SST-1M mini-array progress at the Ondřejov observatory

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Abstract

The Single-Mirror Small-Sized Telescope (SST-1M) was developed as an imaging atmospheric Cherenkov telescope prototype by a consortium of institutes from Poland, Switzerland, and the Czech Republic. Currently undergoing commissioning at the Ondřejov Observatory, two SST-1M prototypes have accumulated dozens of hours of observations. They have successfully observed Cherenkov events in both mono and stereo modes, demonstrating their suitability for carrying out astronomical observations. We present preliminary results from the stereo observation campaigns of the Crab Nebula and the blazar Mrk 421.

SST-1M telescopes

A pair of telescopes is located at the Ondřejov observatory (alt. 510 m asl) in the Czech Republic, positioned 152 m apart. Technical features [1]:

- Dish: 4 m diameter single primary multi-segment mirror composed of 18 hexagonal facets,
- Optical layout: Davies-Cotton design,
- Focal length: 5.6 m, Field of View: 9.1°,
- Mirror effective area: 6.47 m^2,
- Camera: using 1296 hexagonal silicon photo-multipliers (SiPM), digitizes waveforms in individual pixels with 4 ns sampling. It has fully digital readout and trigger system (DigiCam). Optimized to detect high-energy gamma rays, in the energy range from about 1 TeV up to 300 TeV.

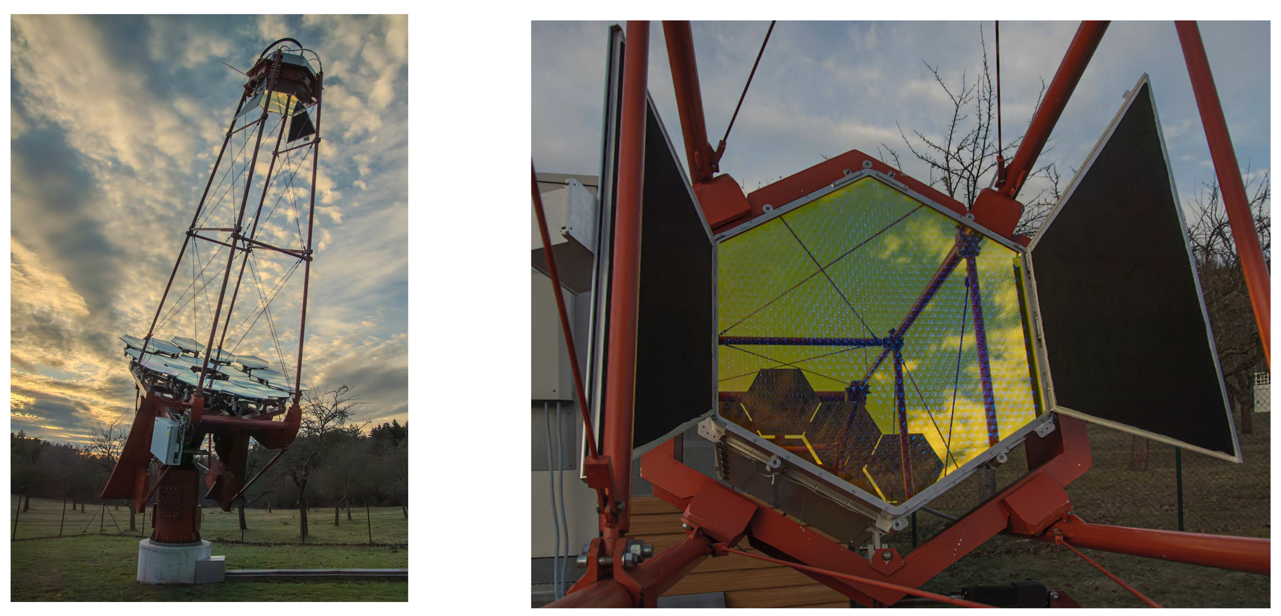

Fig. 1. One of the SST-1M telescope and its camera.

Calibration and analysis

The dedicated data analysis pipeline, **sst1mpipe**[1] [2], is based on the ctapipe framework [3] and utilizes the GADF format for data storage. It includes SiPM's response calibration, event image cleaning, gamma/hadron separation, reconstruction of the energy and direction of the incident photon, classification task. All reconstructions follows Random Forests learning method trained on Monte Carlo (MC) simulations. Sst1mpipe produces Instrument Response Functions. Sky maps, spectra are made though the gammapy [4].

