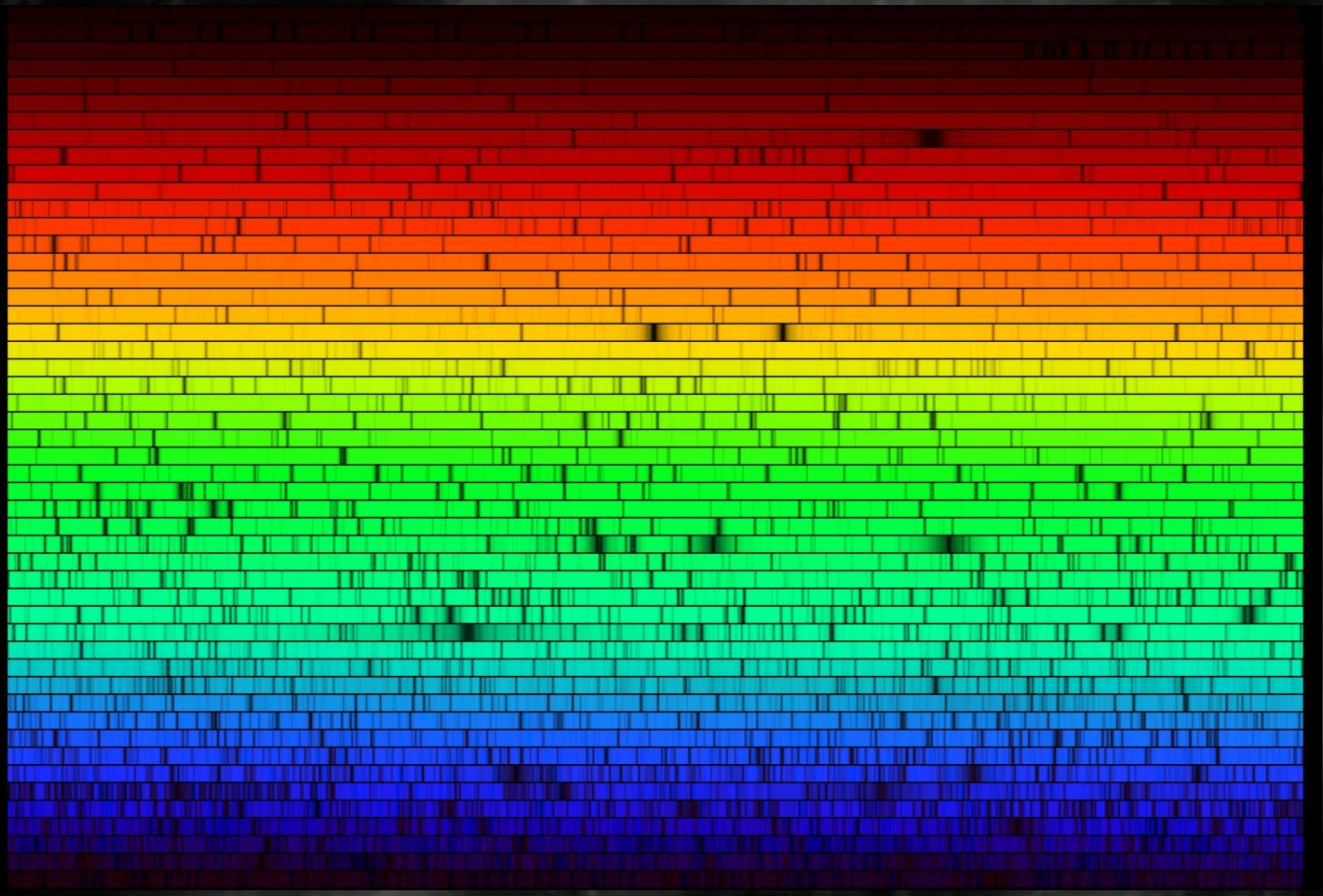
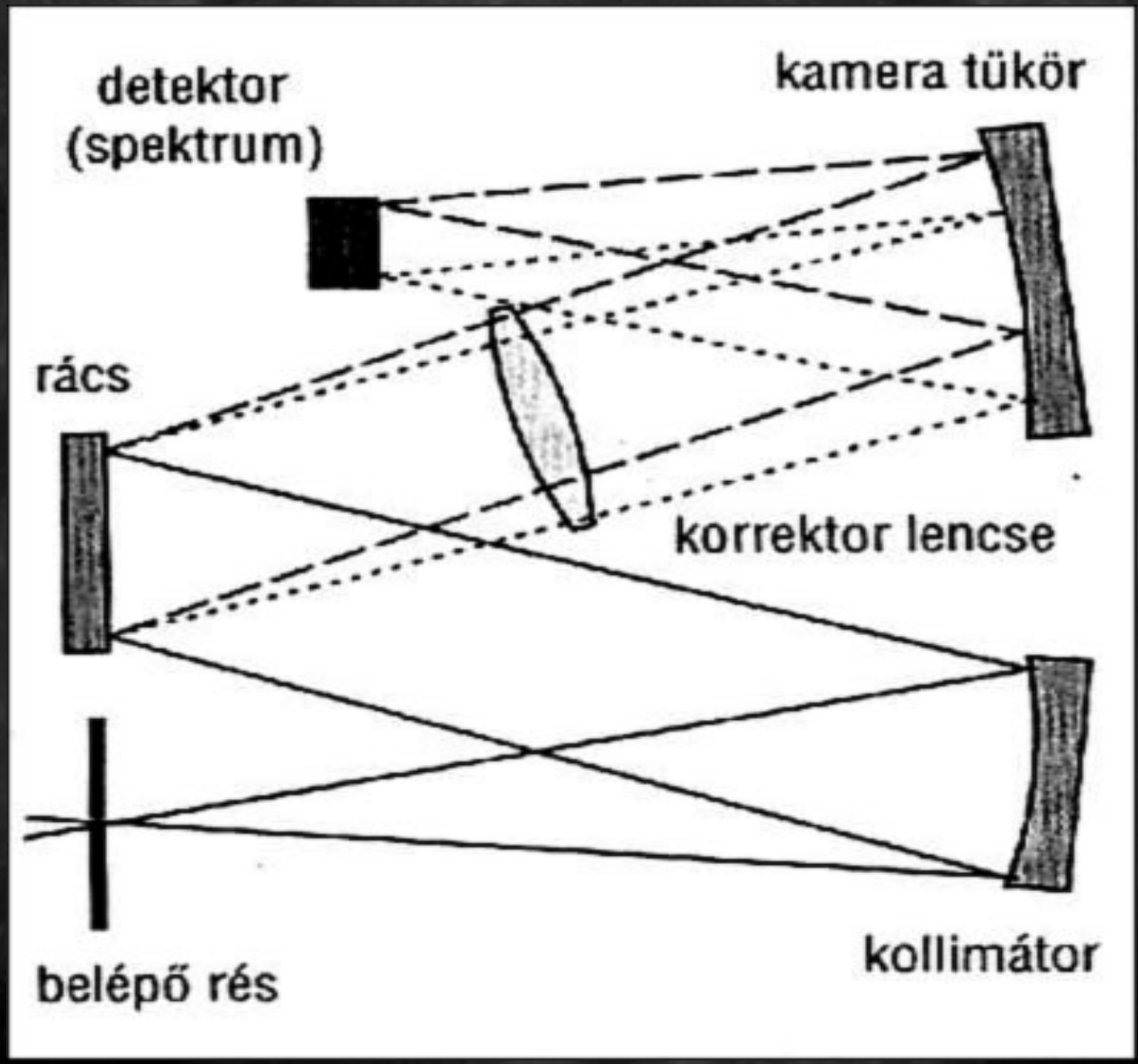
Csillagászati spektroszkópia dióhéjban



Konkoly Spektroszkópiai Nyári Iskola *2016.07.18-22.*

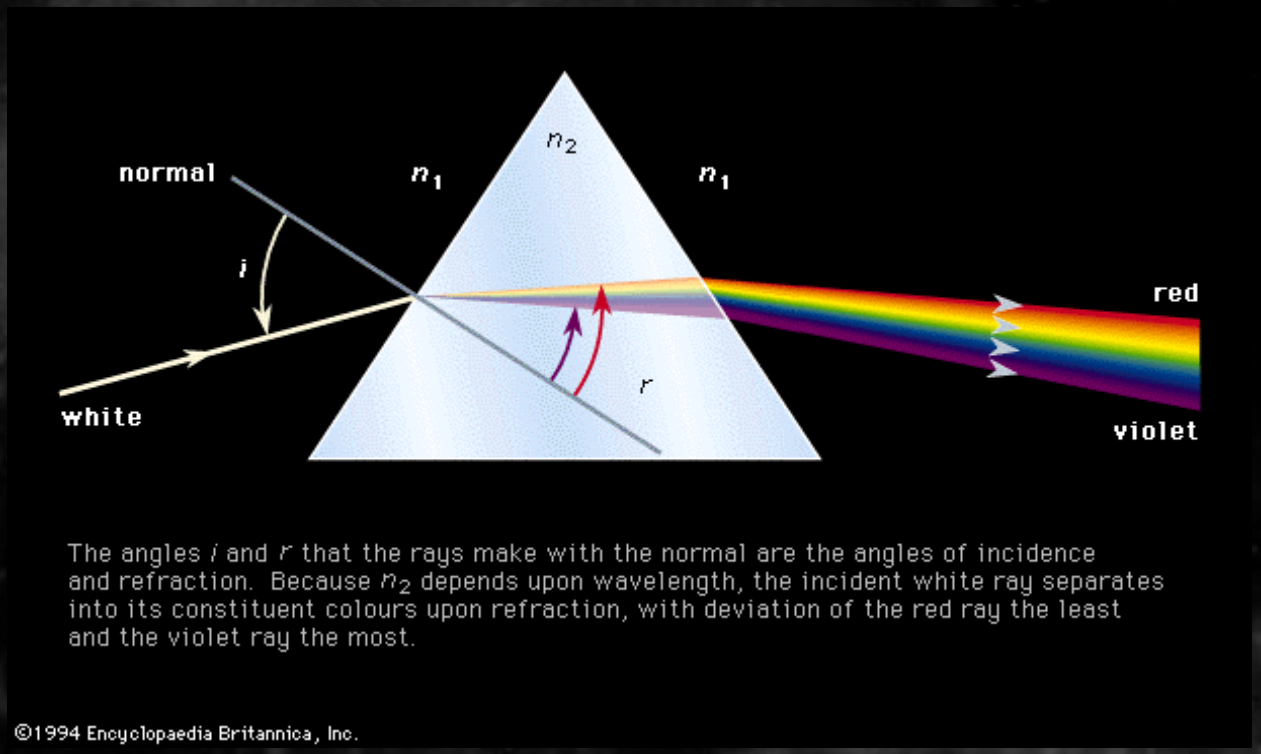
Spektroszkóp általános felépítése



Bontóelem

prizma (prism)

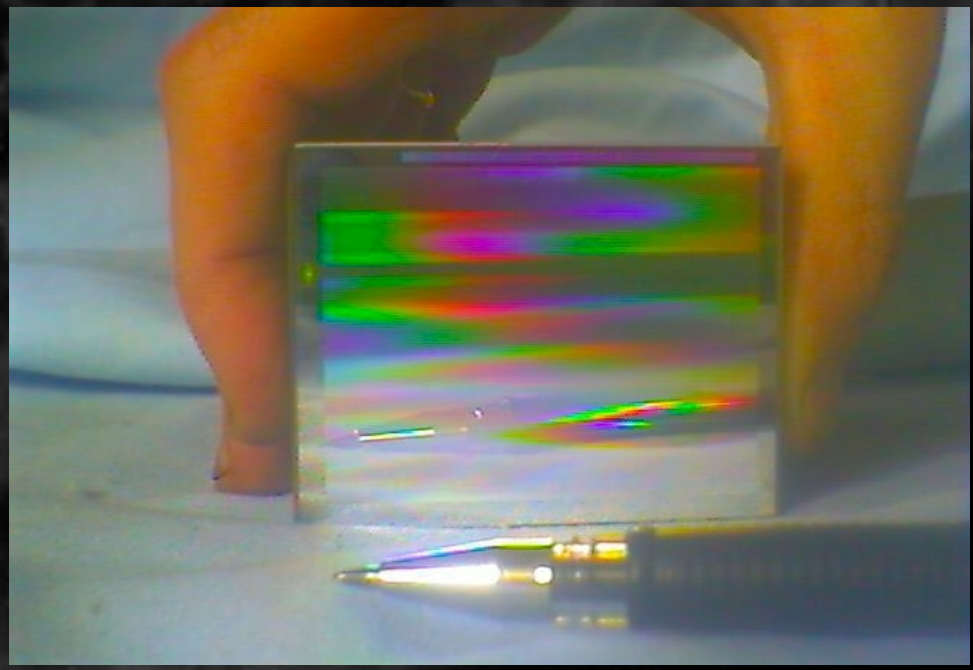
- φ törőszög
- $dn/d\lambda$ diszperzió



The angles *i* and *r* that the rays make with the normal are the angles of incidence and refraction. Because n_2 depends upon wavelength, the incident white ray separates into its constituent colours upon refraction, with deviation of the red ray the least and the violet ray the most.

