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INSTRUMENTATION

TIRCAM2 camera interface on the side port of 3.6-m Devasthal Optical Telescope

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Abstract. TIFR Near Infrared Imaging Camera-II (TIRCAM2) is being used at the 3.6-m Devasthal Optical Telescope (DOT) operated by Aryabhatta Research Institute of Observational Sciences (ARIES), Nainital, Uttarakhand, India. Earlier, the TIRCAM2 was used at the main port of the DOT on time-shared basis. It has now been installed at the side port of the telescope. Side port installation allows near simultaneous observations with the main port instrument as well as longer operating periods. Thus, the TIRCAM2 serves the astronomical community for a variety of observations ranging from lunar occultations, transient events and normal scheduled observations.

Keywords. Optical telescope—near-infrared camera—side port—infrared observation.

1. Introduction

The 3.6-m Devasthal Optical Telescope (DOT) has been built by the Aryabhatta Research Institute of Observational Sciences (ARIES) in collaboration with the Belgian firm, Advanced Mechanical and Optical System (AMOS, see Figure 1 (left), Sagar *et al.* 2019). The DOT is located at the Devasthal observatory site near Nainital (Uttarakhand district) at an altitude of 2450 m above mean sea level. The DOT is currently the largest single mirror telescope in India. The operational wavebands of the DOT run from 0.35 μm to 5 μm. Some of the specifications of the DOT are given in Figure 2.

2. TIRCAM2: An NIR imaging camera at DOT

TIFR Near Infrared Imaging Camera-II (TIRCAM2) has imaging capability from 1 μm to 3.7 μm (Naik *et al.* 2012; Baug *et al.* 2018). Figure 1 (right) shows the TIRCAM2 instrument. The camera has an InSb focal plane array with 512 × 512 pixels. It operates at a temperature of 35 K, cooled by a closed cycle helium cryo-cooler. Many successful science observations have been done with this camera from the main (axial) port of the DOT. For example, Baug *et al.* (2018) described imaging capabilities and results of TIRCAM2 in J, H, K and narrow-band L (nbL) bands. Anand *et al.* (2020) presented imaging capabilities in polycyclic aromatic hydrocarbon and nbL bands. Richichi *et al.* (2020) presented milliarcsecond resolution results on cool giants and binary stars from lunar occultations at Devasthal. Sharma *et al.* (2020) described a detailed analysis of the Cz3 open cluster using deep NIR observations taken from TIRCAM2. After commissioning of the TIFR-ARIES Near Infrared Spectrometer (TANSPEC), an NIR imager and spectrometer at DOT, it was decided to shift the TIRCAM2 camera to the side port of the DOT, thus becoming the first instrument at the side port of the DOT. This required designing a new mechanical structure to interface the TIRCAM2 considering many

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technical aspects, such as optical alignments, mechanical envelop, TIRCAM2's requirements of cryogenic cooling setup, etc.

3. Instrument envelop for the side port

DOT provides three cassegrain ports for mounting the instruments, one is the main axial port and other two are the side ports. Figures 3 and 4 show the envelops for designing and developing instruments for the main axial port and the side ports of the DOT. Figure 3 shows the front view of the main axial port and both side ports and Figure 4 shows the top view of the side port instrument envelops for DOT. TIRCAM2 main port envelop was 1020 mm (H) × 612 mm (W) × 712 mm (L), whereas TIRCAM2 side port envelop is 862 mm (H) × 360 mm (W) × 800 mm (L). The side port instruments can have a weight of 250 kg each, with a center of gravity at a

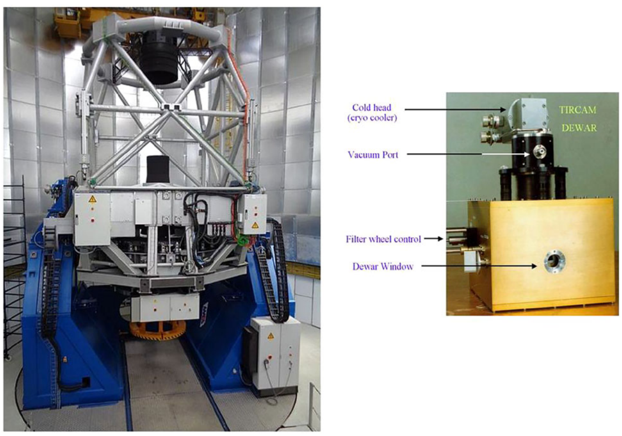

Figure 1. Left: 3.6-m Devasthal Optical Telescope. Right: TIRCAM2 imaging camera.

