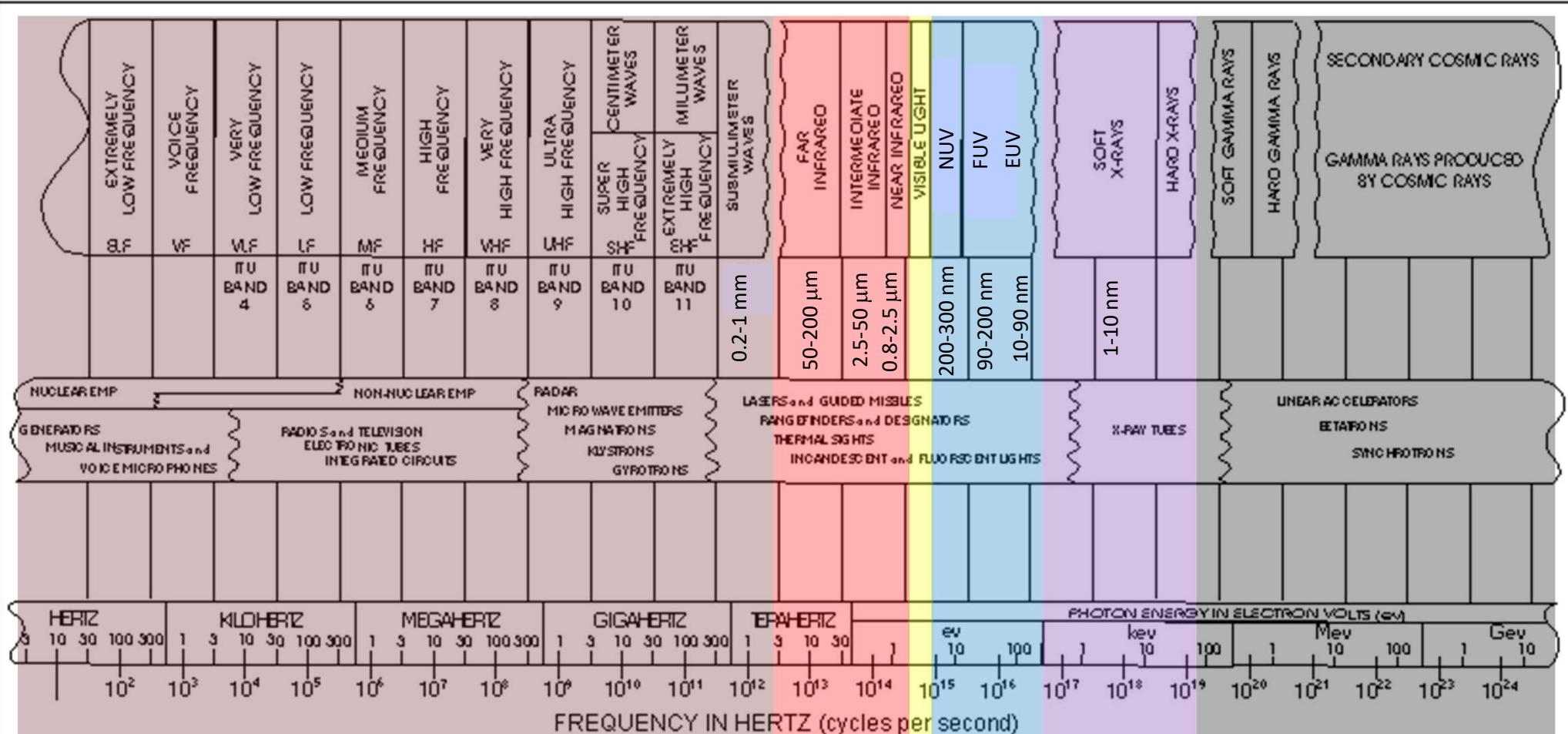


Fundamentos de Astronomía y Astrofísica

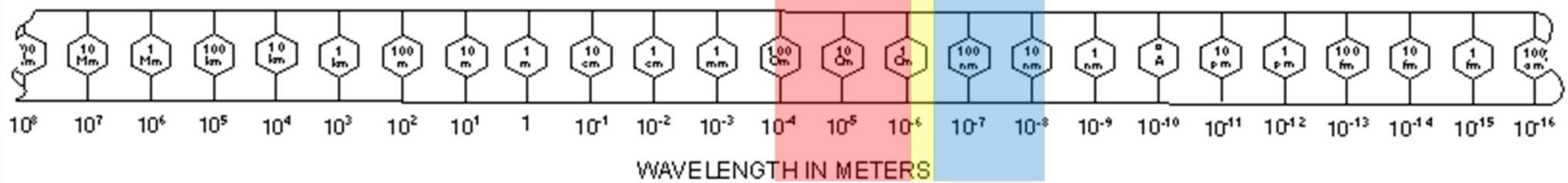
*Tema: Espectros
Astronómicos*

Prof. Dr. César A. Caretta
Dep. de Astronomía – Universidad de Guanajuato
2022



$$1 \text{ Hz} = \text{onda/s}$$

$$1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}$$



$$E = h \nu = h c / \lambda$$

$$1 \mu\text{m} = 10^{-6} \text{ m} \quad 1 \text{ \AA} = 10^{-10} \text{ m}$$

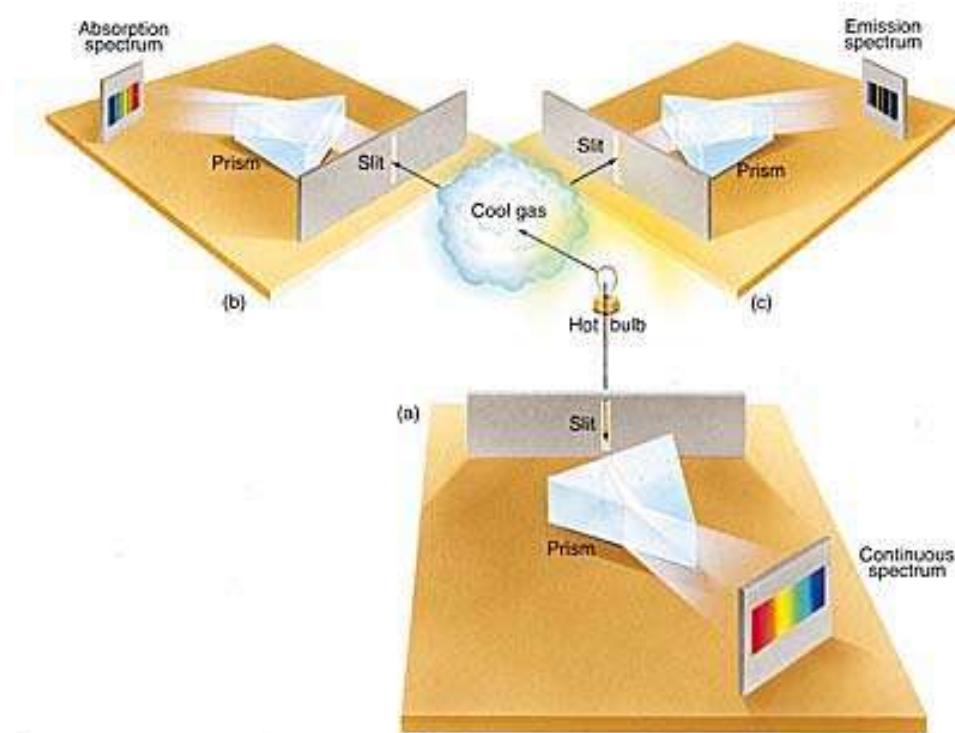
$$c = \lambda \cdot v$$



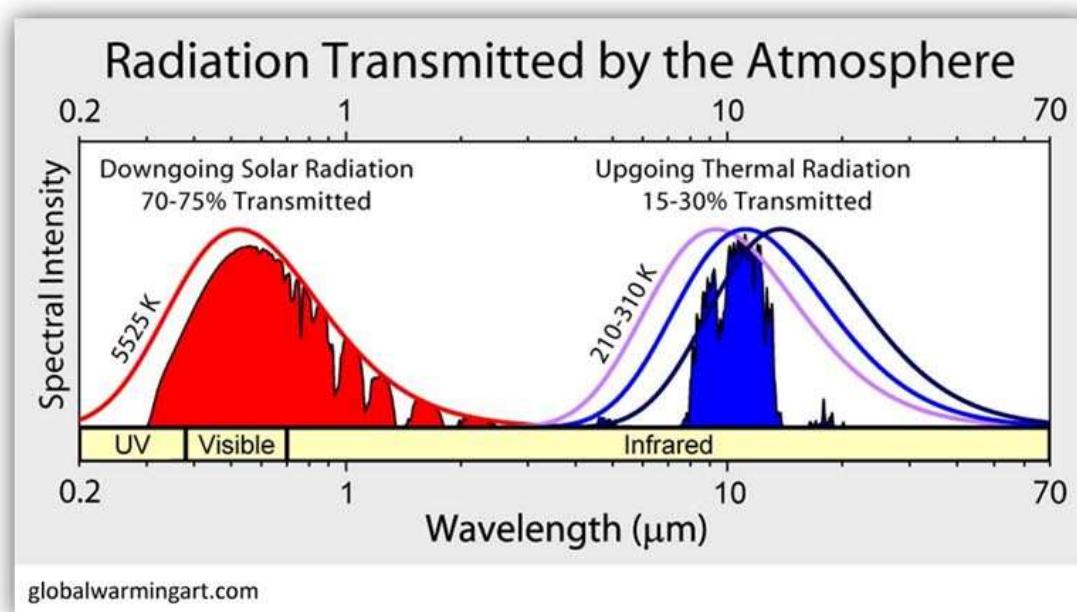
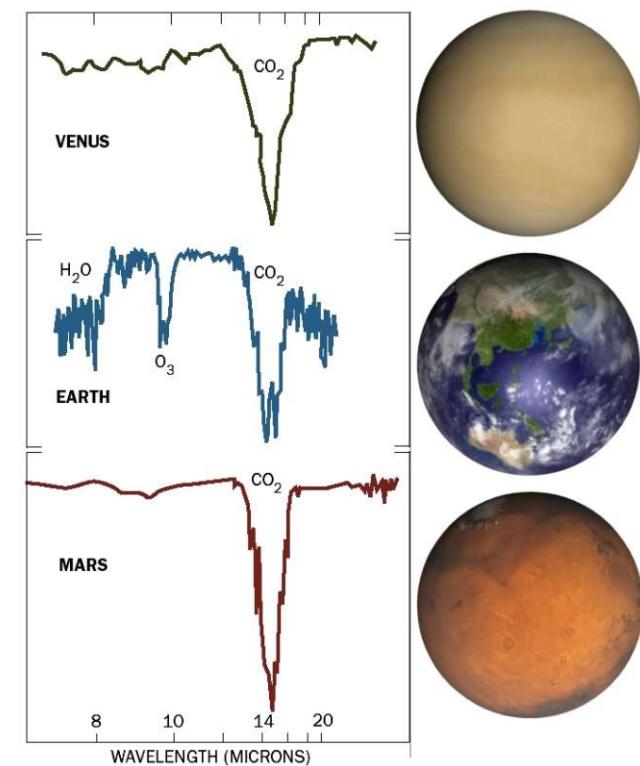
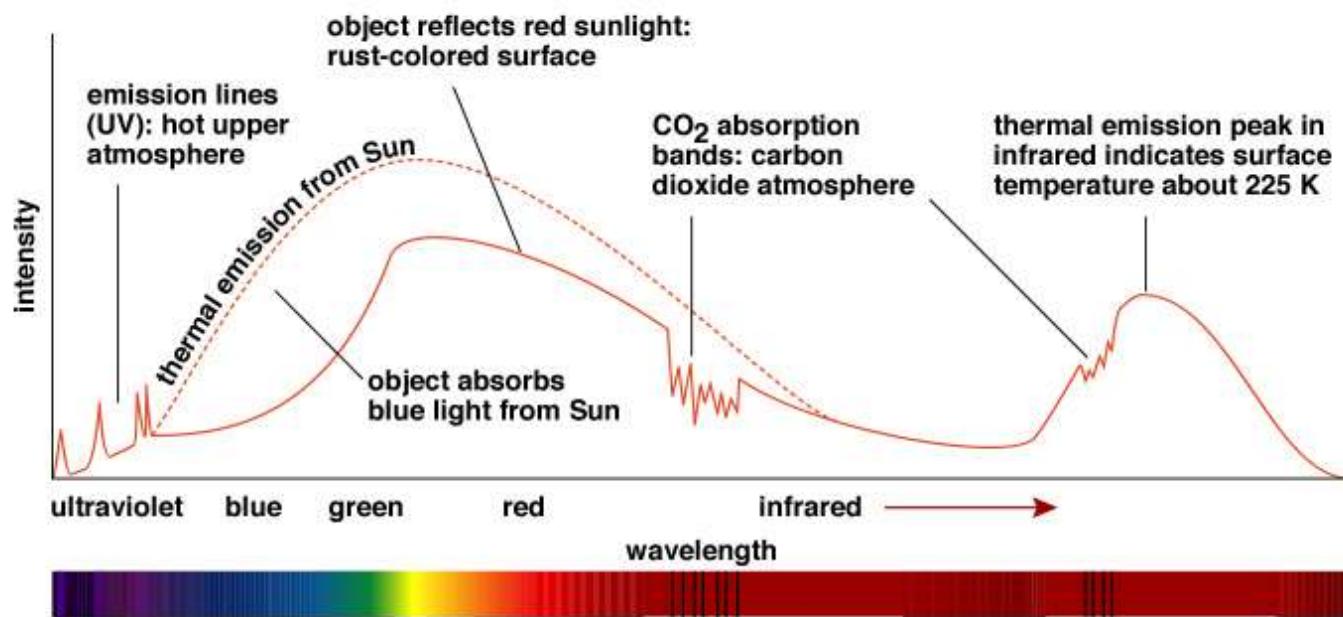
A) Objetos astrofísicos y su radiación

1. Planetas, pequeños cuerpos
(Sol + reflexión/absorción + emisión)
2. Estrellas
(interior + atmósfera)
3. Cúmulos de estrellas
(estrellas)
4. Nebulosas brillantes
(planetarias,
SNe, HII)

5. Galaxias tempranas
(estrellas viejas)
6. Galaxias tardías
(estrellas jóvenes,
regiones HII)
7. Galaxias activas
(BLR=tipo 1, NLR=tipo 2)
8. Cúmulos de galaxias
(galaxias,
bremsstrahlung
térmico del MIC,
reliquias radio, SZ)
9. Bosques Ly- α
(QSO + HI)

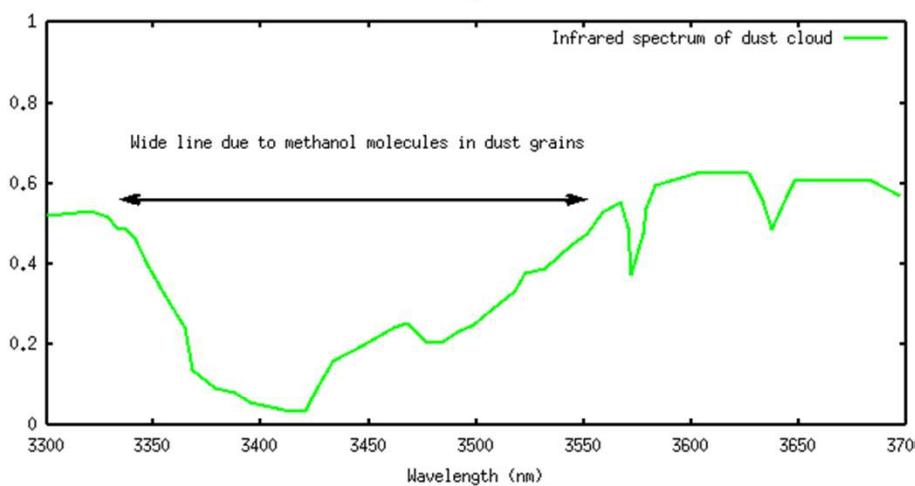
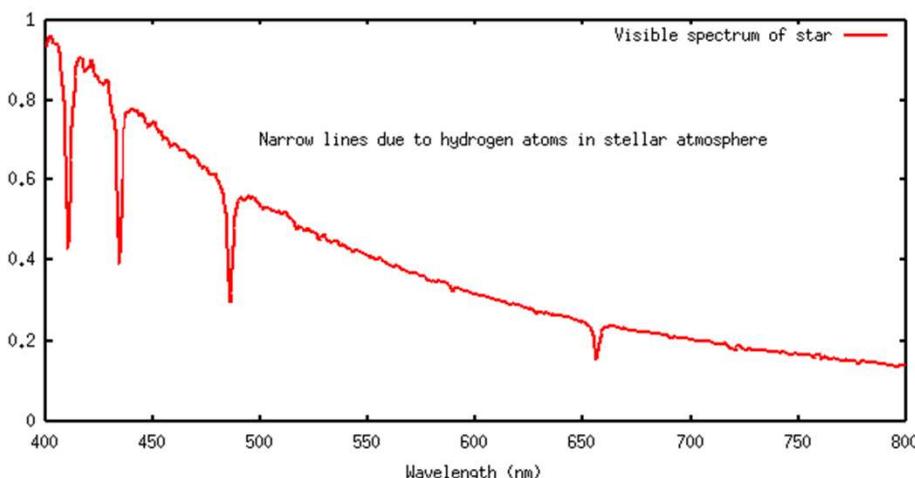


Planetas



Planetas, planetas enanos y satélites

Comparison of spectral features of stellar atmospheres and dust grains



Methane in Saturn & Titan's atmospheres

1994 Dec 5 - 26cm f/4 refl + 23cm OG prism (=f/4.5) +SX-M CCD

C=H α B a AIR.....

