Development of a Robotic DIMM Seeing Monitor

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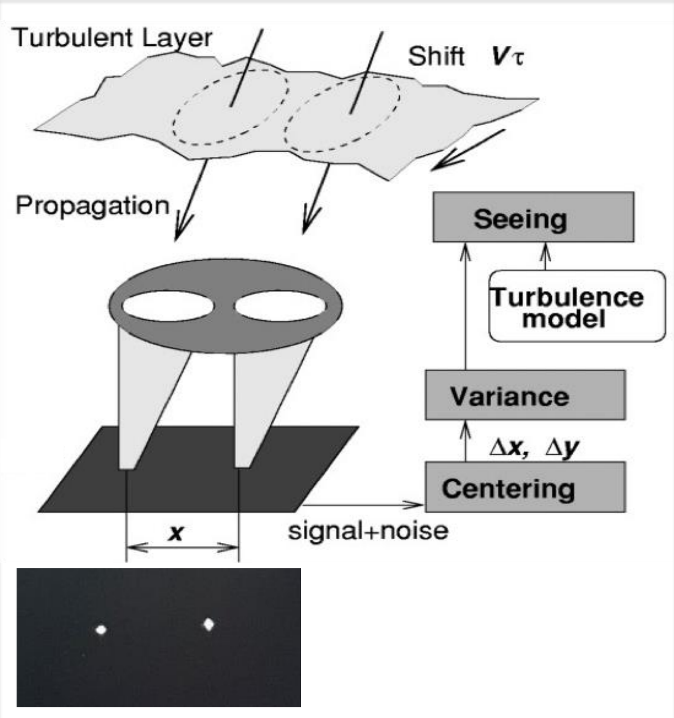
ABSTRACT

After the availability of the clear sky, seeing is the most important parameter to characterize any new astronomical sites. There are different ways to measure atmospheric seeing, however, the Differential Image Motion Monitor (DIMM) is considered one of the best method to explore the integrated effect of the turbulent atmosphere. Considering the need to identify a few good candidate sites for the National Large Optical Telescope (NLOT) project as well as to support other groups working to set up smaller observatories in different parts of the country, we decided to develop a robotic DIMM system. The overall development is aimed to achieve a portable seeing monitor which can be efficiently and reliably used in remote places without any human intervention, and is modular in architecture so that it can be easily integrated with other smaller telescope , imaging camera and weather station. We intend to make the code open-sourced so that anyone interested in validation and developing robotic DIMM can get benefited. After an year long effort, the system is operational from 31st January 2023 at the proposed NLOT site (32:46:47"N 78:57:45"E , 4547m amsl.) in robotic manner. The median over February is found be 1.2". We plan to develop two more similar systems and conduct seeing campaign at other places in the region.

CONCEPT

- The turbulent atmospheric layers cause beam propagation disturbances that degrade the quality of astronomical images
- The DIMM principle involves using the same telescope to produce twin images of a star via two entrance pupils separated by a distance. The differential method measures the angular differences over the two small pupils.
- By using a turbulence model to determine the phase structure function, we can evaluate the longitudinal and transverse variances (parallel and perpendicular to the aperture alignment) of differential image motion.



The DIMM concept. Fig. Cr: ESO

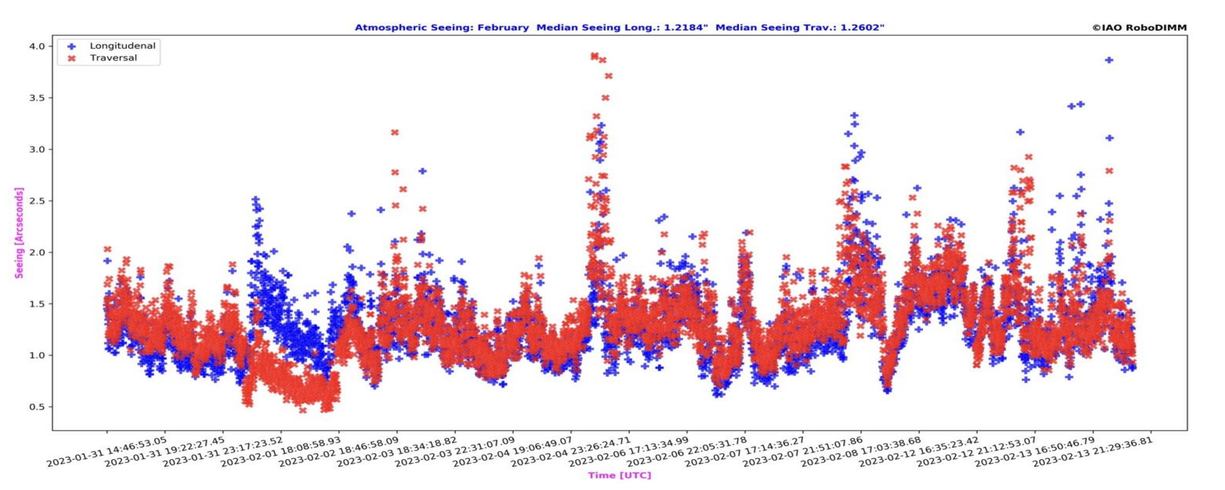
Sarazin & Roddier et al. turbulence model:

$$\mathrm{FWHM}(\epsilon_0) = 0.98\left(\frac{D}{\lambda}\right)^{0.2}\left(\frac{\sigma_d^2}{K}\right)^{0.6}, \quad K_{lZ} = 0.364(1-0.532b^{-1/3}-0.024b^{-7/3}), \quad K_{tZ} = 0.364(1-0.798b^{-1/3}+0.018b^{-7/3}).$$

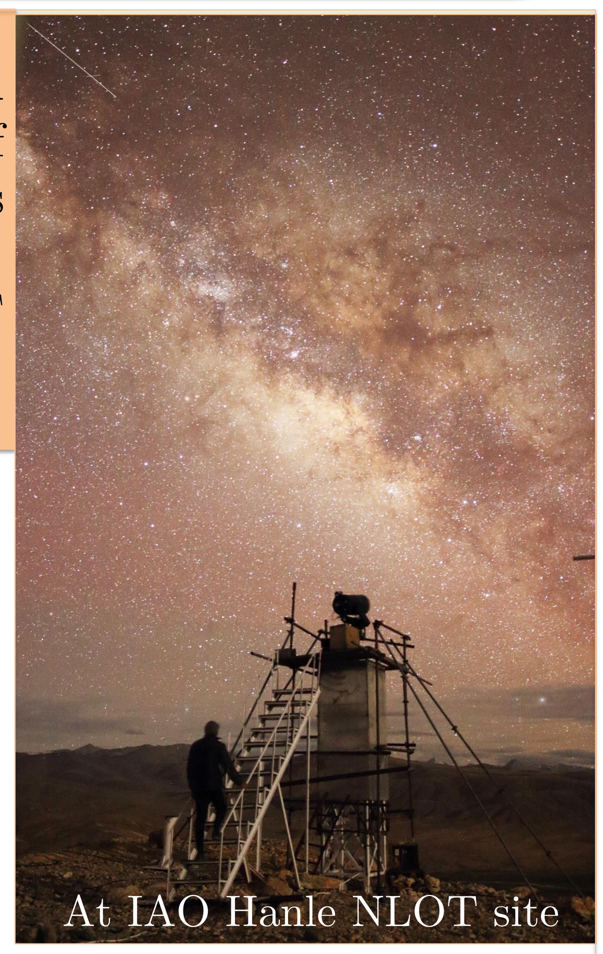
Fried et al. turbulence model:

$$\mathrm{FWHM}(\alpha) = 0.976\left(\frac{\lambda}{r_0}\right) \quad \sigma_l^2 = 2\lambda^2 r_0^{-5/3}[0.179D^{-1/3} - 0.0968d^{-1/3}] \quad \sigma_t^2 = 2\lambda^2 r_0^{-5/3}[0.179D^{-1/3} - 0.145d^{-1/3}]$$

- A major challenge i.e analysis against high wind speed and image quality is rigorously done and wind speed of <7m/s is found to meet roundness and sharpness criteria
- Compared the centroid algorithm exploited with IRAF "daofind" and "phot" tasks and is found to be precise.



