Measurement of the optical Polarization of the Crab pulsar with OPTIMA

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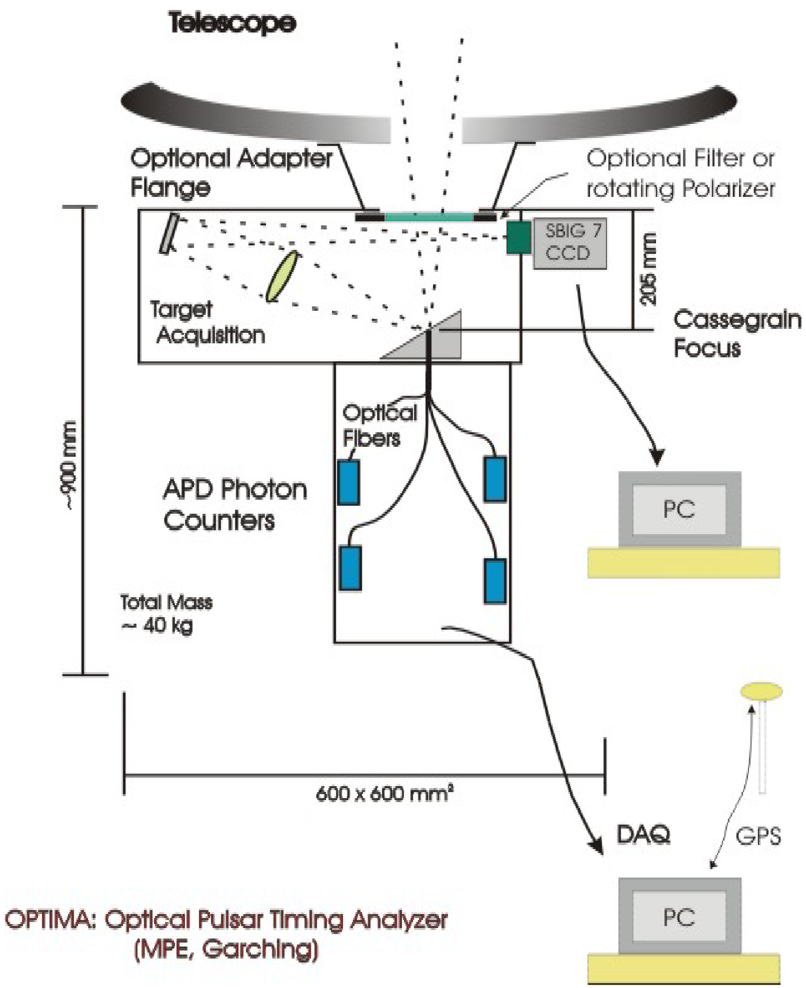
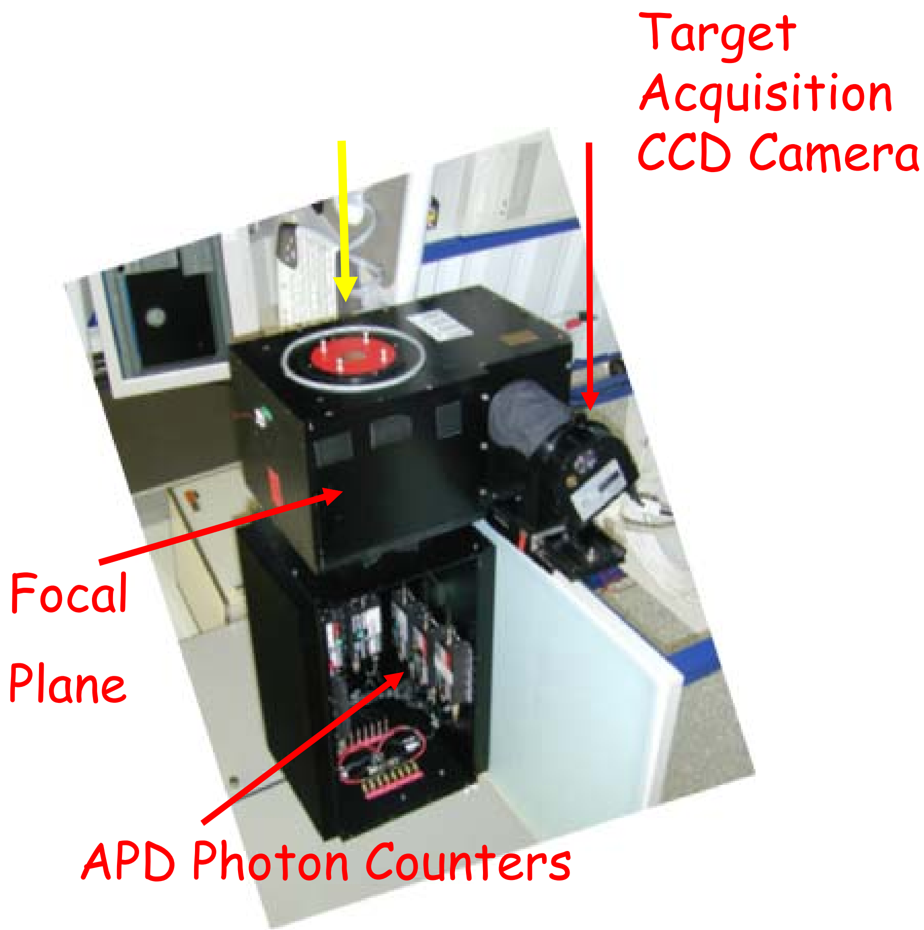
- Description of the MPE-OPTIMA („ Optical Pulsar Timing Analyzer “) high-speed photo-polarimeter
- Measurements on the Crab pulsar in January 2002 at Calar Alto
- Verification of the polarimeter and data analysis
- Results

The OPTIMA photometer

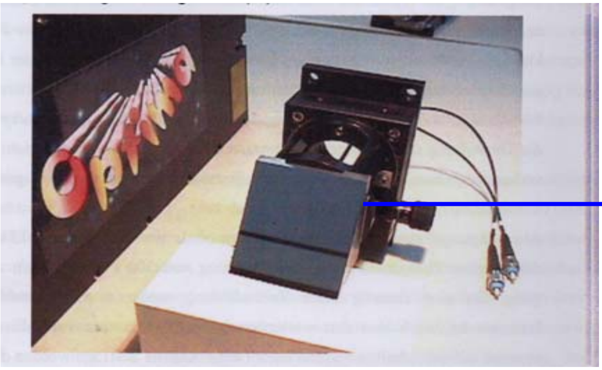




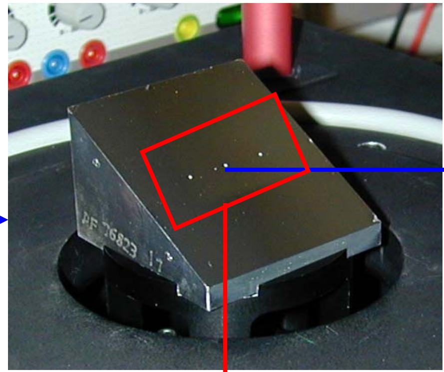
single photon counting and timing:
APDs: high Q.E. ~60% (450-950 nm) -> ~6 times more sensitive than PMT system
Timing with GPS: ~ 2 μs

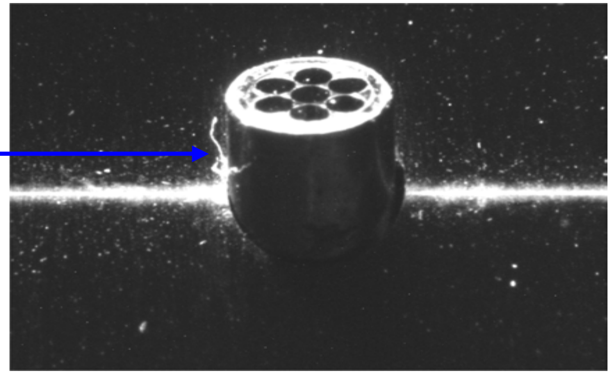
Options:
Linear Polarization using a rotating filter, 4 colour-band prism spectrometer

Target Aquisition



Mirror with fiber bundles

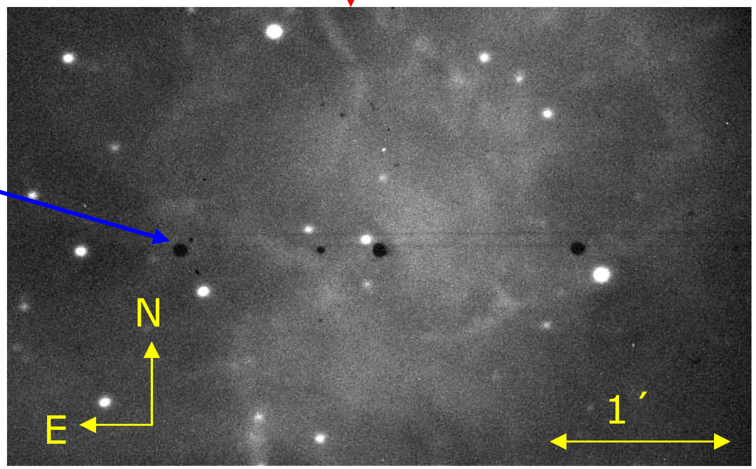




Target Fibers dia ~300 mm

(maximum signal/noise ratio)