Mars



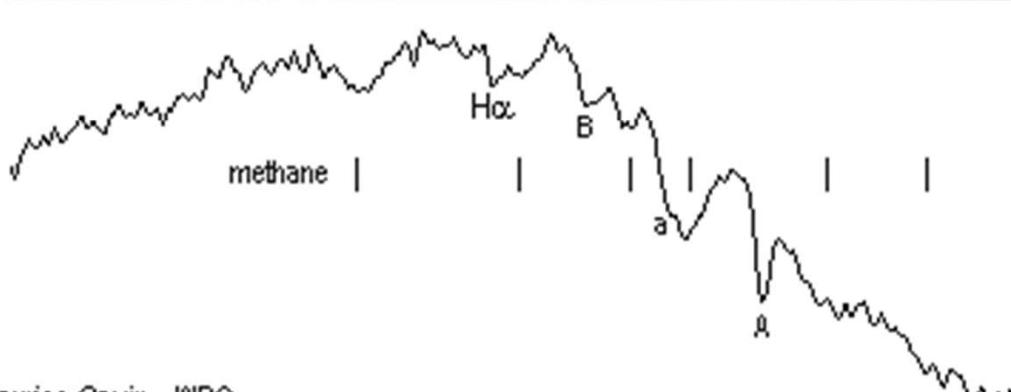
Saturn



Titan



Titan



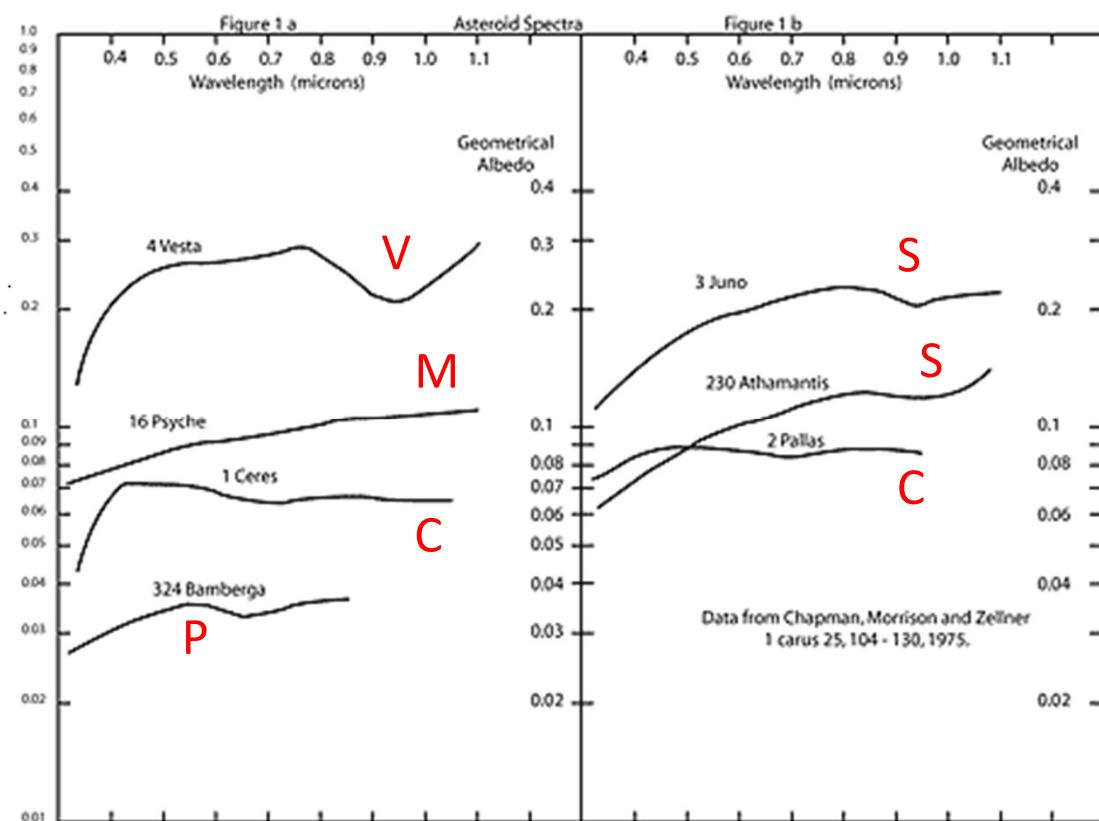
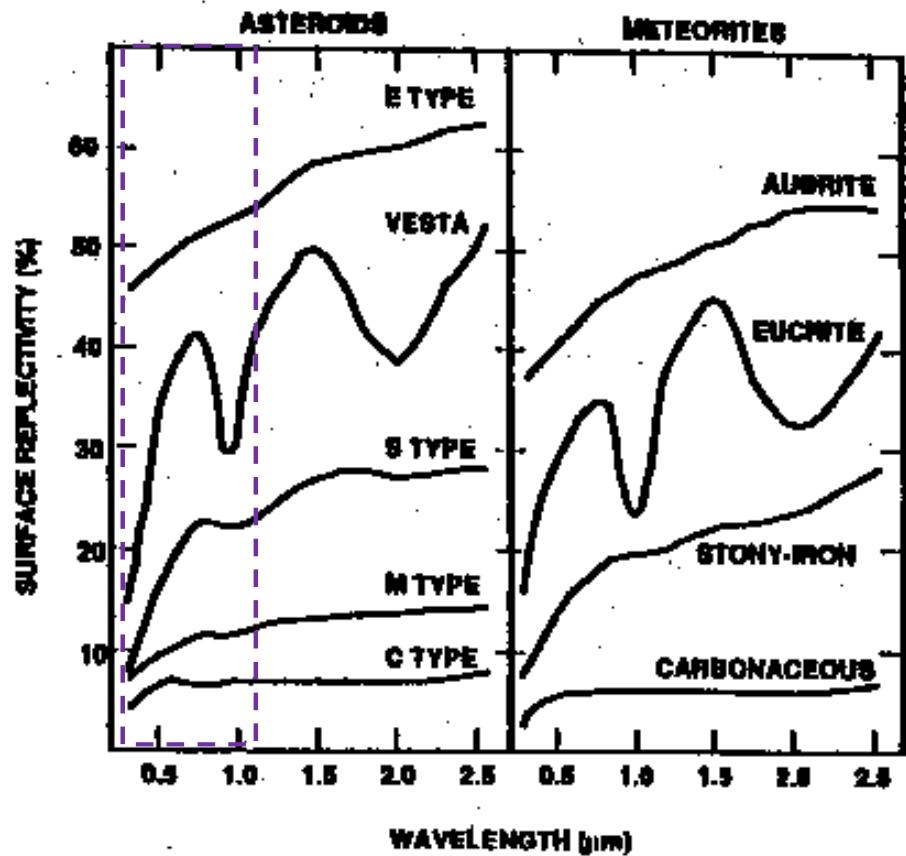
Rocosos → bandas de absorción de minerales

Gaseosos → bandas de moléculas de la atmósfera

[c] Maurice Gavin - IAP

Asteroides

NEO MATERIAL PROPERTIES AND INTERACTIONS

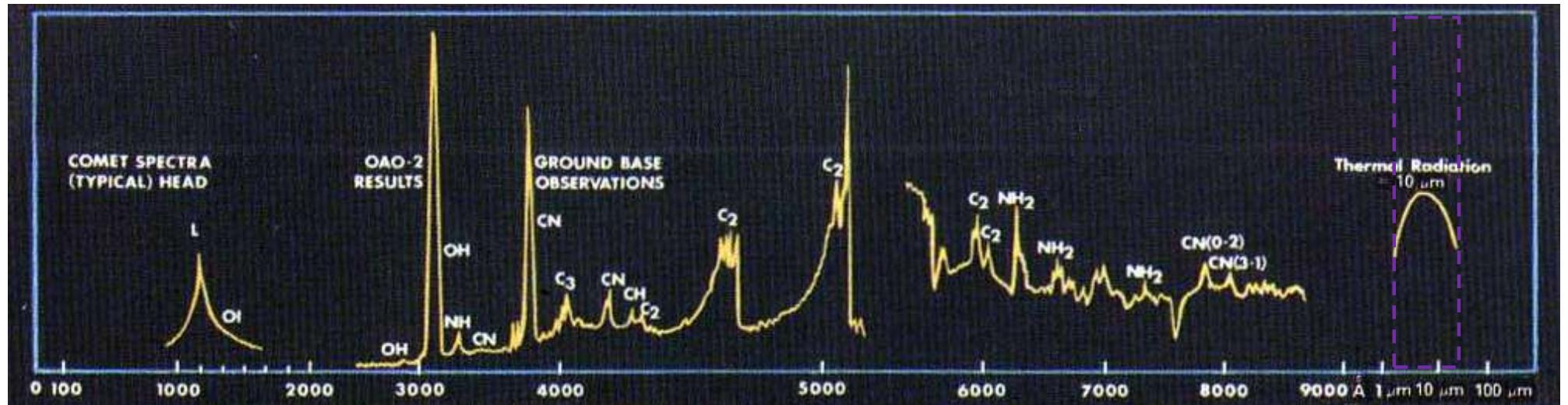


C → carbonáceos oscuros (75%)

M → metálicos (E = alto albedo, P = bajo albedo)

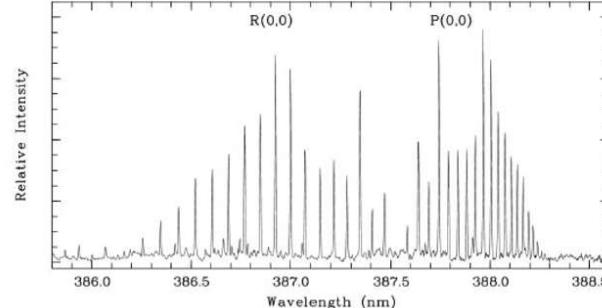
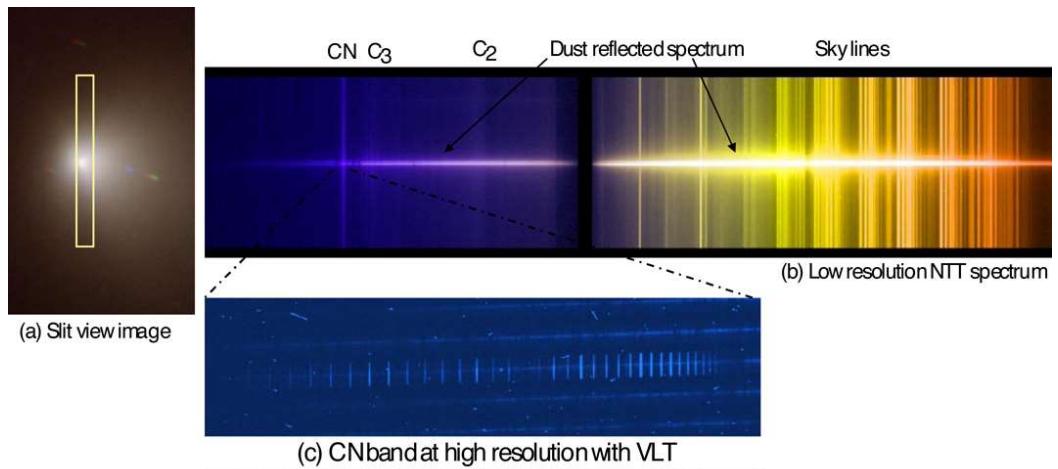
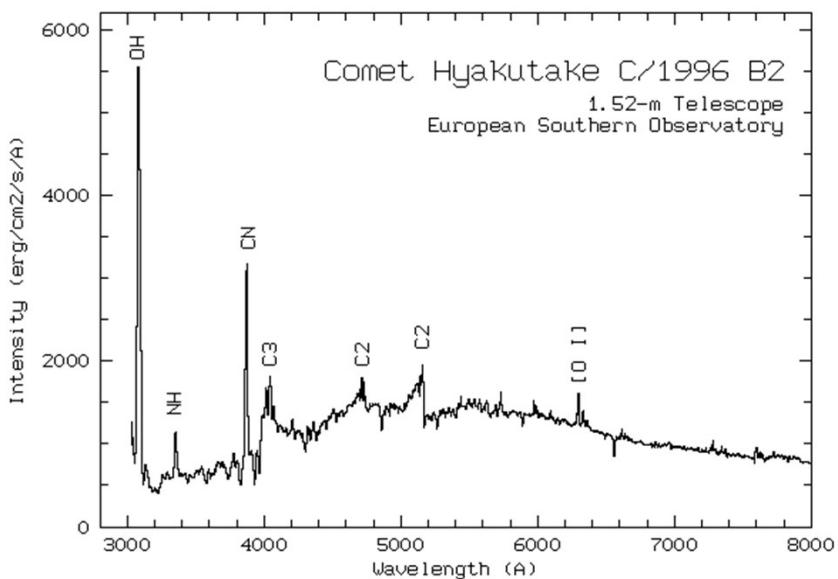
S → rocosos (silicatos, 17%)

V, Q, ... → otros tipos

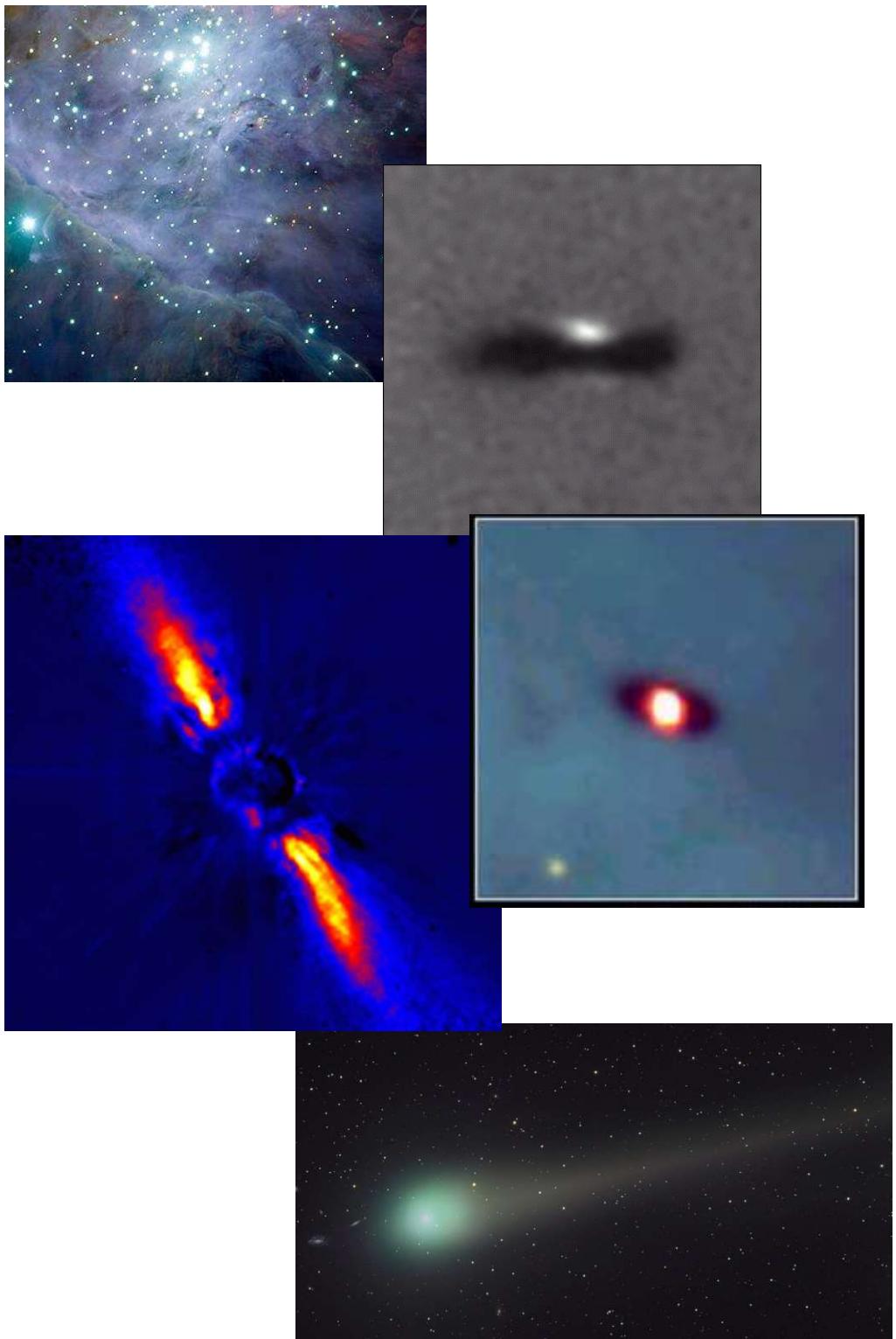
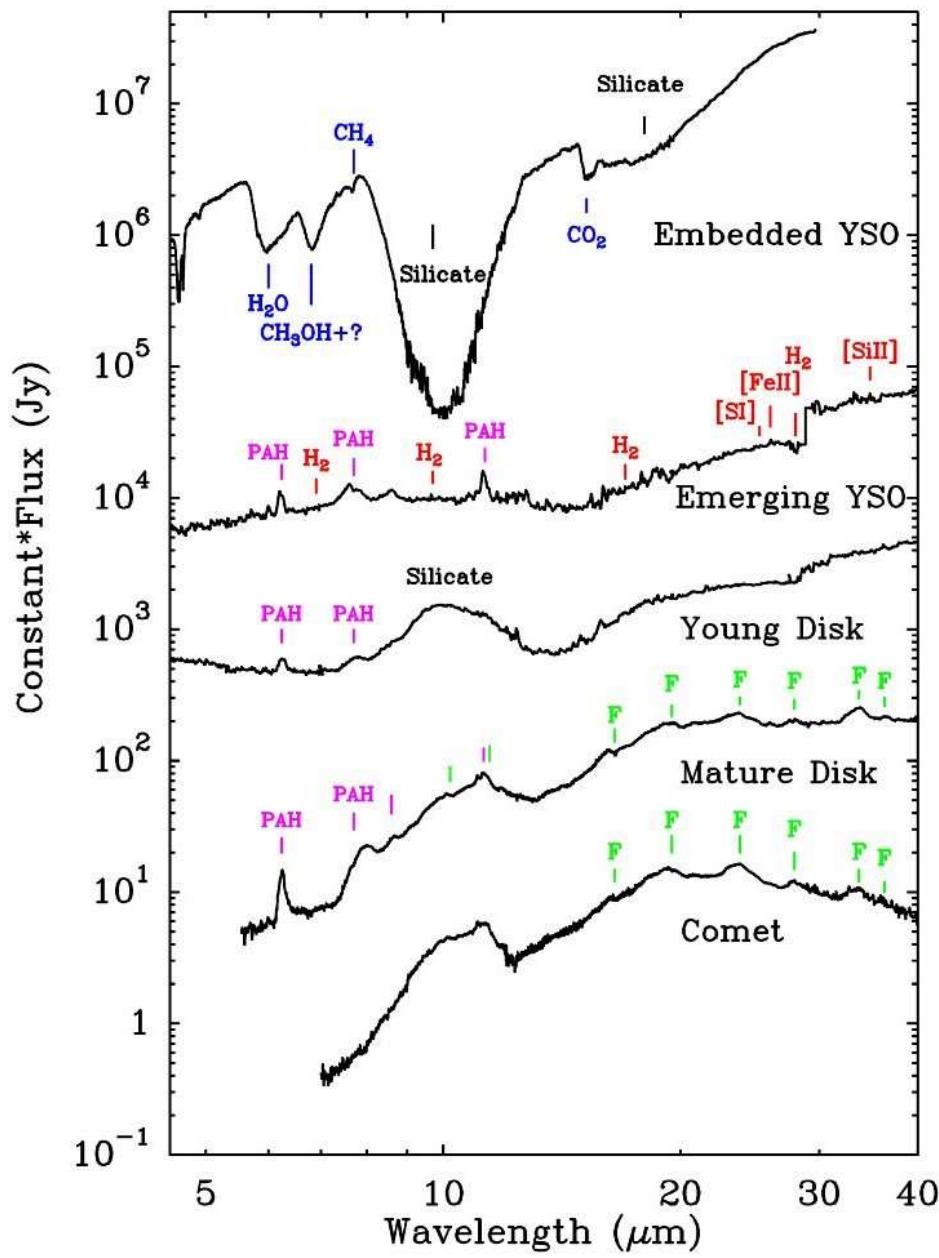


