AGA5802 Polarimetry

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Super-niche

Very few people work on this all over the world. People who really know about it that I know:

- South Africa (1)
- Austria (1)
- UK (1)
- US (1)
- Brazil (3)

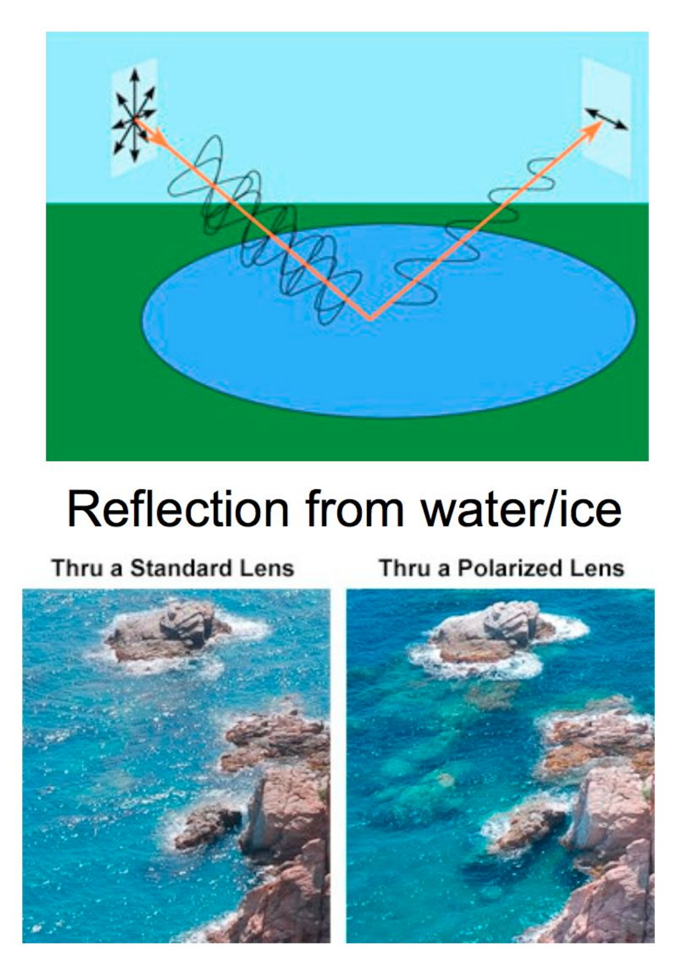
Then other people in Sweden, Finland, Estonia,...

You are in a privileged place!

Polarised light in “real life”

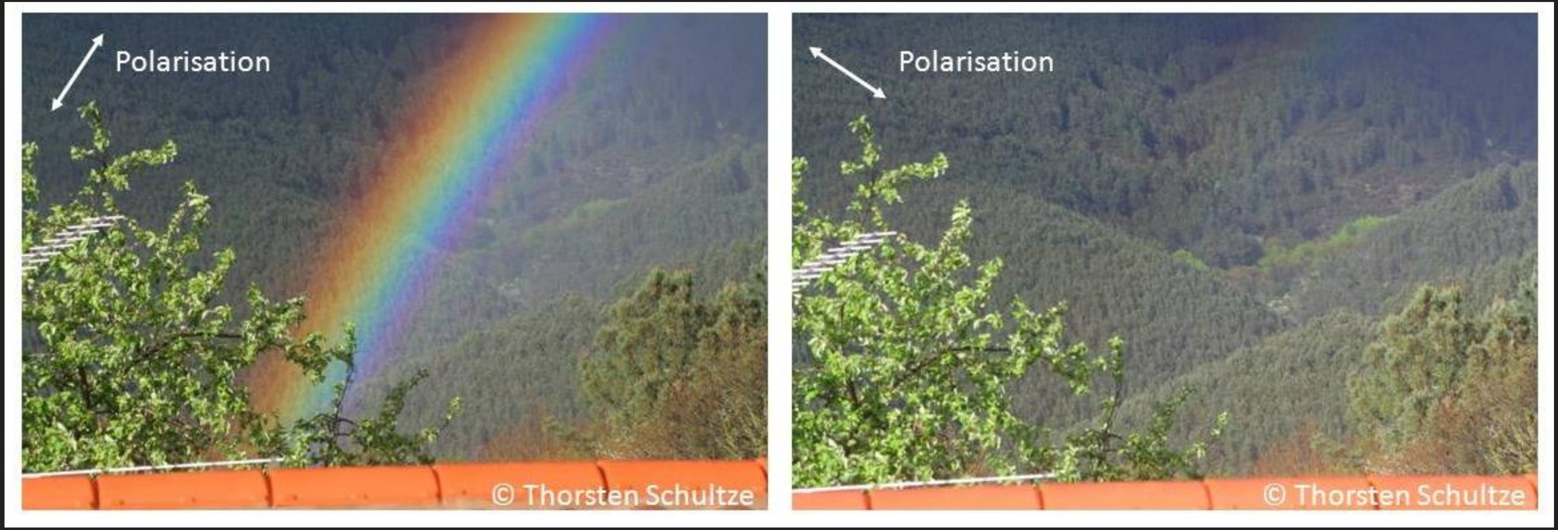
Reflection on water.

