Polarimetry

IOT Overview Talk

The 2007 ESO Instrument Calibration Workshop
Garching, January 23-26, 2007

Presented by
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Plan

- Introduction
- Instruments involved
- Near-infrared polarimetry & calibration plan
- Visible wavelength polarimetric instruments & calibration:
  - EFOSC2
  - FORS1
- Opened questions

Introduction

- Why polarimetry?
  - All sources of radiation are (partially) polarised
  - Learn how photons oscillate
  - Magnetic field studies
  - Create 3D maps of dusty environments
- How to measure polarisation?
  - Need a polarising (& analysing) optical element
  - Measure at 4 angles (0, 22.5, 45 & 67.5 deg)

    ==> Derive the Stokes parameters:
    - $Q = I_0 - I_{90}$ - $U = I_{45} - I_{135}$ - V (circular polarization)
    - $P = SQRT(Q^2 + U^2)$, $\Theta = {}^1/_2 \arctan(U/Q)$

Kind of science performed

- Trans-neptunian objects (FORS1)

  ./ Polarimetric and Photometric Phase Effects Observed on Transneptunian Object (29981) 1999 TD10, **P. Rousselot, A. C. Levasseur-Regourd, K. Muinonen and J.-M. Petit**

  Earth, Moon, and Planets, Volume 97, Issue 3-4, pp. 353-364

  ./ A.Exploring the surface properties of transneptunian objects and Centaurs with polarimetric FORS1/VLT observations, **Bagnulo,S. et al**., 2006, A&A .450.,1239
- Supernovae (FORS1)

  ./ Analysis of the Flux and Polarization Spectra of the Type Ia Supernova SN 2001el: Exploring the Geometry of the High-Velocity Ejecta, **Kasen,D. et al.**, 2003, ApJ 593, 788
- Open clusters (FORS1)

  ./ A.Searching for links between magnetic fields and stellar evolution. I. A survey of magnetic fields in open cluster A- and B-type stars with FORS1, **Bagnulo,S.; Landstreet,J.D.; Mason,E.; Andretta,V.; Silaj,J.; Wade,G.**, 2006, A&A 405, 777
- Magnetic field measurements (FORS1)

  Evolution of magnetic fields in stars across the upper main sequence: I. Catalogue of magnetic field measurements with FORS 1 at the VLT, **Hubrig, S.; North, P.; Schoeller, M.; Mathys, G.,** 2006, AN 327, 289
- ULIRGS (EFOSC2)

  Spectropolarimetric search for hidden active galactic nuclei in four southern ultraluminous infrared galaxies**,** **Pernechele, C. et al**, , 2003, MNRAS 338, Issue 1, pp. L13-L17.
- Gravitational lens (EFOSC2)

  PKS 0537-441 - an elusive case of a gravitationally lensed blazar, **Falomo,R., Melnick,J., Tanzi,E.G.,** 1992**,** Astronomy and Astrophysics (ISSN 0004-6361), vol. 255, no. 1-2, p. L17-L19.
- Planetary nebula (SofI)

  Ks polarization mapping of OH 231.8+4.2 (OH 0739-14) with SOFI, **Ageorges N., Walsh JR.**, 2000, A&A 357, 801
- Young molecular nebula (SofI)

  Multi-wavelength imaging of the peculiar Vela Molecular Ridge nebula BBW 192E34, **Burkert,A.; Stecklum,B.; Henning,Th.; Fischer,O.**, 2000, A&A 353, 153

Instruments involved

Near-infrared instruments

Linear imaging polarimetry:

- ✓ SofI
- ✓ ISAAC
- ✓ NaCo

Circular spectro polarimetry:

- ✓ CRIRES

"Optical" instruments

Linear & circular imaging & spectroscopic polarimetry:

- EFOSC2 (IPOL, SPOL,PMOS)
- FORS1 (IPOL, PMOS)

Near- IR polarimetric instruments

- All instruments installed at Nasmyth Focus

  ==> Variable instrumental polarization
- Polarimetry = last minute addendum (except for CRIRES)
  - ✓ CRIRES: cryogenic Wollaston prism & retarder (located close to UT focal plane)
  - ✓ SofI & ISAAC: Wollaston prism
  - ✓ NaCo: half-wave plate + Wollaston prism + 4 wire-grids
- Problem with IR polarimetric calibrators

  ==> Search for secondary polarimetric standards for NIR (Ageorges & Walsh - on going work)

Calibration plan for NIR polarimetric instruments

- CRIRES not considered here
- This observing mode is not really supported by any of the calibration plan.
- No ETC, no pipeline
- **Standards to be requested by user**
- **Calibration plan:**
  - ISAAC: Normal twilight flats without Wollaston
  - NaCo: polarimetric (& normal) lamp flats
  - SofI: flats

Flat field problem !