- . Coma (polvo) → luz solar reflejada
- . Átomos y moléculas excitados por fluorescencia de la luz solar o reacciones químicas → líneas de emisión
- . Interacción con el viento solar → rayos-X

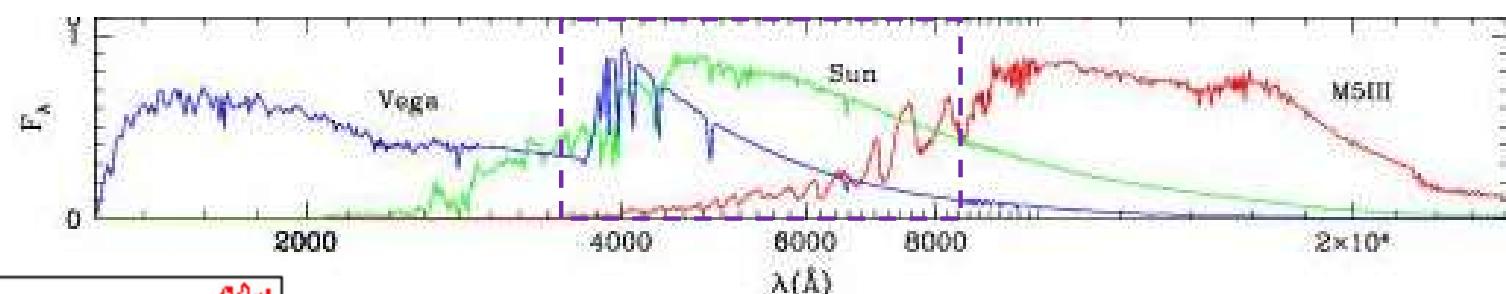
Cometas



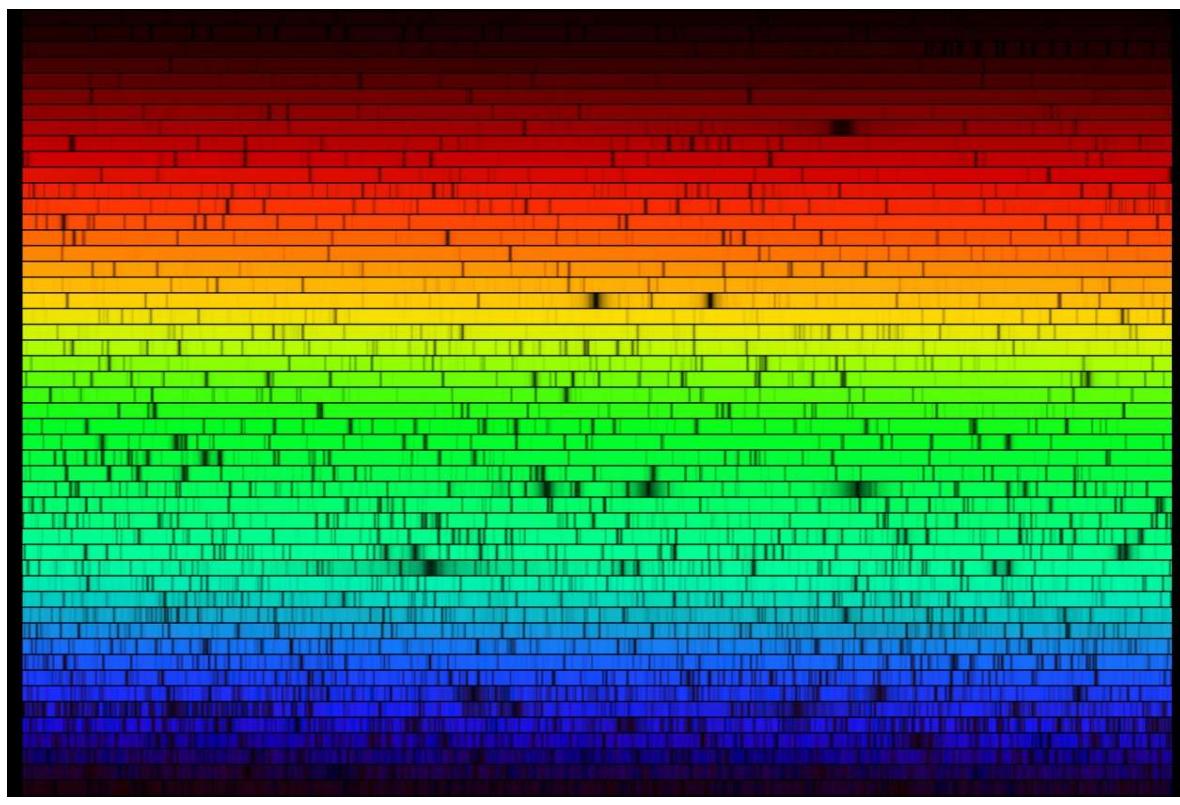
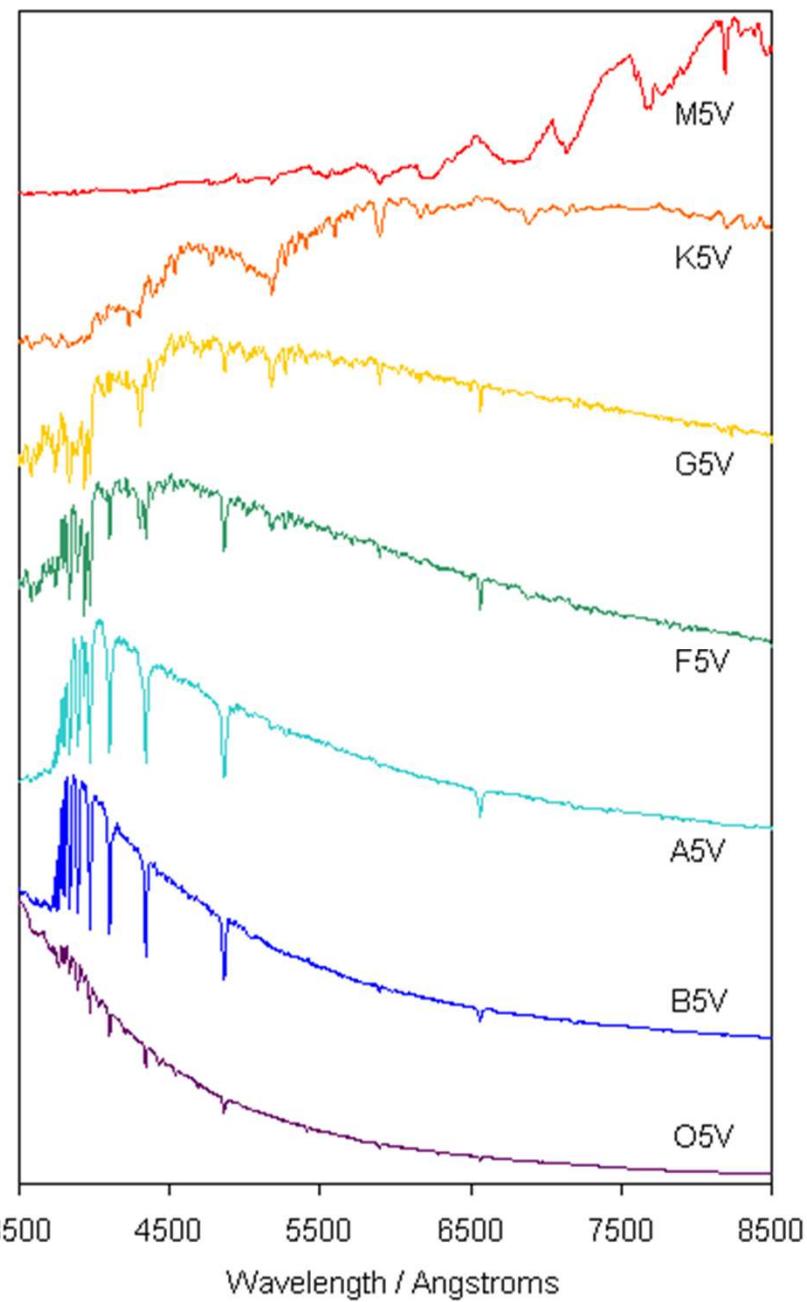
Sistemas planetarios



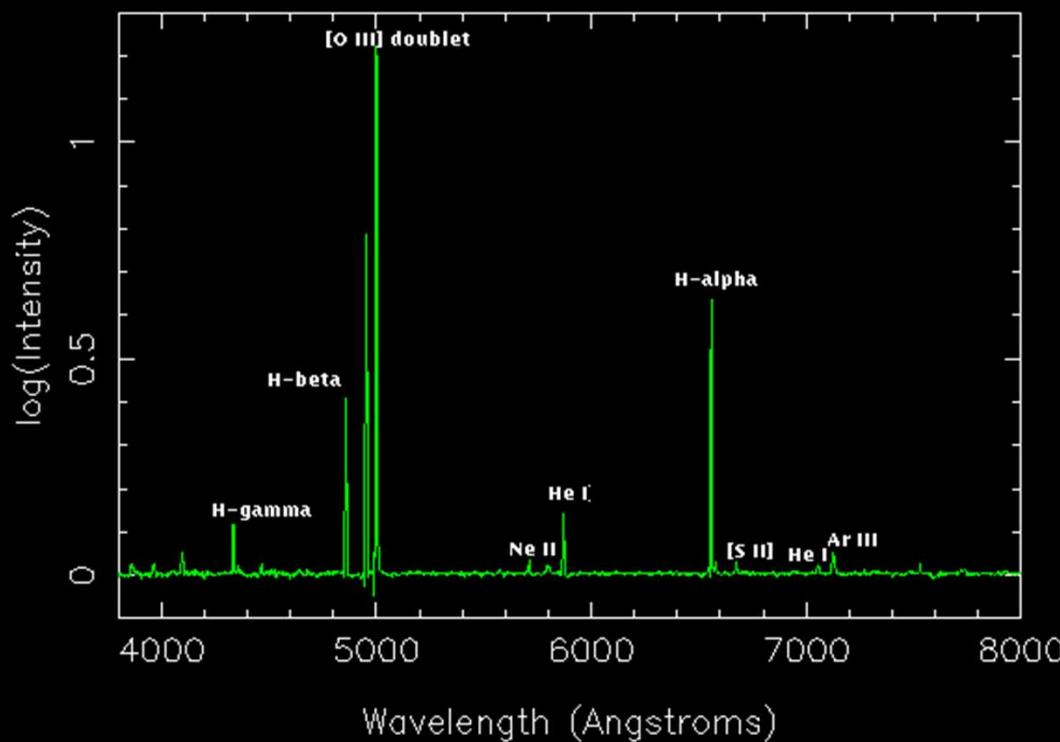
Estrellas



Relative brightness

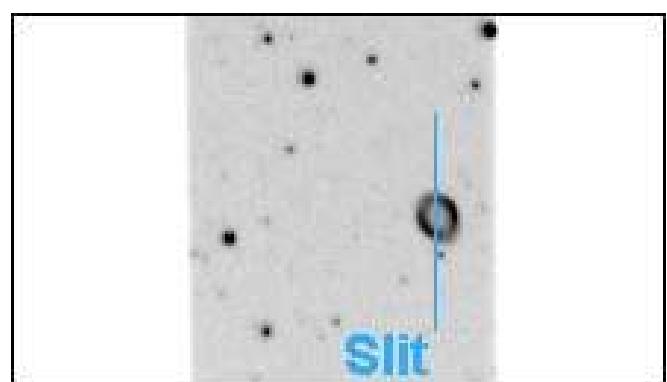


NGC 6826 Spectrum



Nebulosas

Líneas de emisión



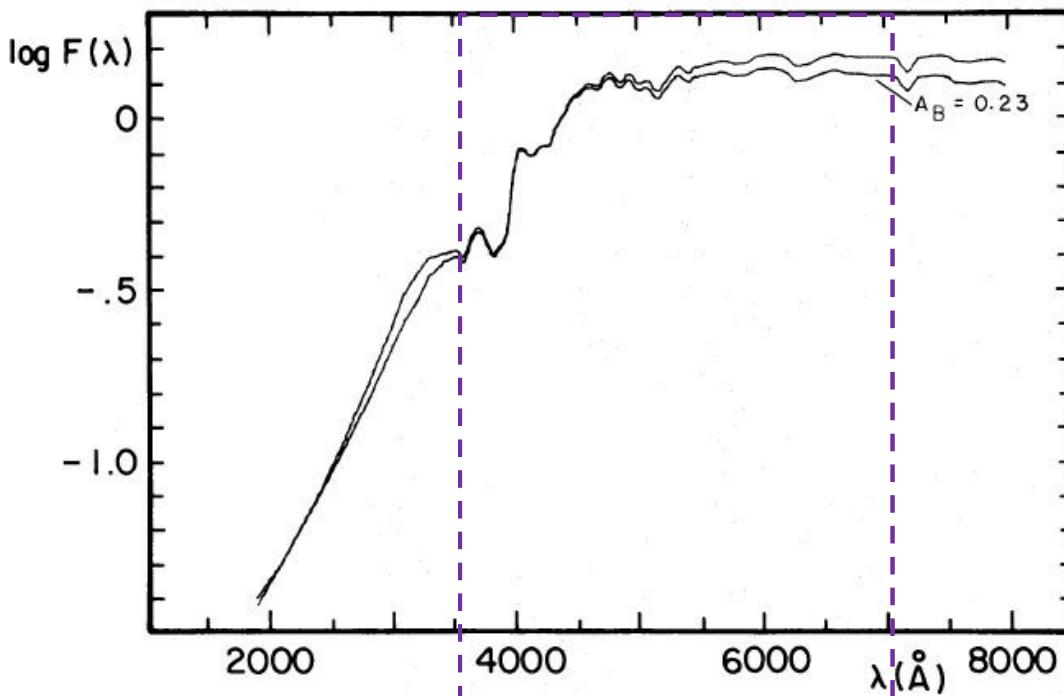


FIG. 1.—Mean E-S0 energy distributions with [$A_B(\text{pole}) = 0.23$] and without correction for galactic extinction