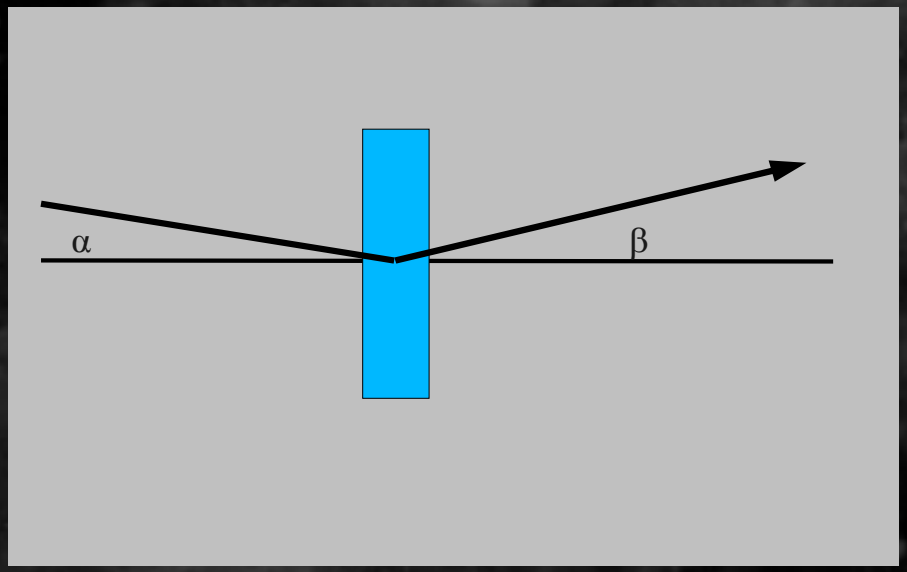
optikai rács (grating)

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



Szögdiszperzió
(angular dispersion)

$$d\beta / d\lambda$$



rácsegyenlet:

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

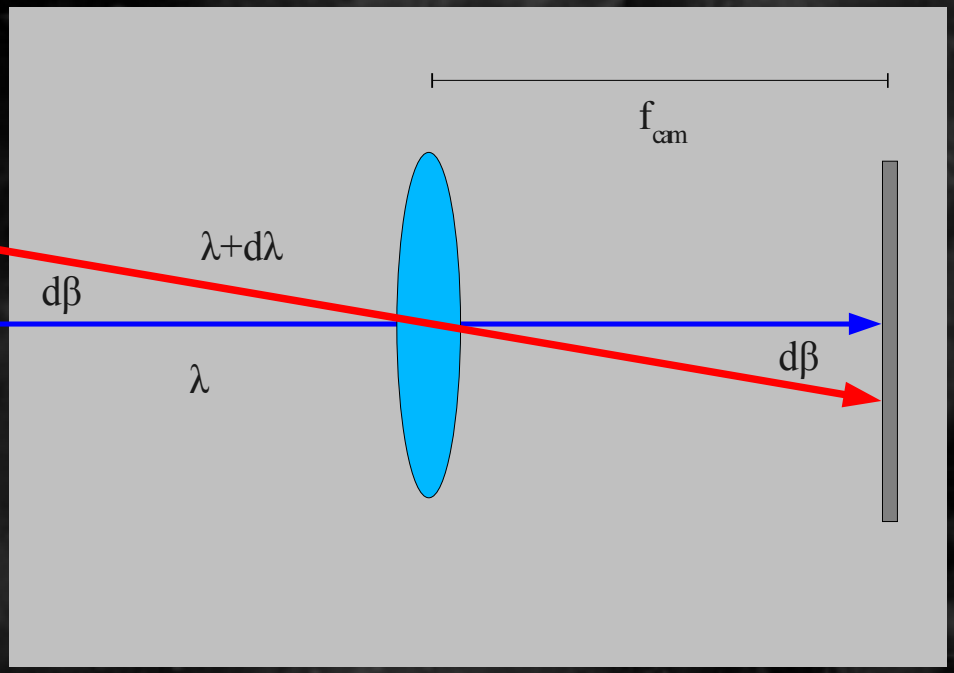
$$\frac{d\beta}{d\lambda} = \frac{m}{d\cos(\beta)}$$

prizma

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

Lineáris diszperzió
(linear dispersion)

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



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

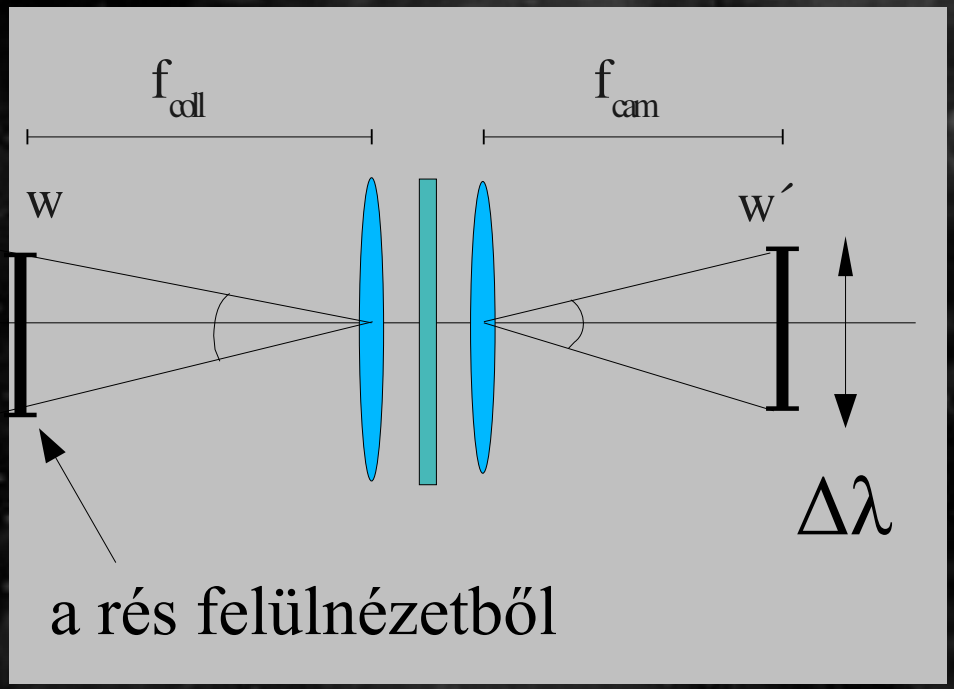
$$\frac{dx}{d\lambda} = f_{cam}\frac{d\beta}{d\lambda}$$

reciprok lineáris diszperzió:

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

(Å/mm)

Felbontóképesség
(resolution)



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

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

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

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

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

Felbontóképesség

kisfelbontású sp.: $R < 1000$

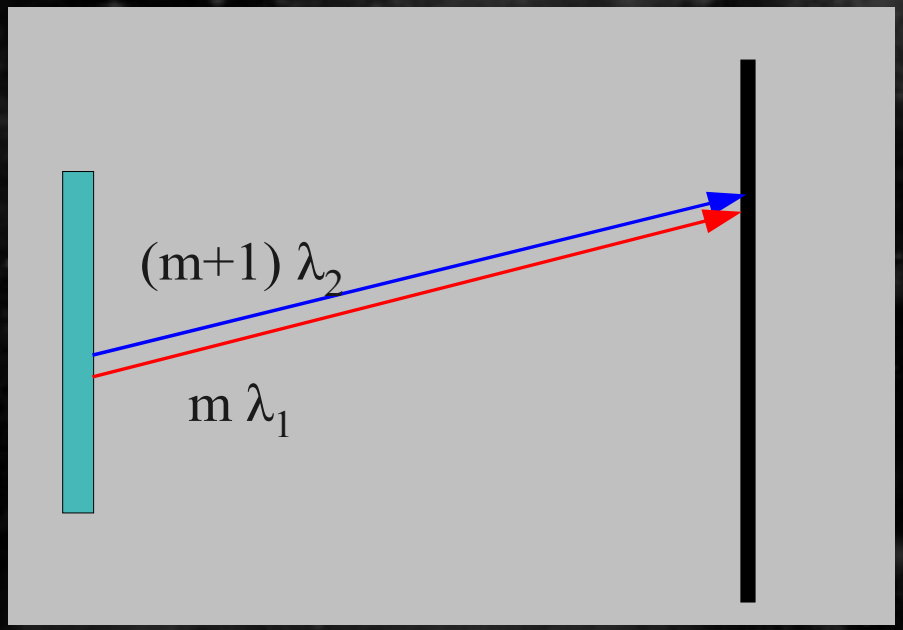
közepes felbontású sp.: $1000 < R < 20\,000$

nagyfelbontású sp.: $R > 20\,000$

extrém nagy felbontás: $R > 100\,000$

Szabad spektráltartomány

(free spectral range, FSR)

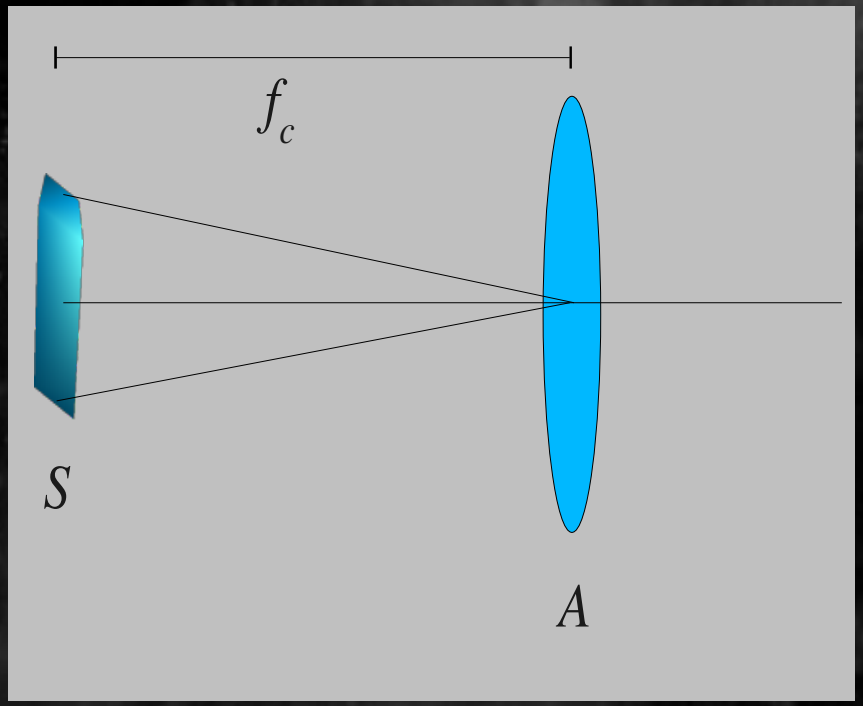


$$m\lambda_1 = d\sin(\beta)$$
$$(m+1)\lambda_2 = d\sin(\beta)$$

$$\delta\lambda = \lambda_1 - \lambda_2$$
$$\delta\lambda = d\sin(\beta)\left(\frac{1}{m} - \frac{1}{m+1}\right)$$

