Panoramic SETI: on-sky results from prototype telescopes

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INTRODUCTION

The Pulsed All-sky Near-infrared and Optical SETI instrument (PANOSETI, or Panoramic SETI) is dedicated to the search of techno-signatures in the visible and near-infrared [1,2,3]. Previous SETI programs have adopted either a targeted or a transit observing strategy [6]. However, assemblies of single-aperture telescopes capable of observing different parts of the sky instantaneously are still needed to survey the entire sky efficiently and continuously. PANOSETI can detect nanosecond pulsed light signals that could have been emitted for instance, for interstellar communications or energy transfer.

PANOSETI: a search for techno-signatures over 4,441 square-degrees in the optical and near-infrared

Based upon two assemblies of 45 (0.46-m) Fresnel-lens telescopes comprising custom-made fast photon-counting hardware operating in the 0.32- 0.9μm spectral range, the PANOSETI instrument provides sufficient sensitivity to detect petawatt pulsed signals that could have been sent from kiloparsec distances and beamed toward our direction, that would be distinguishable from most known astrophysical sources from our perspective. PANOSETI will be capable of detecting gamma-rays and cosmic rays with energy above some tens of TeV. Each part of the sky will be observed simultaneously from two locations for direct detection and confirmation of transients.

The telescope 32x32-pixels detector array is made of four adjacent detectors, each one subdivided into four adjacent 8x8-pixels MMPC (Multi-Pixel Photon Counter, Hamamatsu S13361-3050AE-08) detector arrays [4]. These silicon photomultipliers (SiPM) are comprised of Geiger-mode-operated avalanche photodiodes with a high internal gain to enable single photon detection while featuring low dark count (<1 Mcps), high photon detection efficiency (45%), and excellent timing resolution.

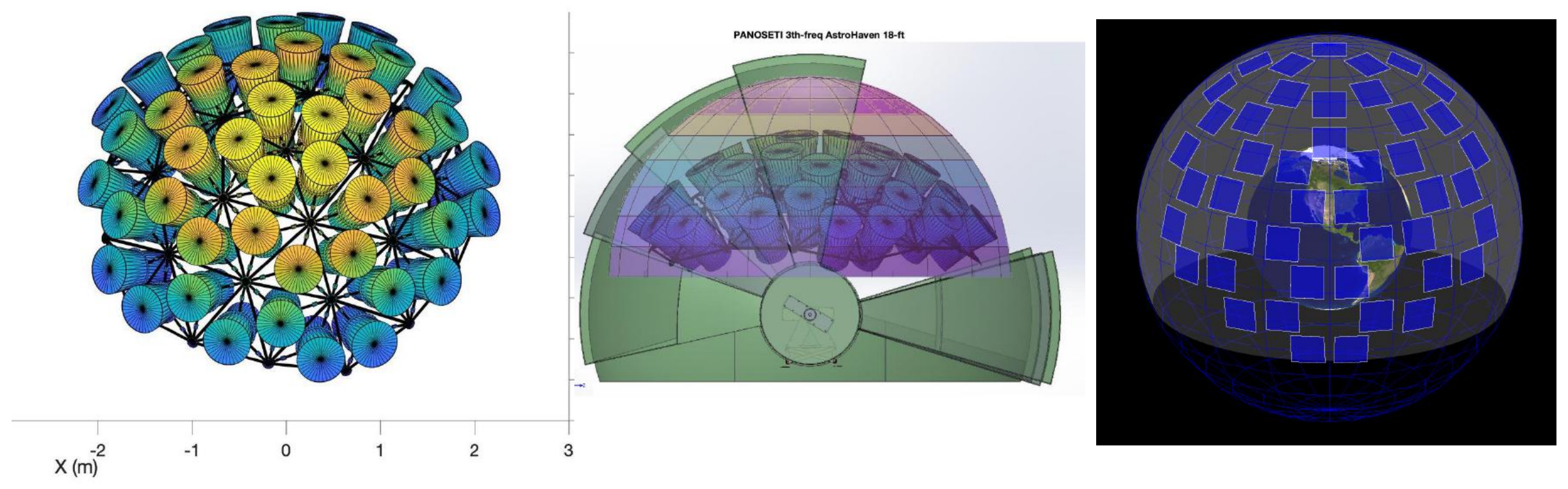

Fig.1: PANOSETI 45-telescopes all-sky layout and instantaneous field-of-view coverage (4,441 sq.deg.)

