Introduction to Spectroscopic Techniques

(low dispersion)

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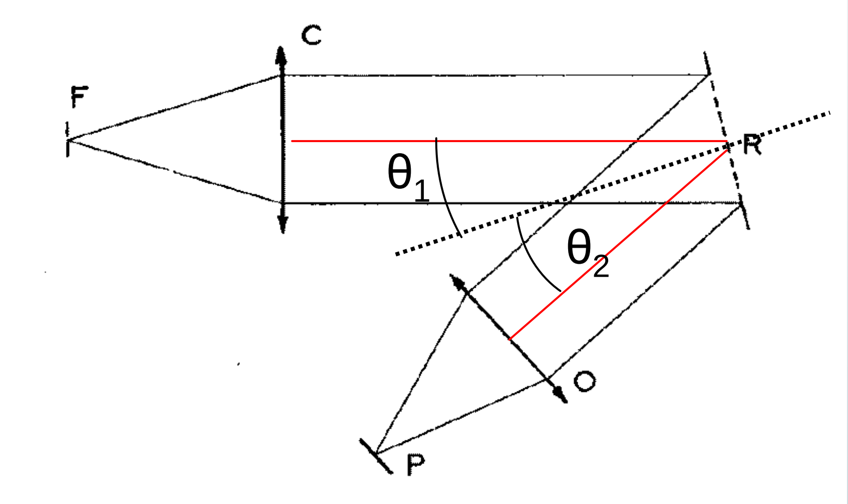
Outline

- Basic optics of gratings and spectrographs (with emphasis on long-slit spectroscopy)
- Observing steps, and data-reduction
- Other types of spectrographs, and future instrumentation of large telescopes

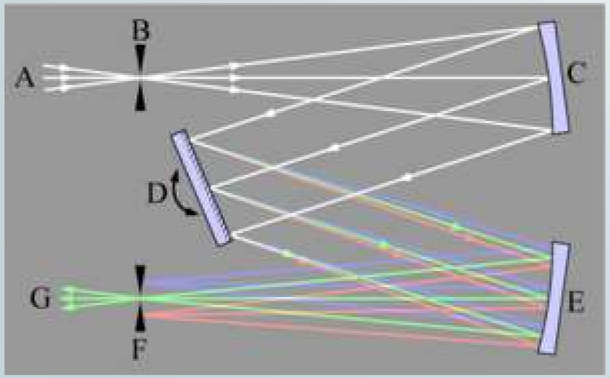
Principles of gratings (1)



- Grating needs to be illuminated in // beam
- Hence a collimator C and an objective O
- $\sin\theta_2 - \sin\theta_1 = n\,k\,\lambda$ (k: order; n: groves/mm)
- Intrinsic resolution: $\check{R}_0 = n\,k\,L$ (L size of grating)

(by definition: $R = \lambda/\Delta\lambda$, with $\Delta\lambda$ the smallest resolvable element)

Principles of gratings (2)



- $a = L \cos \theta_2$ (a: size of exit beam = Ø of camera)
- To $\check{R}_0$ corresponds an exit size (for an infinitely small entrance slit) $d_o = f\ \lambda/a$ (f: focal length of the camera; diffraction limit of element of size a)
- To be resolved, we need $d_o > 2$ pixels, that is:

  $f/a > 2\ X/\lambda$ With X = ~25 μ and λ ~ 0.5 μ, this gives:

  $f/a > 50$ → Camera not open enough! (luminosity)

  Conversely, if one wants f/a ~ 3, one needs X = ~ 1 μ)

  (remember, pixel was much smaller, ~3μ, in photography!)
- Thus will use $d > d_o$, i.e. not use full resolution of grating
- The exit image is optically conjugated to the entrance slit of size l_o !

Match of spectrograph to telescope (1)

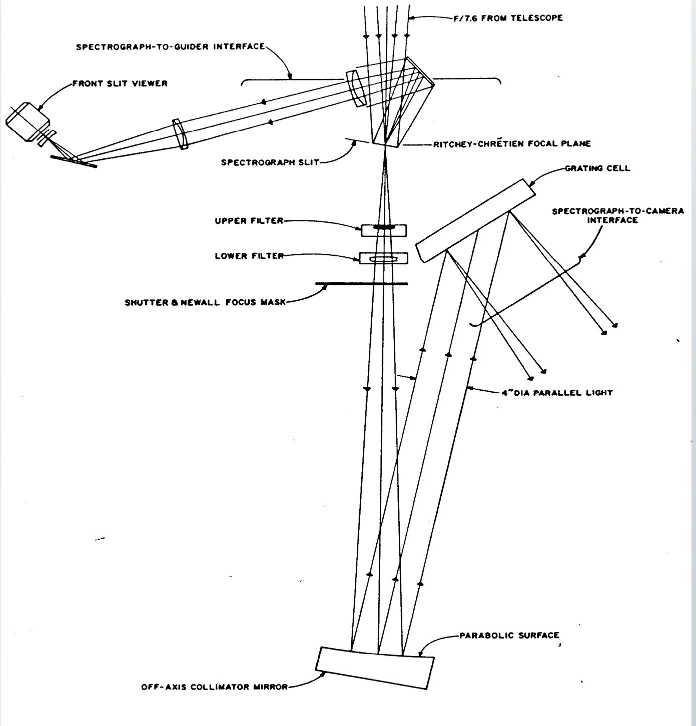


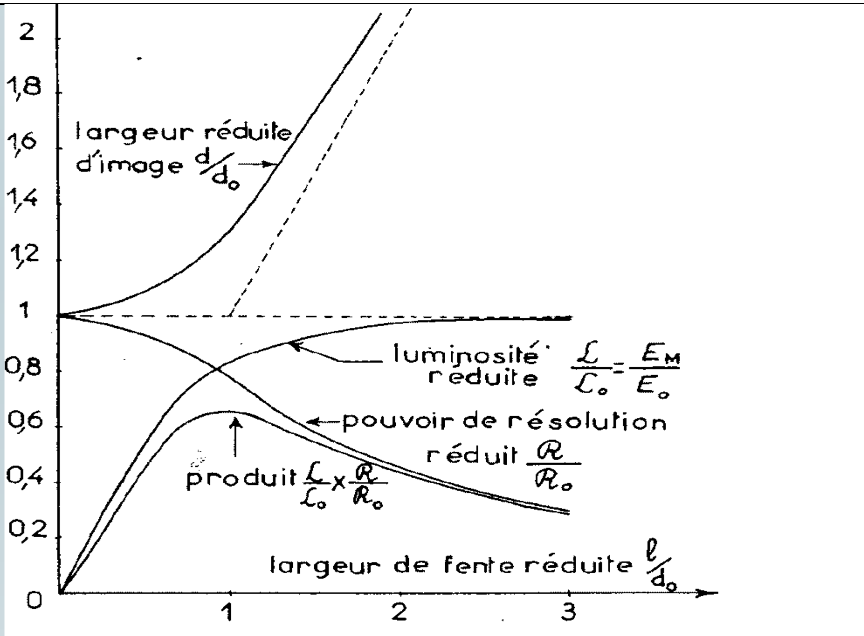
Figure 1. Optical diagram of the KPNO 4.0m Telescope "RC" spectrograph.

But entrance slit needs also to be matched to telescope and seeing, and opened to increase light throughput.

If you open the entrance slit, you degrade the spectral resolution, i.e. one gets $Ř < Ř_0$: $Ř = Ř_0\ d_0/d$

In addition, one can use a reduction factor in the spectrograph: d (exit) / l (entrance) < 1, (typically 1/6) to minimise size of optics.

Compromise with spectrographs



. — Influence de la largeur de la fente sur la résolvance et la luminosité rographe (d'après P. Jacquinot et Ch. Dufour, *J. Rech. Cent. nat.* ıt., **2** (1948-1949), 91-103).

- If equal weight given to Ř and £, best choice is for $l/d_0 = 1$ (but then camera not open enough...)
- In astronomy, preference given to £, so intrinsic resolution is not used.

Match of spectrograph to telescope (2)

- In the focal plane of telescope D, you need:

  l (width of entrance slit) = D m_T α (α seeing angle)
- Thus $\check{R} = \check{R}_0\, d_0 /d = \check{R}_0 .f\lambda/a.1/d \sim\check{R}_0\, \lambda/\alpha\ 1/D$

  that is for a given Ř, the size of the grating (which governs $\check{R}_0$) is proportional to D !

This is a problem for large telescopes!

- Full formula is:

$\check{R}\alpha = 2\ L/D\ \ tg\beta\ [\cos\theta_2/\cos\theta_1]$ (anamorphism)

Řα is the « efficiency » of the system

β blaze ~θ_2 « R2 » grating: tg β = 2 (63°)

« R4 » grating: tg β = 4 (75°)

Application: VLT

Photon-starved Mode

- $D = 8$ m Telescope diameter
- 0.5 μm seeing = 0".65-median; 0".3-10%
- $p = 12\ \mu$m $(4k)^2$ V/NIR pixels (market)
- F/ω Camera: $\omega \geq 1.4$; $L \geq 80$ mm (optics)

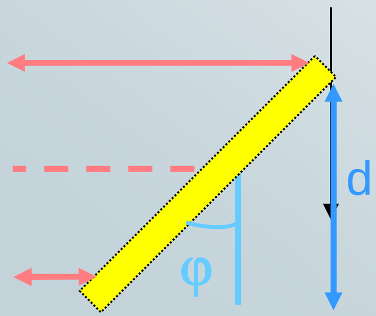
  ⇨ $\alpha_{sky} = 0".44$ (2-pixel sampling)

$$\alpha D \approx p\omega$$

sampling ~ OK; A.O. correction optional

Grating diameter L; on-sky slit width α

⇨ $\Re\alpha = \lambda/\delta\lambda = 2\,(L/D)\tan\varphi$



$\tan\varphi = 1\text{-}2 \rightarrow 4$

Littrow

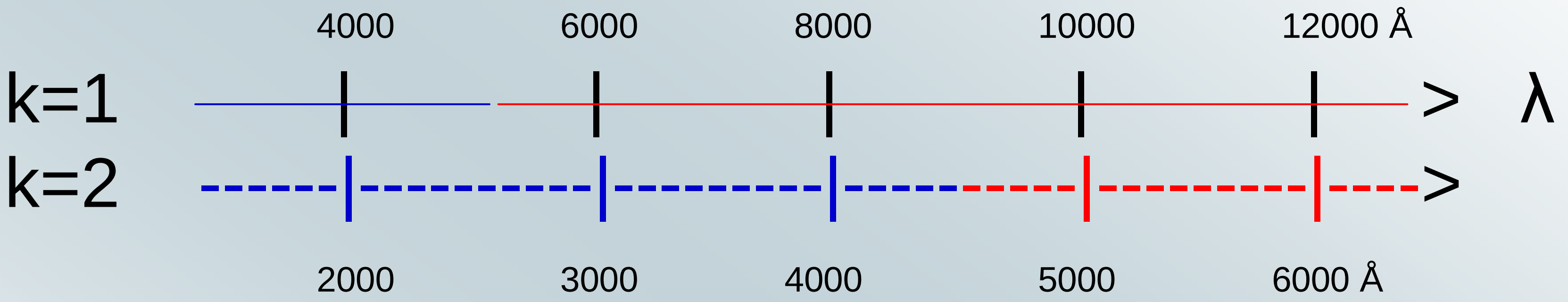
L = 80 mm; $\tan\varphi = 1$ ⇨ $\Re_{1"} = 4.10^3$ *(FORS)*

L = 200 mm; $\tan\varphi = 4$ ⇨ $\Re_{1"} = 4.10^4$ *(UVES)*

image slicers not always required

Order superposition

- At given θ_2 (i.e. on given pixel of detector), k λ = cste

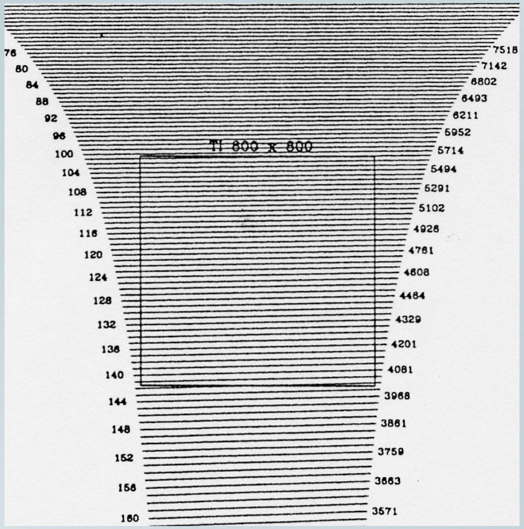


e.g. first order red is superposed by 2. order blue.

