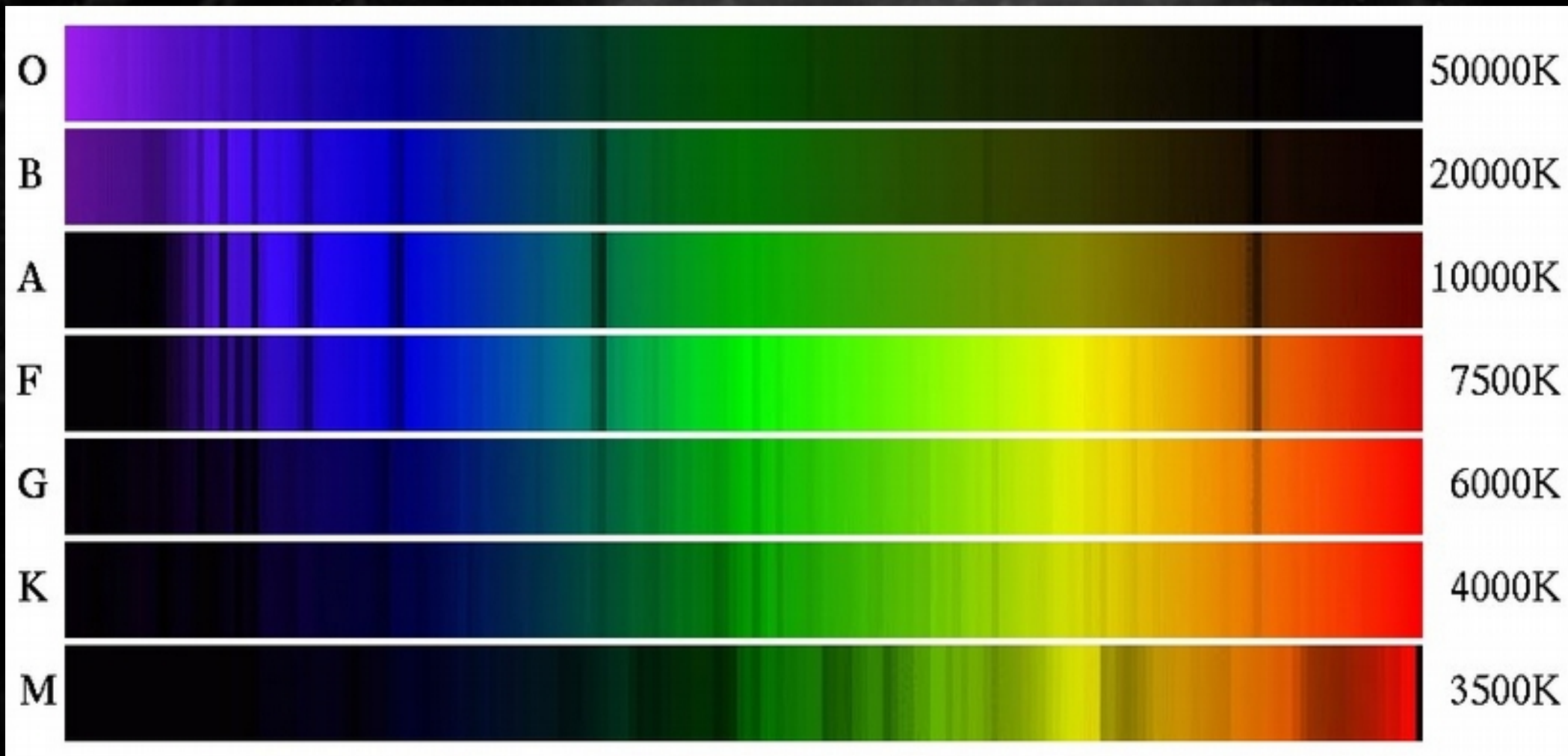
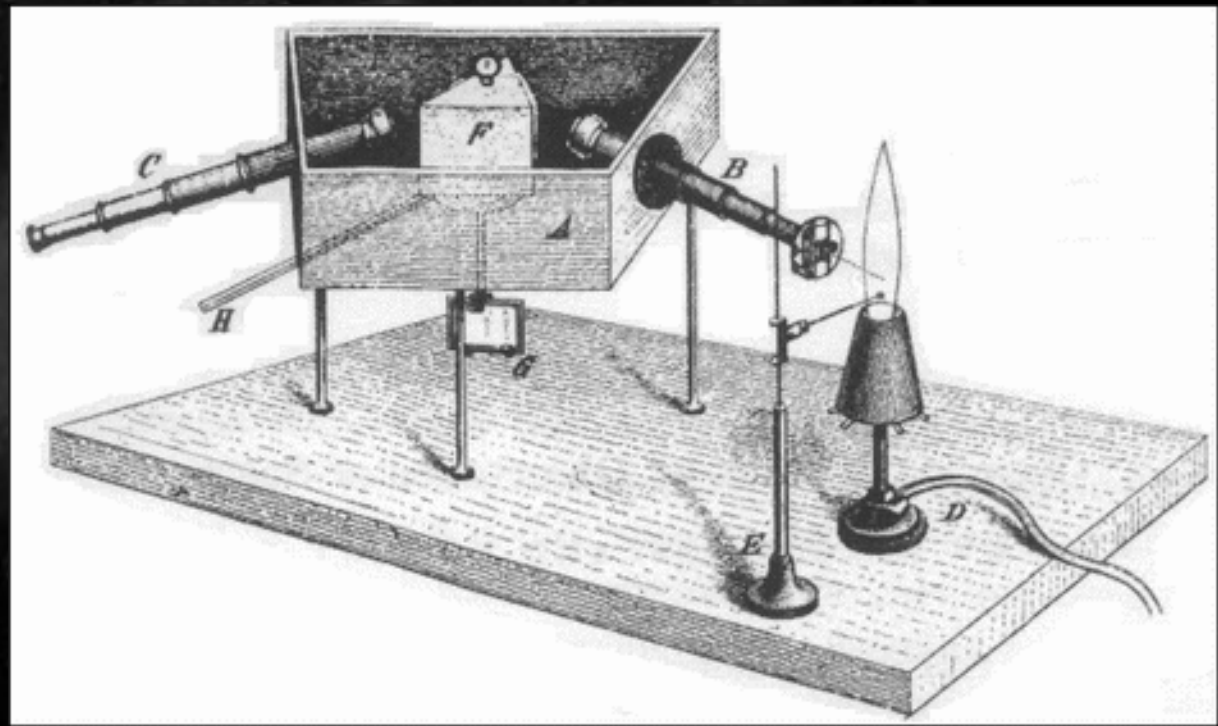


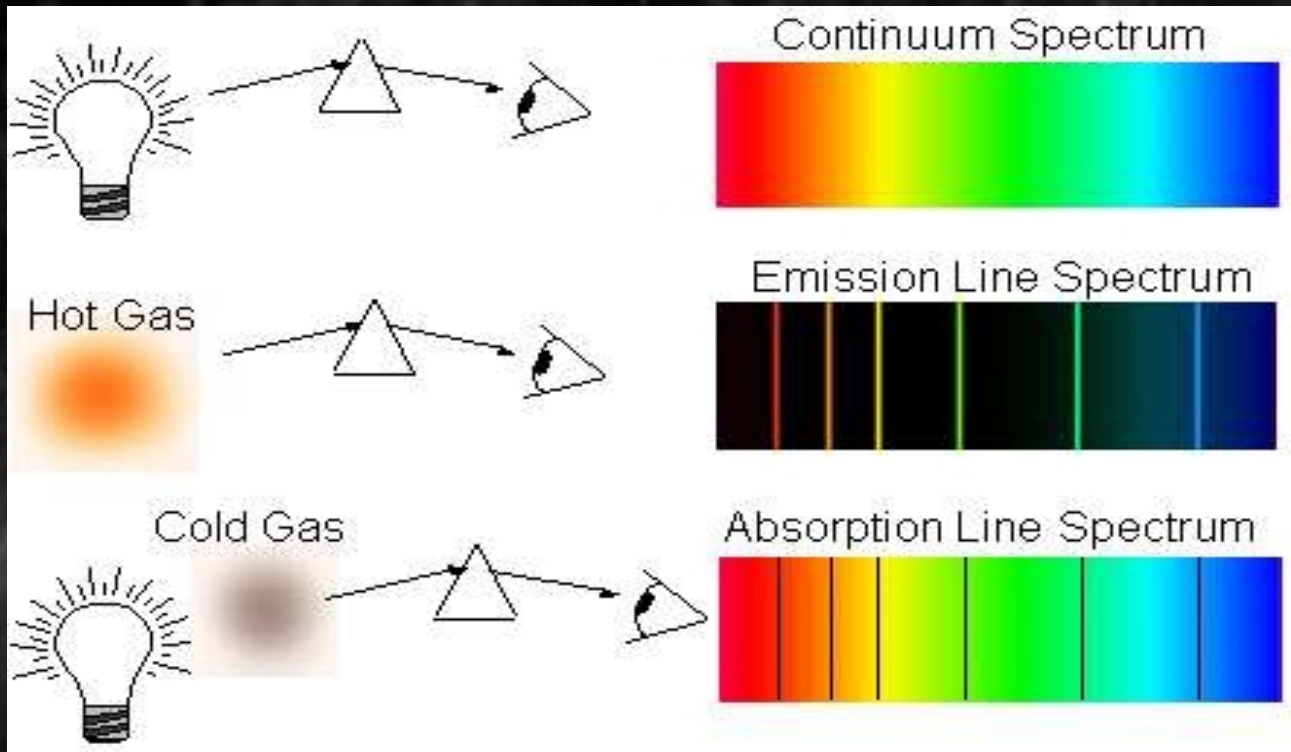
Csillagászati spektroszkópia dióhéjban

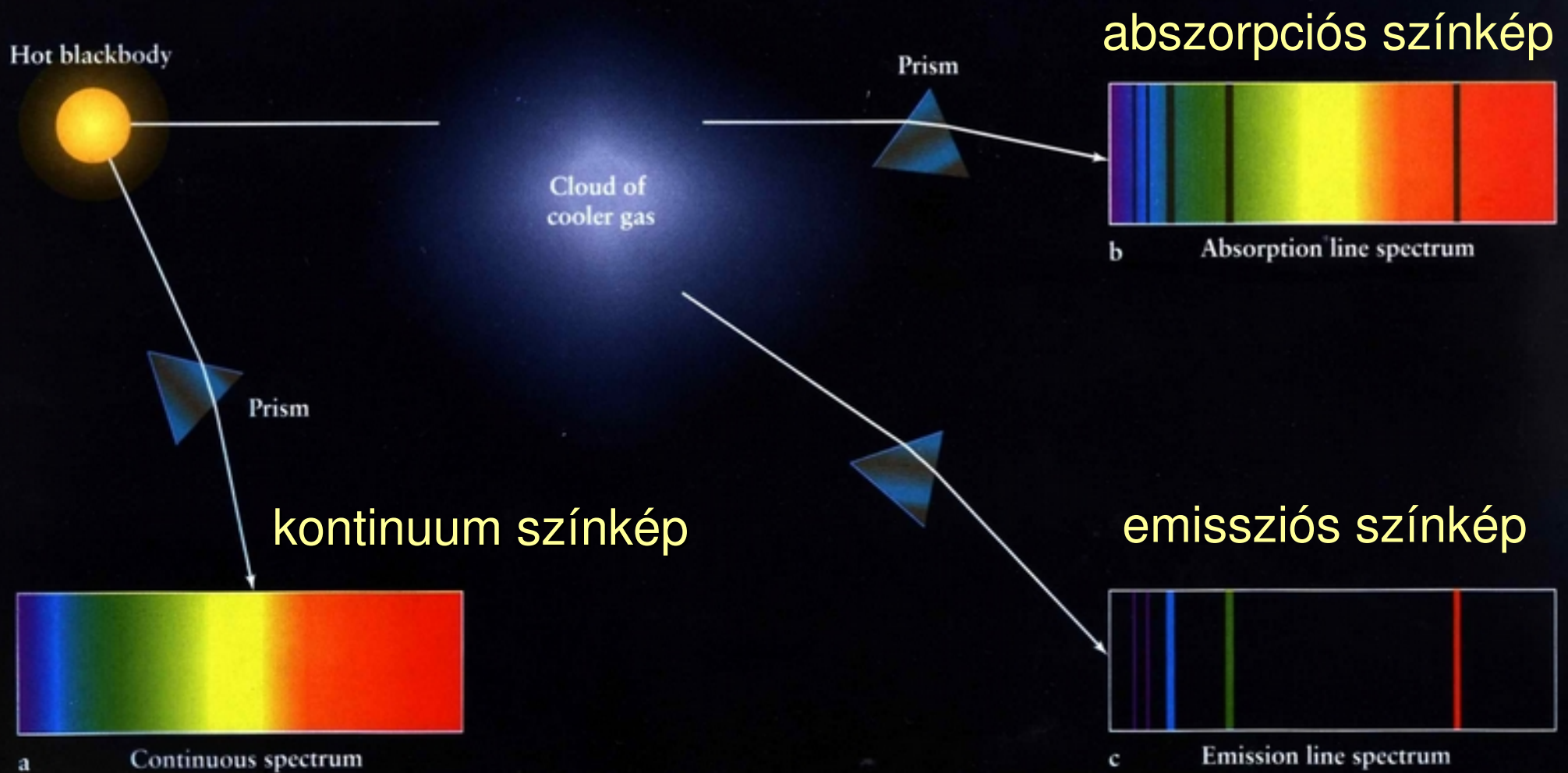
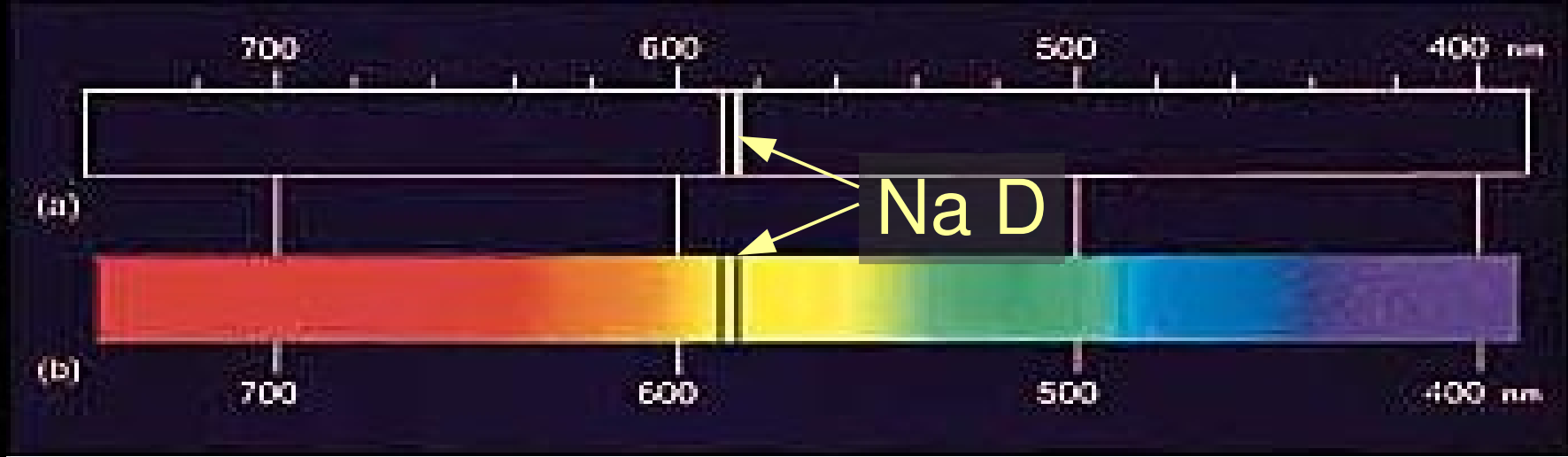


