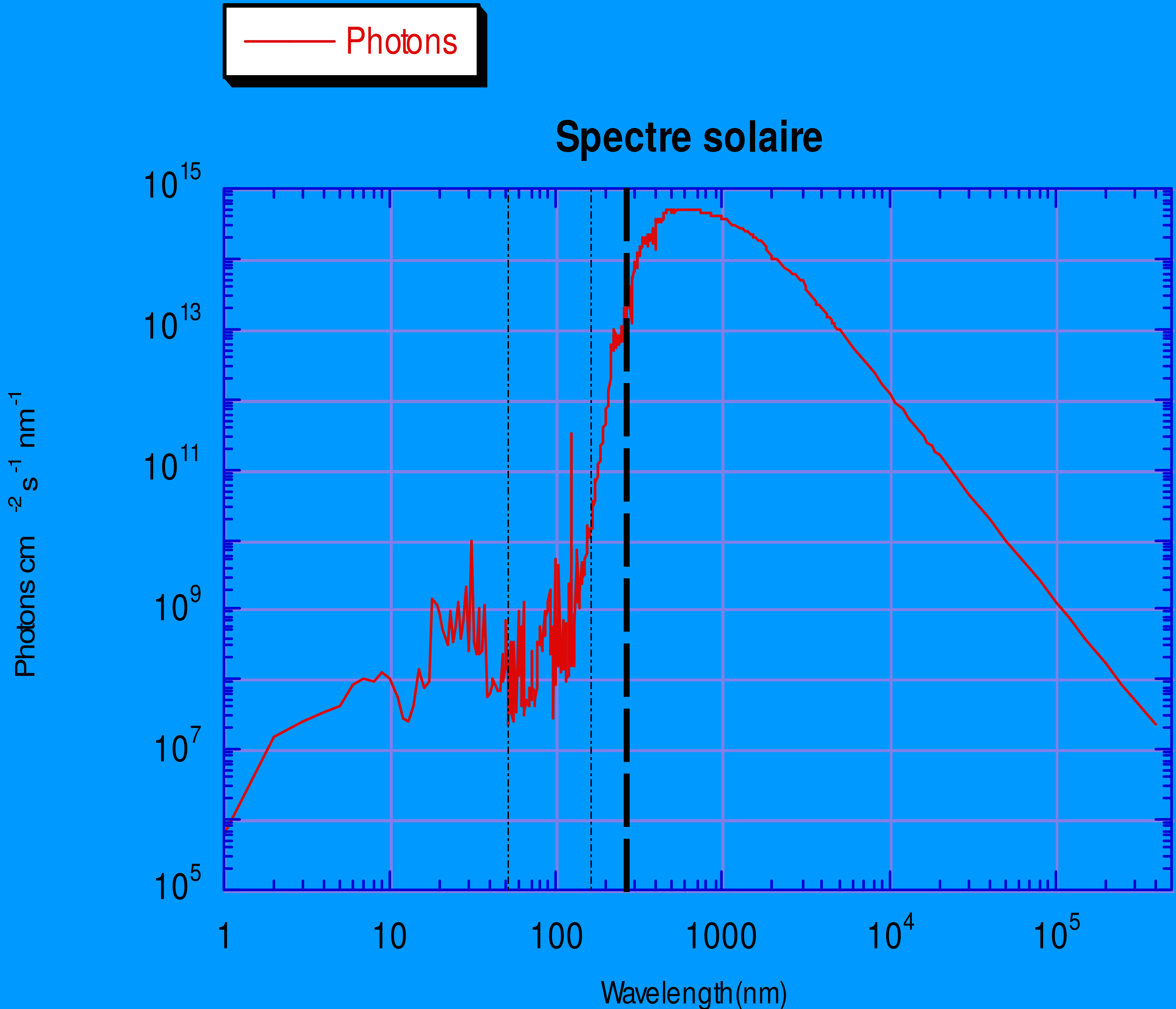
Four Solar Cycles of Space Instrumentation

- Few comments
- The case of solar ultraviolet spectrum
- Some historical snapshots
- Future of solar UV spectroscopy
- Some thoughts

Few comments

- I was lucky to be introduced in Astrophysics and space instrumentation by very kind people at a time when all things have to be built
- I owe a debt of gratitude to many people who have worked with me
- I have learned a lot from them
- Any science project or instrumentation is the result of the work of a team. I had the chance to cooperate with dynamic and talented persons.



Photons
Spectre solaire
10^{15}
10^{13}
10^{11}
10^{9}
10^{7}
10^{5}
Photons cm $^{-2}$ s $^{-1}$ nm $^{-1}$
1
10
100
1000
10^{4}
10^{5}
Wavelength (nm)

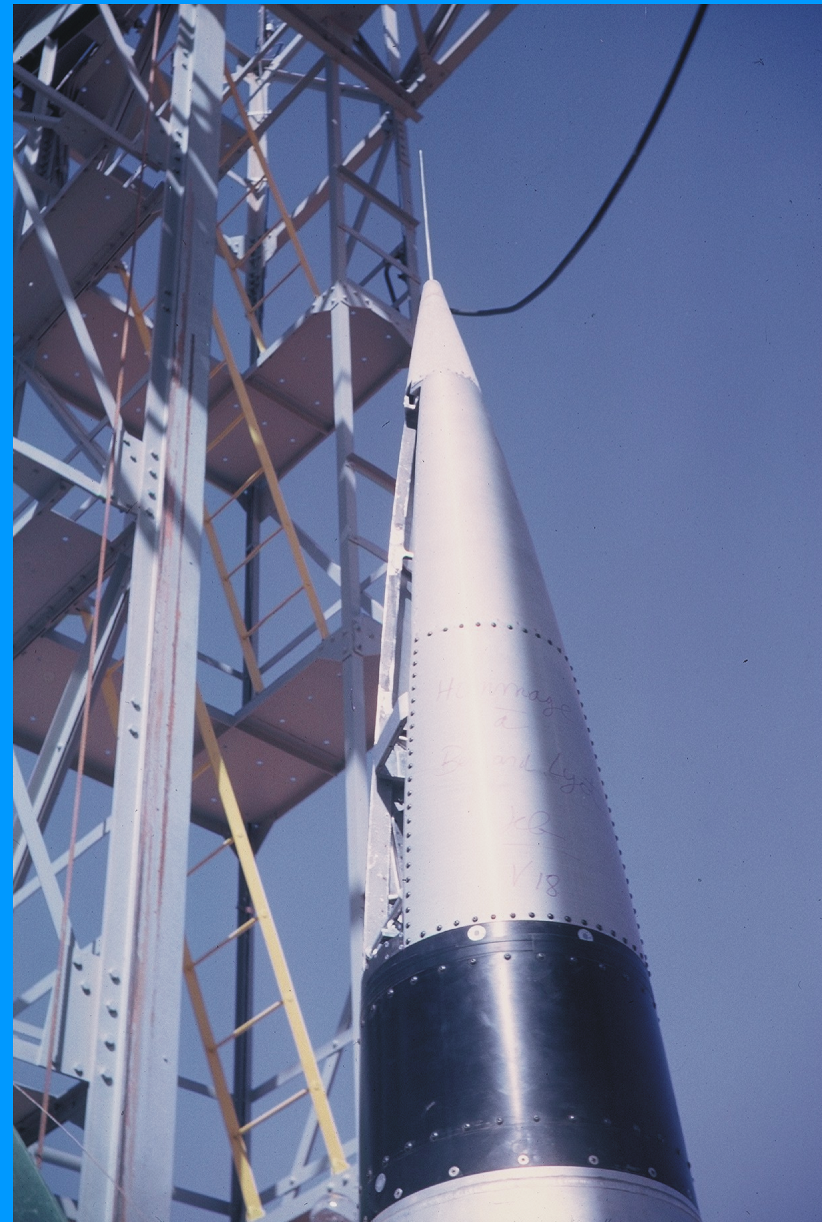
Hammaguir (Algérie)

