 10^4$ s



žarnica + senčnik:

$\Delta t = R/c$

Kaj če žarnica utripa z Δt_u?

- če $\Delta t_u < \Delta t = R/c$, se utripanje zabriše
- spremembe vidimo le, če $\Delta t_u > \Delta t = R/c$

oz.

če vidimo spremembe na $\Delta t'$ vemo, da je $\Delta t' \geq R/c$ oz. $R \leq c\,\Delta t'$

ocena za velikost AGJ: $R \approx c\,\Delta t'$

primer: $\Delta t = 10^4$ s : $R \approx 0.0001$ pc ≈ 20 a.e.

izsev AGJ

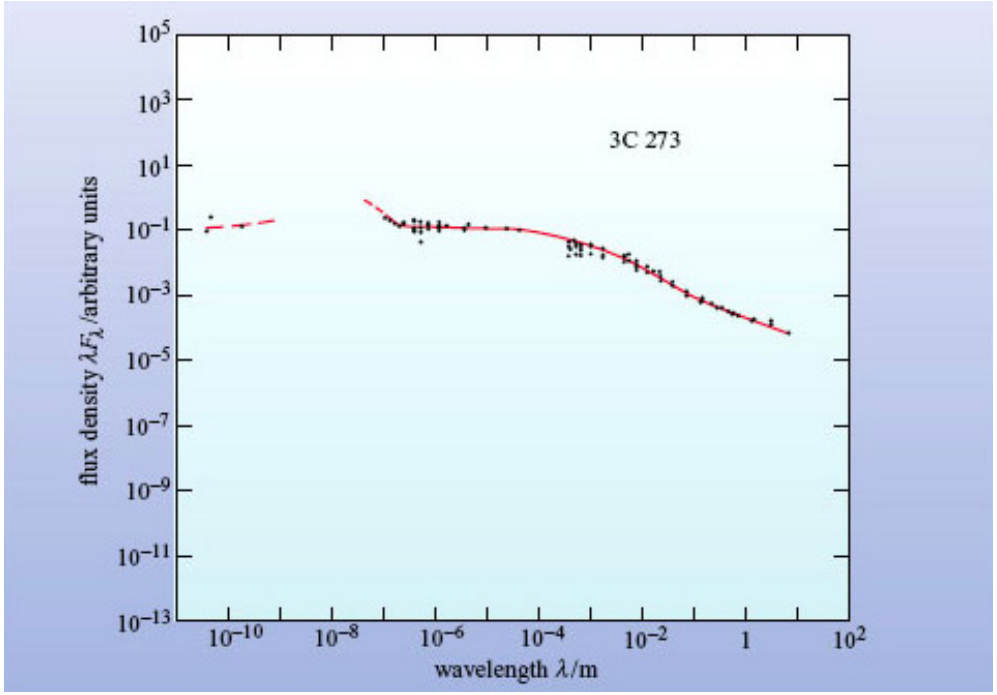
sevajo v širokem območju valovnih dolžin – skupno vsaj nekajkrat več kot normalne galaksije!

naša Galaksija:

$L_{Galaksije}=2 \times 10^{10}\ L_S = 8 \times 10^{36}$ W

"karakteristični izsev" AGJ:

$L_{AGJ} \approx 10^{38}$ W



Ogromen izsev iz majhnega območja! Kaj jih "poganja"?

supermasivna črna luknja

$R_{Schwarzschild} = 2GM/c^2$ ... horizont dogodkov

Kakšno črno luknjo lahko spravimo v AGJ?

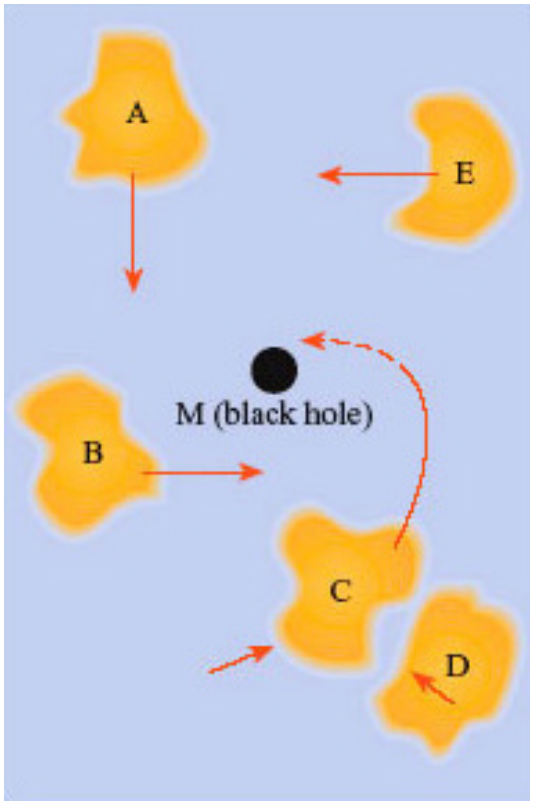
$\Delta t \approx 1$ dan : $R < c\,\Delta t = 3\times 10^{13}$ m

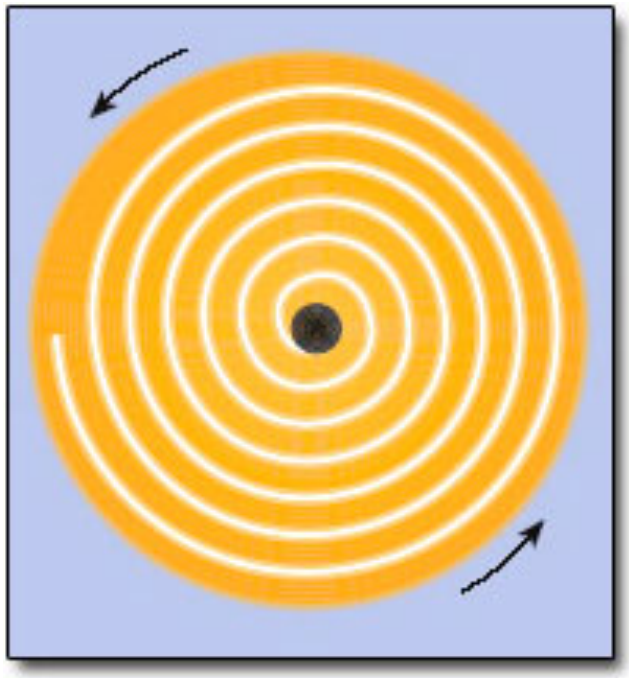
naj bo $R \approx 10\ R_{Sch}$:

$M = R_{Sch}c^2/2G = 10^9\ M_{Sonca}$

To je samo zgornja meja, ne dokaz, da ima črna luknja tako veliko maso!

akrecijski disk





disk se segreva, notranji deli najbolj!
velikost primerljiva z Osončjem

akrecijska moč

prihaja iz gravitacijske energije:

$\Delta E_{grav} \approx GMm/r_{končen}$

$r_{končen} \approx 5\ R_{Sch}$:

$\Delta E_{grav} \approx 0.1\ mc^2$ (jedrsko zlivanje vodika v helij: $\Delta E_{fuzija} \approx 0.007\ mc^2$)

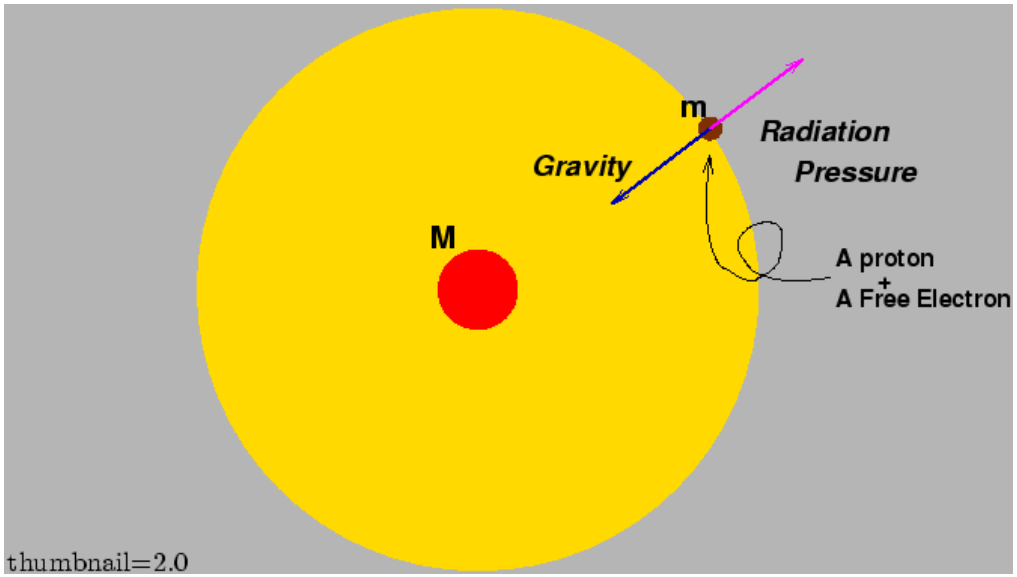
izsev AGJ odvisen od hitrosti padanja snovi: dm/dt

$L_{AGJ} \approx 0.1\ dm/dt\ c^2$

$L_{AGJ} \approx 10^{38}$ W: $dm/dt \approx 10^{22}$ kg/s $\approx 0.2\ M_{Sonca}$/leto

Ali je lahko L poljubno velik?

Eddingtonova limita



$F_g \geq F_{sev}$

$GMm/r^2 \geq \sigma_T \, j/c$

$L \leq (4\pi G m_p c/\sigma_T) \, M = L_{Edd}$

$L_{Edd} = (1.3 \times 10^{31}) \, M/M_{Sonca}$

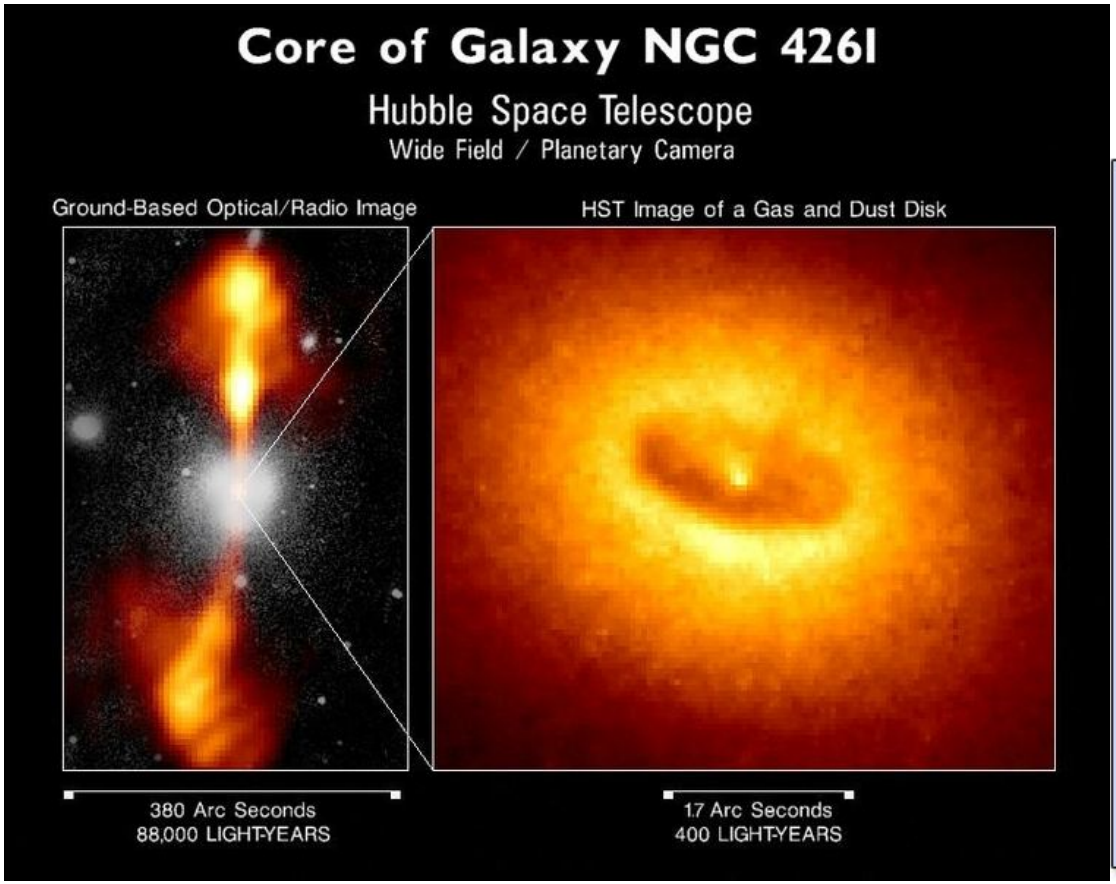
$p_{sev} = j/c$
$j = L/4\pi r^2$
Thomsonov presek za sipanje fotonov na e^-:
$\sigma_T = 6.65 \times 10^{-29} \, m^2$