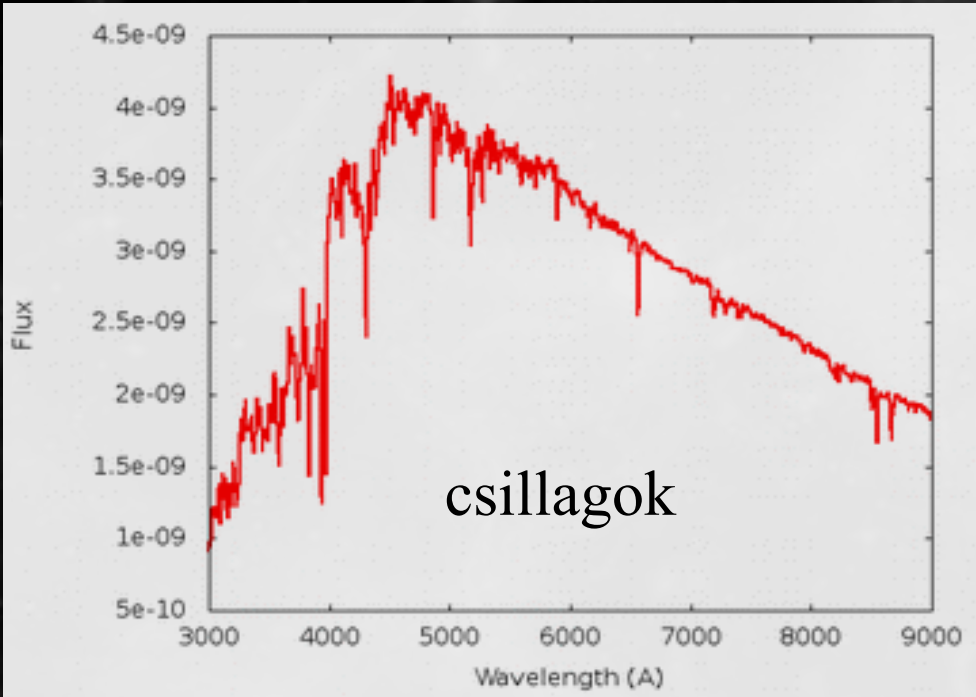
Gustav Kirchhoff



Robert Bunsen

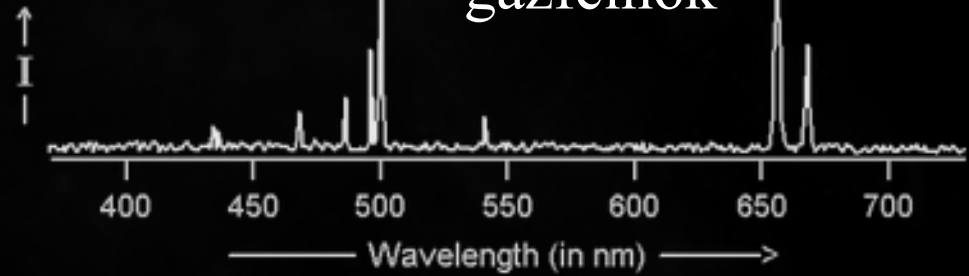




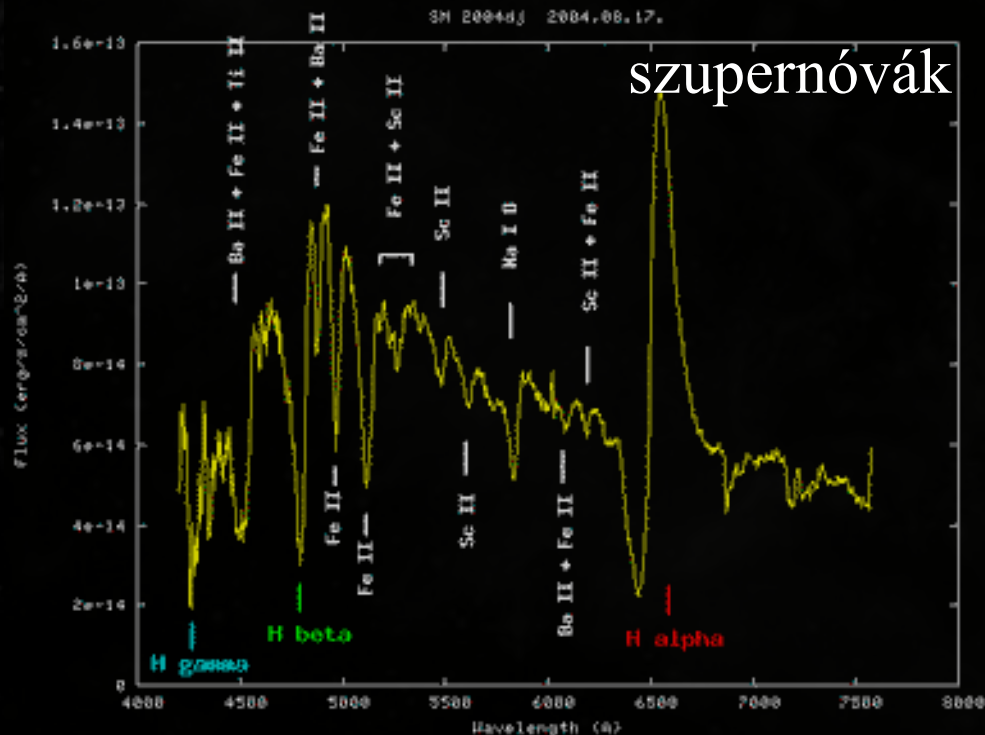
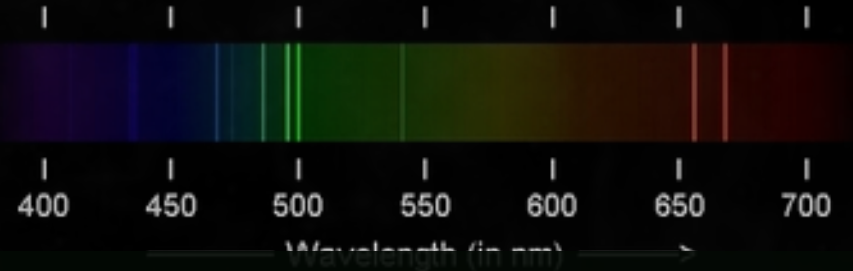