You can use polarised filters to enhance the colours of pictures.



Polarised light in “real life”

The light of the rainbow is polarised. If you are wearing polarised glasses (with the right polarisation angle), you may not see the rainbow.



Polarised light in “real life”

3D movies

When you go to watch a movie in 3D, they may give you these “gray” glasses.

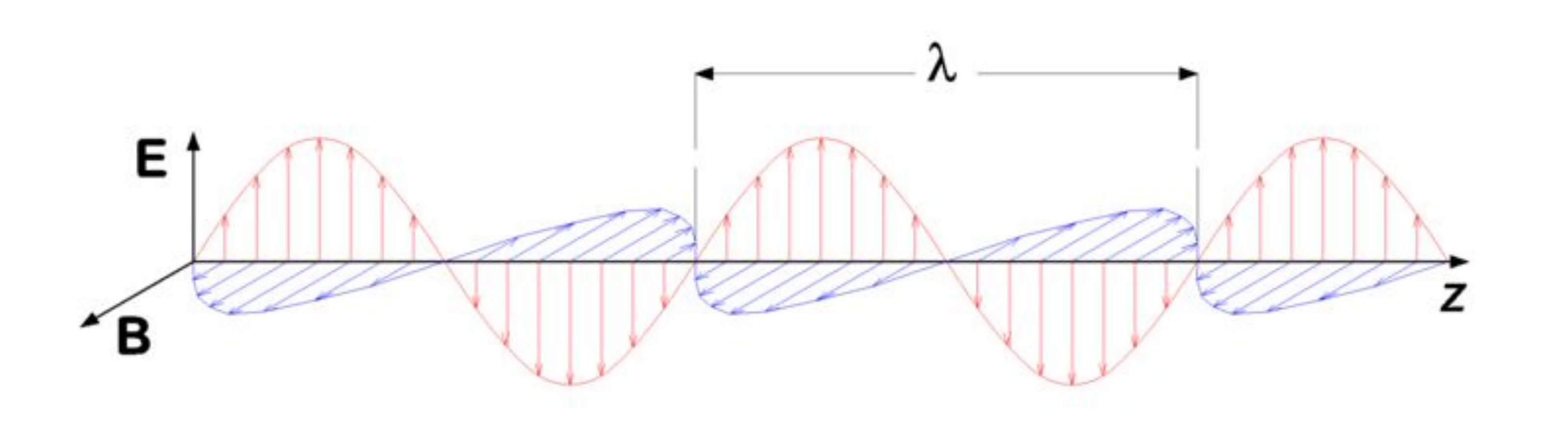
Ask your friend (you don’t want to go alone to a movie theatre, do you?) to give you his/her glasses and put one lens in front of another.

Look through it and start turning the glasses. You will notice that there is an angle where no light goes through. You will also notice that at 90º from that angle, all light is going through.

What is polarimetry?

Light is an electromagnetic wave.

What we plot normally is a linearly polarised wave (the electric field oscillates on a plane).



https://en.wikipedia.org/wiki/Polarization_(waves)

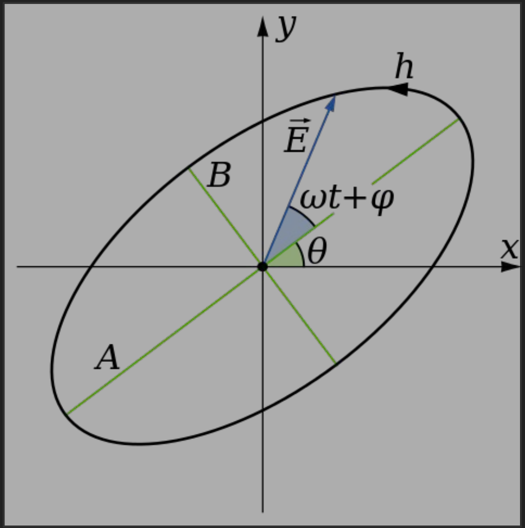
What is polarimetry?