April 1963

Coronographe UV

Hammaguir (Algérie)
November 1963

Coronographe UV



Balloon observations of the near UV solar spectrum

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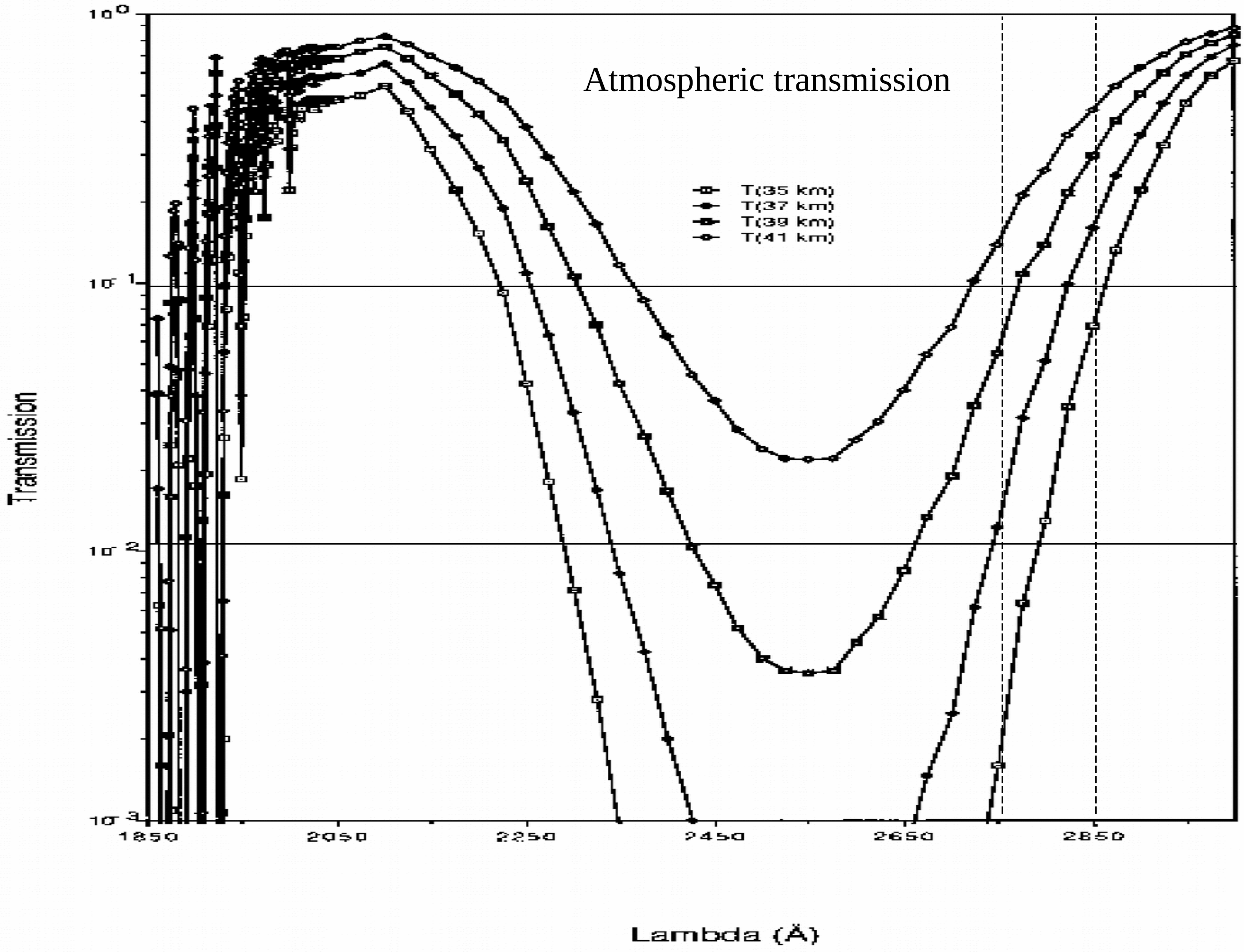
to play with the atmospheric transmission



Atmospheric transmission
T(35 km)
T(37 km)
T(39 km)
T(41 km)
Transmission
Lambda (Å)
10^0
10^{-1}
10^{-2}
10^{-3}
1850
2050
2250
2450
2650
2850

Balloon 1967 - 33 km – Transmission 0.3 %

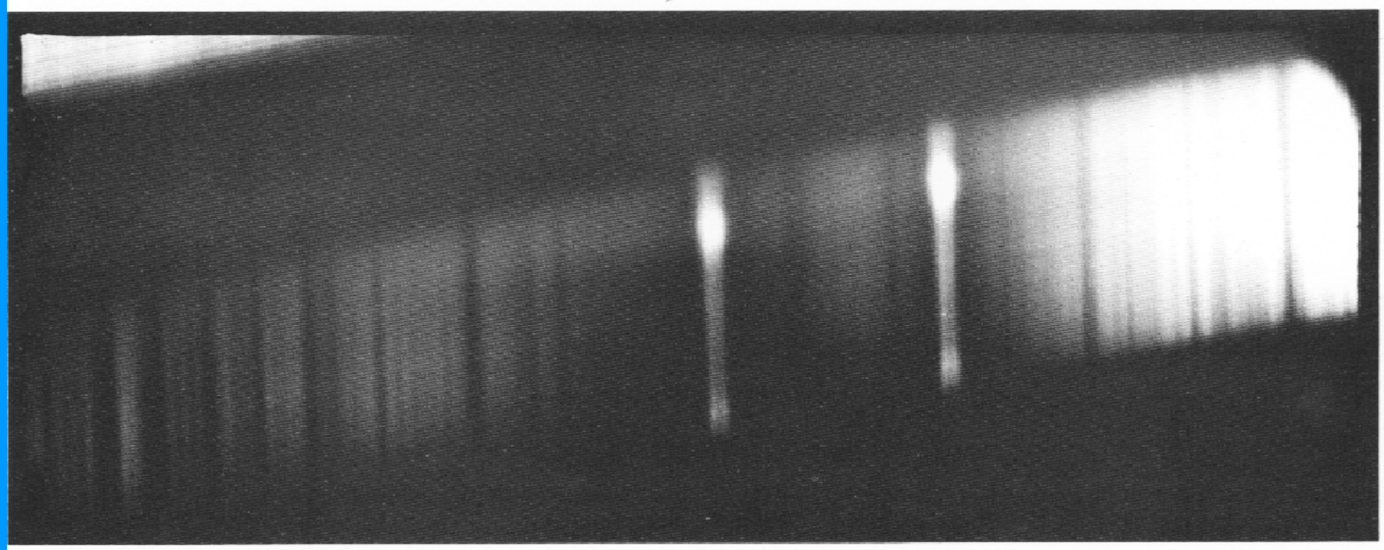
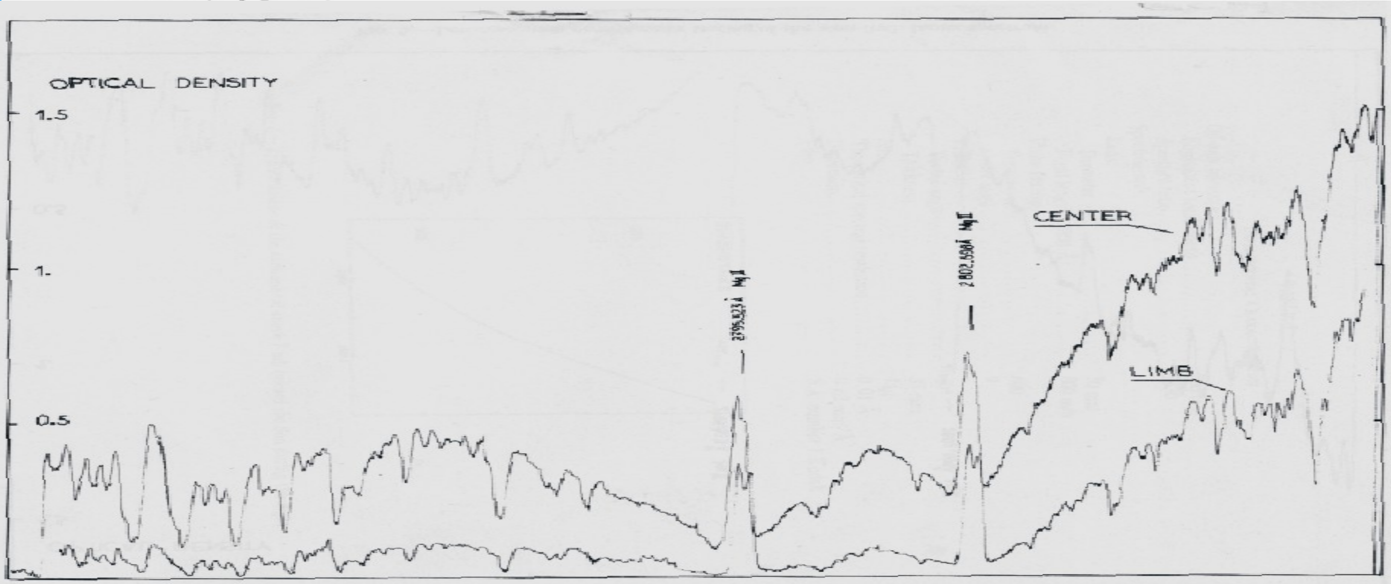


PLATE L2

FIG. 4.—Typical spectrum corresponding to 230-sec exposure. Note the faculae in the upper and lower parts of the spectrum which appear in Mg II H and K

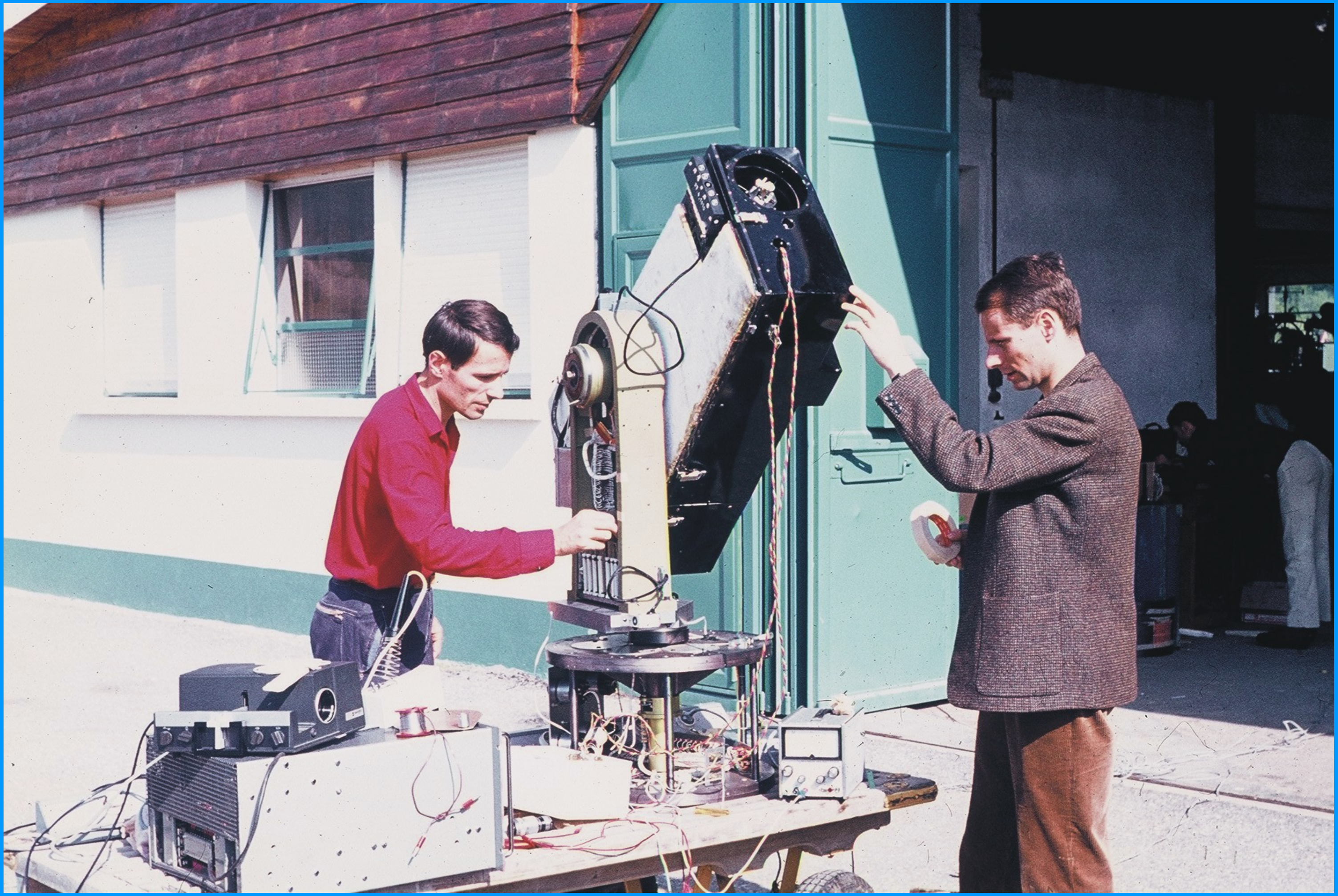
LEMAIRE AND BLAMONT (see page L129)