Graphical

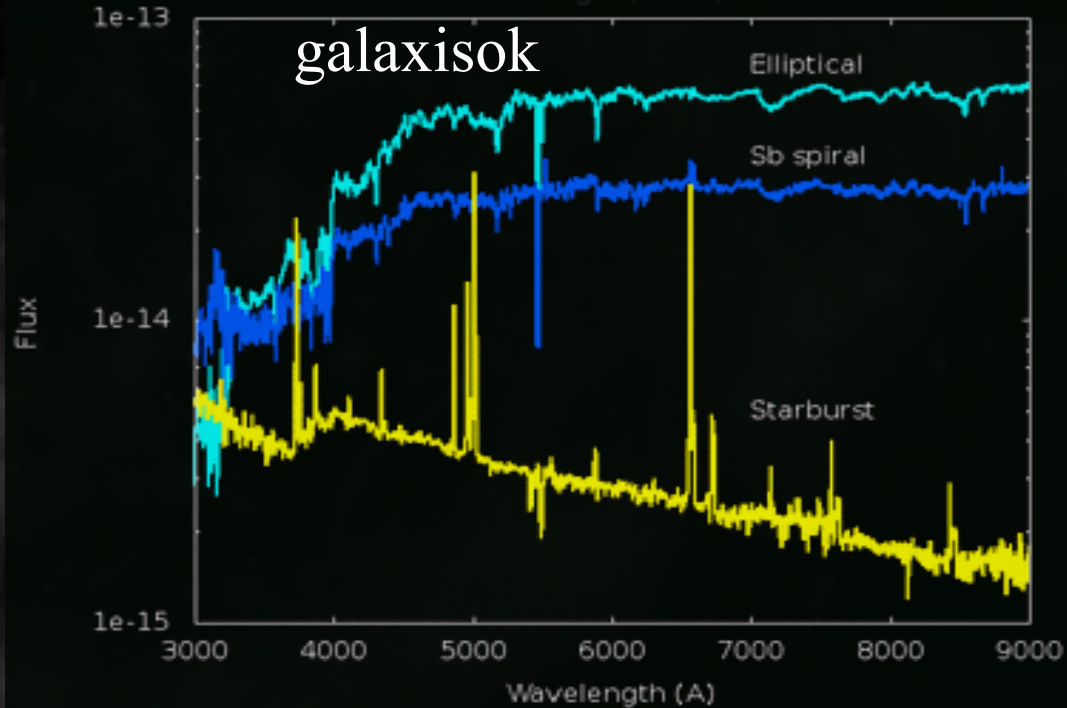
gázfelhők



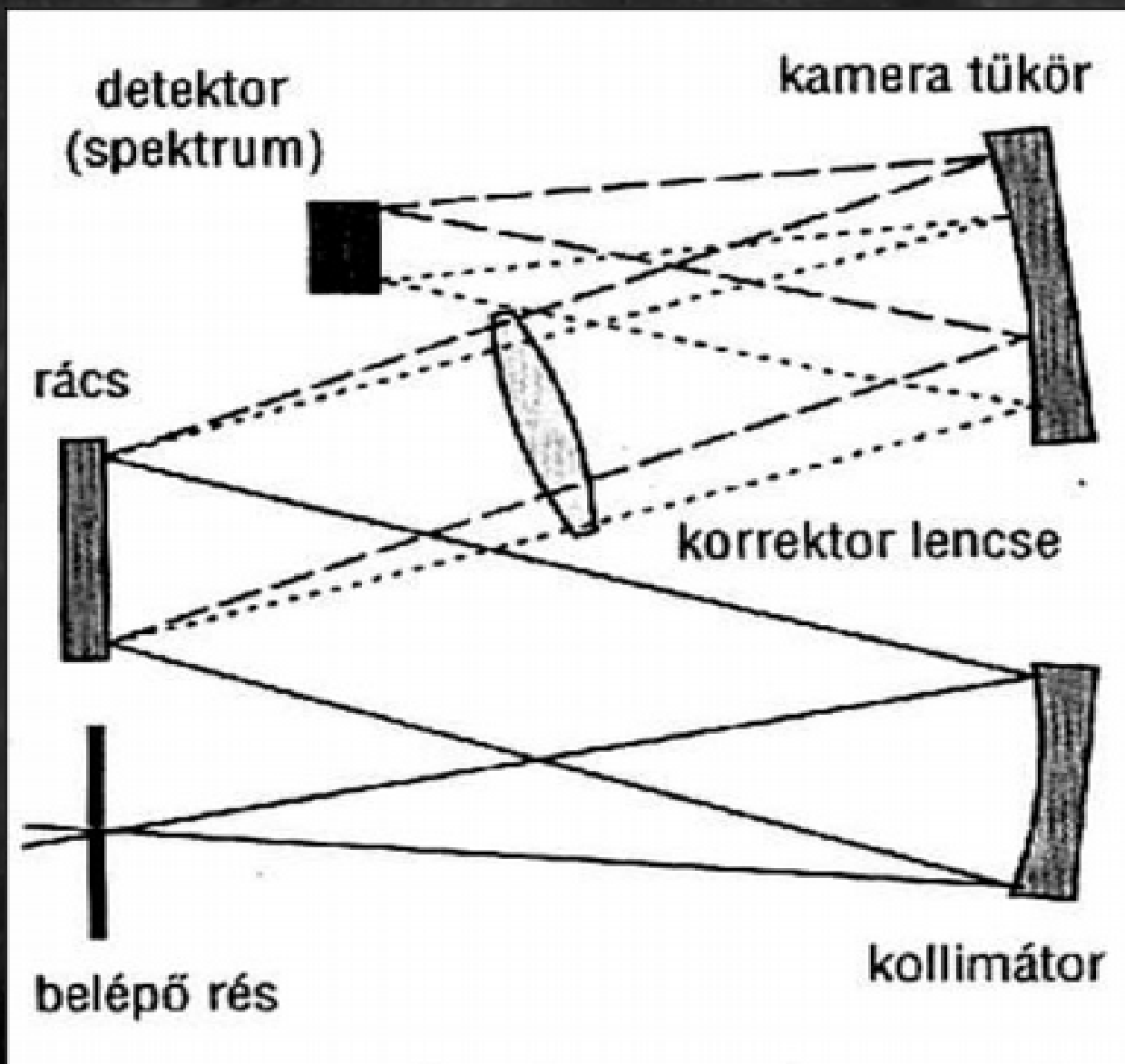
Visual



galaxisok



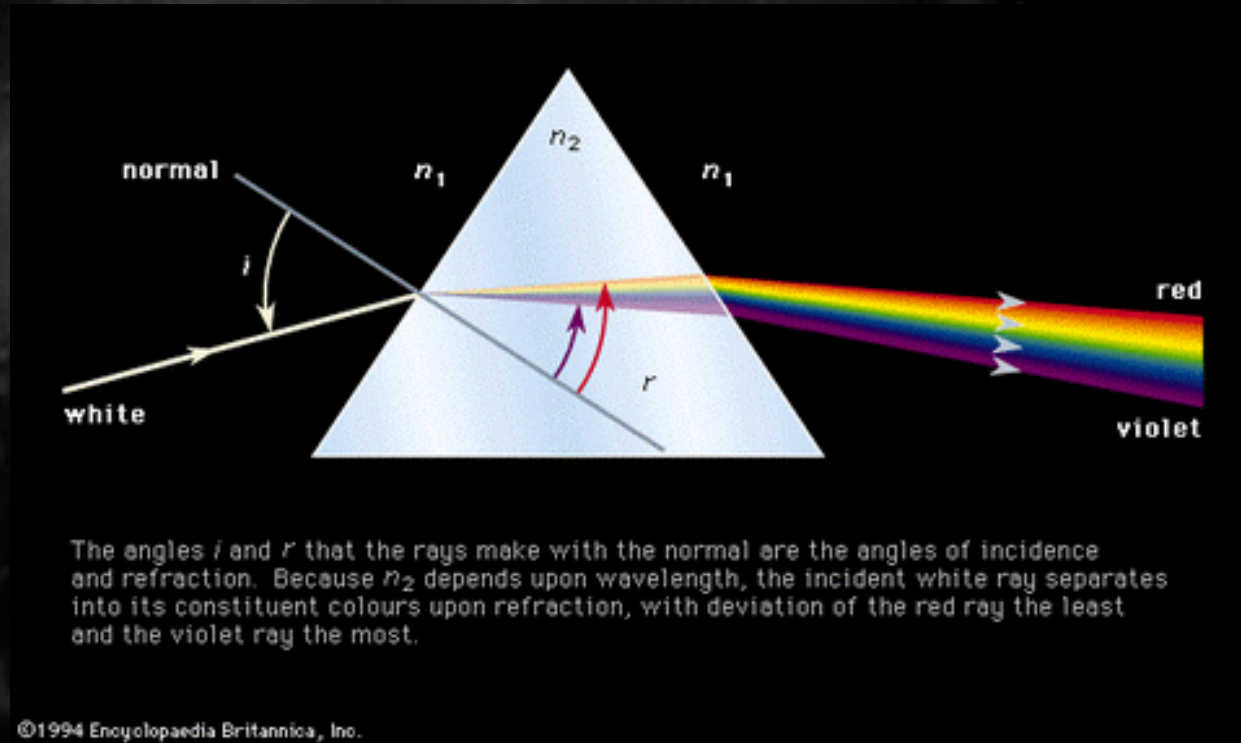
Spektroszkóp általános felépítése



Bontóelem

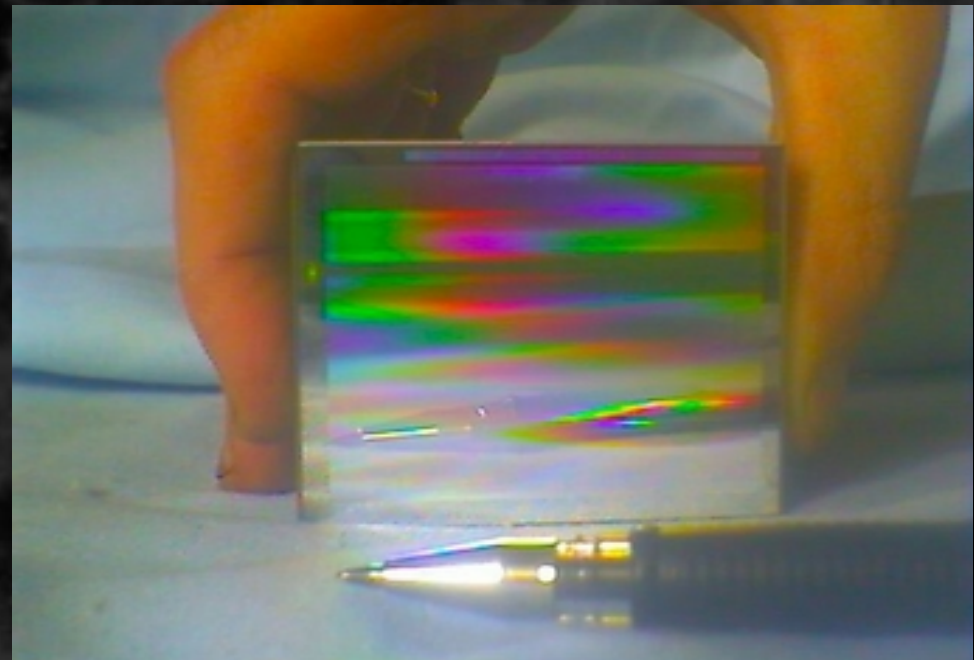
prizma (prism)

- φ törőszög
- $dn/d\lambda$ diszperzió



optikai rács (grating)

- transzmissziós
- reflexiós
- d osztásköz
- $1/d$ (mm) rácsállandó



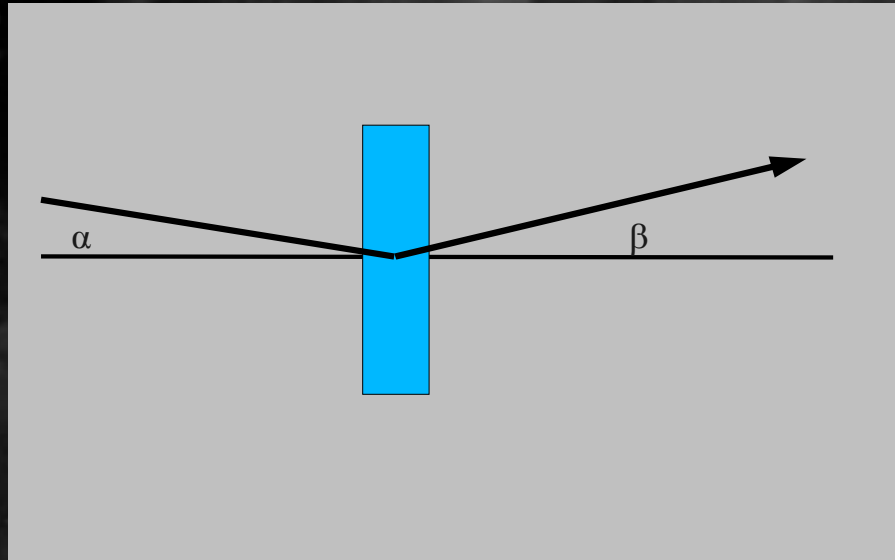
Szögdiszperzió (angular dispersion)

$$d\beta / d\lambda$$

rácsegyenlet:

$$\sin(\alpha) + \sin(\beta) = \frac{m\lambda}{d}$$

$$\frac{d\beta}{d\lambda} = \frac{m}{d \cos(\beta)}$$



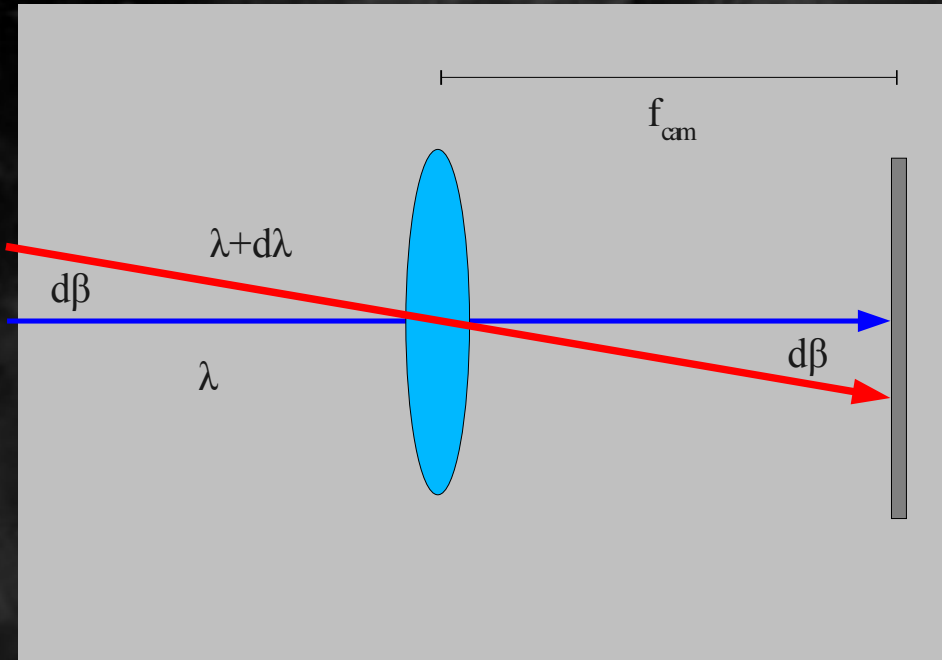
prizma

$$\frac{d\beta}{d\lambda} = \frac{2 \sin\left(\frac{\varphi}{2}\right)}{\cos\left(\frac{\beta + \varphi}{2}\right)} \frac{dn}{d\lambda}$$

Lineáris diszperzió

(linear dispersion)

$$\frac{dx}{d\lambda}$$



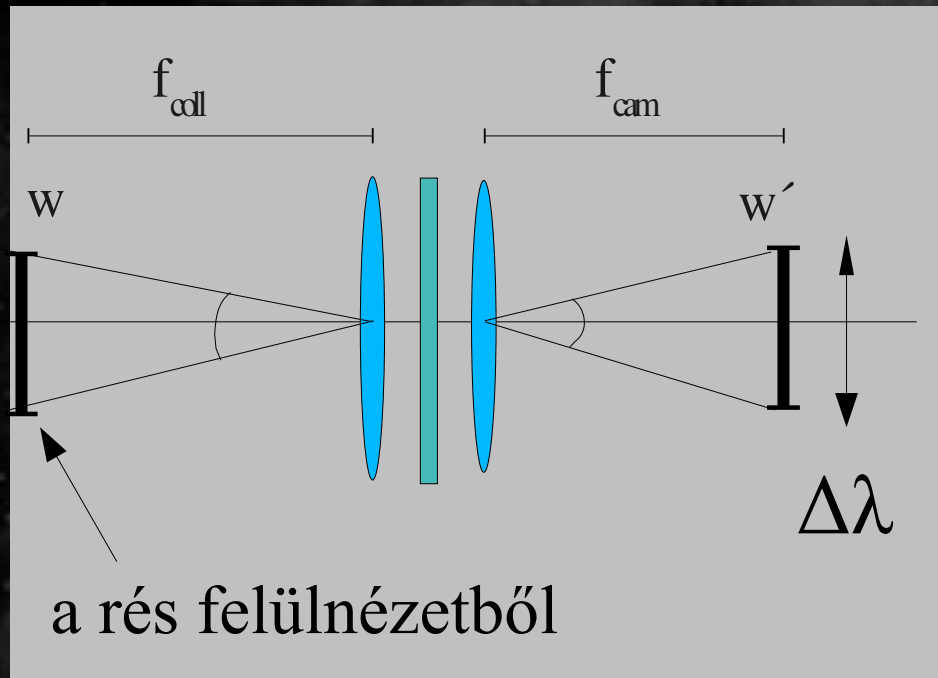
$$dx = f_{cam} d\beta$$

$$\frac{dx}{d\lambda} = f_{cam} \frac{d\beta}{d\lambda}$$

reciprok lineáris diszperzió:

$$\frac{d\lambda}{dx} = 1/f_{cam} \left(\frac{d\beta}{d\lambda}\right)^{-1} = \frac{d \cos(\beta)}{m f_{cam}} \quad (\text{\AA}/\text{mm})$$

Felbontóképesség (resolution)



$$\frac{w}{f_{coll}} = \frac{w'}{f_{cam}}$$

$$\Delta \lambda = w' \frac{d \lambda}{d x} = w \frac{f_{cam}}{f_{coll}} \left(\frac{d \lambda}{d x} \right)$$

$$\Delta \lambda = \frac{d \cos(\beta)}{m} \frac{w}{f_{coll}}$$

felbontóképesség:

$$R = \frac{\lambda}{\Delta \lambda} = \frac{m}{w \cos(\beta)} \frac{\lambda f_{coll}}{d}$$

Felbontóképesség

prizma: $\left(\frac{\lambda}{\Delta\lambda}\right)_{prizma} = b \left(\frac{dn}{d\lambda}\right)$ b : bázishossz

rács: $\left(\frac{\lambda}{\Delta\lambda}\right)_{rács} = W \frac{m}{d}$ W : rács szélessége

A spektroszkóp és a rács felbontóképességének aránya:

$$\frac{R_{sp}}{R_{rács}} = \frac{\lambda f_{coll}}{W w \cos(\beta)} = \frac{\lambda}{w} \frac{f_{coll}}{D_{coll}}$$

← a kollimátor átmérője

$$\frac{f_{coll}}{D_{coll}} > 1 \quad \text{és} \quad \frac{\lambda}{w} \ll 1 \quad \rightarrow \quad \frac{R_{sp}}{R_{rács}} \ll 1$$

Felbontóképesség

kisfelbontású sp.: $R < 1000$

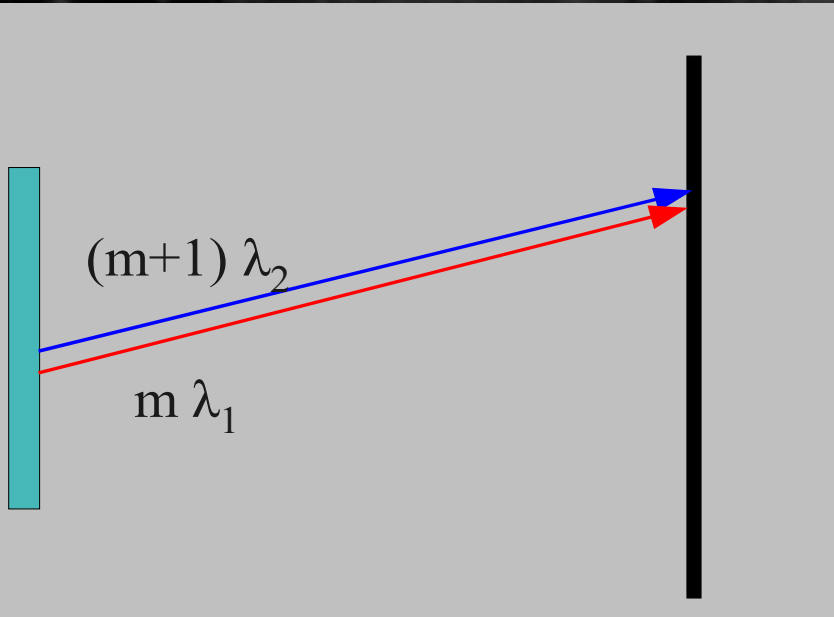
közepes felbontású sp.: $1000 < R < 20\ 000$

nagyfelbontású sp.: $R > 20\ 000$

extrém nagy felbontás: $R > 100\ 000$

Szabad spektráltartomány

(free spectral range, FSR)



$$m \lambda_1 = d \sin(\beta)$$

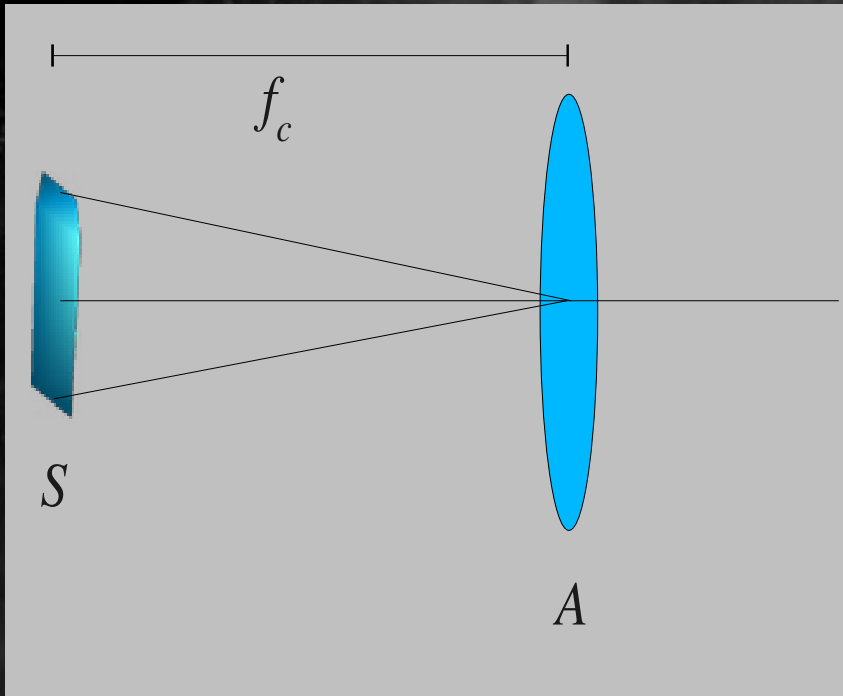
$$(m+1) \lambda_2 = d \sin(\beta)$$

$$\delta \lambda = \lambda_1 - \lambda_2$$

$$\delta \lambda = d \sin(\beta) \left(\frac{1}{m} - \frac{1}{m+1} \right)$$

$$FSR = \delta \lambda = \frac{d \sin(\beta)}{m(m+1)}$$

Fényerő (luminosity)



$$S = w \cdot l$$

$$A = \pi / 4 \cdot D_{coll}^2$$

$$\Omega = S / f_c^2$$

etendue:

$$E_{sp} = A \cdot \Omega = \pi / 4 \cdot \left(\frac{D_{coll}}{f_c} \right)^2 \cdot w l$$

