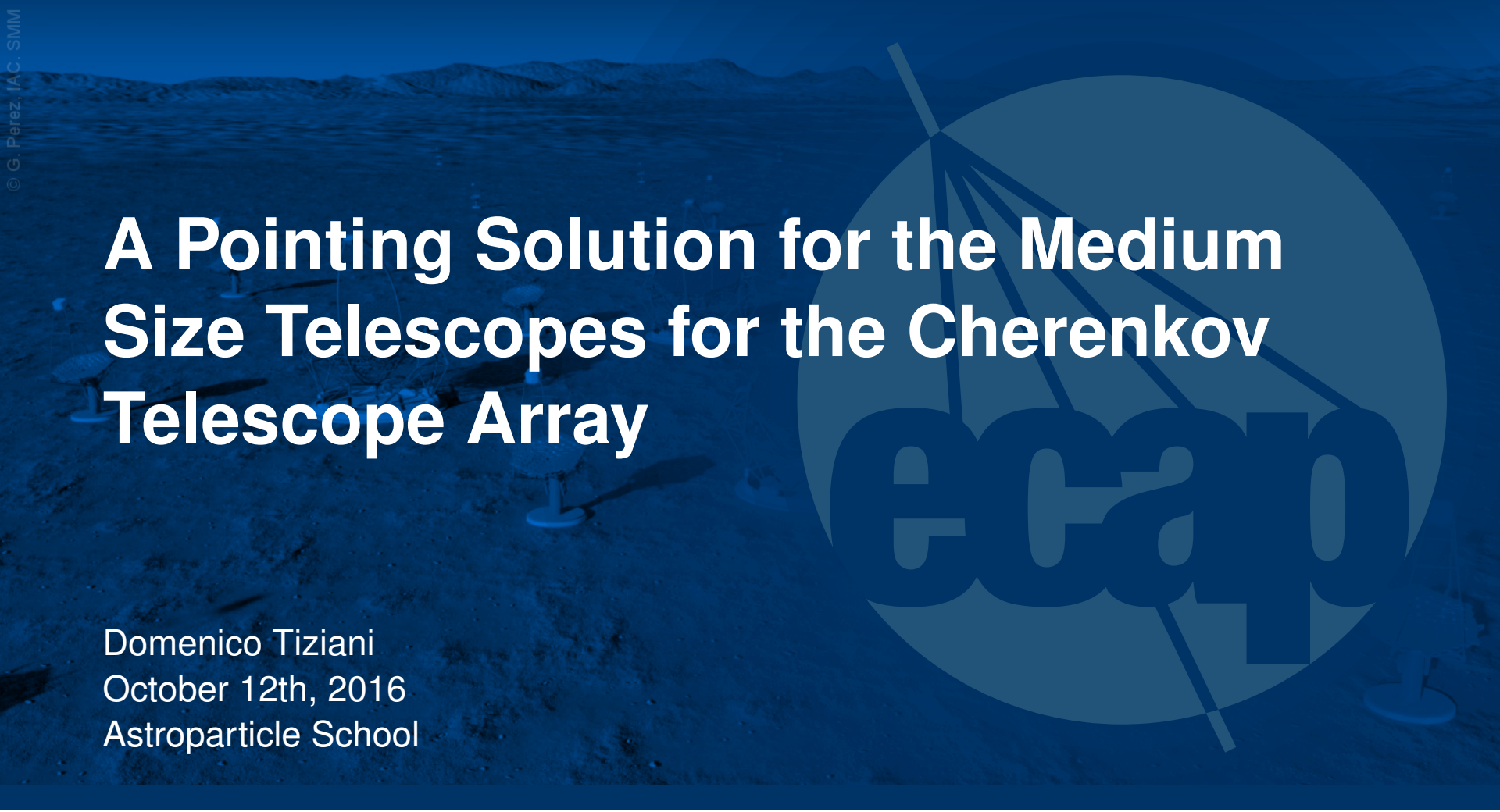
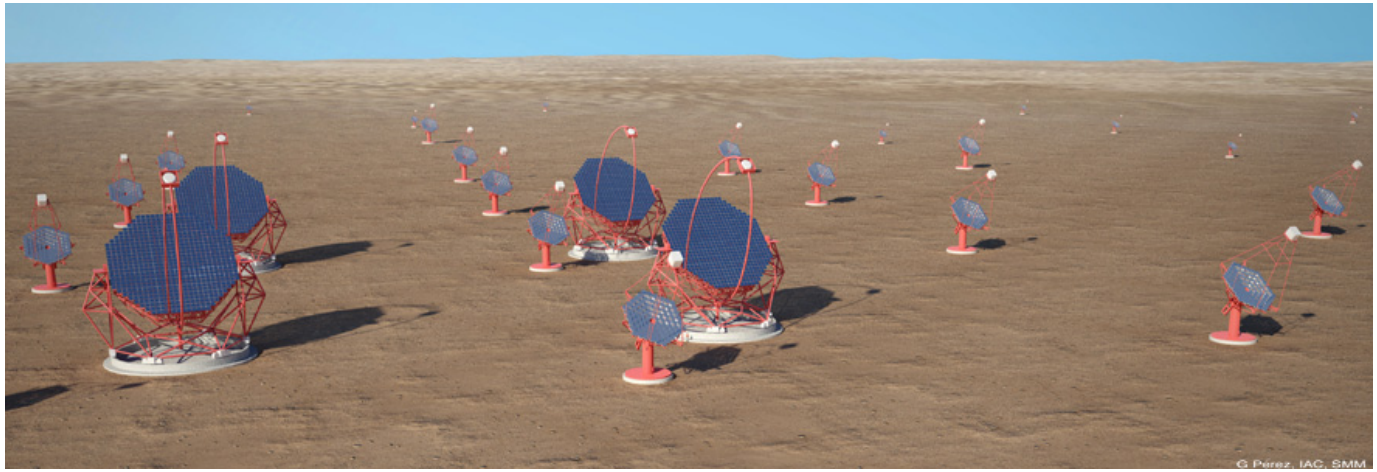


