DEEP SOUTH TELESCOPE

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ABSTRACT. The US Naval Observatory acquired a 1-meter telescope, the Deep South Telescope (DST). It was deployed at Cerro Tololo Interamerican Observatory (CTIO), Chile in March 2019. A 4k CCD camera will be used to image selected optical counterparts of ICRF sources which display significant radio-optical position offsets. This high cadence observing program is a joint effort between USNO and Paris Observatory. DST will also be used for other programs in the future, including near infra-red (IR) observations with a camera mounted at the 2nd Nasmyth focus.

1. HISTORY OF THE DST PROJECT

Around 2015, the era of ground-based, astrometric, all-sky surveys (e.g. Zacharias et al. 2013) came to an end due to the success of the Gaia space mission (Gaia collaboration, 2016). The U.S. Naval Observatory shifted focus toward going deeper on selected fields of interest in its southern hemisphere operations. In 2018 a 1-meter telescope (PW1000) was purchased from PlaneWave Instuments together with a 4k CCD camera (Sophia) from Princeton Instruments. Construction of the telescope was completed in December 2018 with on-sky testing in the factory backyard near Los Angeles.

2. DEPLOYMENT OF INSTRUMENT AT CTIO

In March 2019, the telescope was deployed at Cerro Tololo Interamerican Observatory (CTIO) (Figure 1). Delivery of the camera was delayed due to ongoing repairs after a shipping accident. Waiting for the 4k camera, system integration and testing took about 5 months. Routine operations began in August 2019. This telescope is particularly suited for astrometry due to the optical design with a fixed, spherical secondary mirror and a 3-lens corrector system. Using an elaborate pointing model, blind tracking is performed without a guider in the focal plane. A summary of the telescope and camera specifications is given in Table 1, while Figure 2 shows the focal plane layout.

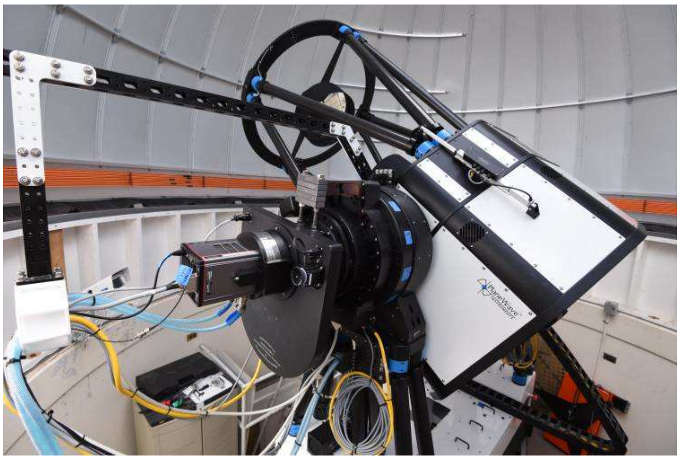

Figure 1: The Deep South Telescope at CTIO.

telescope aperture	1.00	m
focal length	6.00	m
optical field of view	1.00	deg diameter
mount	alt-az	2 foci
number of pixels	4k by 4k	
pixel scale	0.515	arcsec/pixel
field of view	35 by 35	arcmin

Table 1: Specifications of DST and camera.

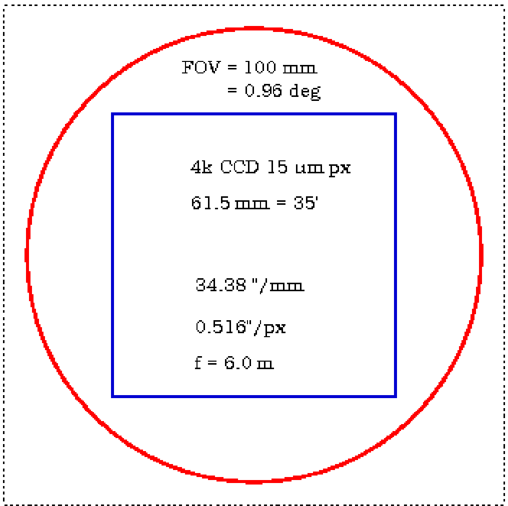

Figure 2: DST focal plane layout.

3. SCIENCE PROGRAM

The first observing program to be conducted with DST is monitoring selected ICRF sources with high cadence with the goal to obtain a better understanding of why about 10% of reference frame sources (Makarov, Frouard & Berhea 2016) display a significant position offset between the radio (VLBI) and optical (Gaia) centers of emission. Indications for such outliers were noticed even before the first Gaia data release (e.g. Zacharias & Zacharias 2014). Each source on our list is observed through B, V, R, I filters every other night during visibility season of about 6 months. A total of about 200 sources are being monitored as part of the FRAMEx collaboration between USNO and Paris Observatory.

Sources were selected from 4 groups: nearby AGN (Secrest, priv. comm.), large optical-radio offset sources from ICRF3 (Makarov, priv. comm.), those from the Radio Fundamental Catalog (Petrov 2018), and about a dozen sources where radio and optical positions agree as control sample. All sources are brighter than about $R = 18.5$ mag, resulting in high S/N observations of 3 to 4 minute exposures with the DST. All sources are south of $\mathrm{Dec} = +25°$ and about evenly distributed along RA to allow observing near the meridian at all times. The distribution of radio-optical position offsets of our sources is given in Table 2.