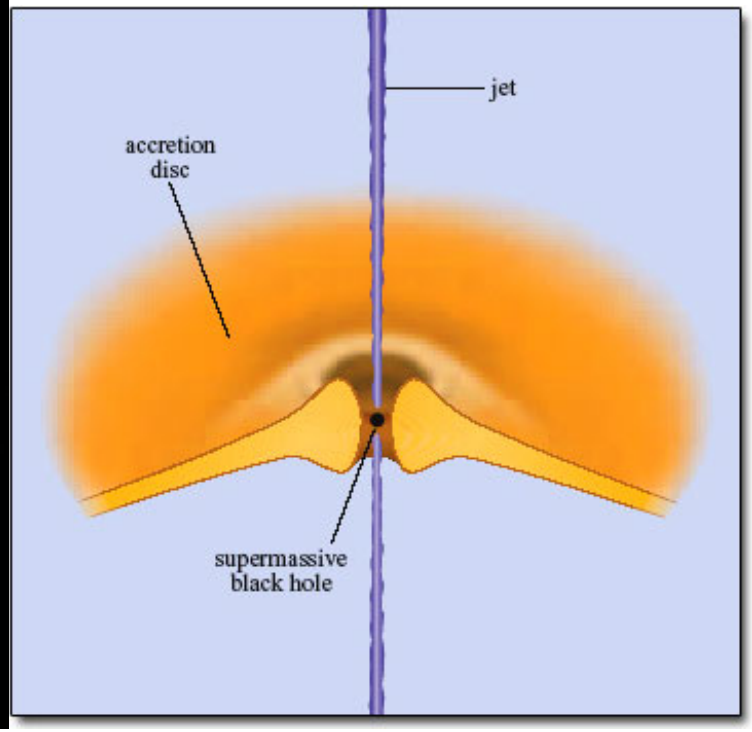
če $L=10^{38}$ W:
$M \geq 7.7 \times 10^6 \, M_{Sonca}$

Zato rabimo supermasivno črno luknjo!

tipično: $M \approx 10^8 - 10^9 \, M_{Sonca}$ ($R_{Sch} \approx$2-20 a.e.)
$dm/dt \approx$ nekaj 0.1 M_{Sonca}/leto