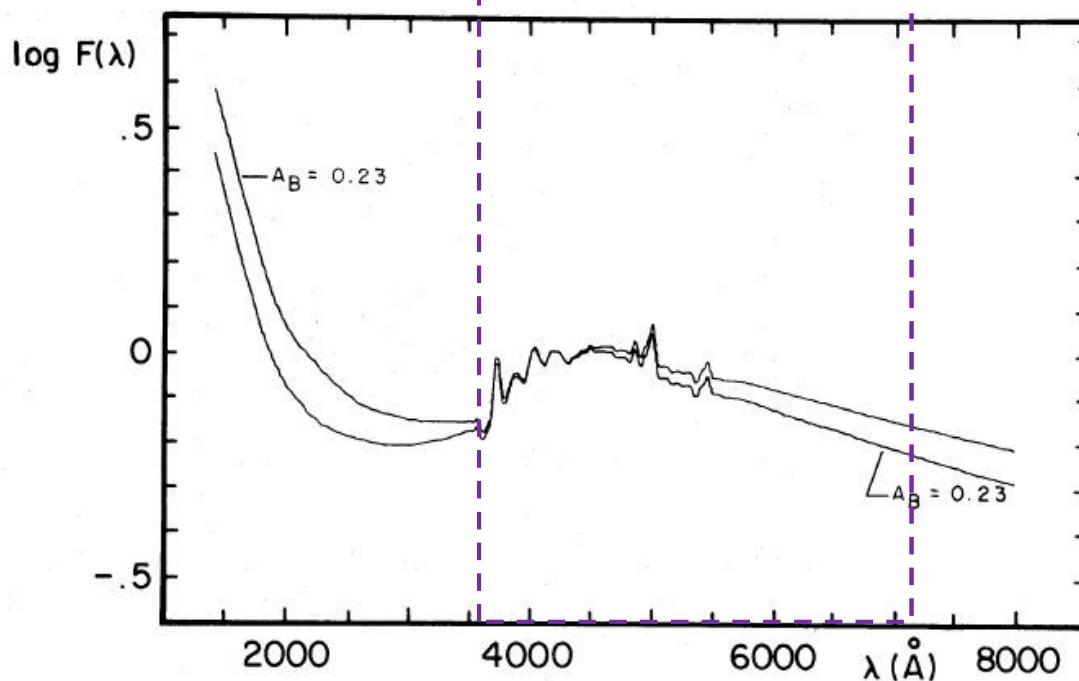
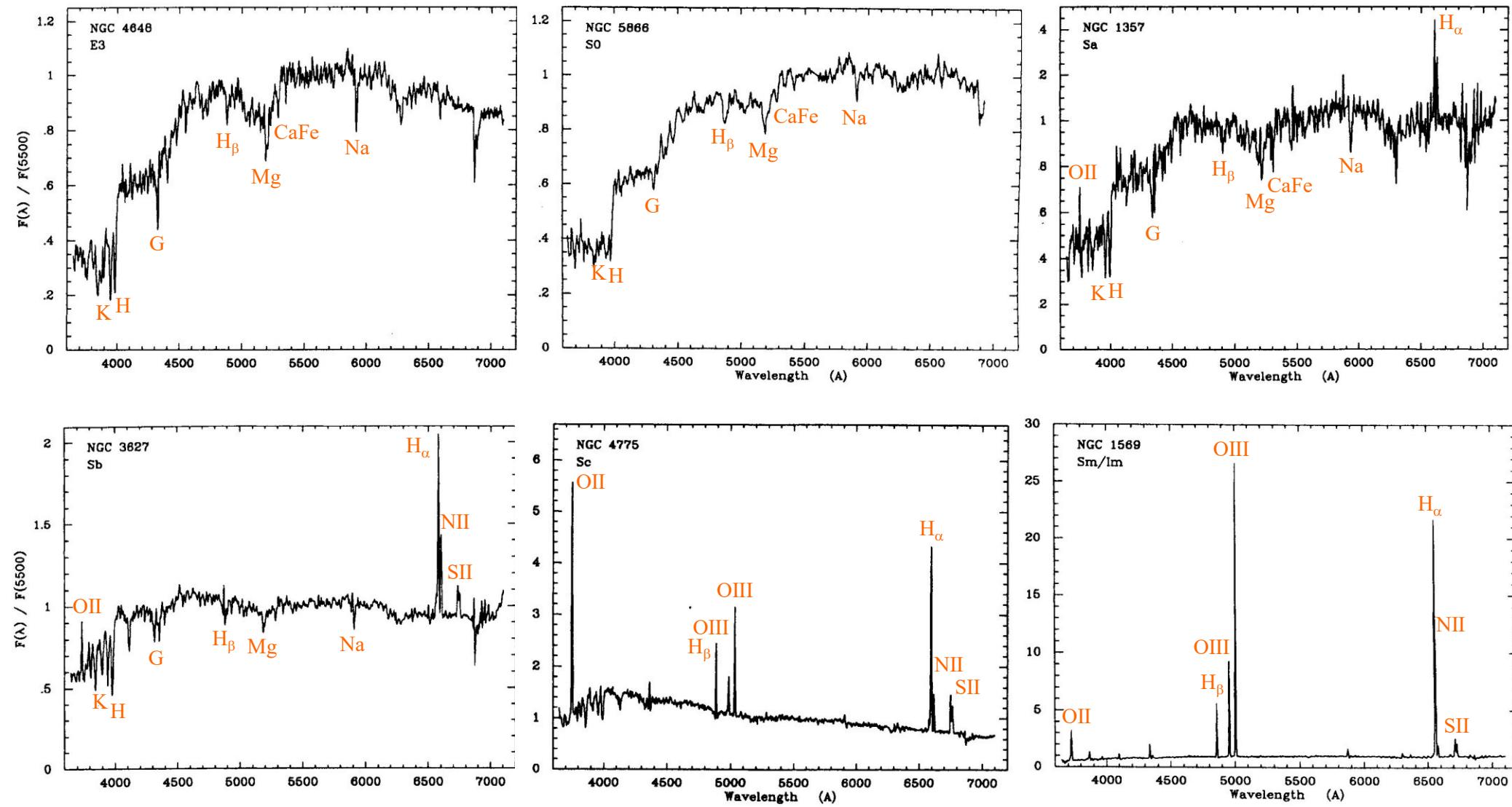


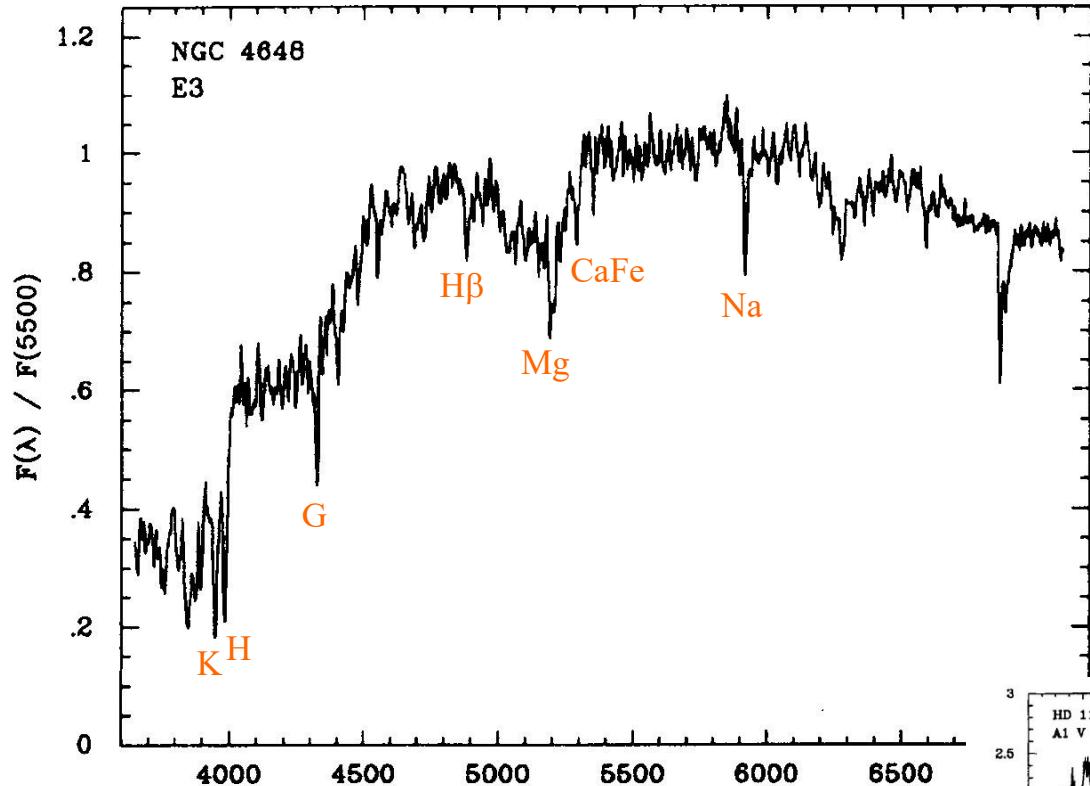
FIG. 2.—Mean Scd energy distributions with [$A_B(\text{pole}) = 0.23$] and without correction for galactic extinction

Galaxias

tipos morfológicos (atlas)

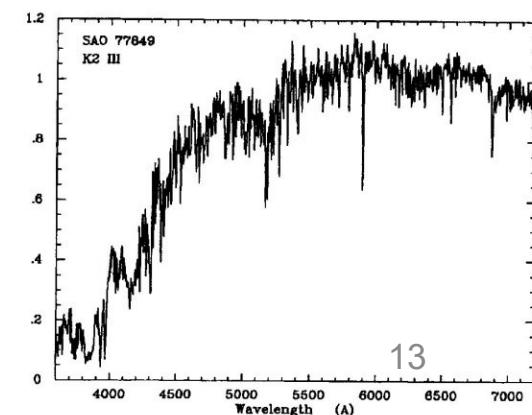
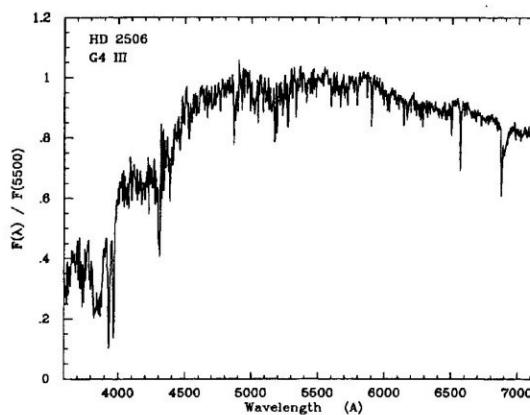
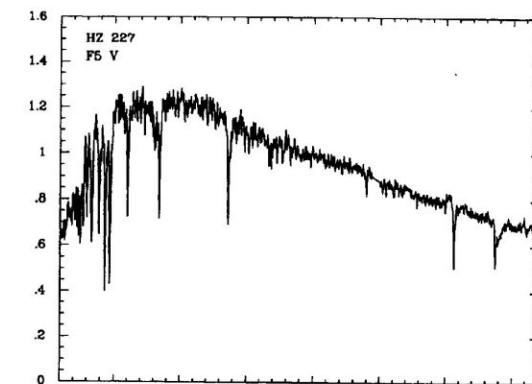
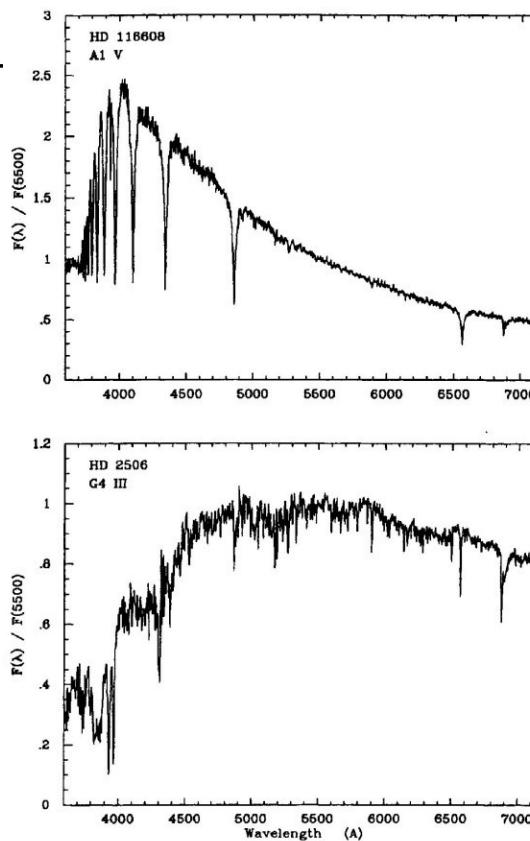


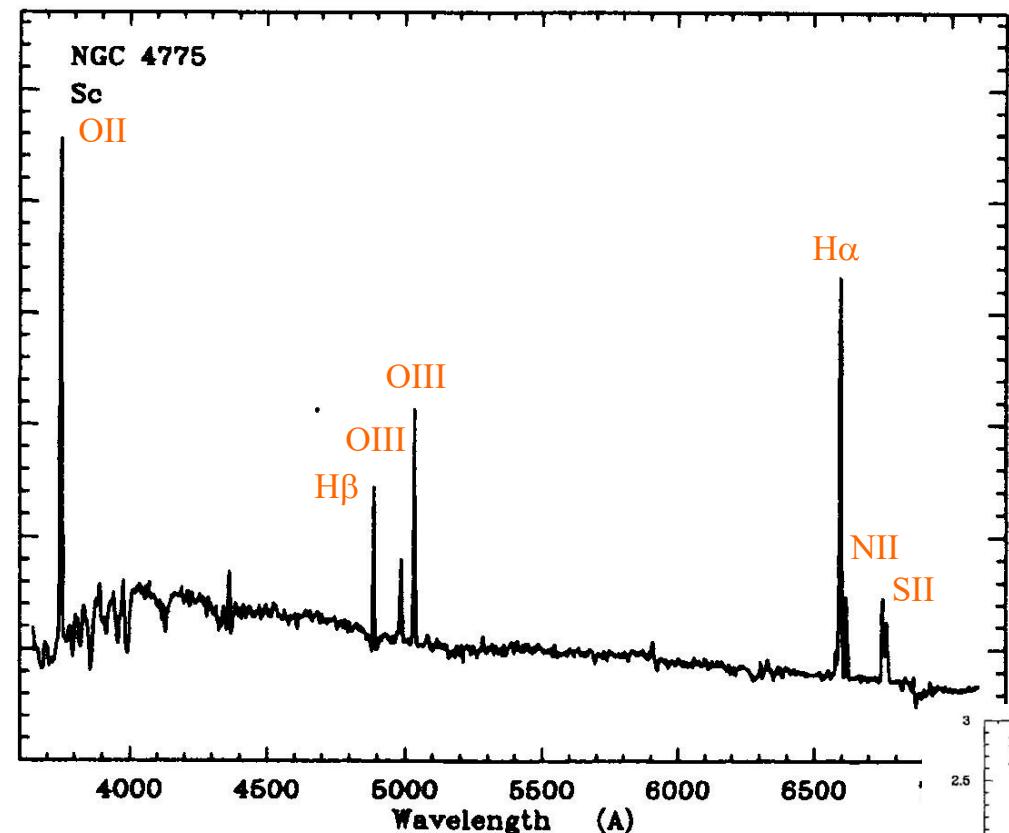
[Kennicutt 1992, ApJS 79, 255]



espectro de absorción
(early-type)

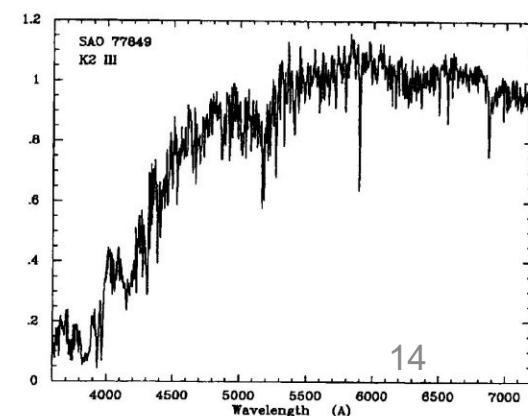
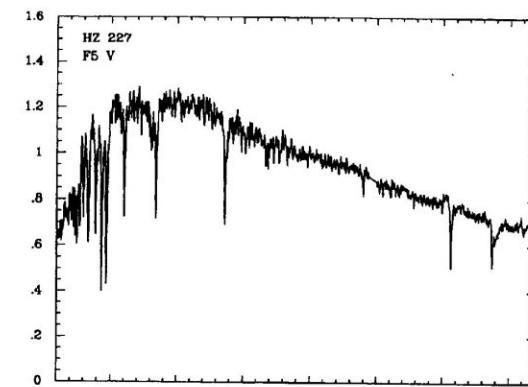
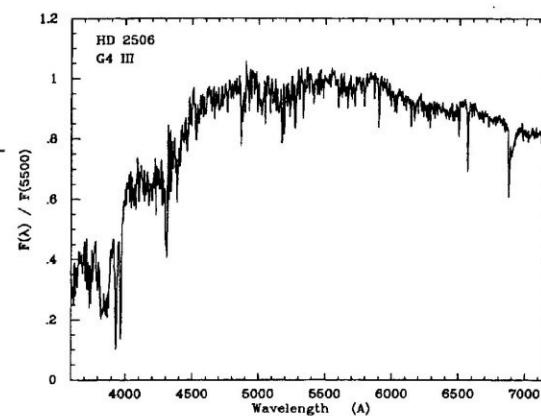
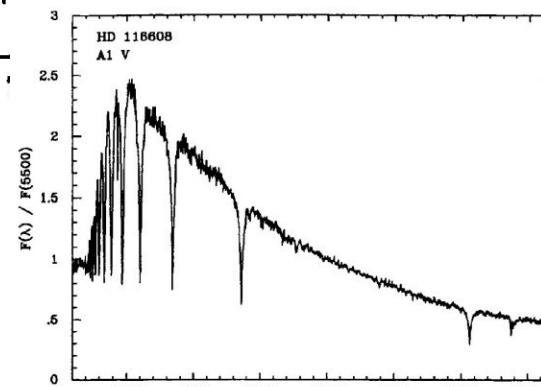
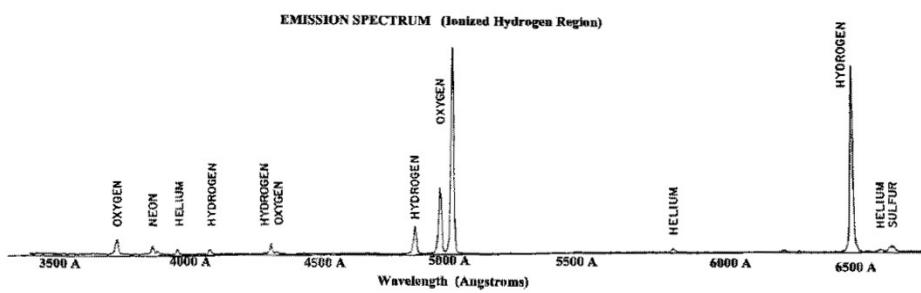
espectros estelares
para comparación





espectro de emisión
(late-type)