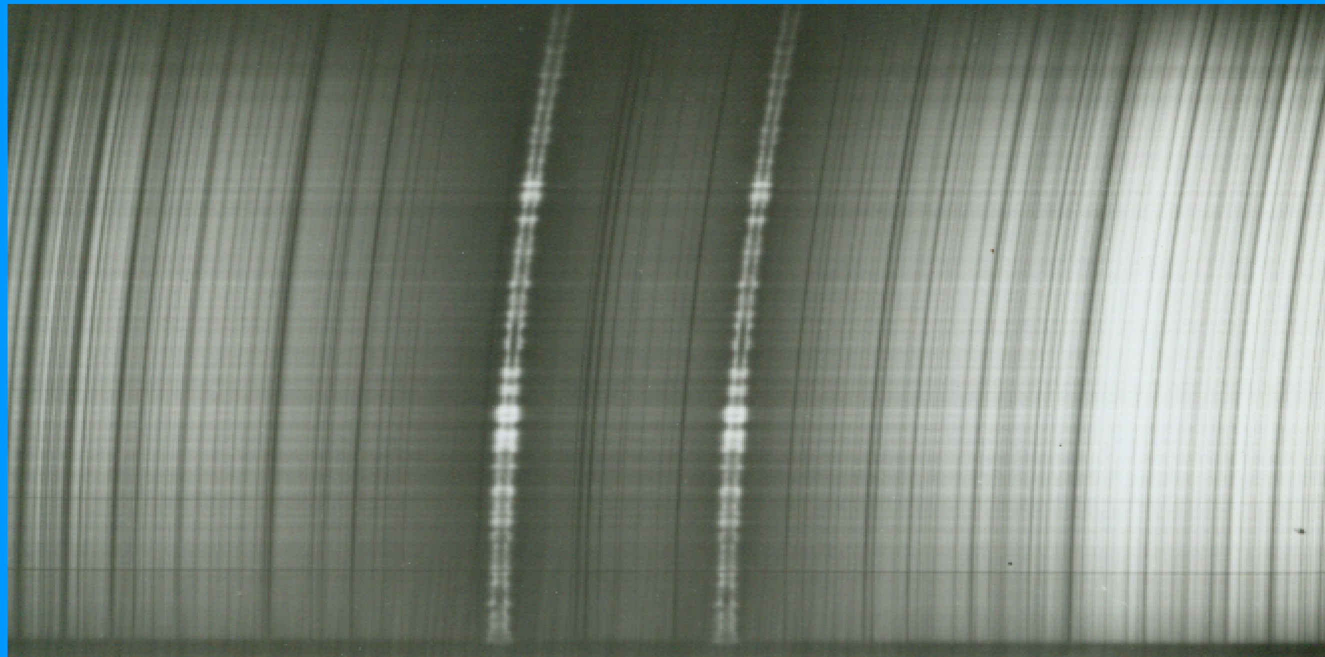


L131

FIG. 5.—Low-resolution densitometer tracings of the center and limb spectra. The ordinates represent the optical density of a 118-sec exposure

Balloon 1969 – MgII spectrometer and pointing system





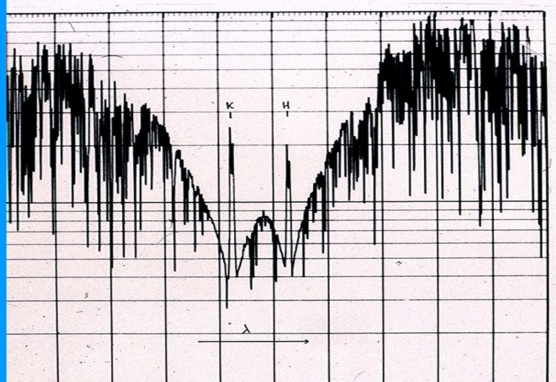


Figure II - 12 - Variation de l'intensité du spectre solaire au centre du disque au voisinage des raies H et K de Mg II

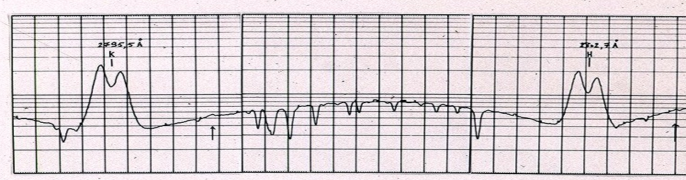
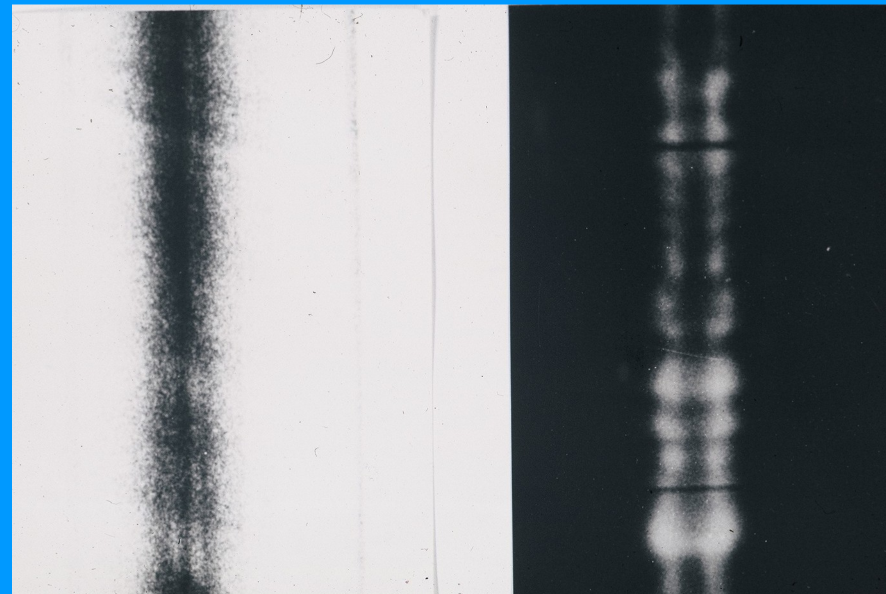


Figure II - 13 - Variation de l'intensité du spectre au centre du disque entre les deux raies H et K de Mg II. La position des deux raies faibles en émission est indiquée par les flèches.