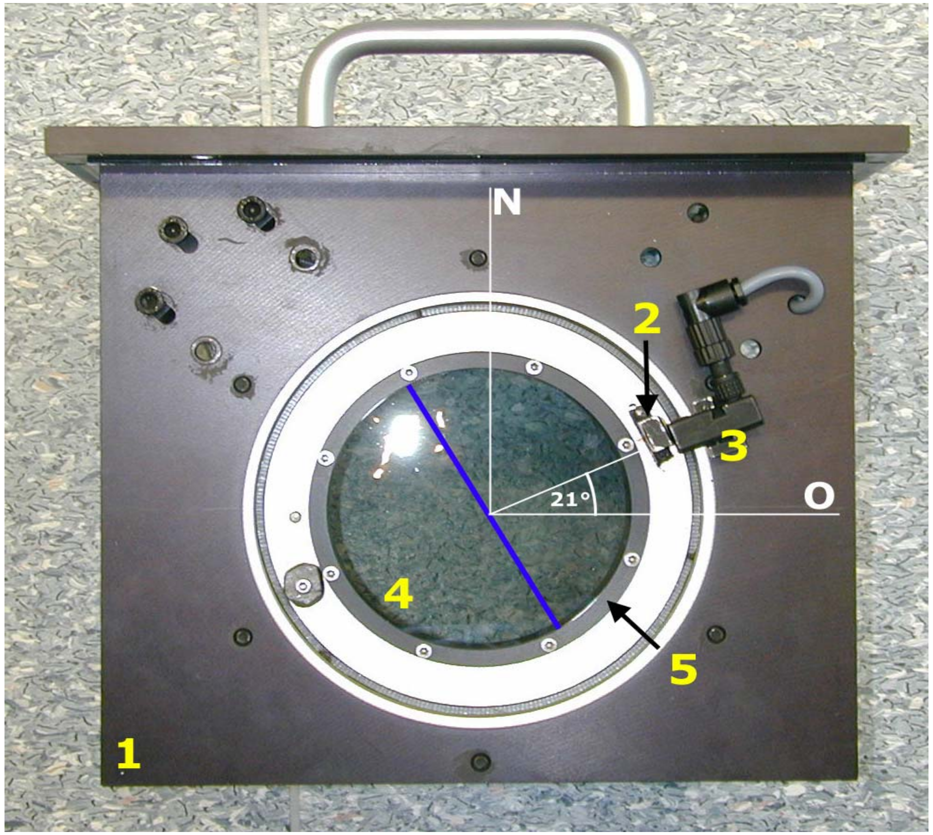
Sky Background fiber



The Crab Nebula

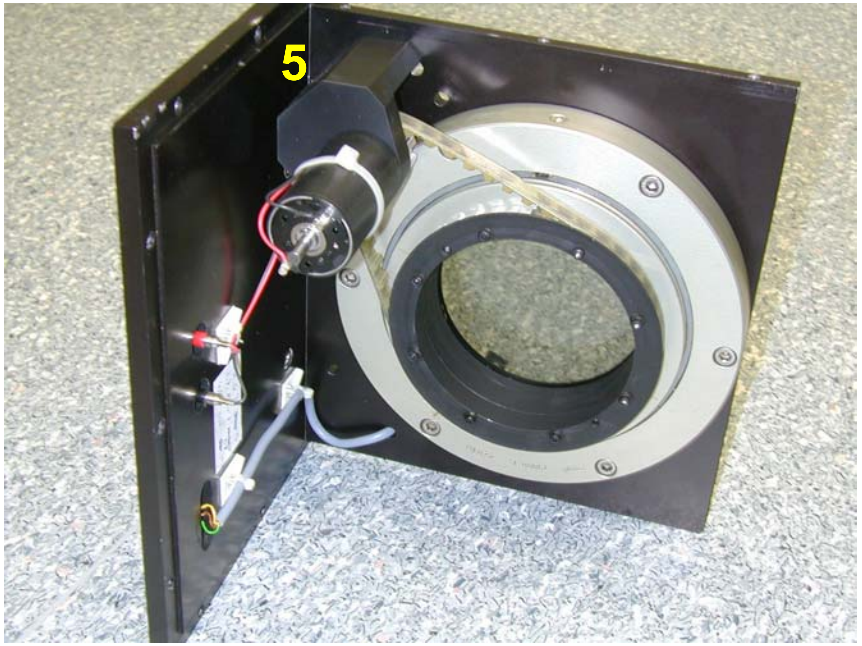
(3.5m Calar Alto, 99/00)

The OPTIMA Rotating Polarization Filter



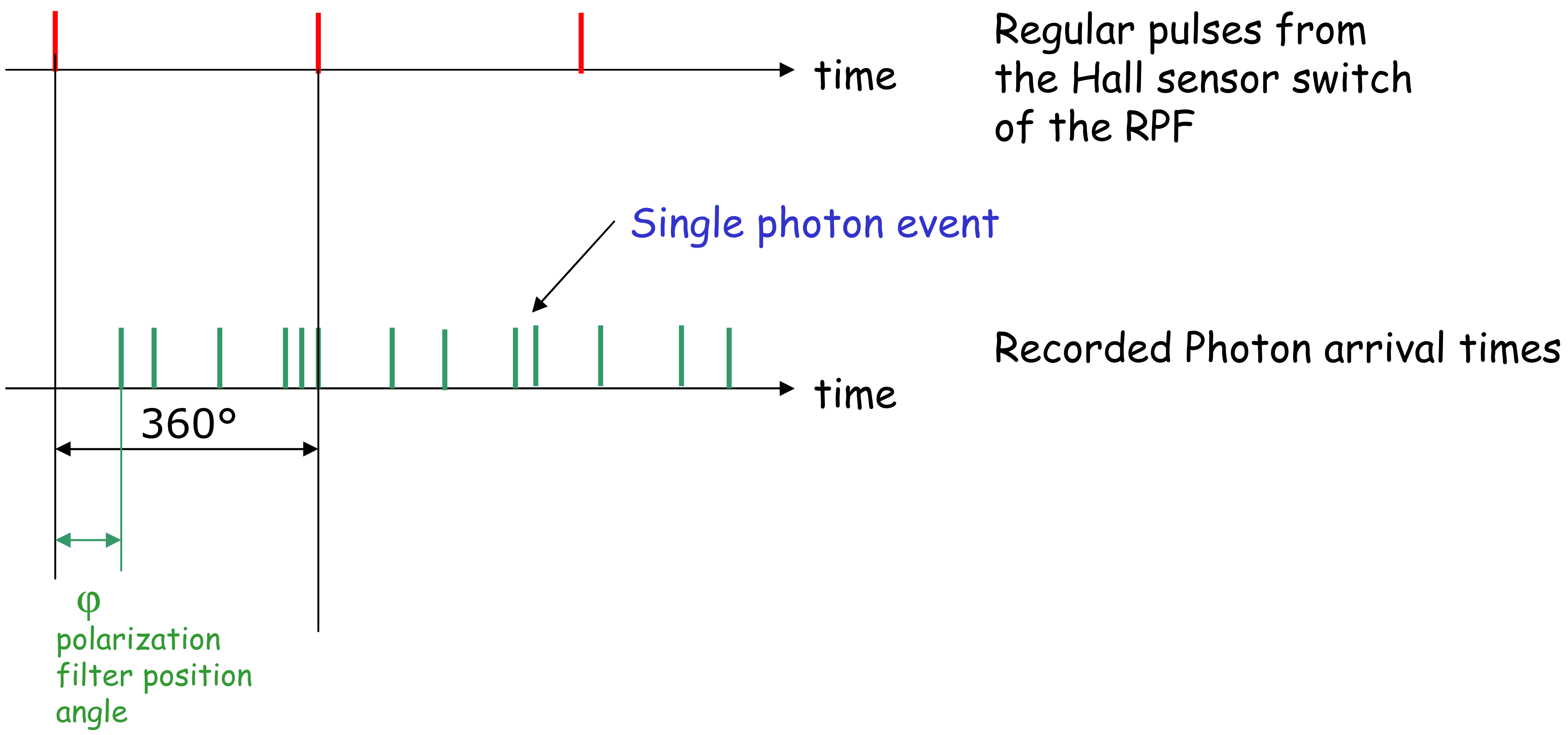
Advantage: total field of view is analysed for polarisation simultaneously -> essential for Crab nebula!