Parameters	Value
Focal ratios	Primary : F/2, Effective : F/9
Science field of view	10 arcmin on side ports 30 arcmin on axial port
Mounting	Alt-azimuth
Instruments	1 main axial port instrument: Instrument flange: 40 cm before the focus. Mass: 2000 kg. 2 side port instruments: Instrument flange : 10 cm before the focus. Mass: 250 kg per instrument.

Figure 2. Some of the specifications of DOT.

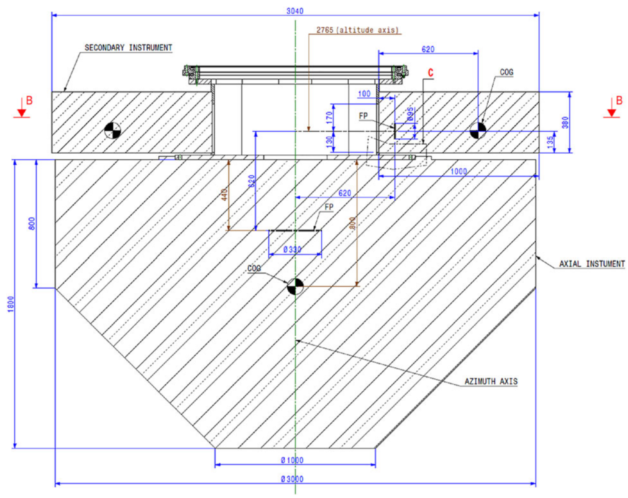

Figure 3. Front view of the focal planes showing the main axial port and both side ports' instrument envelops for DOT.

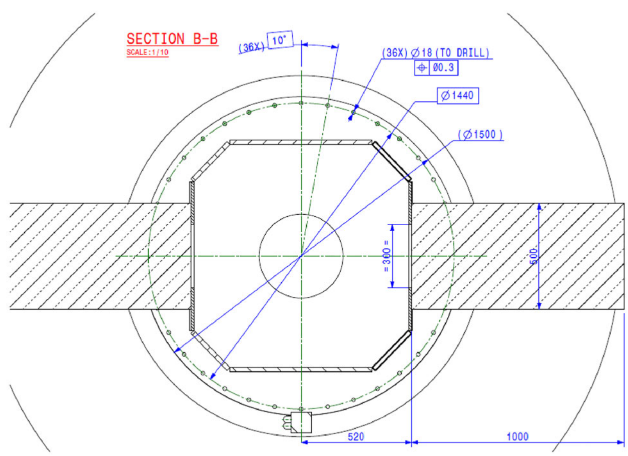

Figure 4. Top view of the side port instrument envelops for DOT.

Figure 5. DOT side port with dummy cover (left) and without dummy cover (right).

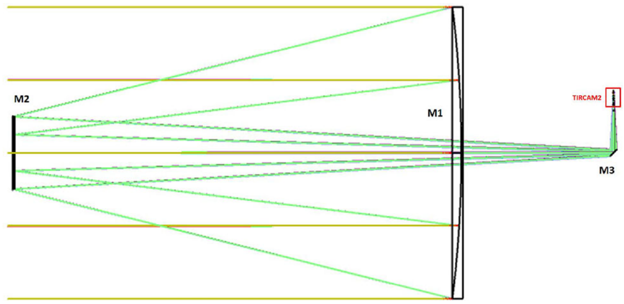

Figure 6. Raytrace of the DOT with the TIRCAM2 camera on the side port.

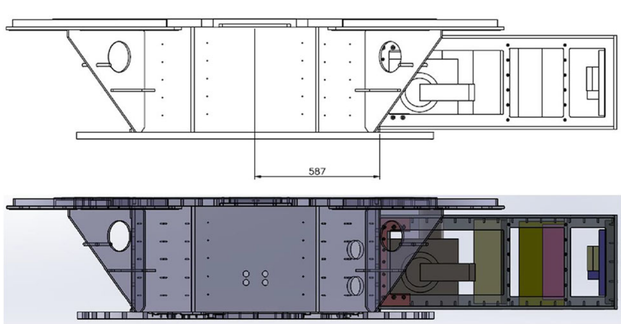

Figure 7. AutoCAD drawing and SOLIDWORKS model of the complete assembly of the TIRCAM2 mounted on the side port of the DOT.

position of 620 mm away from the instrument interface plate. The focal plane is available at 100 mm from the interface plate and 620 mm from the fold mirror. Actual photograph of one of the side ports with and without dummy cover is shown in Figure 5.