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

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 ~ 1/w => felbontás növelése = résszél. csökkentése

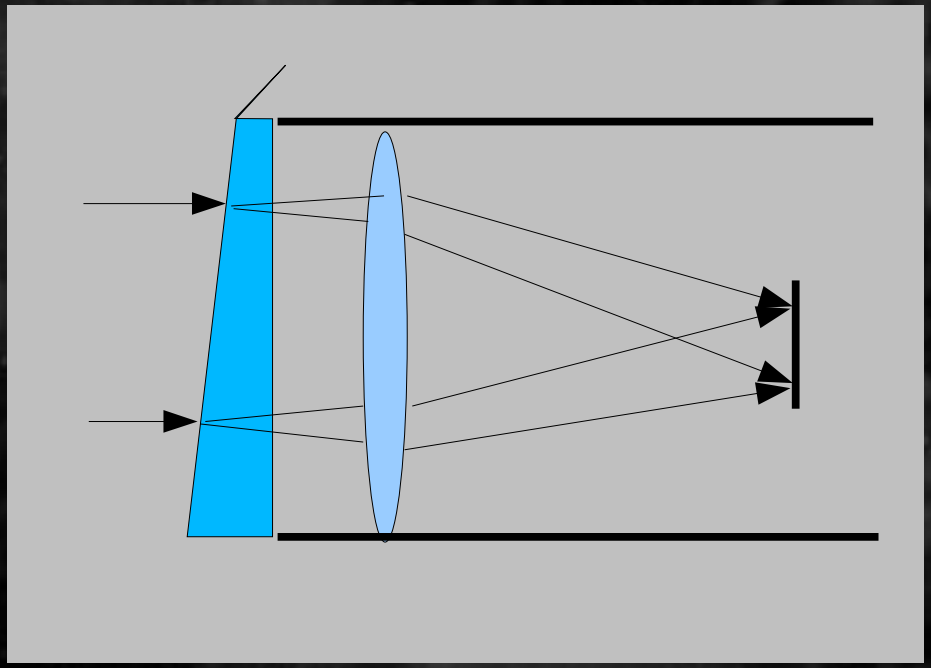
L ~ w => résszélesség csökkentése = fényerő csökken

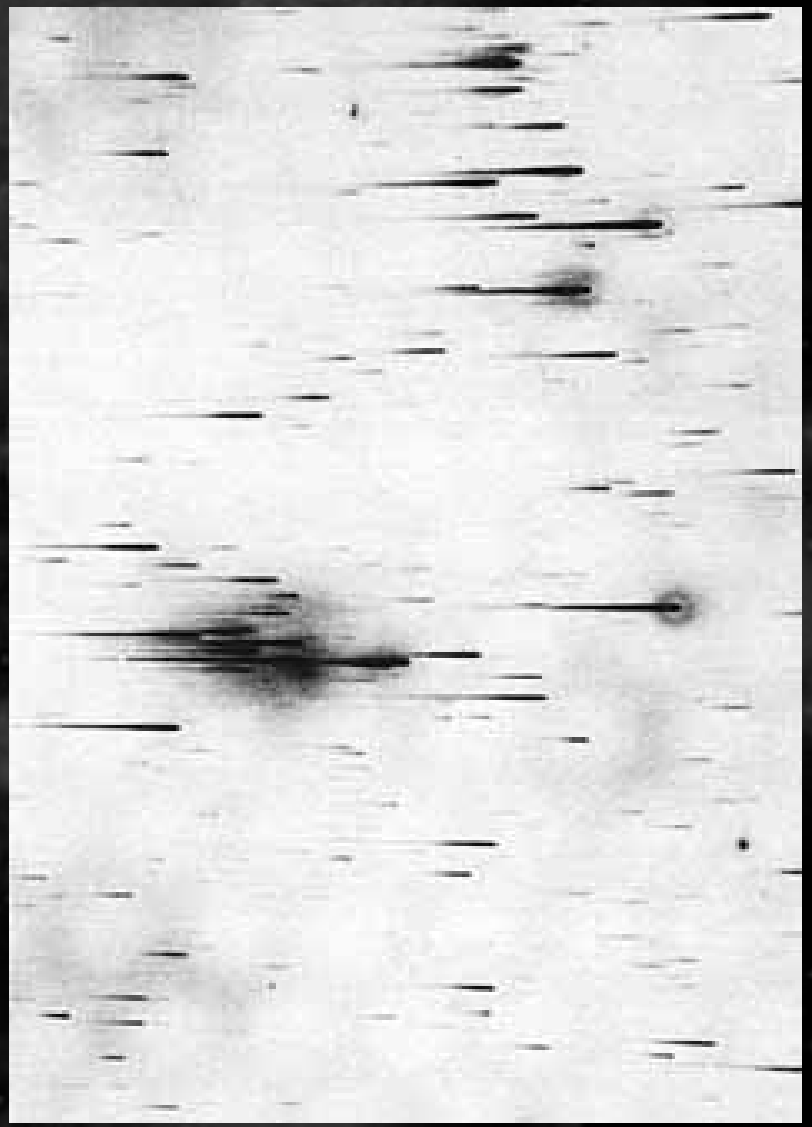
A rés kivilágítása ~ D_{tel}^{2} =>
a fényveszteség csökkentéséhez nagyobb távcső kell!

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

Objektív prizma

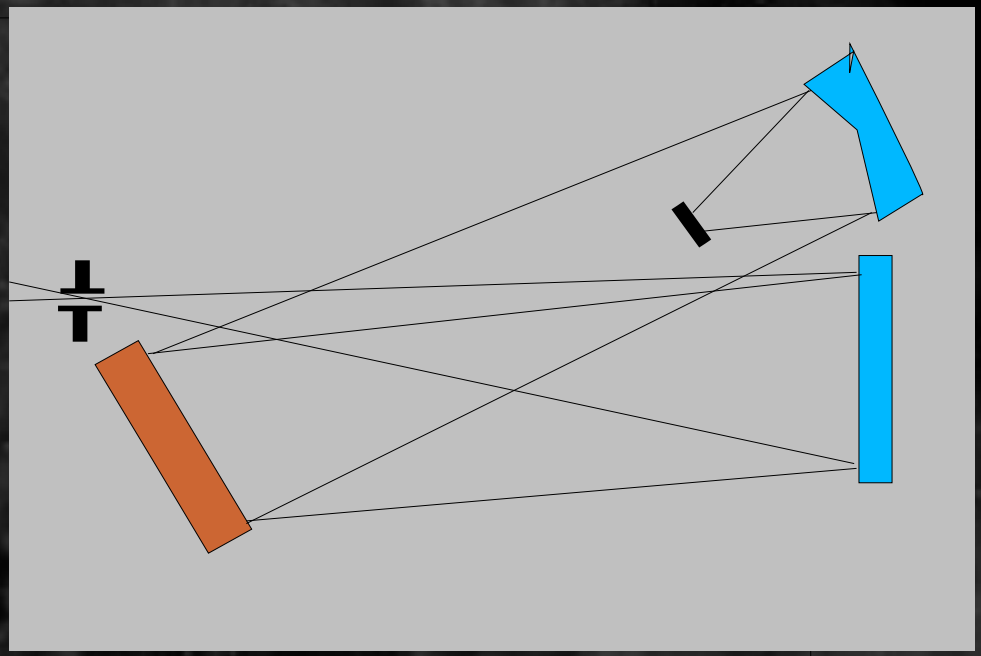
- kis felbontás
- nemlineáris diszperzió