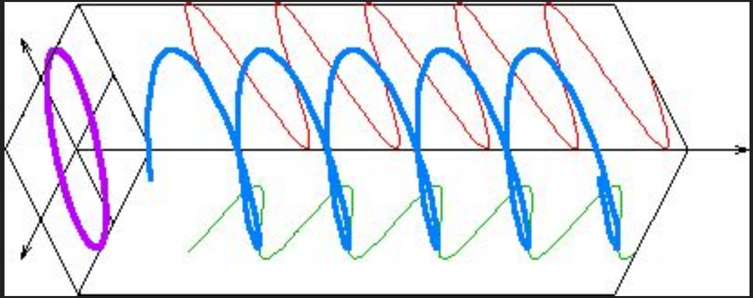
In general, the oscillation can be off of a plane.

If I look at the e.m. wave from the front, I would see the oscillation being an ellipse.

Linear or circular polarisation are extreme cases of elliptical polarisation.

Similarly, you can model elliptical polarisation in terms of linear and circular polarisation.





https://en.wikipedia.org/wiki/Elliptical_polarization

The Stokes parameters

I is the intensity of the polarisation.

Q and U measure linear polarisation.

V measures circular polarisation.

P = I / F (where F is the total flux) is the percentage of polarisation

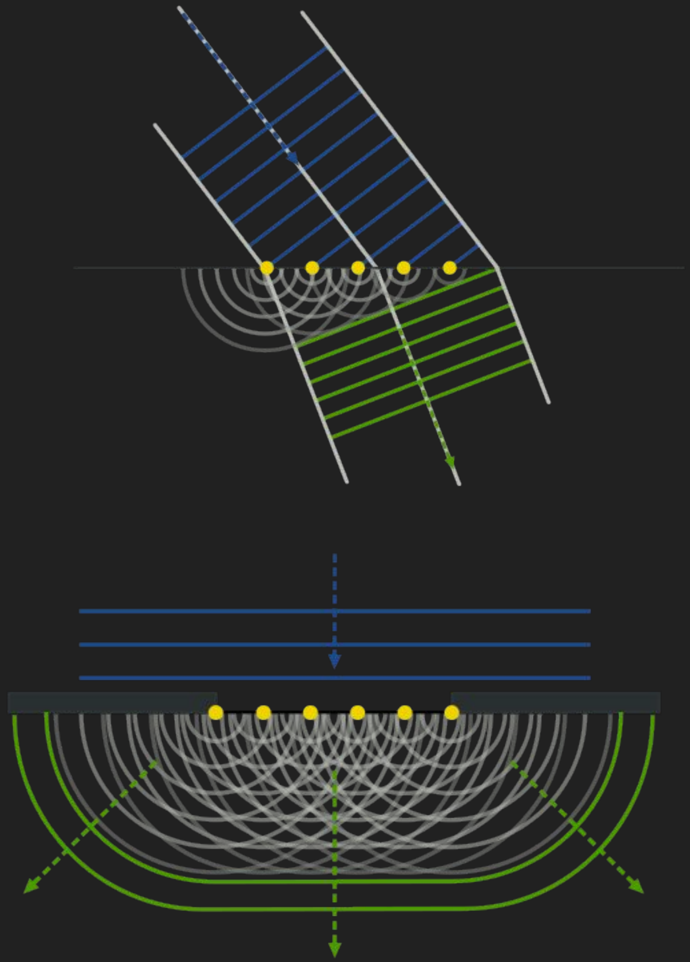
Fractional linear polarisation:

- $P_L = (Q^2 + U^2)^{1/2}/I$
- Θ - 1/2 arctan(U/Q)

$$I = \langle E_x^2 \rangle + \langle E_y^2 \rangle$$
$$Q = \langle E_x^2 \rangle - \langle E_y^2 \rangle$$
$$U = 2\langle E_x E_y \cos\delta \rangle$$
$$V = 2\langle E_x E_y \sin\delta \rangle$$

What is polarimetry?

