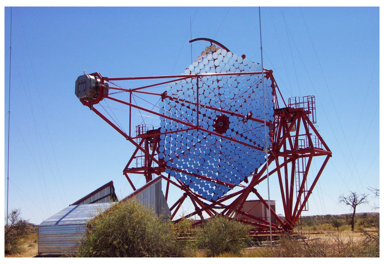
Poster 54



Mirror alignment and performance of the optical system of the H.E.S.S. imaging atmospheric Cherenkov telescopes

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Abstract

H.E.S.S. is a stereoscopic system of large imaging atmospheric Cherenkov telescopes currently under construction in the Khomas Highland of Namibia with the first two telescopes already in operation. The reflector of each telescope consists of 380 mirror facets with 60 cm diameter and a total area of 107 m². The alignment of the mirror facets is performed by a fully automated alignment system using stars imaged onto the lid of the PMT camera. All mirror facets are mounted onto supports which are equipped with two motor-driven actuators while optical feedback is provided by a CCD camera viewing the lid. The alignment procedure, implying the automatic analysis of CCD images and control of the mirror alignment actuators, has been proven to work reliably. On-axis, 80% of the reflected light is contained in a circle of less than 1 mrad diameter (1 mrad corresponds to 0.057° or 1.5 cm in the focal plane), well within specifications.

Mirror Alignment Technique

The mirror alignment is based on a fully automated scheme:

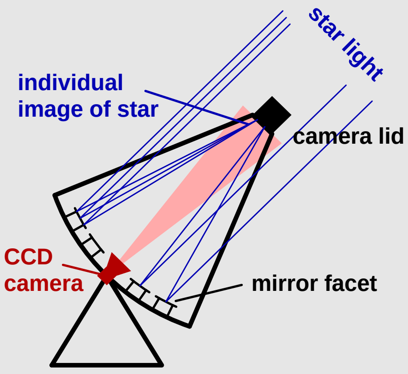
- Mirror supports with motor-driven actuators.
- Sophisticated control electronics.
- CCD camera for optical feedback.
- **Completely computer controlled.**

Major advantages of alignment technique:

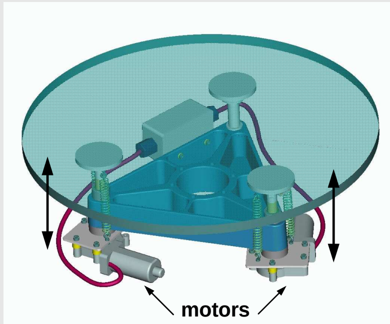
- Natural point-like source at infinite distance.
- Direct imaging in the focal plane.
- **Alignment of mirror facets at optimum elevation (55° – 75°).**

Duration of mirror alignment:

- Initial alignment (only once): 2 weeks
- **Realignment of all mirror facets (if required): 1–2 nights**

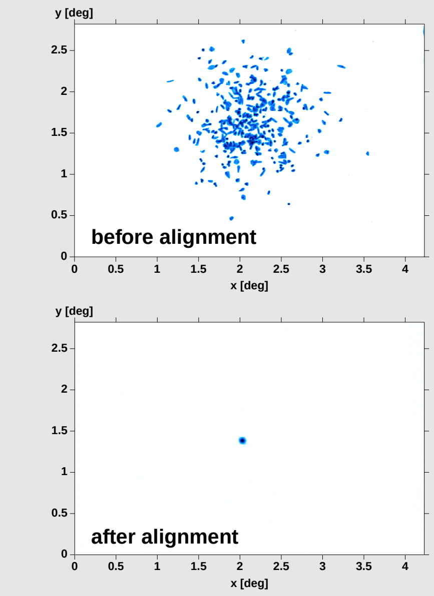


Mirror alignment technique: The telescope is pointed towards an appropriate star whereupon all mirror facets generate individual images of the alignment star in the focal plane (closed lid of the PMT camera). Actuator movements change the location of the corresponding image which is observed by a CCD camera.



Mirror facet with adjustable support:

- Mirror held by special joints to avoid stress.
- Two motor-driven actuators with two Hall sensors on each motor shaft for recording of movement.
- Resolution of actuator movement: 3.4 μm corresp. to 0.013 mrad. Range of adjustment: ± 1.4 cm corresp. to ± 52 mrad.



Light spots before and after the mirror alignment as seen by the CCD camera (log. scale).

