Development of a Robotic DIMM Seeing Monitor

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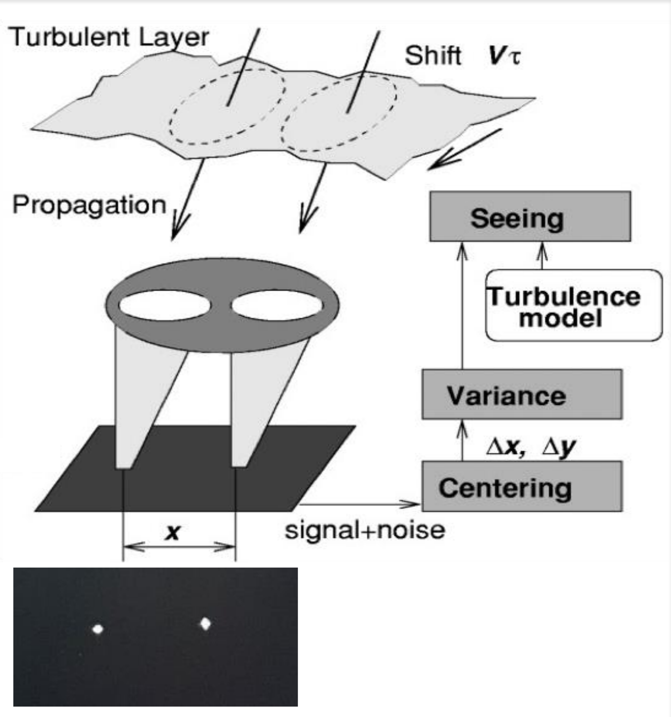
ABSTRACT

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. 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 seeing observed over 22 nights of the February 2023 is found be 1.1". 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 determining the phase structure function, we can evaluate the longitudinal/parallel and transverse/perpendicular variances of differential image motion. The final estimate is the average of both parallel and perpendicular motions