Disadvantage: only 50% transmission



1. Rotating polarisation filter unit
2. & 3. Hall sensor switch (reference)
4. Polaroid filter
5. motor driven roller bearing (typical rotation frq.: 3 Hz)

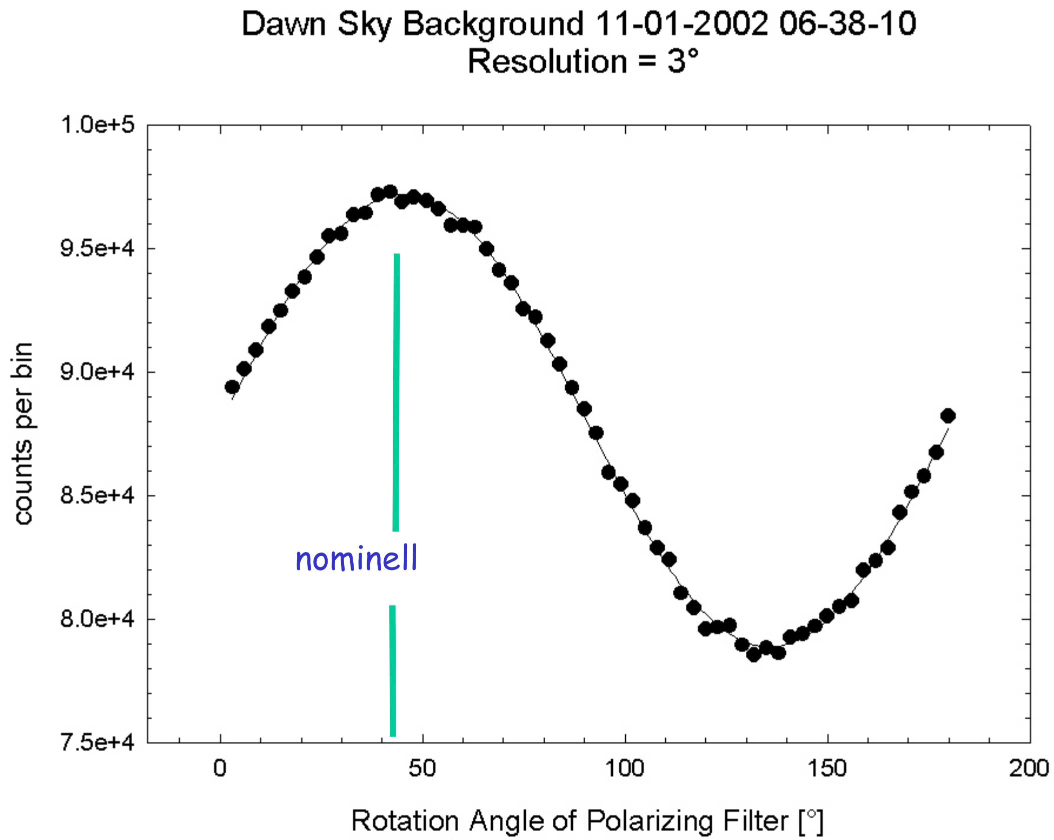
Assignment of polarization angle to individual recorded photons

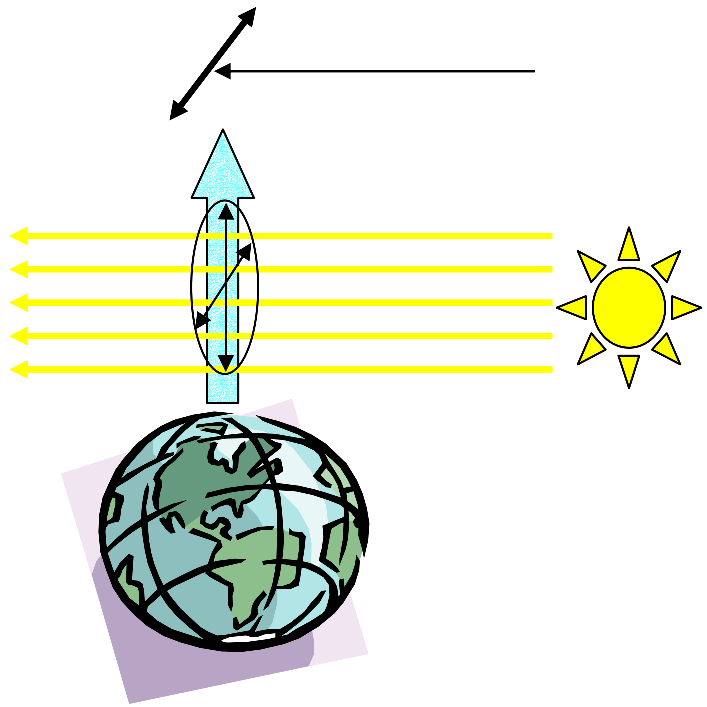


Verification of Polarimeter: Morning Sky Polarization

Rayleigh scattered sunlight (dawn or dusk) is highly polarized (~50%)
The E-vector in the zenith is orthogonal to the azimuth of the Sun.
For this exposure: Sun azimuth 111° (E of N), E-Vector: 21° (E of N)

Filter Rotation Angle 0° corresponds to E-vector 339° (E of N)
i.e. 42° filter rotation angle corresponds to E-vector 21° (E of N)





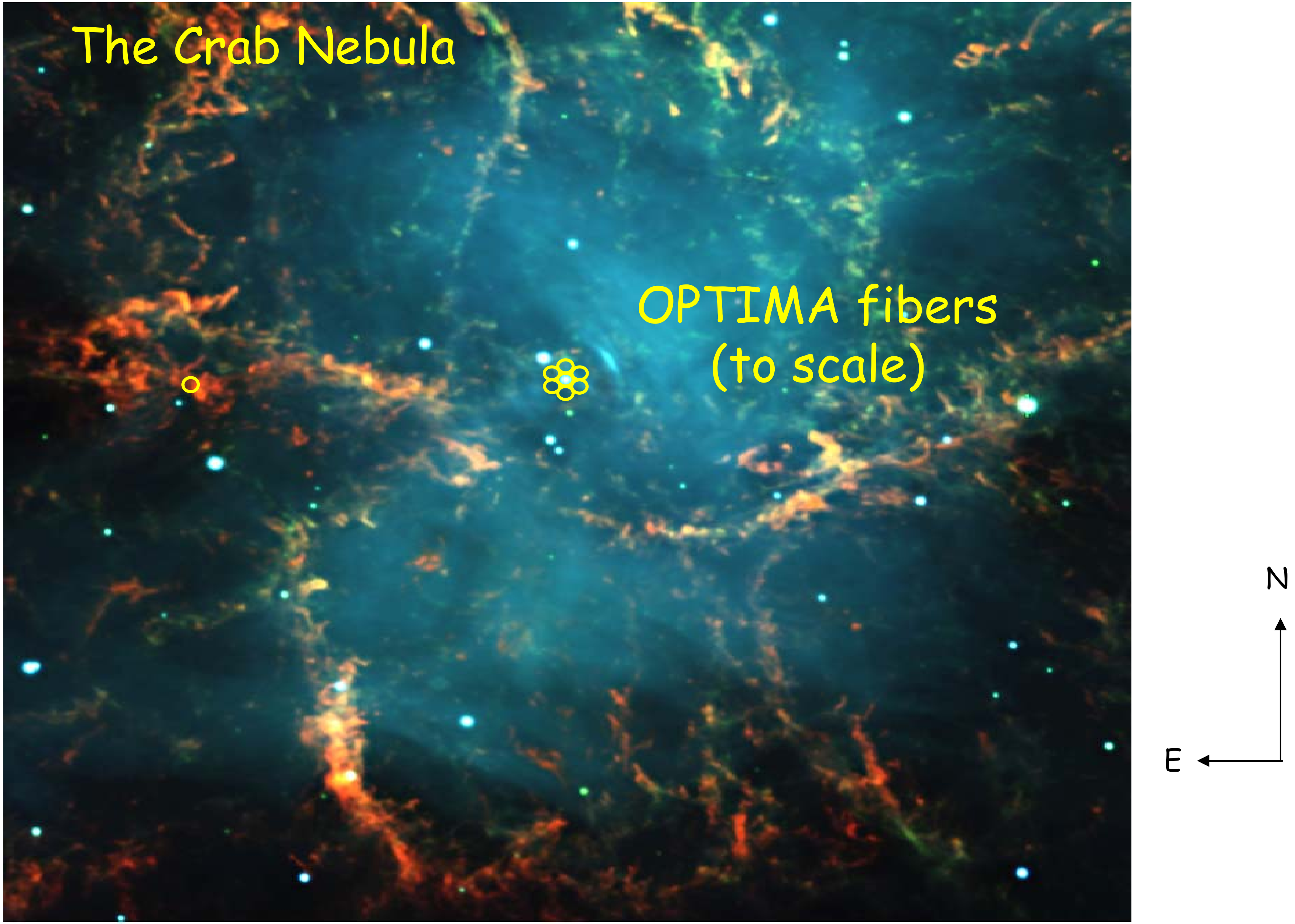
OPTIMA at the
Calar Alto 3.5mTelescope
(Jan. 2002)

