First measurement of the polarization of the flash spectrum during a total solar eclipse

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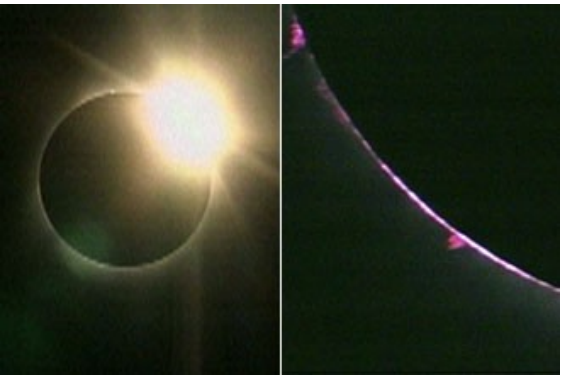


Presented by R.Ramelli

Coimbra, 13 October 2006

Outline

- Motivation
  - eclipses → unique opportunity
  - scientific interest
- The experiment
  - the instrument
  - the observing strategy
  - the location
  - the measurement
- Conclusion

Motivation: eclipse is a unique opportunity

The flash phase of a total solar eclipse offers the unique opportunity for a clean observation of the light emitted by the extreme limb and by different chromospheric layers

Moon is operating as a sharp knife edge!

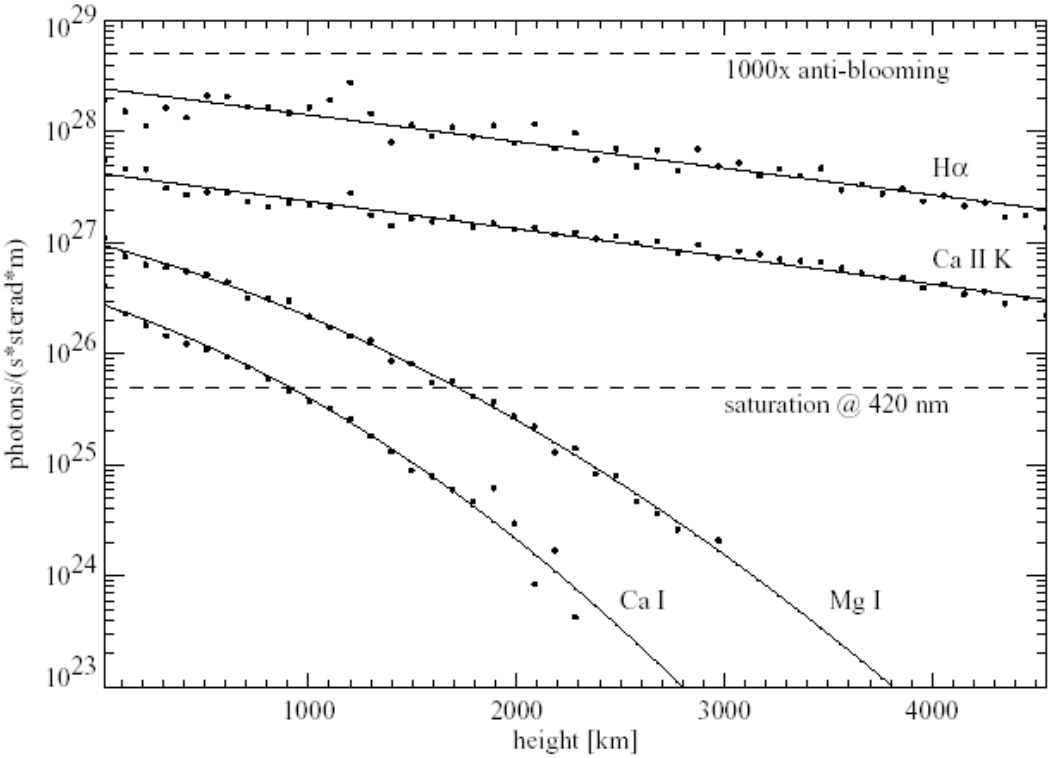
- The measurement is essentially stray light free
- With 50 frames per second we get a height resolution of order 10 km

Previous observations of the flash spectrum (1)

Intensity

Cillié and Menzel (1935), Mitchell (1947), Dunn et al. (1968), Shen et al. (1981)

Decremental plot of intensity as a function of height for few selected spectral lines



(data from Dunn et al., 1968)

TABLE II
Lines of interest sorted by flux

Line	Wavelength nm	flux at h=0† photons · s^{-1} · $sterrad^{-1}$ · m^{-1}
Hα	656.3	$2.0 \cdot 10^{28}$
Ca II	854.2	$9.4 \cdot 10^{27}$
Ca II	866.2	$8.7 \cdot 10^{27}$
Ca II K	393.3	$5.5 \cdot 10^{27}$
Hβ	486.1	$5.4 \cdot 10^{27}$
Ca II H	396.8	$4.8 \cdot 10^{27}$
Ca II	849.8	$4.3 \cdot 10^{27}$
He D_3	587.6	$3.5 \cdot 10^{27}$
Mg I	518.4	$1.3 \cdot 10^{27}$
Na I D_2	589.0	$8.9 \cdot 10^{26}$
Na I D_1	589.6	$8.9 \cdot 10^{26}$
Mg I	516.7	$7.8 \cdot 10^{26}$
Mg I	517.2	$7.8 \cdot 10^{26}$
Ca I	422.7	$4.3 \cdot 10^{26}$

† from Dunn *et al.* (1968)

Previous observations of the flash spectrum (2)

Polarimetry

Hanson et al., publ. of Lund observatory, 1976

„An objective prism spectrograph with a polarization detection system was used to observe the Ca II H and K lines in the flash spectrum of the solar eclipse of June 30, 1973. Due to adverse circumstances, only a short and faint emission arc could be photographed. The sensitivity of the method did only allow a 5% upper limit to be set on the K line polarization, but at least in principle the observation technique was found to work.“

Stokley, Astron. J. 53, 117 (1948)

“For this observation a small instrument was used consisting of a wooden handle on which was mounted a replica grating and a Polaroid screen which could be rotated by a cardboard diamond-shaped index. As totality approached I held this before my eye ... so that I could study the first order spectrum from the grating.

...

During this [flash] period the polarizer was rotated several times but no change in the lines of the spectrum could be detected.