Calibration of SofI polarimetry: Wolff, Vanzi & Ageorges (2003)

http://www.ls.eso.org/lasilla/sciops/ntt/sofi/archive/pol/tech_rep_polarimetry.ps

Polarimetric mode & NIR instruments conclusion

- Existing modes ‘under-used’
- Most users that do not take polarimetric standards
- Common users polarimetric facilities available to astronomical community since the 80’s.
- ``Despite this development, and the huge benefits in virtually all areas of astronomy, polarimetry has rarely been included in the baseline design of either telescopes or instruments, at least for night time astronomy, and adding polarimeters to existing systems often leads to what should have been unnecessary compromises and perhaps less user-friendly instruments for the non specialist.''

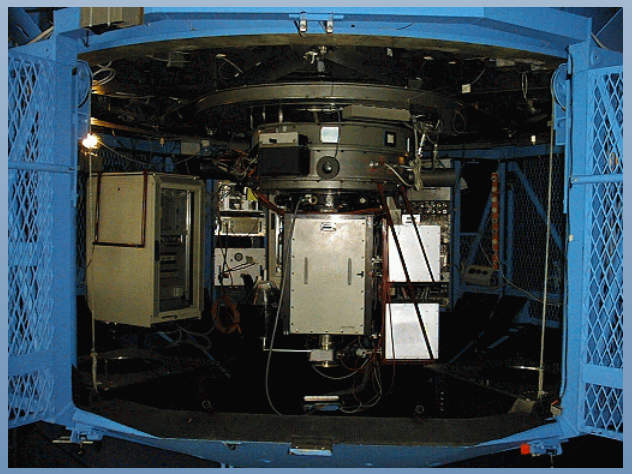
  (Hough 2005)

EFOSC 2

= Focal reducer multi-mode instrument.

part-time mounted on the 3.6m telescope. Wavelength range of operation = [305nm,1100nm].

Field of view is 5.2'x5.2'.



- **Observing modes:**
  - ✓ IMA imaging
  - ✓ MOS multi-object spectroscopy (masks)
  - ✓ LSS longslit spectroscopy
  - ✓ IPOL imaging (linear) polarimetry
  - ✓ SPOL spectropolarimetry
  - ✓ PMOS multi-object spectropolarimetry
  - ✓ COR coronography
- A new polarization unit will be offered in P79; it will allow to measure circular polarimetry, thanks to a quarter-lambda retarder plate (14/08/2006). It will be a copy of the existing one, and holding a new super-achromatic quarter-lambda retarder plate.

EFOSC 2 - calibration plan

IMA

- 10 BIAS
- 3 Dome/Sky-flats per filter

LSS

- 10 BIAS
- 7 Domeflats or internal flats per grism and slit
- 1 HeAr per grism and slit
- Spectrophotometric standards (depends on science case)

MOS

- 10 BIAS
- Domeflats or internal flats
- 1 HeAr per grism and MOS-plate

COR

- 10 BIAS
- 3 Coronographic Sky/Dome-flats

IPOL

- 10 BIAS
- 3 polarimetric Dome/Sky-flats with rotating lambda/2 plate
- Image of the Wollaston mask

SPOL

- 10 BIAS
- 3 Domeflats with rotating lambda/2 plate
- 1 HeAr Spectrophotometric standards (depends on science case)
- Spectropolarimetric standards (depends on science case)

FORS 1

= **FOcal Reducer/low dispersion Spectrograph 1**
= Multi mode optical instrument
UT2 Cassegrain focus
Wavelength range = [330, 1100 nm].
Two different magnifications, on a 2048 × 2048 detector:
0.1"/pixel (High Resolution collimator) ==> 3.4'x3.4' FOV
0.2"/pixel (Standard Res. collimator) ==> 6.8' × 6.8' FOV
Each magnification has to be calibrated independently.