Crab Observations

Jan 9.-13., 2002 Calar Alto 3.5 m telescope

white light:	~ 6 hours
polarization:	~ 3 hours
colour filters:	~ 3 hours

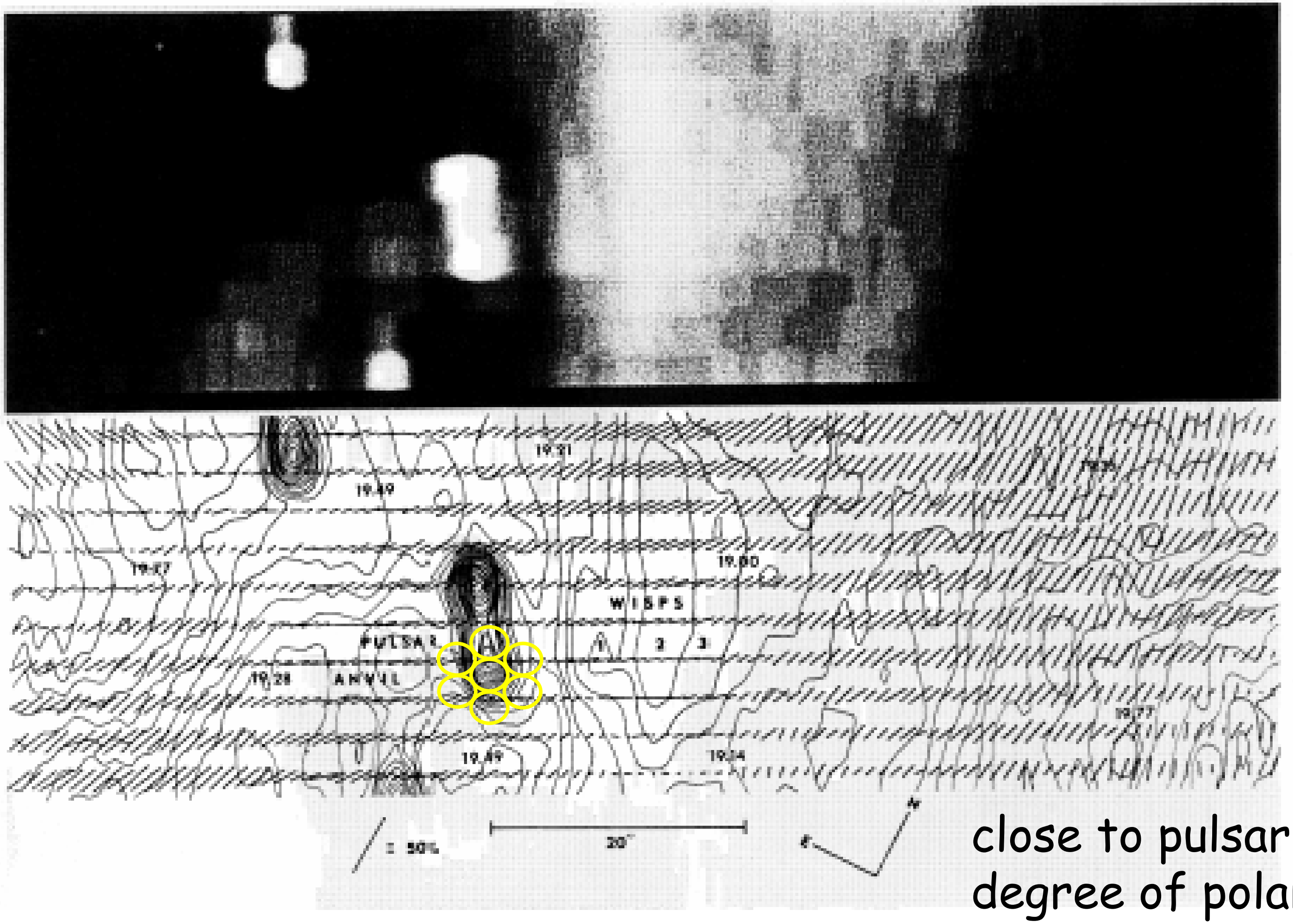
High statistics single pulse studies
Time resolved Polarimetry
3 colour filter photometry (red, green, blue)
Simultaneous optical – radio observations
(Collaboration with Copernicus University,Torun)



The Crab Nebula in Taurus (centre) (VLT KUEYEN + FORS2)

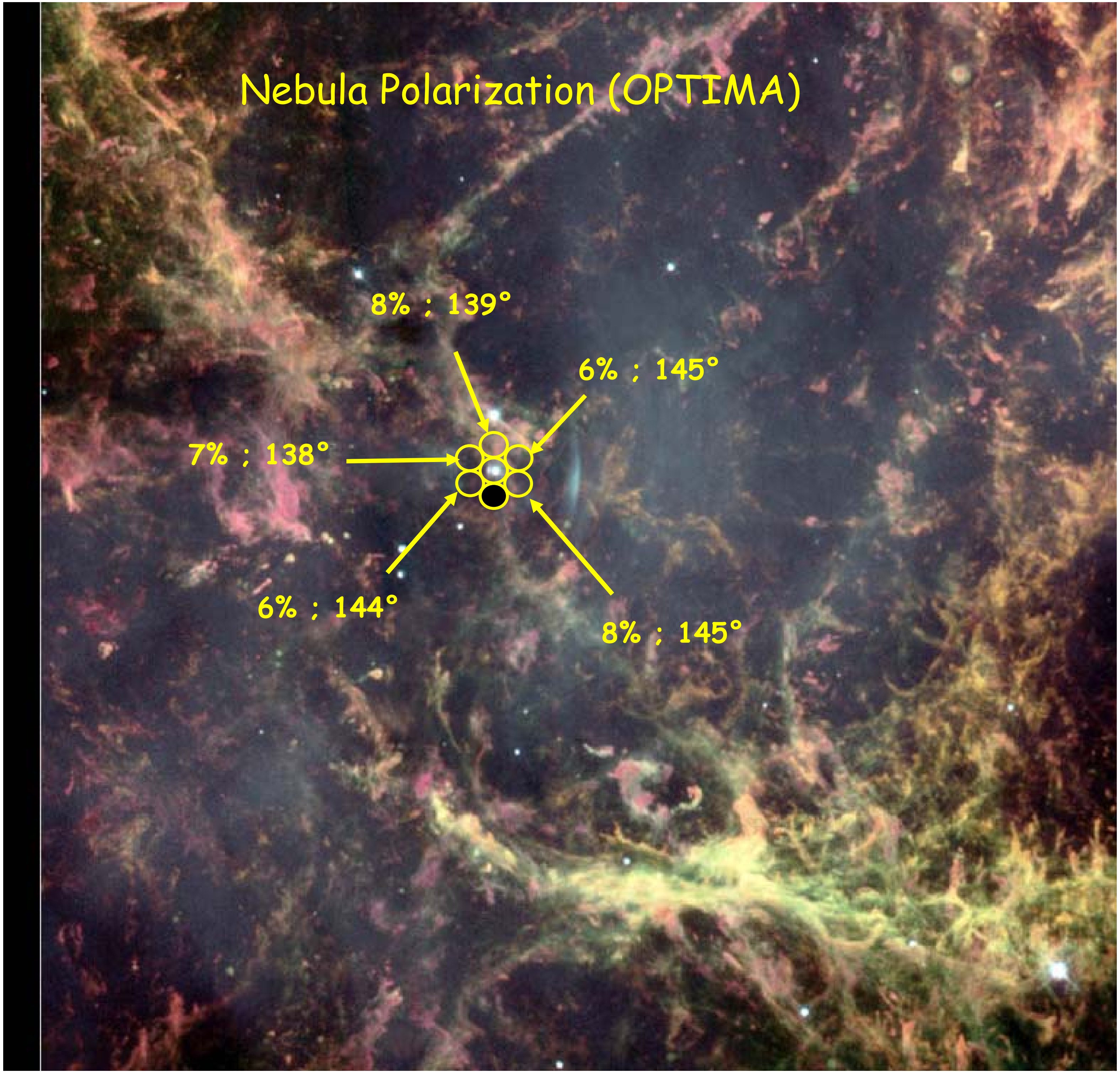
ESO PR Photo 40g/99 (17 November 1999)

The small scale polarization of the Crab Nebula (Schmidt & Angel, 1979)