- Use of filters to separate orders (high-pass red (cuting the blue) in the above example)

- If one wants higher dispersion, go to higher orders (e.g. k ~ 100). But overlap of orders then unavoidable (λ shift between orders too small to use filters as separators), so one needs cross-dispersion to separate orders.

Echelle spectroscopy

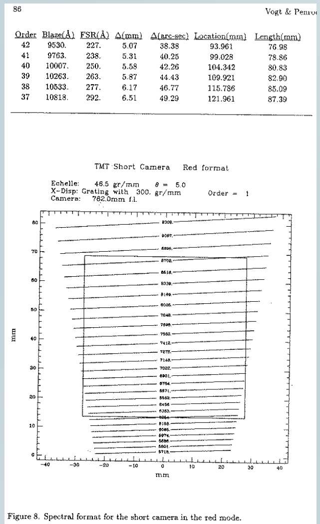


Compromise between resolution, detector size, ………
(here Hamilton spectr. at Lick)

Wavelength ---→

Spatial direction

… and order spacing, for sky or background subtraction
(here HIRES at Keck)


86 Vogt & Penro

Order	Blaze(Å)	FSR(Å)	Δ(mm)	Δ(arc-sec)	Location(mm)	Length(mm)
42	9530.	227.	5.07	38.38	93.961	76.98
41	9763.	238.	5.31	40.25	99.028	78.86
40	10007.	250.	5.58	42.26	104.342	80.83
39	10263.	263.	5.87	44.43	109.921	82.90
38	10533.	277.	6.17	46.77	115.786	85.09
37	10818.	292.	6.51	49.29	121.961	87.39

TMT Short Camera Red format

Echelle: 46.5 gr/mm θ = 5.0
X-Disp: Grating with 300. gr/mm Order = 1
Camera: 762.0mm f.l.

Figure 8. Spectral format for the short camera in the red mode.

Example of long-slit spectroscopy

- Several available:

-IDS at INT in LaPalma

-Carelec at OHP

-Former B&C at 1.52m
at LaSilla

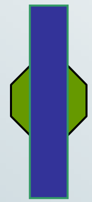
-Long-slit mode in
EFOSC types, etc...

- Typically a few arcmin

long slit, adjustable
width and orientation

Slit losses

- A rectangular slit does not let through all energy from a circular seeing disk! (but is better than circular aperture)
- For standard stars observations, open wide the slit if you want absolute photometry!



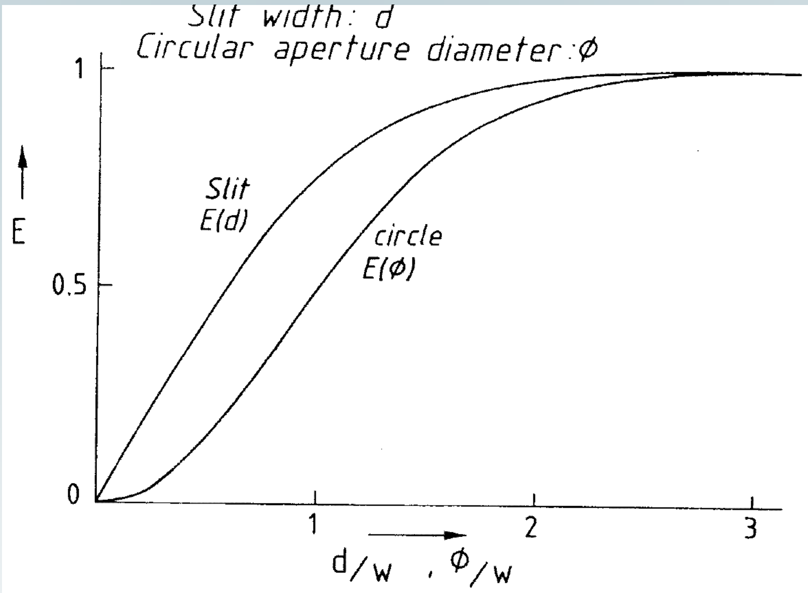


Fig. 2   Energy passed by an aperture for a Gaussian point spread function of FWHM : W

Differential refraction

- $\Delta R(\lambda) = R(\lambda) - R(5000Å) \sim cste\,[n(\lambda) - n(5000)] \tan z$

  Ex: for AM = 1.5, λ=4000 Å, $\Delta R \sim 0.70''$: relative loss of flux

  Depends on P and T (altitude) and humidity

  Worse in the blue, negligible in the near-IR
- Use parallactic angle for slit (oriented along the refraction)

  (see diagram, after Filippenko, PASP, 1982)

Venus (from J. Zhu)

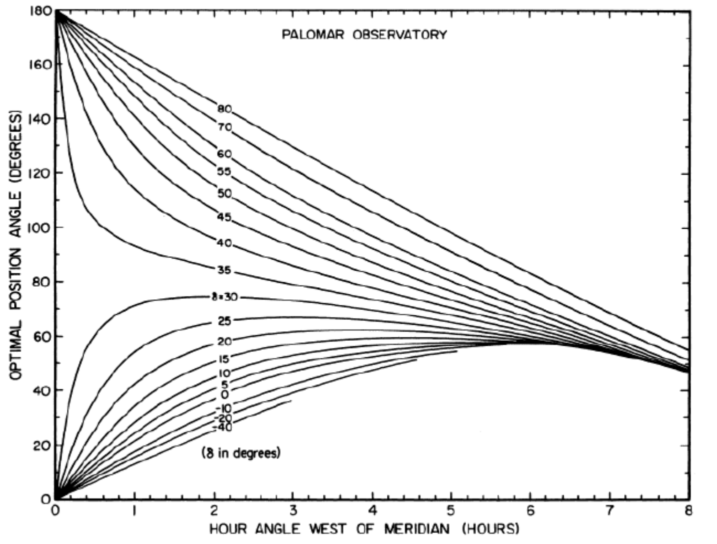


FIG. 1—Optimal slit or aperture position angle as a function of object position west of the meridian, computed for the latitude of Palomar Observatory. The diagram is valid for most other major observatories in the Northern Hemisphere, except at very small air masses. Corresponding position angles for objects east of the meridian are negative.

Blazed gratings

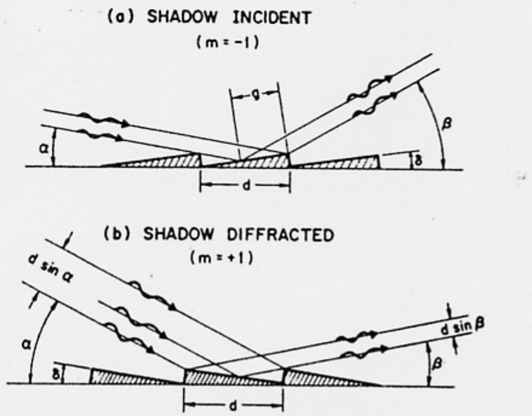


Fig. 14. Geometry of groove shadowing: (a) blaze of an inside spectral order, (b) blaze of an outside spectral order. Shadow factors derived from these geometries may be used to accurately determine the blaze efficiency.

- Blaze angle (δ) choosen such that max. of interferences coincides with max. of diffraction in the selected order
- Some shadowing occurs at large incidence angles, reducing a bit the efficiency

Grating Efficiency

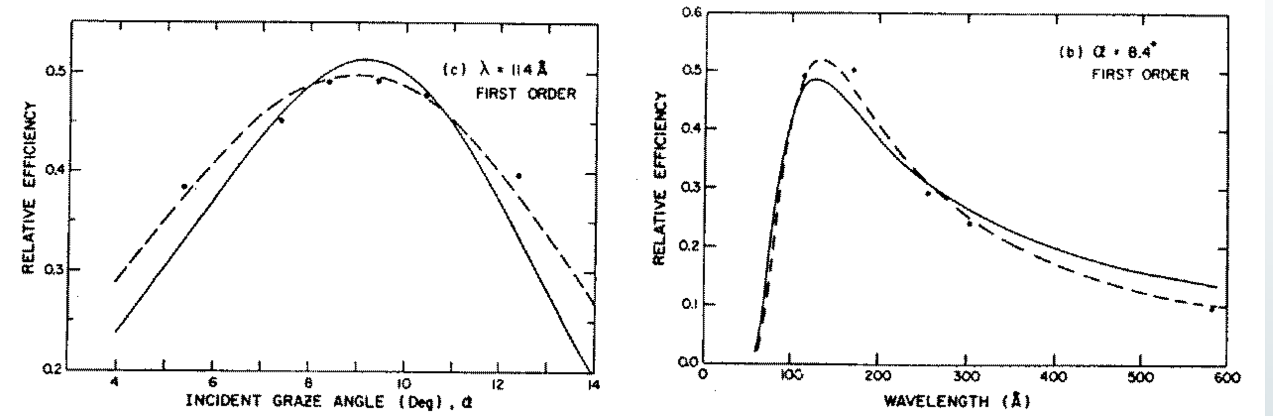


Fig. 13. Measured grating efficiencies. (a) Absolute efficiency in spectral orders 0, 1, 2, and 3 vs wavelength at an 8.4° graze angle to the grating tangent (11.4° to groove facets). The sum $\Sigma \varepsilon_m = \varepsilon_0 + \varepsilon_1 + \varepsilon_2 + \varepsilon_3$ is compared to our reflectance measurements at 11.4° of a flat witness sample (+) and those found in Ref. 38 (□). (b) Relative first-order efficiencies derived from the left-hand panel compared to theoretical curves times ~0.9. (c) Relative first-order efficiencies vs angle at λ = 114 Å compared to theoretical curves times ~0.85. (d) Zero-order relative efficiencies vs wavelength at an 8.4° graze angle compared to a theoretical curve times 1.06.

