



DEPARTMENT FÜR  
PHYSIOLOGIE UND  
MEDIZINISCHE PHYSIK

UV@INNSBRUCK



MEDIZINISCHE UNIVERSITÄT  
INNSBRUCK

# Measured distribution of polarization of sky radiance

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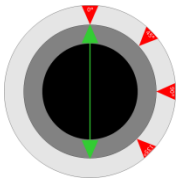
Biomedical Physics  
Innsbruck Medical University

# Overview

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- Polarization and Stokes Parameter
- Spectroradiometer
- Fisheye-Camera
- Combination of Fisheye-Camera images with spectroradiometer data

# Stokes - Parameter



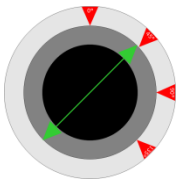
$I(0^\circ)$

## Stokes – Parameter I, Q, U

$$I = I(0^\circ) + I(90^\circ) = I(45^\circ) + I(135^\circ) \quad (\text{quality check})$$

$$Q = I(0^\circ) - I(90^\circ)$$

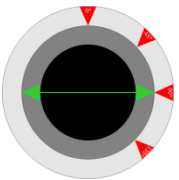
$$U = I(45^\circ) - I(135^\circ)$$



$I(45^\circ)$

## Degree of Polarization

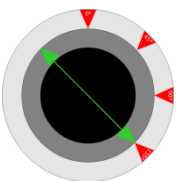
$$P = \frac{\sqrt{U^2 + Q^2}}{I}$$



$I(90^\circ)$

## Angle of Polarization

$$D = \frac{1}{2} \arctan \left( \frac{U}{Q} \right)$$

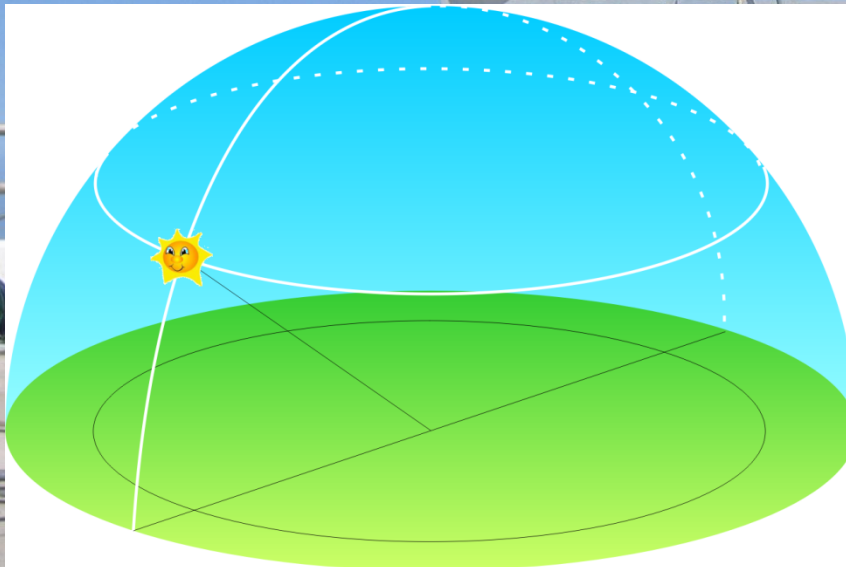


$I(135^\circ)$

# Spectroradiometer with suntracker

Input optics with linear polarization filter  
and stabilized Bentham DM300 monochromator

Measures one point at one wavelength at a time,  
needs to scan sky for the whole picture



+ high precision measurement  
with high wavelength  
resolution

- slow (20 min for Almucentar  
and Principal plane)