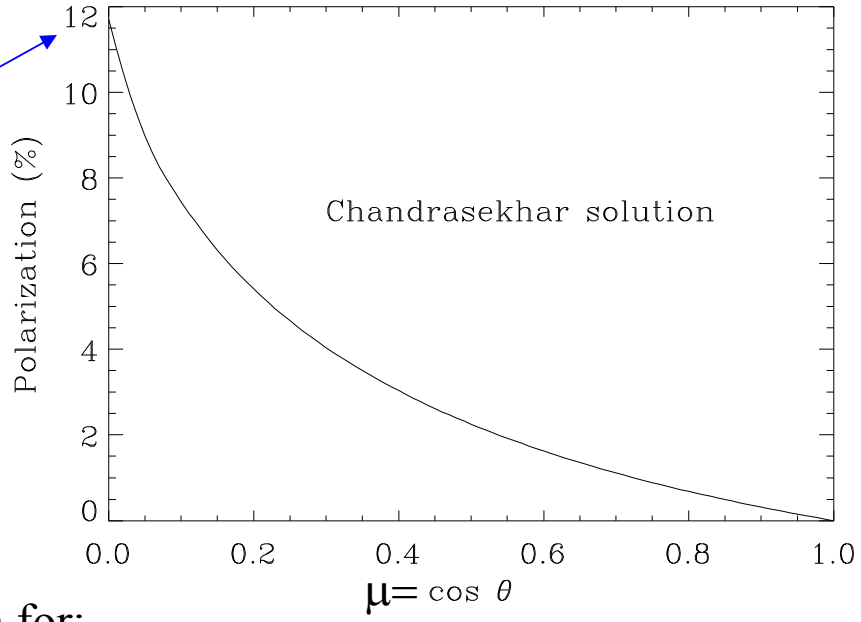
...

Polarization was probably not above 10 percent.”

Motivation: scientific interest (1)

Chandrasekhar's solution (1950)

11.7% at extreme limb



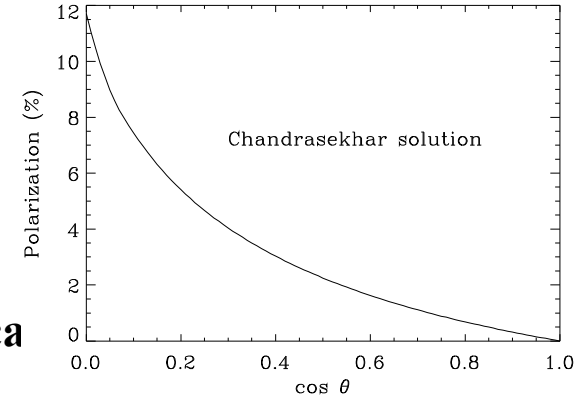
Idealized solution for:

- plane-parallel atmosphere
- radiative transfer governed by classical dipole-type scattering (e.g. Thomson scattering at free electrons)

Of course reality is different from this ideal situation!

Motivation: scientific interest (2)

Factors affecting the flash spectrum polarization:



- **Different opacities**
- **Collisional effects**
- **Deviation from plane-parallel stratification (spherica extreme limb, small-scale inhomogeneities)**
- **Magnetic fields (Hanle effect)**
- **Atomic physics (quantum interferences, optical pumping)**
- **Radiative-transfer physics**

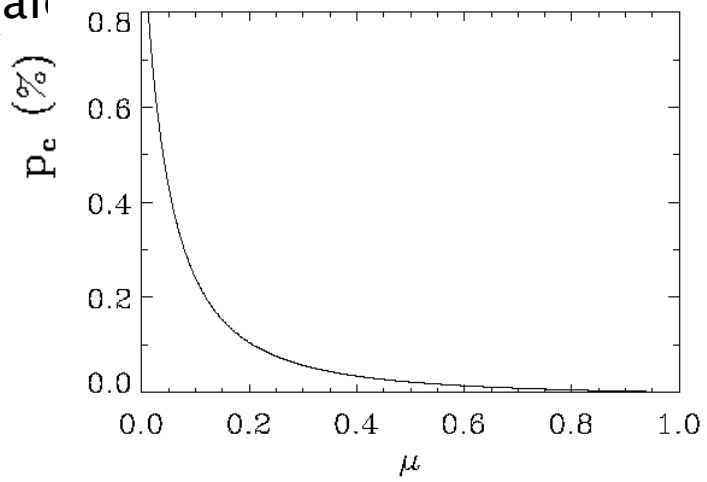
These processes affect the different spectral lines in different ways and may therefore be partially untangled by differential observations.

The real polarization of the flash spectrum can give insights into the basic physical processes that are responsible for the formation of the photospheric and chromospheric spectrum.

Motivation: scientific interest (3)

Example: Center-to-limb variation of the linear polarization of the Sun's continuous spectrum at 4000 Å