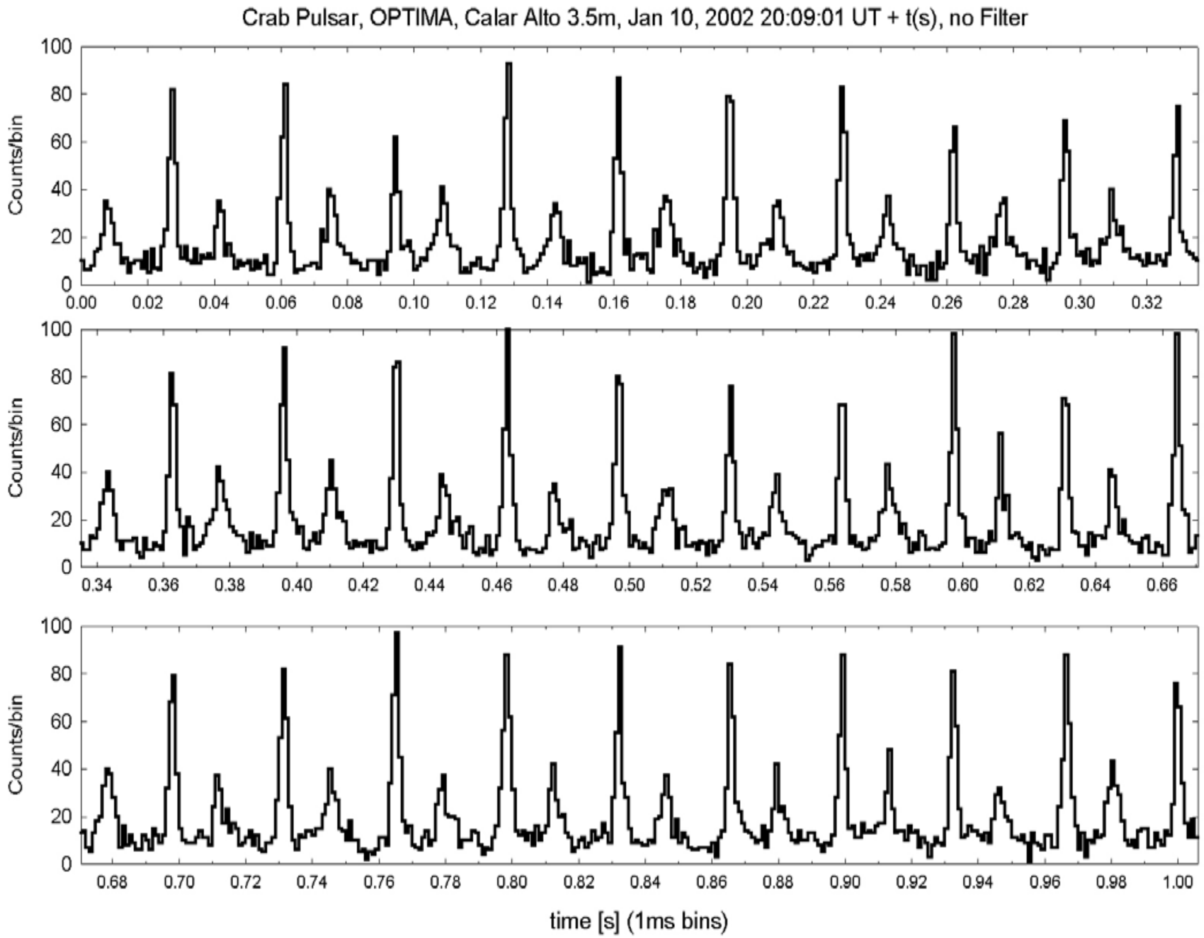


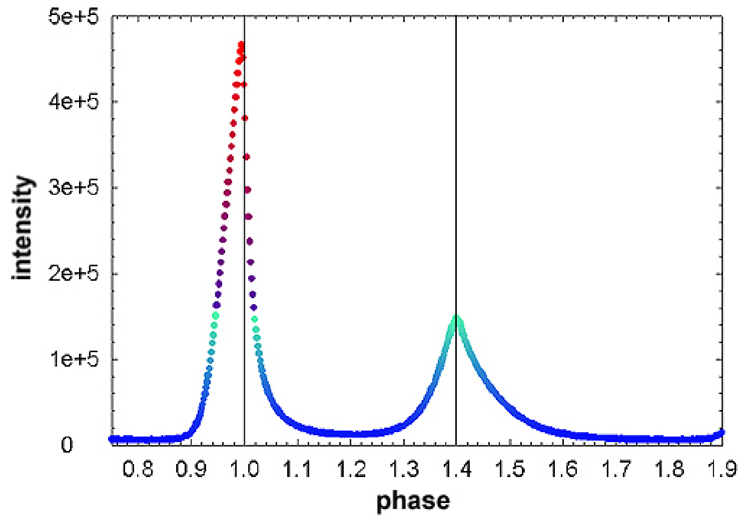
close to pulsar:
degree of polarization: 8-13%
position angle ~ 140°

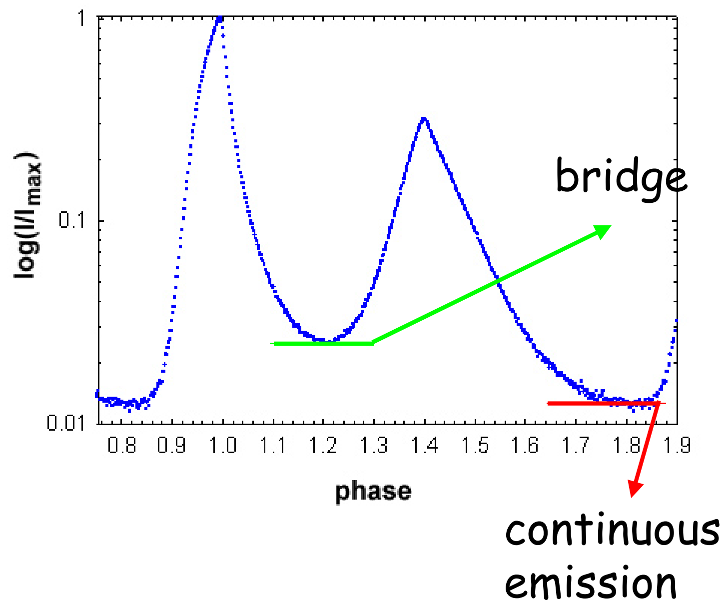
close to pulsar:
degree: 8-13%
angle ~ 140°
(Schmidt&Angel, 79)



Crab single rotation and summed lightcurve

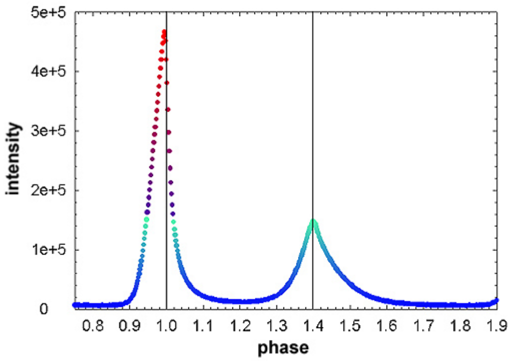






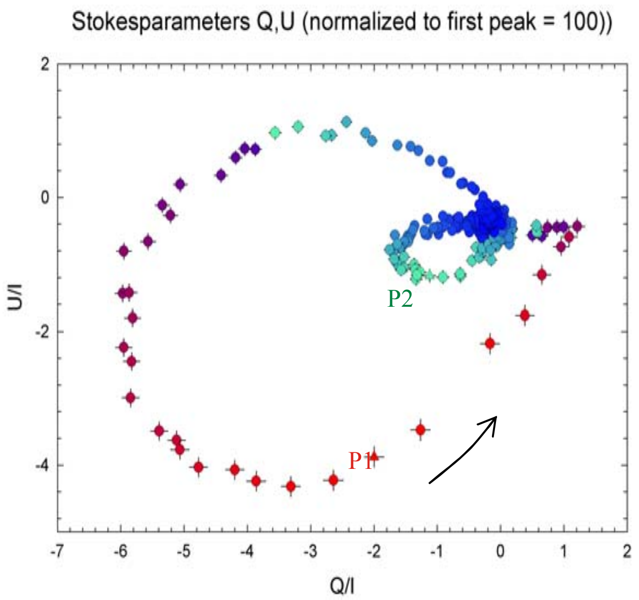
single rotation variability studies
(-> next talk by Aga Wozna)

Crab Polarization (OPTIMA)

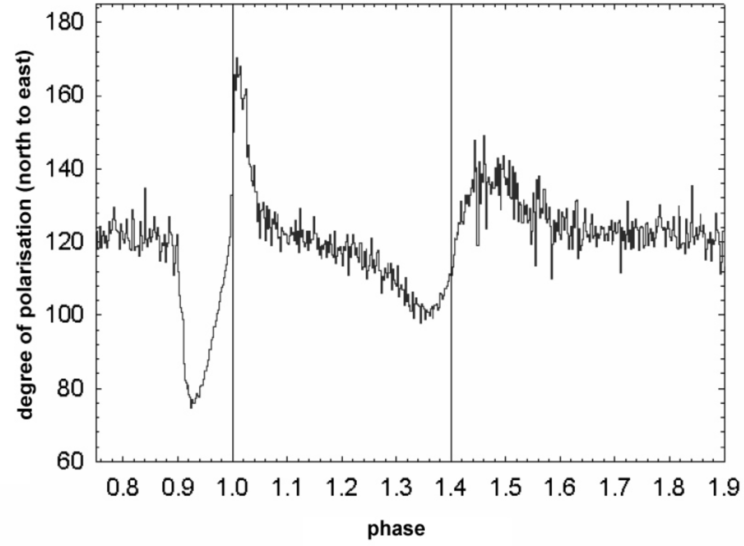


Measure lightcurves for different positions of the rotating polarisation filter at $[\phi_0, \phi_0+90°]$ and $[\phi_0+45°, \phi_0+135°]$.