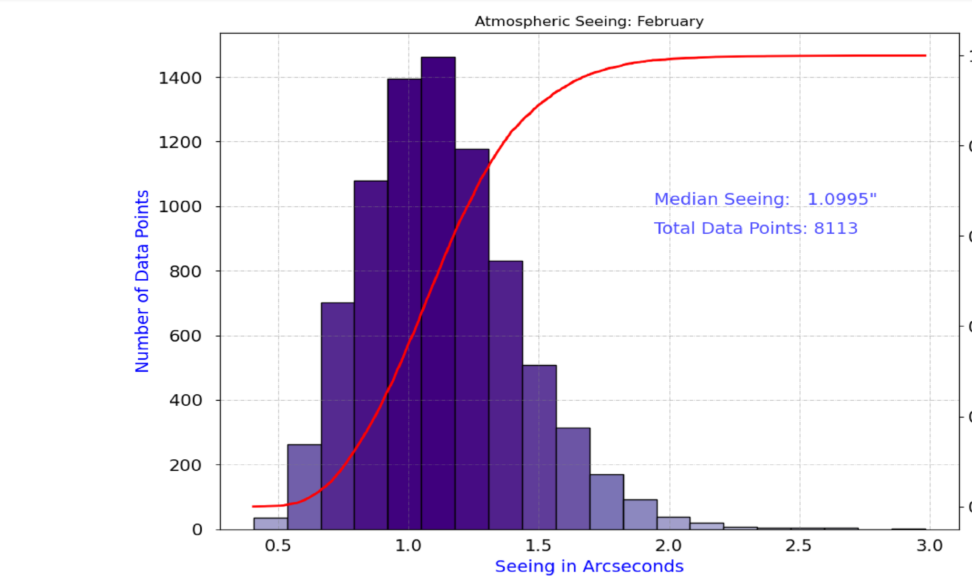
The DIMM concept. Fig. Cr: ESO

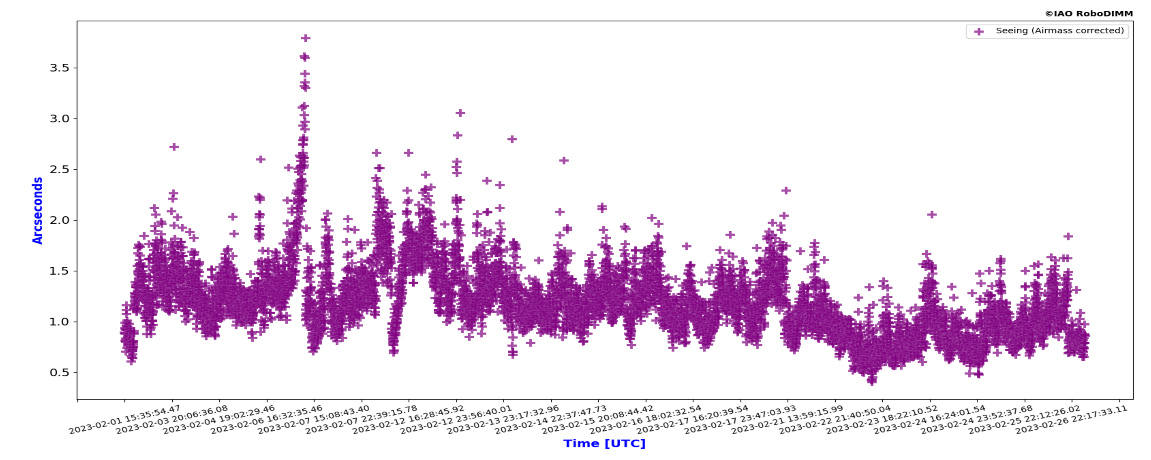
Tokovin [3] formula:

$$\mathrm{FWHM} = \frac{0.98\lambda}{r_0} = 0.98\left(\frac{D}{\lambda}\right)^{0.2}\left(\frac{\sigma_d^2}{K}\right)^{0.6}, \quad K_{lZ} = 0.364(1 - 0.532b^{-1/3} - 0.024b^{-7/3}), \quad K_{tZ} = 0.364(1 - 0.798b^{-1/3} + 0.018b^{-7/3}).$$

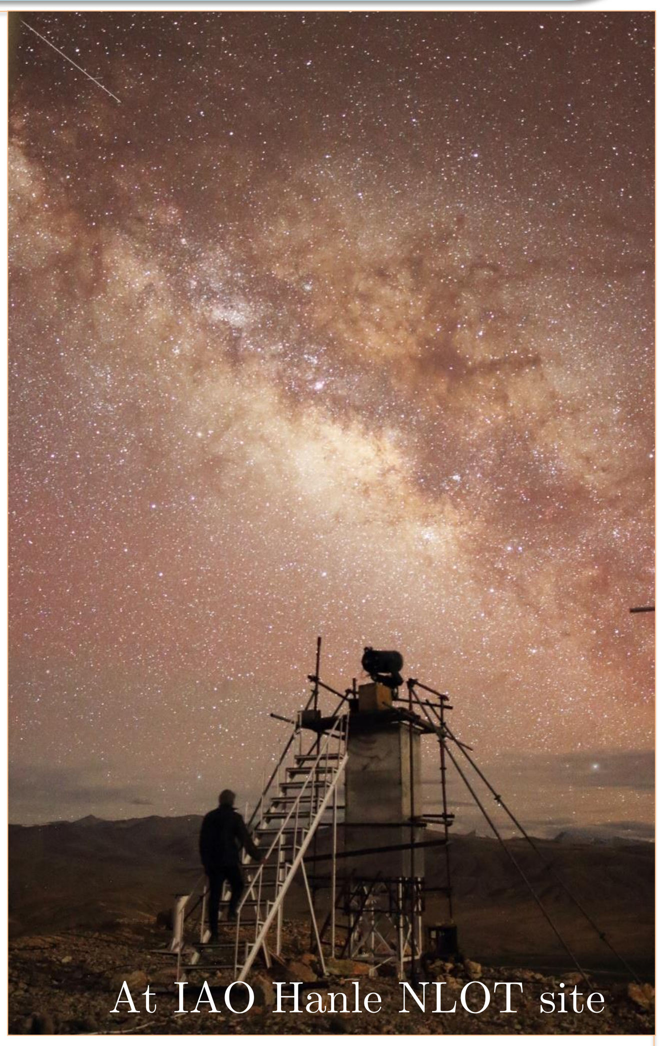
K_{lZ} longitudinal image motion
K_{lZ} transverse image motion