4. Mechanical structure design

Figure 6 shows the Zemax raytrace of the DOT telescope with TIRCAM2 on the side port of DOT. Naik *et al.* (2012) have presented a detailed schematic and Zemax raytrace of TIRCAM2 optics. The telescope side port focal plane is 100 mm away from the instrument interface plate of the side port and 620 mm away from the fold mirror (see Figure 3). The TIRCAM2 window is at a distance of 587 mm and 67 mm from the fold mirror and the interface plate, respectively. The aperture plane of the TIRCAM2 is 33 mm behind the front surface of the window. AutoCAD and SOLIDWORKS models of the mounting are shown in Figures 7 and 8. Figure 9 shows the AutoCAD drawing and SOLIDWORKS model view of the TIRCAM2 camera with instrument rack mounted on the side port of the telescope.

Considering the envelop size, mass and focal plane of the side port, the instrument interface plate and rack

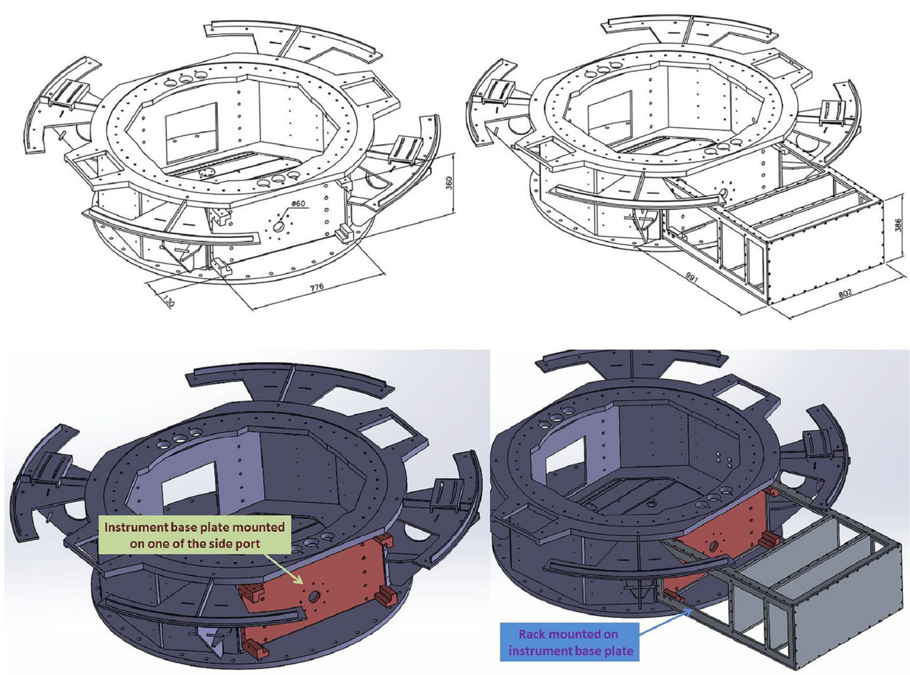

Figure 8. AutoCAD drawing and SOLIDWORKS model of the interface plate and rack for the TIRCAM2 mounted on the side port of the DOT Telescope.

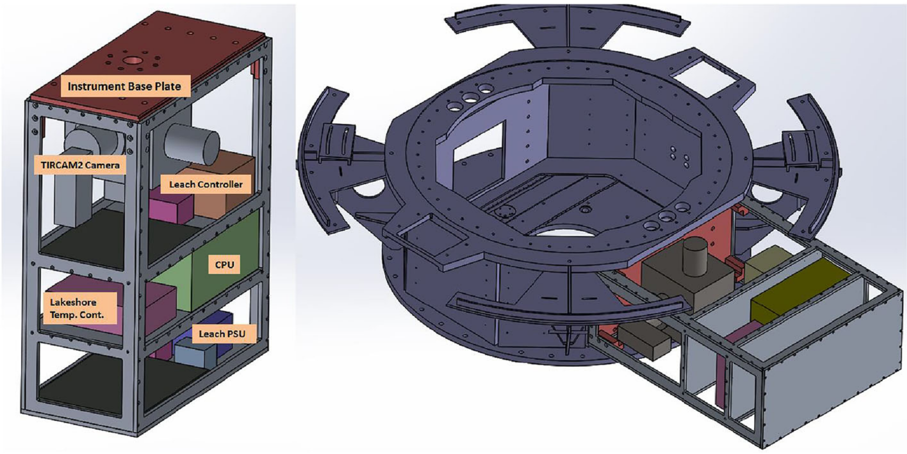

Figure 9. AutoCAD drawing and SOLIDWORKS model of the TIRCAM2 rack assembly.