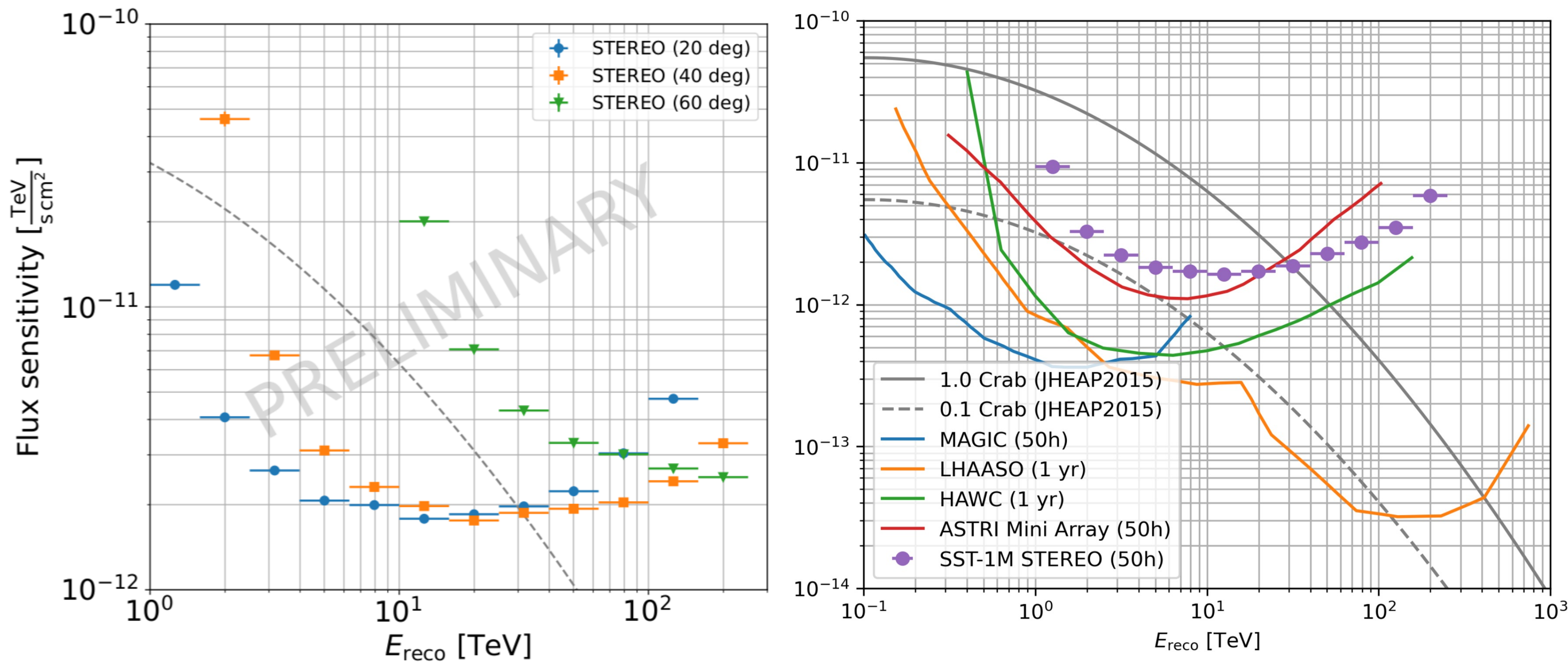

Fig. 2. Differential sensitivity of SST-1M in stereo mode for 50h of exposure at 20°, 30°, 40° zenith angles (left). Comparison with MAGIC, LHAASO, HAWC, ASTRI Mini Array (left) [2].

Observation campaigns

The SST-1M mini-array has performed the observations of the gamma-ray emitting sources (e.g. Crab Nebula, Mrk 421) since 2022 in mono and since Apr. 2023 in stereo mode.

❖ Crab Nebula (Pulsar Wind Nebula):
has exceptional luminosity and almost point like morphology. The source is a standard candle used for calibration.

- First deployment of both telescopes,
- The stereo observation campaign: Nov. 2023 to Mar. 2024,
- Lifetime: 22.52 hours (after quality cuts),
- Crab seen at 5σ after just ∼2h of exposure.

[1] The sst1mpipe repository https://zenodo.org/records/10852981

Preliminary results

Significant detection of the Crab Nebula with an excess of 176 gamma-ray events leading to a Li&Ma significance of 21.3σ, consistent with the theoretical expectations [5].