A Pointing Solution for the Medium Size Telescopes for the Cherenkov Telescope Array

Domenico Tiziani
October 12th, 2016
Astroparticle School

cta cherenkov telescope array
ecap ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS
FAU FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG
NATURWISSENSCHAFTLICHE FAKULTÄT

Cherenkov Telescope Array (CTA)



http://www.hap-astroteilchen.de/aktuelles-2014.php

- Next generation gamma-ray telescope
- Currently in pre-construction phase
- Consisting of $\sim$100 individual mirror telescopes in 3 different sizes
- Detecting Cherenkov light from atmospheric particle showers

Pointing and Sources of Errors

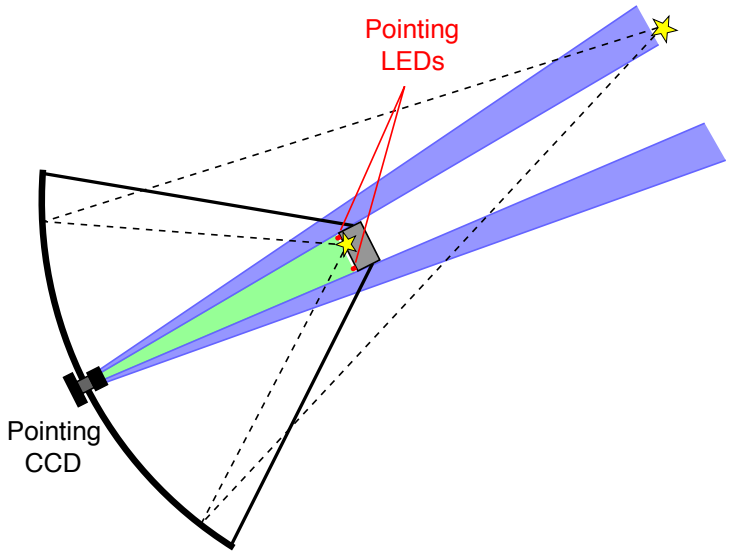
- Pointing:

  Alignment of a telescope to a certain position in the sky
- Possible sources of errors
  - Uncertainties in telescope tracking
  - Offsets and rotations of Cherenkov camera
  - Bending of telescope components
- Caused by:
  - Gravity (elastic)
  - Wind load, thermal expansion (inelastic)
- CTA requirement: precision < 7”

http://www-zeuthen.desy.de/cta_cam/photogallery1/content/Baustelle_2013_09-10_large.html

Pointing Runs

- Step-by-step scanning of the sky above the telescope
- Imaging of star positions and Cherenkov camera by an optical CCD camera
- Comparison of desired pointing and actual alignment
- Generation of a model for mis-pointing
- Additional measurements of short-term deformations during observations increase precision

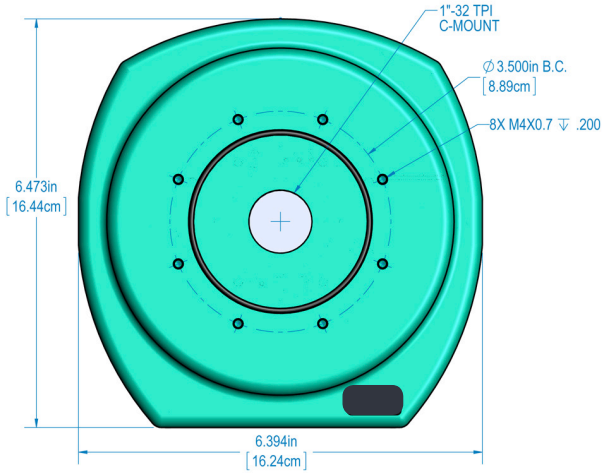


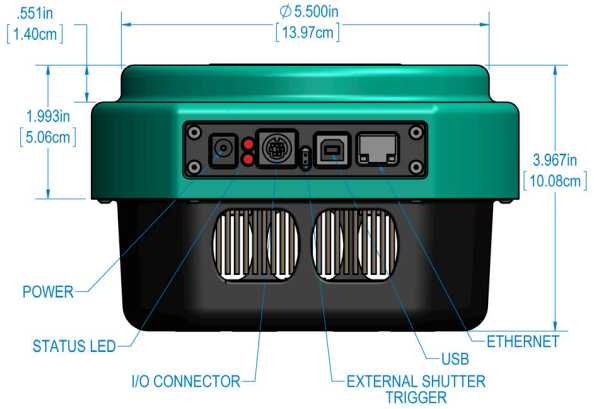
Herpich 2010

Requirements for the Pointing CCD

- Both stars and Pointing-LEDs visible in images
- Active chip-cooling to avoid chip expansion
- High reliability
- Mechanically rigid and weather-proof housing for protection against:
  - Moisture, dust
  - Temperatures during operation: $-15\ ^{\circ}\mathrm{C}$ - $+25\ ^{\circ}\mathrm{C}$
  - Survival temperatures: $-20\ ^{\circ}\mathrm{C}$ - $+40\ ^{\circ}\mathrm{C}$