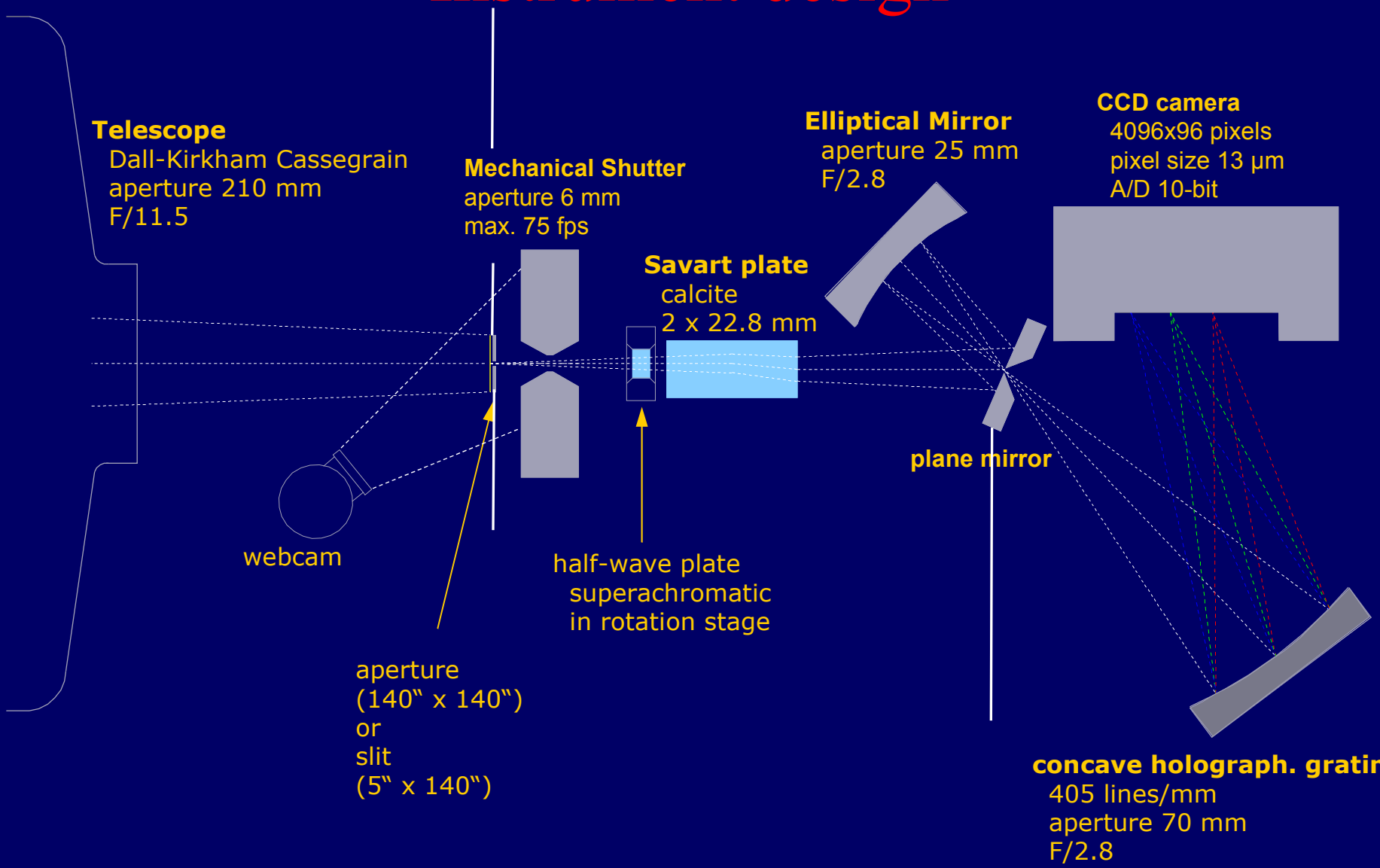
based on a scal… results of Fluri & Stenflo (1999)



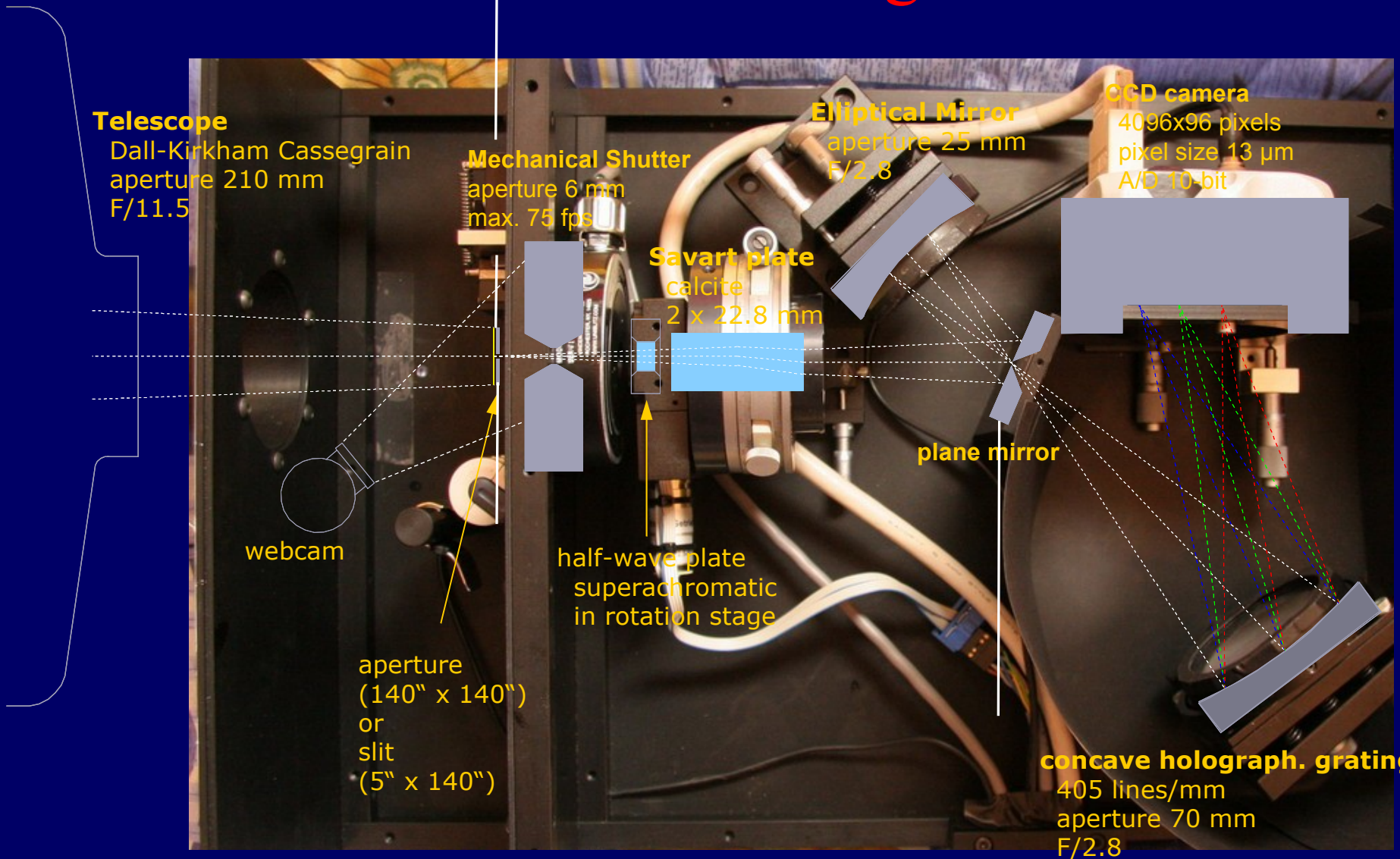
The linear polarization is much lower than in the case of Chandrasekhar solution but near the limb the center-to-limb variation is steeper.

The amount of linear polarization at the extreme limb is still unknown.