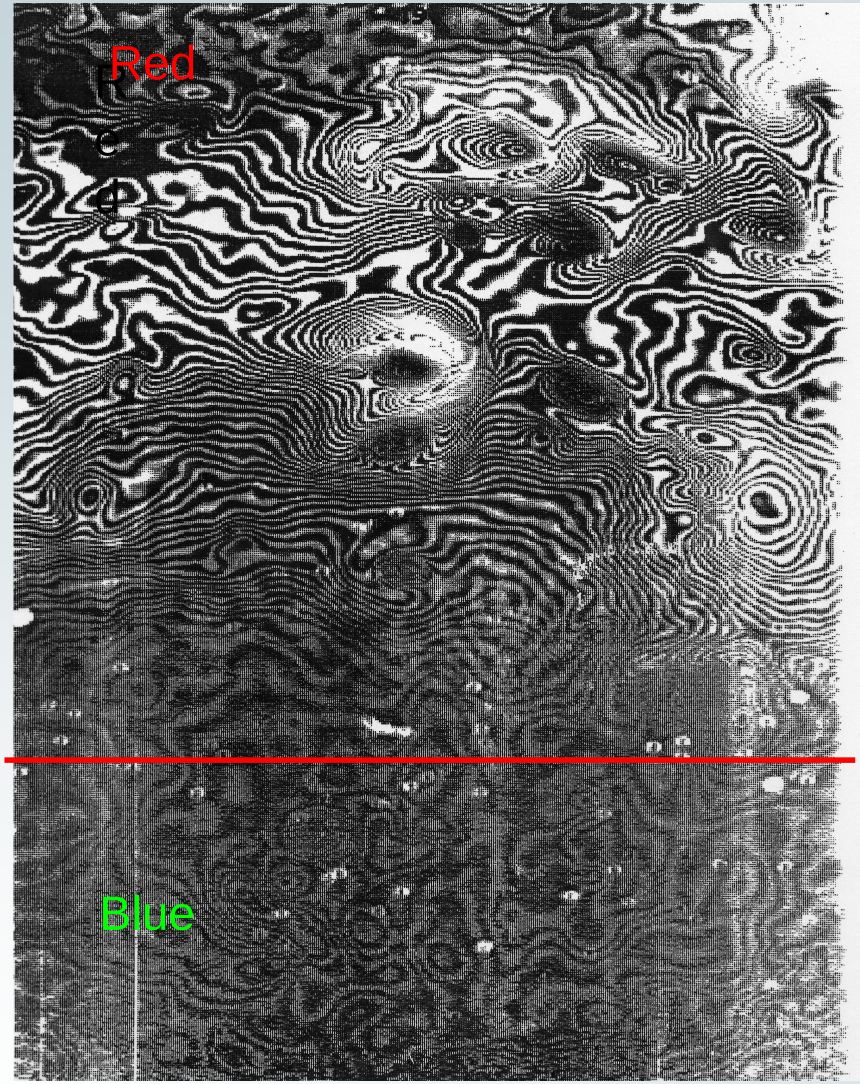
- Blazed gratings are efficient close to blaze angle
- Choose grating according to wished wavelength range
- Keeping in mind that efficiency drops sharply bluewards of blaze, but slowly redwards of it: thus blaze λ should be bluewards of your wished central wavelength !!

Flat Field correction

- To correct the high spatial- frequency variations across the image/spectrum
- Origin of variations: pixel to pixel sensitivity variations (detector); tranmission variations of optics (or dust particles…)

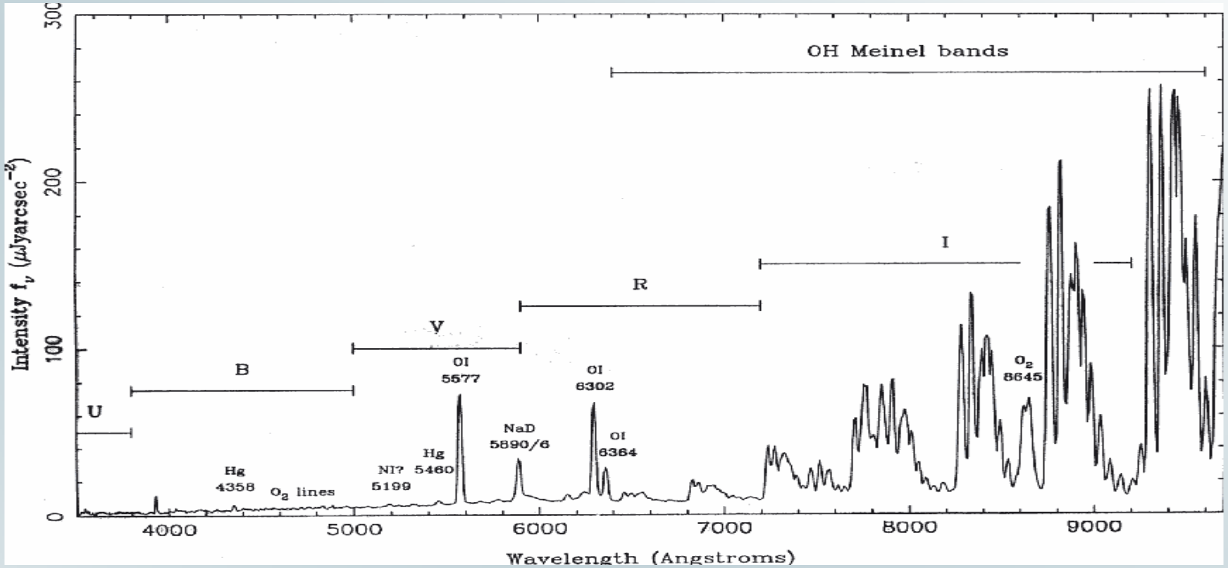
  It is a multiplicative or « gain » effect
- Illuminate with a uniform (« flat ») source and use the same optical path as the astronomical source….Difficult because at infinity!
- Need a high S/N not to degrade the science exp.
- Dome flats or internal calibration lamps not at infinity…corrrection approximate but flux OK
- Sky flats better, but not possible in spectroscopy (not enough signal), only for imaging
- There is an extra additive component due to night sky (emission lines) fringes….

Flat Field correction (2)



- FF is wavelength dependant: to be done through whole spectrograph
- Needs to be normalised to 1 to conserve fluxes
- One can correct vigneting along the slit length if FF illumination is correct (usually not the case with dome flats)

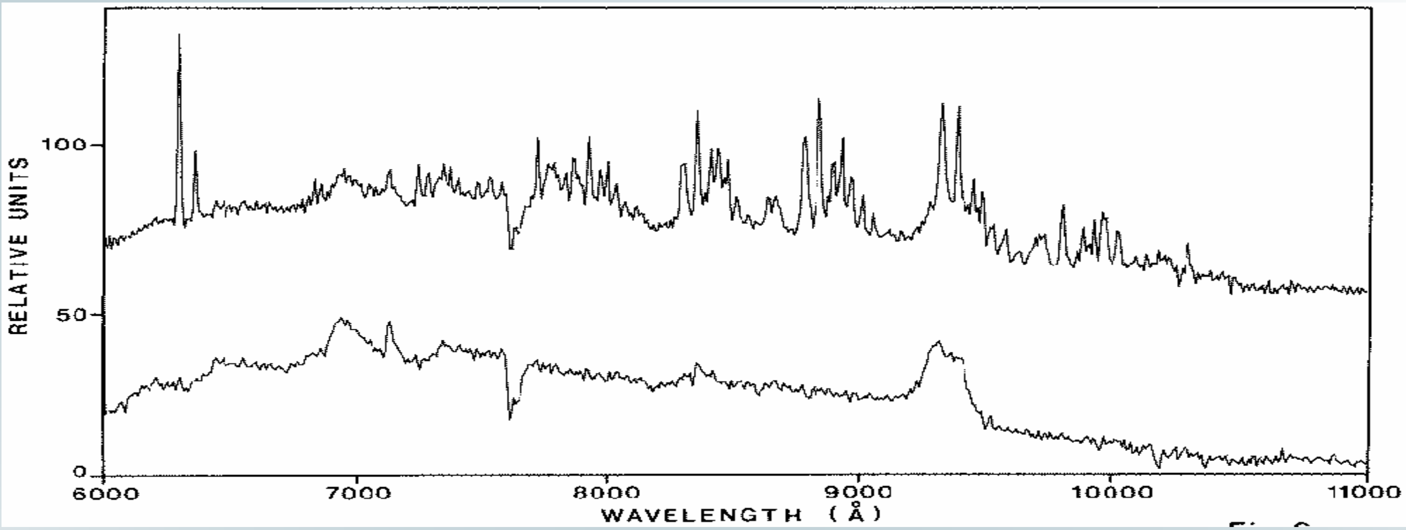
Sky emission



(from Massey et al. 1990)

- Sky is bright, specially in near-IR !!
- Needs to be subtracted
- Requires a linear detector

Importance of sky subtraction



Example of a V=16.5 QSO in the far-red

(that is almost as bright as the full moon…)

Obtained with the ESO 3.6m and Reticon diode array

Top: full spectrum   Bottom: sky subtracted

The important features (broad Balmer lines) are completely hidden in the OH night sky lines…

Becoming worse when going to the near-IR (J, H, K bands)

Atmospheric absorptions

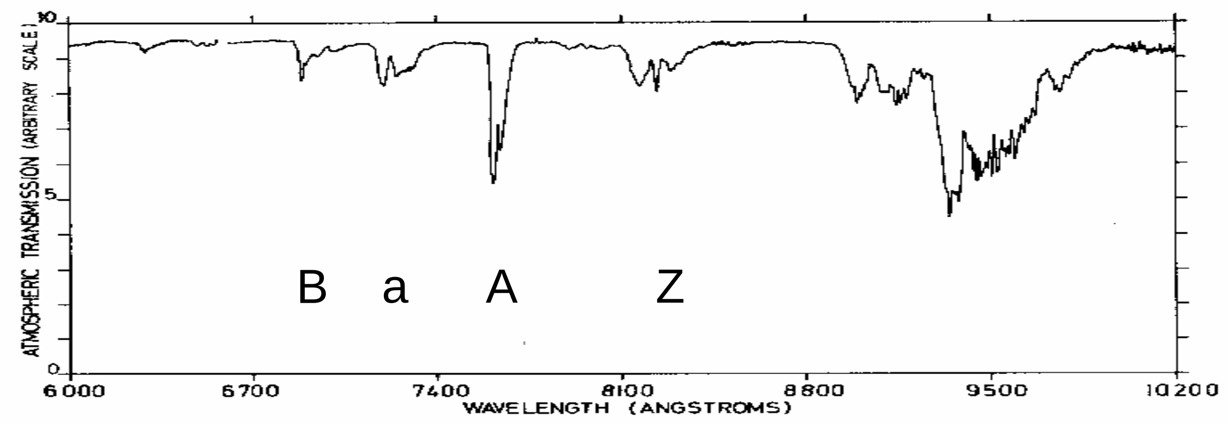
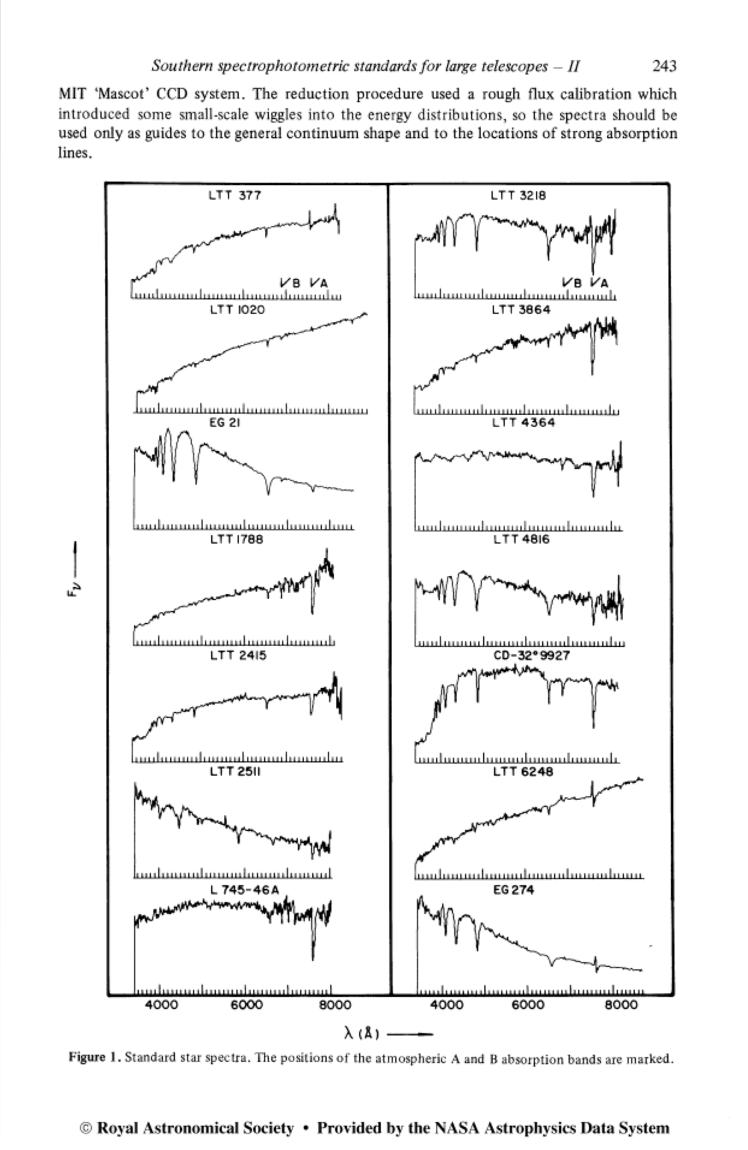


FIGURE 1. — Atmospheric absorption between λ6000 Å and λ12000 Å as seen with the instrument used for the observations. This figure has been obtained by dividing the spectrum of a standard star observed with an air mass of 2.88 by the spectrum of the same star obtained with an air mass of 1.06.

from Vreux, Dennefeld & Andrillat (1983)

- Due to O_2 (A, B, ..) and H_2O (a, Z, ..) in the visible, plus CO_2 , CH_4 , etc… in the near-IR
- Not to confuse with stellar absorption bands…
- To correct: needs to observe a hot star (no intrinsic absorption lines) in the same conditions (similar airmass) and divide the object's spectrum by the hot star's spectrum. Saturated lines (A,…) are difficult to correct completely.
- The A, B, notation comes from Fraunhoffer (1814, solar spectrum)

Standard stars (1)



MIT 'Mascot' CCD system. The reduction procedure used a rough flux calibration which introduced some small-scale wiggles into the energy distributions, so the spectra should be used only as guides to the general continuum shape and to the locations of strong absorption lines.