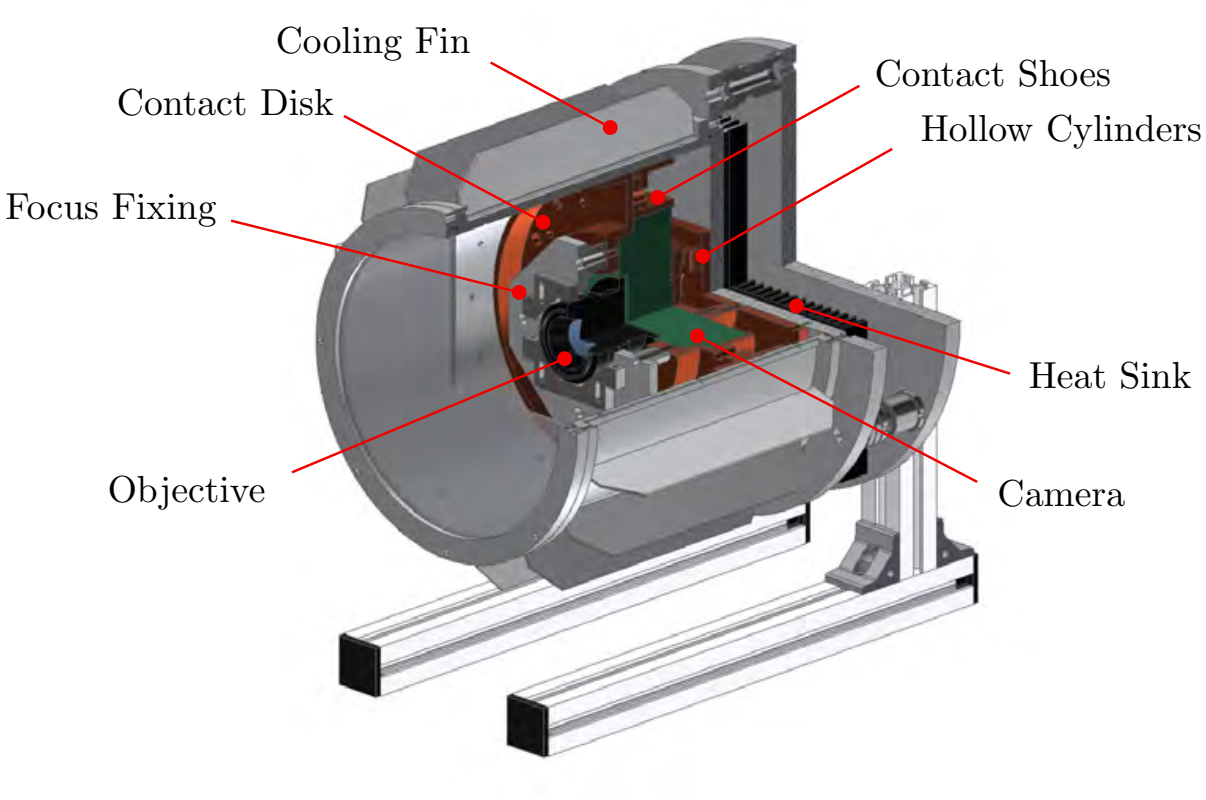
Camera: Apogee Aspen CG8050-S-G01-HSH





- Astronomical CCD camera, 3296 x 2472 Pixels à $5.5\ \mu\mathrm{m}$
- Interline sensor with electronic shutter
- Nikkor lens 50 mm $\rightarrow$ field-of-view about $20.5° \times 15.4°$
- Operating temperature stated by manufacturer: $-20\ °\mathrm{C}$ - $+40\ °\mathrm{C}$

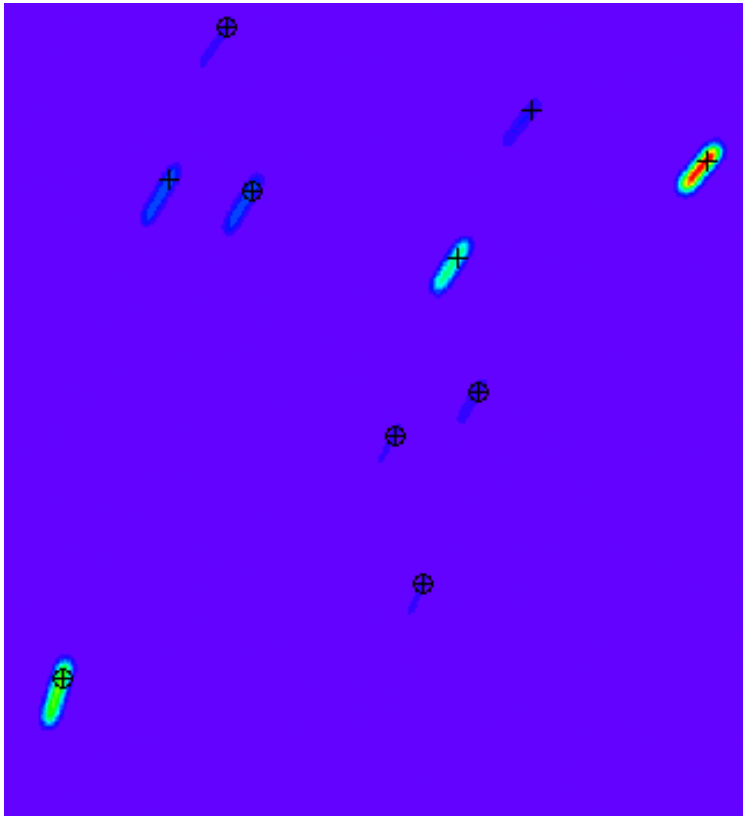
Housing with Optimized Thermal Conduction