CaII K and MgII k
1972



MgII h and k sunspot
1969

Balloon – Mg II spectrometer optical scheme

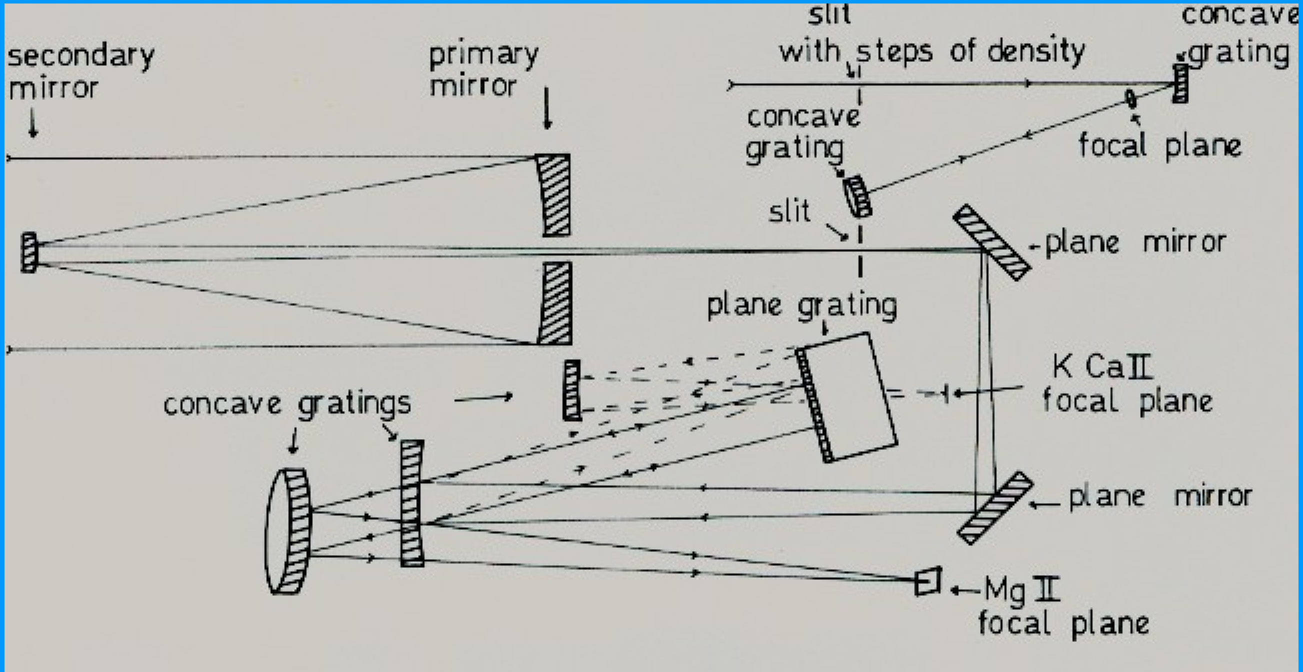
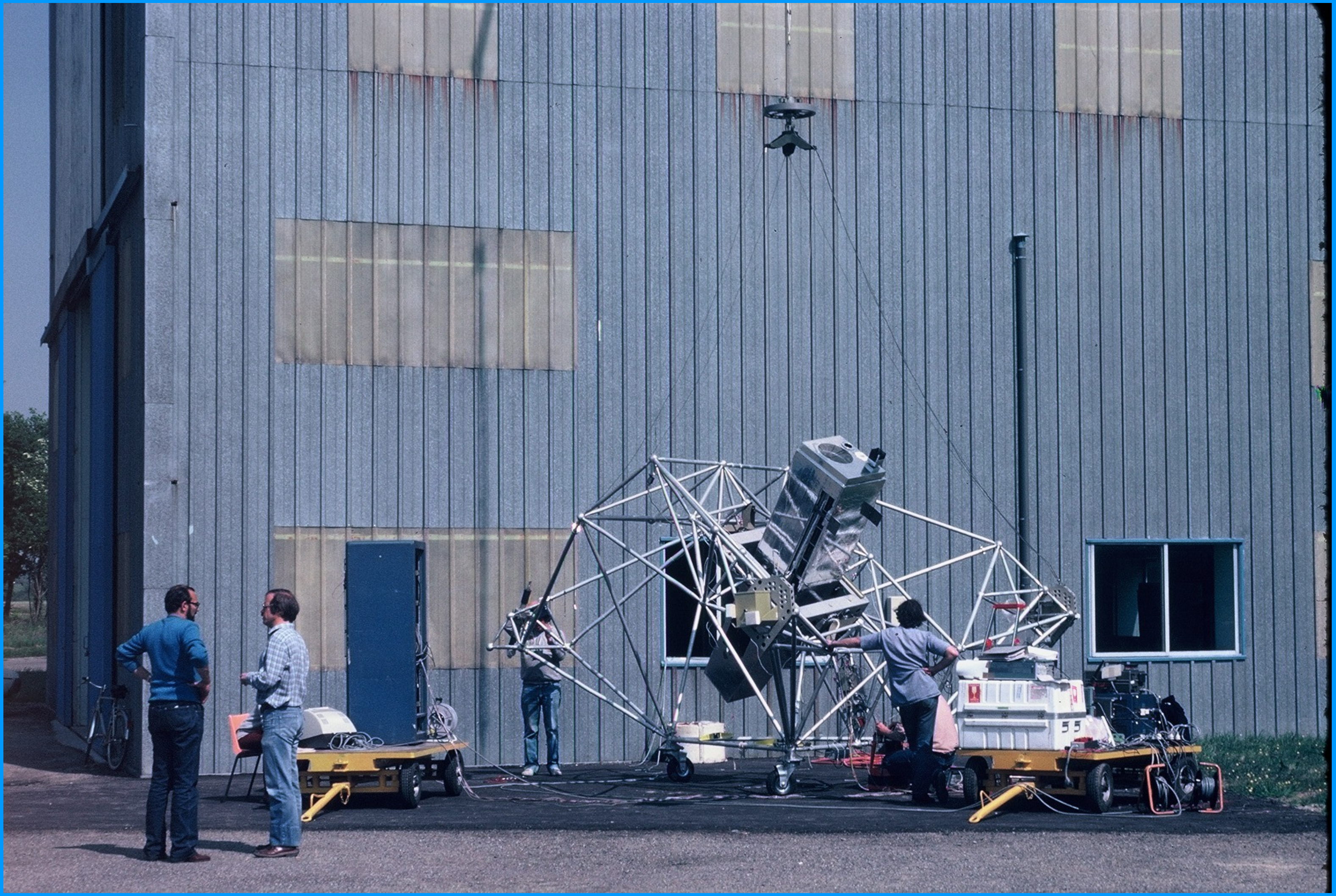


Fig. 3. Schematic of the optical arrangement.

Balloon 1982 – Rasolba spectrometer and equatorial pointing system

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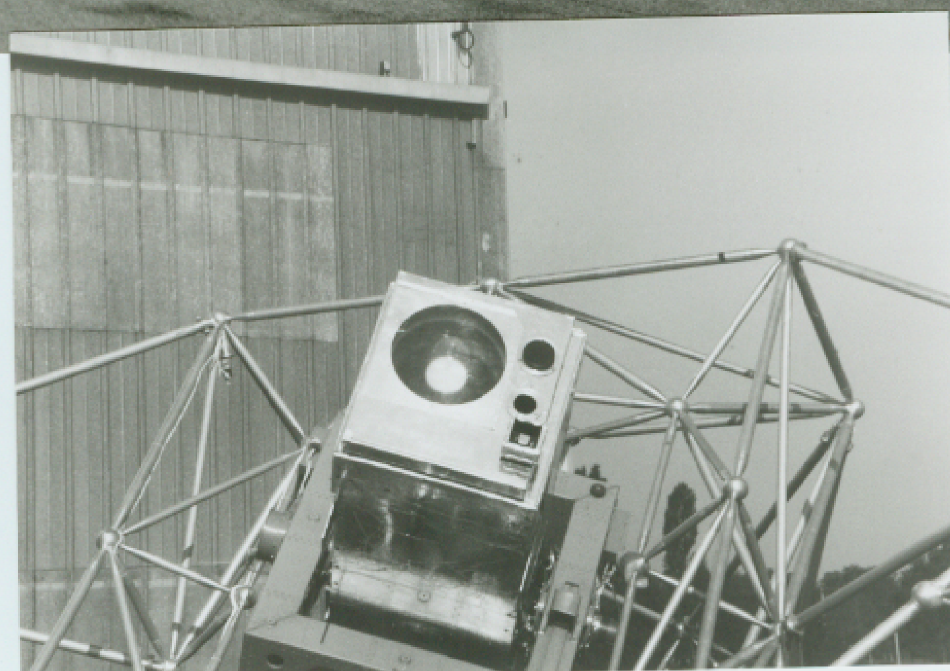
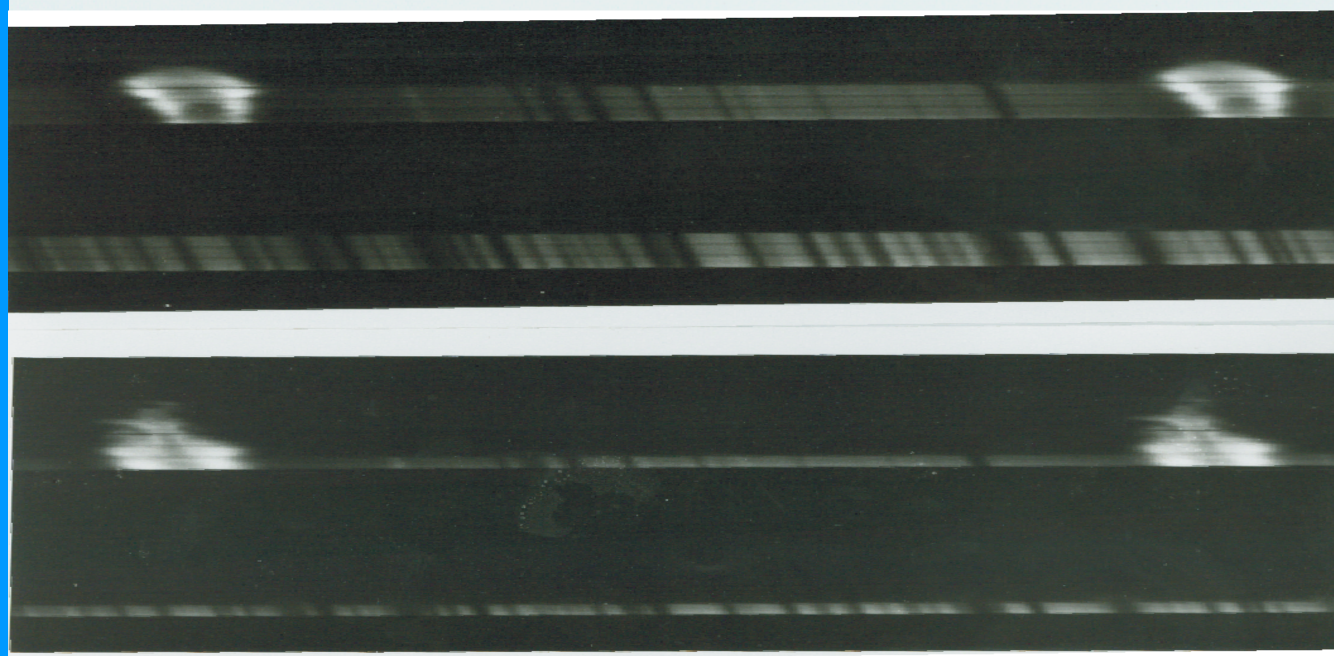