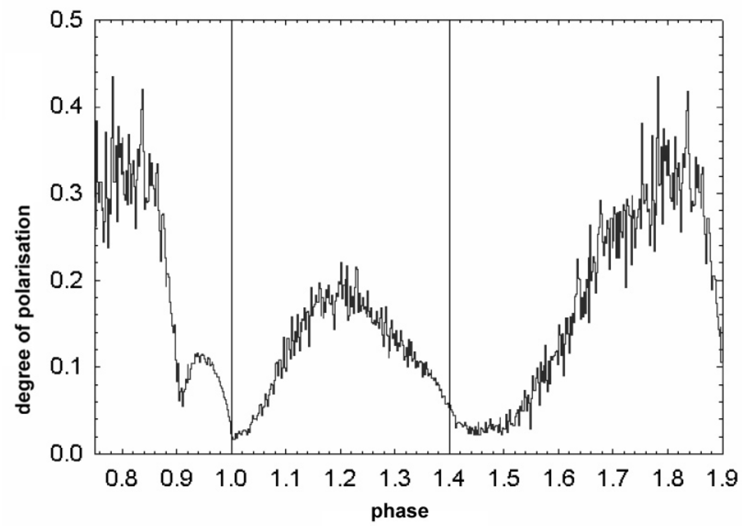
Calculate Stokes-Parameters:
Q=I(0°)-I(90°), U=I(45°)-I(135°)



angle of polarization: $\Theta = \frac{1}{2} \cdot \arctan \frac{U}{Q}$

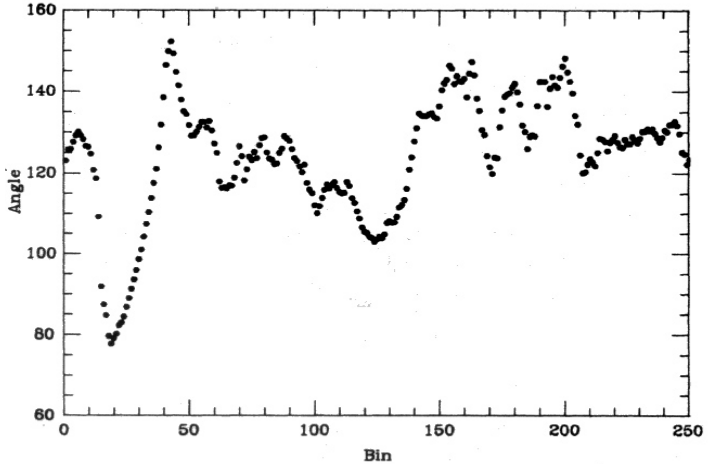


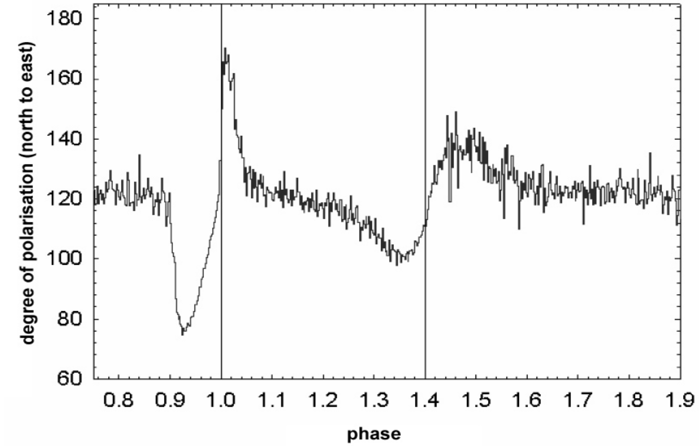
degree of polarization: $V = \frac{\sqrt{Q^2 + U^2}}{I}$