Instrument design



Instrument design

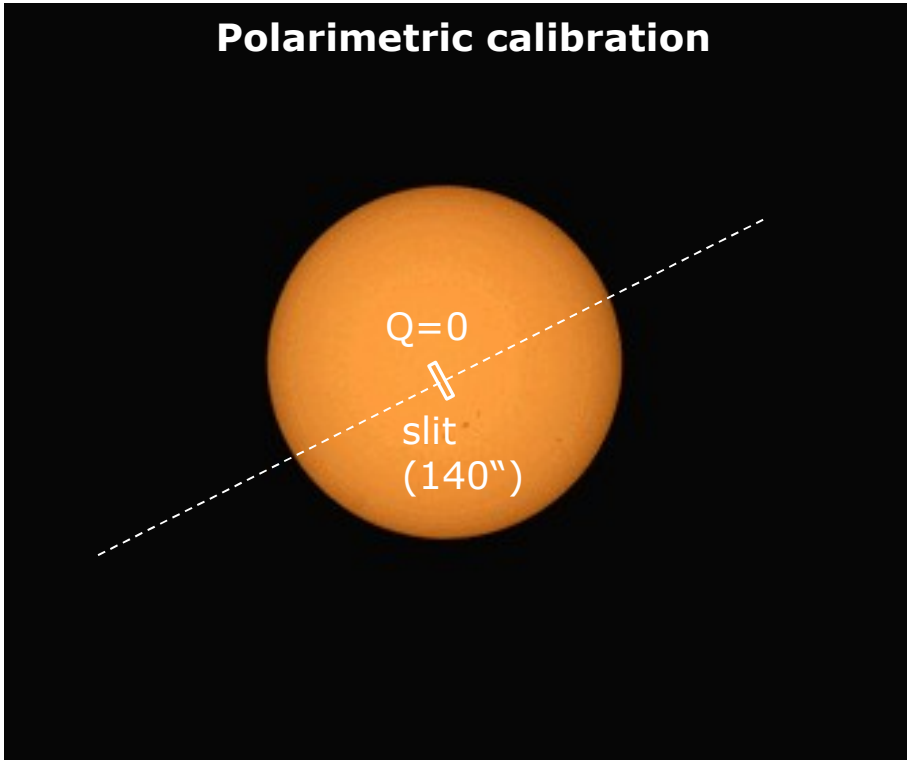


Instrument design

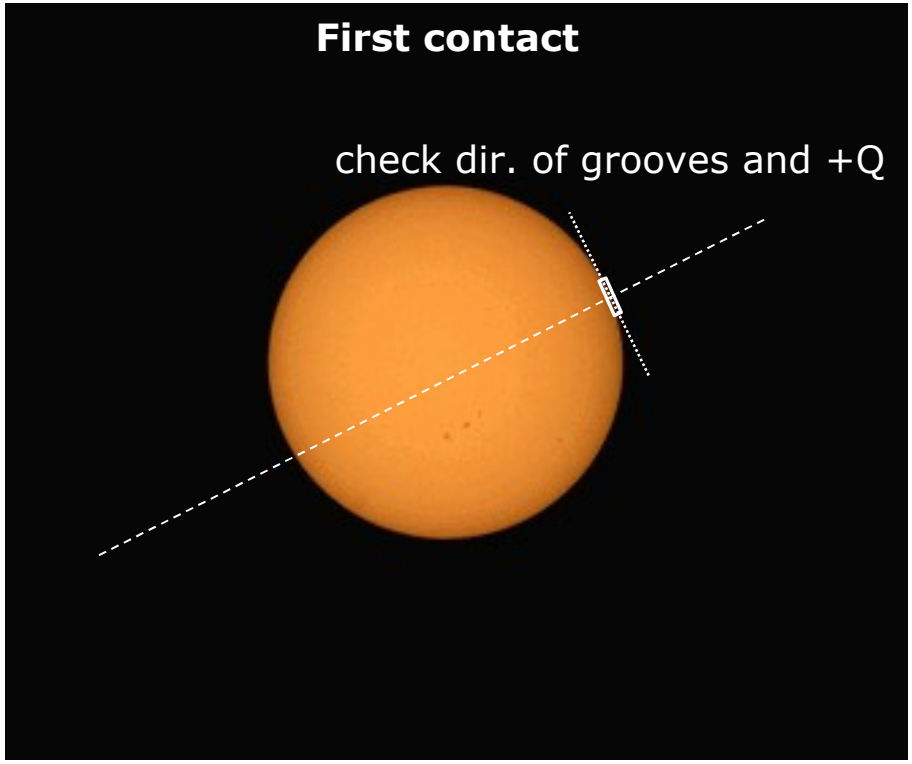
Main characteristics of the instrument

- spectral range 340 – 870 nm
- spectral sampling 0.21 nm/pixel
- time resolution 13 – 40 ms
- spatial sampling 5″/pixel
- field of view 150″