Rasolba 1985

Rasolba 1985

Rasolba 1986 – Mg II lines

Solar disc center



Solar limb and
prominence

Rasolba – Optical scheme

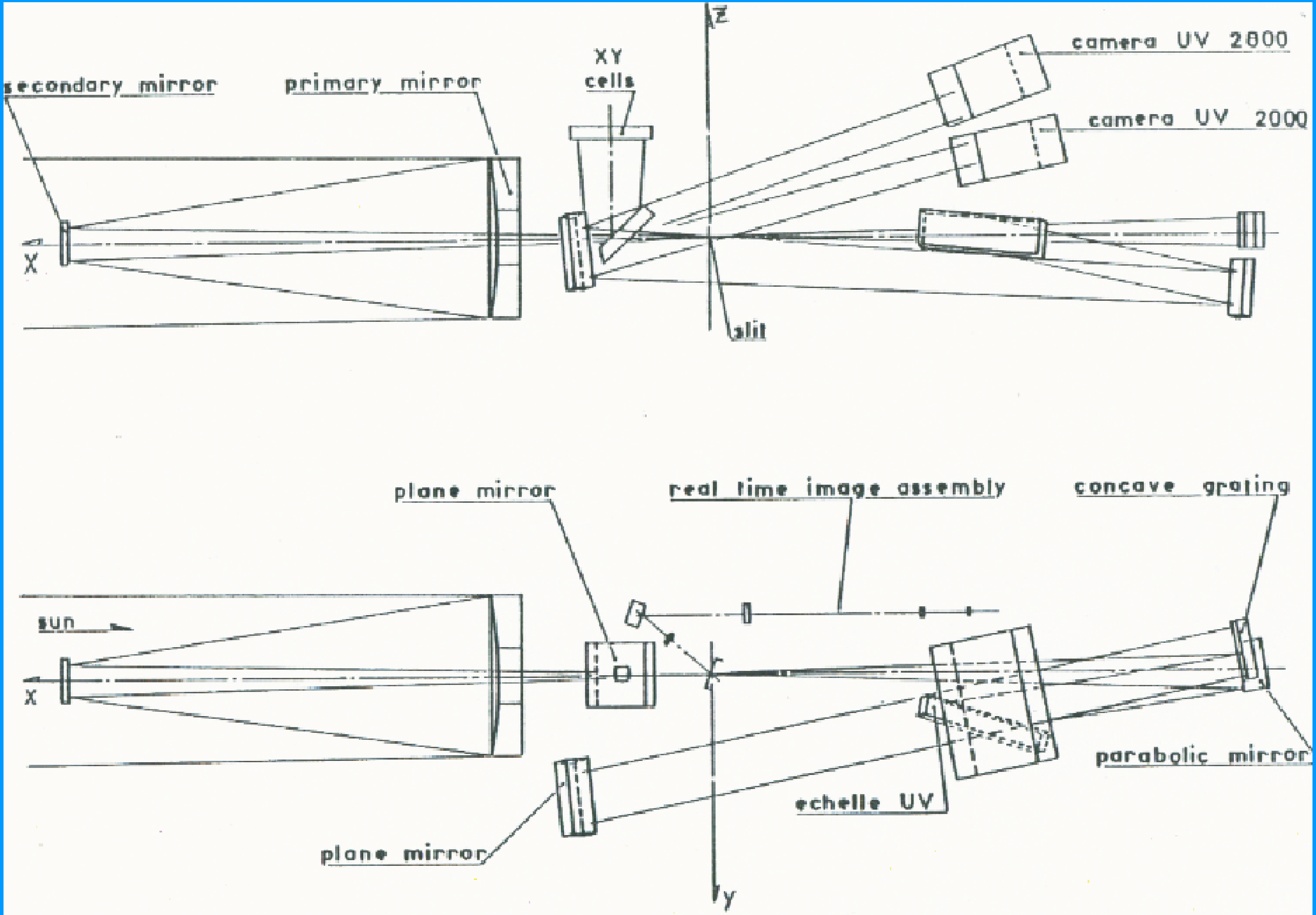
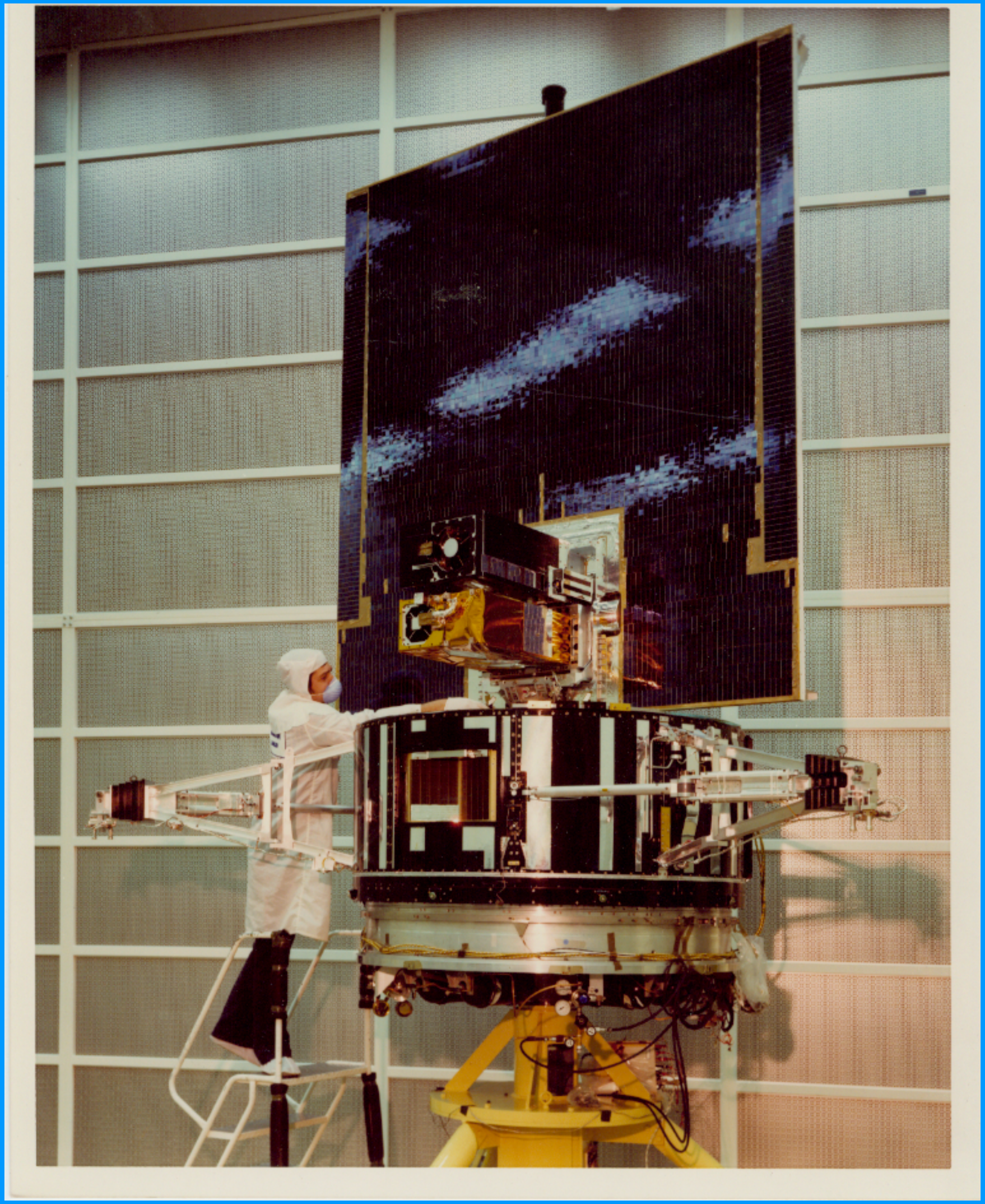