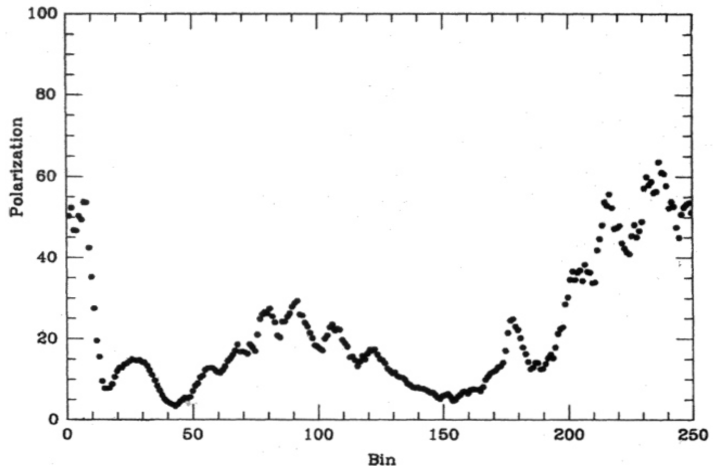


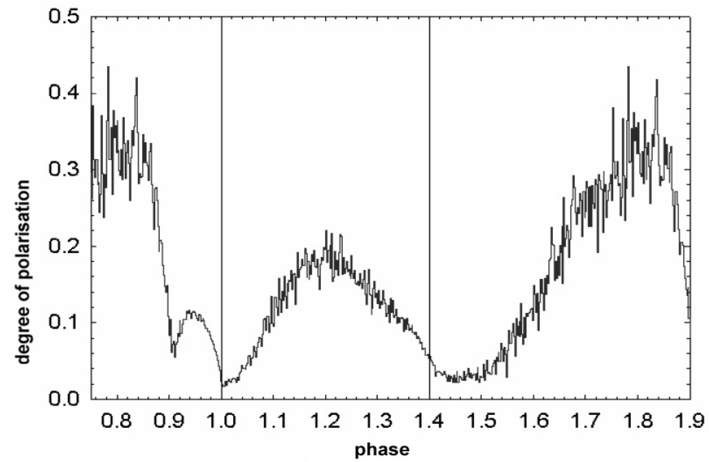
Polarisation Properties of PSR 0531+21

Smith et al. 1988 | **Our results**

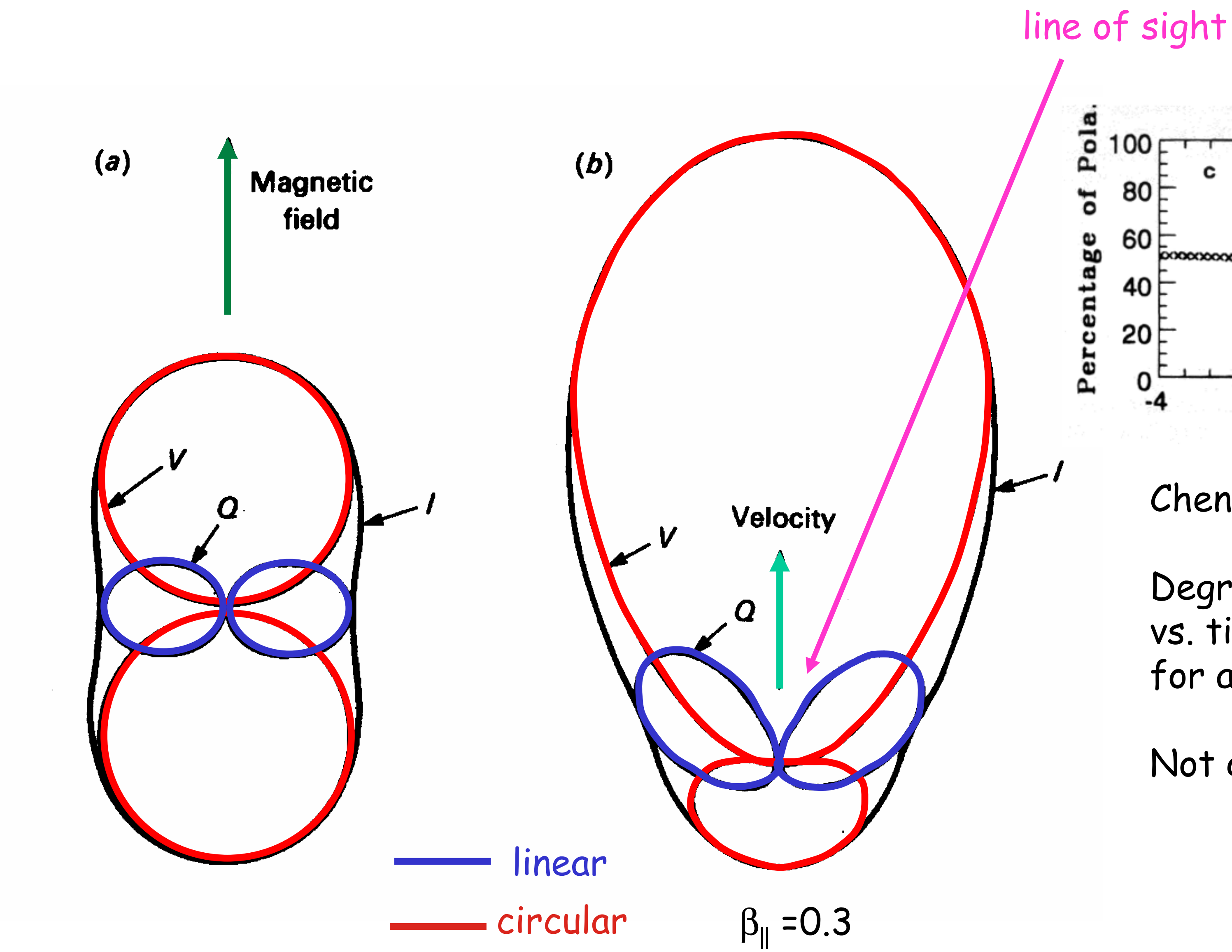


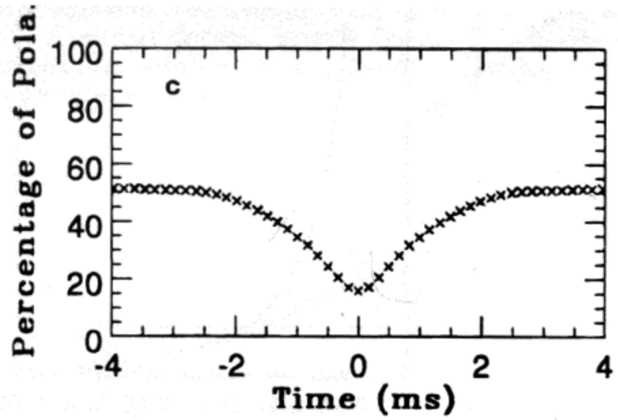






Polarization for Synchrotron emission for relativistic particles with small pitch angles (Epstein, 1973)



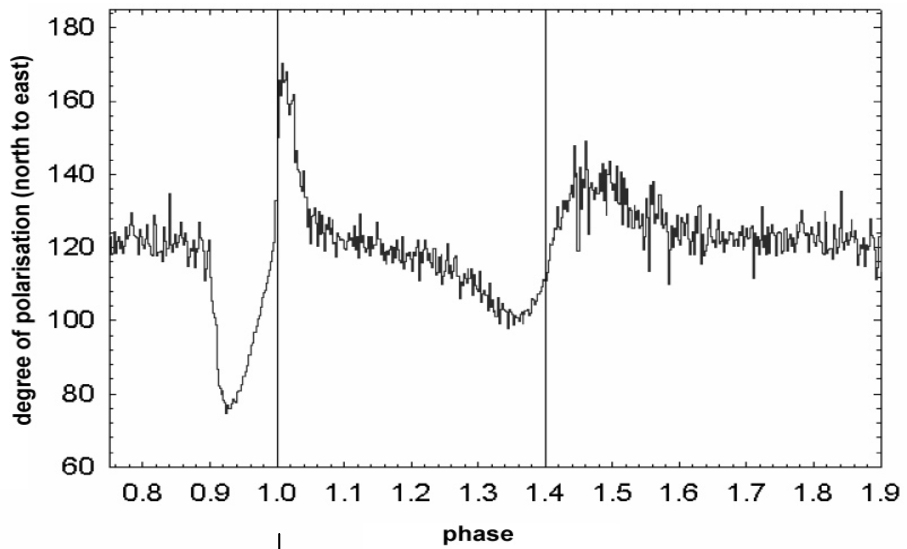


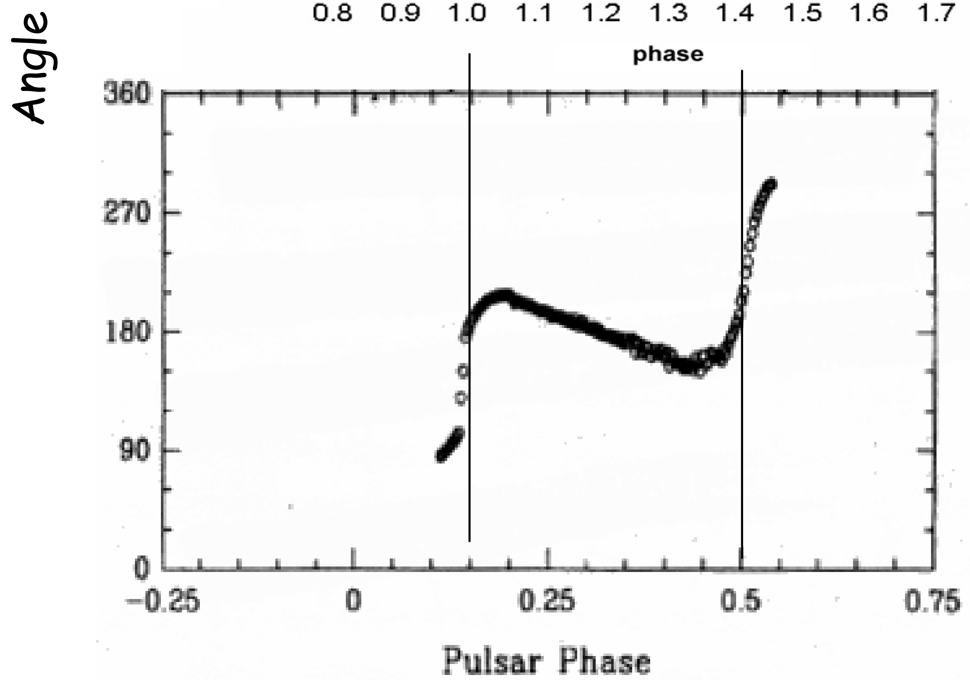
Chen et al., 1996:

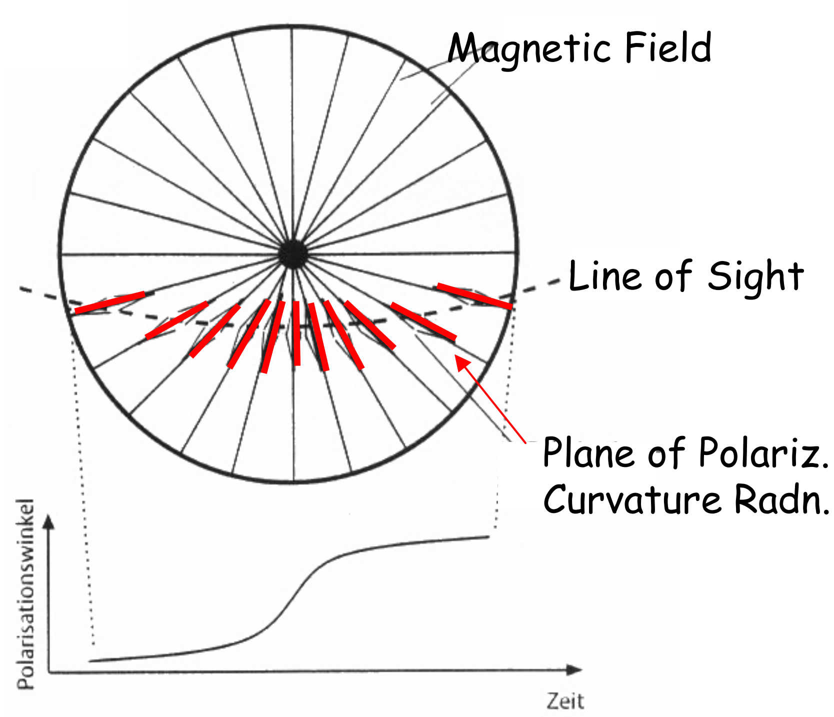
Degree of polarization vs. time (=l.o.s. angle) for an outer gap model

Not quite what we find!