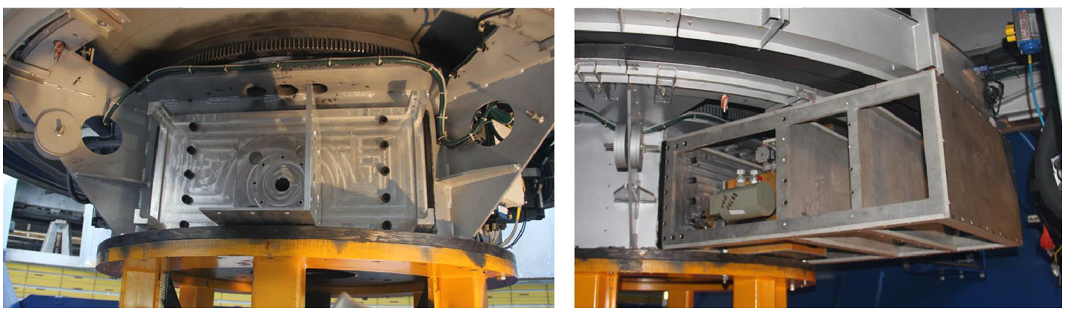

Figure 10. Actual photographs of the instrument base plate (left) and only rack (right), with the TIRCAM2 mounted on the side port.

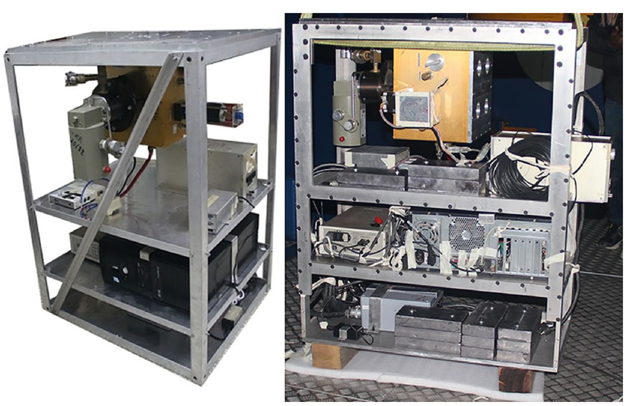

Figure 11. TIRCAM2 complete rack assembly for main port (left) and side port (right) of the DOT.

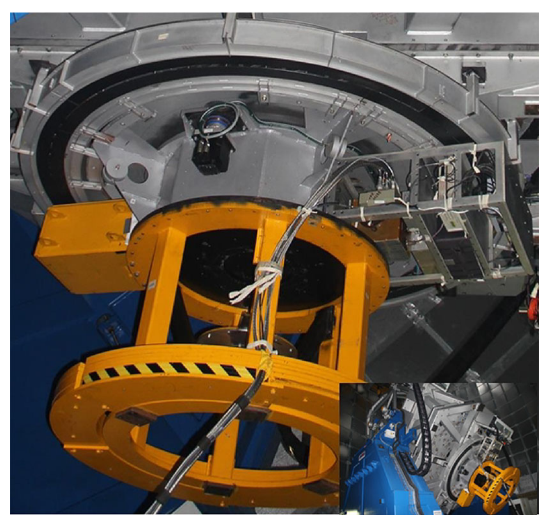

Figure 12. TIRCAM2 instrument rack assembly mounted on the side port of the DOT.

for mounting the TIRCAM2 were designed as shown in Figures 7–9. All camera equipments were suitably mounted within the rack.

Figure 10 shows instrument base plate (left) and rack (right), with the TIRCAM2 mounted on the side port and Figure 11 shows the actual photographs of the complete rack assembly with dummy lead bricks for main port (left) and side port (right). Figure 12 shows the complete rack assembly with its mounting on the side port of the DOT. The total weight of the whole assembly is around 248 kg as required for the side port to balance the telescope. This 248 kg assembly is lifted by the overhead crane during the mounting on the side port (Figure 13). UPS supply cables and ethernet cable are passed through the cable anti-twister in the pier of the telescope. Figure 14 shows the evacuation setup of the TIRCAM2 camera after mounting the camera on the side port.