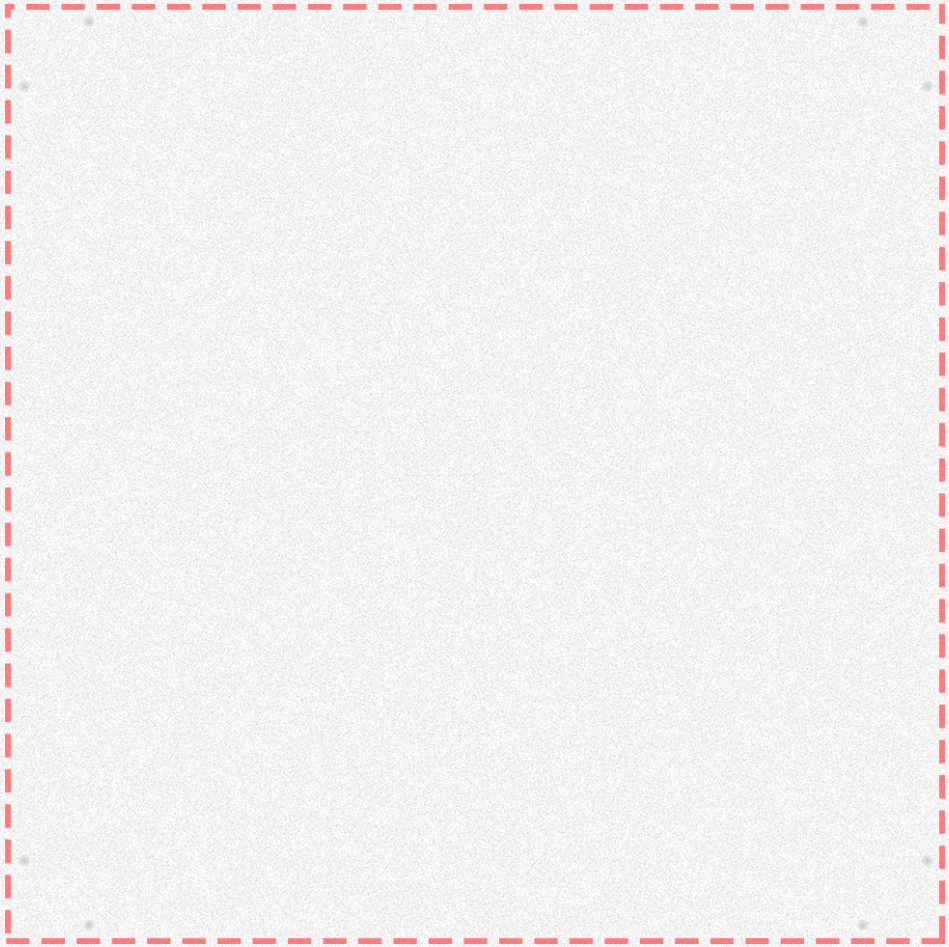


Simulation of Images in CCD Camera

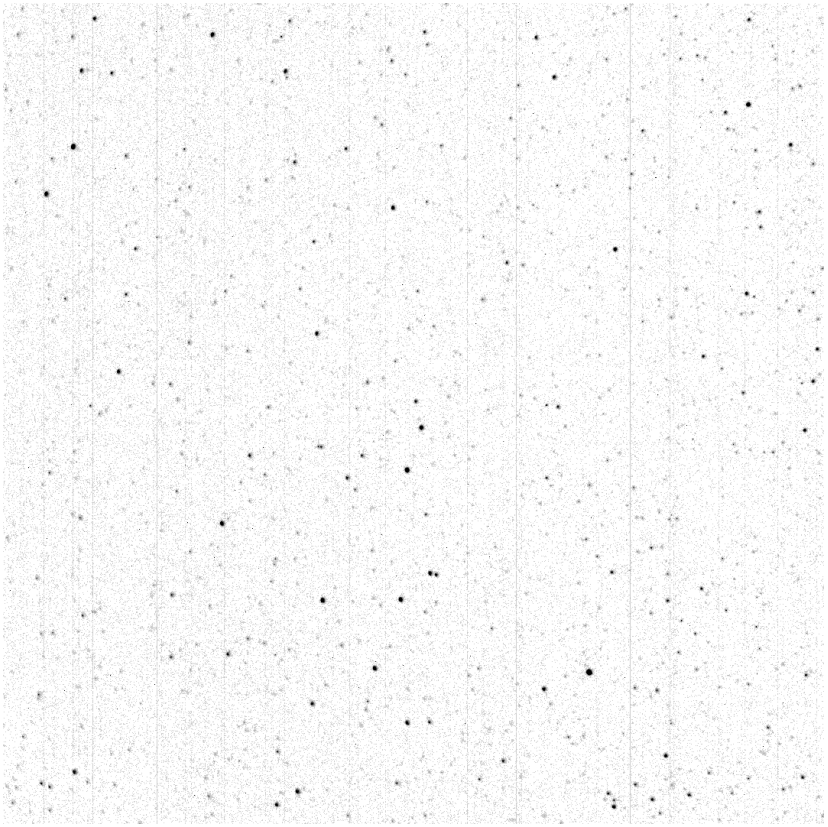
Simplified simulation of an exposure:

- Star positions from catalog
- LED positions on Cherenkov camera
- Mapping into plane of CCD-chip
- Approximating of star images as Gaussian distributions
- Telescope tracking and exposure in discrete time steps