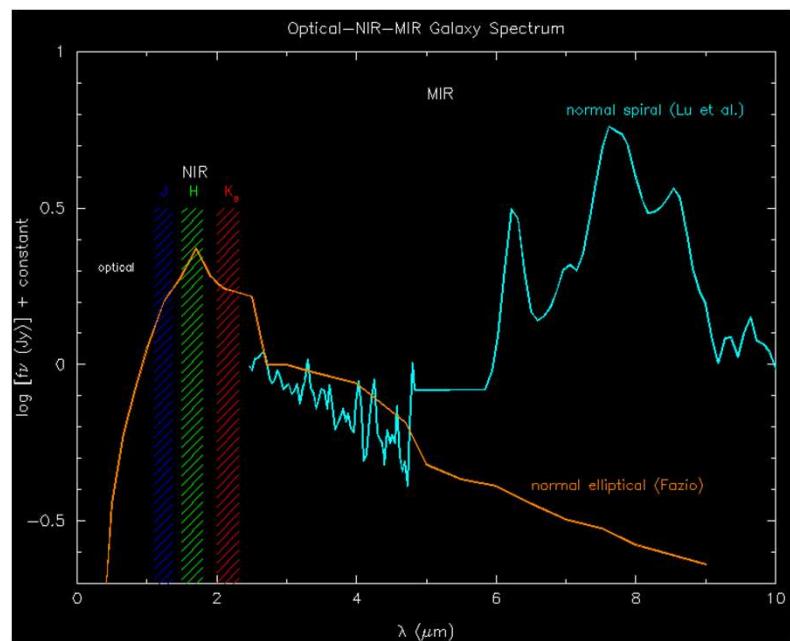
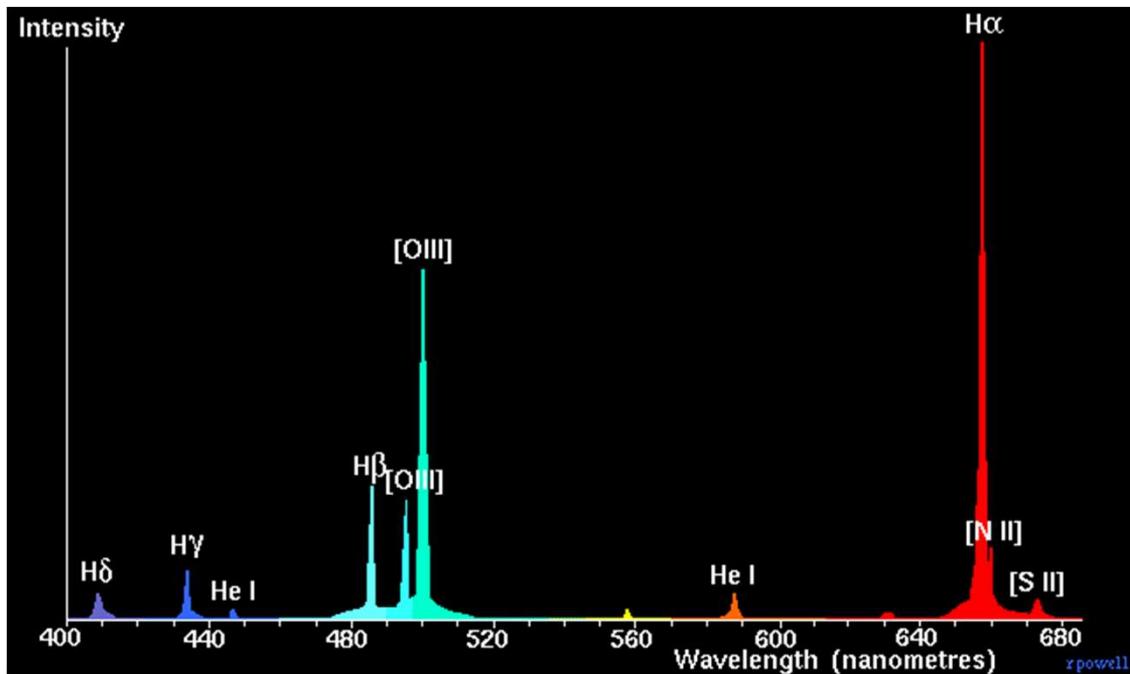
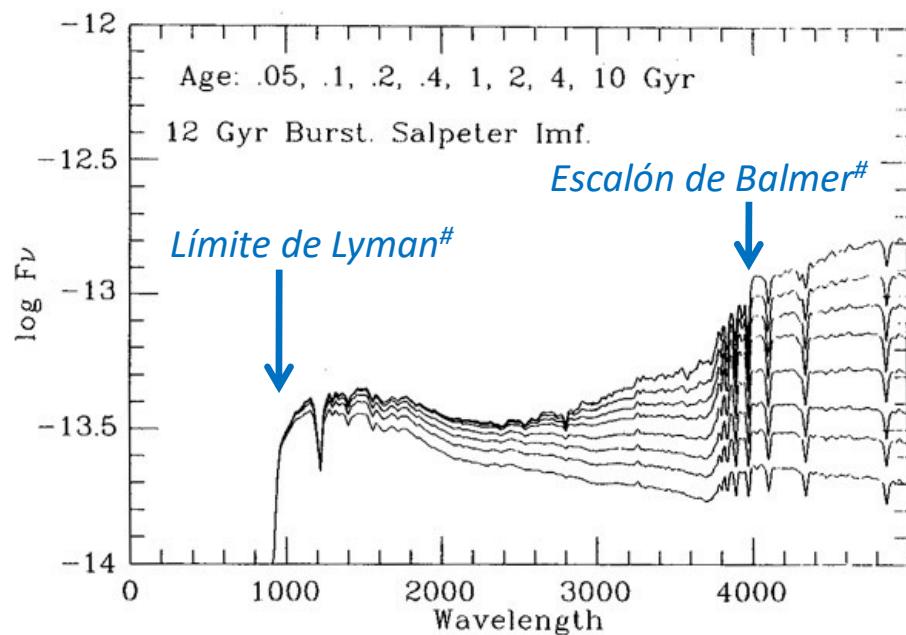
espectros de nebulosa y estrellas
para comparación



B) Indicadores de actividad en espectros de galaxias

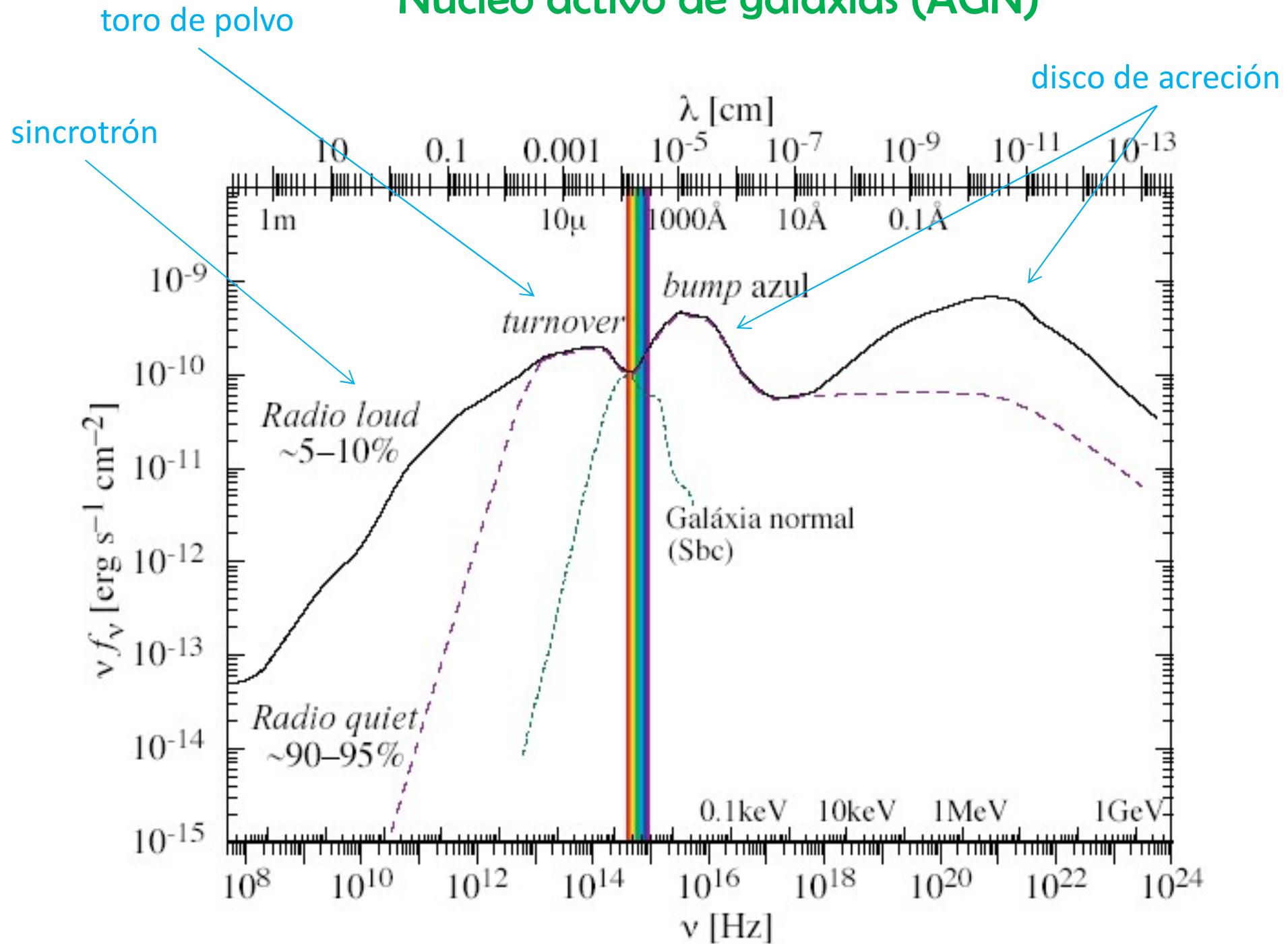
Formación Estelar

- ✓ continuo UV (estrellas calientes)
- ✓ IR lejano térmico (polvo)
- ✓ continuo radio (sincrotrón)
- ✓ líneas de emisión (recombinación, regiones HII)
- ✓ emisión CO (nubes moleculares)

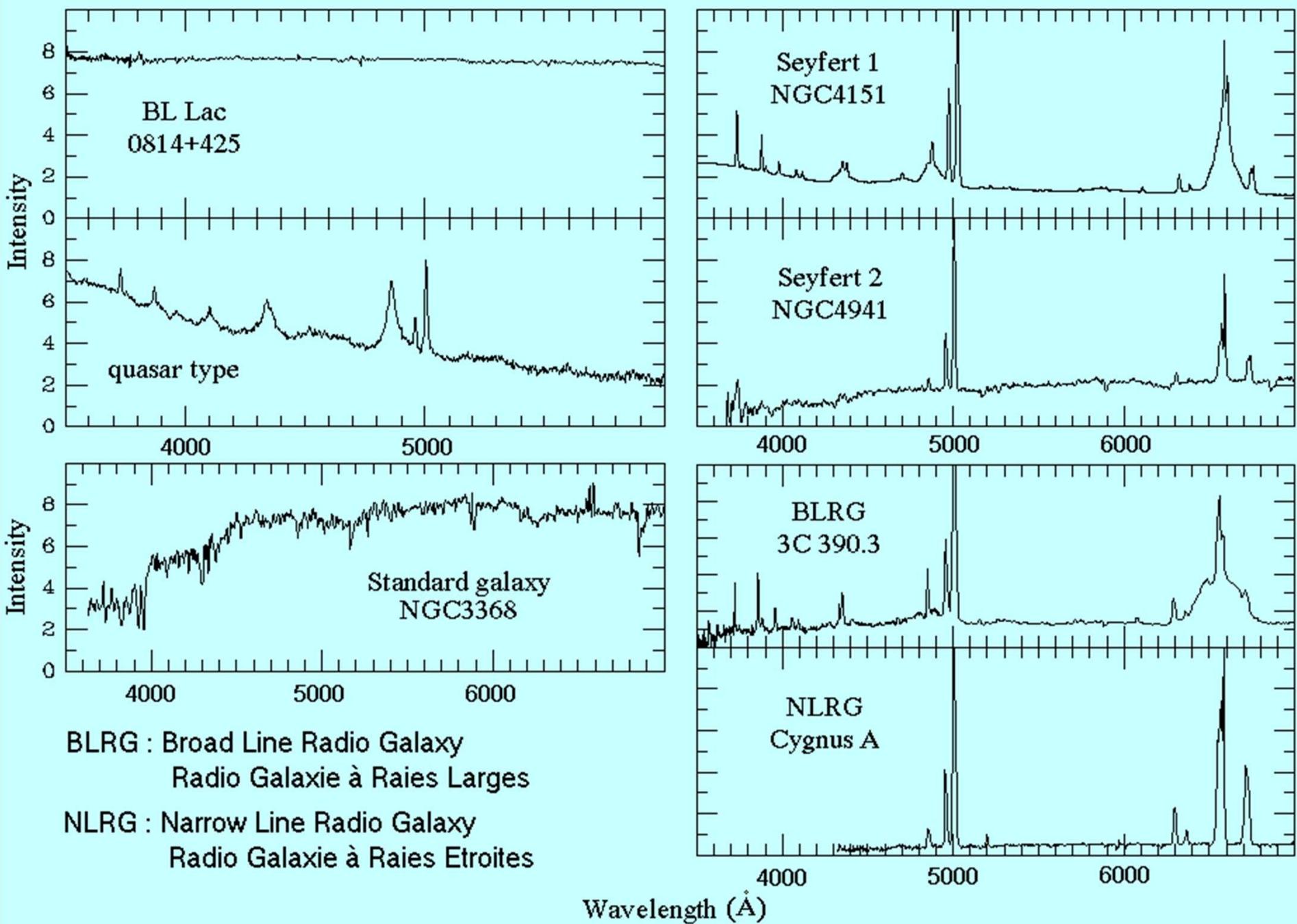


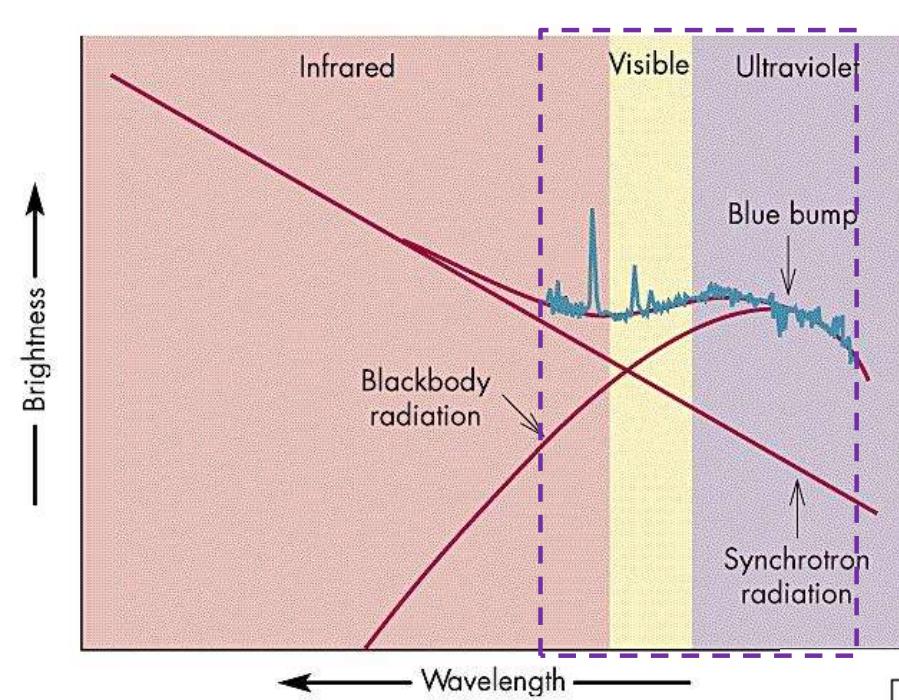
En inglés los términos son, respectivamente, “Lyman break” y “Balmer jump” o “Balmer discontinuity”.