Seeing over February '23. **Median Seeing= 1.2"**

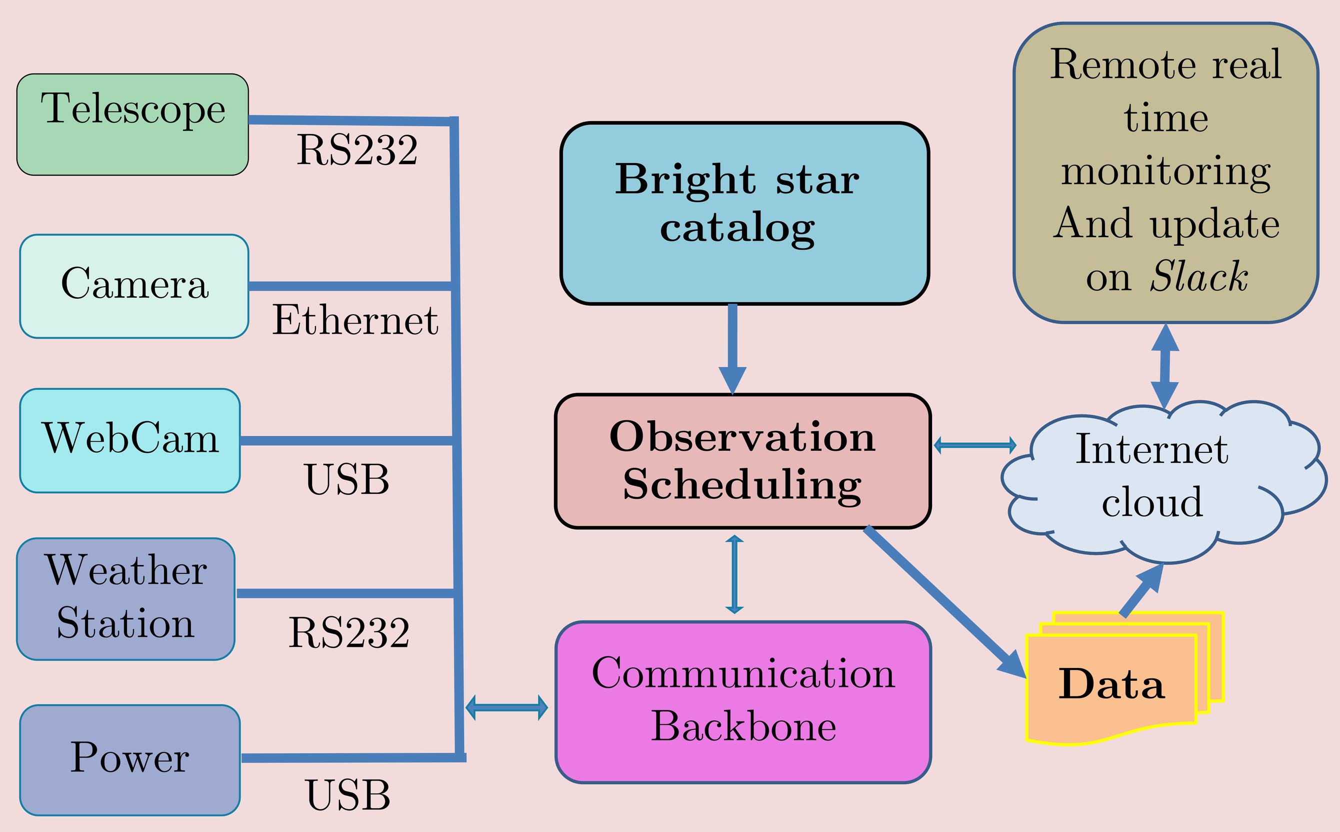


Setup on a 4 meter tower

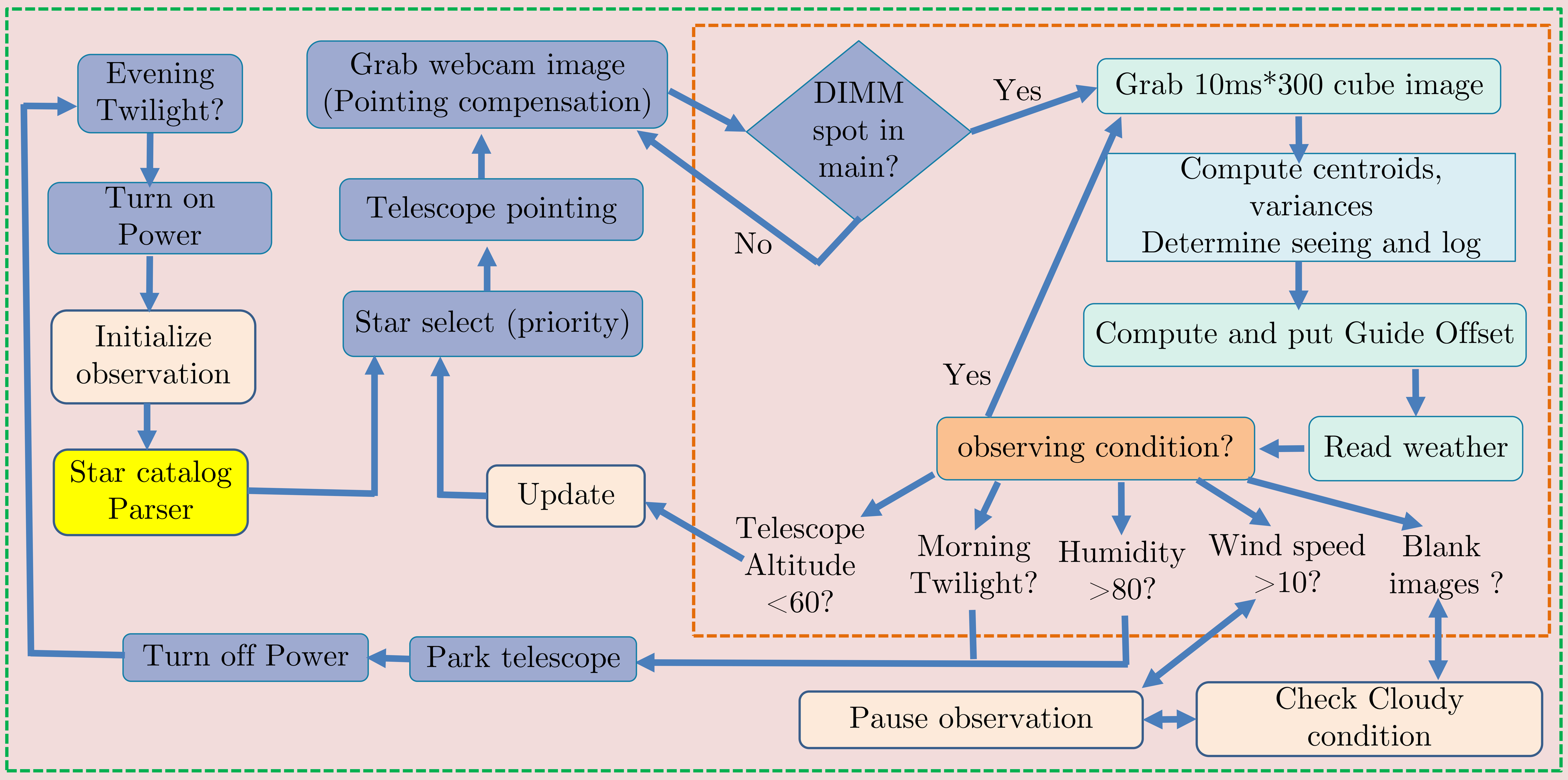
ROBOTIC OPERATION

- The entire software is built with *Python3.6* on *Linux* platform. The code and its description of is made available on *github* [**Scan QR code**]

OVERVIEW



OBSERVATION SCHEDULING



NOTE:

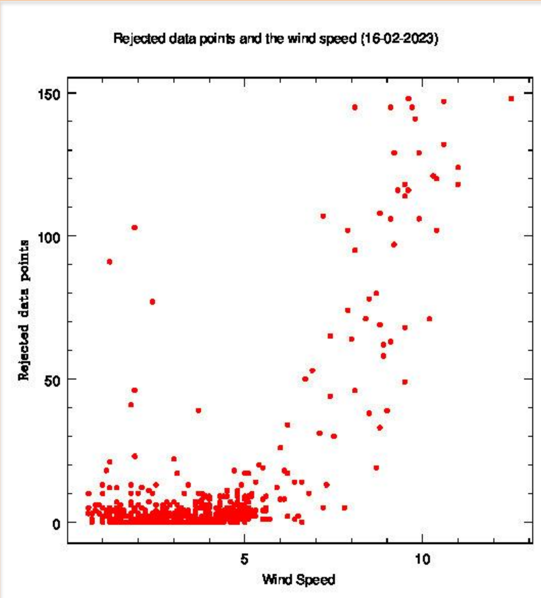
- **Pause observation:** When DIMM observation is paused, other observing conditions are still computed
- **Cloudy condition:** When star is not detected in the main and webcam, next 2 stars will be pointed, based on which decision to continue or pause is taken
- **Pointing compensation:** The telescope have got poor pointing accuracy for main camera FoV. To overcome this problem a wide-angle lens on a webcam is piggybacked onto the telescope and offsets are computed from webcam image until the star appears in main FoV