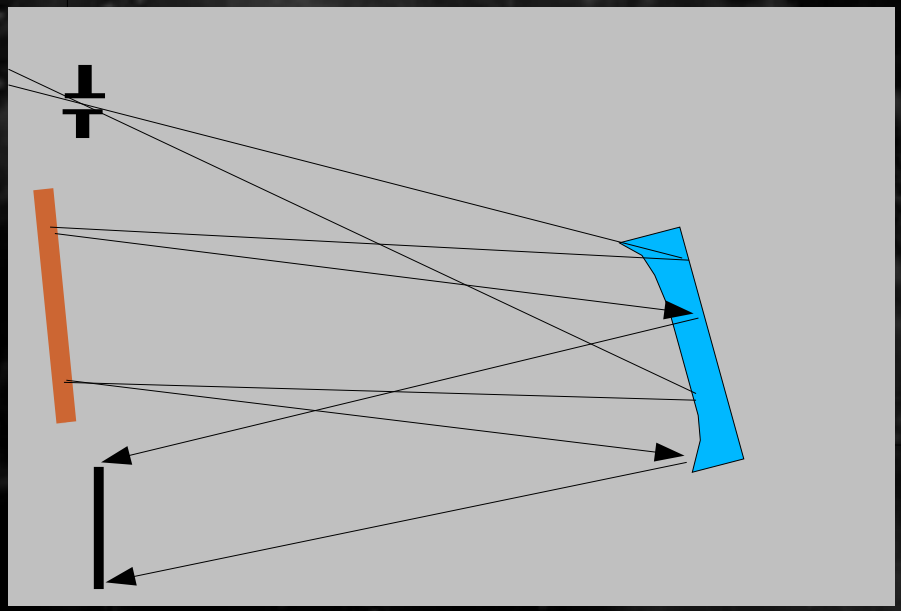


Cassegrain spektroszkóp

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



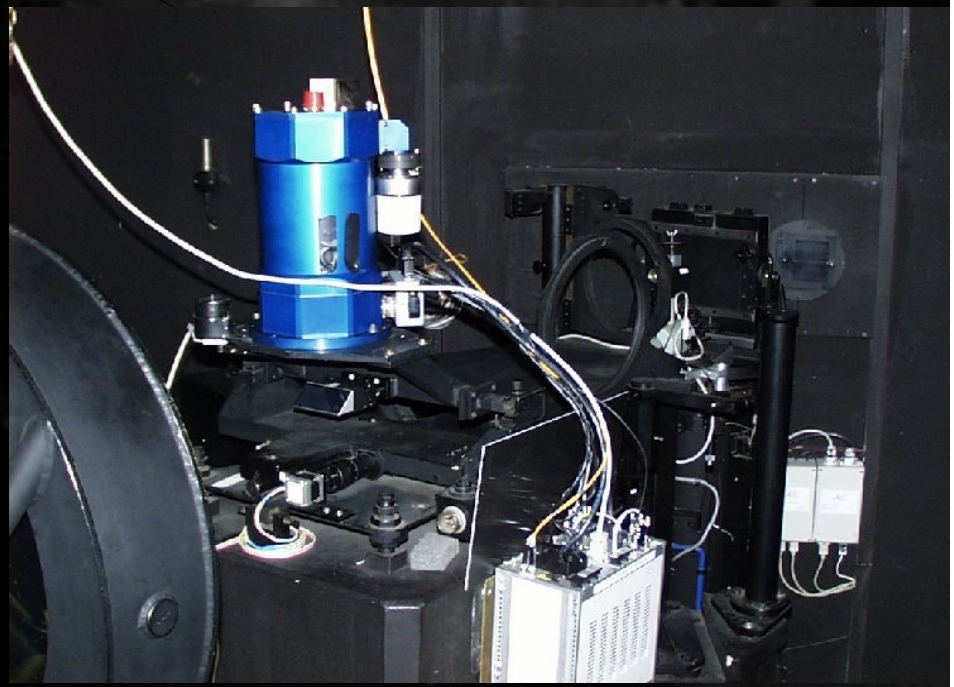
normál

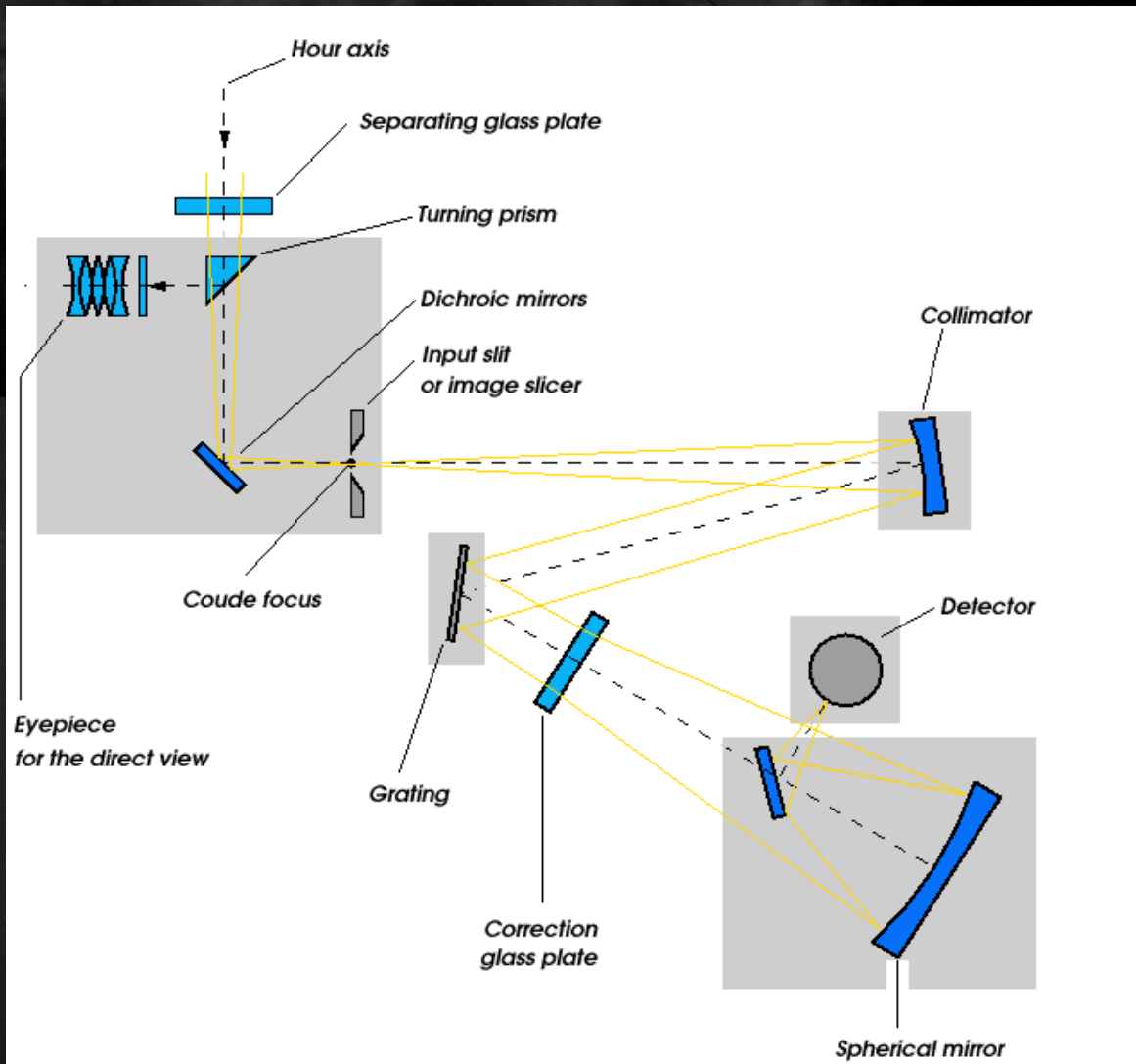


autokollimációs

Coudé spektrográf

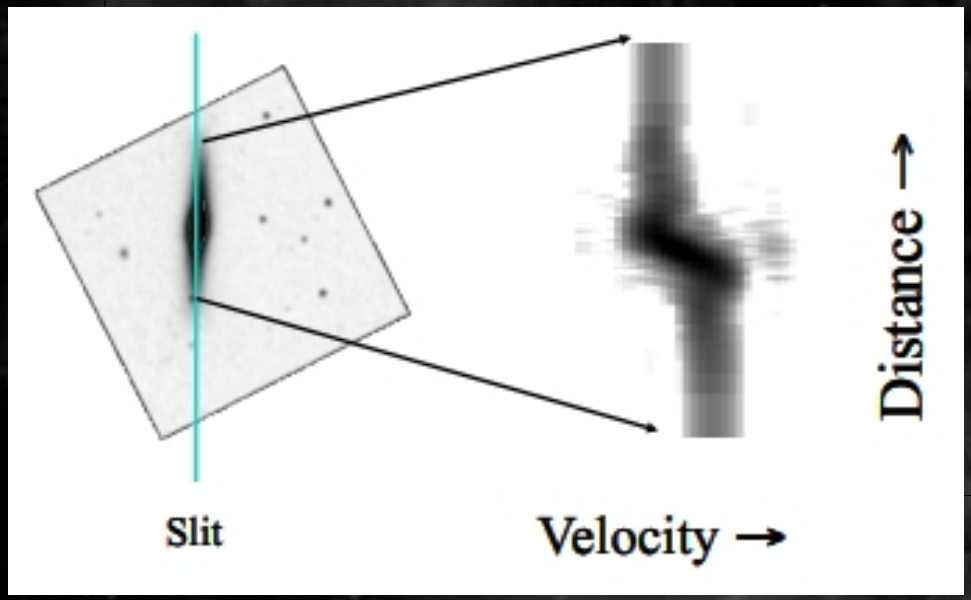
- nagy felbontás (R > 50000)
- fix pozíció (Coudé-fókuszban)
- egyszerre több rend rögzítése