Figure 1. Standard star spectra. The positions of the atmospheric A and B absorption bands are marked.

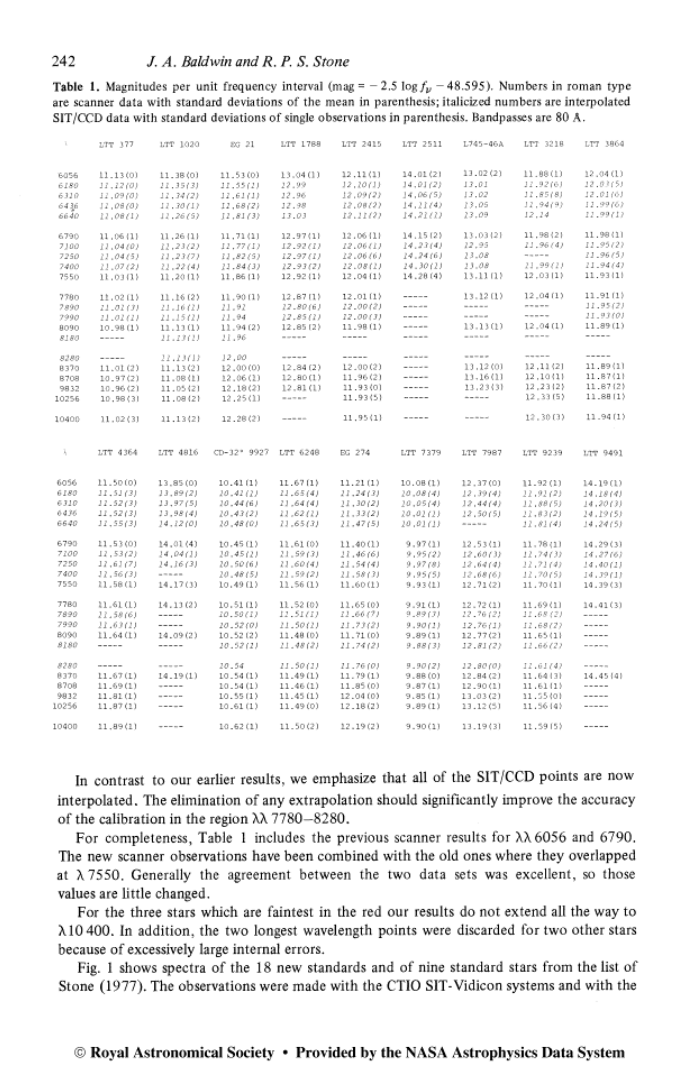
Example from Baldwin & Stone (1984)

Choose Standard with appropriate Spectral Energy Distribution

With as few absoprtion lines as possible

WD's are ideal, but faint…

Standard stars (2)



242 *J. A. Baldwin and R. P. S. Stone*

Table 1. Magnitudes per unit frequency interval (mag = $-2.5 \log f_\nu - 48.595$). Numbers in roman type are scanner data with standard deviations of the mean in parenthesis; italicized numbers are interpolated SIT/CCD data with standard deviations of single observations in parenthesis. Bandpasses are 80 A.

λ	LTT 377	LTT 1020	EG 21	LTT 1788	LTT 2415	LTT 2511	L745-46A	LTT 3218	LTT 3864
6056	11.13(0)	11.38(0)	11.53(0)	13.04(1)	12.11(1)	14.01(2)	13.02(2)	11.88(1)	12.04(1)
6180	11.12(0)	11.35(3)	11.55(1)	12.99	12.10(1)	14.01(2)	13.01	11.92(6)	12.03(5)
6310	11.09(0)	11.34(2)	11.61(1)	12.96	12.09(2)	14.06(5)	13.02	11.85(8)	12.01(6)
6436	11.08(0)	11.30(1)	11.68(2)	12.98	12.08(2)	14.21(4)	13.05	11.94(9)	11.99(6)
6640	11.08(1)	11.26(5)	11.81(3)	13.03	12.11(2)	14.21(1)	13.09	12.14	11.99(1)
6790	11.06(1)	11.26(1)	11.71(1)	12.97(1)	12.06(1)	14.15(2)	13.03(2)	11.98(2)	11.98(1)
7100	11.04(0)	11.23(2)	11.77(1)	12.92(1)	12.06(1)	14.23(4)	12.95	11.96(4)	11.95(2)
7250	11.04(5)	11.23(7)	11.82(5)	12.97(1)	12.06(6)	14.24(6)	13.08	-----	11.96(5)
7400	11.07(2)	11.22(4)	11.84(3)	12.93(2)	12.08(1)	14.30(1)	13.08	11.99(1)	11.94(4)
7550	11.03(1)	11.20(1)	11.86(1)	12.92(1)	12.04(1)	14.28(4)	13.11(1)	12.03(1)	11.93(1)
7780	11.02(1)	11.16(2)	11.90(1)	12.87(1)	12.01(1)	-----	13.12(1)	12.04(1)	11.91(1)
7890	11.01(3)	11.16(1)	11.91	12.80(6)	12.00(2)	-----	-----	-----	11.95(2)
7990	11.01(1)	11.15(1)	11.94	12.85(1)	12.00(3)	-----	-----	-----	11.93(0)
8090	10.98(1)	11.13(1)	11.94(2)	12.85(2)	11.98(1)	-----	13.13(1)	12.04(1)	11.89(1)
8180	-----	11.13(1)	11.96	-----	-----	-----	-----	-----	-----
8280	-----	11.13(1)	12.00	-----	-----	-----	-----	-----	-----
8370	11.01(2)	11.13(2)	12.00(0)	12.84(2)	12.00(2)	-----	13.12(0)	12.11(2)	11.89(1)
8708	10.97(2)	11.08(1)	12.06(1)	12.80(1)	11.96(2)	-----	13.16(1)	12.10(1)	11.87(1)
9832	10.96(2)	11.05(2)	12.18(2)	12.81(1)	11.93(0)	-----	13.23(3)	12.23(2)	11.87(2)
10256	10.98(3)	11.08(2)	12.25(1)	-----	11.93(5)	-----	-----	12.33(5)	11.88(1)
10400	11.02(3)	11.13(2)	12.28(2)	-----	11.95(1)	-----	-----	12.30(3)	11.94(1)

λ	LTT 4364	LTT 4816	CD-32° 9927	LTT 6248	EG 274	LTT 7379	LTT 7987	LTT 9239	LTT 9491
6056	11.50(0)	13.85(0)	10.41(1)	11.67(1)	11.21(1)	10.08(1)	12.37(0)	11.92(1)	14.19(1)
6180	11.51(3)	13.89(2)	10.42(1)	11.65(4)	11.24(3)	10.08(4)	12.39(4)	11.91(2)	14.18(4)
6310	11.52(3)	13.97(5)	10.44(6)	11.64(4)	11.30(2)	10.05(4)	12.44(4)	11.88(5)	14.20(3)
6436	11.52(3)	13.98(4)	10.43(2)	11.62(1)	11.33(2)	10.02(1)	12.50(5)	11.83(2)	14.19(5)
6640	11.55(3)	14.12(0)	10.48(0)	11.65(3)	11.47(5)	10.01(1)	-----	11.81(4)	14.24(5)
6790	11.53(0)	14.01(4)	10.45(1)	11.61(0)	11.40(1)	9.97(1)	12.53(1)	11.78(1)	14.29(3)
7100	11.53(2)	14.04(1)	10.45(1)	11.59(3)	11.46(6)	9.95(2)	12.60(3)	11.74(3)	14.27(6)
7250	11.61(7)	14.16(3)	10.50(6)	11.60(4)	11.54(4)	9.97(8)	12.64(4)	11.71(4)	14.40(1)
7400	11.56(3)	-----	10.48(5)	11.59(2)	11.58(3)	9.95(5)	12.68(6)	11.70(5)	14.39(1)
7550	11.58(1)	14.17(3)	10.49(1)	11.56(1)	11.60(1)	9.93(1)	12.71(2)	11.70(1)	14.39(3)
7780	11.61(1)	14.13(2)	10.51(1)	11.52(0)	11.65(0)	9.91(1)	12.72(1)	11.69(1)	14.41(3)
7890	11.58(6)	-----	10.50(1)	11.51(1)	11.66(7)	9.89(3)	12.76(2)	11.68(2)	-----
7990	11.63(1)	-----	10.52(0)	11.50(1)	11.73(2)	9.90(1)	12.76(1)	11.68(2)	-----
8090	11.64(1)	14.09(2)	10.52(2)	11.48(0)	11.71(0)	9.89(1)	12.77(2)	11.65(1)	-----
8180	-----	-----	10.52(1)	11.48(2)	11.74(2)	9.88(3)	12.81(2)	11.66(2)	-----
8280	-----	-----	10.54	11.50(1)	11.76(0)	9.90(2)	12.80(0)	11.61(4)	-----
8370	11.67(1)	14.19(1)	10.54(1)	11.49(1)	11.79(1)	9.88(0)	12.84(2)	11.64(3)	14.45(4)
8708	11.69(1)	-----	10.54(1)	11.46(1)	11.85(0)	9.87(1)	12.90(1)	11.61(1)	-----
9832	11.81(1)	-----	10.55(1)	11.45(1)	12.04(0)	9.85(1)	13.03(2)	11.55(0)	-----
10256	11.87(1)	-----	10.61(1)	11.49(0)	12.18(2)	9.89(1)	13.12(5)	11.56(4)	-----
10400	11.89(1)	-----	10.62(1)	11.50(2)	12.19(2)	9.90(1)	13.19(3)	11.59(5)	-----

In contrast to our earlier results, we emphasize that all of the SIT/CCD points are now interpolated. The elimination of any extrapolation should significantly improve the accuracy of the calibration in the region λλ 7780–8280.

For completeness, Table 1 includes the previous scanner results for λλ 6056 and 6790. The new scanner observations have been combined with the old ones where they overlapped at λ 7550. Generally the agreement between the two data sets was excellent, so those values are little changed.