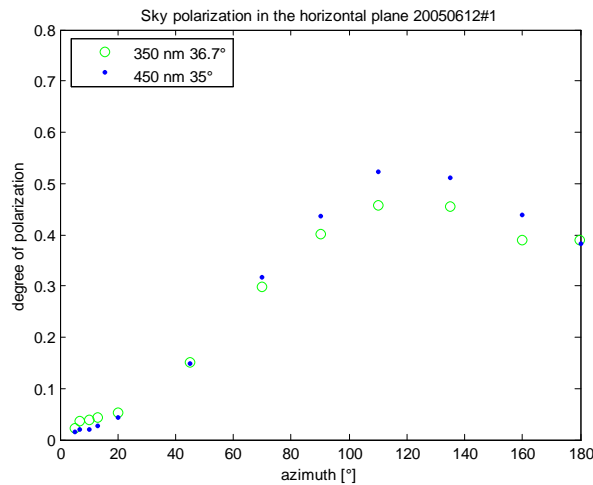
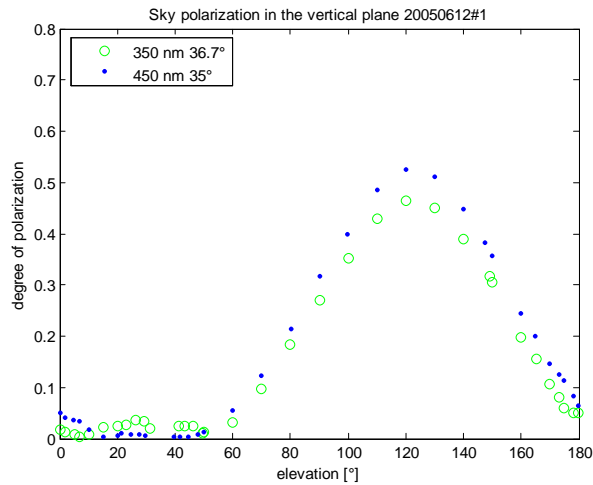
# Measurement data

## Spectroradiometer

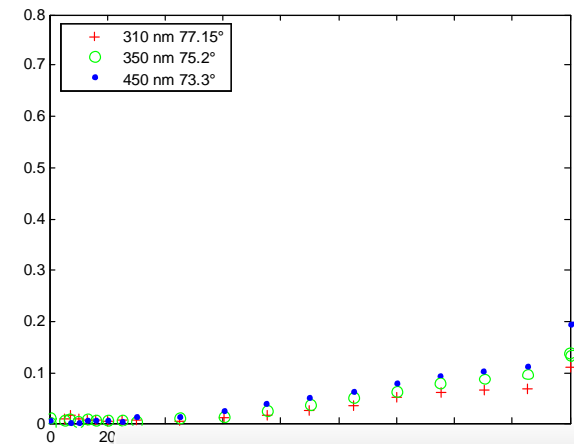
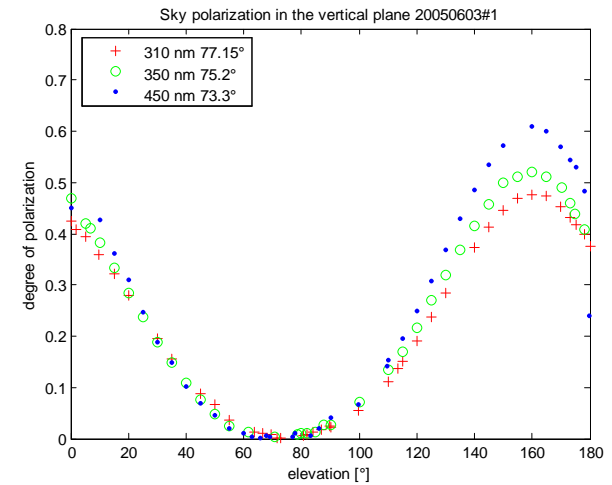
Principal plane

Almucantar

### Low solar elevation



### High solar elevation



# Fisheye Camera

A fisheye camera view of a snowy mountain peak. In the foreground, a person wearing a red and blue jacket and a black beanie is visible. The background shows a vast, snow-covered mountain range under a clear blue sky. The camera's wide field of view captures the entire scene within a circular frame.

+ whole sky in less than 1 minute

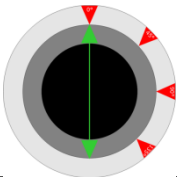
- Broadband measurement
- no UV data
- 8 bit resolution

# Fisheye Camera

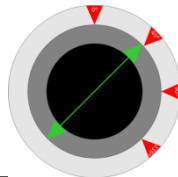
March 06 Kastelorizo, Greece



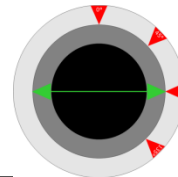
I(0°)