Núcleo activo de galaxias (AGN)

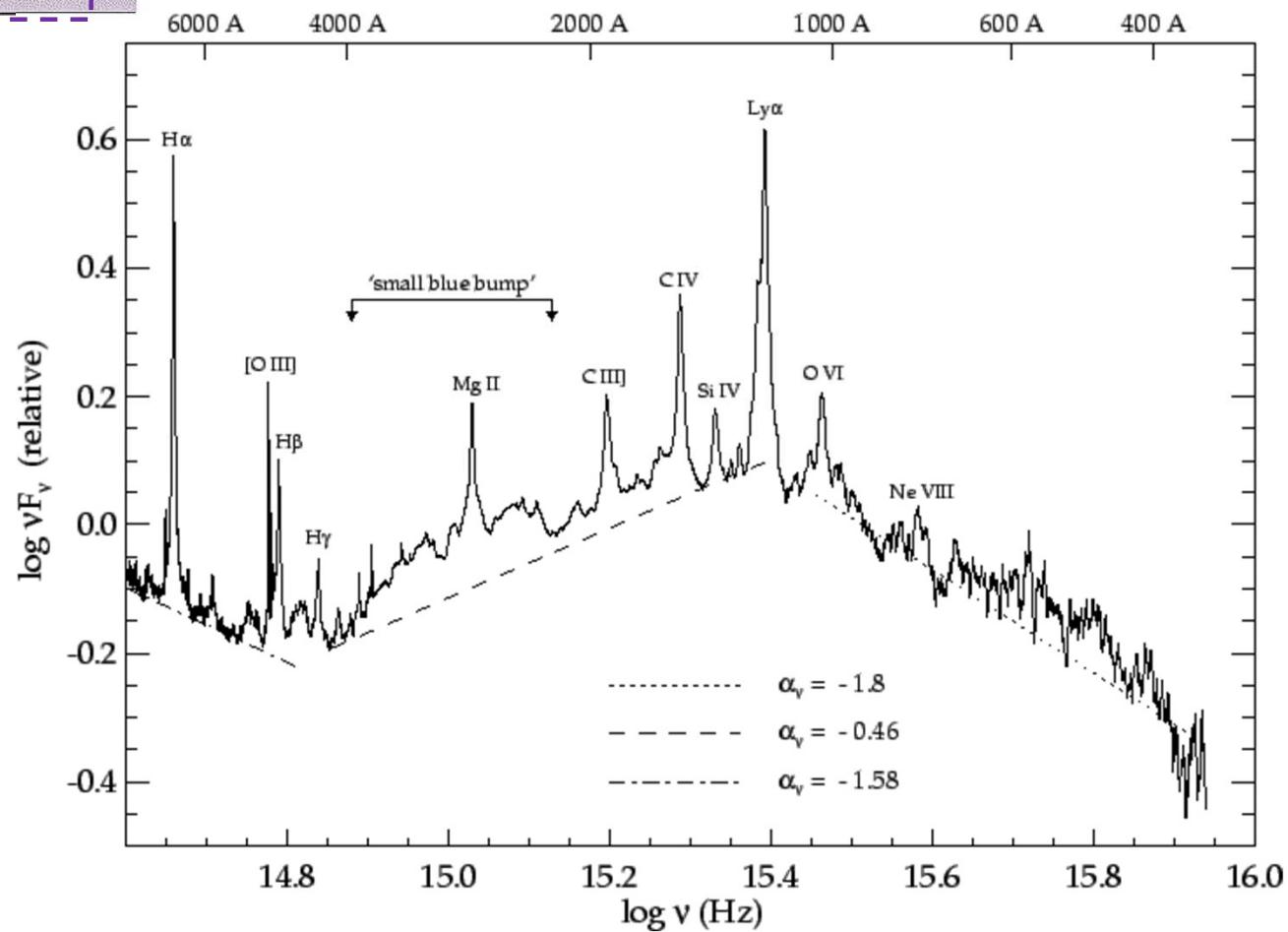
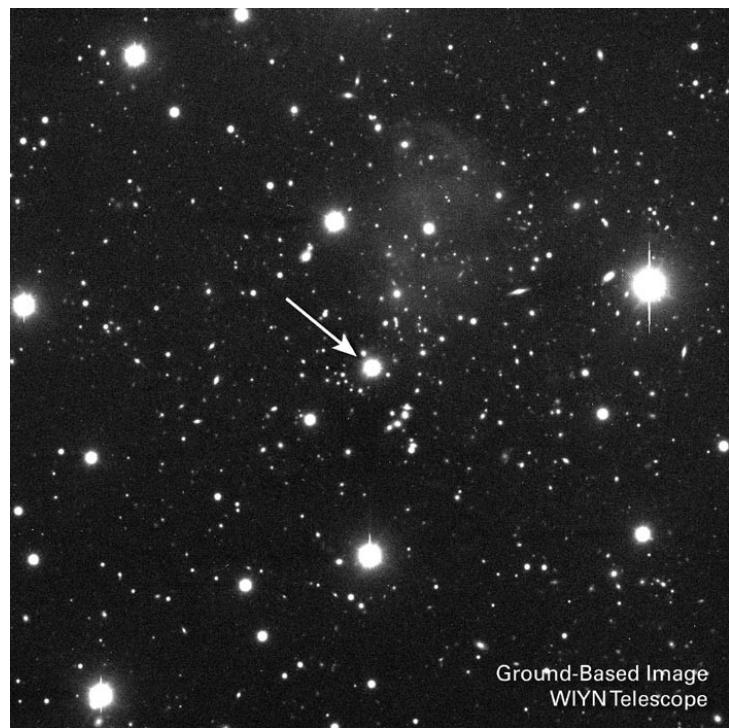


espectro de los diferentes tipos de AGNs

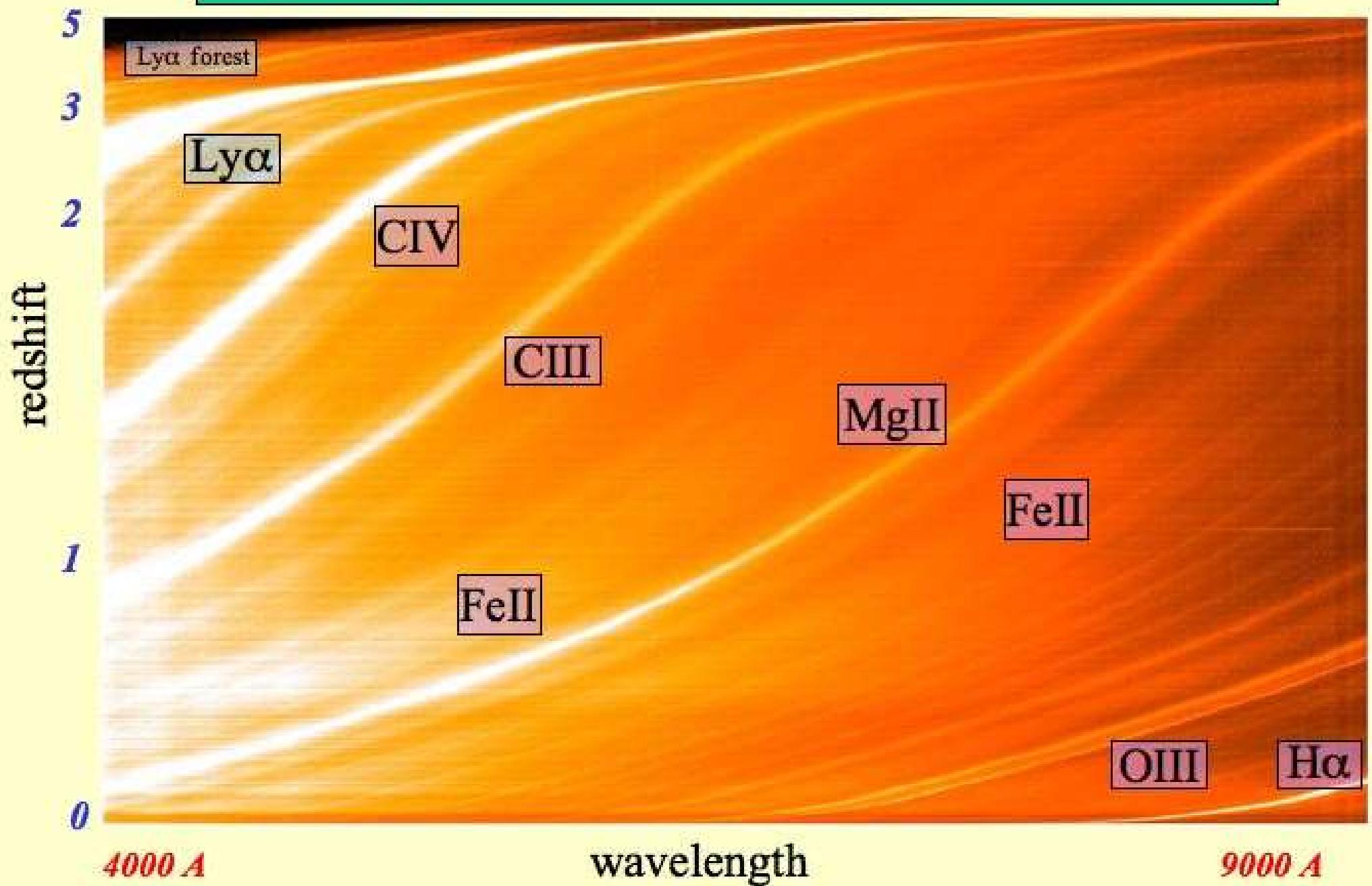




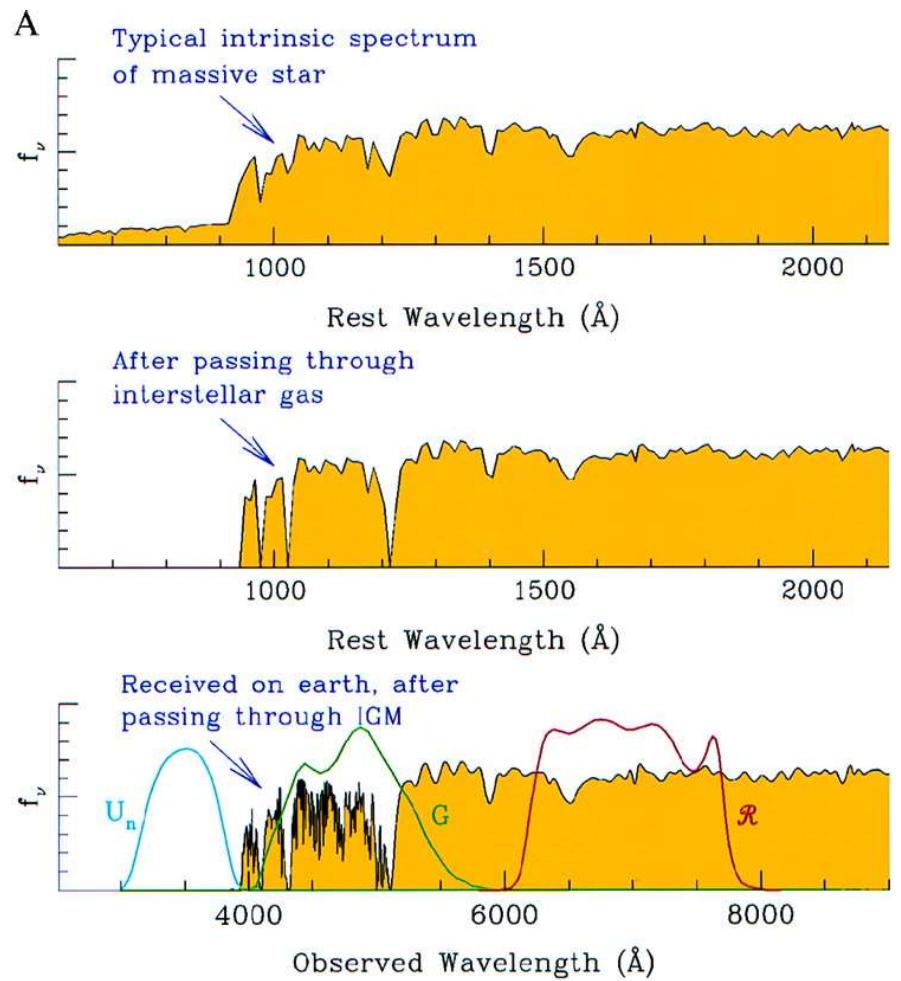
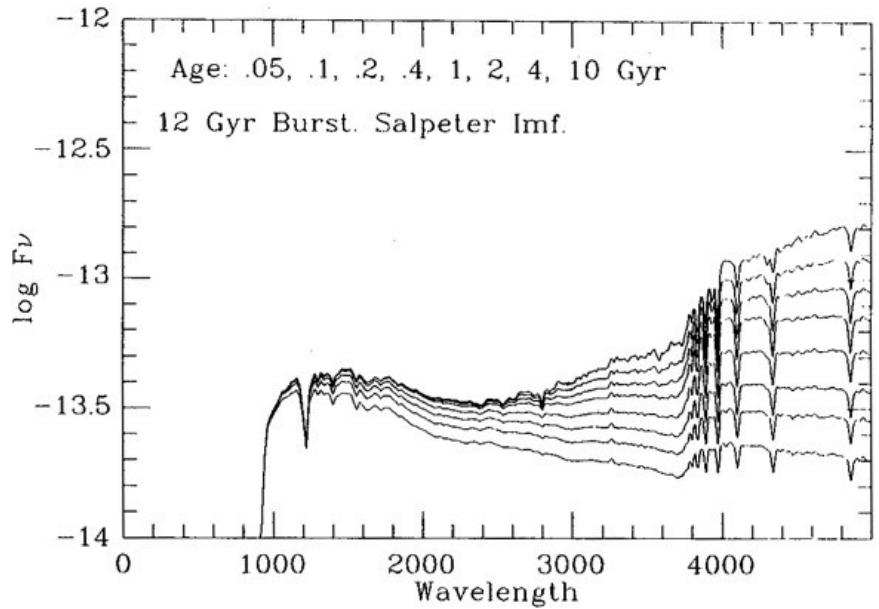
Cuásares



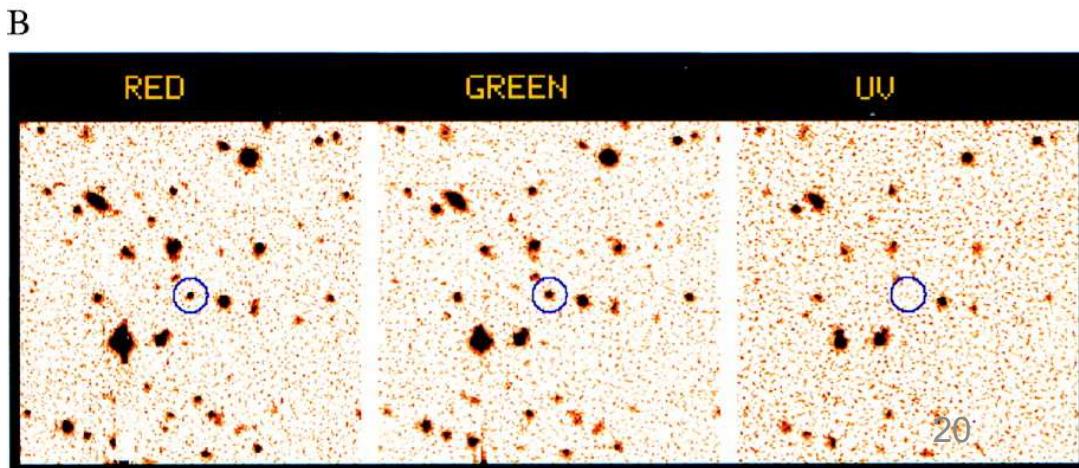
46,420 Quasars from the SDSS Data Release Three



Galaxias en altos redshifts



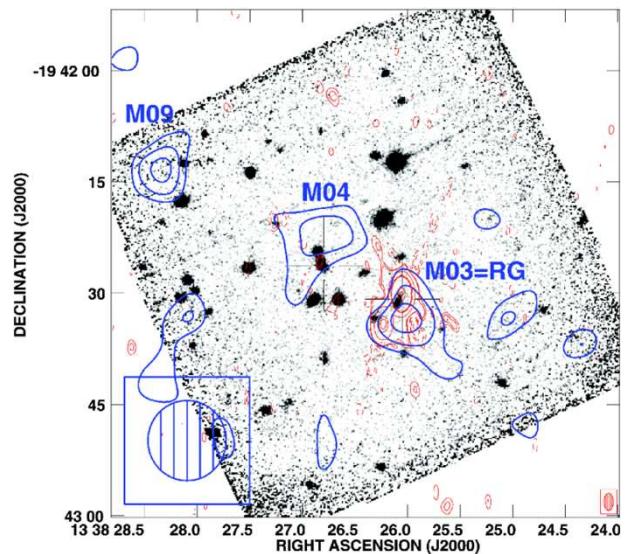
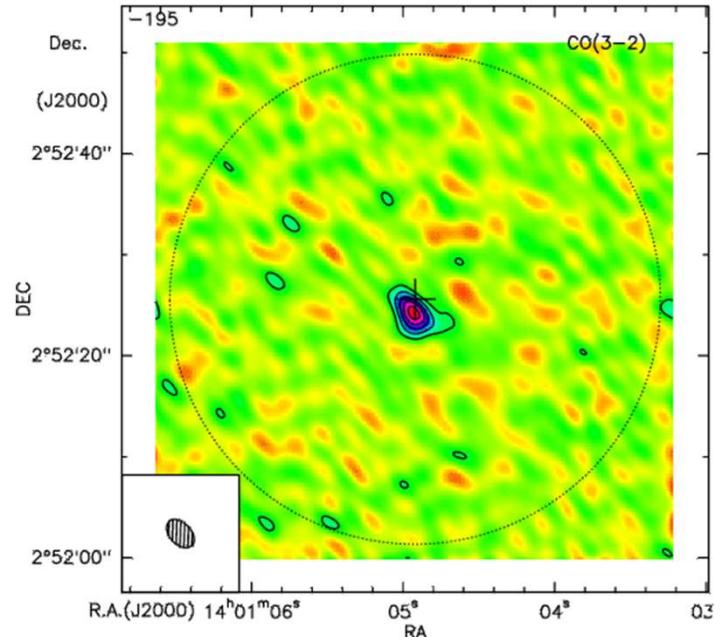
Galaxias Lyman Break (LBGs)