Figure 2

Optical schematic of the instrumentation

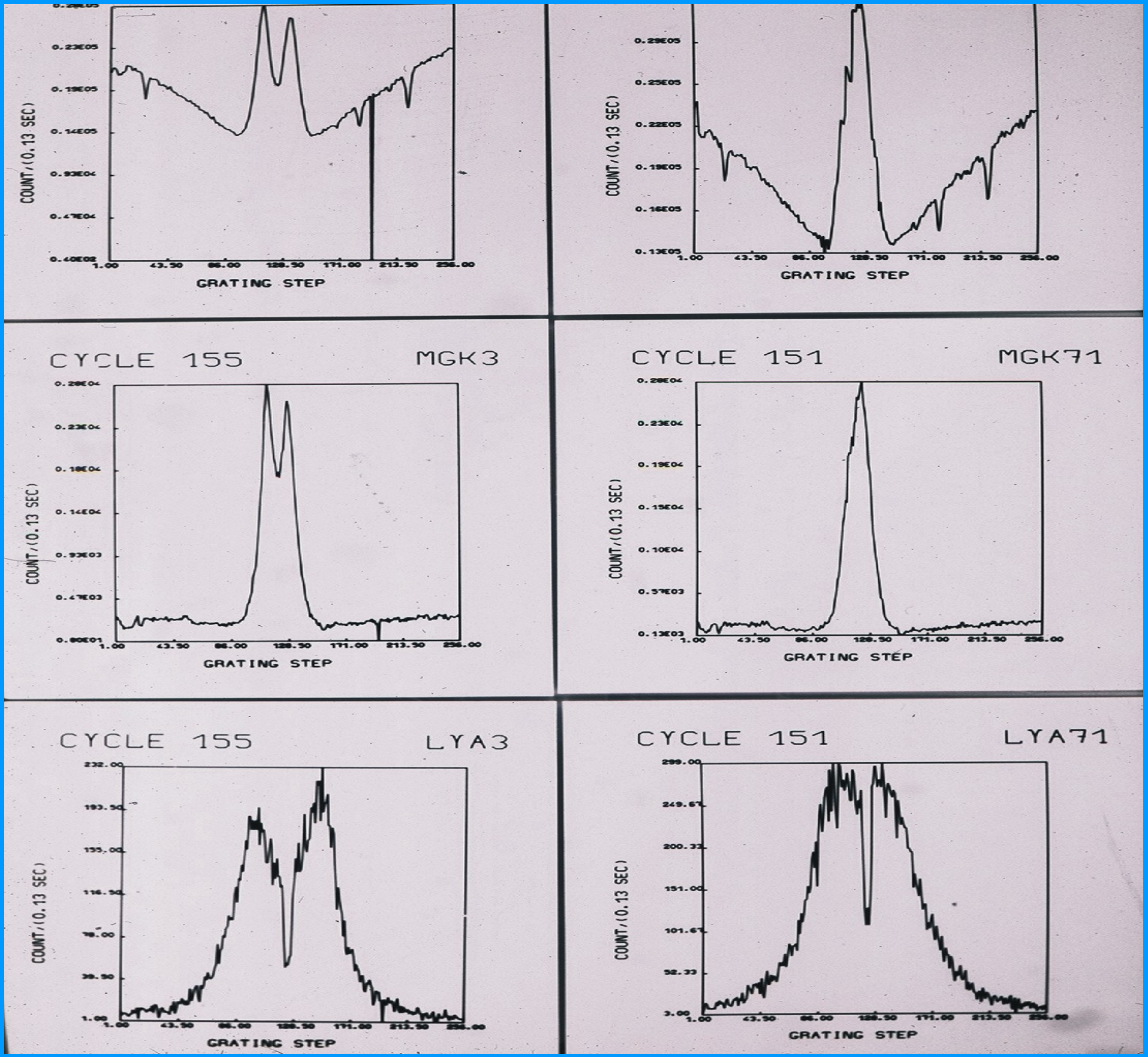
MgII 1972 – Calibration rocket

OSO8 - 1975

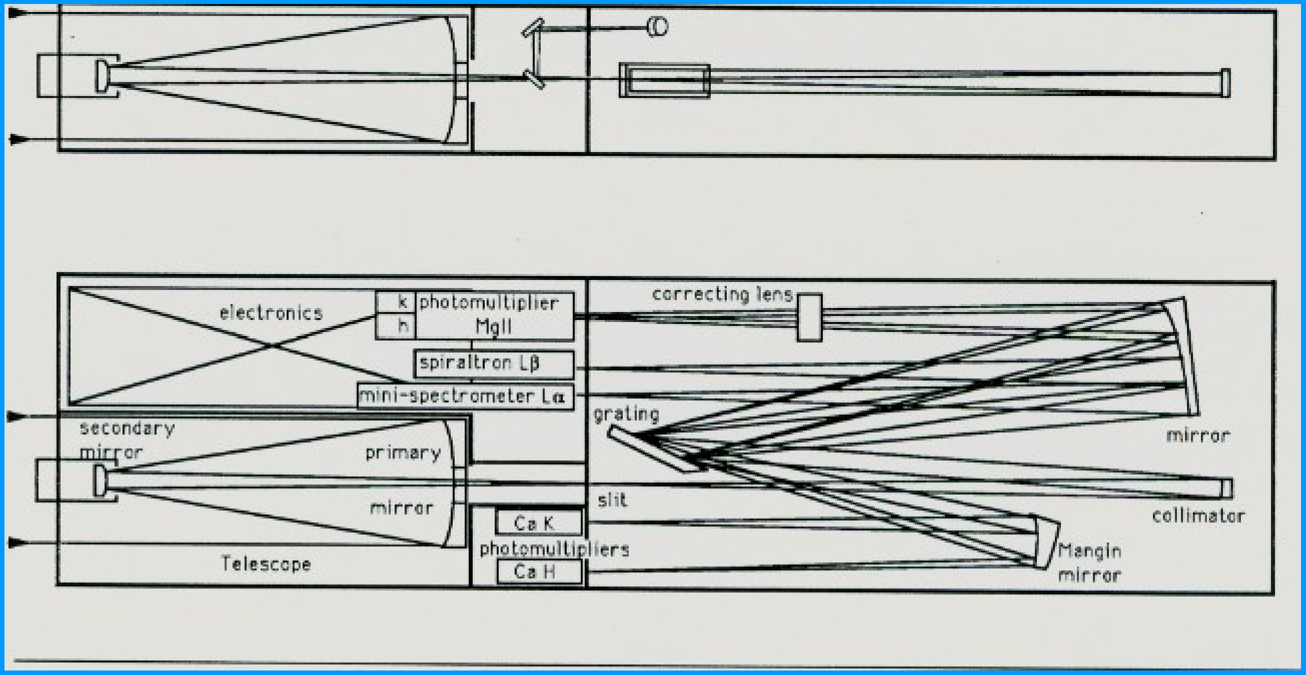


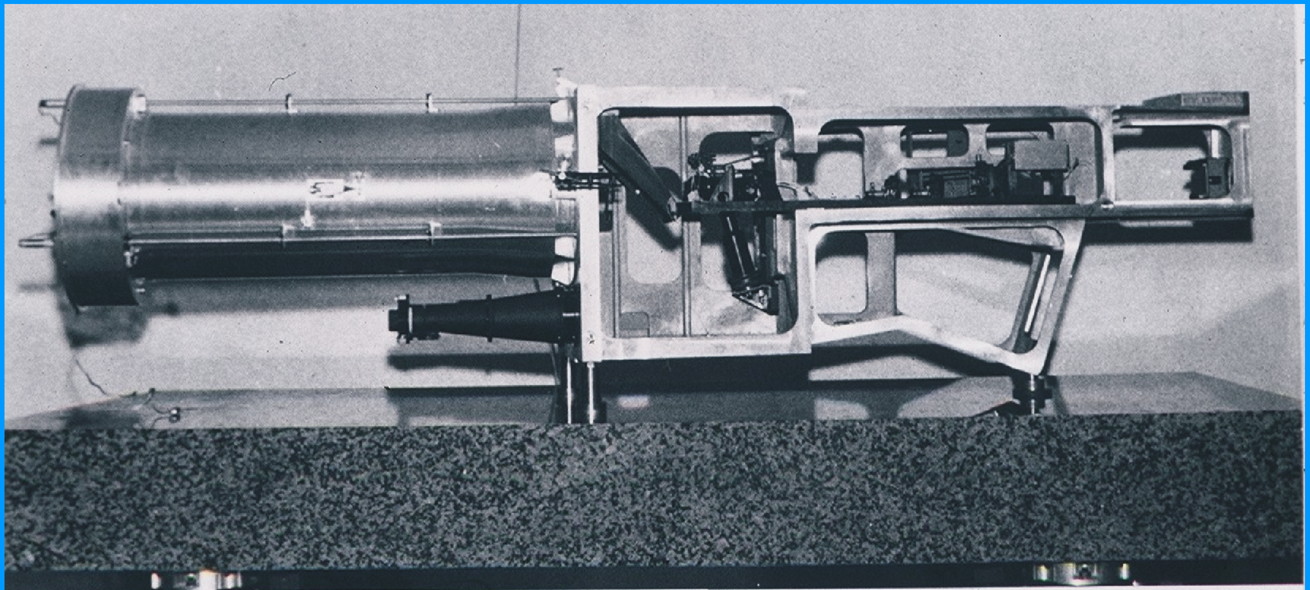
OSO8 1975 – CaII K, MgII k, H Lalpha

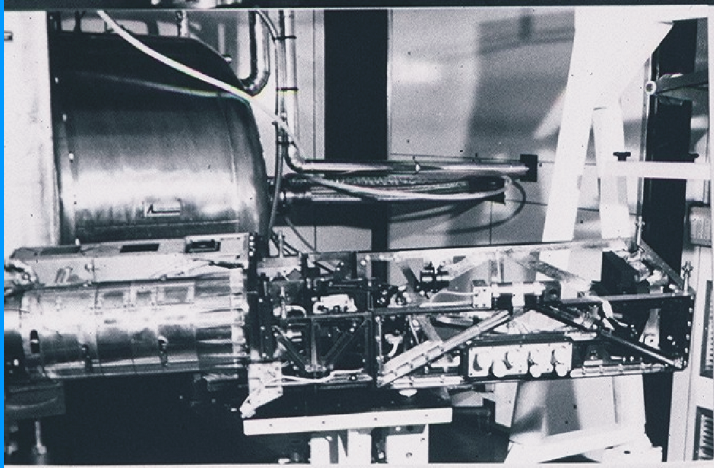