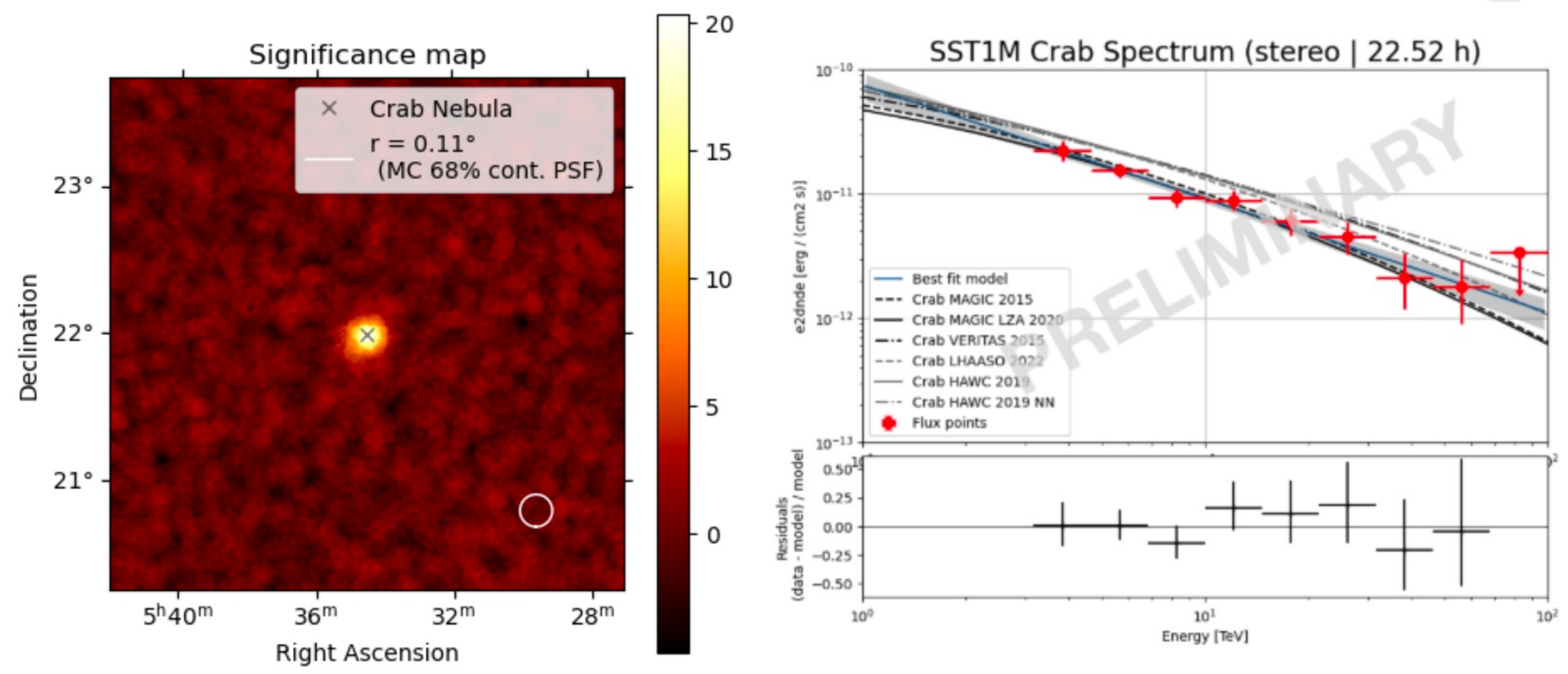

Fig. 3. Significance map (left) and spectrum (right) derived from the Crab observation during the winter 2023/2024 campaign [5].

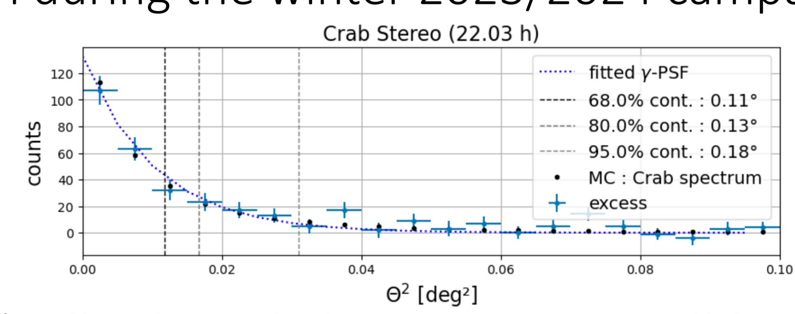

Fig. 4. Theta^2 distribution of the γ-ray excess (blue points) compared with Gaussian Point Spread Function (dotted line) using MC simulations.

❖ Mrk 421 (blazar):

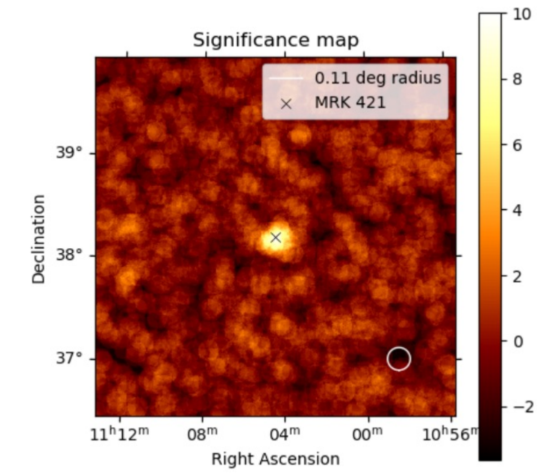

Fig. 5. Significance map of Mrk 421 from observ. on March 13-17, 2024. Mrk 421 has shown an increase in flux, resulting in $\sim 8\sigma$ detection during a 5.3h exposure and exhibits a γ-ray excess up to 7 TeV [6].

Conclusion: *The SST-1M mini-array has proven its capability for detailed astronomical observations, achieving significant results under the current commissioning conditions at Ondřejov Observatory. These successes lay a strong foundation for further performance improvements and expanded research capabilities as the array moves toward its final operational location.*

References

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