r_0 *Fried paramter* σ_d covariance , λ wavelength, B aperture separation, D aperture diameter , $b = \frac{B}{D}$





DIMM Seeing over Feb 2023 [22 nights]

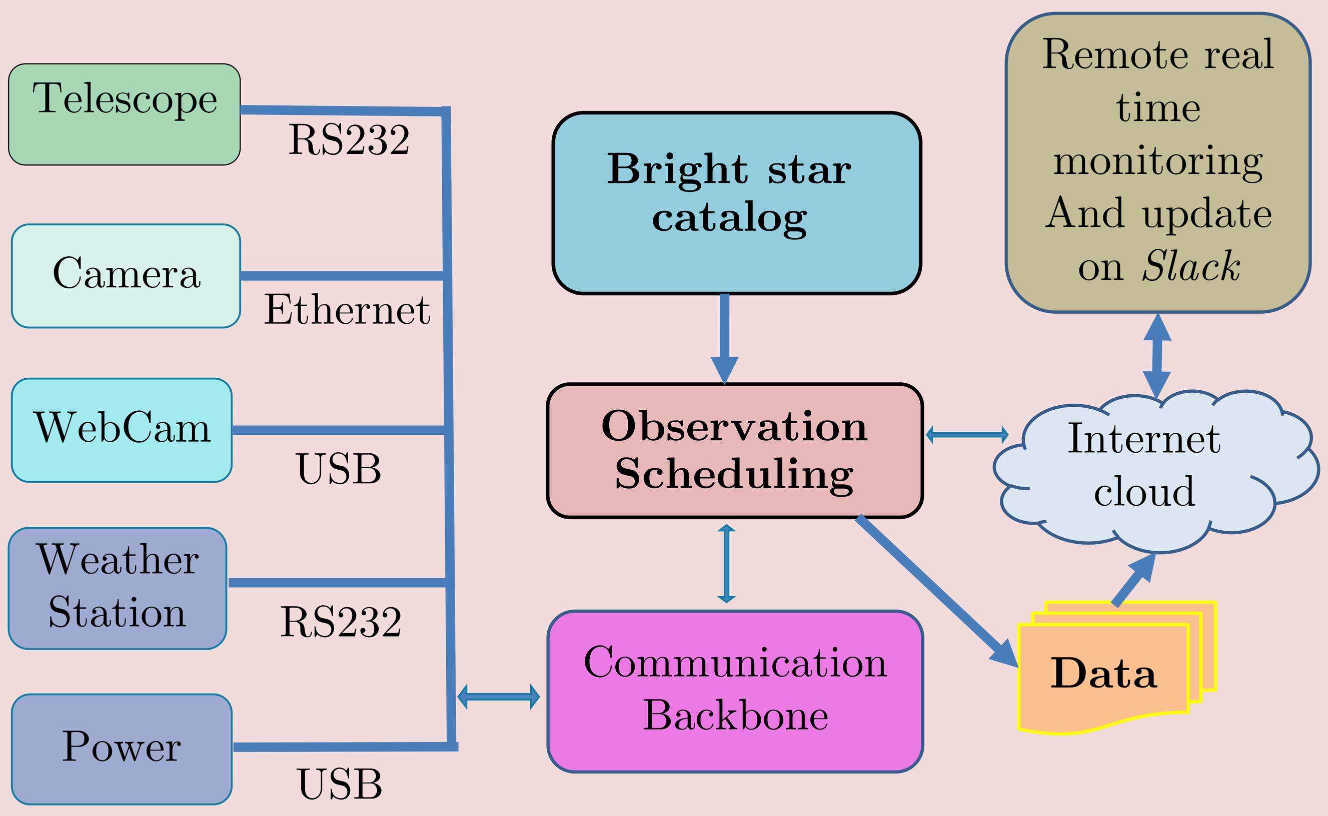