Light propagation: Huygens-Fresnel principle



Why use polarimetry

“Polarimetry is easy, it is all differential!”

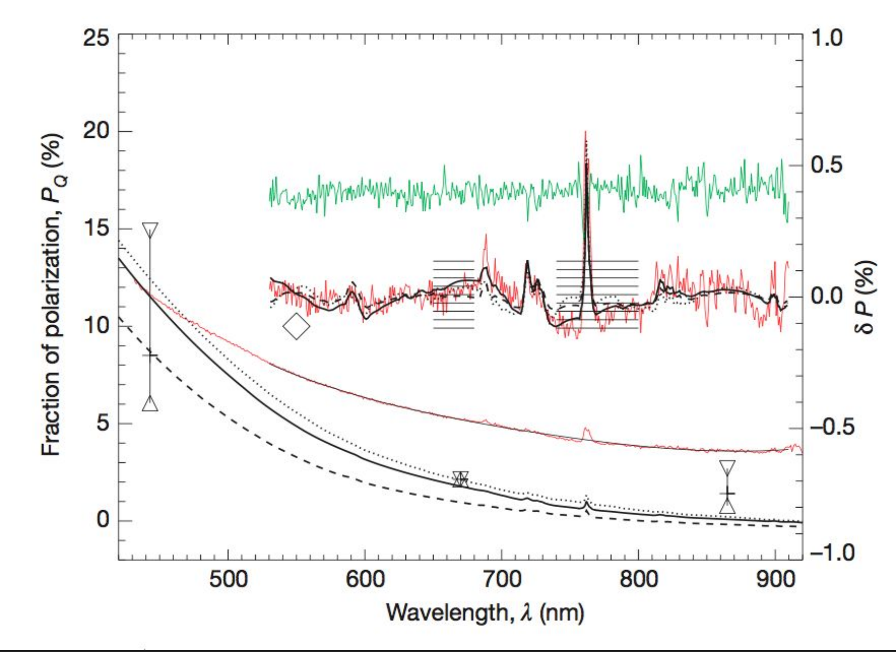
A few examples:

- Exoplanets
- Stellar magnetism
- Accretion discs

Biological tracers

Low-resolution spectropolarimetry (red line) of the Earth-shine reflected by the Moon.

Sterzik et al. (2012)



Exoplanets

In a classical article, Carciofi & Magalhaes (2005) computed the flux difference due to a transiting exoplanet (and this is something many people do) as well as the impact on the observed polarisation.

One needs to have a S/N > 10^6 !

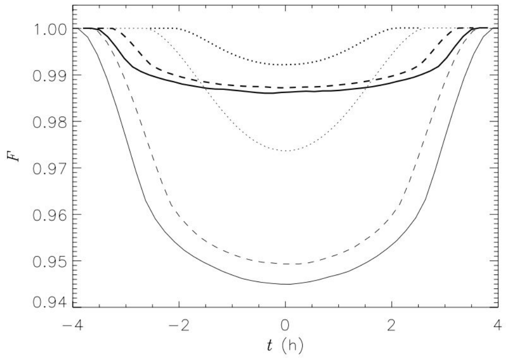


FIG. 3.—Normalized flux at 4600 Å for the transit of an ESP in front of a Sun-like star, showing results for two planet radii, $R_p = 1R_{\rm Jup}$ (*thick lines*) and $R_p = 2R_{\rm Jup}$ (*thin lines*). The solid lines correspond to central transits ($i = 90°$), the dashed lines correspond to an inclination of $i = 87°$, and the dotted lines correspond to an inclination of $i = 84°$. The planet orbital radius is 0.04 AU. [*See the electronic edition of the Journal for a color version of this figure.*]

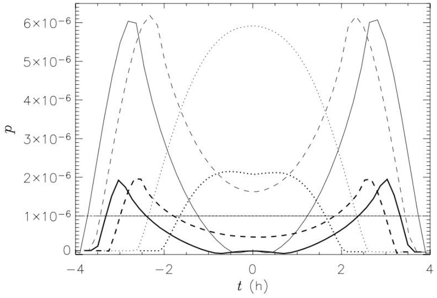


FIG. 4.—Occultation polarization at 4600 Å for the transit of an ESP in front of a Sun-like star, showing results for two planet radii, $R_p = 1R_{\rm Jup}$ (*thick lines*) and $R_p = 2R_{\rm Jup}$ (*thin lines*). The solid lines correspond to central transits ($i = 90°$), the dashed lines correspond to an inclination of $i = 87°$, and the dotted lines correspond to an inclination of $i = 84°$. The planet orbital radius is 0.04 AU. The horizontal line indicates the best polarization sensitivity for current broadband polarimeters. [*See the electronic edition of the Journal for a color version of this figure.*]

Cataclysmic Variables

In the case of magnetic CVs, the polarisation arises from the effect of the magnetic field.