Galaxias en altos redshifts

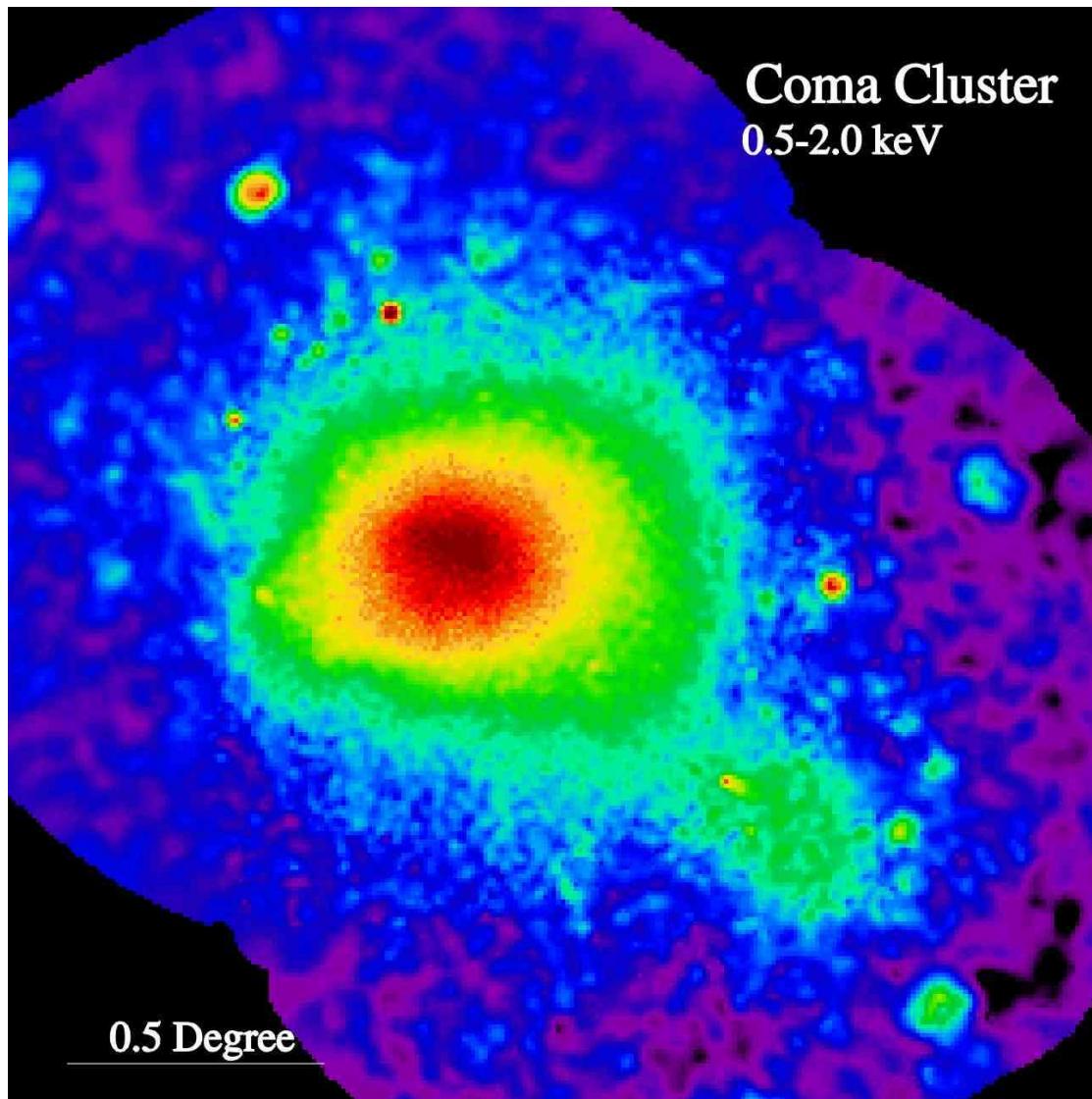
- ✓ La emisión del polvo tiene un máximo en $\sim 100 \mu\text{m}$, la cual no es observable a partir del suelo. No obstante, en λ cercanos, como 450 y 850 μm , hay ventanas espectrales en la atmósfera (en el caso ambas en el **sub-milimétrico**).
- ✓ Las condiciones de observación en esas bandas son, sin embargo, extremadamente dependientes de la **cantidad de vapor de agua** presente en la atmósfera, de forma que los sitios de observación deben ser secos y muy elevados (como “Sierra Negra”, por ejemplo).

Galaxias Submilimétricas (SMGs)



C) Espectros de importancia en Cosmología

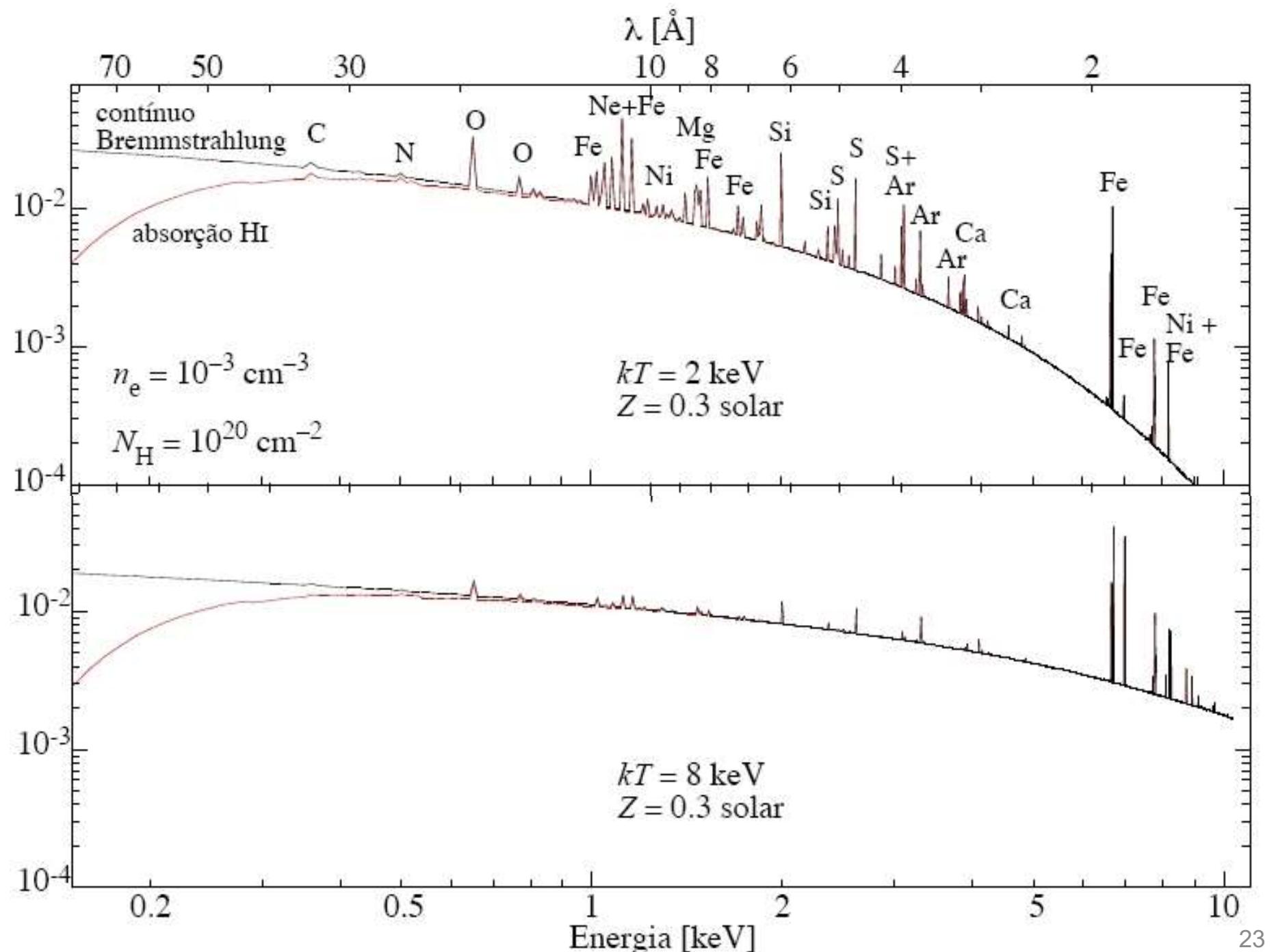
Cúmulos de galaxias: MIC



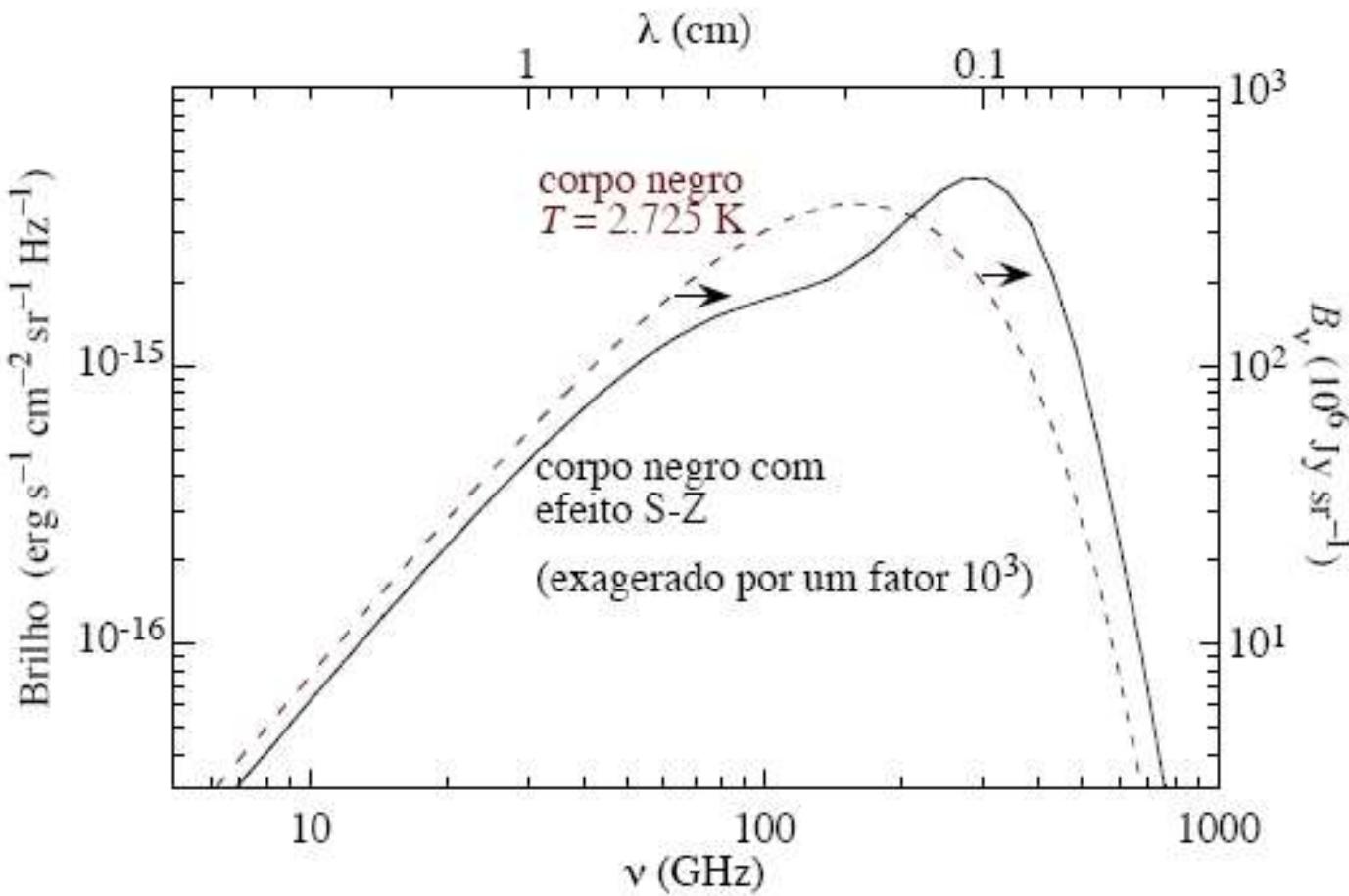
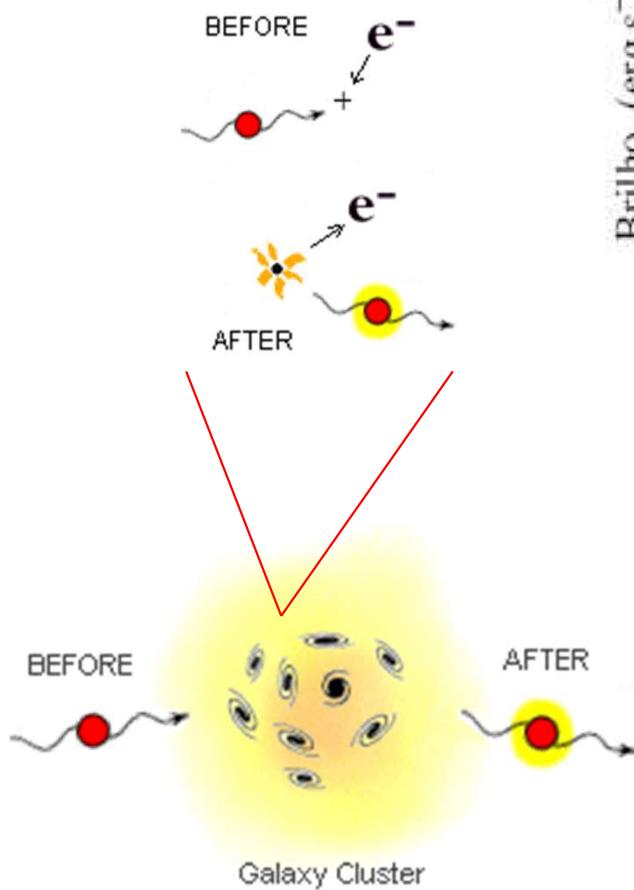
Detección

- ✓ el MIC puede ser observado de 4 formas:
 - emisión en rayos-X (libre-libre)
 - efecto Sunyaev-Zel'dovich
 - presión de arrastre del MIC sobre el HI de espirales y chorros/lóbulos de AGNs
 - emisión radio del campo magnético del MIC

Espectro del MIC

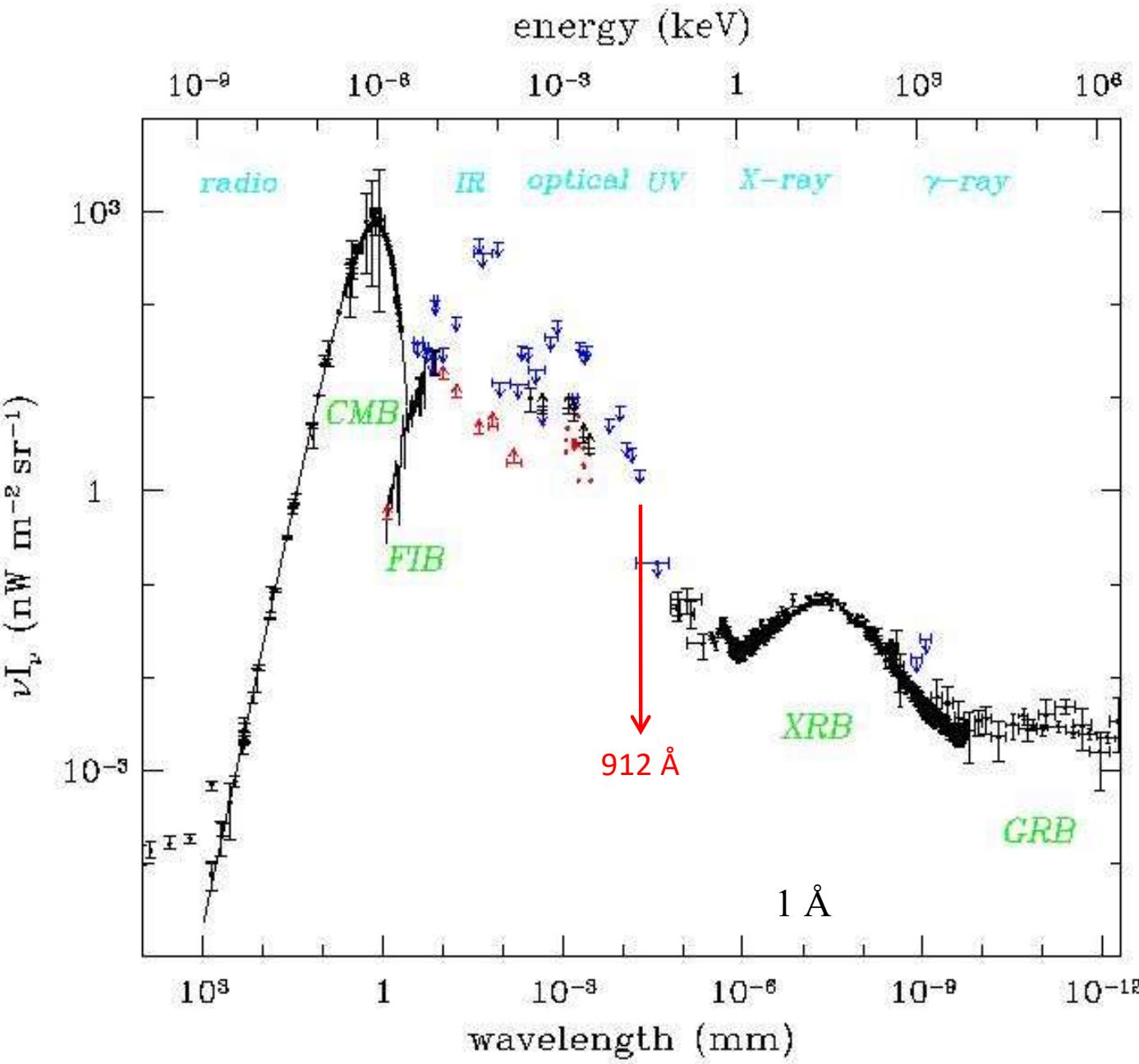


Efecto Sunyaev-Zeldovich



✓ observando desde la Tierra notamos que el **espectro de la RCF es corrido** para energías ligeramente mayores. Así, ocurre un **decremento** en la intensidad del espectro en la región de mayores longitudes de onda (región de **Rayleigh-Jeans**) y un incremento en la región de menores longitudes de onda (región de **Wien**). El numero de fotones es conservado, luego, el brillo superficial es independiente del *redshift!* Los fotones solamente roban energía del MIC.