Quiet Sun Active Region

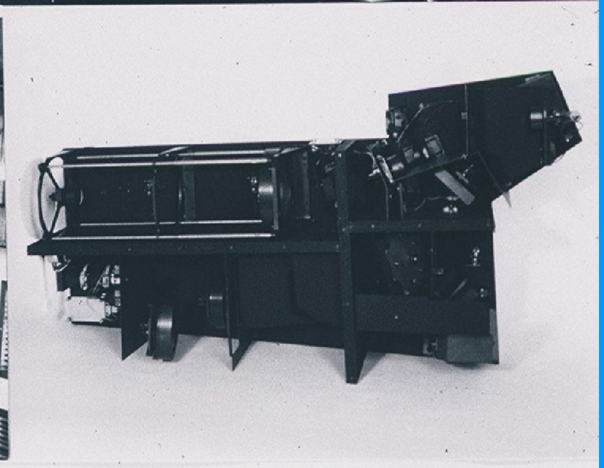


OSO8 – Spectrometer optical scheme









RASOLBA

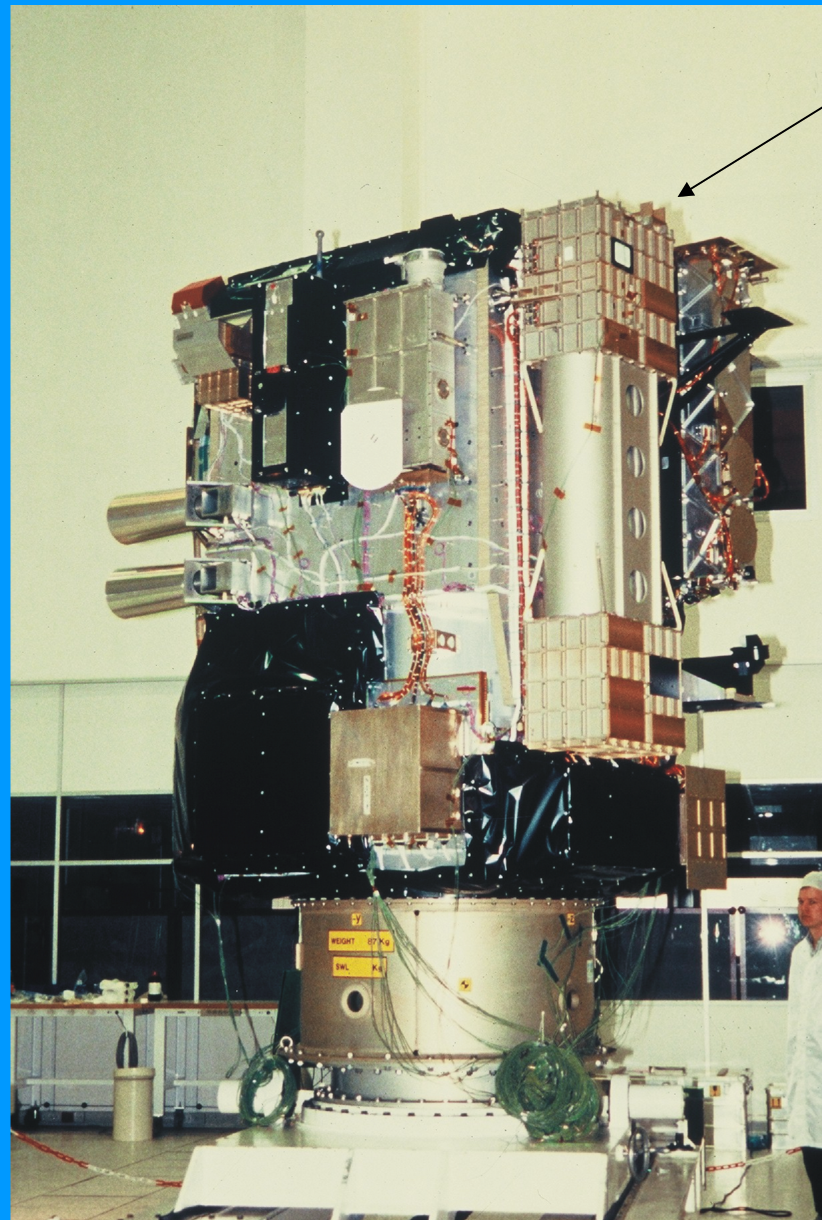
OSO-8

MG II Solaire

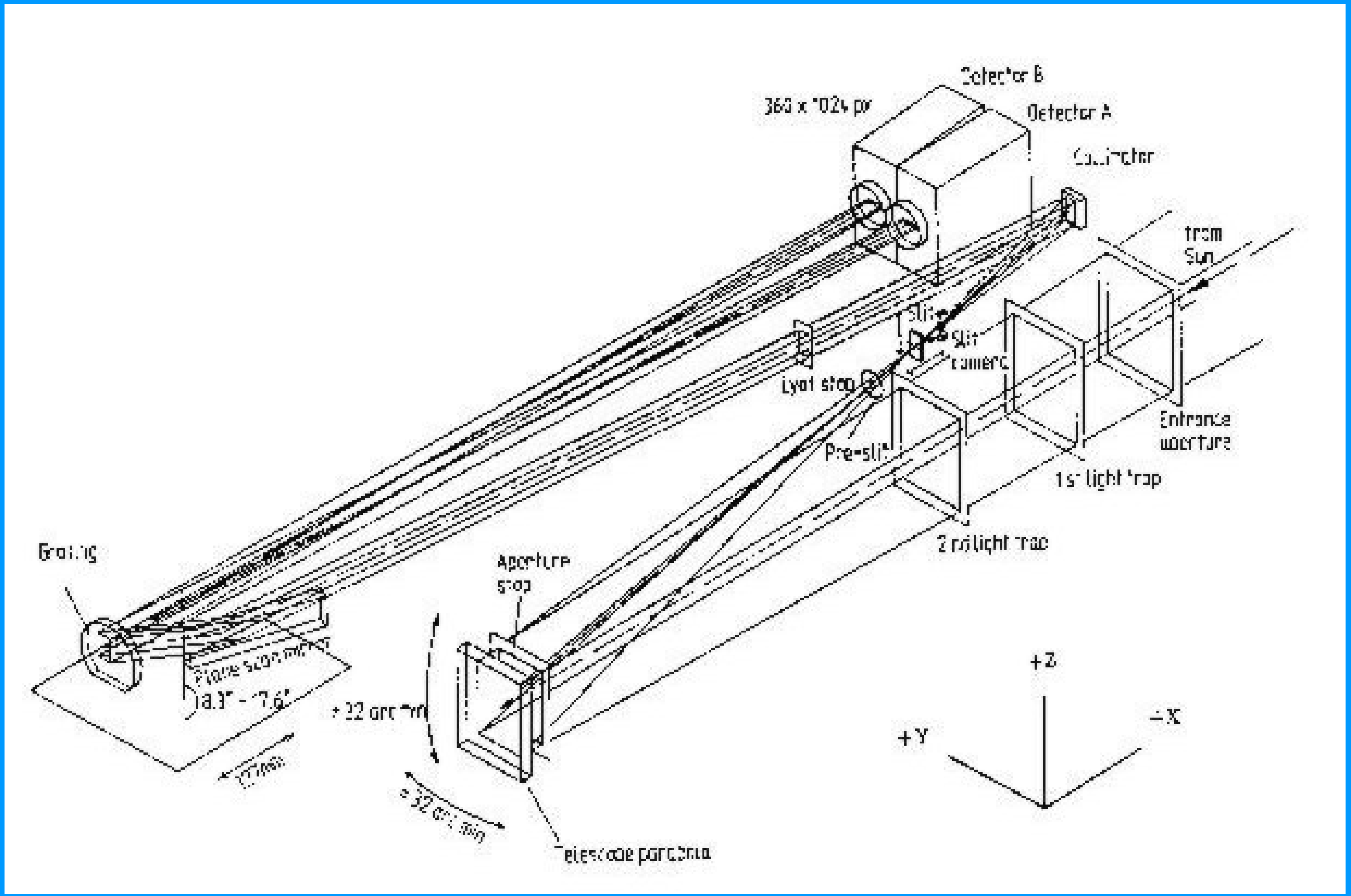
(échelle identique pour les 3 clichés)