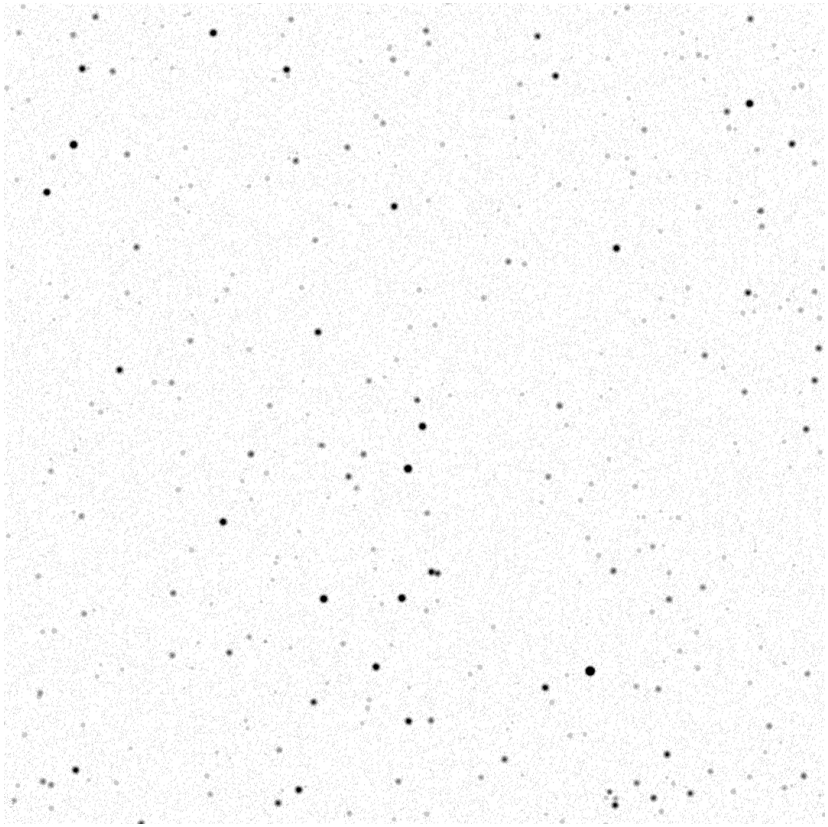




Comparison between Simulation and Real Images



Photography



Simulation

Image Analysis: Astronomical Calibration

Adoption of open source software

1) Source extraction

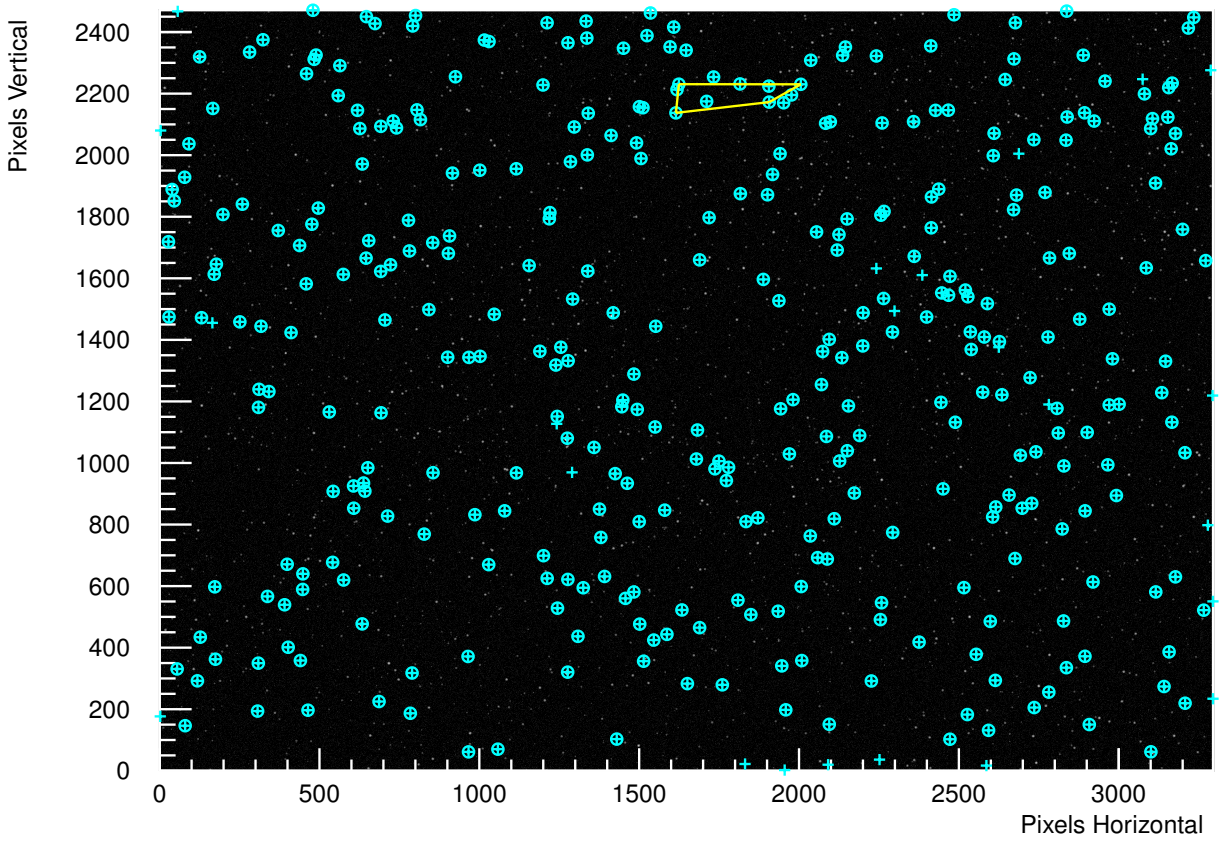
2) Calculating hash-codes of star constellations

3) Search for similar constellations in index files

4) Bayesian decision test of calibration

5) Polynomial fit with remaining stars

Analyzed Image



Verification of the Pointing Reconstruction

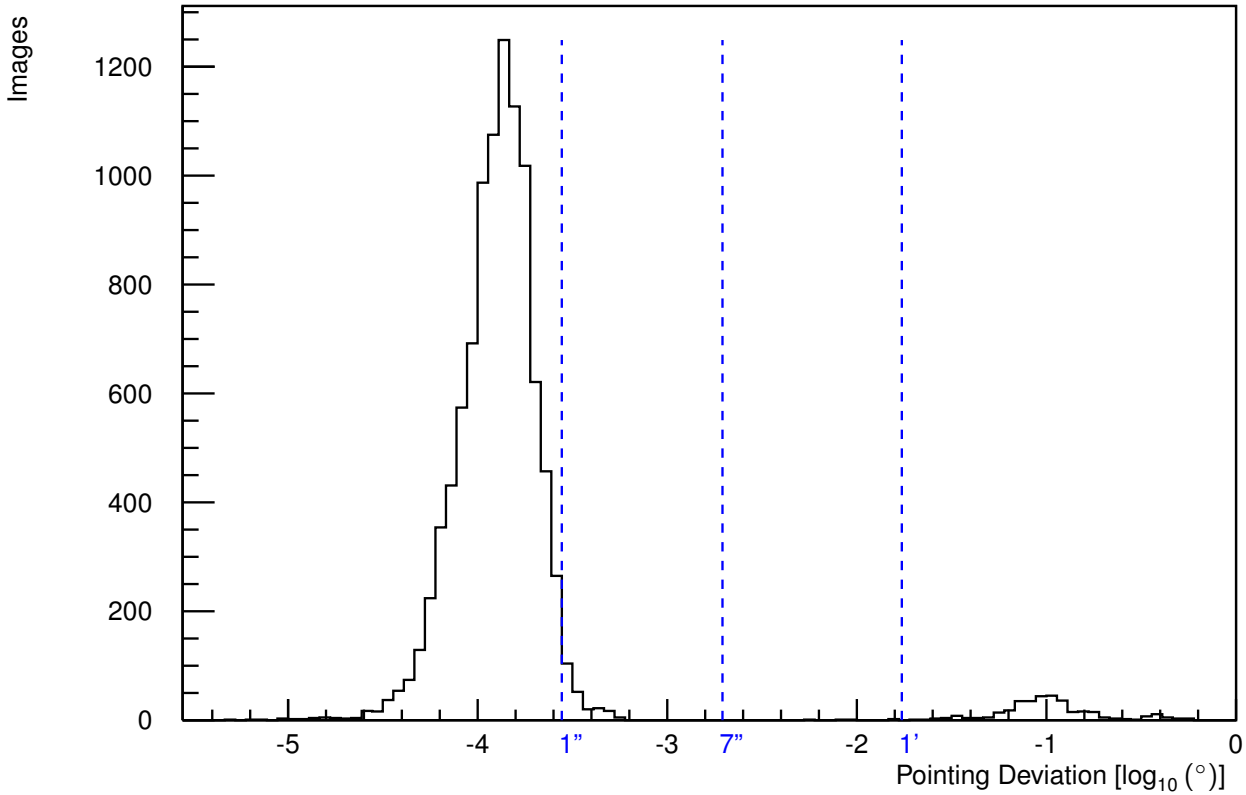
1) Simulation of sets of $\sim 10,000$ images with random Alt/Az-coordinates