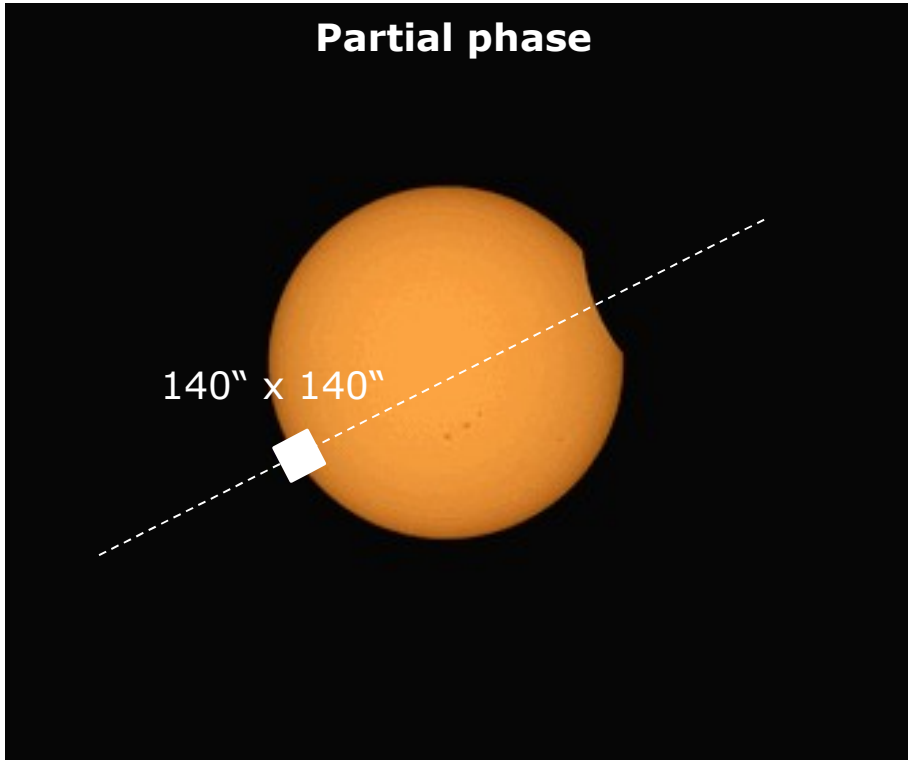
Observing strategy



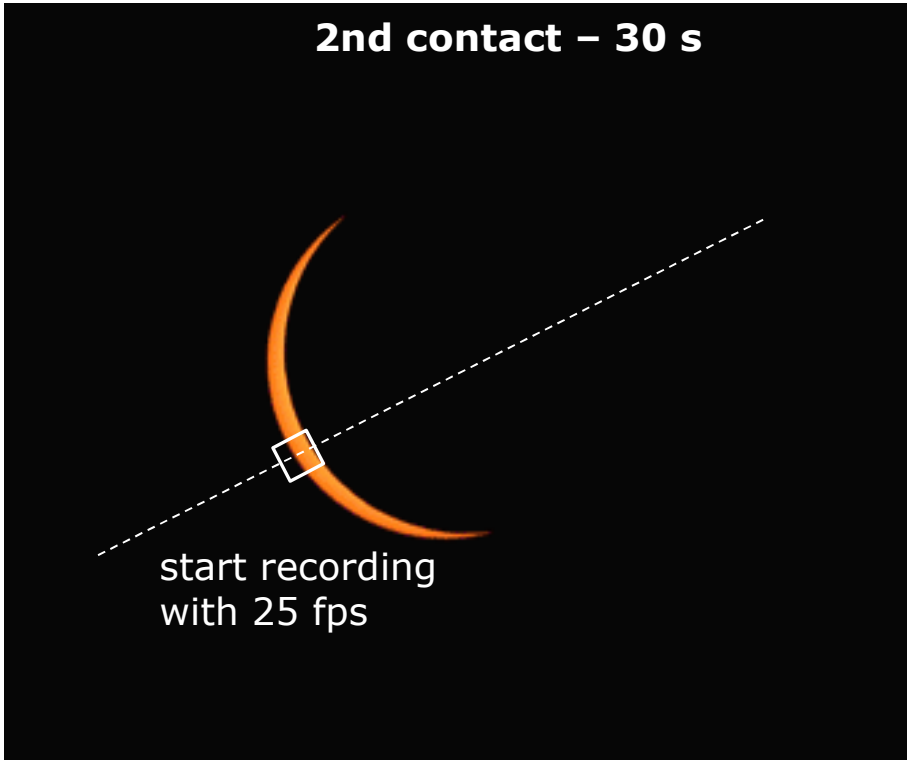
Observing strategy



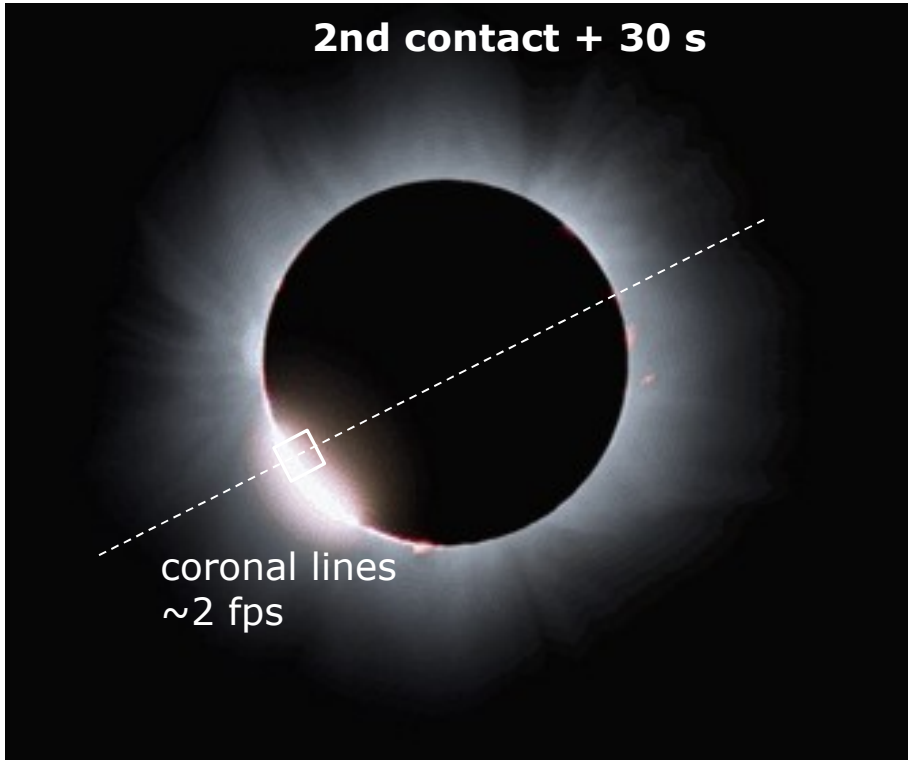