Observing modes:

- IMA imaging fast
- OCC imaging with occulting bars FIMS
- LSS longslit spectroscopy fast
- MOS multi-object spectroscopy (movable slits) FIMS
- IPOL imaging polarimetry fast
- PMOS multi-object spectropolarimetry FIMS & fast
  SR collimator only
  fast mode PMOS observations are only for single target on 1 slit

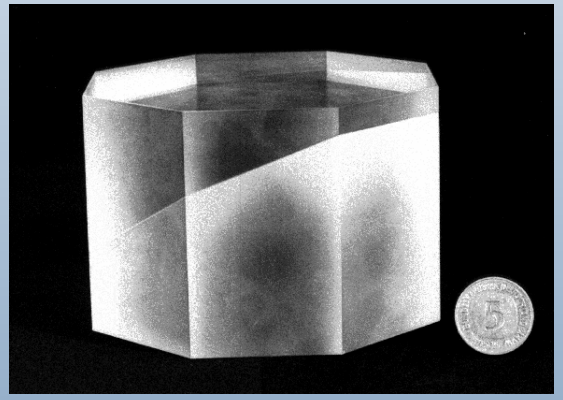
FORS1 Polarimetry

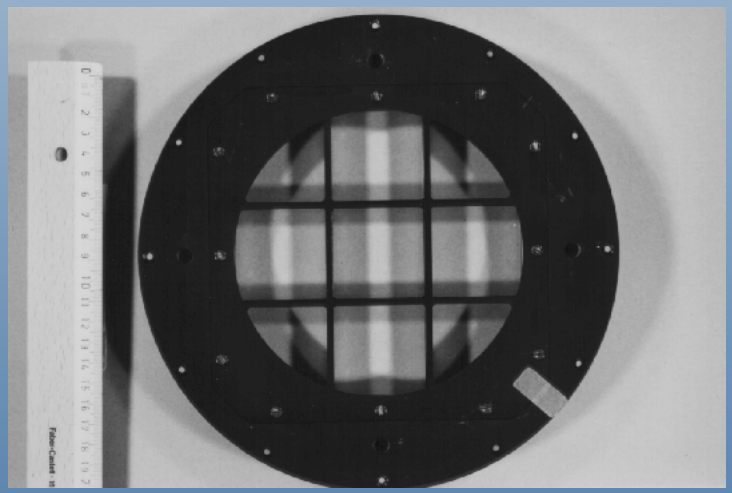
- Use a remotely controlled rotating lambda/2- or lambda/4-plate in front of the Wollaston prism.
- Retarder plate = superachromatic type

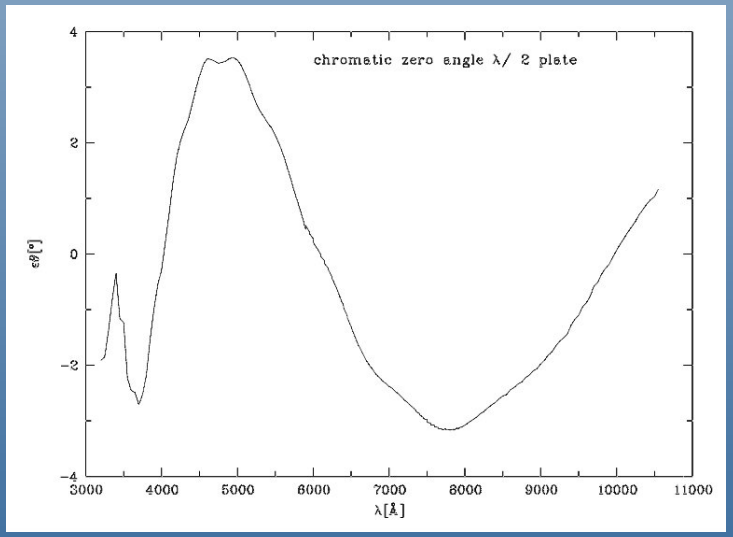
  = mosaic of 3x3 plates of 45.4x45.5mm

  (inter-plate gap 3mm) ==> free mosaic diameter of 138mm

  Positionnning accuracy of 0.1deg
- For Linear polarization, it is necessary to correct for the chromatic zero angles







Amount of chromatism of the wave plate

Request of FORS1 polarimetric modes in service mode

Period	IPOL (#OBs)	Exectime (hrs)	PMOS (#OBs)	Exectime (hrs)	Total # OBs submitted
73	45	48.8	371	258.1	1050
74	43	29.2	32	22.6	329
75	44	28.5	202	112.3	754
76	61	42.1	13	11.3	464
77	65	50.1	58	37.3	807
78	77	79.2	77	38.9	791

FORS 1

- ✓ Imaging (linear/circular) Polarimetry
  BVRIz fi
  R=23. 0 =
  "Mag-limit" =
  dark sky, cle