The polarization angle:
Magnetic field Geometry in the Emission regions



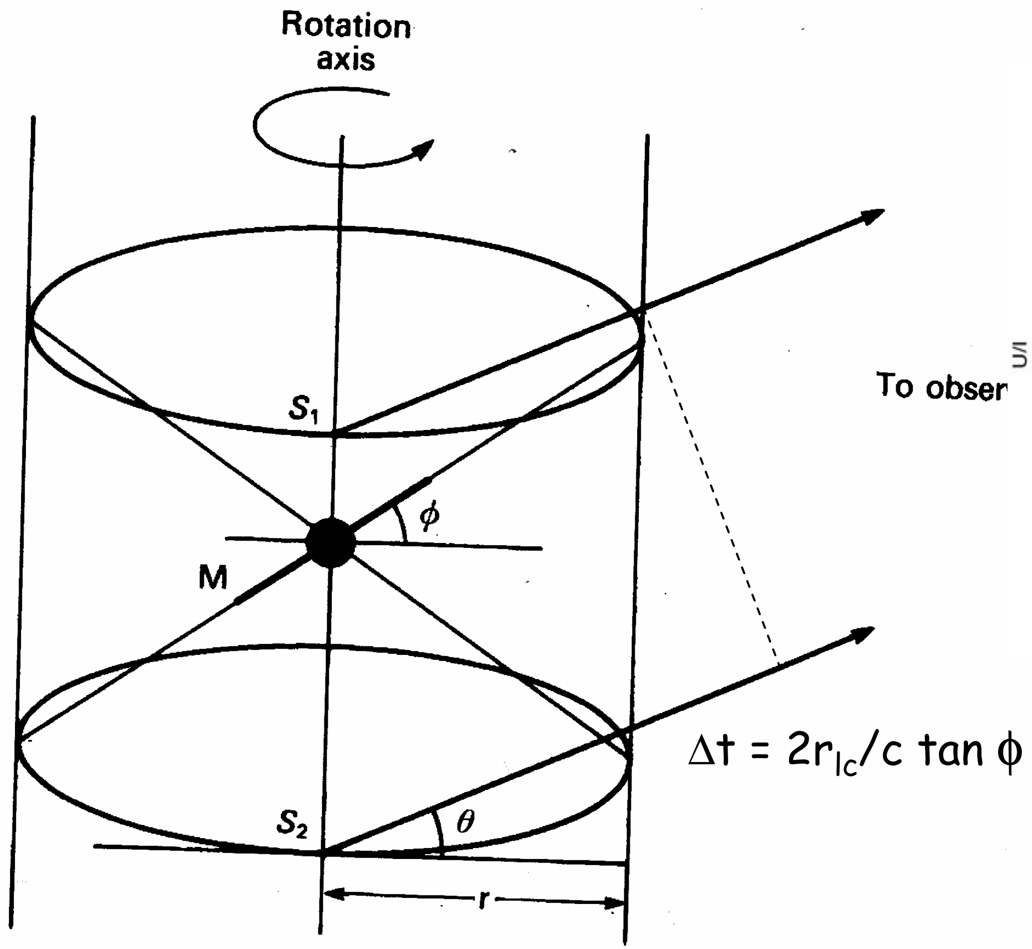


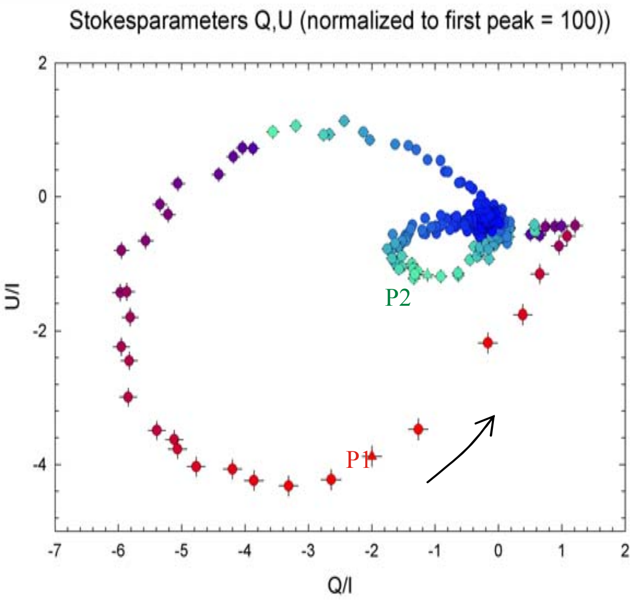


Romani et al., 1995: outer gap model

Two pole emission model (Smith et al., 1988):

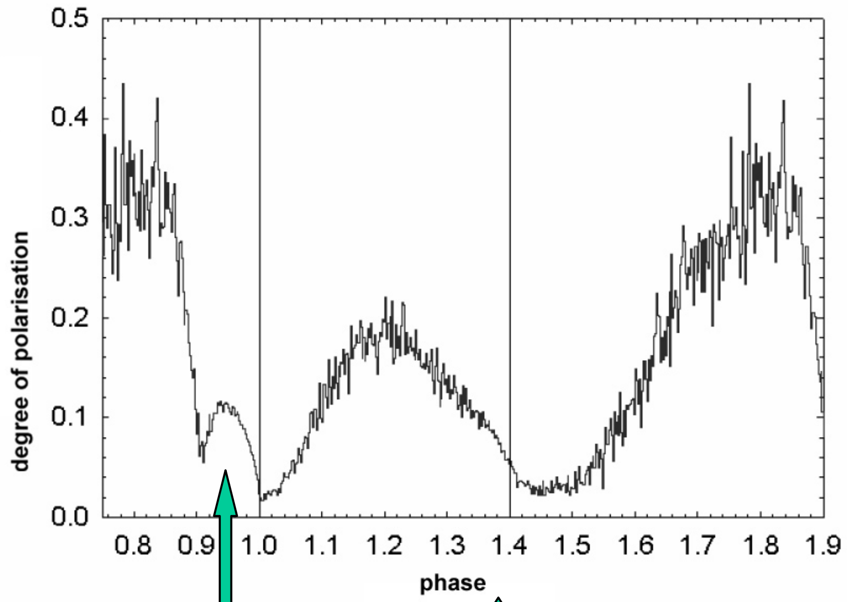
Explanation for the symmetric structure of the Stokes diagram





$\Delta t = 2r_{lc}/c \tan\phi \sin\theta = 2 \tan\phi \sin\theta / \omega$

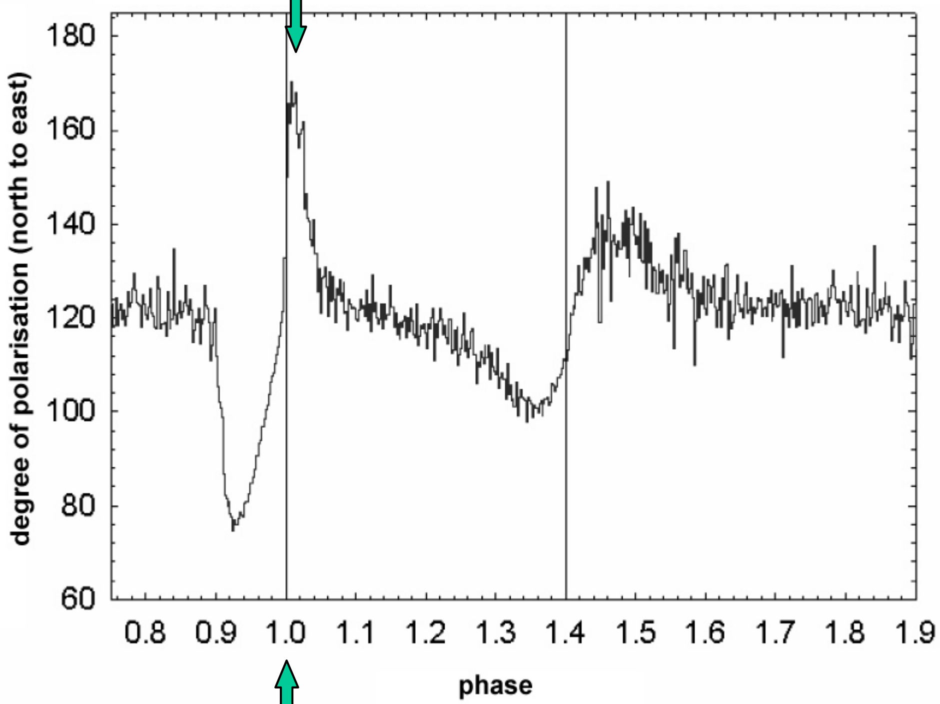
Open Questions



what is this feature on the rising flank of peak 1?

is there a similar feature on the rising flank of peak 2?

what is this overshoot at peak 1?



there is a sharp change of slope of the angular swing at peak 1