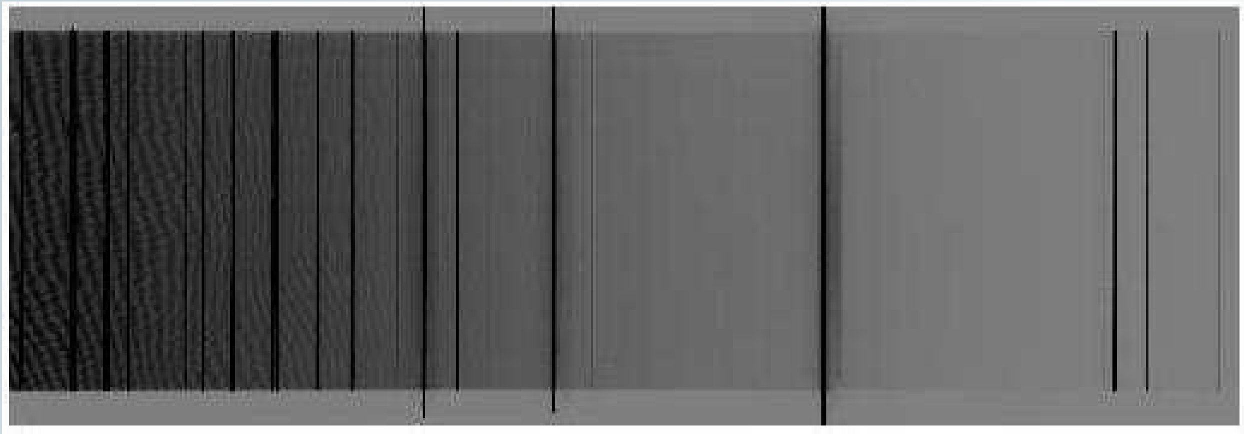
For the three stars which are faintest in the red our results do not extend all the way to λ10 400. In addition, the two longest wavelength points were discarded for two other stars because of excessively large internal errors.

Fig. 1 shows spectra of the 18 new standards and of nine standard stars from the list of Stone (1977). The observations were made with the CTIO SIT-Vidicon systems and with the

Check that:

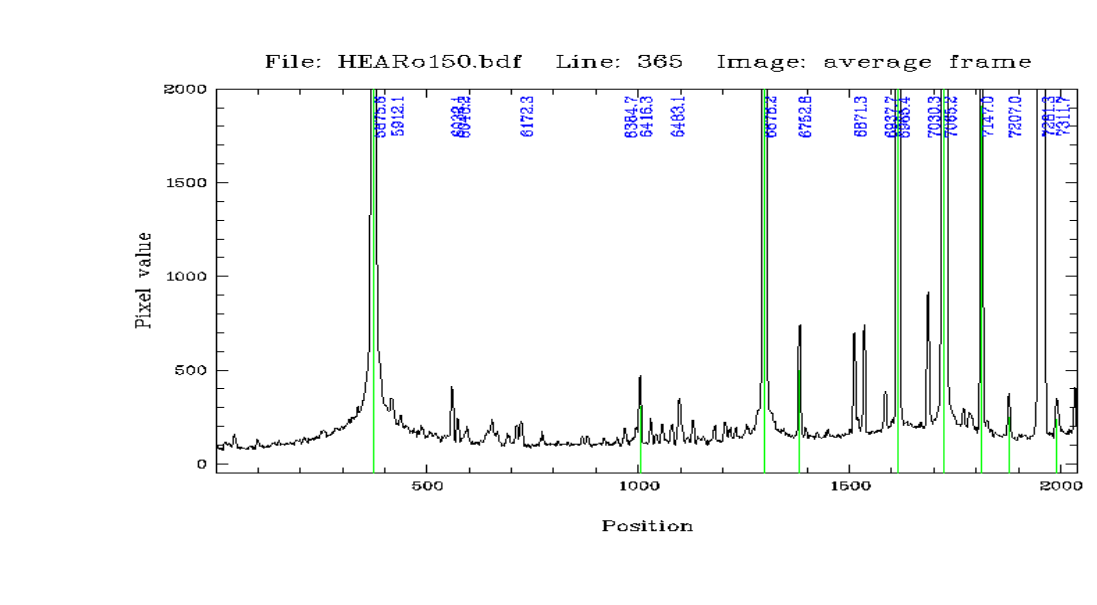
- The sampling is appropriate
- The wavelength range covers your needs (carefull in the far-red…!)

Wavelength calibration



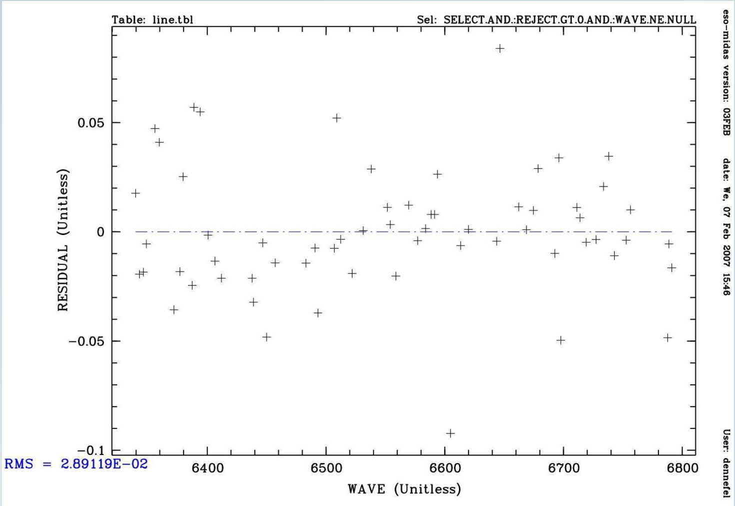
- This image is a raw (He + Ar) exposure
- You may need to saturate some of the lines…
- 2D wavelength calibration (line by line) will also correct the distortion
- If CCD well aligned, 1D calibration may be enough

Wavelength calibration (2)



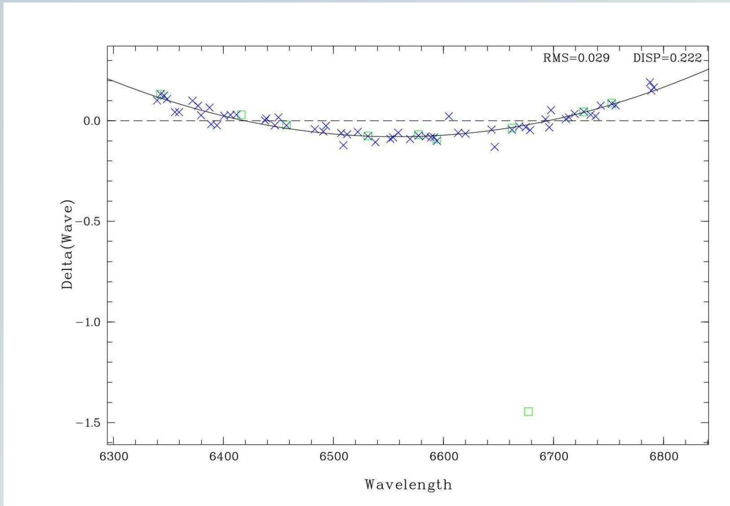
First identify some lines, then mostly automatic

Wavelength calibration (3)

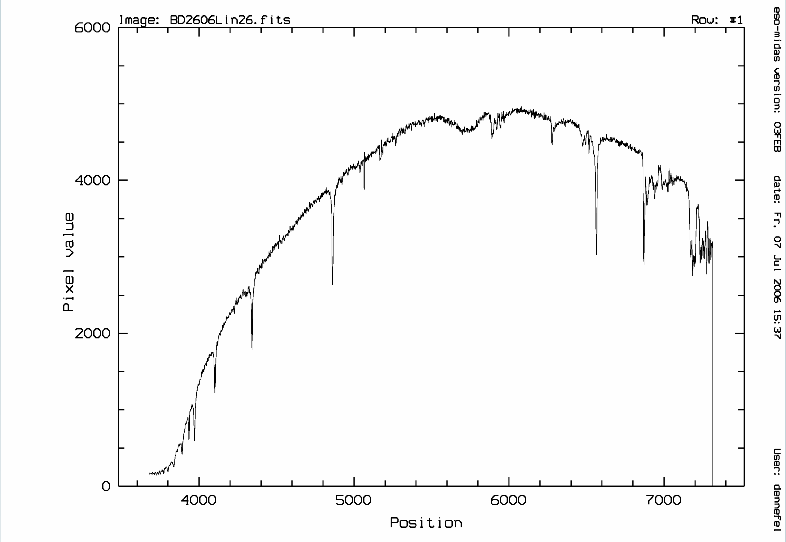


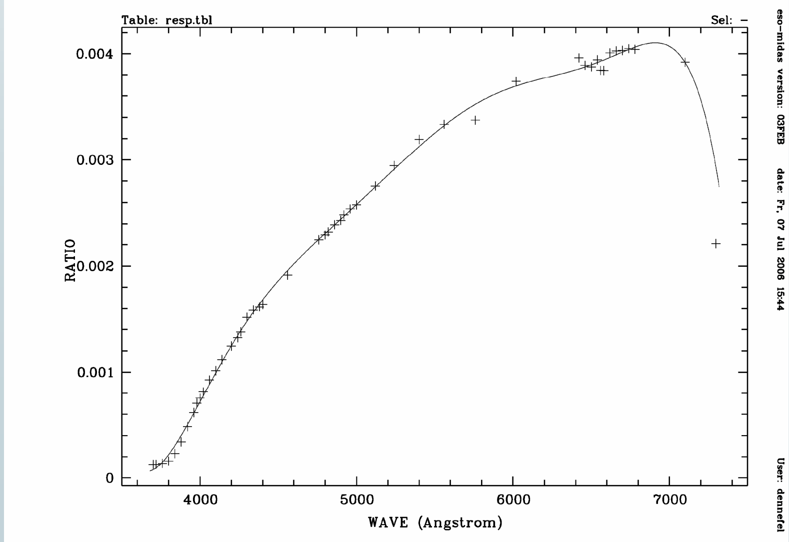
Plot residuals
Eliminate outstanding lines
Recalculate calibration

Plot delta's
If necessary, adjust degree of polynomial (depending on instrument: 2d OK most of the time, but special cases e.g. image tubes have S distorsion, hence 3d degree preferable)



Response curve



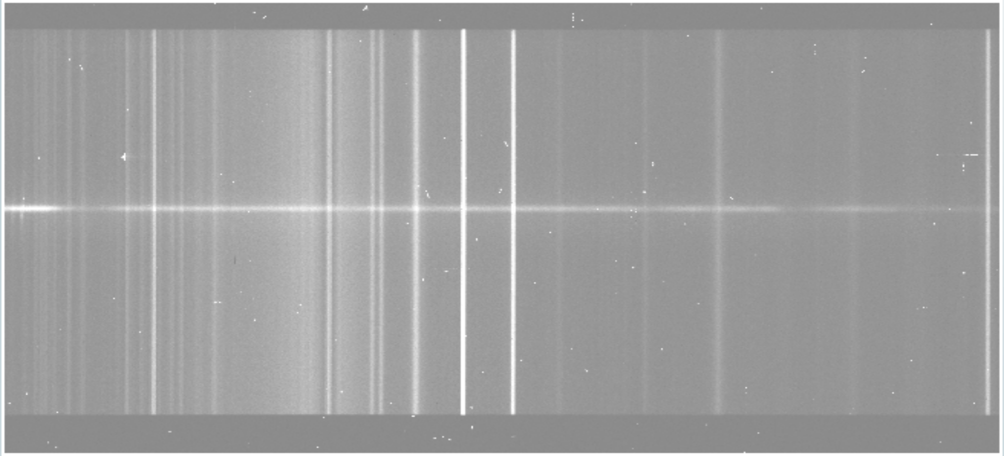


One needs to understand the origin of the shape (grating curve, detector's response, etc..) before deciding fitting method (poly, spline) and smoothing parameter.