SOHO 1995

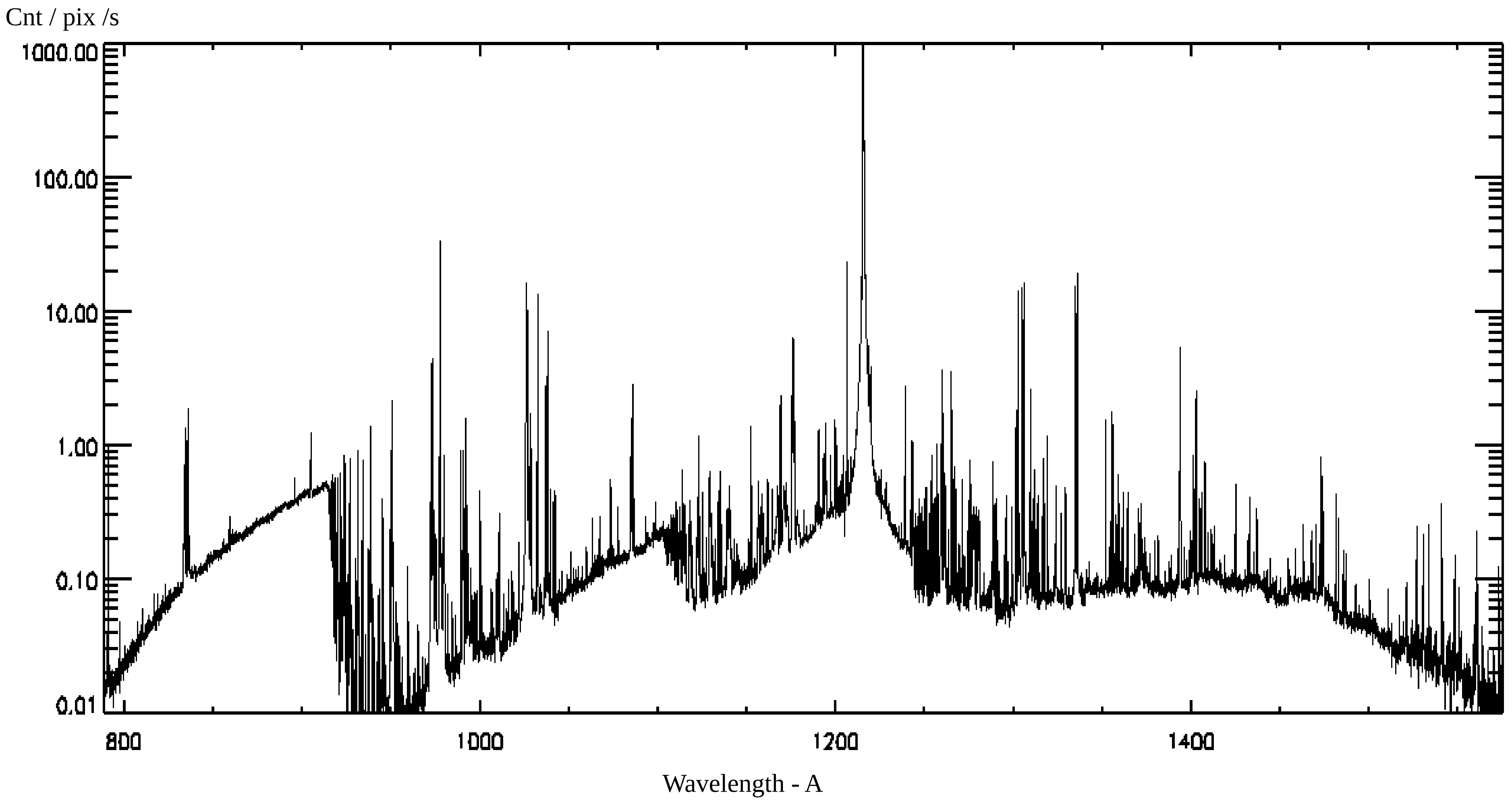
SUMER



SUMER – Optical scheme

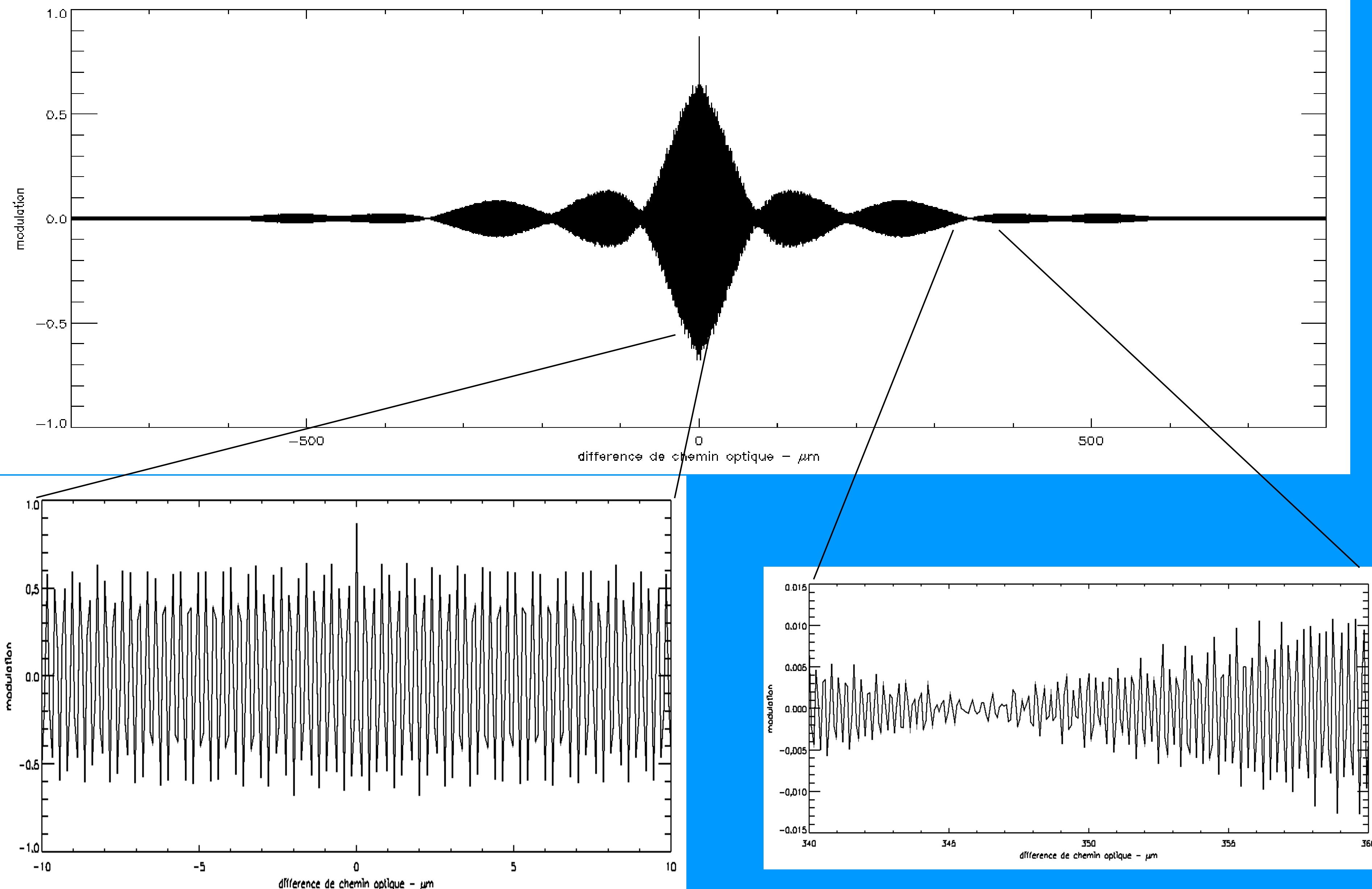


Raw Sumer quiet Sun spectrum



Fourier Transform of the raw SUMER spectrum

Maximum ~20 000 cnt/pix/s



Ideal UV spectrometer (?)

Constraints/objectives

Diffraction limited telescope at 121.6 nm (HI Lα)
Pixel size corresponding to the diffraction limit (e.g. ~ 10 km at Sun disc center)
Study of the nanoflares contribution from chromosphere through Transition Region
Capability to detect 1 km/s Doppler shift and 70 km/s velocity in the sky plane
Efficiency of the telescope+spectrometer+detector ~ 10%

Sizing for 10 km pixel resolution at Sun disc center

$\Rightarrow$ Telescope diameter 2.22 meter (from ~ 1 AU distance)
$\Rightarrow$ From 3.E11 ph/cm2/s (quiet Sun HI Lα irradiance) we obtain ~7. E3 cnt/s/pixel
$\Rightarrow$ Effective resolving power $\lambda/\delta\lambda$=30 000 (Doppler shift ~ 1/10 of the resolution)

Slit spectrometer

70 km/s velocity crosses the slit in 1/7th of second (which direction?)
With 0.004 nm spectral pixel and 0.07 nm FWHM $\Rightarrow$ ~400 cnt/s/pixel for HI Lα line

Imaging Fourier Transform spectrometer

All the photons are on each pixel, modulated by the optical path difference. The simultaneous 2-D field of view can be e.g. 100 pixels x 100 pixels.
With a 2 mm path difference (30 000 resolving power) the sampling can be adjusted to follow the phenomena across the field.

Ideal UV spectrometer

Scaling

At diffraction limit angular pixel size, and same global efficiency,
the number of counts per second per angular pixel does not rely on the size of the telescope

Example 1:

30 cm telescope (0.1 arcsec diffraction limit or 72 km at 1 AU) also gives
7. E4 ph/s/pixel in HI Lα line in the diffraction limited pixel (100% efficiency)

Example 2:

6 cm telescope (0.5 arcsec diffraction limit or 72 km at 0.2 AU) also gives
7. E4 ph/s/pixel in HI Lα line in the diffraction limited pixel (100% efficiency)

New field

Magnetic field measurement ?

Constraints on the solar disk

Zeeman splitting is very small in the UV

$$\Delta\lambda\ (\text{Å}) = 4.67\ \text{E-13}\ \ (\lambda * \lambda)\ Mj\ g\ B$$

when Mj g ~ 1, λ =1216 Å, B = 5000 gauss 3.5 m Å

Hanle effect (depolarisation of line) needs weak fields and very accurate measurement of line intensity, difficult to disentangle from line variation in dynamic atmosphere

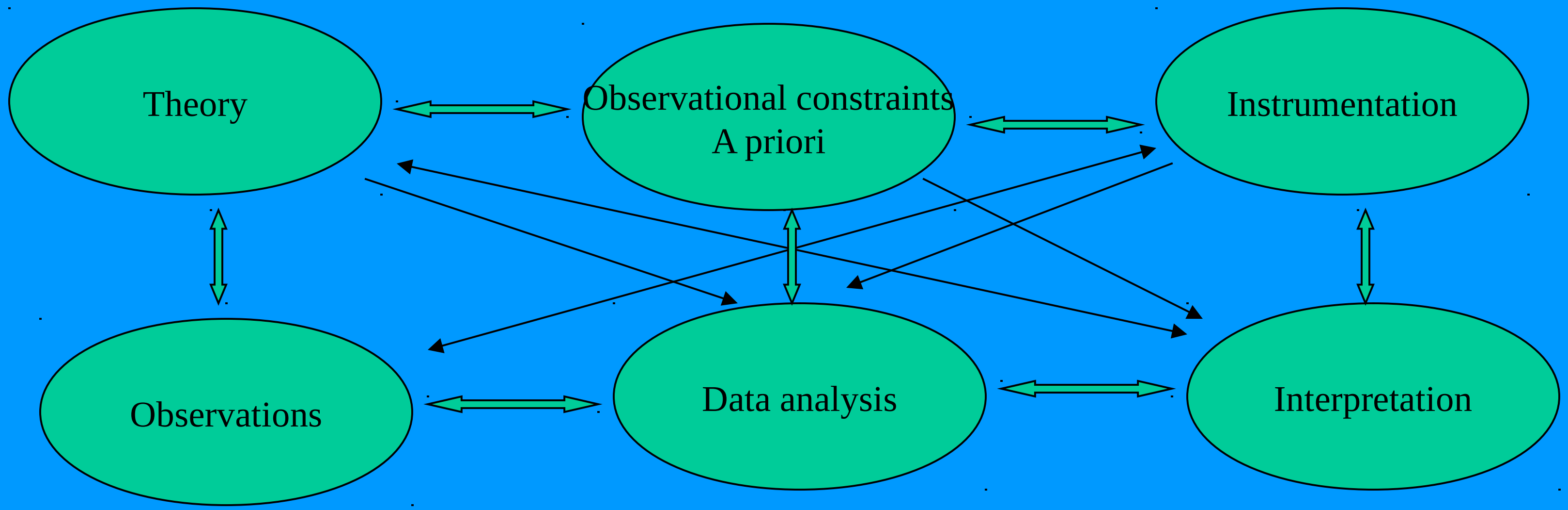
Off-limb

Hanle effect , but again hypothesis of a slowly variable atmosphere, and the lines are weak….

Other ideas !!!!!!

Conclusion or continuation!

How Scientific knowledge progresses:



Requirements: curiosity

Exciting developments are waiting for the contribution of rising generation.

Good luck !