4. STATUS OF OPERATIONS

During commissioning, it was discovered that the focus curve is not symmetric (Figure 3). Stellar image size as a function of out-of-focus distance changed differently for intra– and extra–

no info or <= 0.1 mas		23
> 0.1 to 2.9 mas		50
> 2.9 to 5.0 mas		14
> 5.0 to 10.0 mas		32
> 10.0 to 30.0 mas		38
> 30.0 to 100.0 mas		15
>100.0 to 300.0 mas		8
>300.0 mas		12

Table 2: Number of sources by radio-optical position difference.

focal positions. The focus does correlate very well with temperature, in particular that of the primary mirror, however, not well enough for an accurate prediction of the focus. Best focus is currently obtained by observing focus sequences with many exposures and small step size several times during the night.

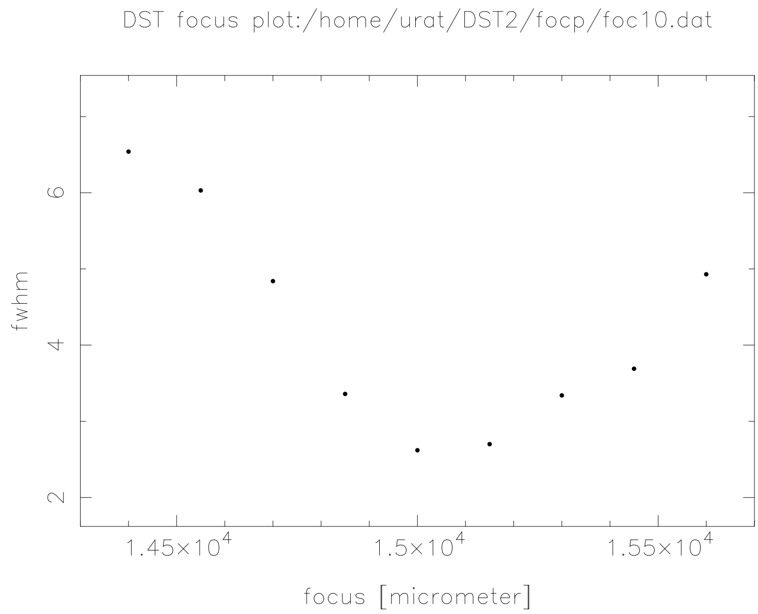

Figure 3: Example focus curve of DST.

The dynamic range of the instrument is very large, about 8 magnitudes, due to the relatively large pixels, sampling and low noise properties of the detector running at $-80°$C cooled by TEC with glycol (no liquid nitrogen, no dewar). Properties of stellar images as a function of magnitude of a single exposure are shown in Figure 4. The top left graph (image fit radius) shows that saturation is near instrumental magnitude 5. The lower left graph (position error) gives the limiting magnitude (here defined as position error reaches 0.1 pixel) near instrumental magnitude 13.

Table 3 provides the observing statistics for the first month of observing. Several issues remain to be solved for improved performance. A relatively large fraction of exposures (about 30%) display image elongation above our stringent threshold. More frequently this is the case for long exposures than short exposures. However, some exposures up to 10 min have been obtained with acceptable quality.

Occasionally, telescope mount drives become disabled or communication to the telescope is lost. The reduction software is still in its early steps. First science results are not expected until mid 2020.

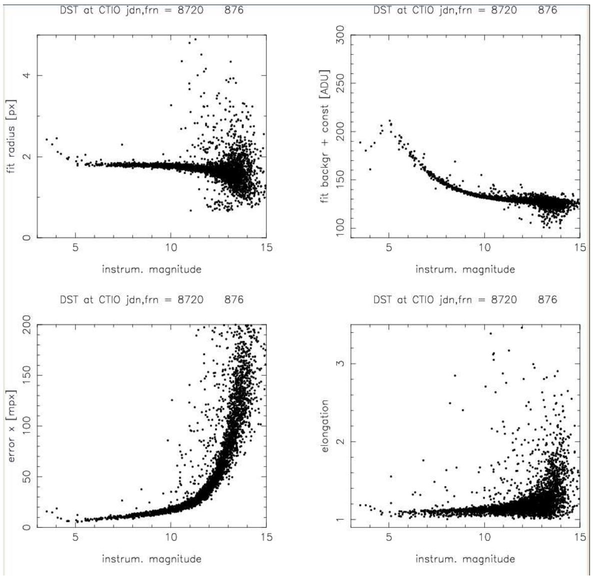

Figure 4: Stellar image properties as function of magnitude.

total number of nights	38
lost due to weather	4
lost due to instrument	4
nights with observing	30
total number of exposures	2797
total number of sources	$\approx$ 100

Table 3: DST observing from Aug 24 to Sep 30, 2019

Acknowledgement. A program like this would not be possible without a large, diverse team of dedicated experts. This paper is based on observations obtained at Cerro Tololo Inter-American Observatory, a division of the National Optical Astronomy Observatories, which is operated by the Association of Universities for Research in Astronomy, Inc. under cooperative agreement with the National Science Foundation. We like to thank the entire staff of CTIO, Greg Bredthauer (STA), Marion Zacharias, the teams from PlaneWave and Princeton Instruments for their contributions to this program. We thank the USNO Instrument shop (Gary Wieder, Chris Kilian and Phil Eakens) for outstanding support, and Valeri Makarov and Jean Souchay for the FRAMEx collaboration.

5. REFERENCES

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