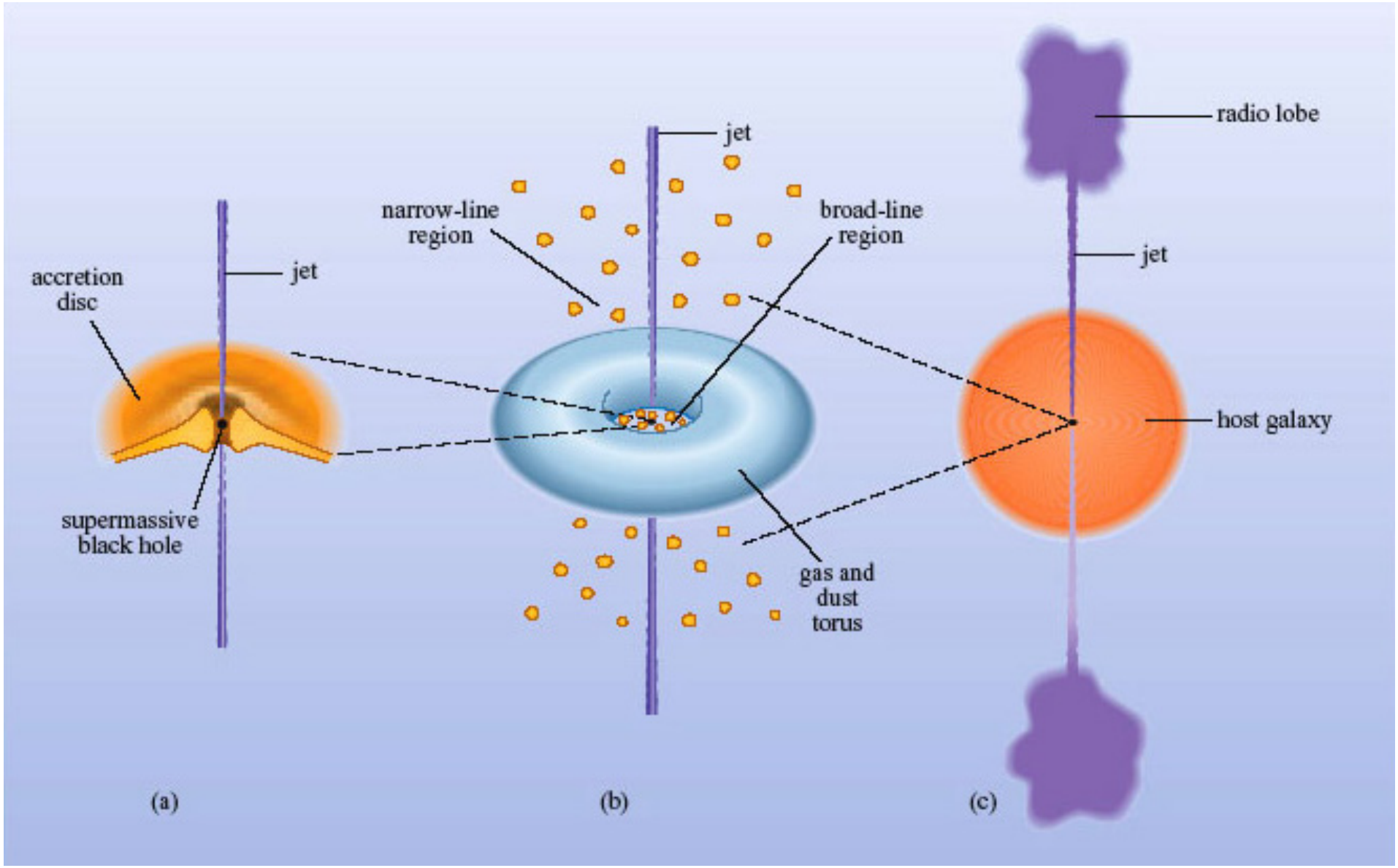
jeti

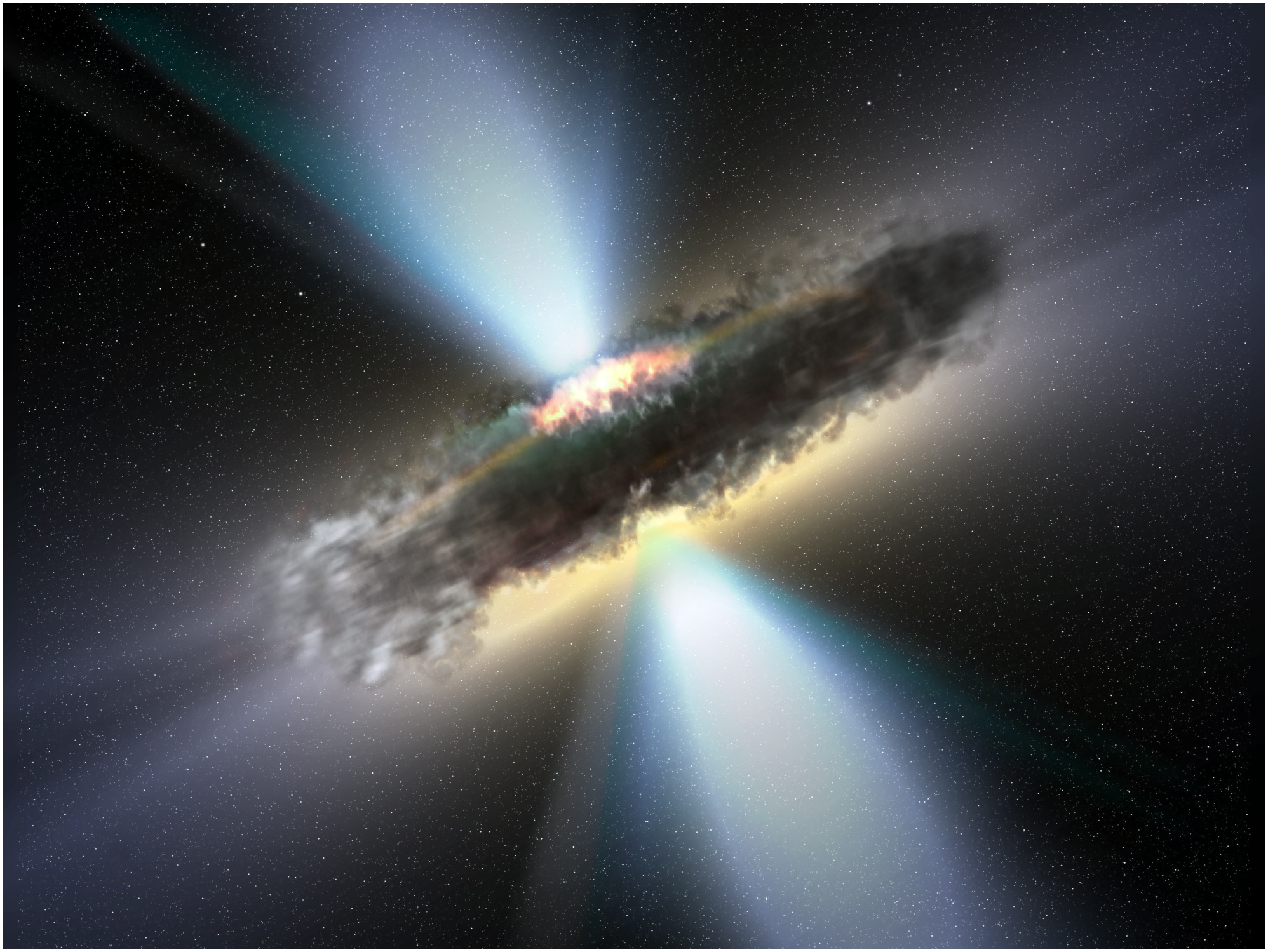




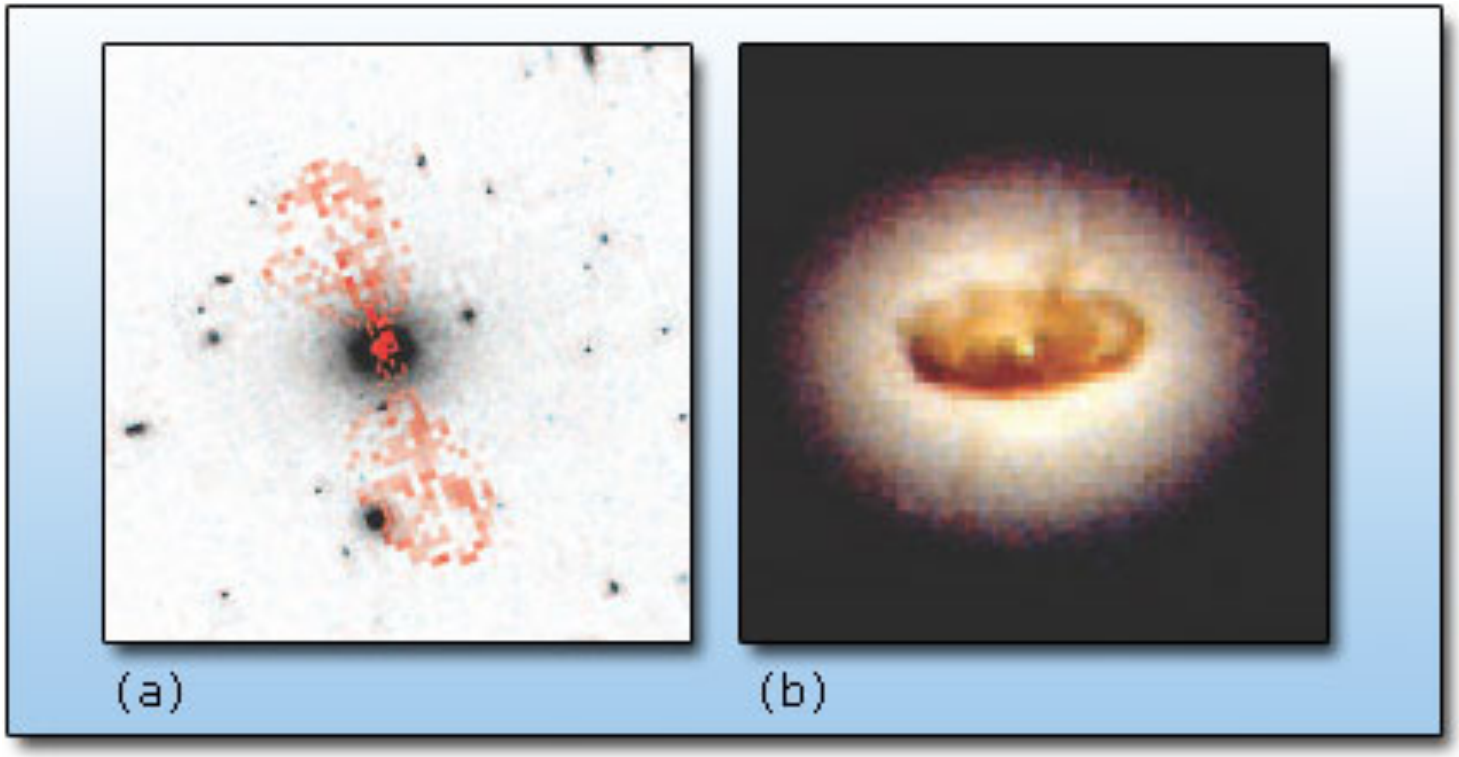
jet – skoraj s c: aberacija svetlobe

model AGJ


jet
radio lobe
narrow-line region
broad-line region
jet
accretion disc
jet
host galaxy
supermassive black hole
gas and dust torus
(a)
(b)
(c)