EXPERIMENTAL DESIGN

Two pairs of telescopes were deployed side-by-side at Lick Observatory with the use of a 1-km baseline at Palomar Observatory.

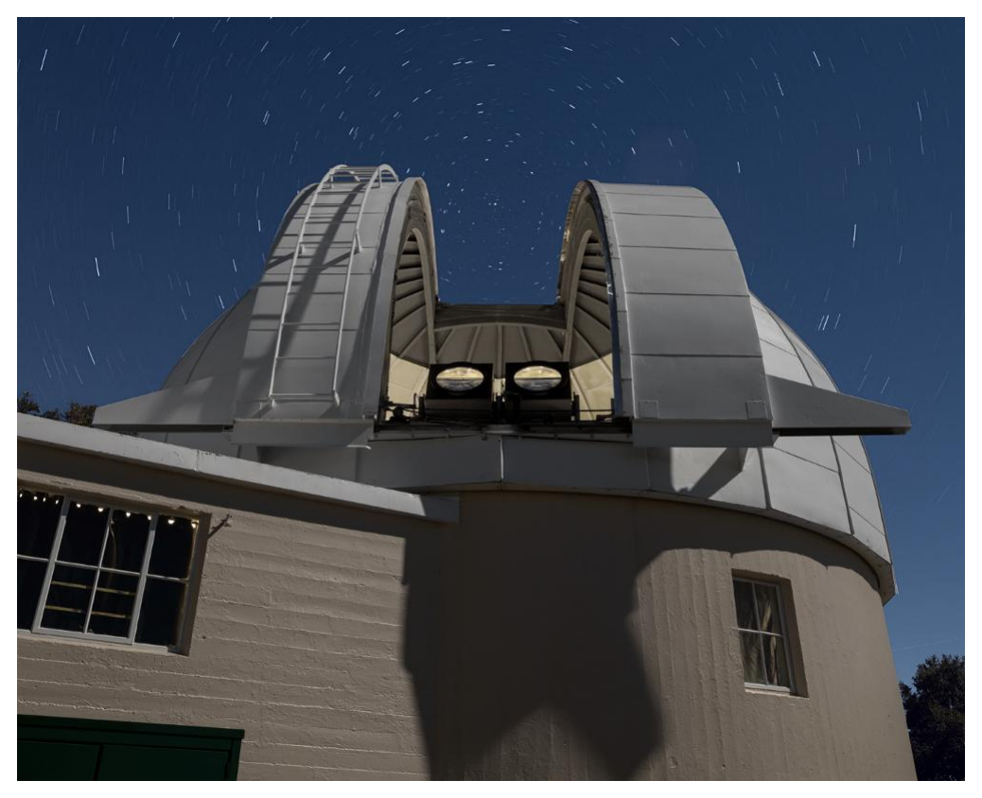

Figure 2: wo side-by-side PANOSETI telescopes pointing in the same direction have been deployed inside the Astrograph dome at Lick Observatory (photo courtesy: Laurie Hatch Photography).