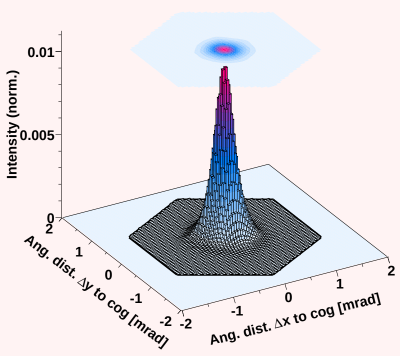
Point Spread Function

Results: The mirror facets of the first (CT03), second (CT02), and third (CT04) H.E.S.S. telescopes have been aligned in Jan/Feb 2002, Nov/Dec 2002, and Jul/Aug 2003, respectively. The resulting point spread function of all reflectors is well within specifications:

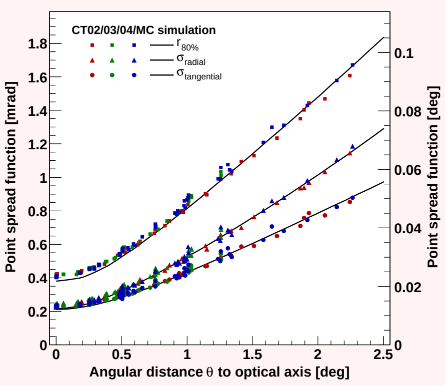
width of psf	CT03	CT02	CT04	specs
σ_{proj} [mrad]	0.23	0.23	0.23	$\leq$ 0.50
σ_{2D} [mrad]	0.32	0.33	0.32	$\leq$ 0.71
$r_{80\%}$ [mrad]	0.40	0.41	0.40	$\leq$ 0.90
$r_{80\%}$ for individual mirrors				$\leq$ 0.50

σ_{proj}: rms of projected intensity distribution
σ_{2D}: rms of two-dimensional distribution
$r_{80\%}$: 80% containment radius

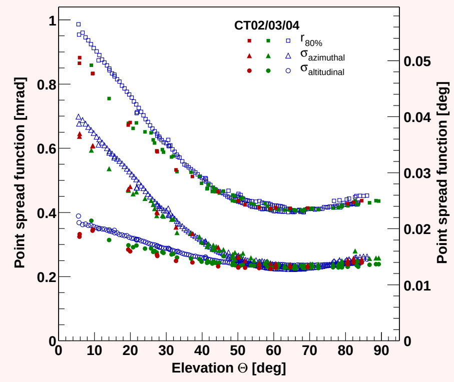
⟹ **Very good average mirror quality.**
⟹ **Excellent alignment accuracy.**



On-axis intensity distribution of a star on the camera lid after alignment (CT04). The hexagonal border indicates the size of a pixel of the PMT Cherenkov camera. **The complete amount of light is well within one pixel.**



Off-axis behaviour of the point spread function. The measurements are in good agreement with Monte Carlo simulations.

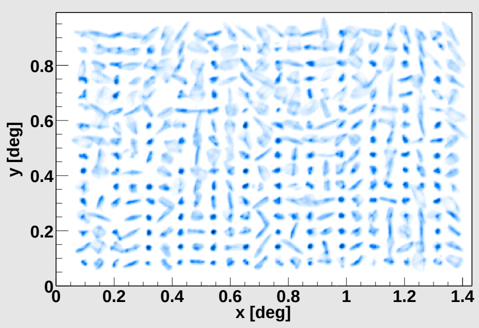


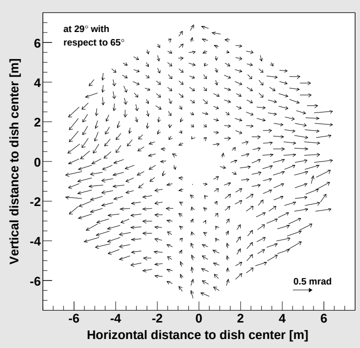
Point spread function with varying elevation. The curves are nearly flat in the usual working range (45°–90°), indicating a **good stability of the support structure**. In addition, **all reflectors behave very similar**.

Dish Deformation

The alignment system provides a mechanism to study the deformation of the support structure in detail: Rather than combining all individual spots to a uniform main spot, the spots can be arranged in arbitrary patterns.

Spot matrix: Each spot corresponds to an individual mirror facet at a certain location in the dish (facets of CT03).





CCD images of spot matrix at different elevations
⟶ **relative movement of spots**
⟶ **deflection of mirror facets**
⟶ **deformation of dish structure**.

Left: Mirror deflections of CT03 at 29° elevation with respect to 65° (mean alignment elevation), arrows scaled by the square root of the deflection.

Conclusion

The mirror alignment of the first three H.E.S.S. telescopes was a proof of concept and test of all technologies involved: mechanics, electronics, software, algorithms and the alignment technique itself. All components work as expected and the resulting point spread function significantly exceeds the specifications. The widening of the spot with increasing angle to the telescope axis is in accordance with the expected behaviour based on simulations and the variation of spot size with elevation is completely uncritical. All three reflectors behave very similar which demonstrates the high accuracy of the support structure and the reproducibility of the alignment process.

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