Egyenletesen kivilágított résnél:

$$L = B \cdot E$$

Optimális illesztés:

$$E_{tel} = \pi / 4 D_{tel}^2 \sigma = E_{sp}$$

seeing diszk szögmérete

Fényerő vs. felbontás

$R \sim 1/w \Rightarrow$ felbontás növelése = résszél. csökkentése

$L \sim w \Rightarrow$ résszélesség csökkentése = fényerő csökken

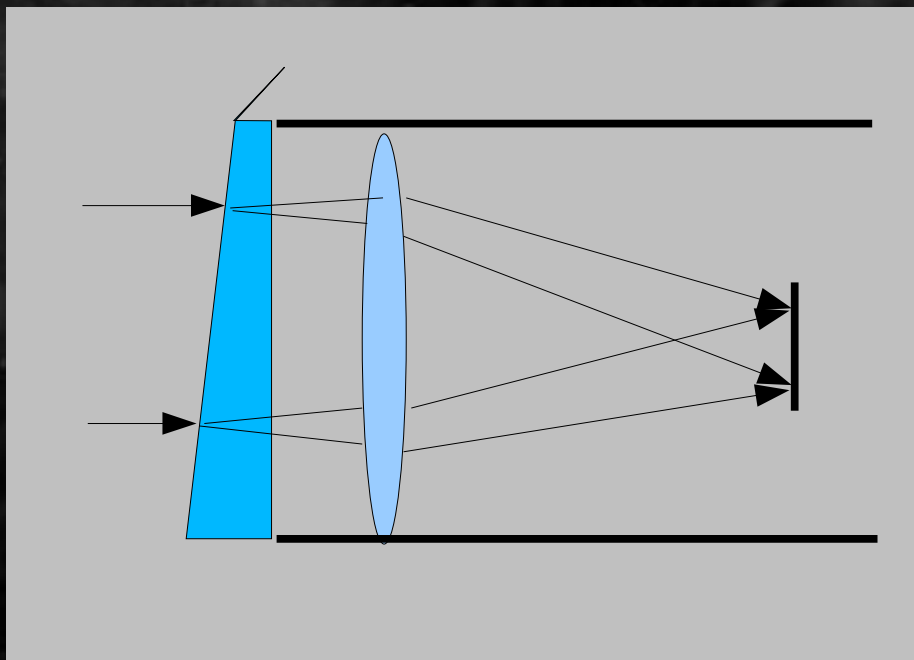
A rés kivilágítása $\sim D_{tel}^2 \Rightarrow$

a fényveszteség csökkentéséhez nagyobb távcső kell!

Illesztési feltétel: $(D/f)_{tel} = (D/f)_{coll}$

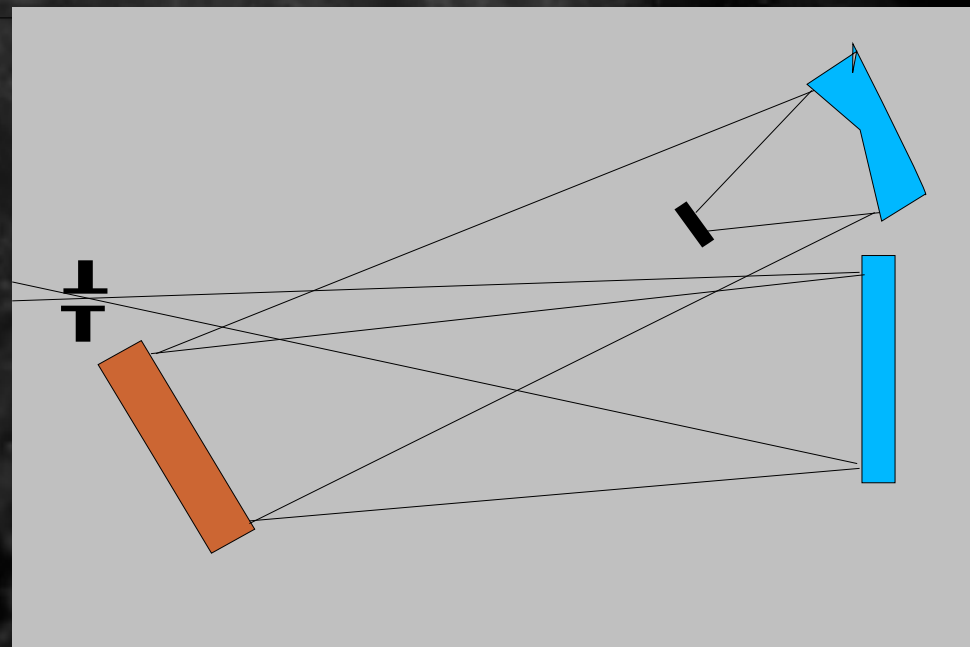
Objektív prizma

- kis felbontás
- nemlineáris diszperzió

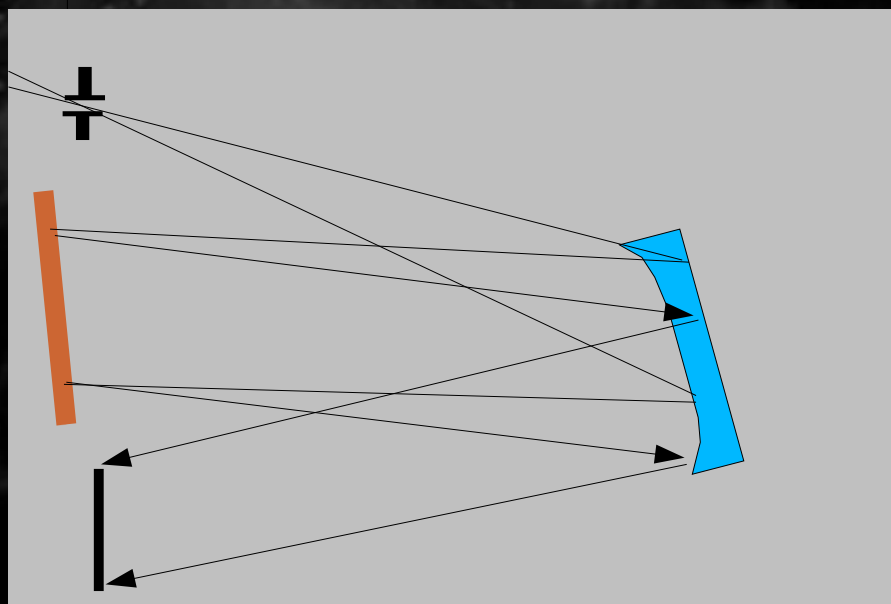


Cassegrain spektroszkóp

- alacsony rend
- $R = 1000-15000$
- lineáris diszperzió (majdnem...)



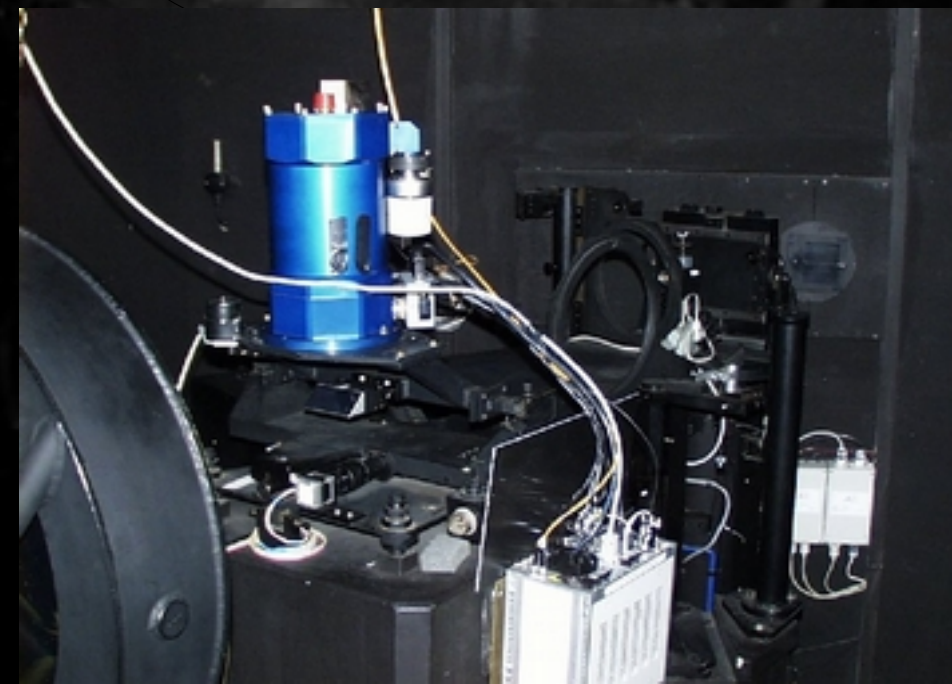
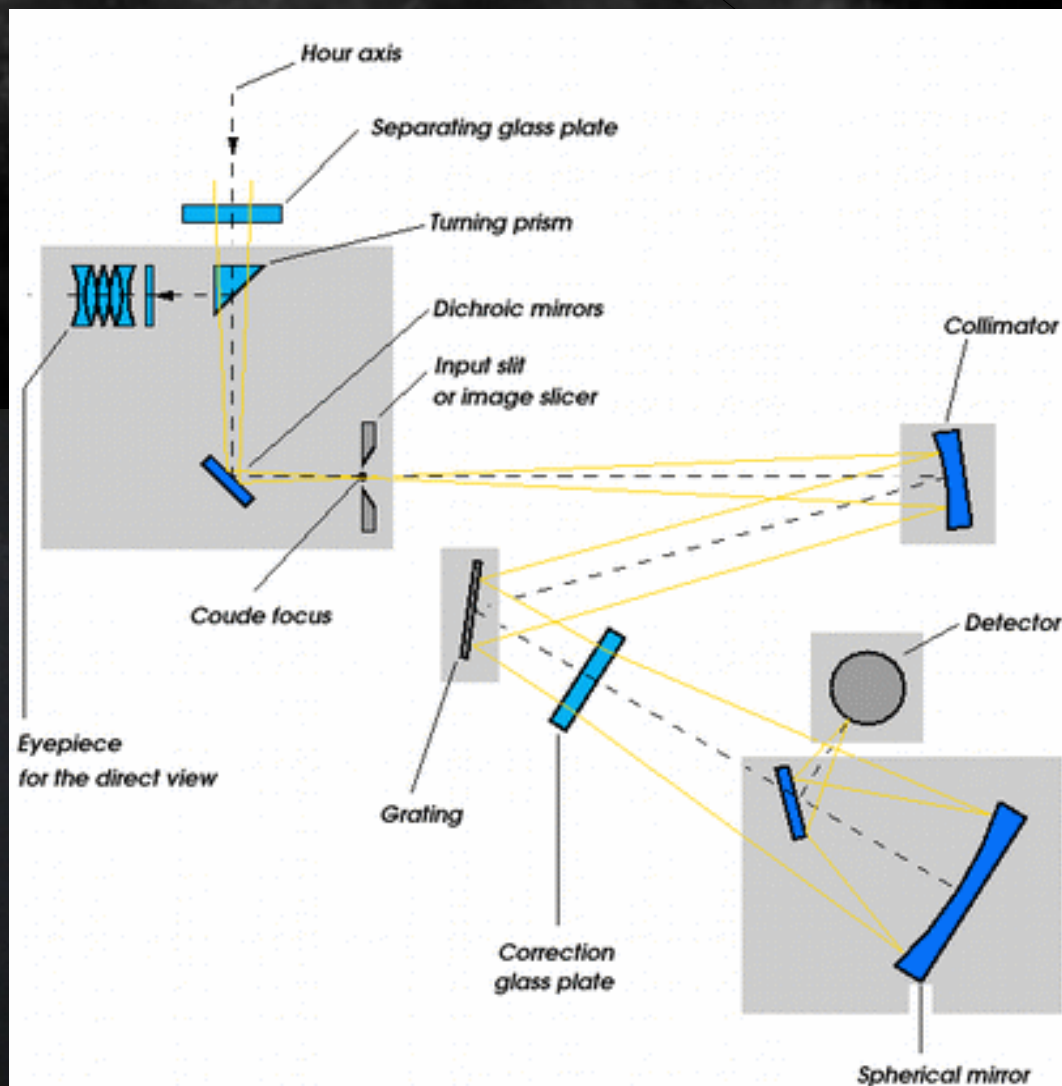
normál