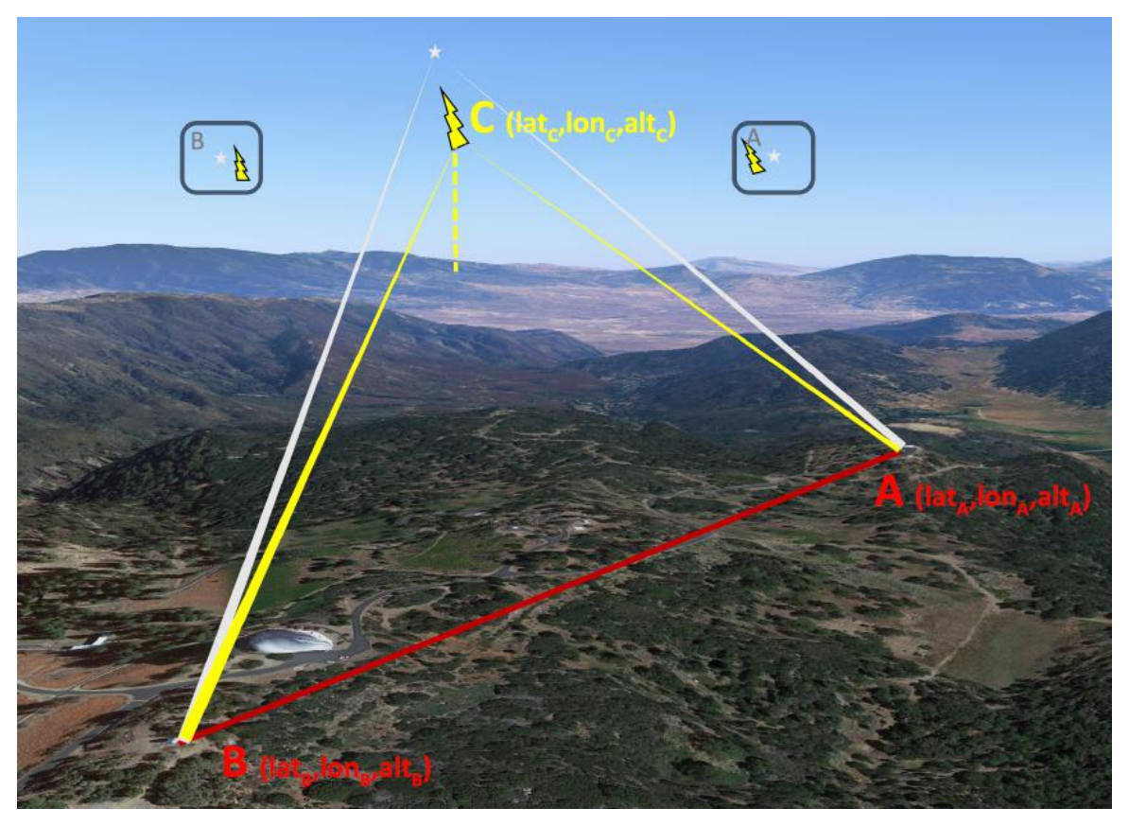

Figure 3: 1-kmbaseline experiment at Palomar Observatory, the two telescopes are located on sites A and B and pointing at the same star. This baseline introduces a measurable parallax angle for flashes of light generated at finite distances in Earth's atmosphere and a time of arrival difference offset with respect to astronomical sources.

Time of Arrival difference:
Accurate time stamping of detected events at multiple sites enables the ability to measure the distance of nearby phenomena in Earth's atmosphere or low-Earth orbit, e.g., false alarms from atmospheric Cherenkov radiation or optical transients from satellite glints.

Parallax:
The Palomar 1-km baseline yields large parallax angles (several degrees) for optical flashes occurring in Earth's atmosphere that are observed by two separated telescopes. The parallax of such an event is the difference in the apparent positions of the shower maxima on both telescopes.

Coincidence detection:
A time coincidence occurs when both telescopes pointing in the same direction detect an event above our sensitivity threshold (15 p.e.) within a time interval Δtwindow.