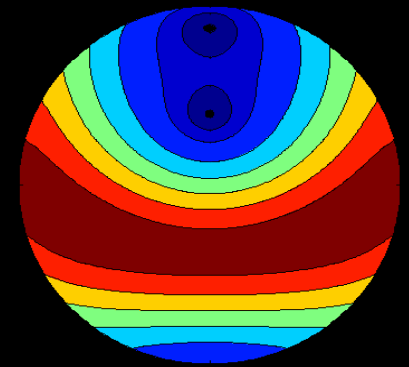
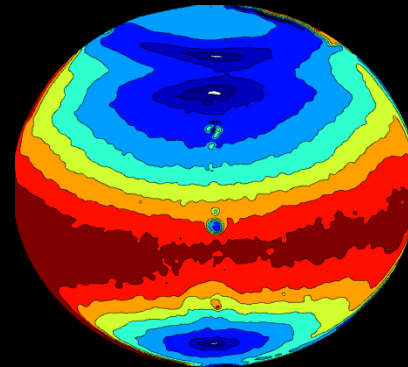
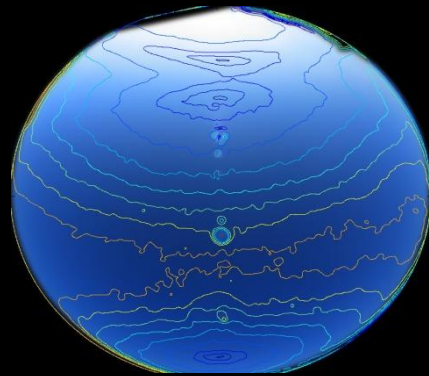
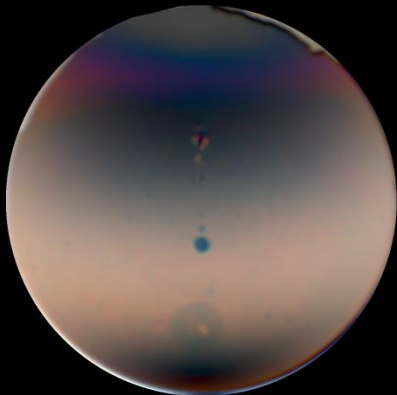
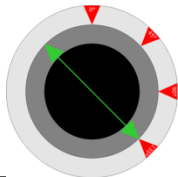
I(45°)



I(90°)



I(135°)



# Fisheye Problems

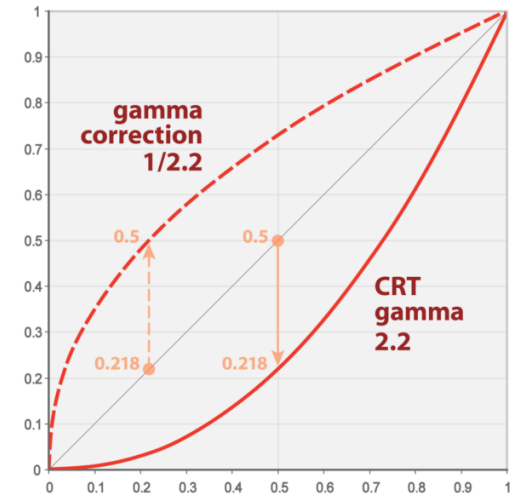
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- Reflections
  - removing (by shadowfinger, by software)
- Noise, alignment, image „improvements“ in camera
  - smoothing (averaging over several pixels)
- Gamma
  - correcting
- Limited dynamic range
  - taking pictures at different exposure times

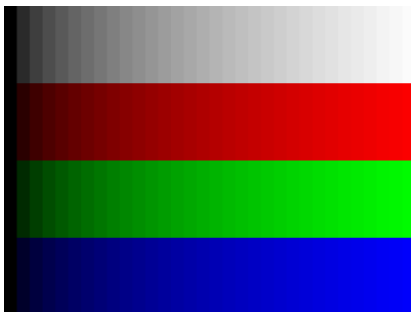
# $\gamma$ -correction

Digital compact camera does not store Intensity  $I$  directly, but stores  $A=I^\gamma$  ( $\gamma=2$ )

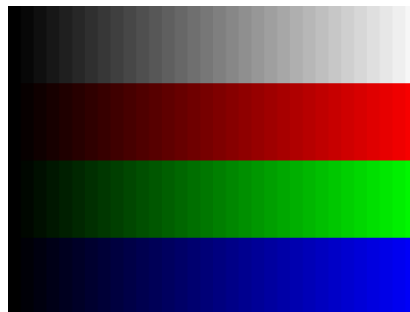
$\gamma$ -correction uses  $I=A^{-\gamma}$  to reconstruct Intensity