Setup on a 4 meter tower

ROBOTIC OPERATION

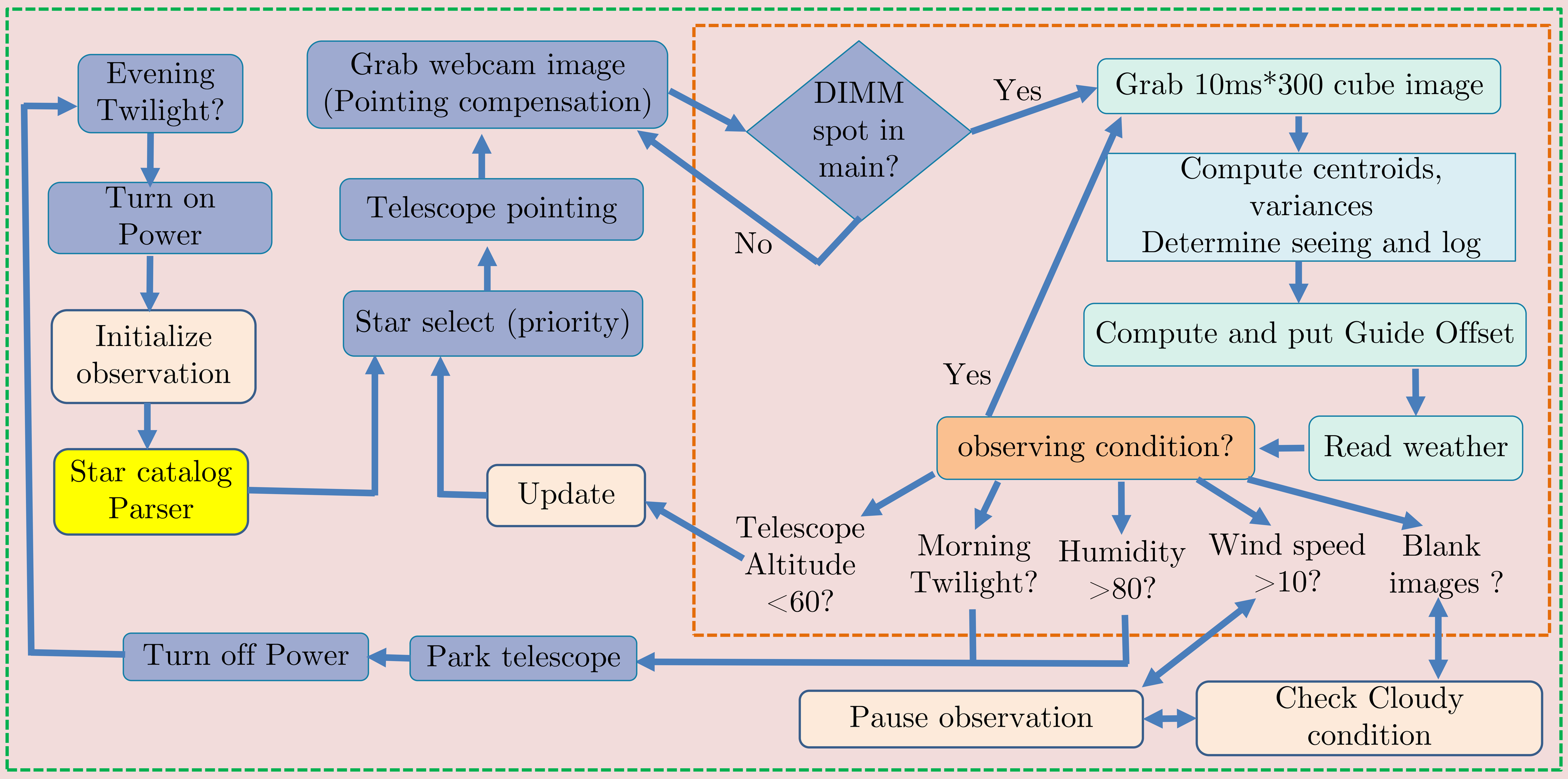
- India's first robotic DIMM seeing monitor. The entire software is built with *Python3.6* on *Linux* platform.