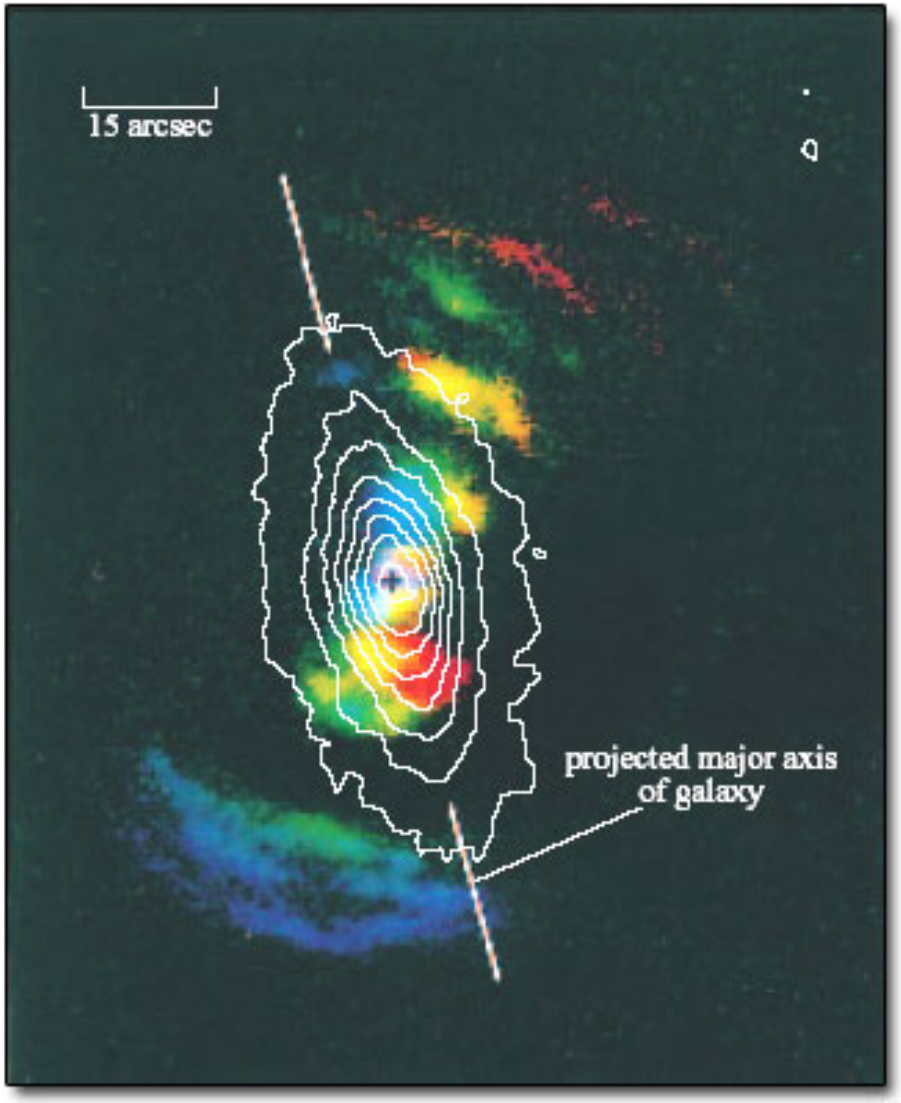


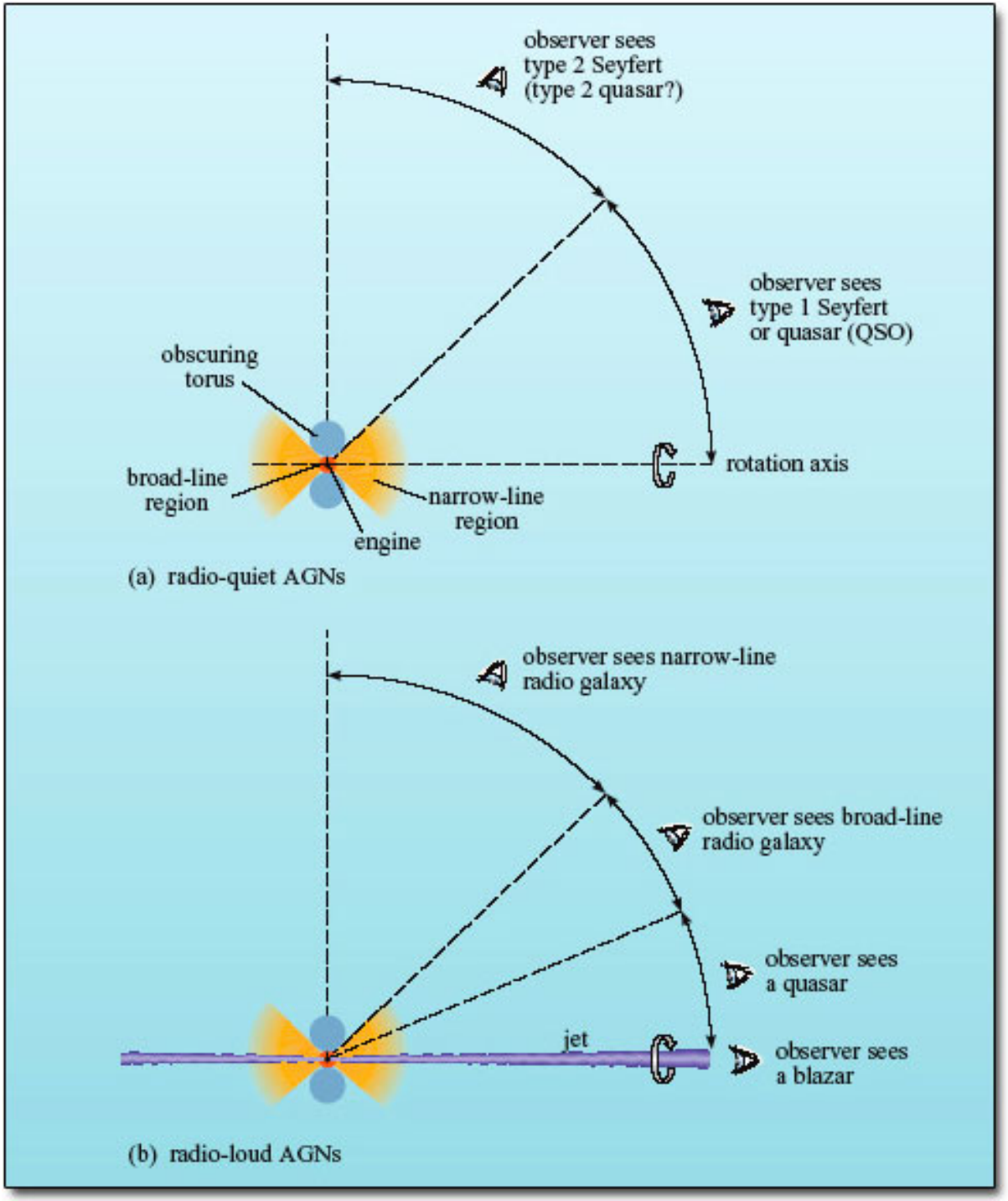
torus



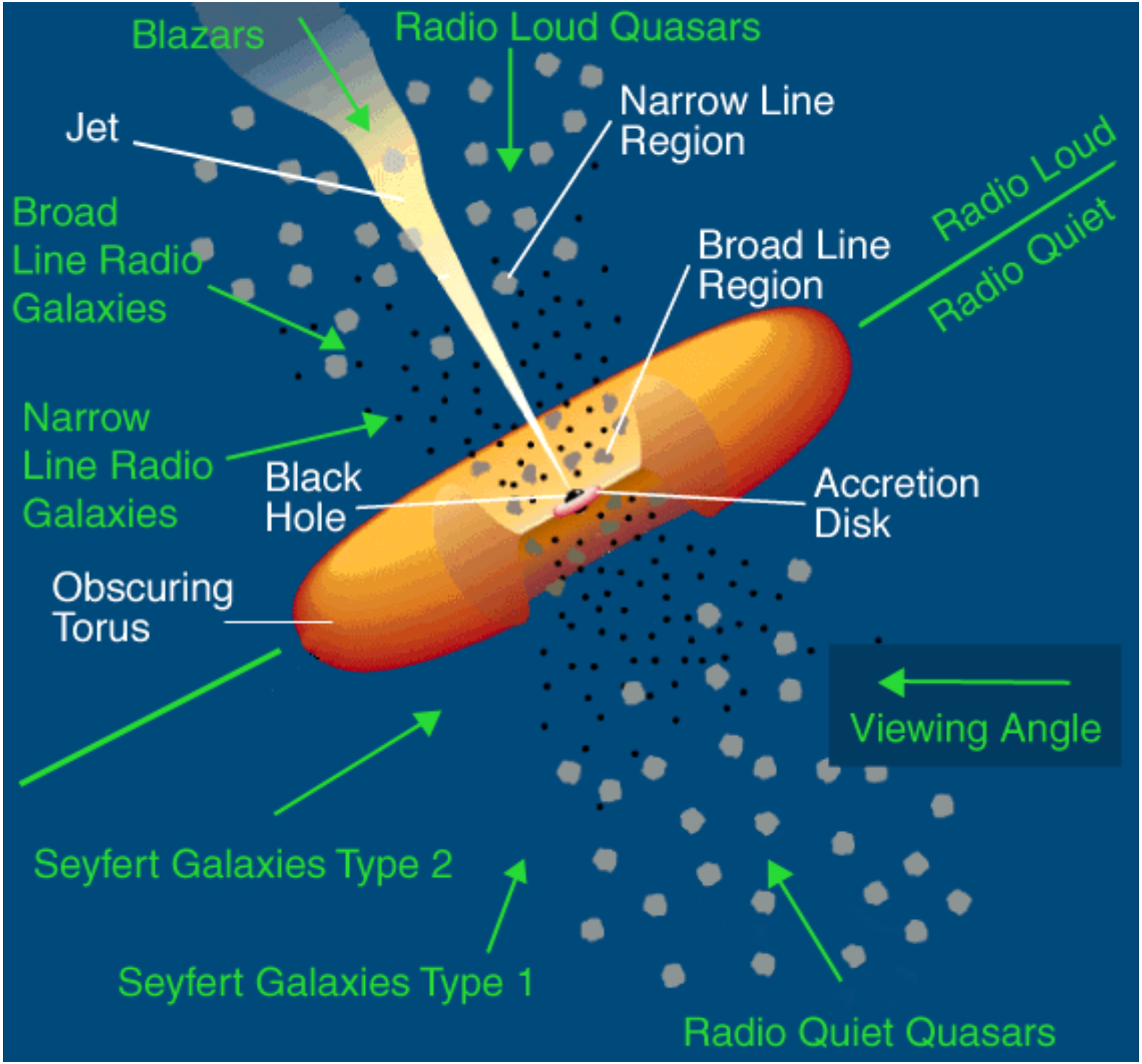
NGC 4261

BL in NL območja

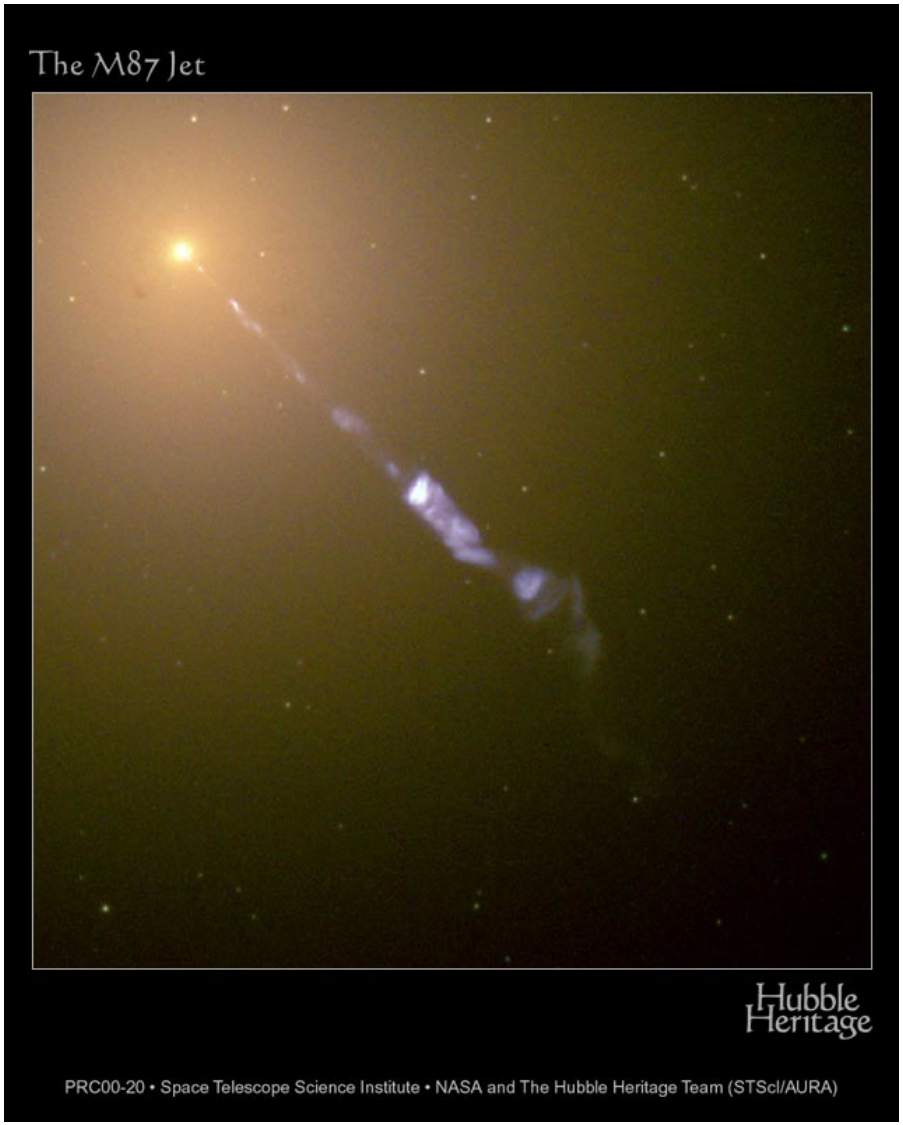


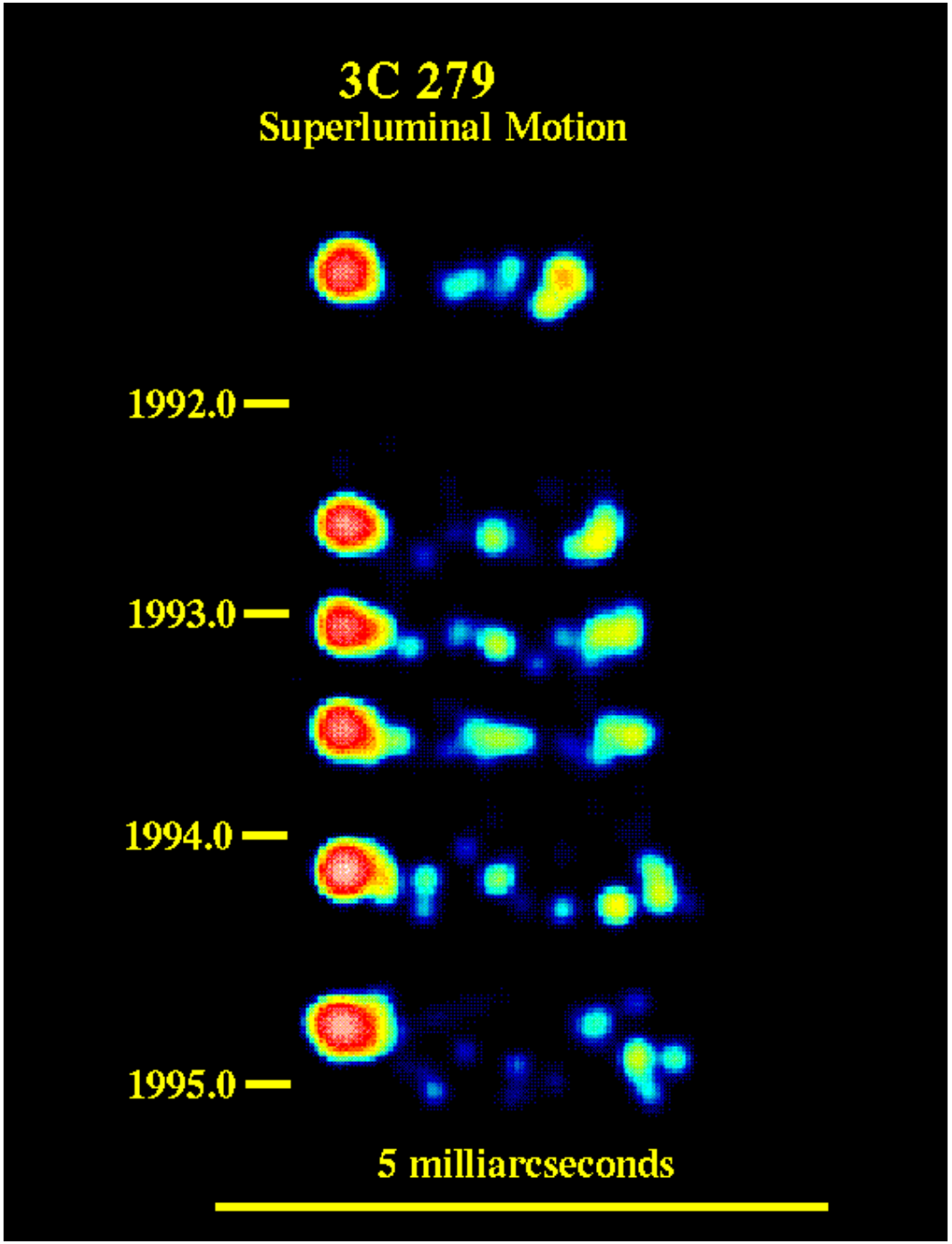


enoten model

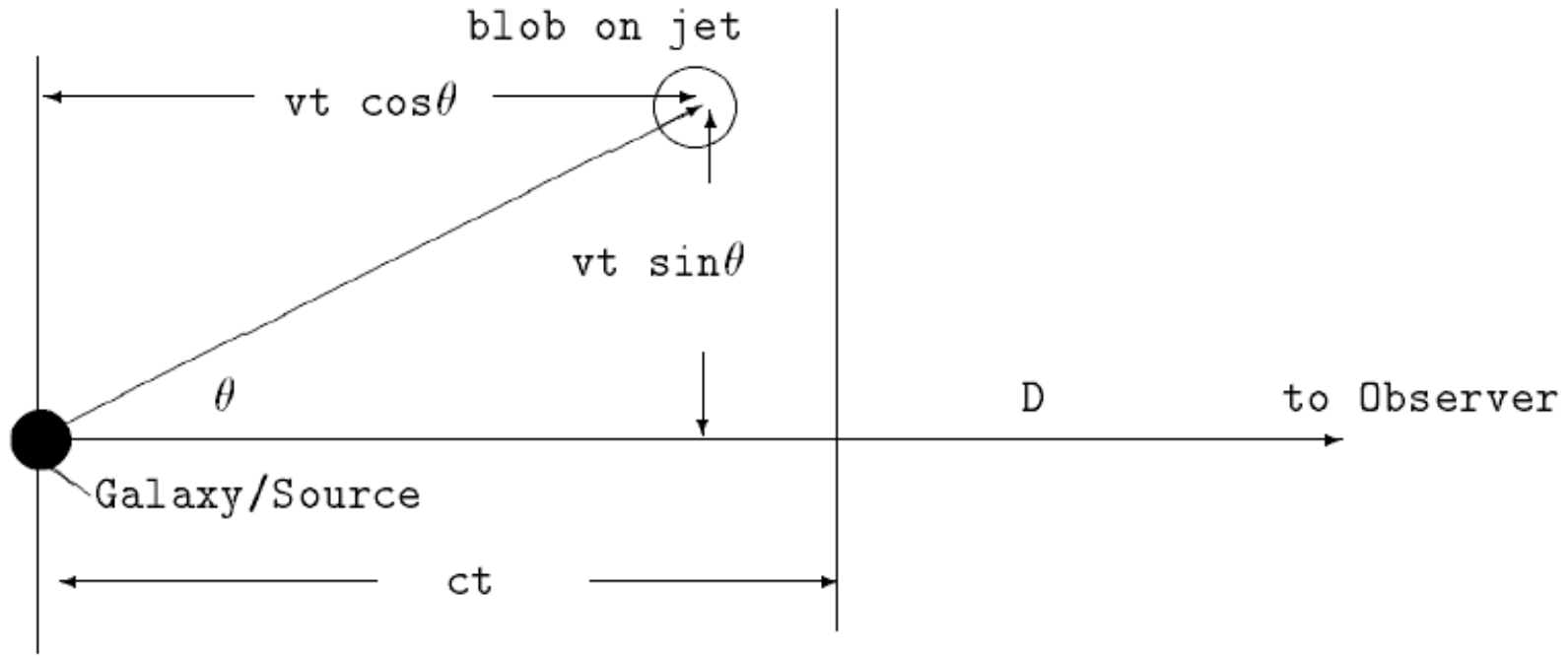

Blazars
Radio Loud Quasars
Jet
Narrow Line Region
Broad Line Radio Galaxies
Broad Line Region
Radio Loud
Radio Quiet
Narrow Line Radio Galaxies
Black Hole
Accretion Disk
Obscuring Torus
Viewing Angle
Seyfert Galaxies Type 2
Seyfert Galaxies Type 1
Radio Quiet Quasars

"Nadsvetlobno" (superluminalno) gibanje





$v_{navidezna}$=4 c



$t = 0$ $\qquad$ t

$t_0 = D/c$ $\qquad$ $t_r = t + (D - vt\ cos\theta)/c$

$$t_r - t_0 = t(1 - \beta cos\theta)$$

delimo vt sin θ s tem časom, da dobimo navidezno hitrost/c:

$$\beta_{apparent-transverse} = \frac{\beta sin\theta}{1 - \beta cos\theta}$$

maksimum, ko je β= cos θ:

$\beta_{apparent-transverse-max} = \beta/\sqrt{1-\beta^2} = \gamma\beta$ oz. ko v ≈c: $v_{navidezna}$=γ c

http://openlearn.open.ac.uk/mod/oucontent/view.php?id=398724