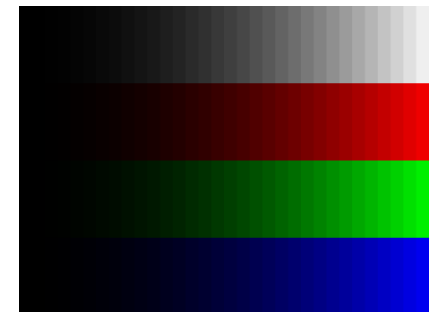
$\gamma=0.5$



$\gamma=1$

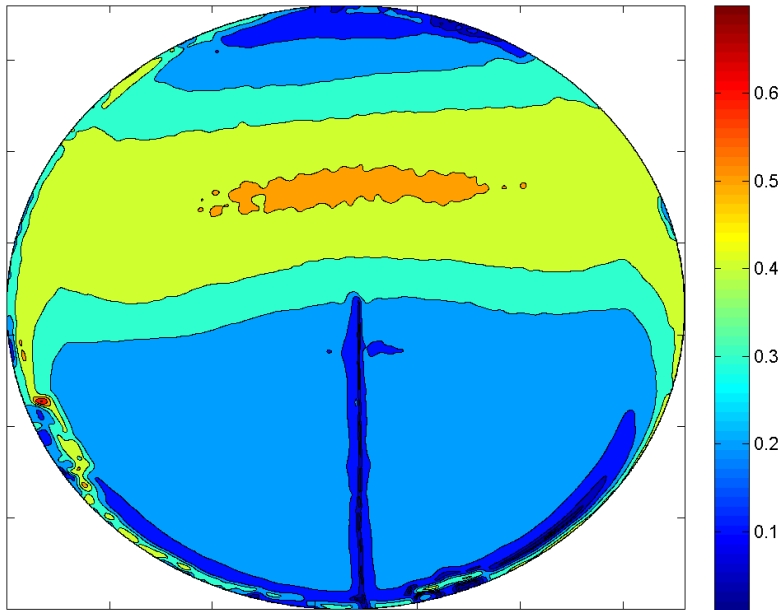


$\gamma=2$



# Reflections

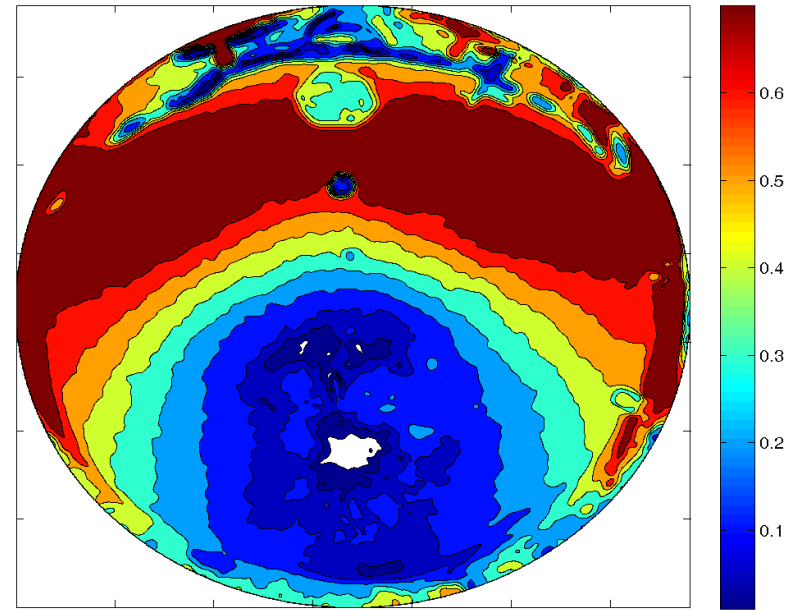
## Shadow finger



July 23<sup>rd</sup>, 2006, Thessaloniki, Greece

- + almost no reflections
- half of principal plane covered
- mechanically tricky