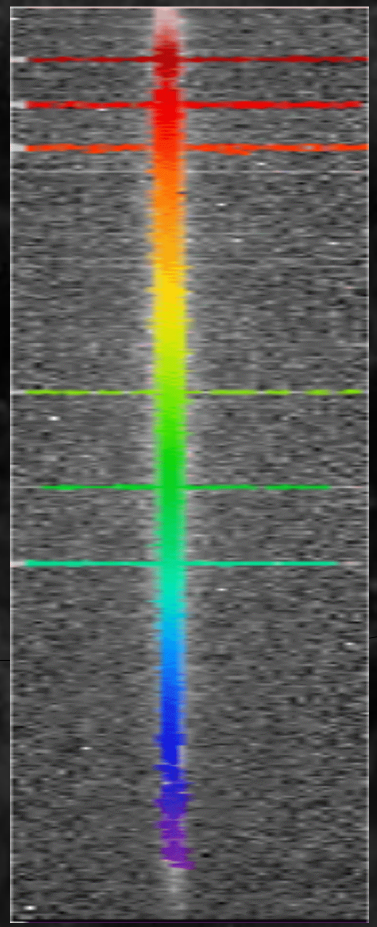


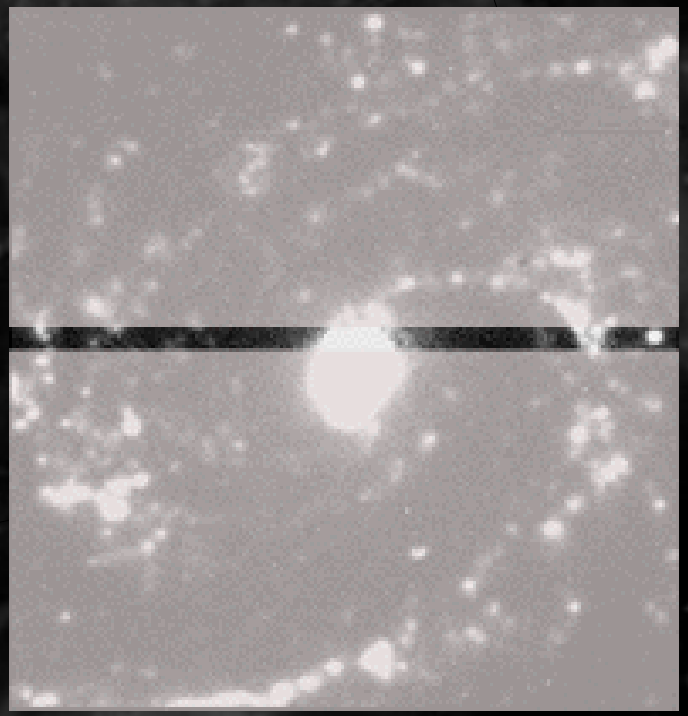


Long slit spektrográf

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

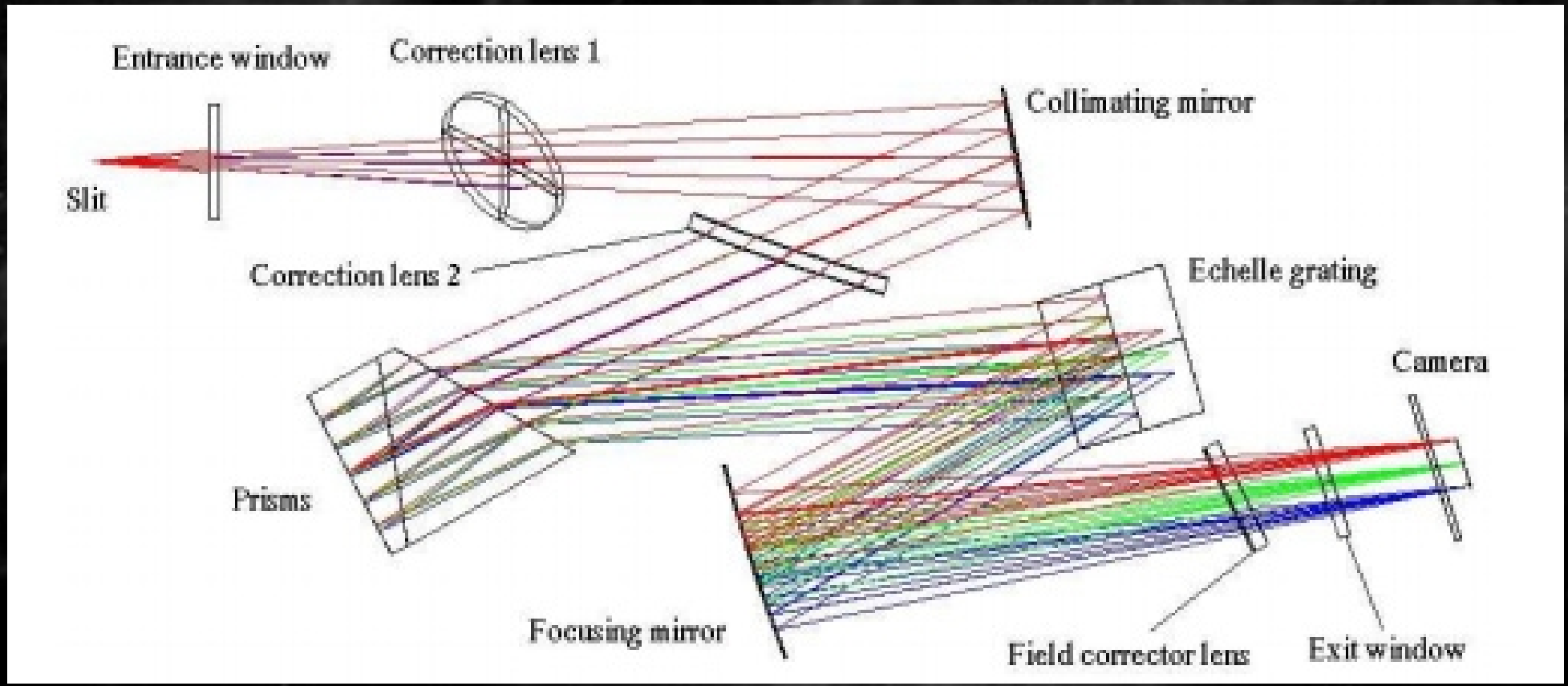




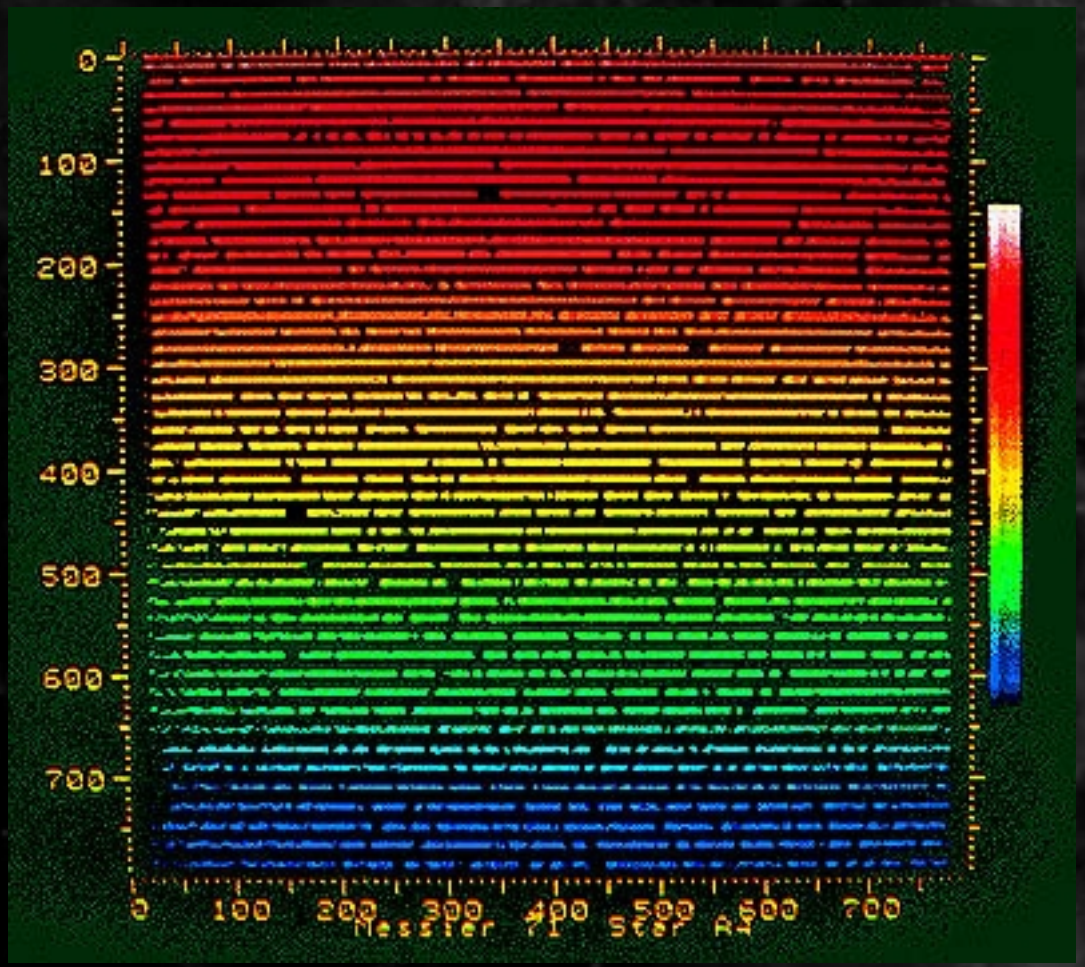


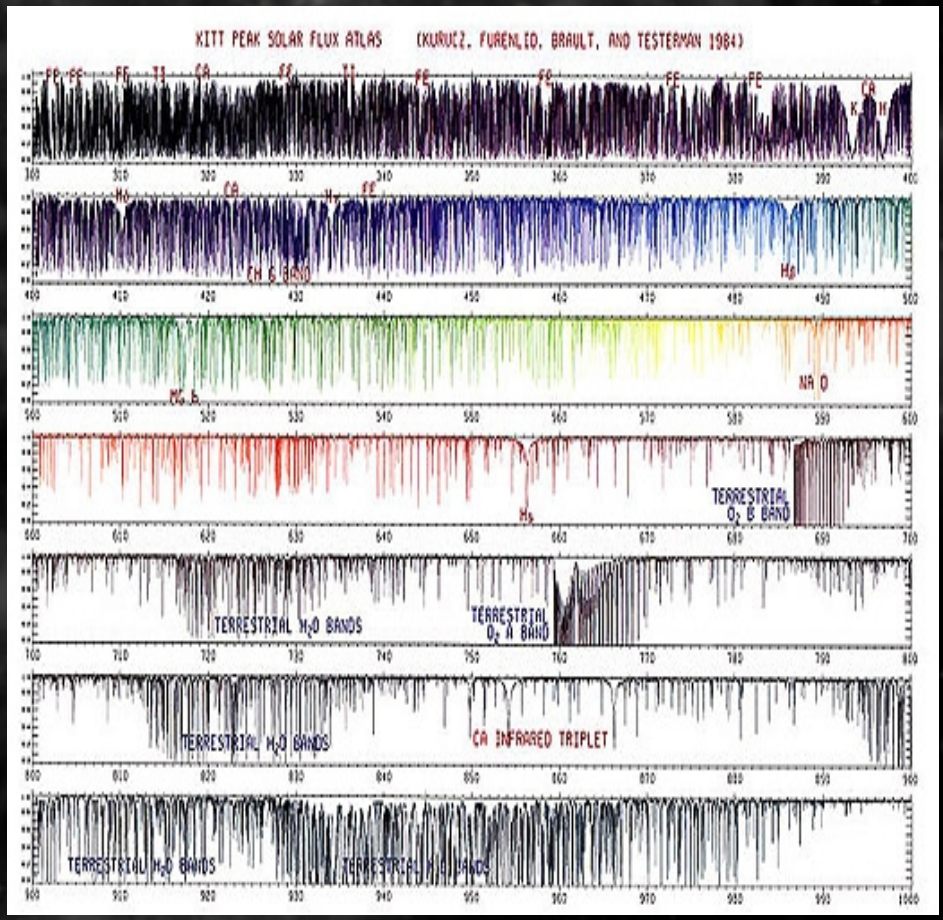
Echelle spektrográf

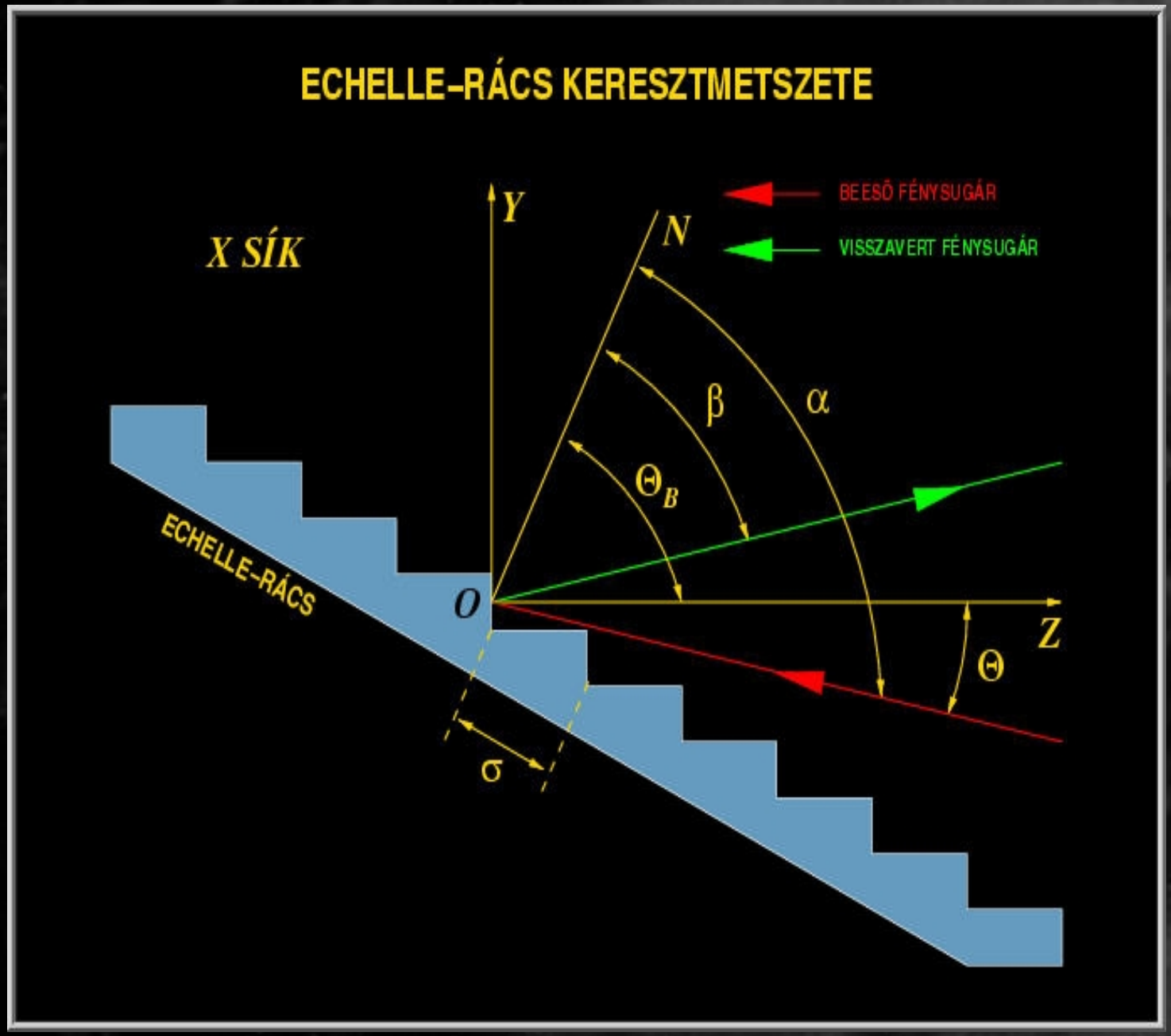
magas rend: m>20
echelle rács + keresztdiszperziós elem
nagy felbontás: R = 30 000 - 200 000



magas rend: m>20
echelle rács + keresztdiszperziós elem
nagy felbontás: R = 30 000 - 200 000
széles lefedett spektrális tartomány