2) Reconstruction of the pointing

3) Calculation of the deviation from actual pointing

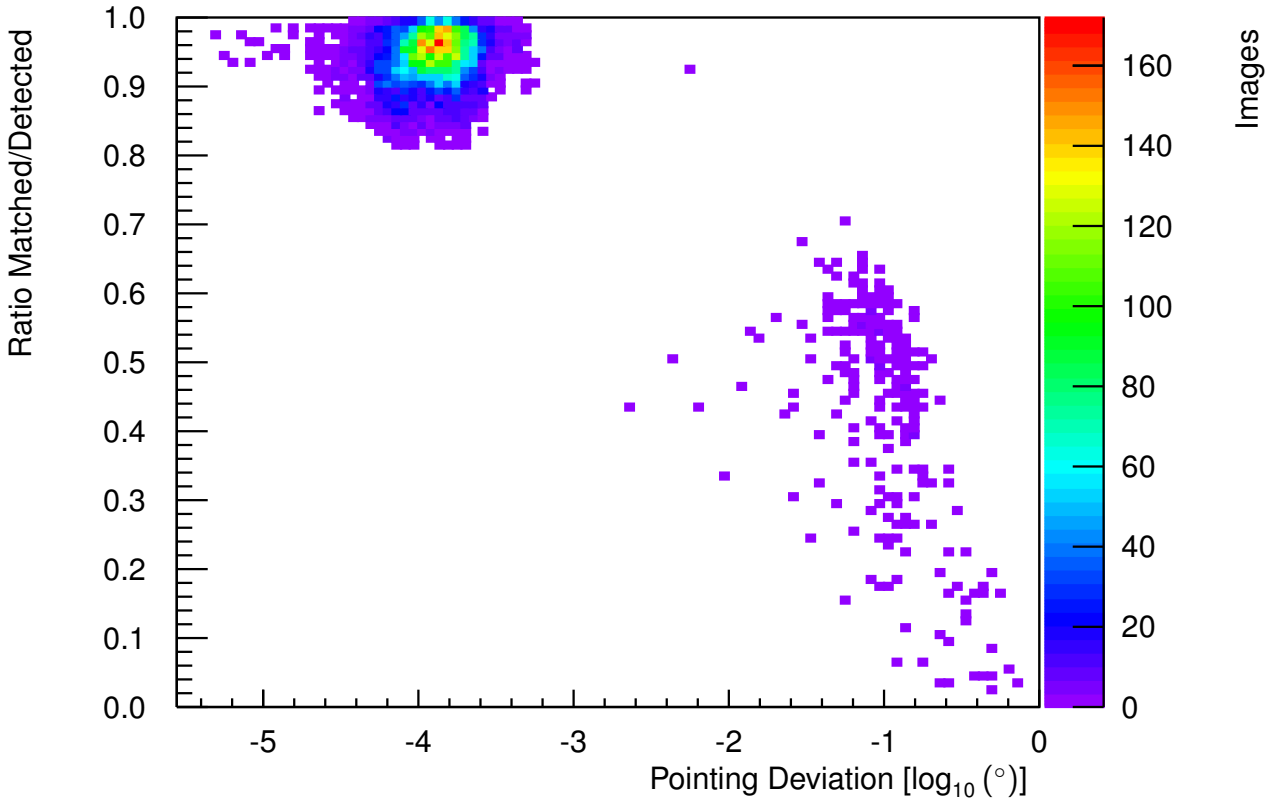
Test of the Algorithm

No exposures, only star positions simulated and passed to reconstruction



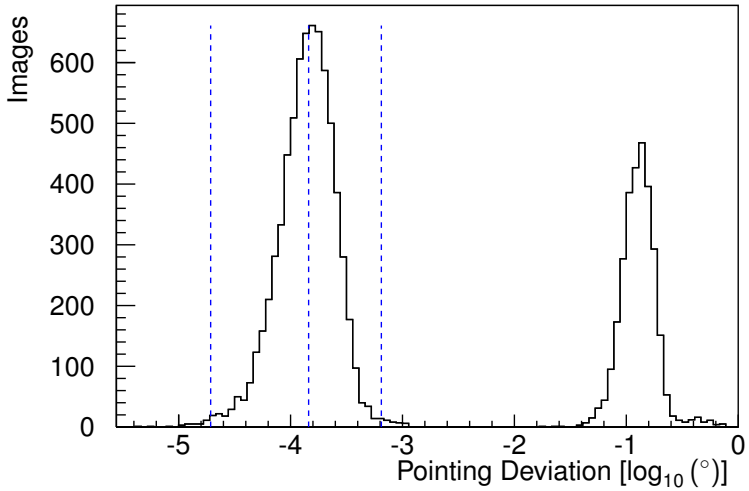
$\rightarrow$ 2 classes of reconstructions