## Exclusion after measurement



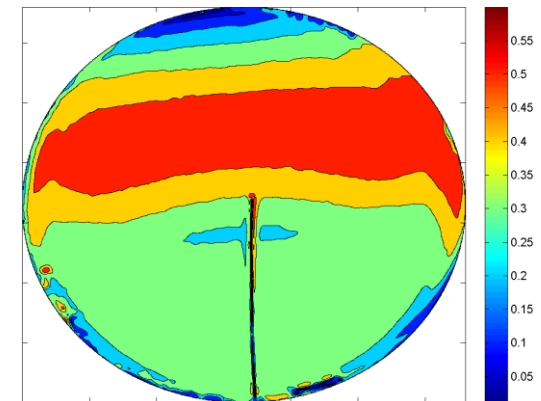
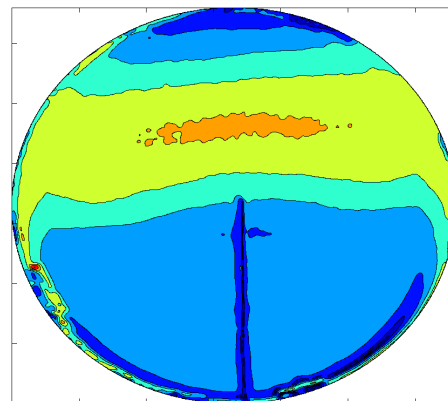
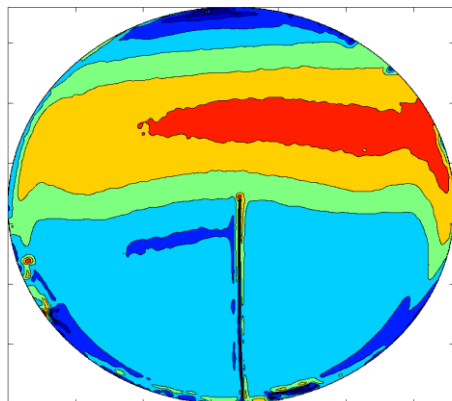
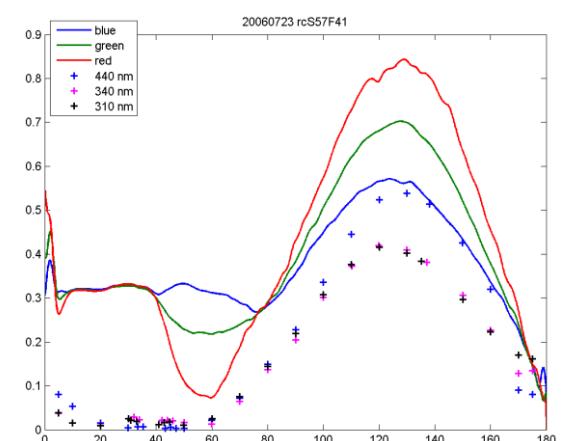
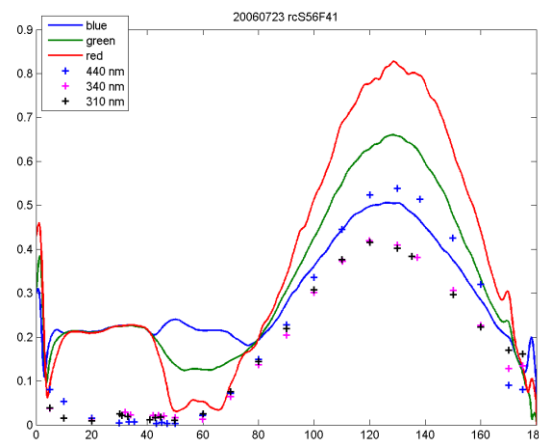
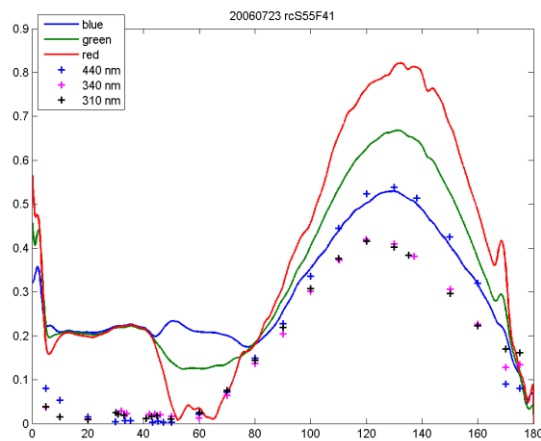
July 13<sup>th</sup>, 2007, Innsbruck, Austria

- + data at  $\sim 90\%$  of principal plane
- tricky for automated data analysis

# Comparison Camera - Radiometer

## Principal Plane

July 2006, Thessaloniki, Greece





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Thanks to: Barbara Schallhart

Last, but not least: Thank you for your attention!