Assumes FF has removed small scale features

Try to have more than one Std star observed (odd number if possible)…

Extraction of spectrum



- Assumes Offset and FlatField corrected
- 2D wavelength calibration (corrects distortion)
- See if vignetting (transmission changes along the slit); can be corrected by the FF
- Cosmic rays removal
- Simple sum, or weighted sum of object lines
- Sky subtraction (average on both sides of object)

Summary of operations

S_{*} (ADU) $= G_{x,y} F_{*} . t + O_f$ (Dark current negligible)

$S_{FF} = G_{x,y} F_{FF} .t' + O_f$

- Do $F_{*} / F_{FF} = (S_{*} - O_f)/(S_{FF} - O_f) . t'/t$

and same for Standard star

- Cosmic rays correction
- Wavelength calibration
- Extraction of spectrum (with sky subtraction)
- Extinction correction
- Division by the response curve

→ final spectrum in absolute units

A rough calculation of signal to noise

- S(ignal) = $E_* D^2 \Delta\lambda\ \eta\ \tau\ t$

  E in ergs/cm^2/s/Å or W/m^2/Å, flux from object

  D Diameter of telescope, $\Delta\lambda$ (bandpass), η (quantum efficiency), τ (transmission), t exposure time

- N(oise) = square root of **total** signal

  $= [\ (E_* + (2)E_s\alpha^2)\ D^2\Delta\lambda\eta\tau t + n^2L^2\ ]^{1/2}$ (α seeing)

  n number of pixels corresponding to α

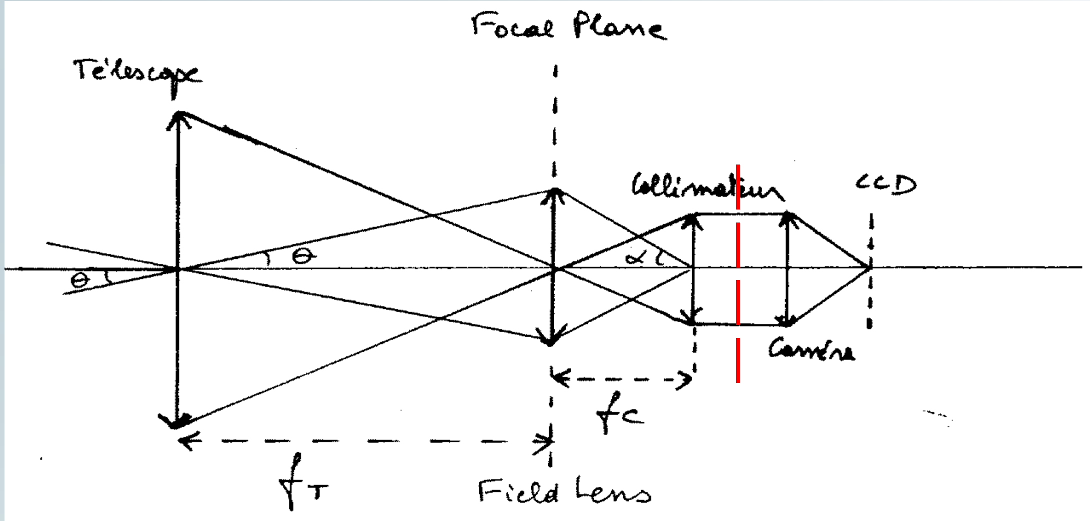
- IF object fainter than sky, AND r.o.n. negligible, then:

  $S/N = E_* \,.\, D/\alpha \,.\, [\Delta\lambda\ \eta\ \tau\ t\ /E_c]^{1/2}$ or:

  Limiting magnitude: $\mathbf{E_* = S/N \,.\, \alpha/D \,.\, [E_S / (\Delta\lambda\ \eta\ \tau\ t)]^{1/2}}$

Seeing as important as diameter of telescope...!

Focal Reducer



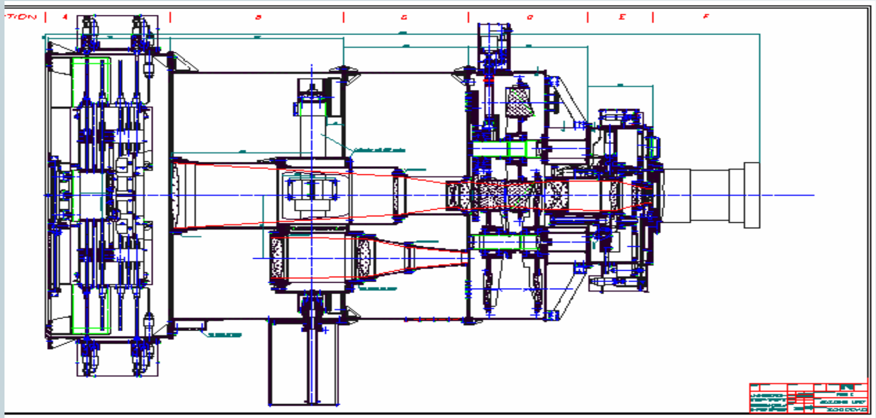
- Spectrograph is 'straightened' out, thus grating works in transmission instead of reflection
- Field of view (2θ) defined by field lens:

$D_{FL} = 2f_T\,\theta = 2f_c\,\alpha$ Final focal length $f' = m'_{cam}\,D_T$

Reduction factor is $m_{Tel}\,/m'_{cam}$

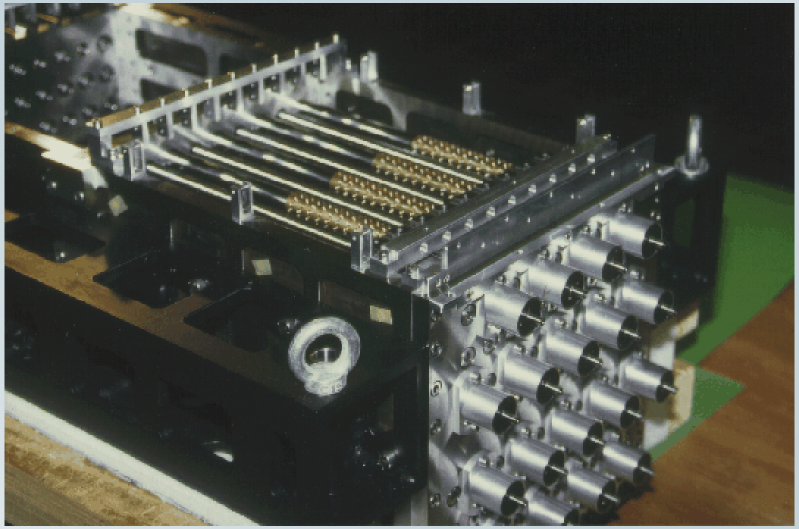
To keep exit rays 'on axis', one adds a lens or a prism to the grating: grens, or grism!

Focal reducer (2)



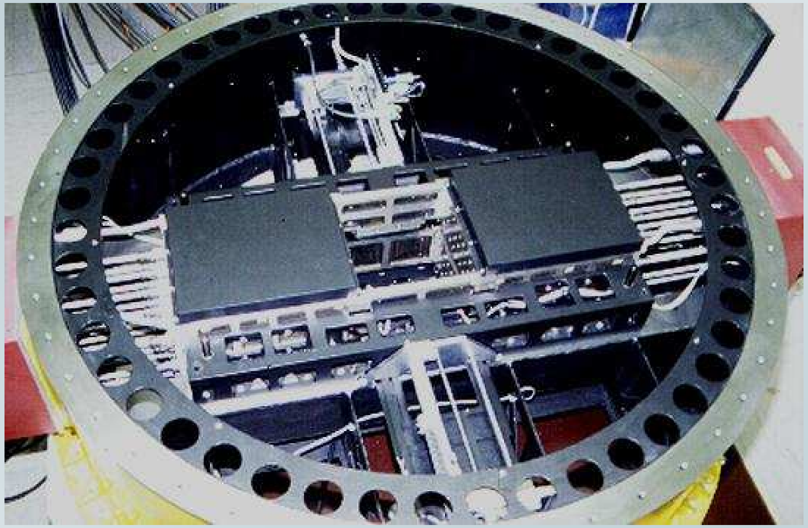
- Parallel beam: can introduce filters (in particular interference filters), gratings, Fabry-Perot's, polarimeters, etc…
- Very versatile instrument
- Entrance plate (telescope focal plane) versatile too
- Exemple of FORS/VLT (with slits or masks)

Slits, or masks?

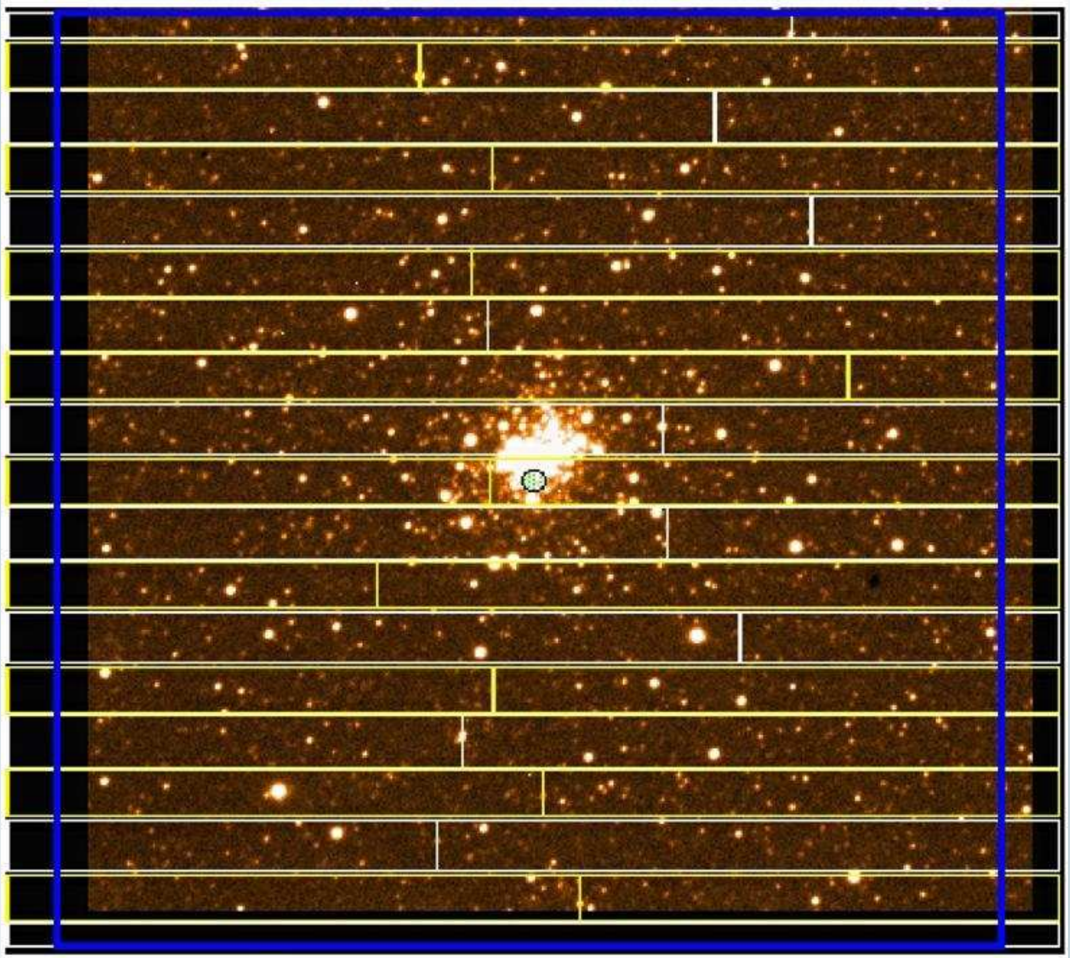


19 slits, fixed length

~30 slits, variable length



Exemple of multi-objects (slits)

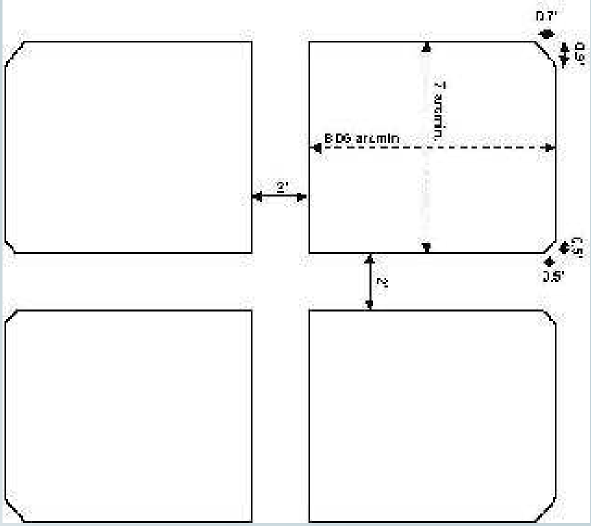


Open Cluster NGC 330 in SMC - VLT UT1 + FORS1 (MOS-mode)