Correlations of Pointing Deviation

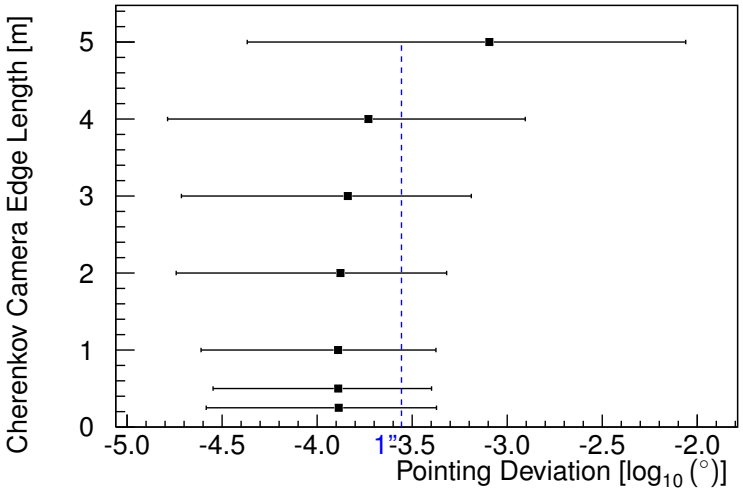


Separable after reconstruction

Obstructing Cherenkov Camera



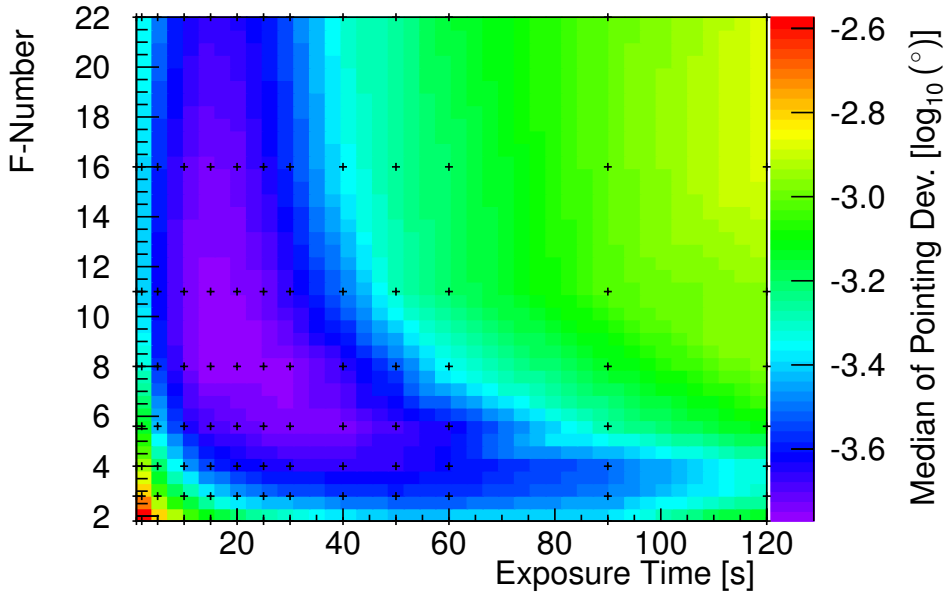
Camera with edges of 3 m



Various camera sizes

Optimum for Exposure and Aperture

Images simulated pixel by pixel

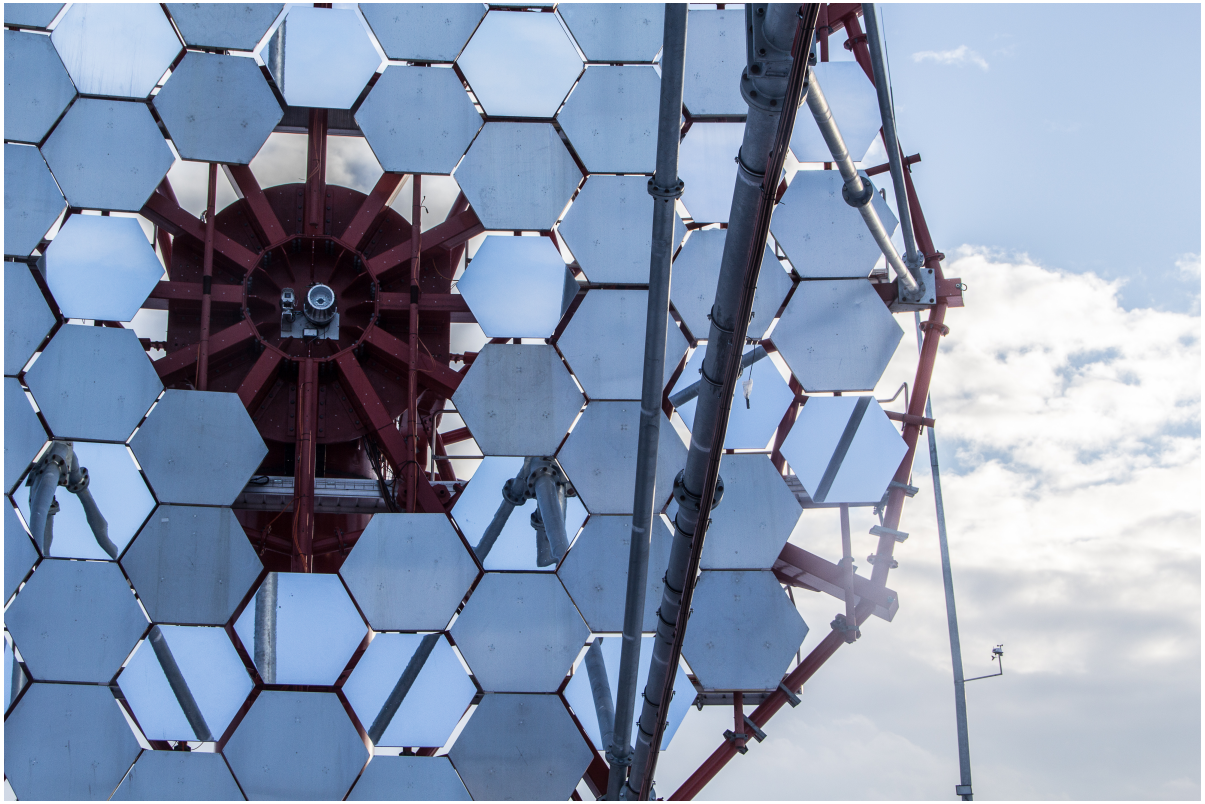


Smallest deviations (< 4”) at:

- Exposure 10 - 20 s
- f/8 - f/11

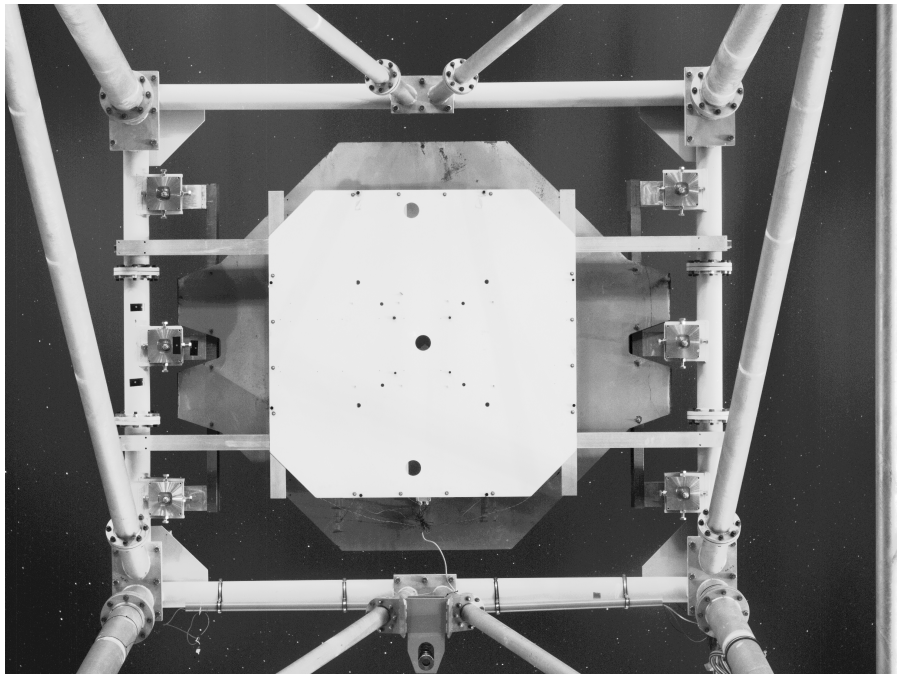
Studies at Prototype Telescope in Berlin/Adlershof

Test of camera hardware and pointing concept under realistic conditions



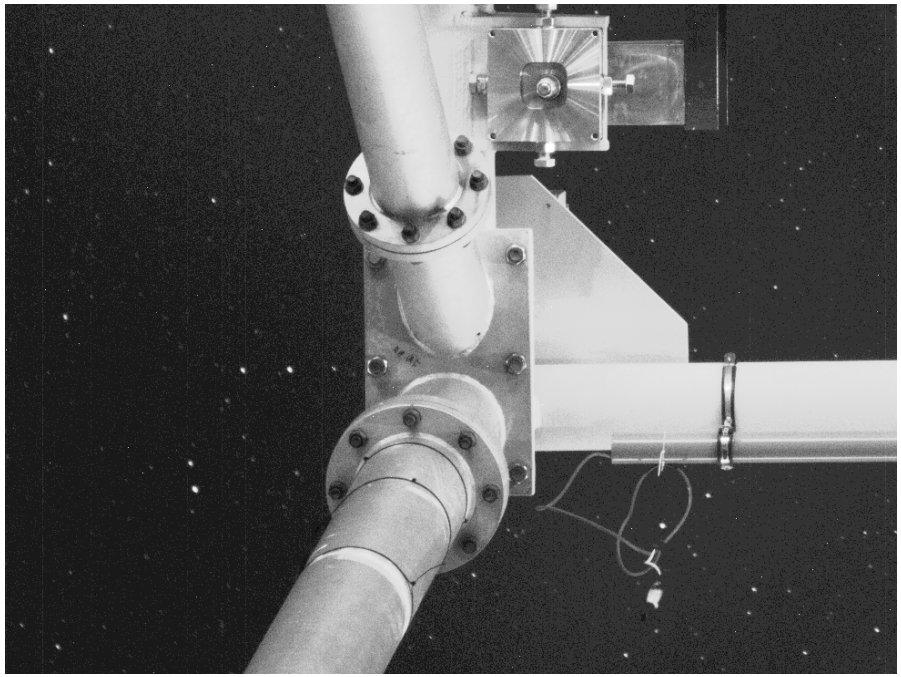
Studies at Prototype Telescope in Berlin/Adlershof

- Large part of images is blocked by telescope structure
- More than 70 stars up to magnitudes ~ 7 can be detected per image
- Precision of pointing measurements currently under investigation



Studies at Prototype Telescope in Berlin/Adlershof

- Large part of images is blocked by telescope structure
- More than 70 stars up to magnitudes ~ 7 can be detected per image
- Precision of pointing measurements currently under investigation



Summary

- Concept for measuring the pointing of CTA telescopes
- Development of housing
- Simulation for camera images
- Image analysis with astrometry.net
- Astronomical calibration tested

$\rightarrow$ Precision better than 4”

- Now: Long term tests at prototype telescope in Berlin/Adlershof

Thanks for your attention!