autokollimációs

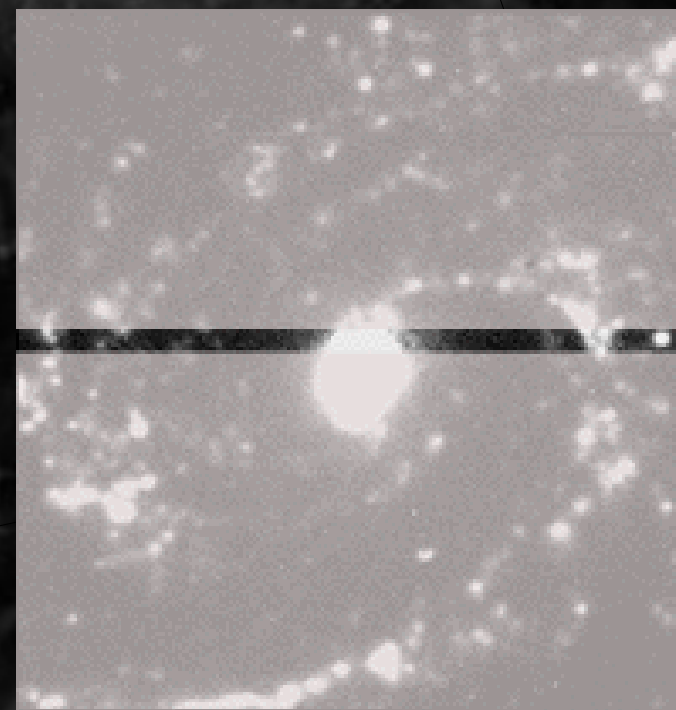
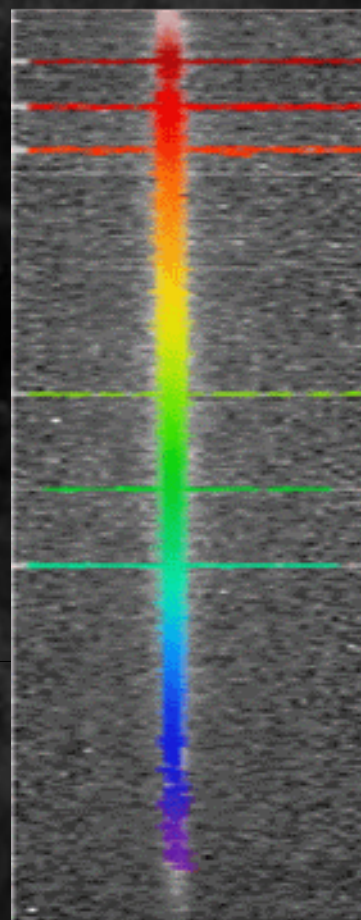
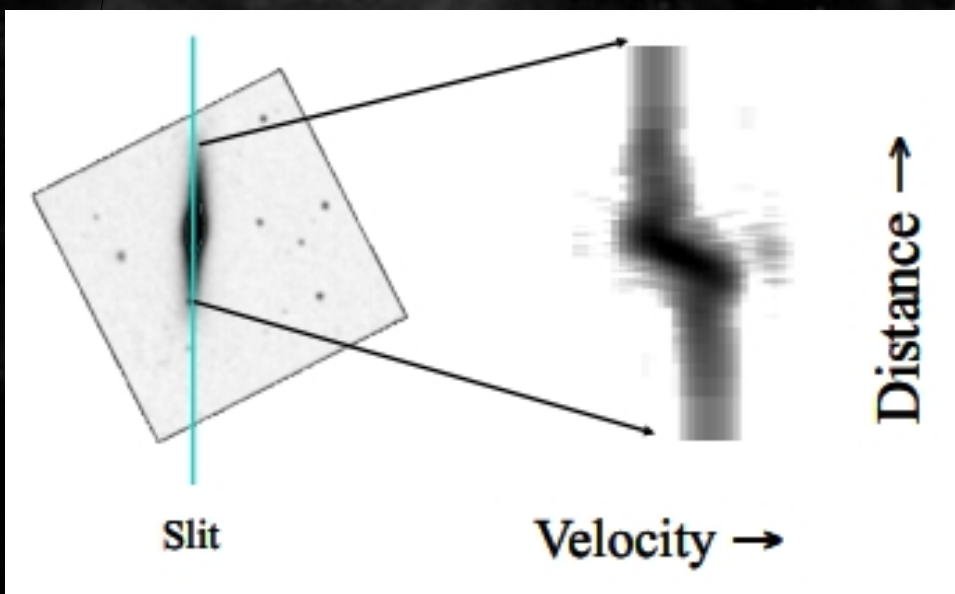
Coudé spektrográf

- nagy felbontás ($R > 50000$)
- fix pozíció
(Coudé-fókuszban)
- egyszerre több rend rögzítése



Long slit spektrográf

- kiterjedt objektumok vizsgálata
- a rés kül. pontjaiból más-más spektrum

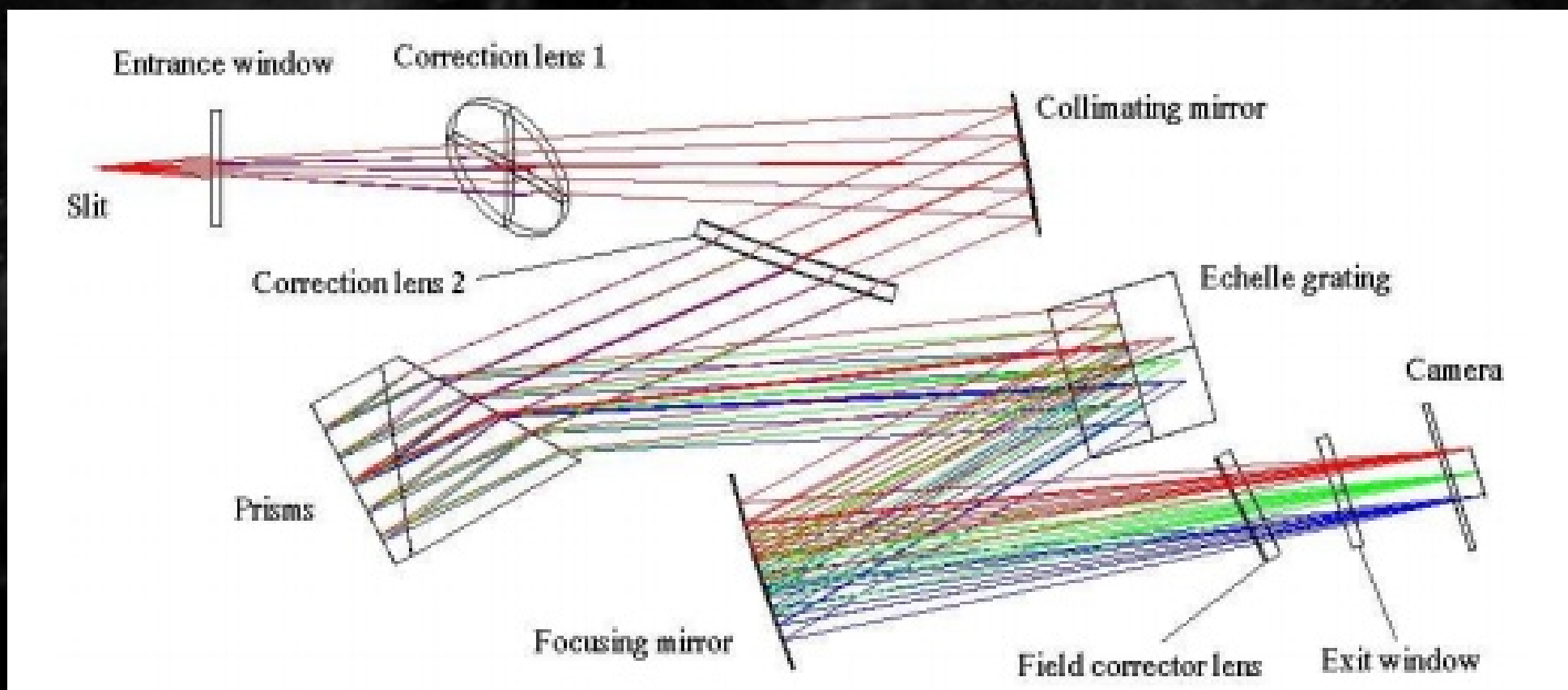


Echelle spektrográf

magas rend: $m > 20$

echelle rács + keresztdiszperziós elem

nagy felbontás: $R = 30\,000 - 200\,000$

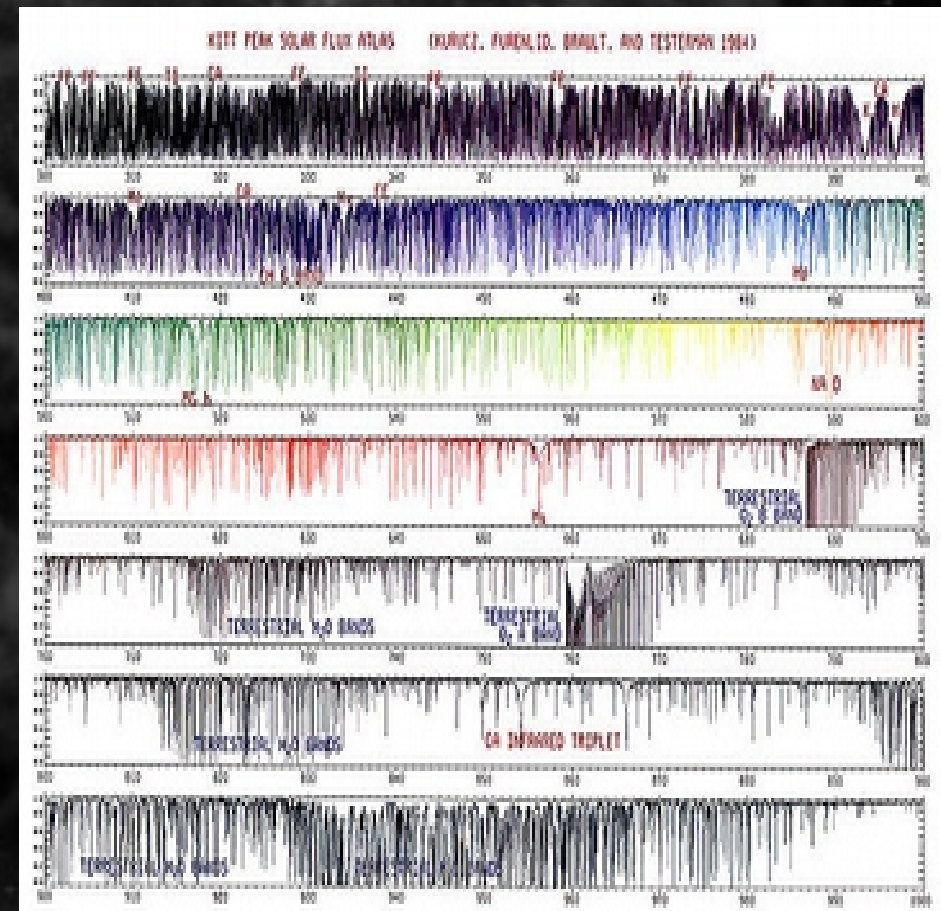
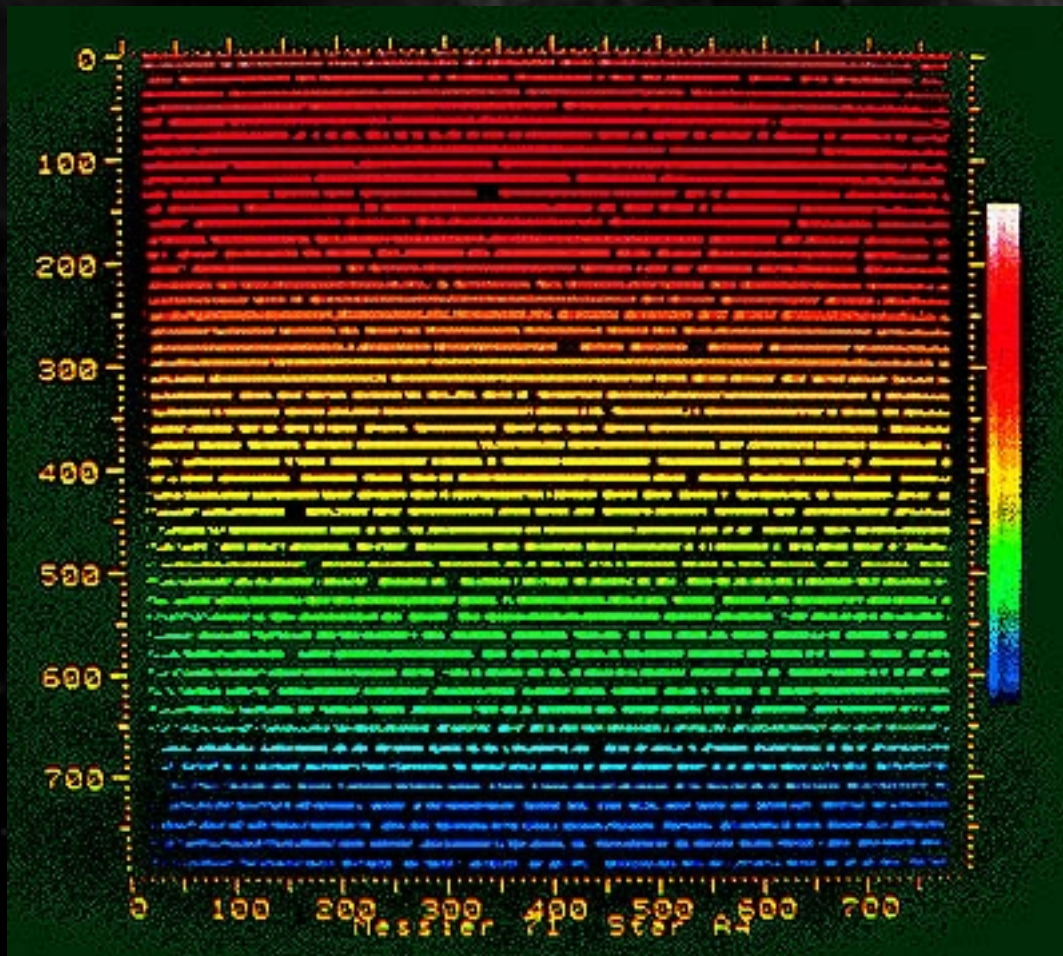