Observing strategy



Observing strategy



Observing strategy



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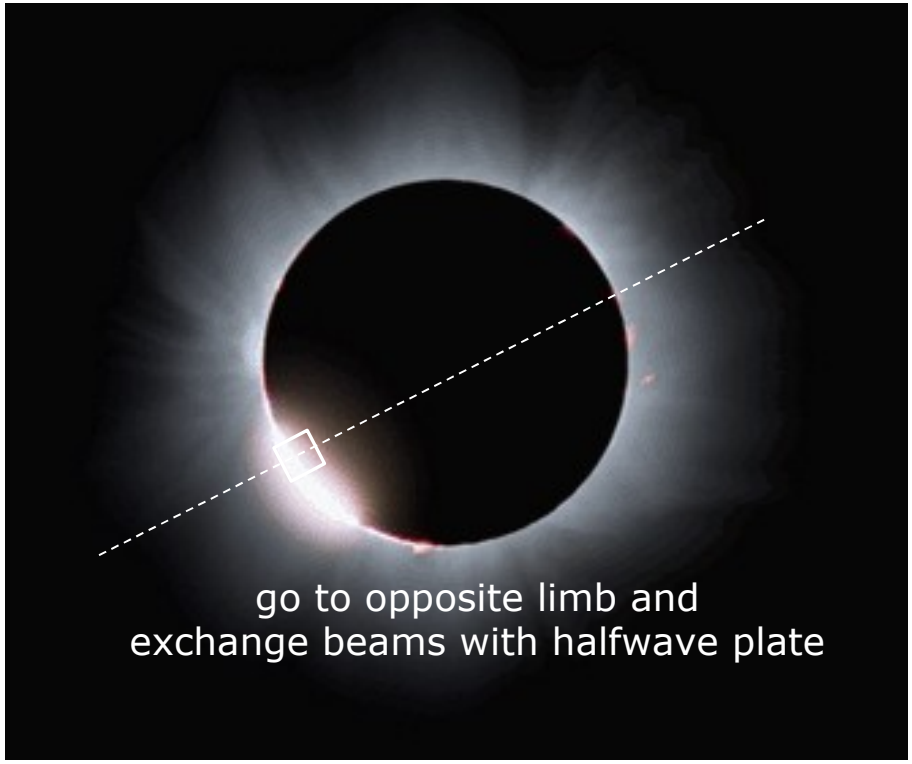