OVERVIEW



- **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

OBSERVATION SCHEDULING



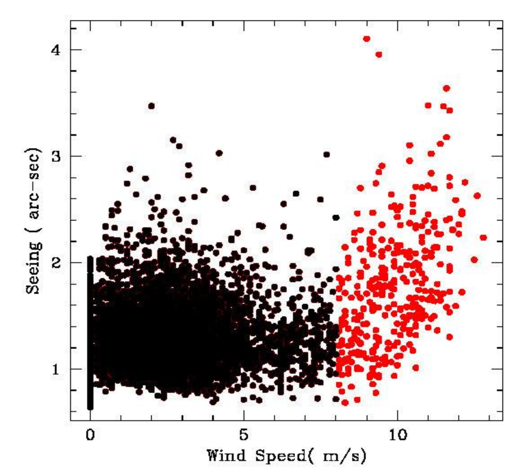
HARDWARE CONFIGURATION

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

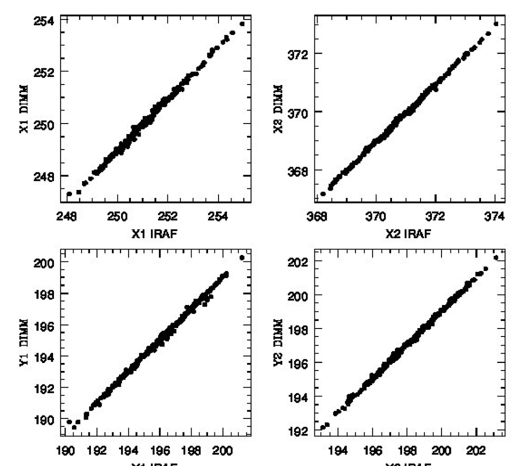
RESULT

- The instrument is currently operational in unmanned/robotic manner and is planned to be operated at the site for at least 1 year
- Typical efficiency of 1 seeing data point/minute is achieved which include centroiding, analysis, pointing and guiding overhead
- Automated actions based on weather observing condition like humidity/rain, wind Speed and cloud is implemented and tested
- Real time update of observation and observing condition/error is sent on *Slack*
- There are preliminary indication of surface layer wind speed and direction dependency of the seeing

- Rejection criteria set based on image quality i.e. roundness, fwhm and sharpness
- Exclusion of the wind induced data (>8m/s)
- Cross checked the centroid algorithm exploited with IRAF *"daofind"* and *"phot"*



Wind speed v/s seeing



Centroid algorithm v/s IRAF

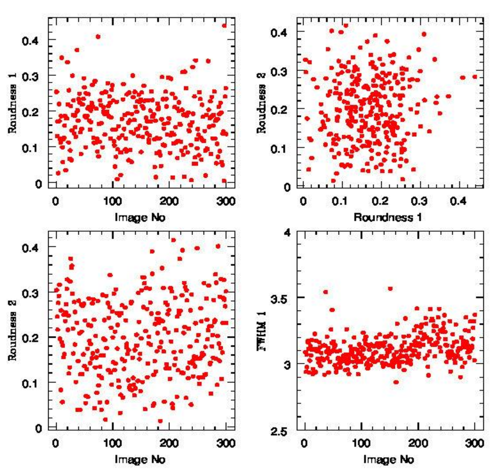


Image quality parameters

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