You can even see how the amount of polarisation and the direction of polarisation varies with the orbital period.

E.g.:http://www.das.inpe.br/~claudia.rodrigues/

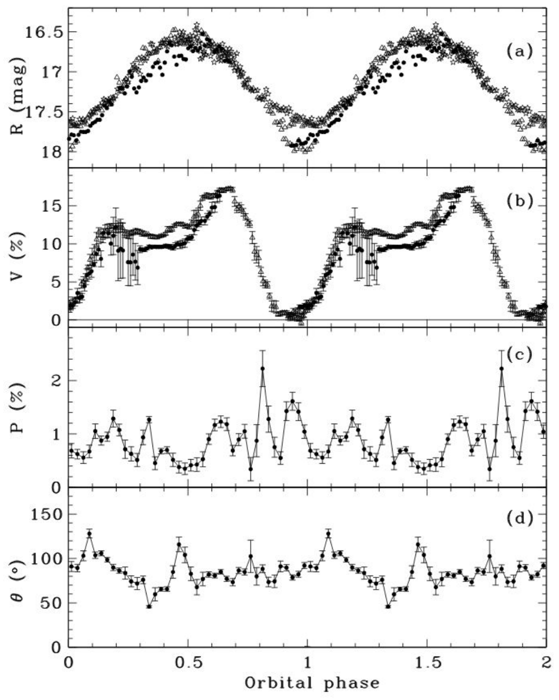
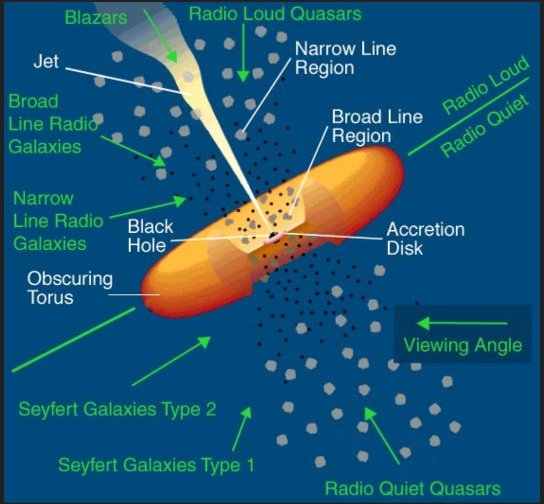


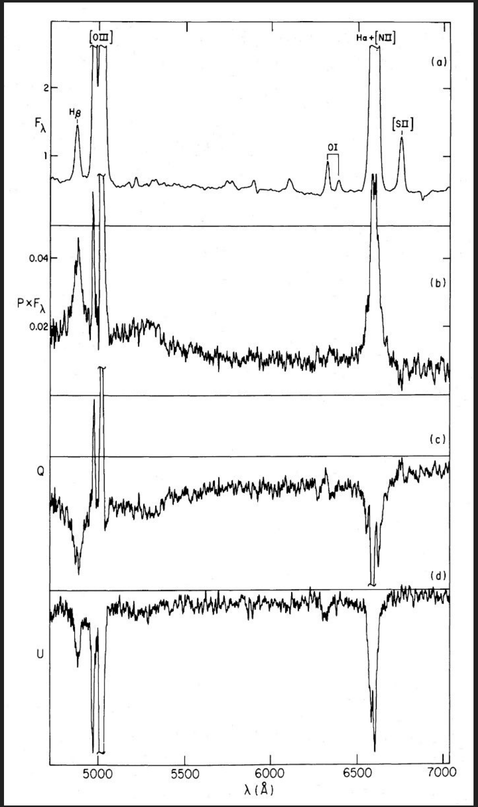
Figure 1. Observations of 1RXS J161008.0+035222 in the R_C band done in 2003 April. (a) Photometry, (b) circular and (c) linear polarization, and (d) polarization position angle. The different symbols in panels (a) and (b) represent distinct days of observations: full dots stand for April 22, open triangles stand for April 23 and open stars stand for April 26. In panels (c) and (d) the data from all days were binned in 40 phase intervals. These data were plotted assuming the ephemeris of Eq. 1. The circular polarization sign is the instrumental one.