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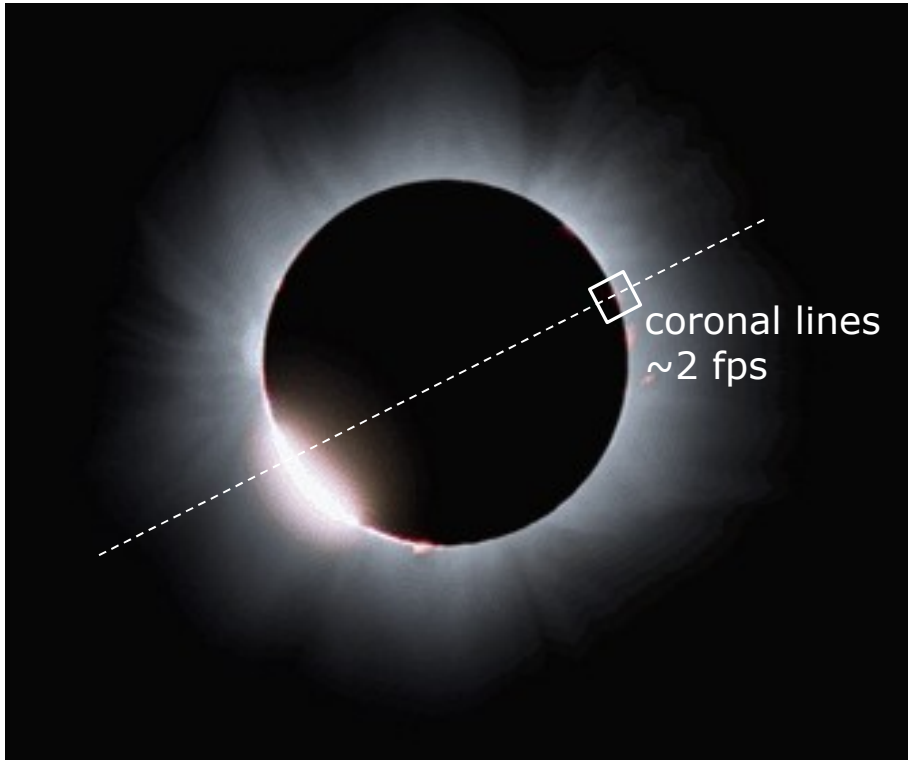
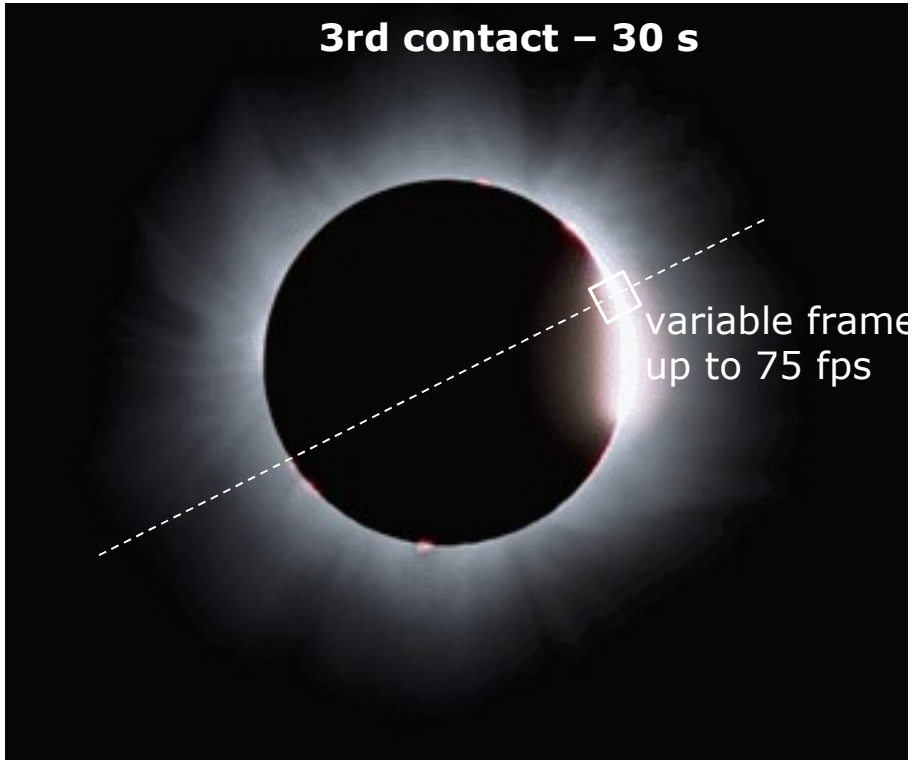
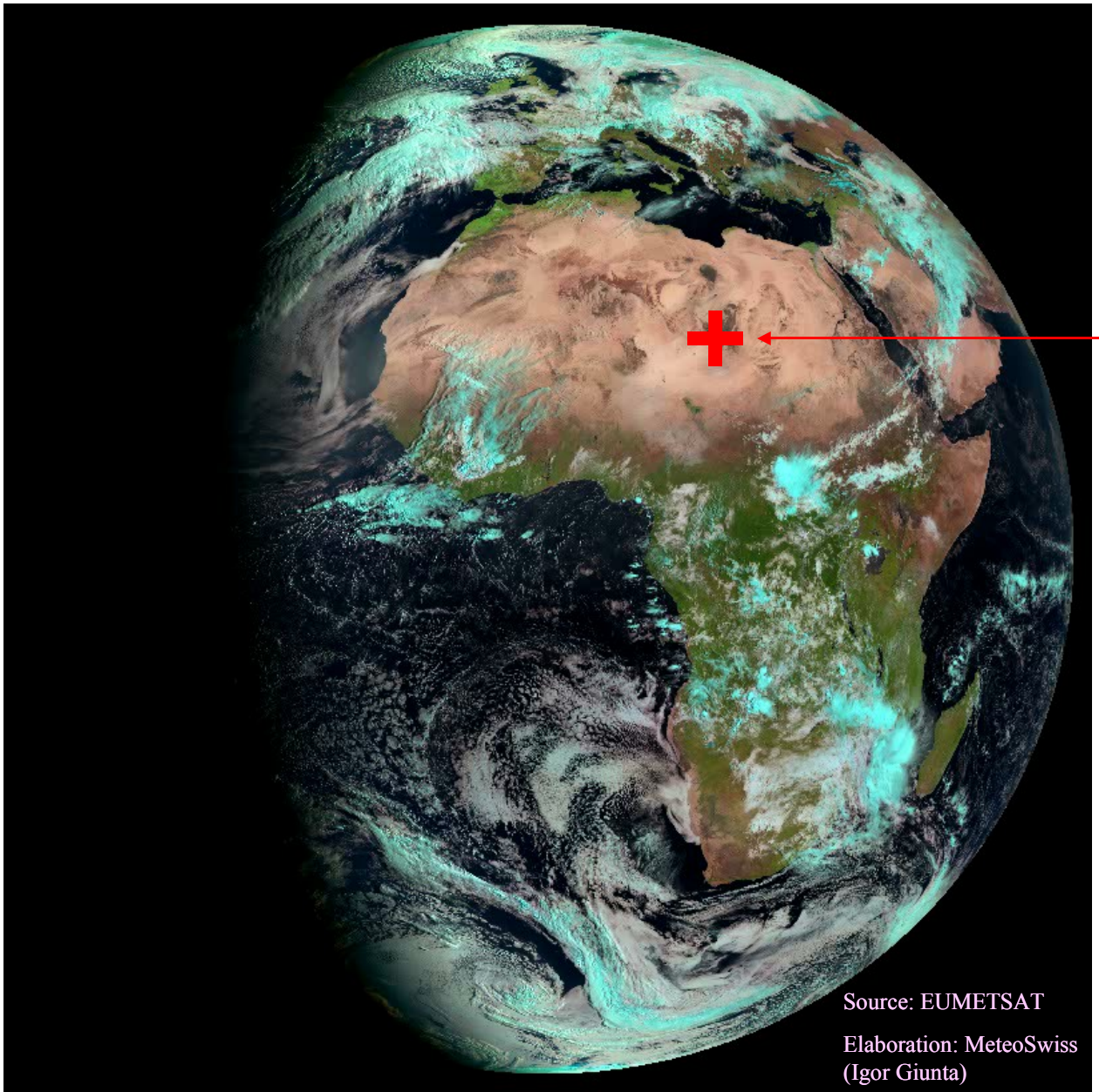