5. Performance at side port

During the first light of the TIRCAM2 at the side port, the M53 globular cluster was observed on 5 May 2020. The M53 J-band image was taken at five dithered positions with one frame at each position. The image was cleaned for sky-background by subtracting the median of the dithered frames. Mosaic of the M53 is formed by combining the dithered frames. A part of the mosaic (field-of-view (FoV) $\sim 1.45' \times 1.45'$) is shown in Figure 15 (left) and is compared with the corresponding FoV of the 2MASS image (Figure 15; right). The Palomar 2 globular cluster was observed during regular science observations on 17 November 2021. The J-band image was taken at five dithered positions with 11 frames at each position. Image cleaning process was similar to that of the M53 J-band image. A part of the mosaic (FoV $\sim 1.3' \times 1.3'$) of the Palomar 2 taken with the TIRCAM2 is shown in Figure 16 (left) and for comparison, the 2MASS J-band image of the same region is also shown in Figure 16 (right). The full width at half maximum (FWHM) of the marked sources in the TIRCAM2 images of the M53 (Figure 15; left) and the Palomer 2 (Figure 16; left) are 5.30 pixels ($\sim 0.9''$) (Figure 17; left) and 3.53 pixels ($\sim 0.6''$) (Figure 17; right), respectively.

Figure 13. Complete 248 kg TIRCAM2 assembly lifted by the overhead crane during the mounting on the side port.

6. Achievements at side port

With a new optimized mechanical setup, the TIRCAM2 was installed on the side port of the DOT and it has become the first light instrument on the DOT side port. A new design and fabrication of the filter mechanism and filter controller were carried out for the side port by replacing the older filter mechanism and controller. Further tuning of the setup was done especially with the He gas pipe routing within the telescope structure. The TIRCAM2 side port performance is comparable to the main port performance. The TIRCAM2 is now regularly used for astronomical observations as per scheduled proposals. The TIRCAM2 at the side port is also regularly used for lunar and planetary occultation observations.

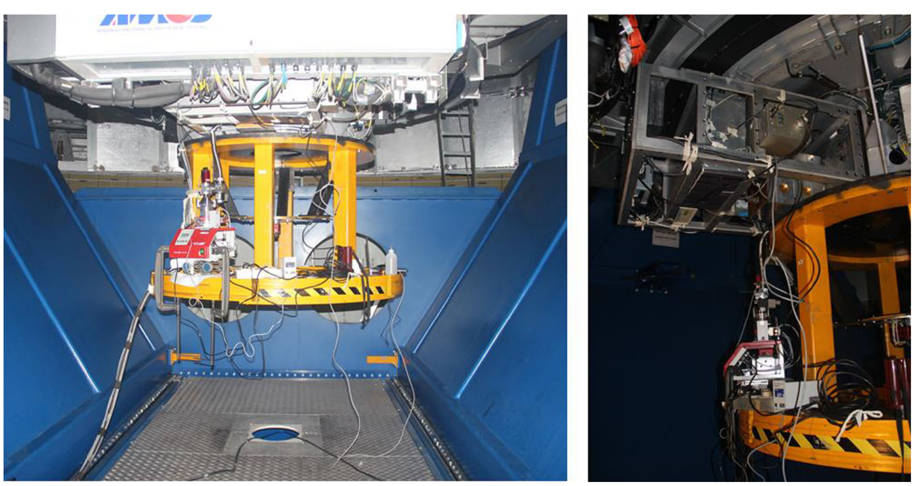

Figure 14. Evacuation setup of the TIRCAM2 camera at the telescope floor after mounting the camera on the side port.