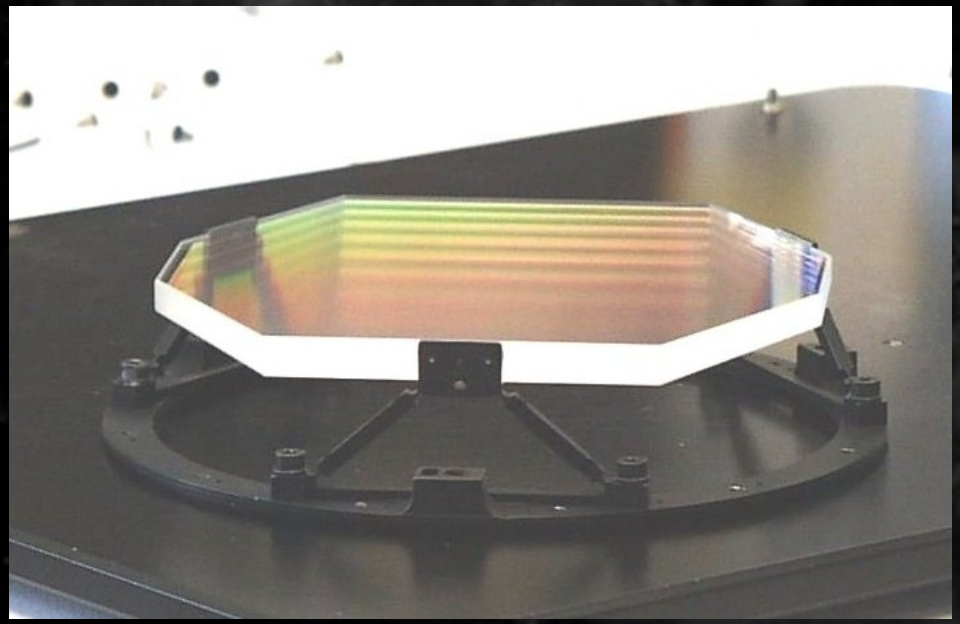


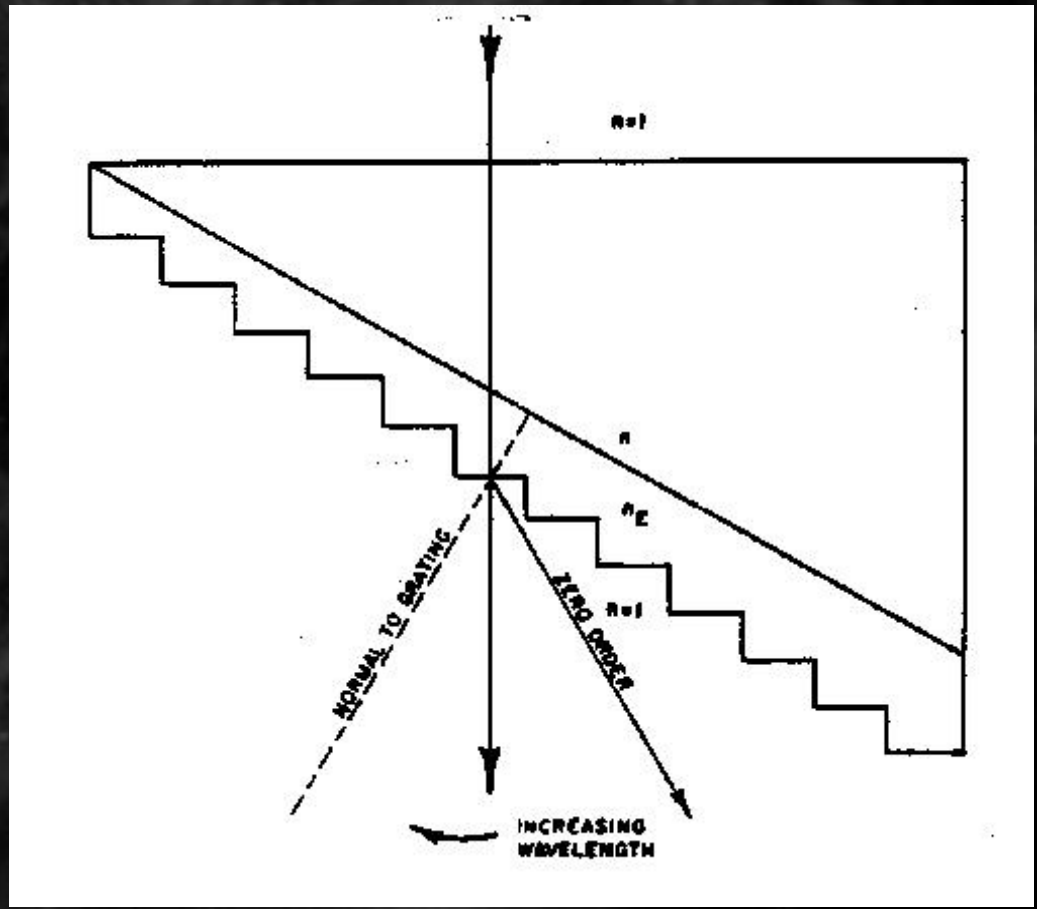
θ_B: blaze angle (csillogási szög)

σ : rácsállandó

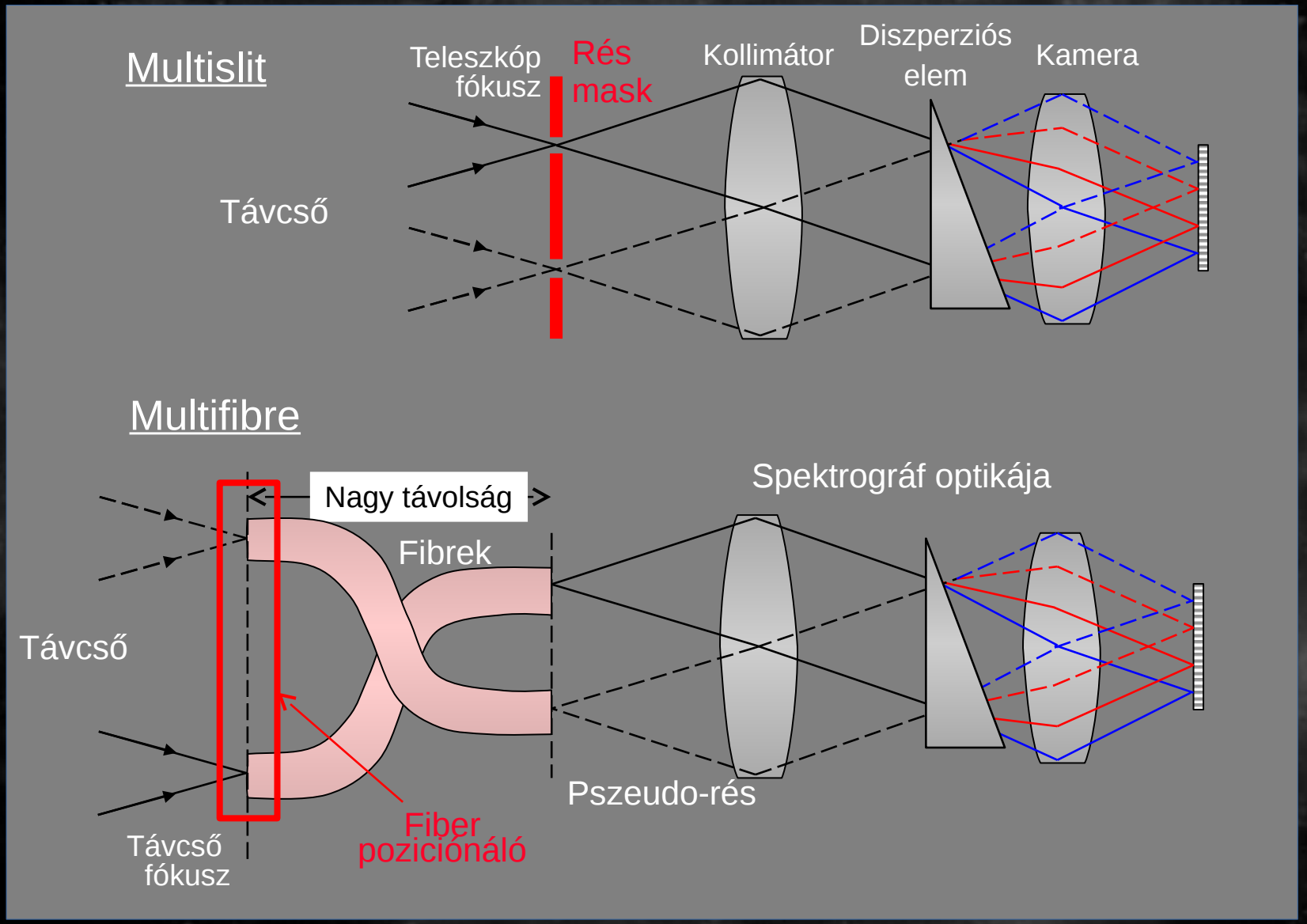
Grism (prizma+rács, "prács")