HARDWARE CONFIGURATION

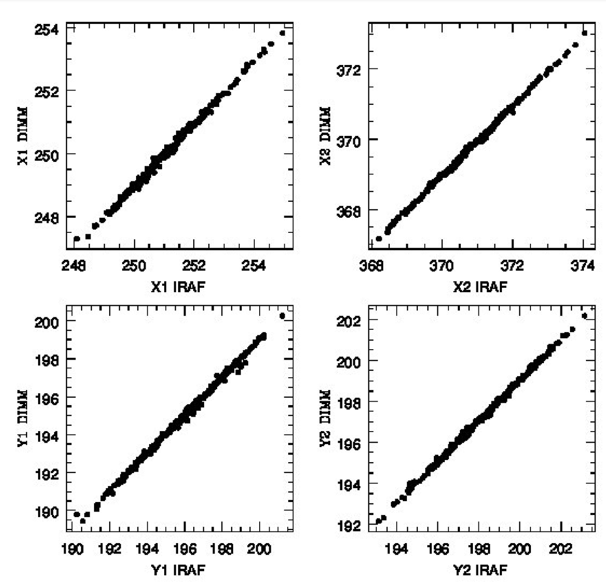
Components	Description *fabricated in-house
Telescope	*Meade* LX200 GPS 12" f/10
Wedge prism	Material N-BK7, AR coating , Surface flatness λ/4, Wedge angle:1.0 ± 0.1 arc-min.
Mask*	Hole diameter: 54.94mm Hole separation: 242.66m
Camera	*Lucid Vision* PHX023S-MC Gigabit Ethernet based Plate scale : 0.2334" /px
Webcam	*Arducam* IMX291with 100 mm lens mount*
Computer	*Adlink* MXE1400 embedded PC
PowerController*	*Arduino* MCU based
Weather Station	*Thies Clima* DLxMET9.1

RESULT

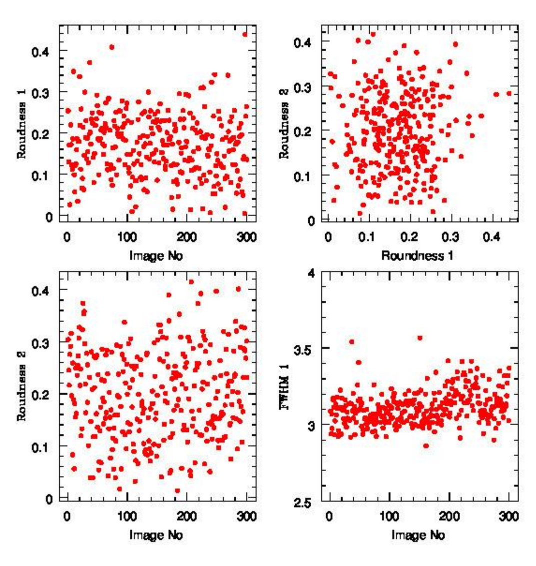
- The instrument is currently operational in unmanned/robotic manner and is planned be operated at the site for at least 1 year.
- 2 similar systems are being replicated to conduct seeing in campaign mode in other regions of Ladakh
- Automated actions based on weather observing condition like humidity/rain, wind Speed and cloud is implemented and tested
- Roundness and sharpness of 0.0 to 0.4 is set as image quality parameter for rejection of data points
- Real time update of observation and observing condition/error is sent on Slack



Wind speed v/s rejection



Centroid algorithm v/s IRAF



Roundness/Image quality

ACKNOWLEDGEMENT

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