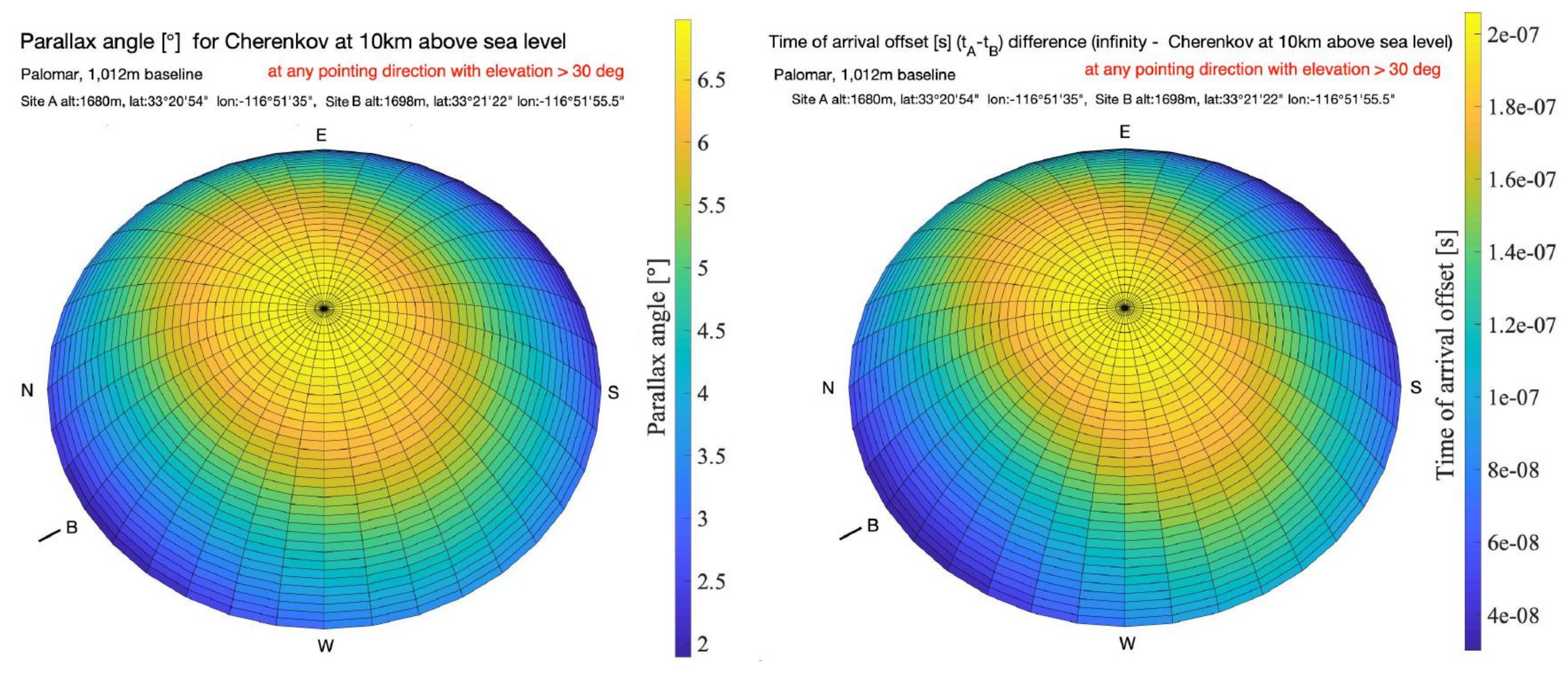

Fig.4: LEFT: Expected parallax angle of a Cherenkov shower occurring at 10 km above sea level for a 1-km PANOSETI baseline in any pointing direction above 30 deg elevation. RIGHT: Expected difference between time of arrival difference for a source at infinity and a phenomena occurring 10 km above sea level (e.g., Cherenkov shower) using the same 1 km Palomar baseline, in any pointing direction above 30 deg elevation.

Instrument parameters		Instrument parameters	
Number of telescopes	2 x 45	Focusing optics	Fresnel lens Orafol SC214
Detectors	Hamamatsu MMPC S13361-3050AE-08	Focal length	0.6m (f/1.32)
Operating wavelengths	0.32- to 0.85µm	Lens diameter	0.46m
Nb of pixels per telescope	32x32	Field-of-view per telescope	9.9x9.9 deg
Plate scale	0.31 deg per pix	PANOSETI instantaneous coverage	4,441 sq. deg. (10.8%of the sky)

RESULTS

Preliminary on-sky results from pairs of PANOSETI prototype telescopes (100 sq.deg.) are presented in terms of false alarm rates.