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

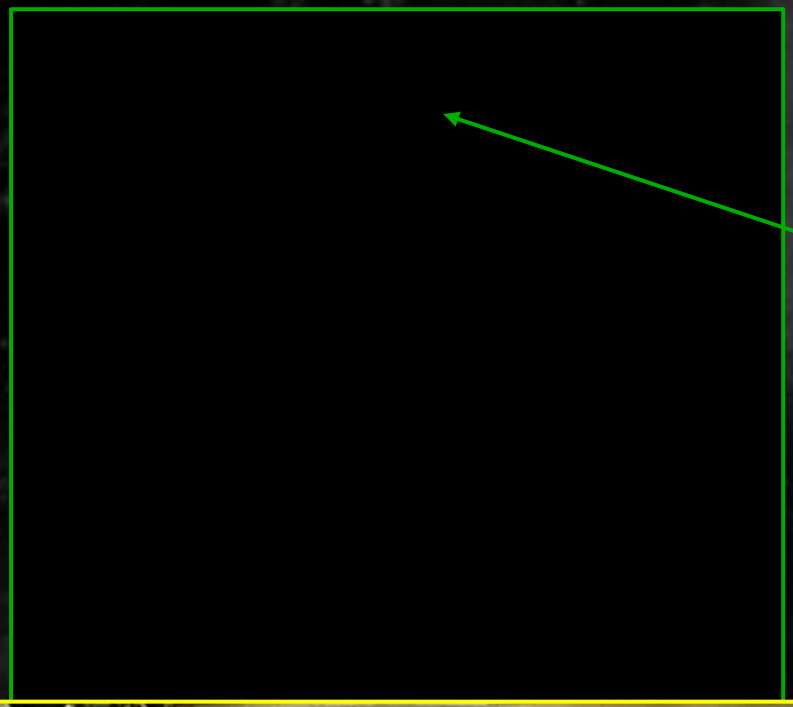


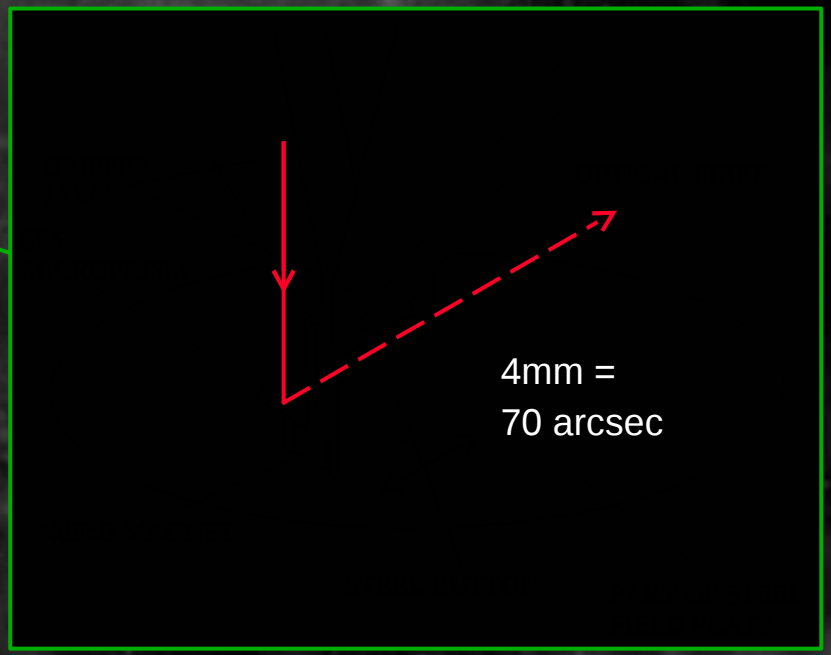


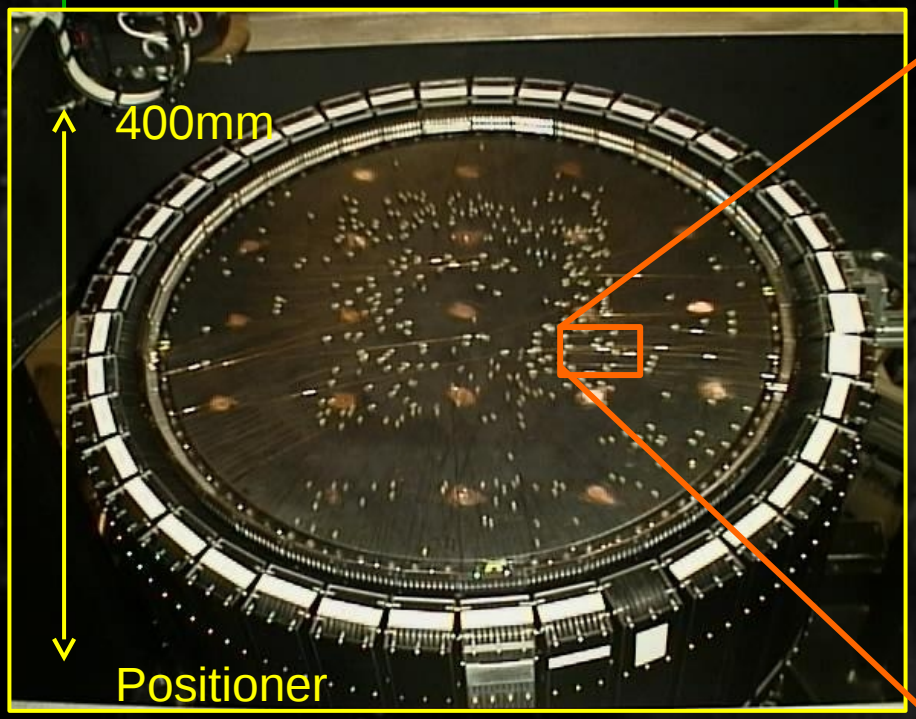
Multiobjektum-spektrográf



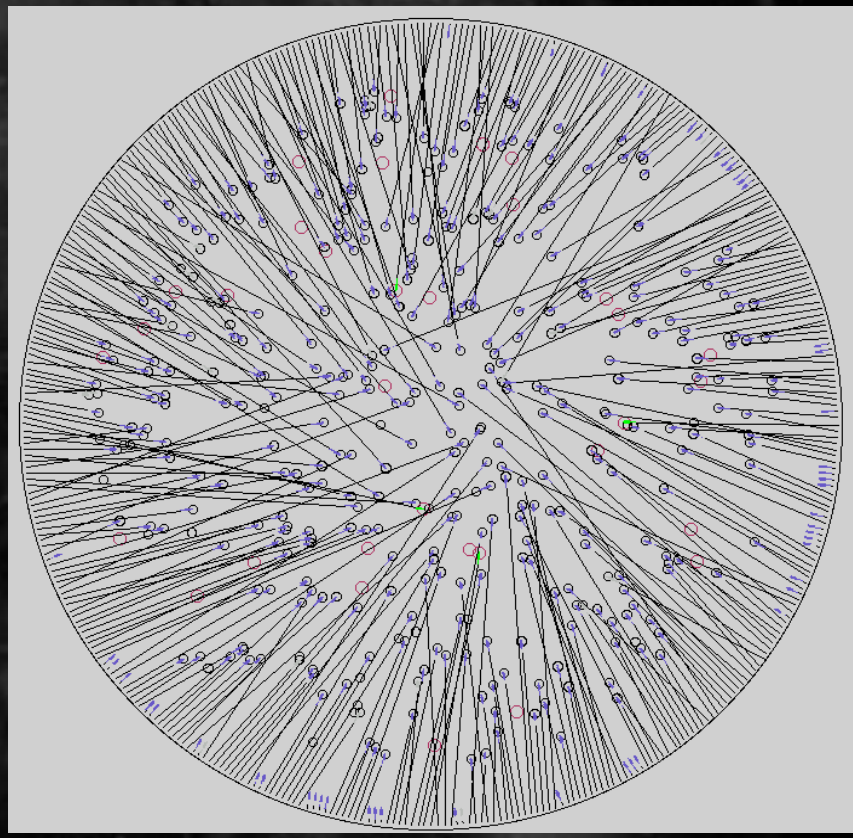
2dF



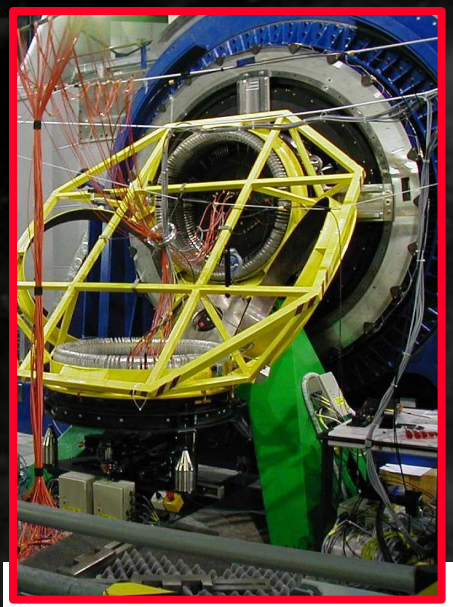




Fiberek pozícionálása a látómezőben

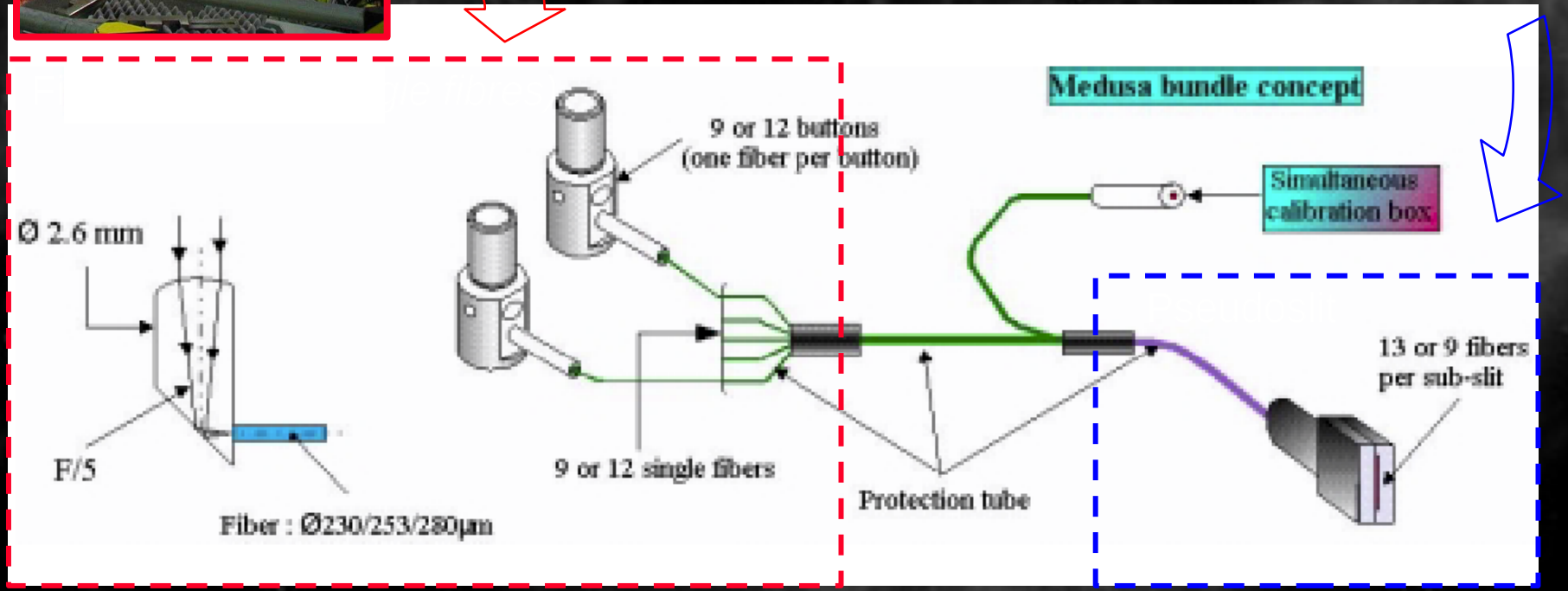


Flames (ESO VLT)



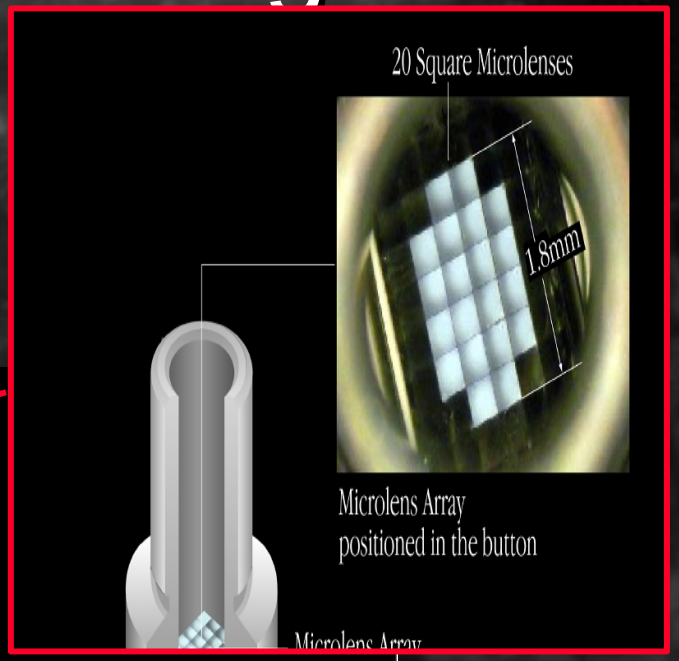
OzPoz (AAO)
double-buffered
fiber positioner at
VLT Nasmyth