Observing strategy

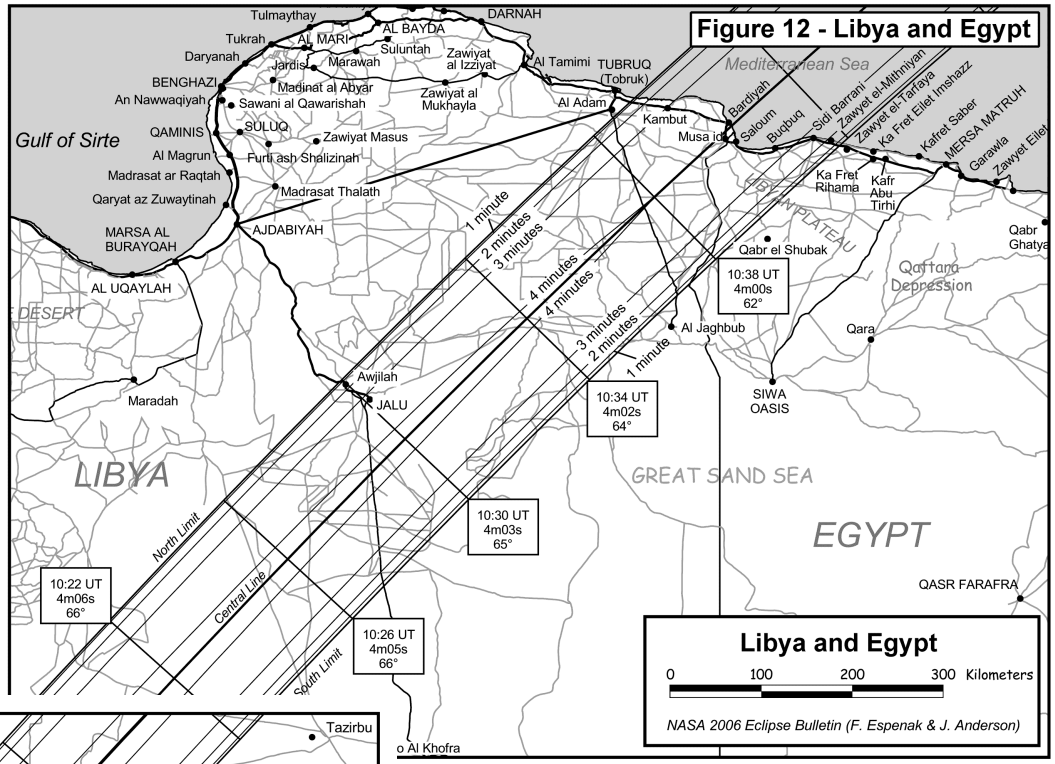


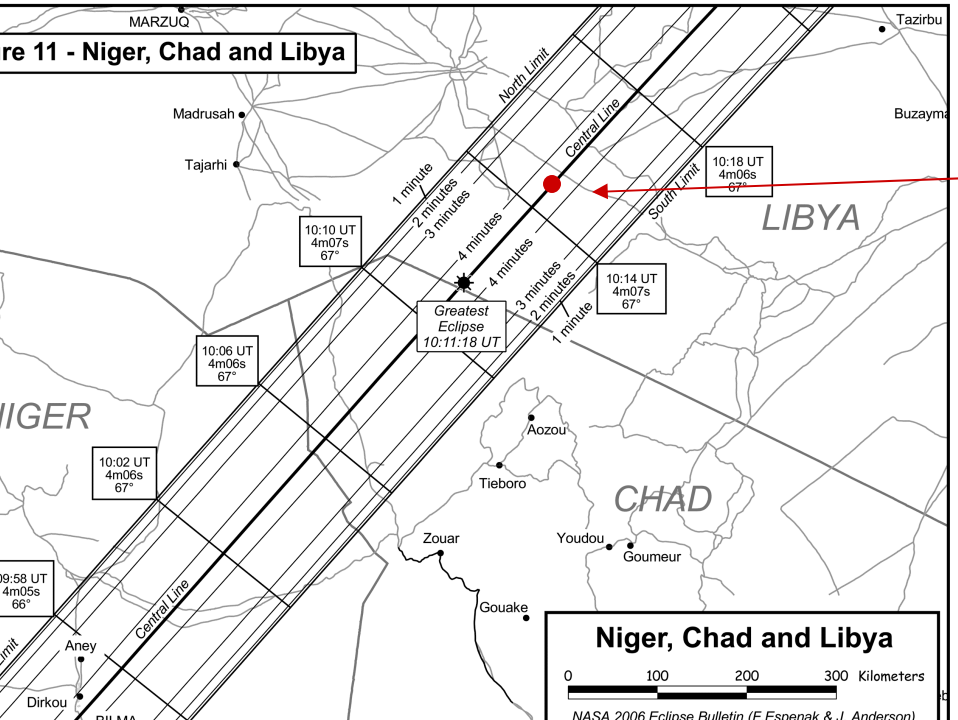
Measurement Location



Waw an Namos
(Libya)

29 March 2006



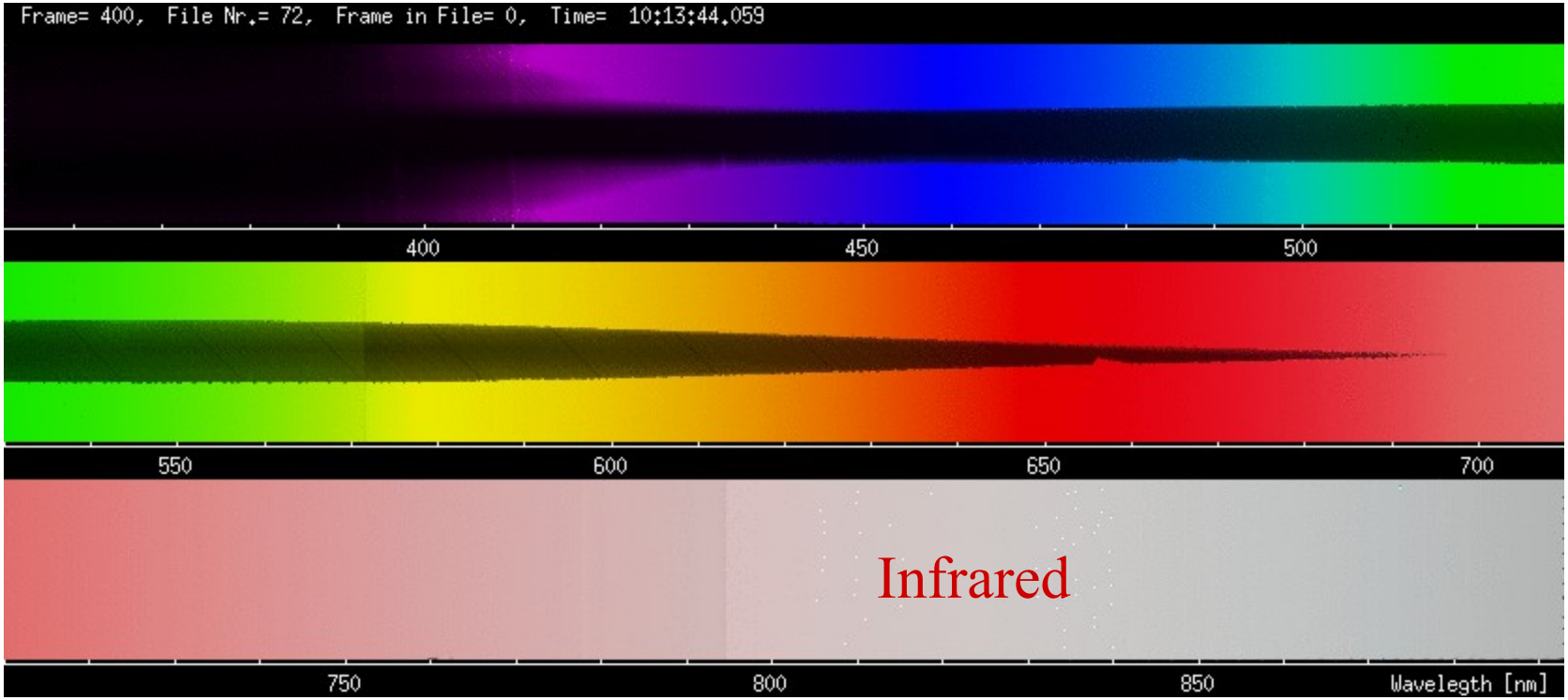


experimental camp

The travel to the Sahara desert

The experimental team

2nd contact measurement



Raw data! (not corrected for flat field and dark current)

Conclusion

- We could nicely register the flash spectrum of the 29 March 2006 total solar eclipse in the Libyan desert with a slitless spectropolarimeter
- The data reduction and analysis of the polarisation measurement is ongoing.
- Taking advantage from the experience gained with this solar eclipse experiment we are planning a new improved instrument for one of the next eclipses.