The Unified Model of AGNs

Urry & Padovani (1995)

Antonucci & Miller (1985) observe a “hidden type 2 spectrum” in a type 1 AGN which comes from the reflection on the BLRs.





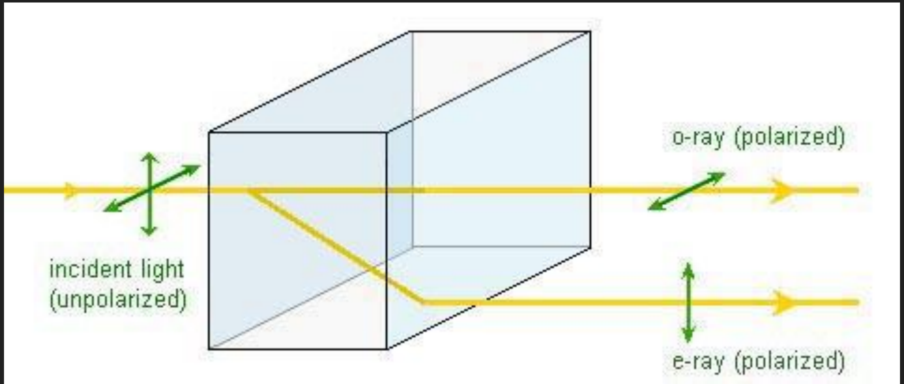
How to measure polarimetry

Kitchin - Section 5.2

Birefringence

Light propagates with different refractive indexes depending on the direction inside the birefringent material.

An example of this material is calcite.



Dichroic

This is a material which only lets pass light with a specific linear polarisation.

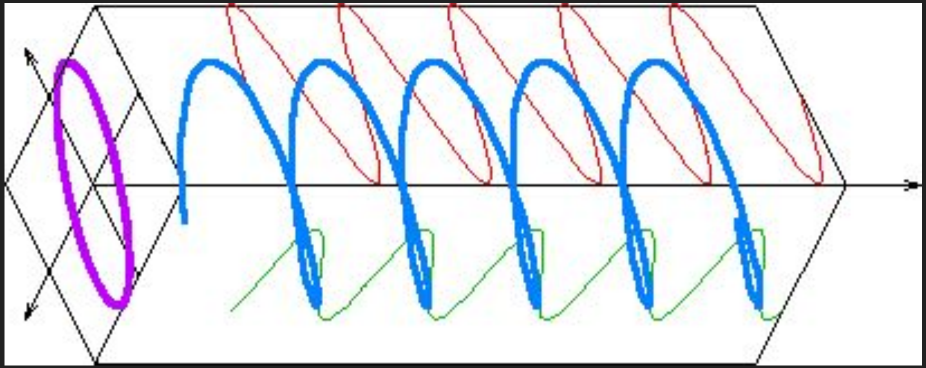
(This is what the 3D movie glasses are made of)

Converters

One can orient a birefringent material so that the ordinary and the extraordinary beams travel in the same direction.

This will cause a phase shift.

We use this to create retarder plates (half-wave or quarter-wave plates) which can convert circularly (or elliptically) polarised light into linearly polarised and vice versa.