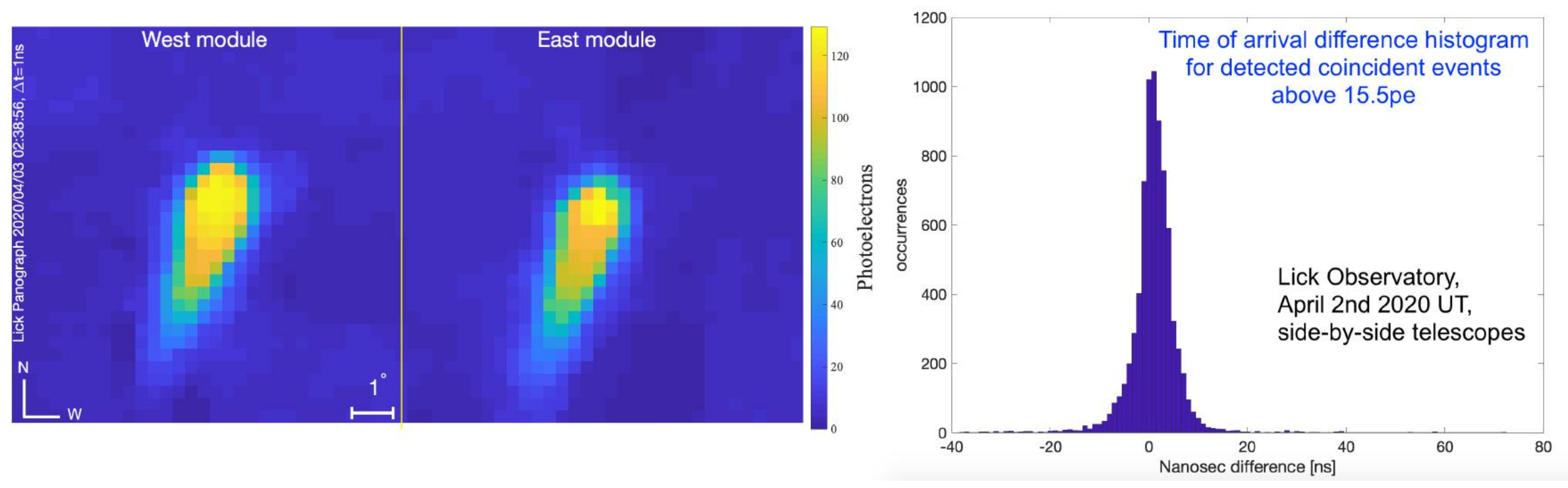

Figure 5: LEFT: An example of a Cherenkov shower detected at Lick Observatory
Right: Histogram of time of arrival difference for detected coincidences above 15.5 p.e. at Lick Observatory, on April 2nd2020 UT showing that these events are detected within less than 10 ns difference.