Field of view: ~ 7'

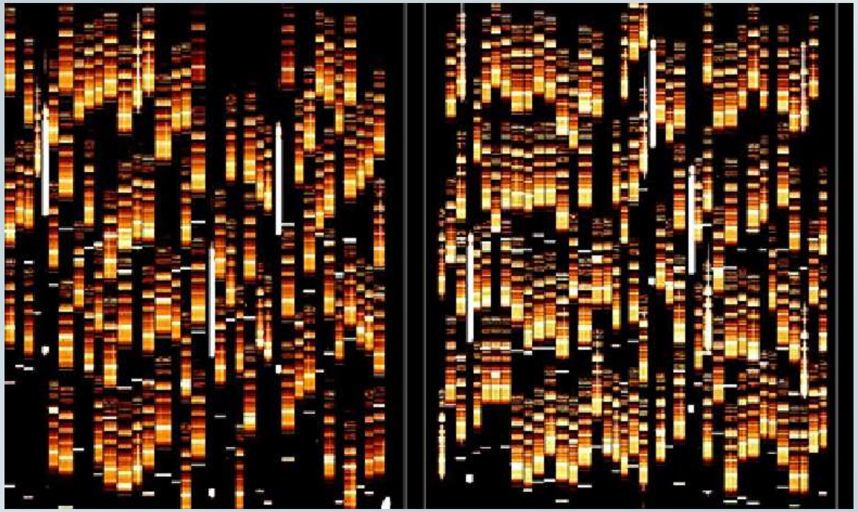
The wavelength range depends on the position of the target in the field!

Multi-objects (masks)

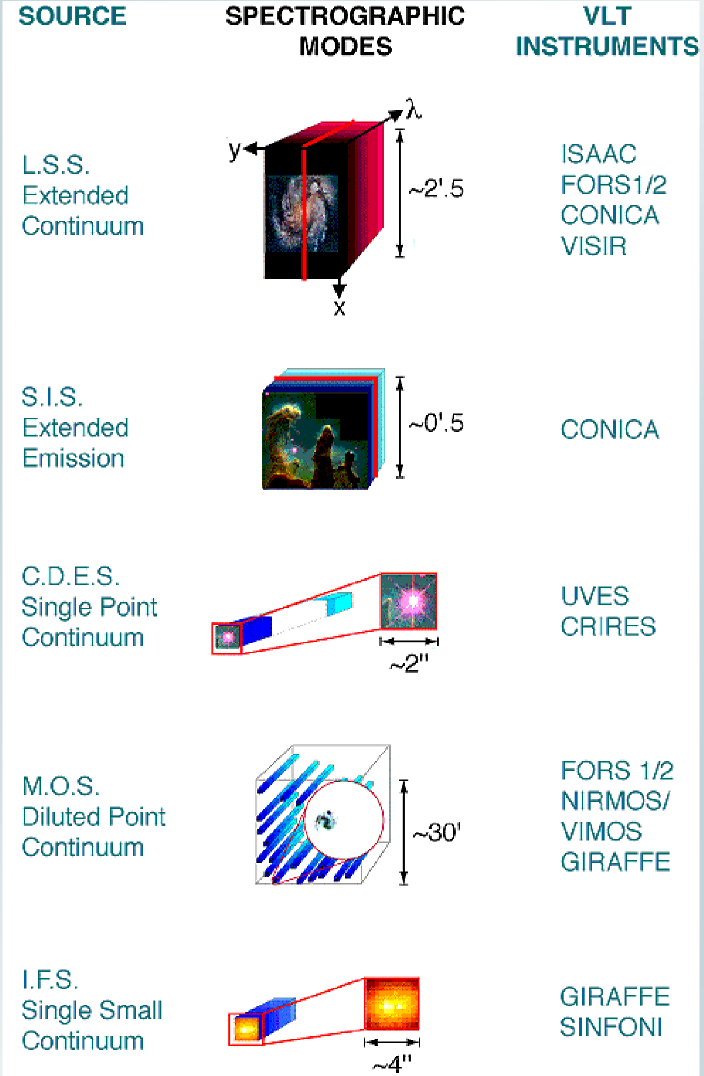


For larger fields of view:
Vimos: several quadrants, with independant optics and cameras (gaps in the field!)

Two quadrants, with about 100 slits in each mask

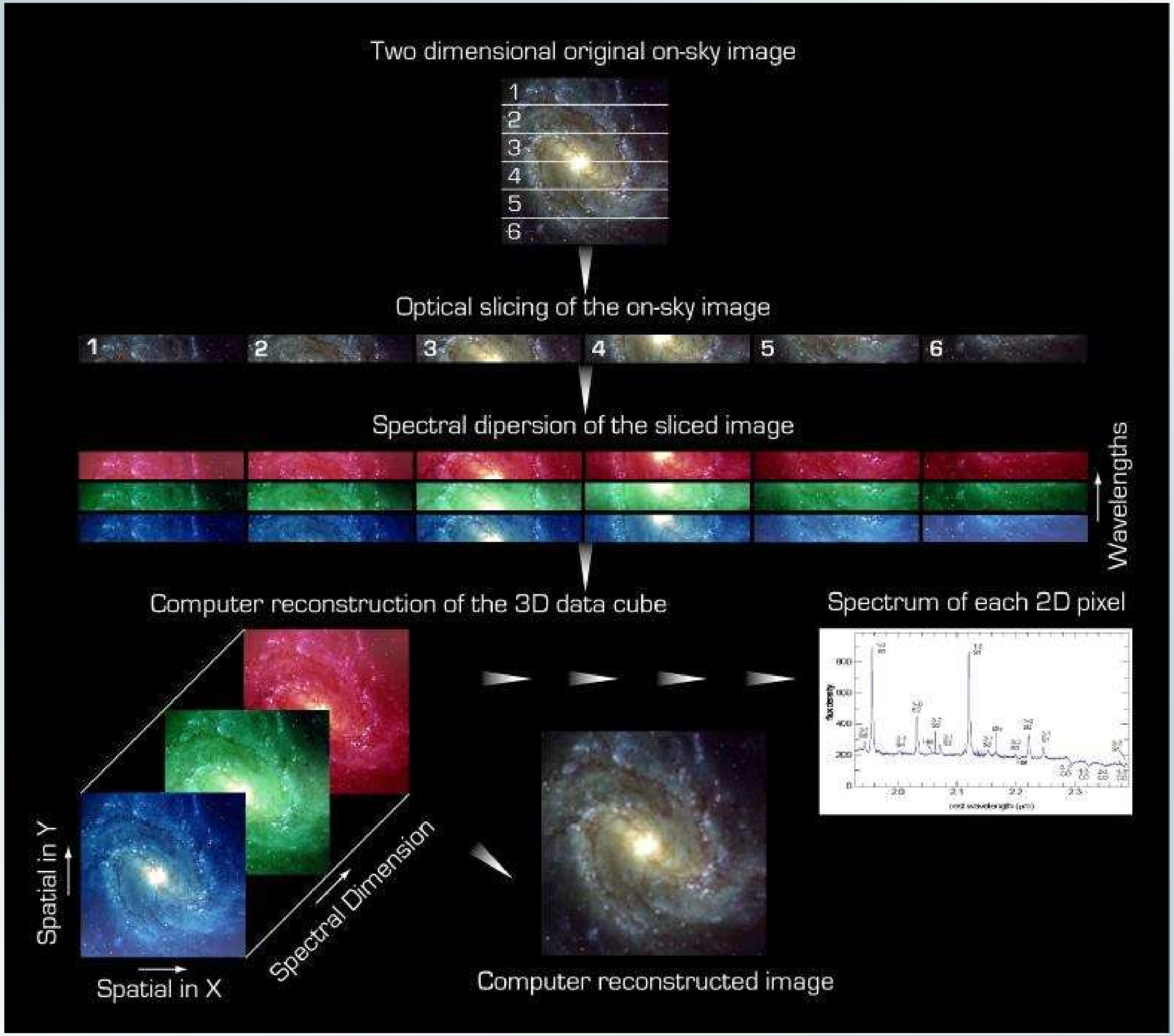


Spectroscopic modes



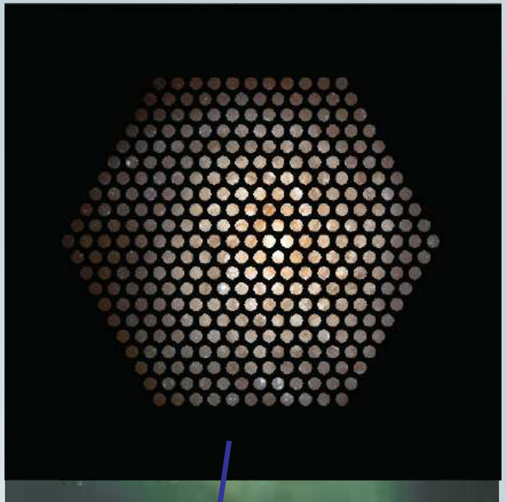
Note: also slit-less spectroscopy (objective prism or grism)

Integral field spectroscopy

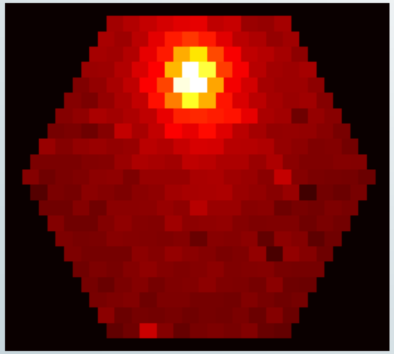


3D Spectroscopy (principle)

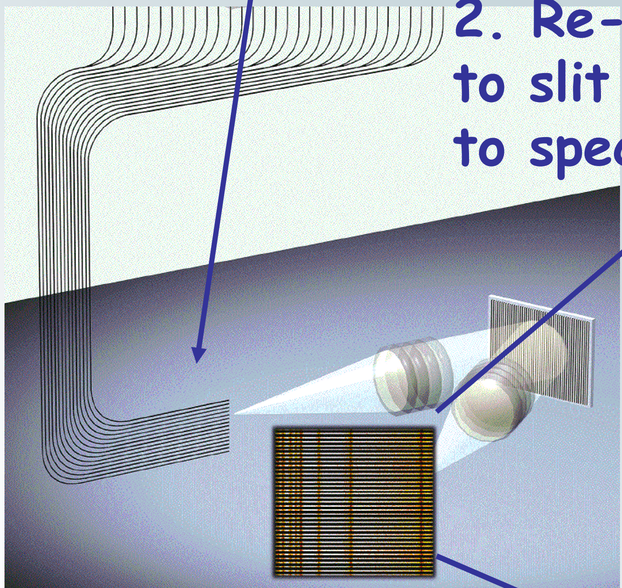
1. Sample object in
spatial elements

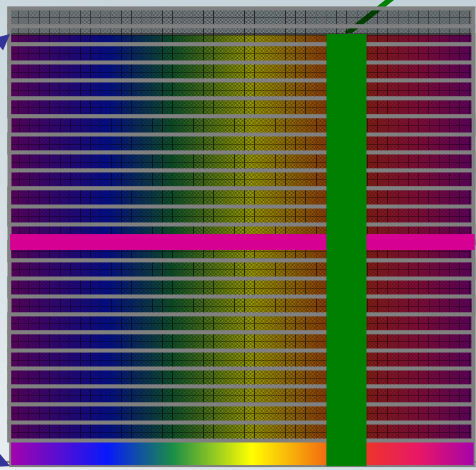


3b. Reconstruction of narrow-
& broad-band images



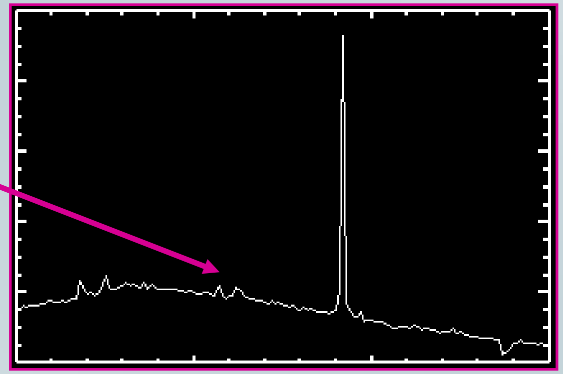
2. Re-arrange spaxels
to slit and feed light
to spectrograph