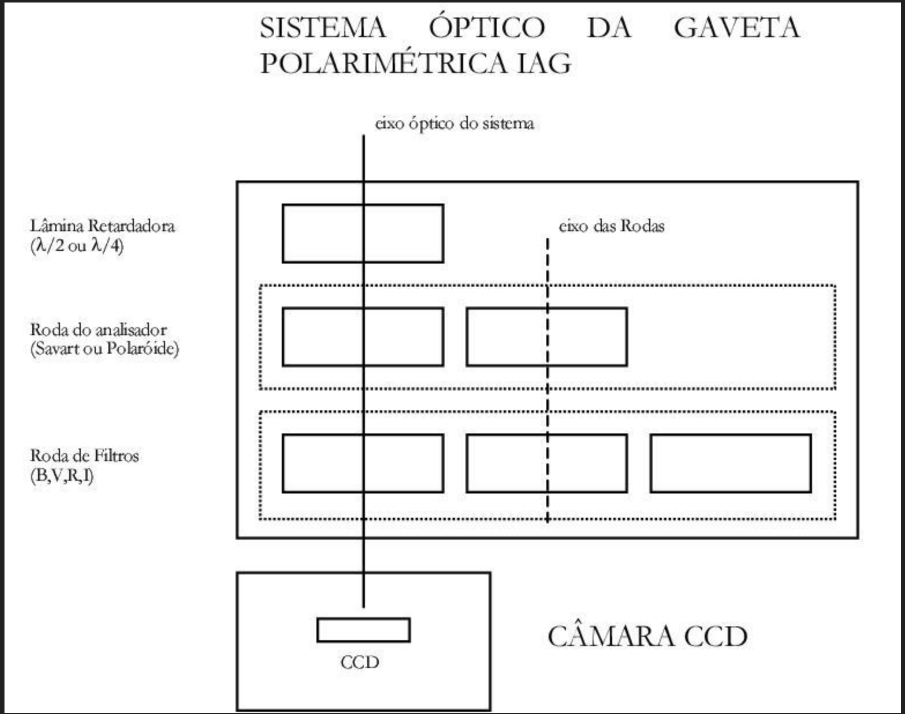


Polarimeters

You want to have a retarder plate and then a polarimeter (a bringefringent material) to split the two beams.

Moving the retarder plate, you can measure the difference of flux in the ordinary and the extraordinary beam and you can measure the Stokes parameters.

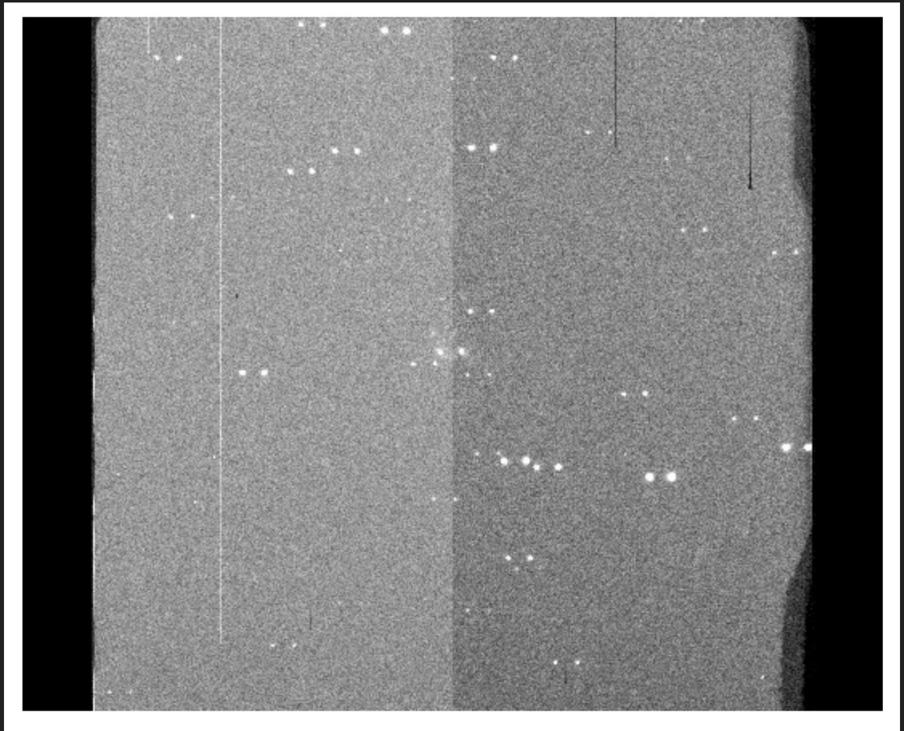
[Optical scheme of the “Gaveta Polarimetrica” at LNA]



Polarimetric imaging

The two images of the stars in a field observed with NTT/EFOSC2 with a Wollastone prism (a birefringent device).

Need to take images at different positions of the retarder plate.



Spectropolarimetry

You put one star in the slit and get two spectra, one for each beam.

You take several exposures at different positions of the retarder plate.

Sorry, could not find an image
To illustrate this!

Next time you go to watch a movie in 3D, ask the glasses to your friend and try to block light from passing through.

… next time, finally, radio :-)