magas rend: $m > 20$

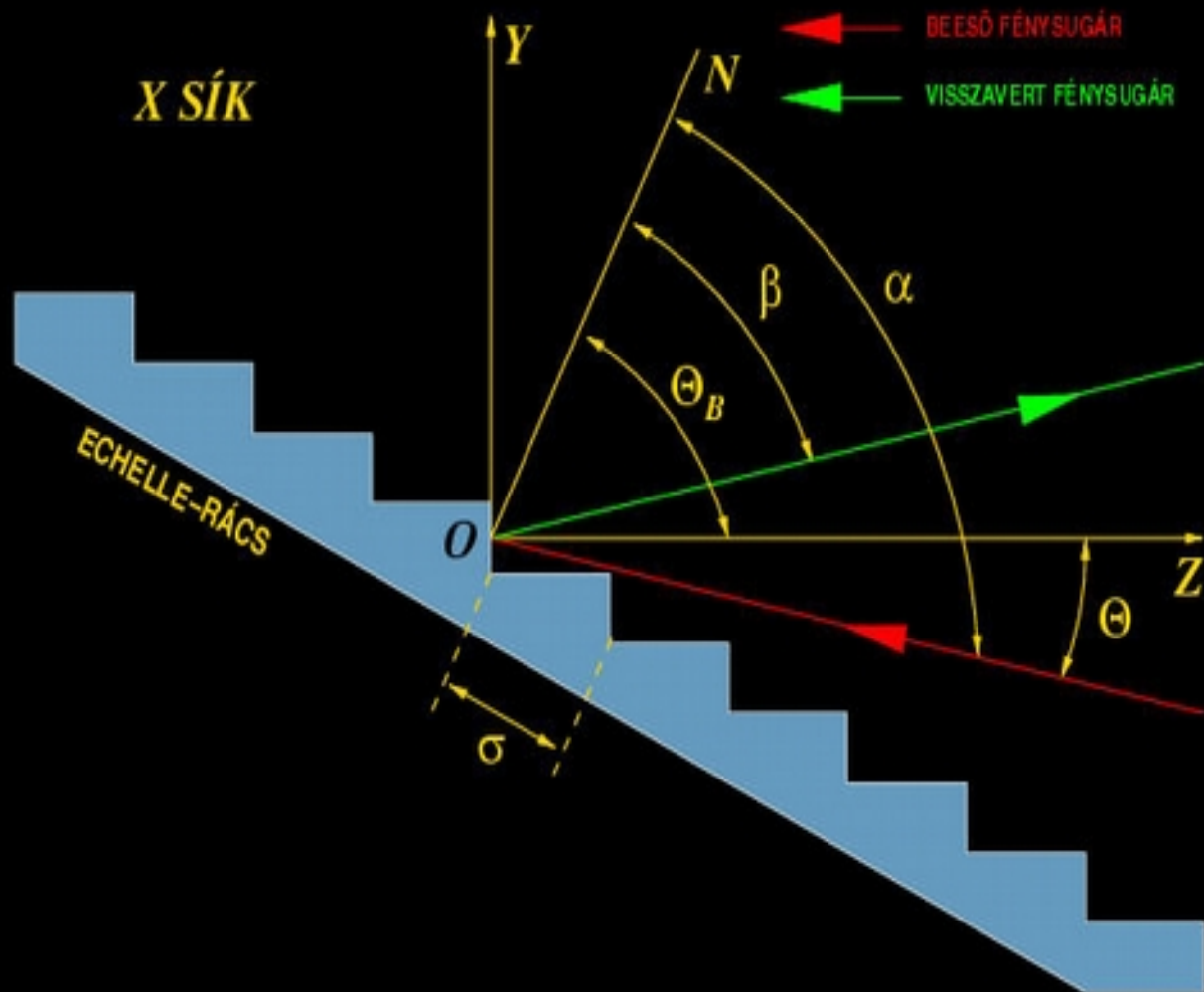
echelle rács + keresztdispersiós elem

nagy felbontás: $R = 30\,000 - 200\,000$

széles lefedett spektrális tartomány



ECHELLE-RÁCS KERESZTMETSZETE

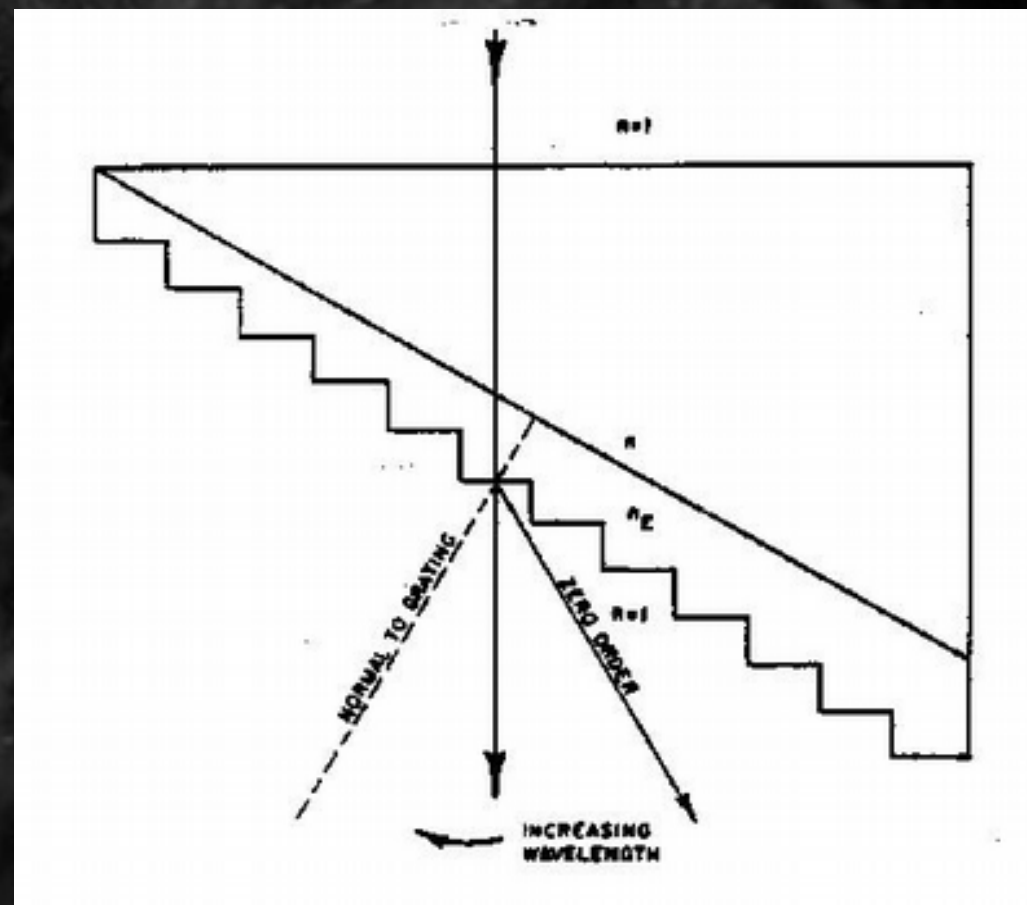
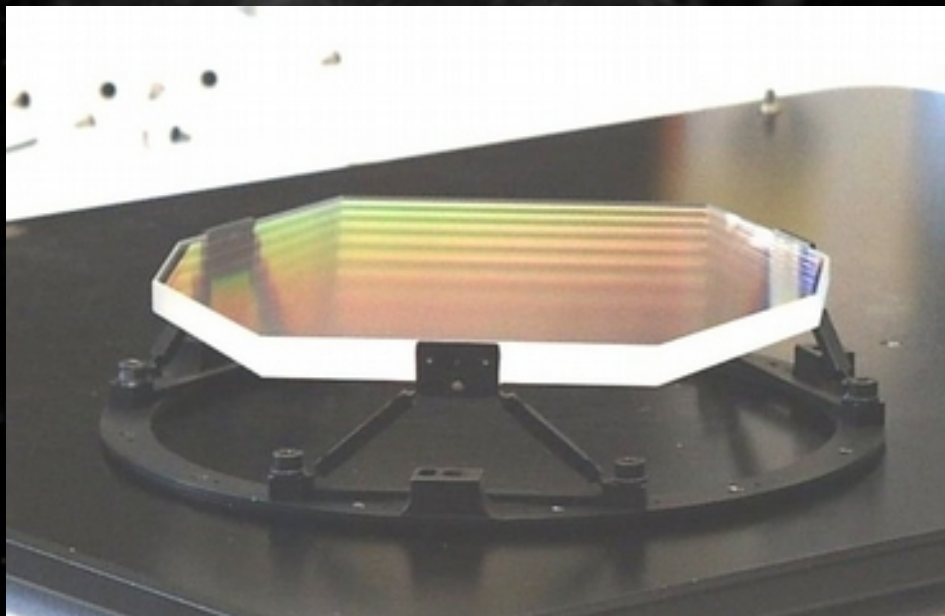


θ_B : blaze angle
(csillogási szög)

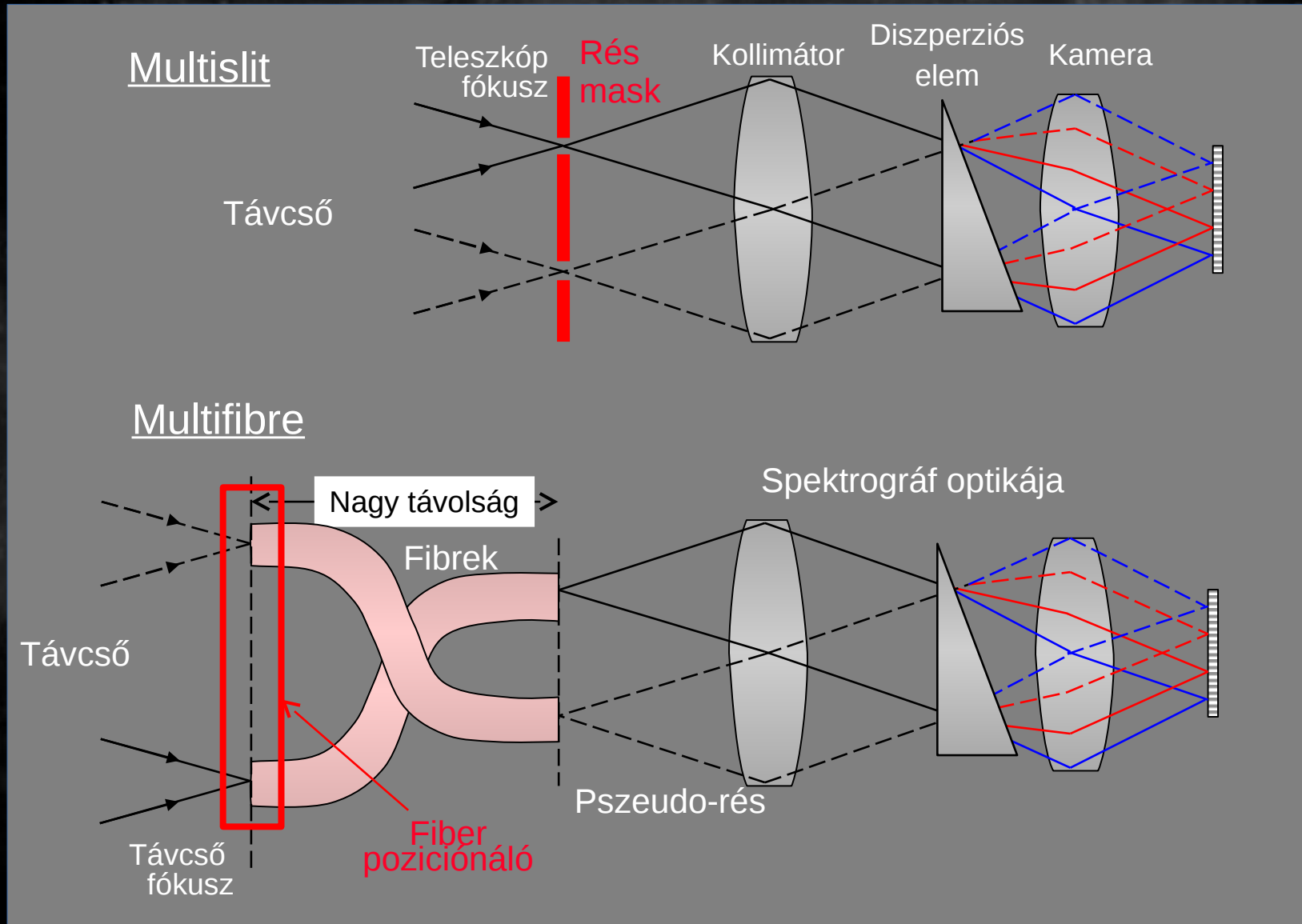
σ : rácsállandó

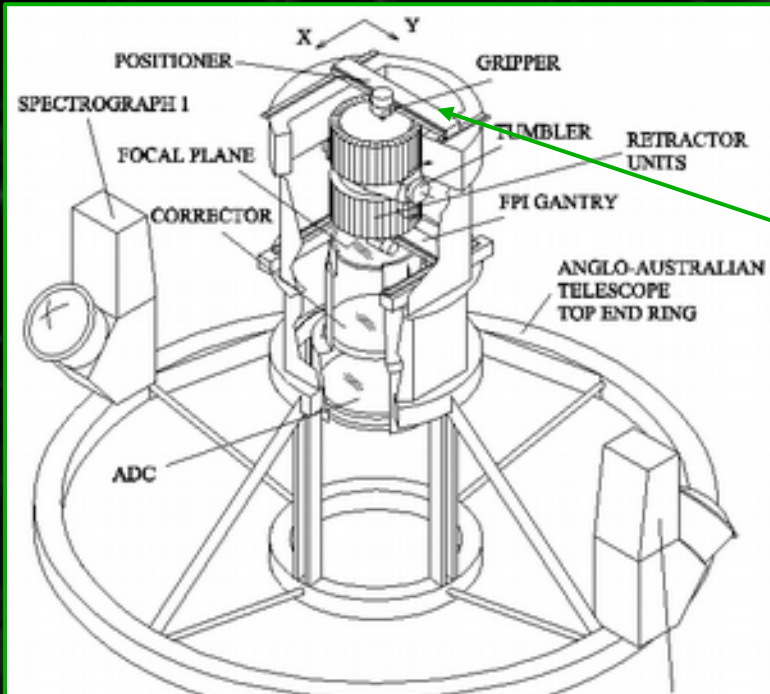
Grism (prizma+rács, "prács")