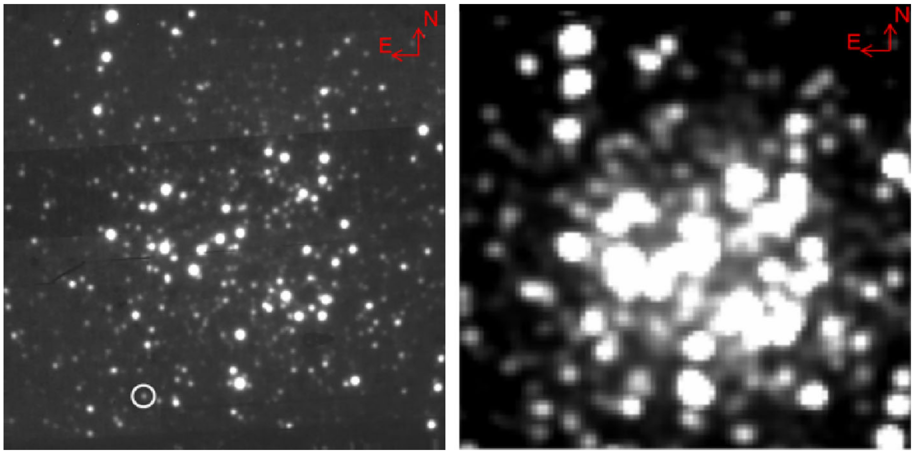

Figure 15. Left: A part of the mosaic ($\sim 1.45' \times 1.45'$) image of the M53 globular cluster in the J-band image taken with the TIRCAM2 at the DOT side port. Right: M53 J-band image taken by 2MASS. Both images correspond to the same FoV. North is up and East is at left.

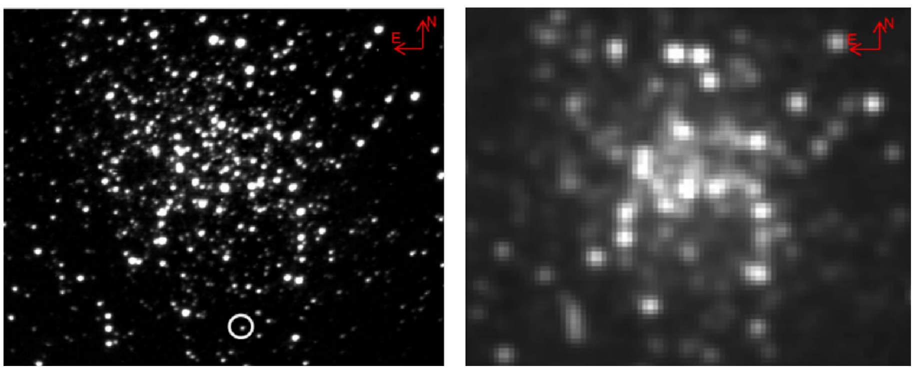

Figure 16. Left: The Palomar 2 globular cluster in the J-band observed with the TIRCAM2 at the side port. Right: Palomar 2 J-band image taken by 2MASS in J-band. Both images correspond to the same FoV. North is up and East is at left.

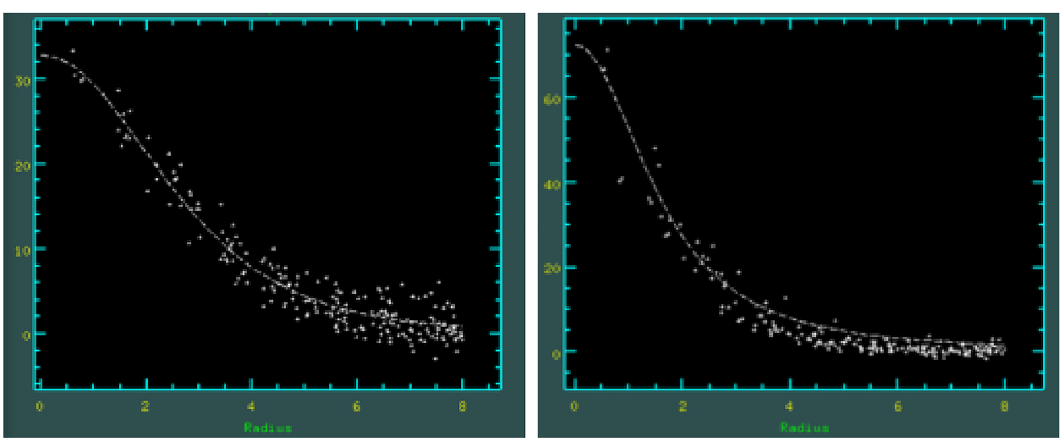

Figure 17. The radial profiles of the stars marked in TIRCAM2 J-band images (see Figures 16 and 17) of the M53 (left) and the Palomar 2 globular cluster (right).

7. Conclusion

Interfacing of the TIRCAM2 camera on the side port of the DOT has been completed successfully as shown in Figure 12. The first light with the TIRCAM2 camera setup on the DOT side port was achieved on 5 May 2020. Currently, the TIRCAM2 camera is being used successfully at the DOT side port for science observations.

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