Radiación de fondo



Radio:

- bremsstrahlung (HII)
- sincrotrón (nubes HI, SNe)
- líneas (21cm, molec., ...)
- AGNs

CMB:

- cuerpo negro (2.725 K)

FIR, sub-mm

- polvo (Galaxia, SFGs)

NIR, opt.

- estrellas (Gal., otras gal.)

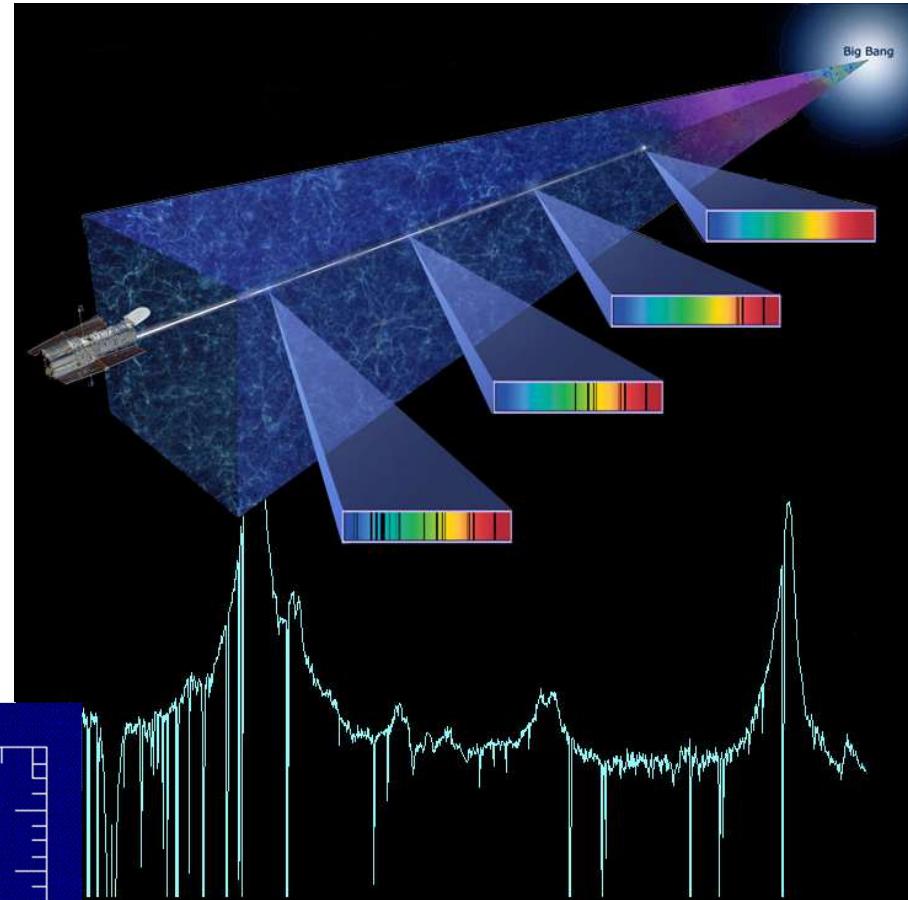
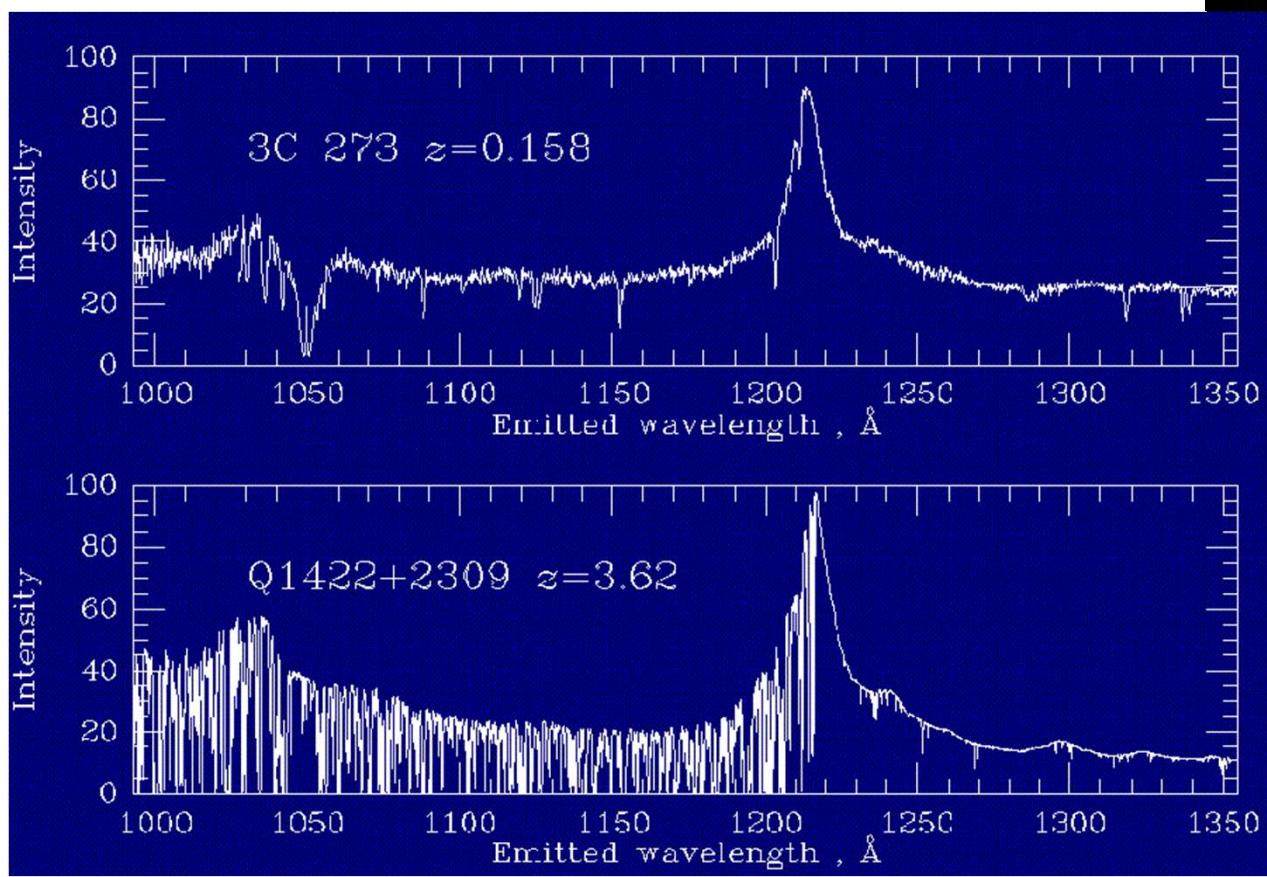
UV

- estrellas O, B...

Rayos-X, rayos-γ

- AGNs (predominante)
- fuentes Galácticas (binarias, reman. compact.)
- rayos cósmicos ($\pi \rightarrow 2\gamma$)

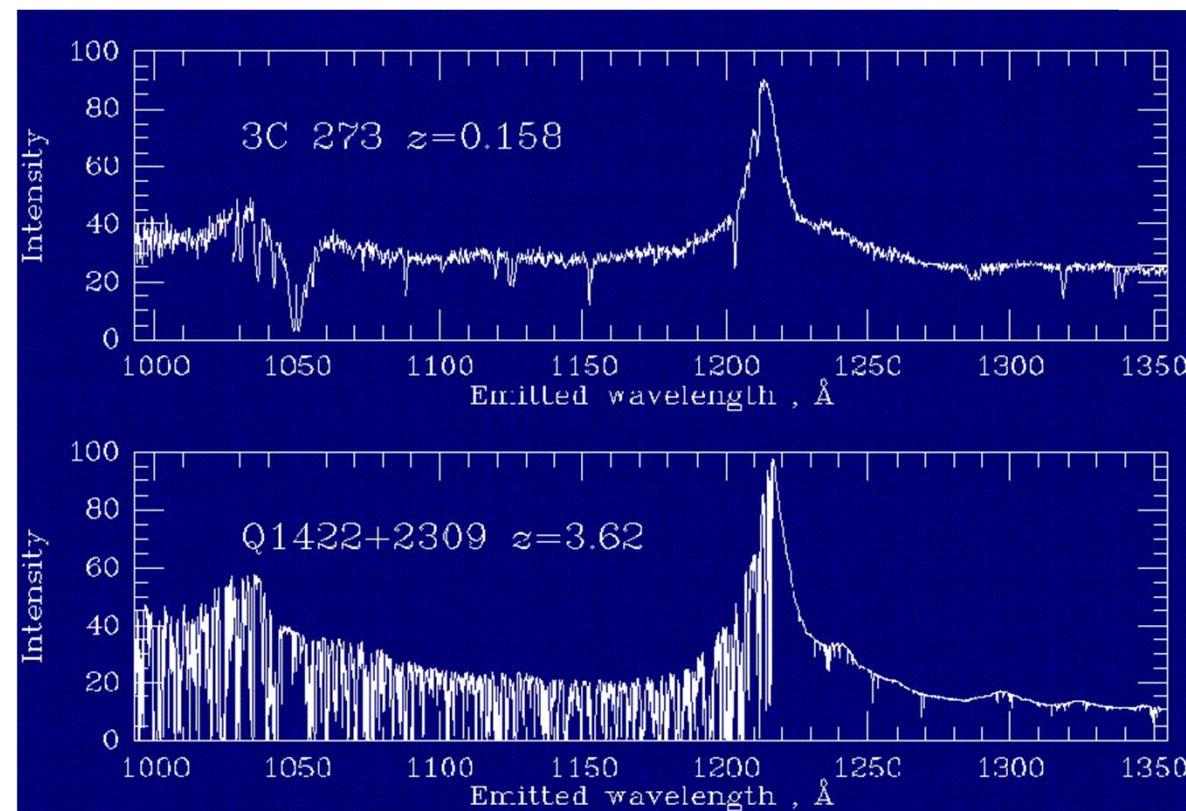
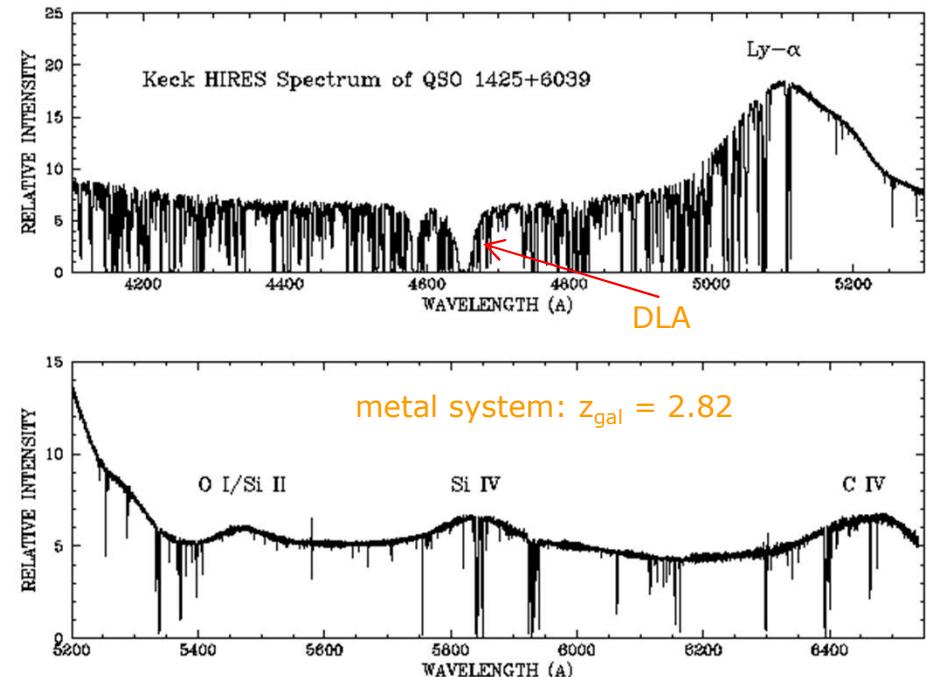
Medio Inter-Galáctico (MIG)



Bosques Ly- α

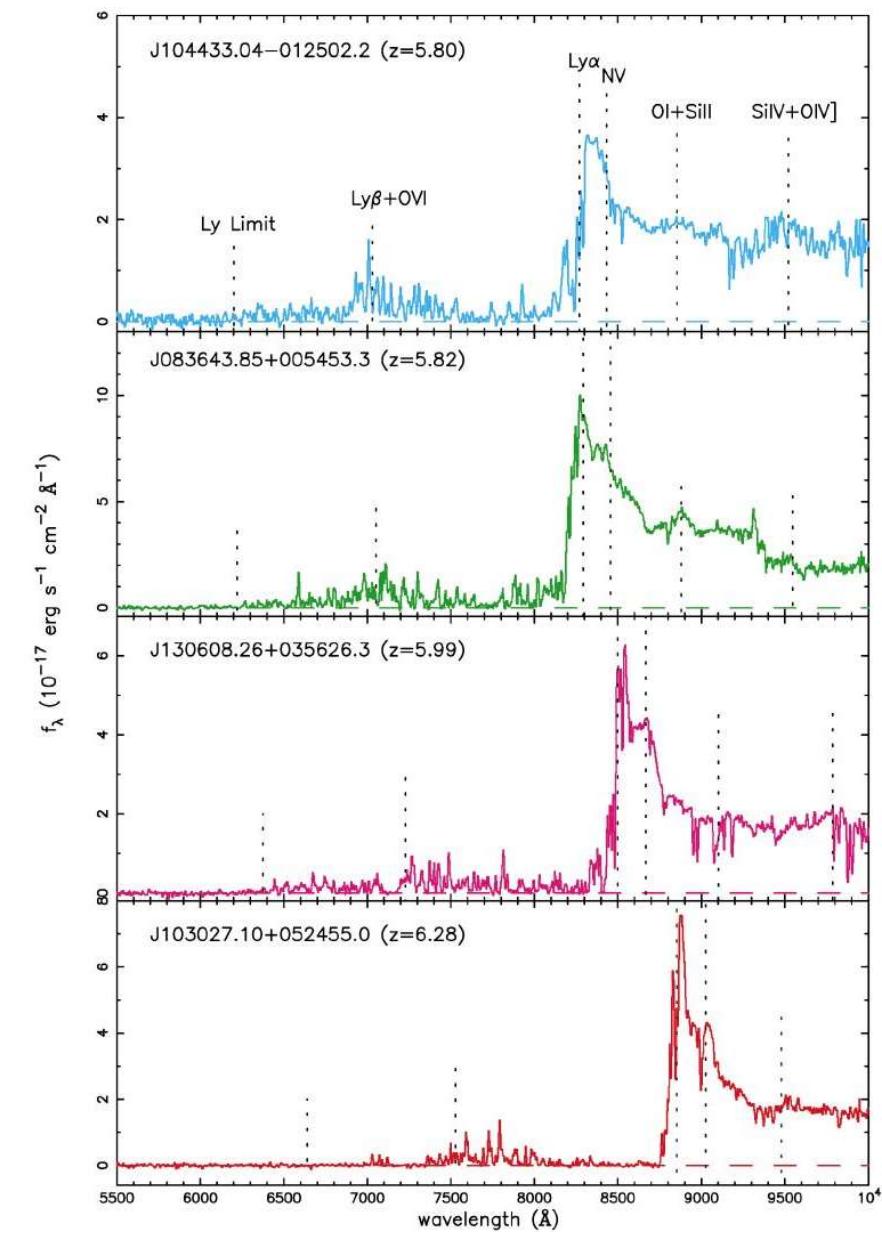
Metal Systems (all lines at the same z)

- ✓ $z_{\text{abs}} < z_{\text{QSO}}$: when there is a **foreground galaxy** (halo) in the LOS of the QSO, usually containing appreciable amounts of metals (that produce narrow absorption lines: MgII, CIV, etc)
- ✓ $z_{\text{abs}} \sim z_{\text{QSO}}$: absorption from material associated with the **QSO host** galaxy



Ly α forest (different z's)

- ✓ Ly α absorption by HI of **intergalactic clouds** along the LOS of the QSO [$\lambda < \lambda_{\text{Ly}\alpha} = (1+z_{\text{QSO}}) 1216 \text{ Å}$]; their amount depend on the z of the QSO
- ✓ when the column of H in Ly α systems has higher densities, the absorption lines are broad and their are called **damped Ly α systems (DLA)**



Efecto Gunn-Peterson