- alacsony rend ($m=1,2,3$)
- kis felbontás
- kompakt méret

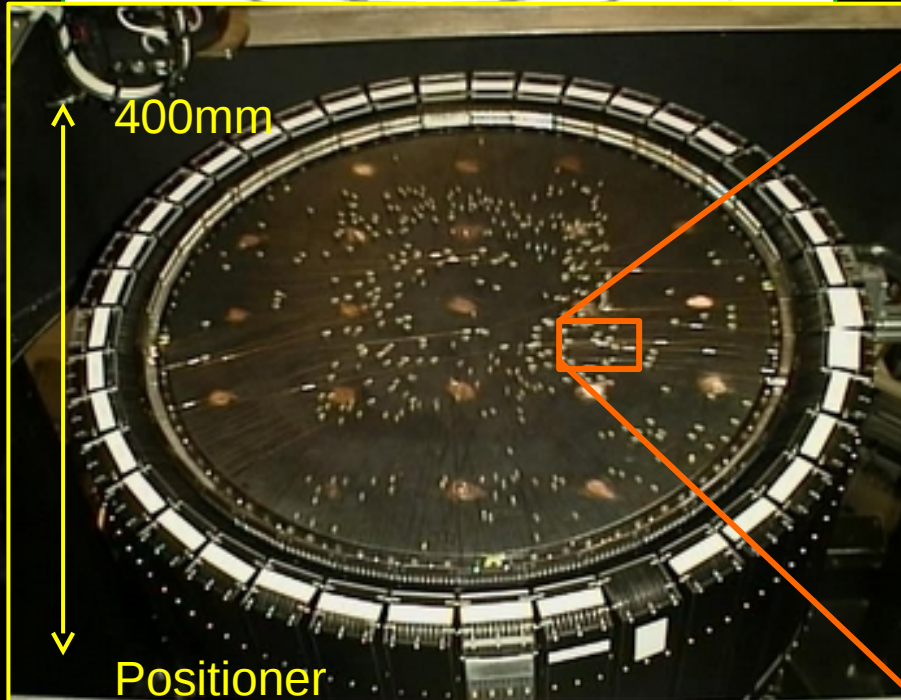
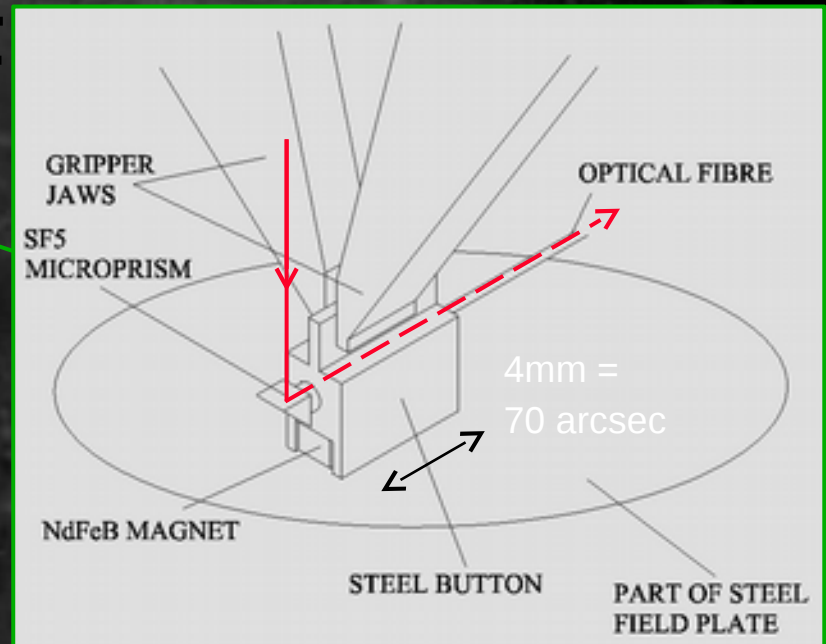


Multiobjektum-spektrográf

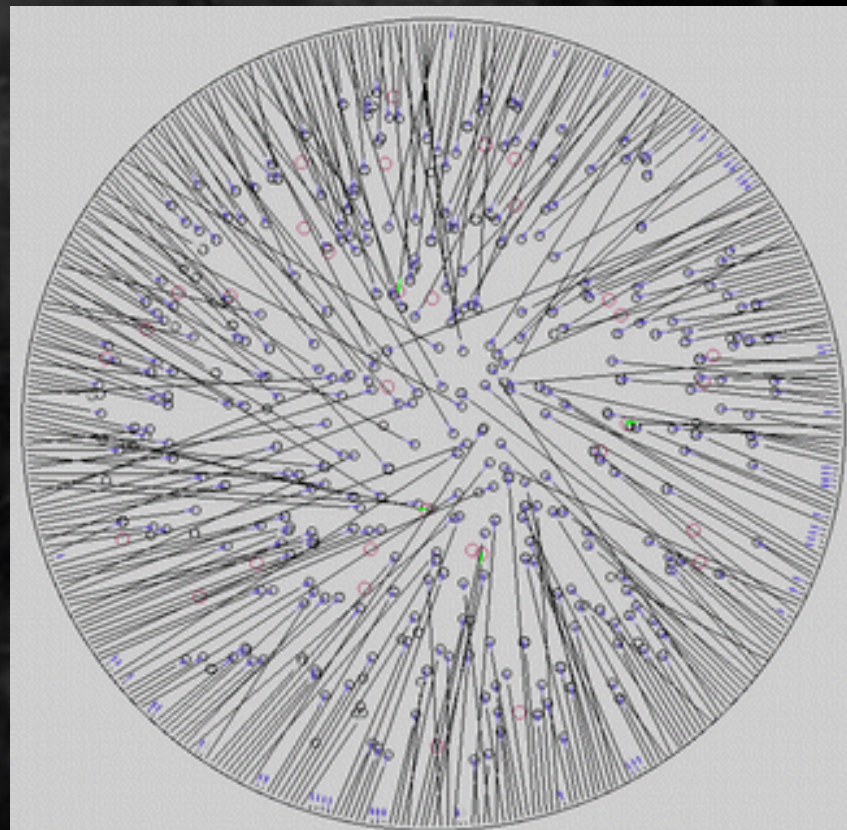
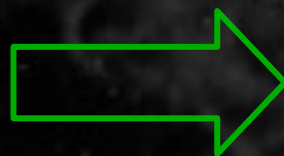
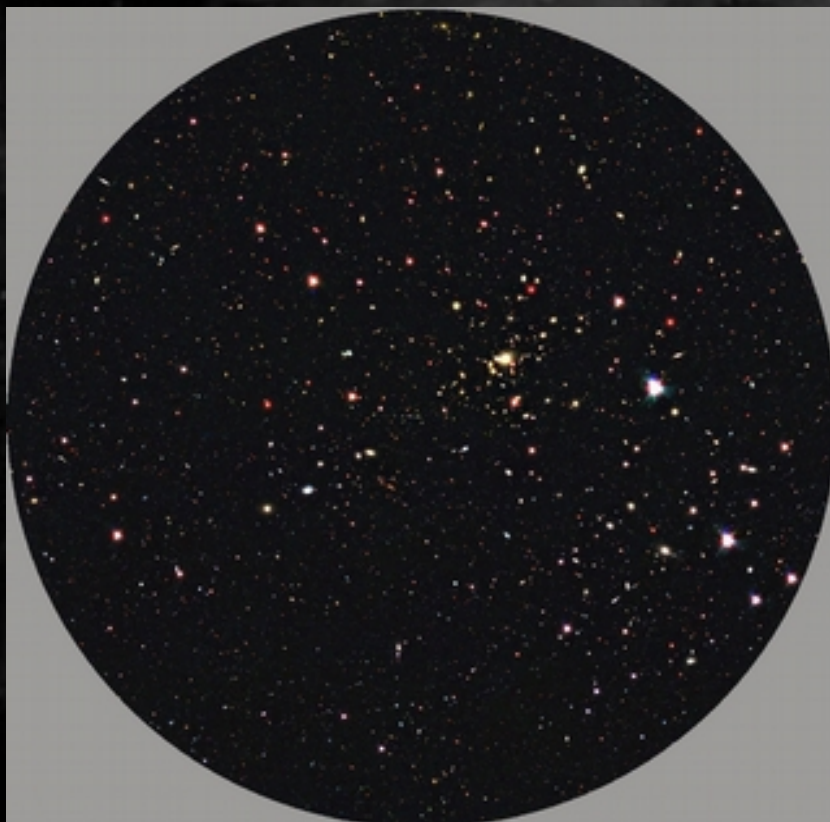




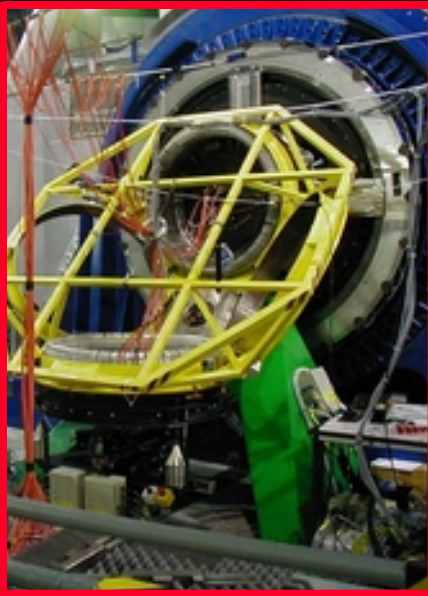
2dF



Fiberek pozícionálása a látómezőben



Flames (ESO VLT)

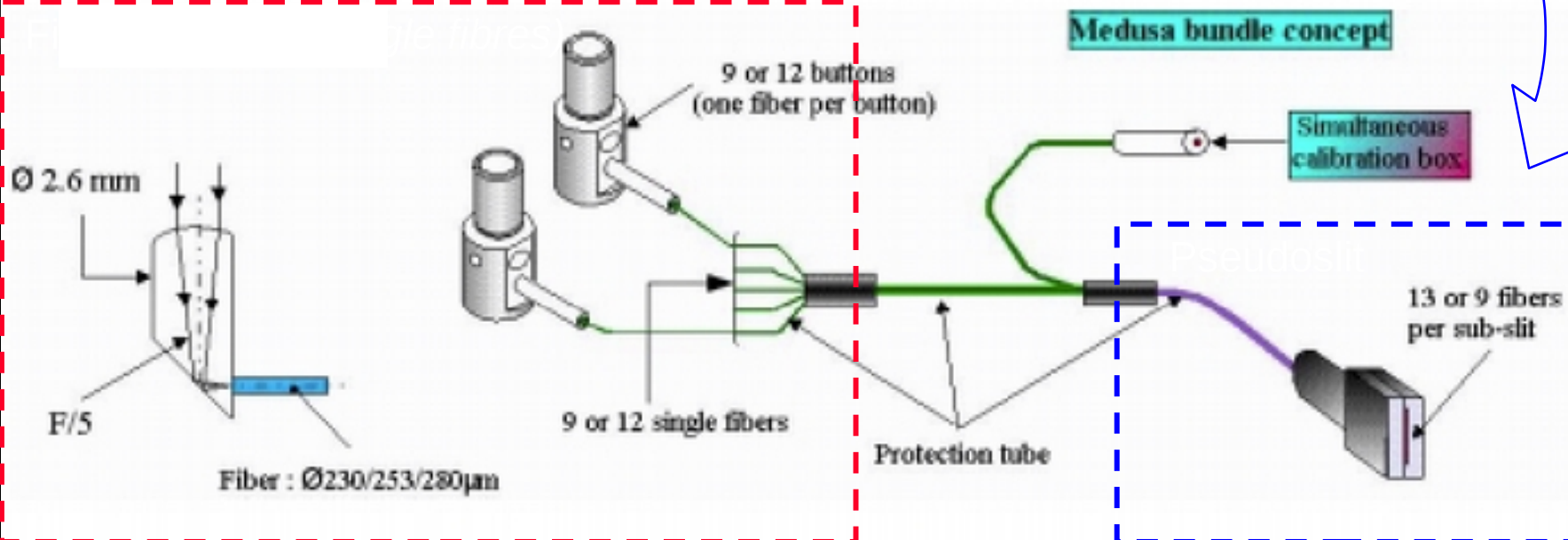


OzPoz (AAO)
double-buffered
fiber positioner at
VLT Nasmyth

- 0.1" accuracy
- 10" minimum dist.

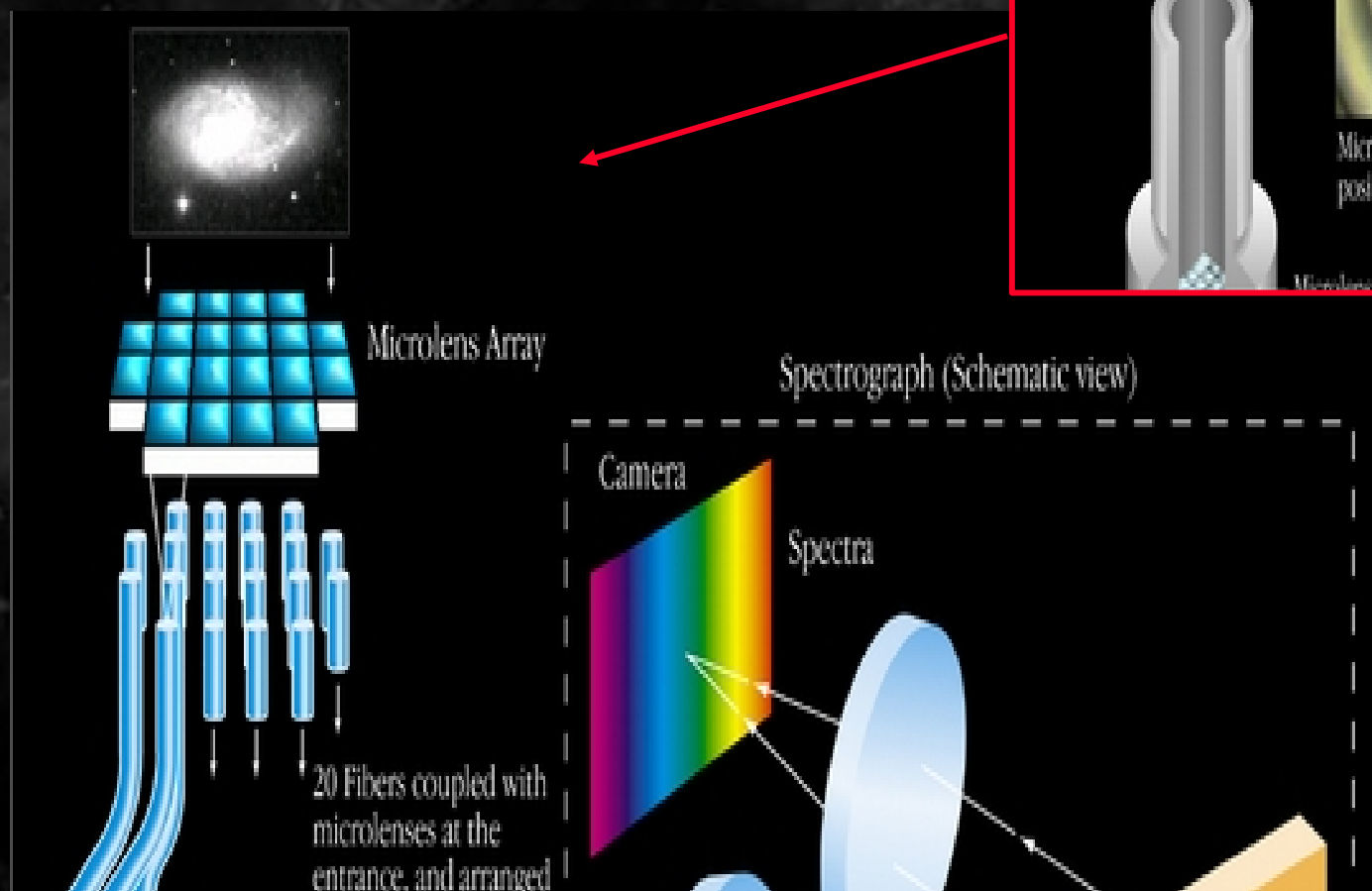
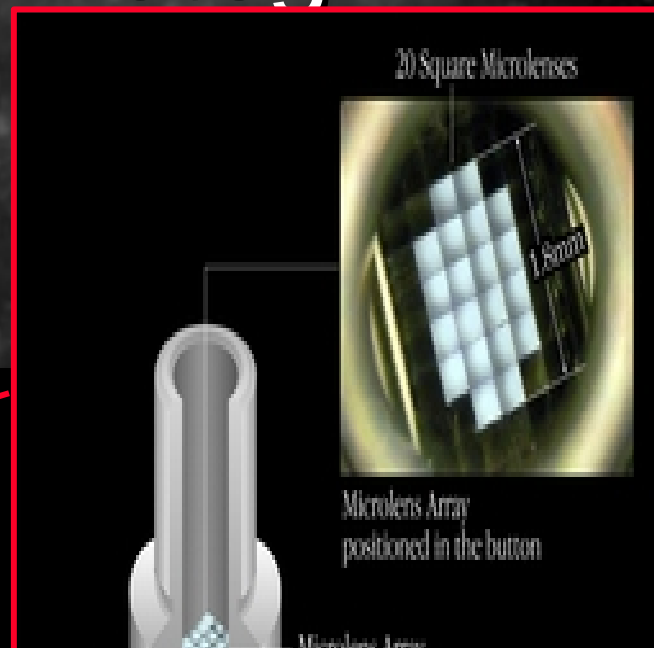