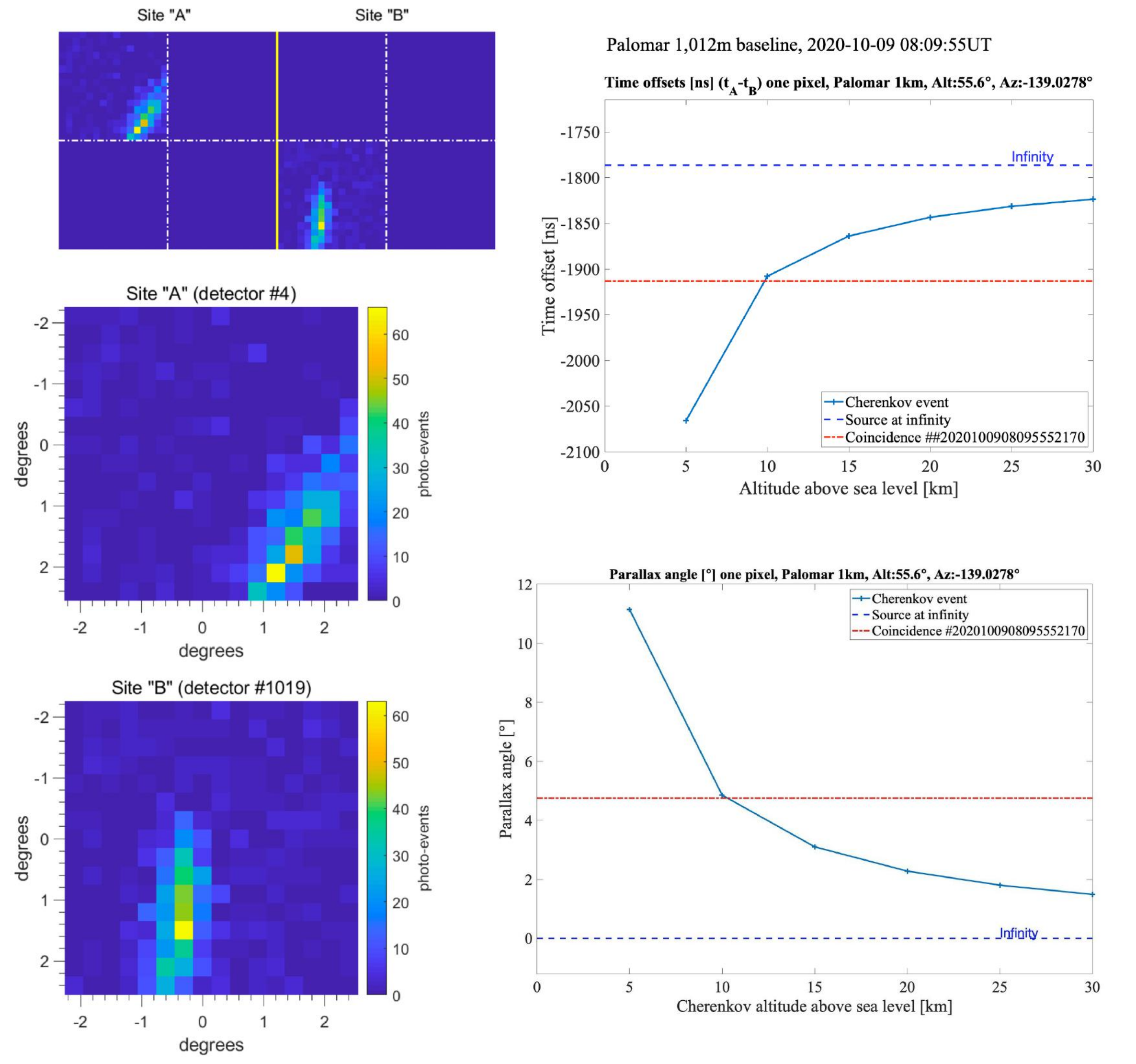

Figure 6: LEFT: Example of a Cherenkov shower detected by the two PANOSETI telescopes at Palomar Observatory using a 1-km baseline on Nov. 9th, 2020. The images show the triggered events on both detectors and their respective positions on the entire telescope field-of-view (top). The 4.75 deg offset in position of the shower maximum is due the parallax that the 1km baseline provides for nearby objects. Both the time of arrival difference (1913 ns) and the parallax (4.75deg) are in agreement with an event that occurred at about 10 km above sea level.

Location	Baseline	Elevation[a]	Obs. Duration	False Alarm Rate [coincidences/s/pair of telesc.] ($\Delta t_{\mathrm{window}}$ =200 ns)	False Alarm Rate [coincid./s/pair of telesc.] ($\Delta t_{\mathrm{window}}$ =10 ns)
Lick	Side-by-side	60°	3 h 2 min	0.31 (1 coinc. per 3.3 s)	0.3 (1 coinc. per 3.2 s)
Palomar	Side-by-side	30°	8 min 34 s	0.2 (1 coinc. per 5 s)[b]	0.2 (1 coinc. per 5 s)[b]
Palomar	250 m	28°	13 min 39 s	0.034 (1 coinc. per 29.3 s)[b]	0.023 (1 coinc. per 42.8 s)[b]
Palomar	1,012 m	55°	1 h 15 min	$8.8\ 10^{-4}$ (1 coinc. per 18 min 45 s)	0 (no coincidence)

a: related to field-of-view center. b: extrapolated from 3/4 of the detectors (full detector otherwise).

Table 1: Measured PANOSETI false alarm rates at Lick Observatory and Palomar Observatory considering coincident events detected by the two telescopes above 15.5 p.e. (without rejection based on parallax or shape of the event).

CONCLUSIONS

PANOSETI experiment has shown proof-of-concept for detecting astronomical transients over a wide field-of-view with high sensitivity. The deployment of pairs of telescopes has confirmed the benefit of using a long baseline >1km to identify and characterize false alarms generated by nearby transient phenomena (e.g., Cherenkowv showers).

REFERENCES

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3. Maire et al, *SPIE 2018*
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6. Howard et al, *Acta Astron., 2007*