- ✓ Spectro
  All grism
  [λ/Δλ]=260
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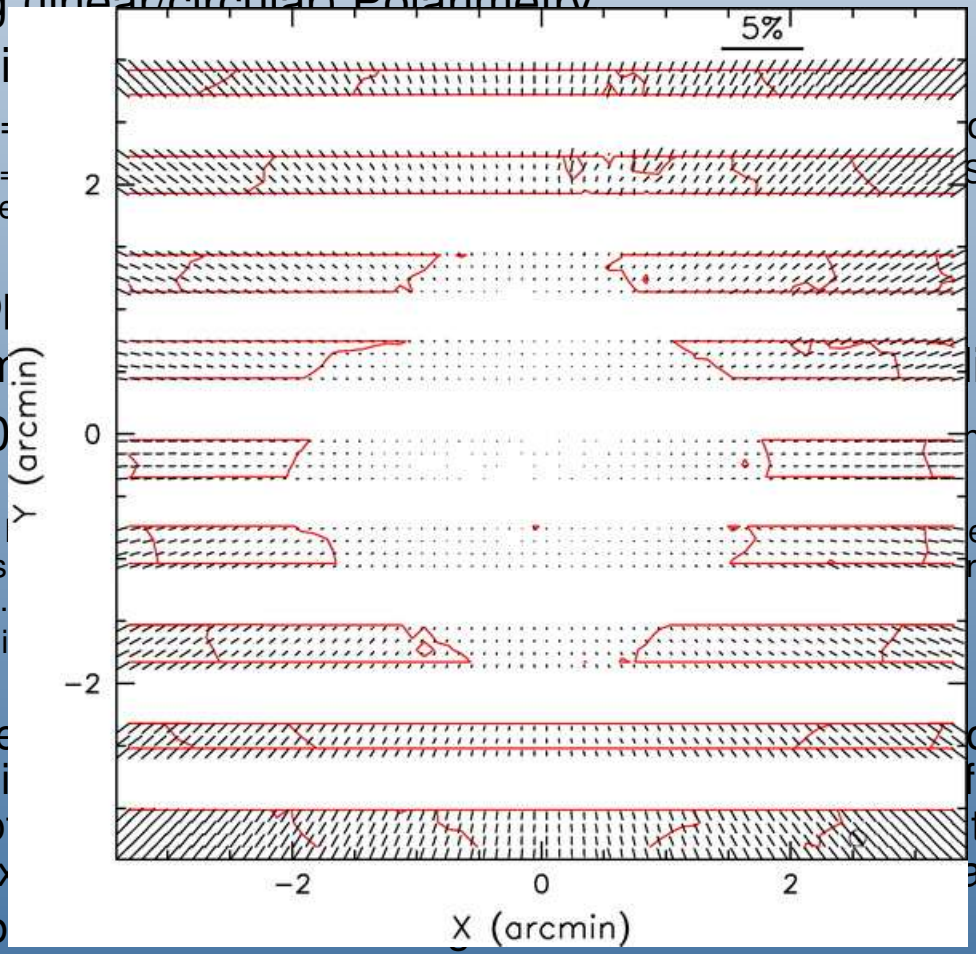

FORS1 instrumental polarization
B band. Contours at 0.3%, 0.6% & 0.9% polarization levels.
Coordinates (') refer to the geometrical center of the detector

FORS1 calibration plan

- Observations of 1 polarized standard star every night polarimetric science observations are performed

  (For linear polarisation, the same mode & set as for the observations)

==> Check that polarimetric optics are correctly positionned

==> Improve the characterisation of the the achromatism of the retarder plate

- Observations of 1 unpolarized standard star at least once a year

==> Measure the instrumental polarisation

Accuracy reached with IPOL is not sufficient to measure the instrumental polarisation with high precision

FORS1 calibration plan - 2

Missing:

- ✓ Monitor the instrumental polarization as derived from the calibration plan
- ✓ Check of the circular polarization

  Instrumental circular polarization ~ 0 (Bagnulo et al. 2002). However results of survey of magnetic stars in open cluster indicates there might be some cross-talk

  ==> Investigation of lunar polarization by Sterzik & Bagnulo on granted technical time
- ✓ Further characterisation of the instrumental polarization is needed as showed by Patat & Romaniello

  Fossati et al (2007) = Analysis of observations obtained within the calibration plan.

  TBC to better characterised the $\lambda/4$ retarder plate.

Opened questions

What can we do to get you interested in NIR polarimetry?

How can we help you performing good observations leading to publications?

We need your feedback

More about science: the next talk (H.M Schmid) & poster # 16

More about calibration sources in the NIR: Poster #2

More about instruments & polarimetry: poster #12