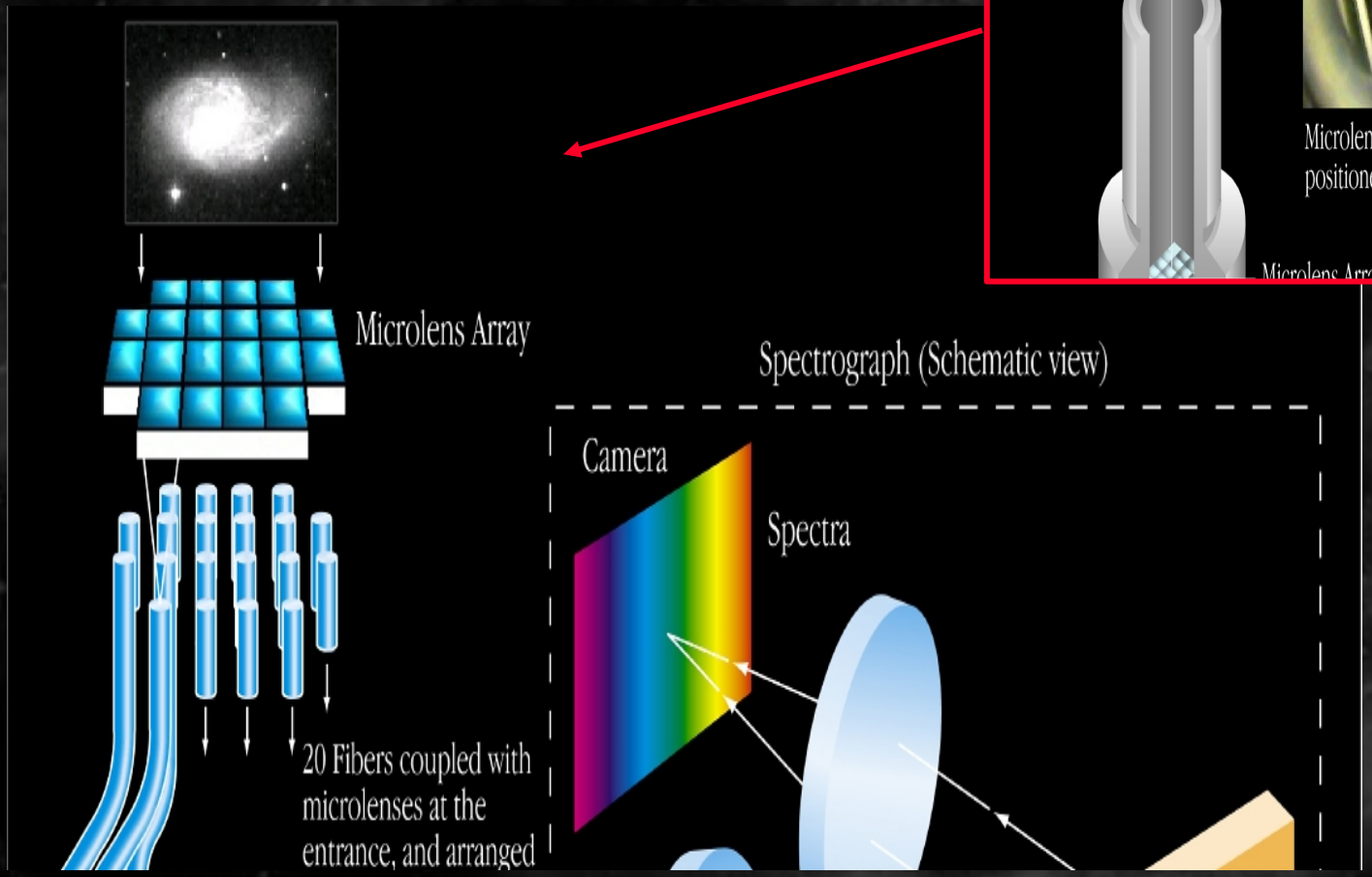
- 0.1" accuracy
- 10" minimum dist.

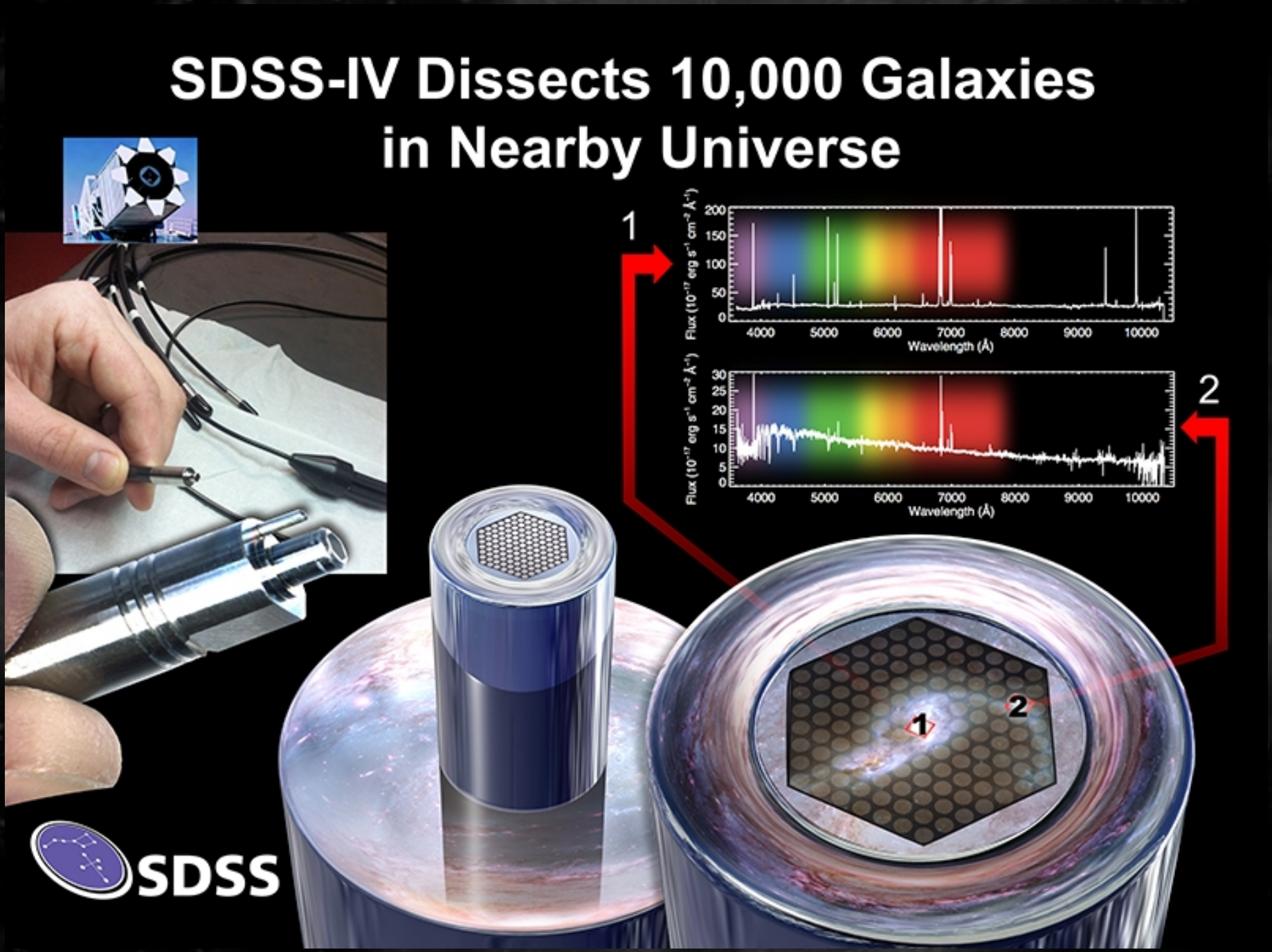


Flames fiber köteg

1 fiber helyett 20



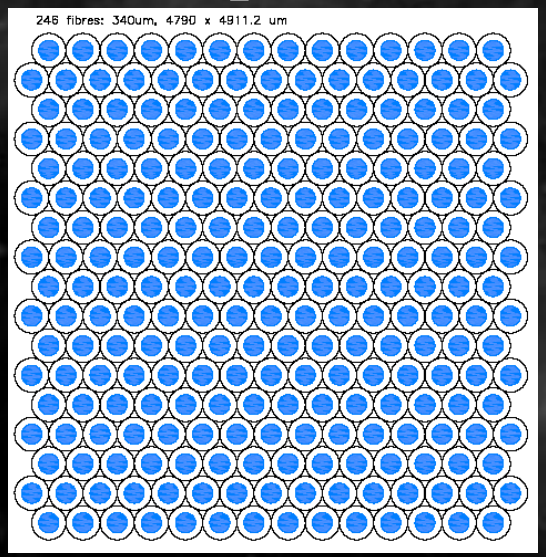


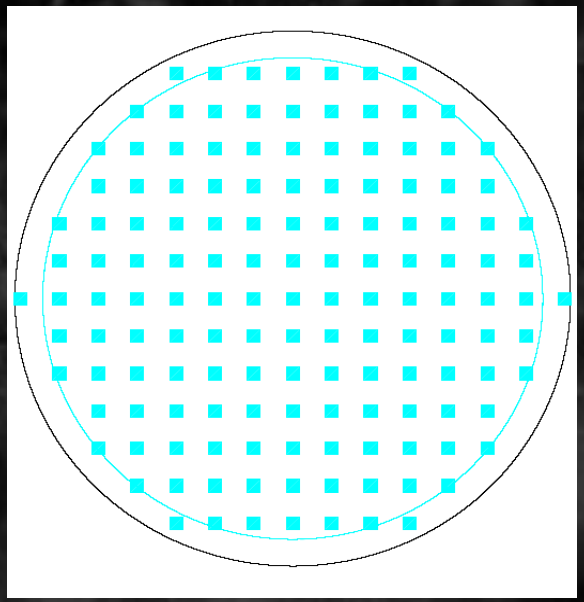

SDSS-IV Dissects 10,000 Galaxies
in Nearby Universe
1
2
Flux (10^{-17} erg s^{-1} cm^{-2} Å^{-1})
Wavelength (Å)
4000
5000
6000
7000
8000
9000
10000
SDSS

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

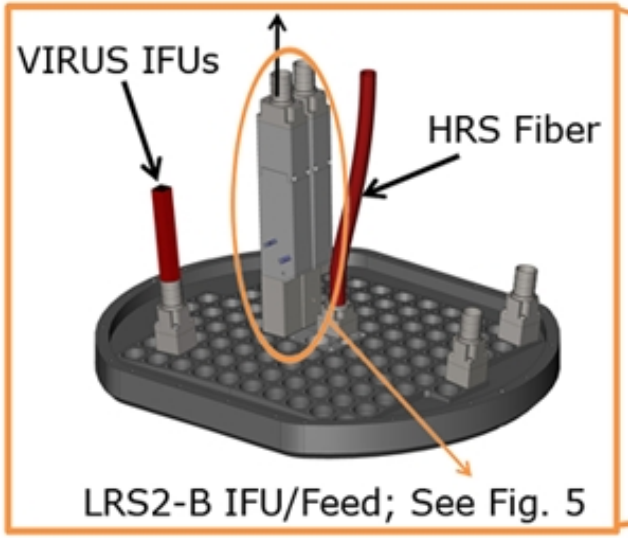
0.22 sq. arcmin



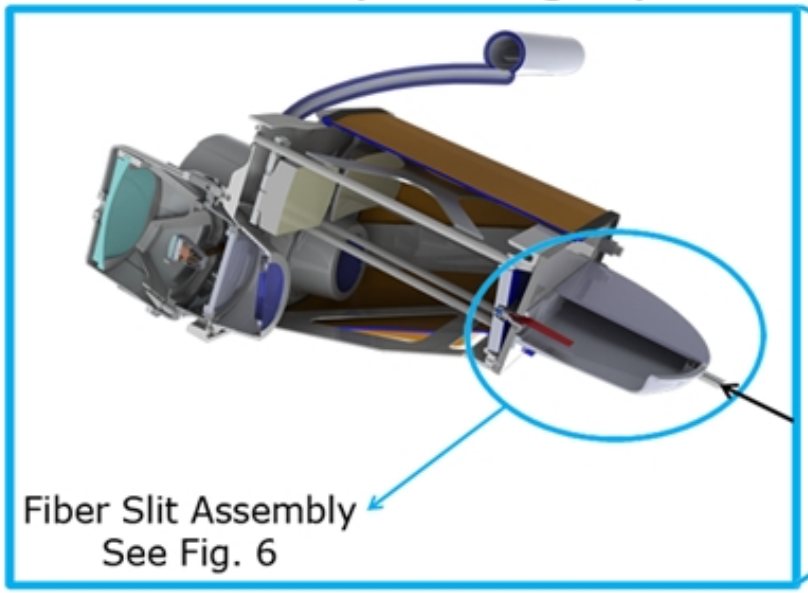


20'

HET WFU Focal Plane



LRS2-B Spectrograph



Hobby Eberly Telescope
McDonald Obs., Texas

Bundle of
Fiber Cables