Gravity-stable
Giraffe spectrograph

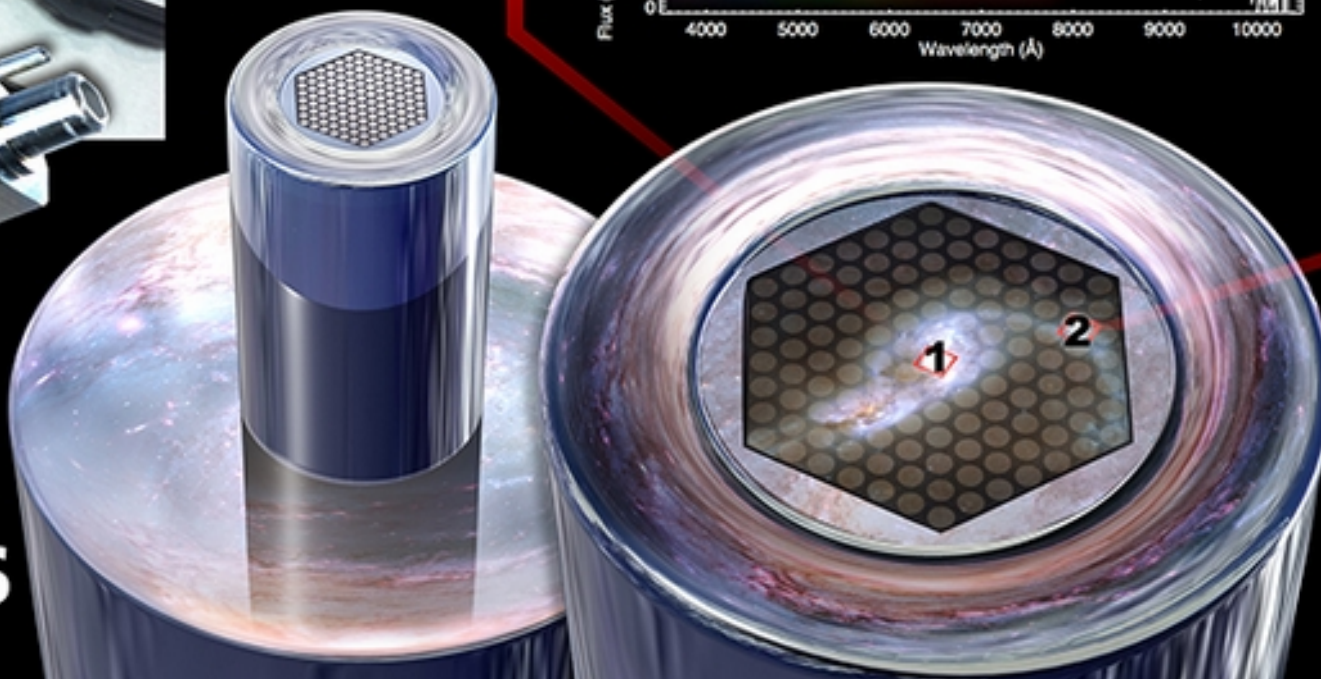
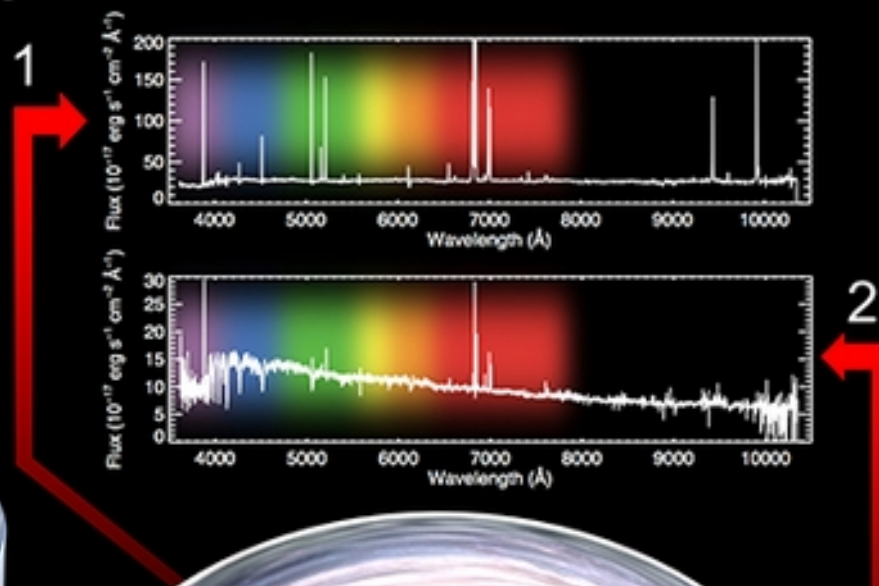


Flames fiber köteg

1 fiber helyett 20



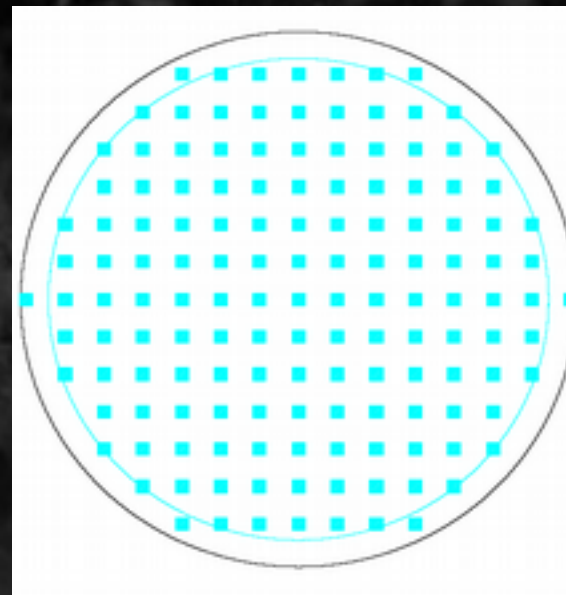
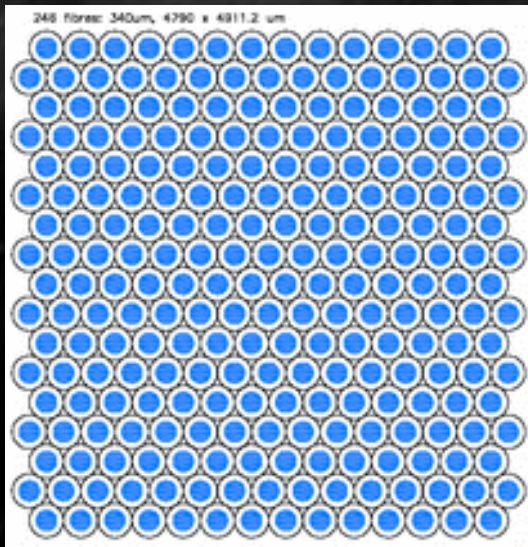
SDSS-IV Dissects 10,000 Galaxies in Nearby Universe



VIRUS (Hobby-Eberley Telescope)

- Visible IFU Replicable Unit Spectrograph
- 1 IFU: 0.22 sq.arcmin, 340-550 nm, R=850
- 448 fiber, 1 fiber = 1 sq.arcsec
- 78 IFU = 30 sq.arcmin per obs., 14 million res.element

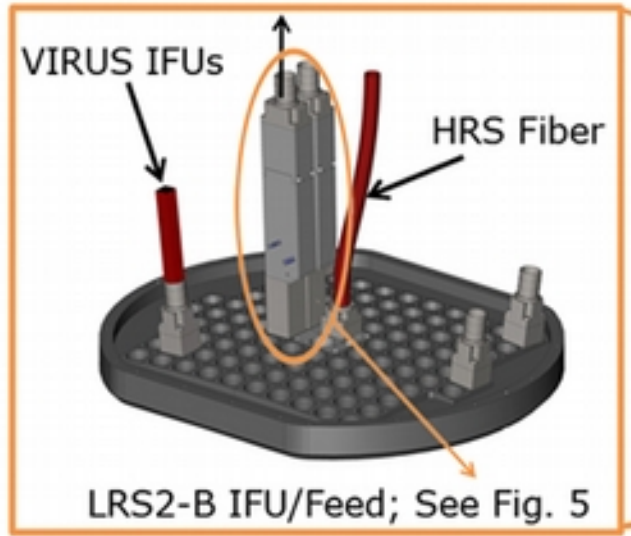
0.22 sq. arcmin



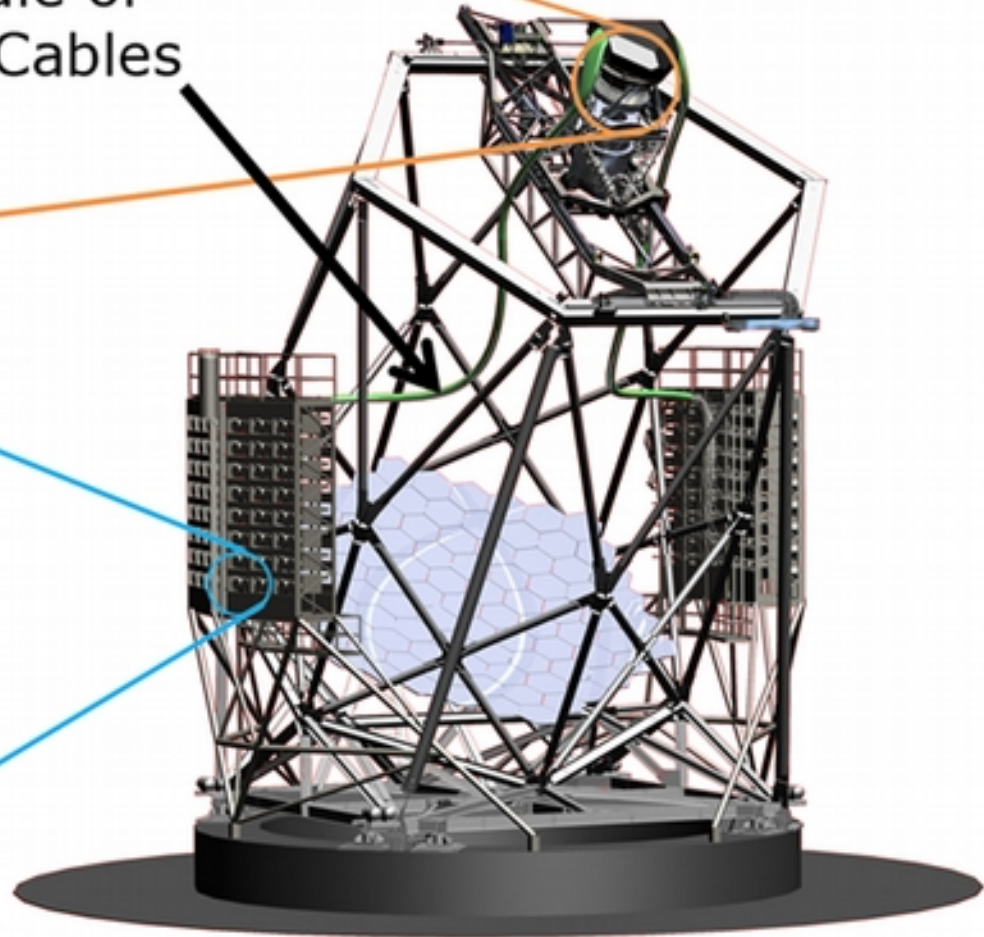
20'

Hobby Eberly Telescope McDonald Obs., Texas

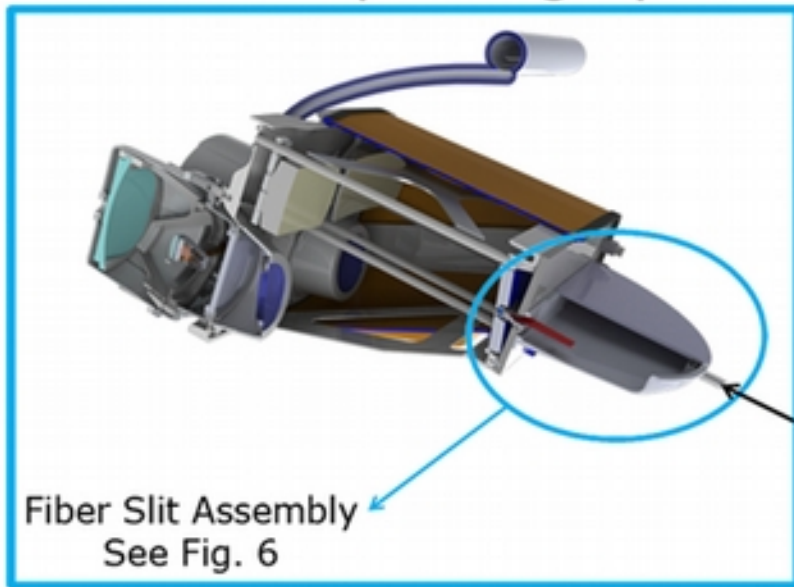
HET WFU Focal Plane



Bundle of Fiber Cables



LRS2-B Spectrograph



Konkoly Spektroszkópai Nyári Iskola

2018.07.23-27.