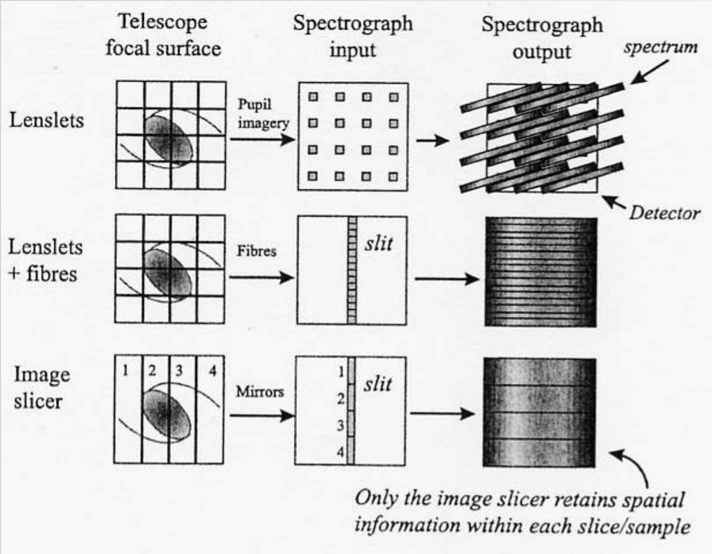


340 nm 950 nm

3a. Extract spectra

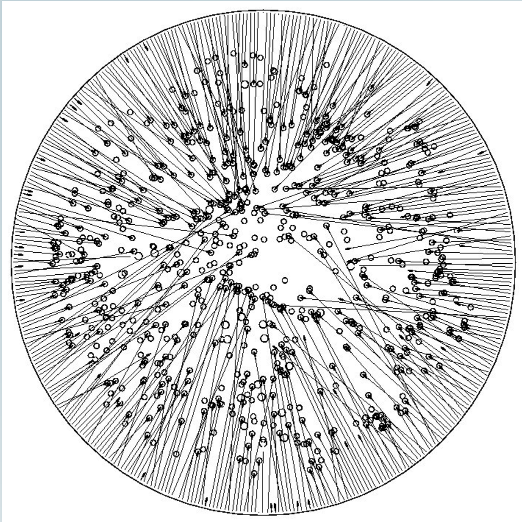


Different modes (1)



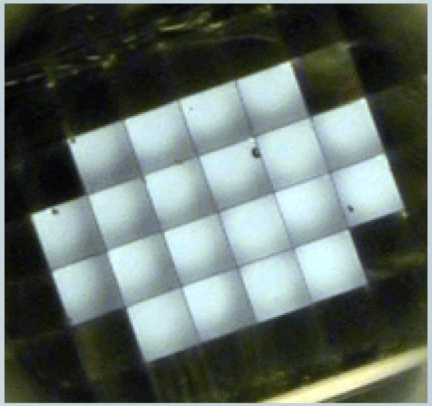
- Image slicer retains spatial information within each slice. Is used also for stellar spectroscopy with high-resolution (e.g. 1.52m at OHP)
- FOV limited because total number of pixels in detector is limited (must contain x . y . z)

Different modes (2)



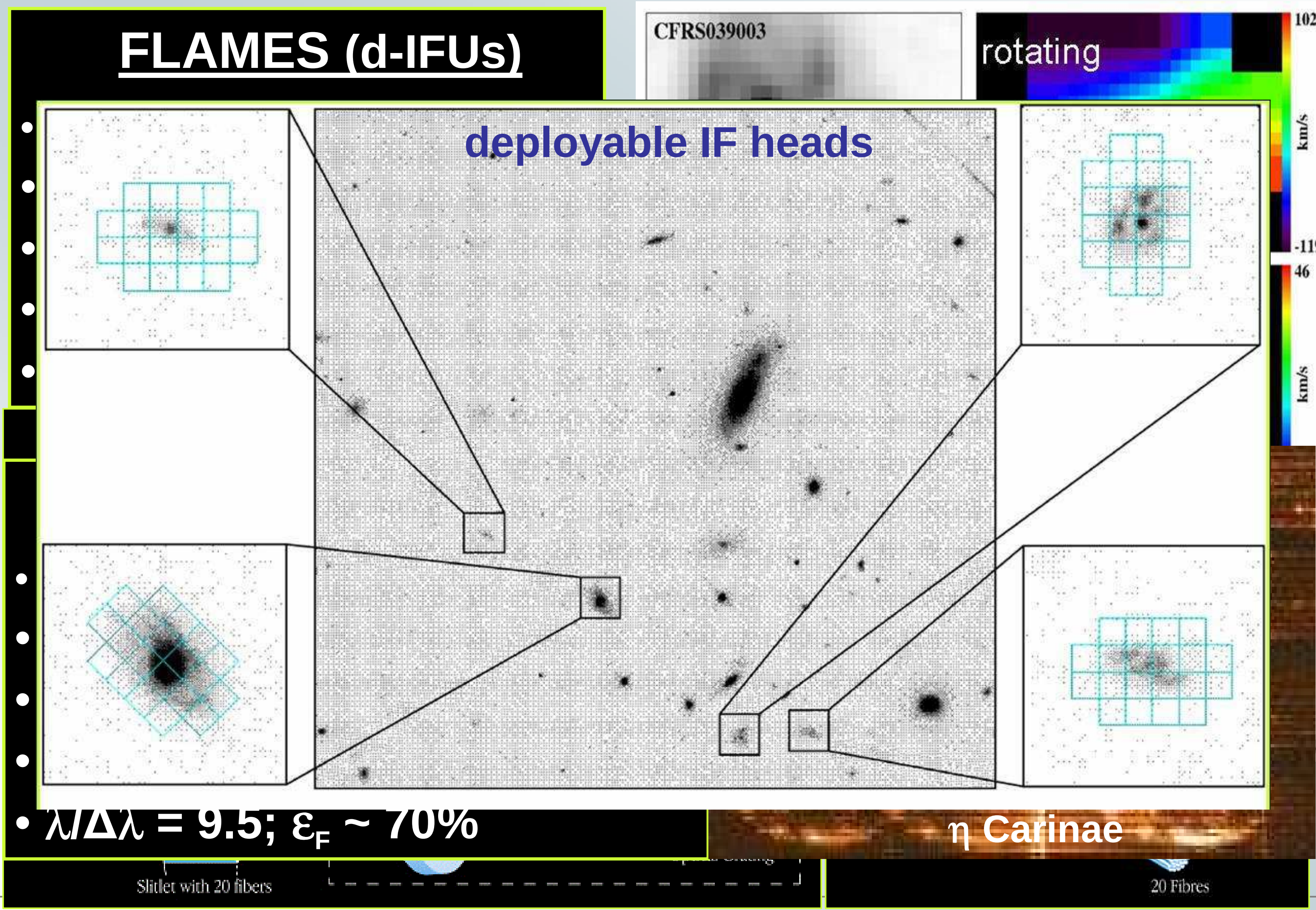
Wide field: fibers
(here 2dF)
Discontinued sampling
(Medusa mode)

Continued sampling:
IFU with lenslets
Small field of view
(a few ‘)
Limited by total number
of pixels in detector
(X x Y x λ)



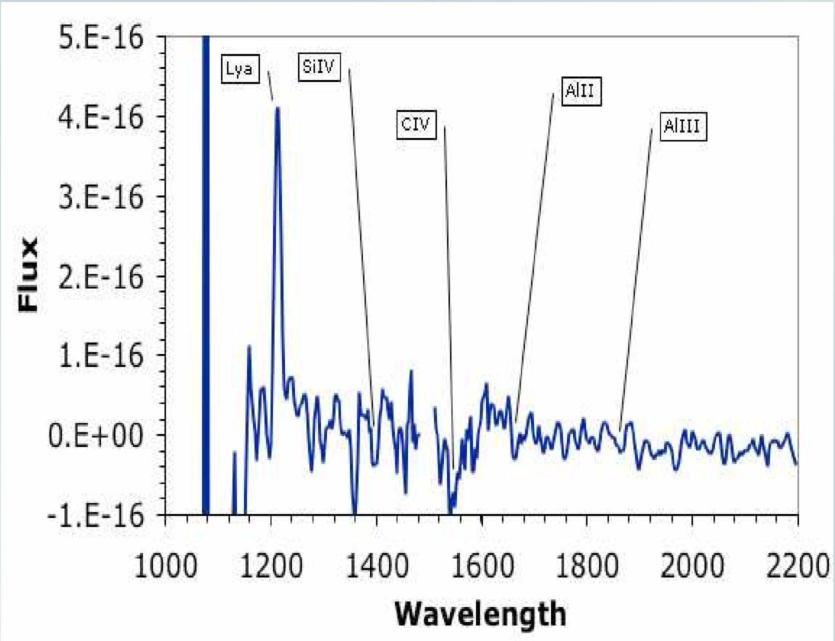
Combination: FLAMES-IF

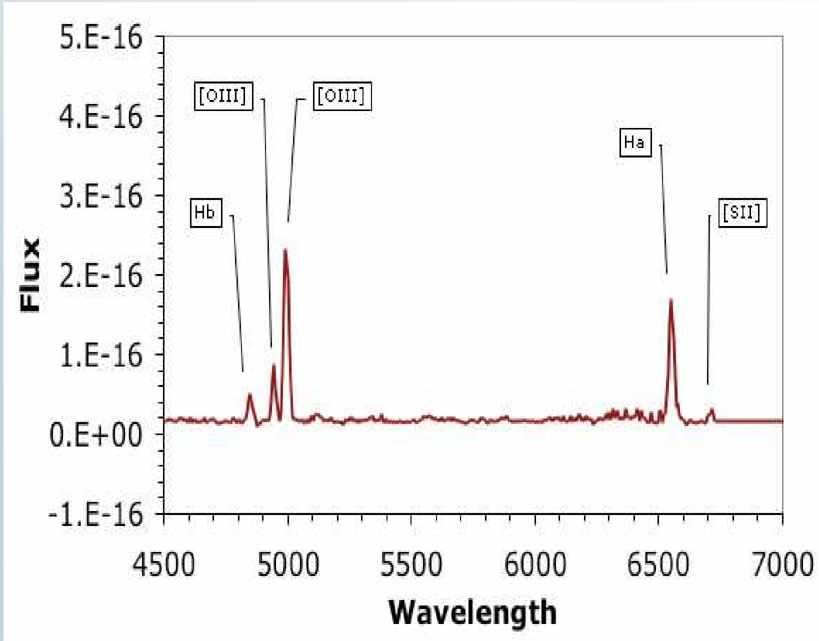
FLAMES (d-IFUs)



- $\lambda/\Delta\lambda$ = 9.5; ε_F ~ 70%

Multi-wavelength studies





Example of Galex + Vimos: **needs flux calibration to connect!!**
Starburst in the Chandra Deep Field South observed by GALEX in UltraViolet and by VIMOS (http://cencosw.oamp.fr/)
A clear Lyman α emission is detected in the spectrum of this galaxy at a redshift z = 0.2258.

End of presentation

Thank you for your attention…

and have a good observing run!