Development of the NLOT Site Characterization Instruments

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Outline

1) Optical Astronomy in India: Present and Future.

2) Indian Astronomical Observatory Hanle.

3) Effort to develop various site characterization instruments for the NLOT

Optical Astronomy in India: Present and Future

1) Total six telescopes of 1-2 meter sizes, distributed all over India.

2) One 3.6 meter project in midway and the first light is expected in 2014-15.

3) India has got observers status to the TMT project.

4) Indian astronomical community has no access to 8-10 meter (limited access to SALT)

5) Need to have 8-10m size telescope: NLOT

Optical Observatories in India

VBO

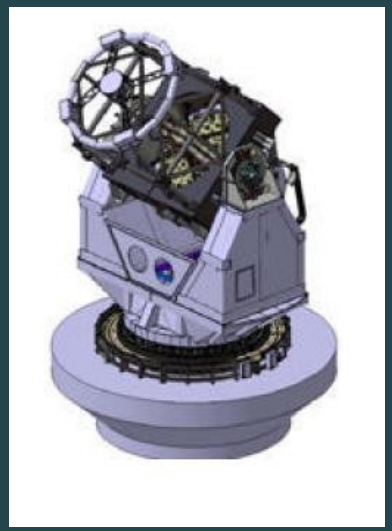
VBT 2.3m

2.3 m VBT with the new Boller and Chivens Spectrograph, equipped with an Astromed CCD at the Cassegrain focus

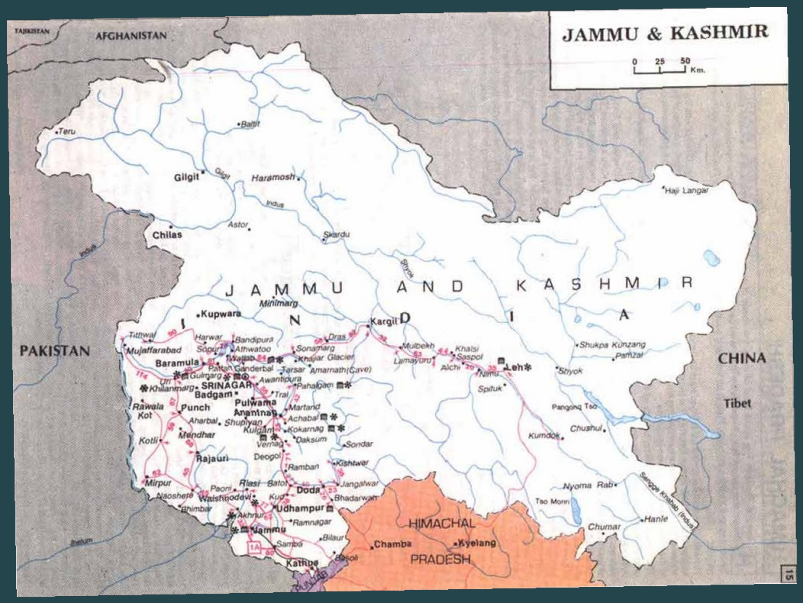
IUCAA 2m

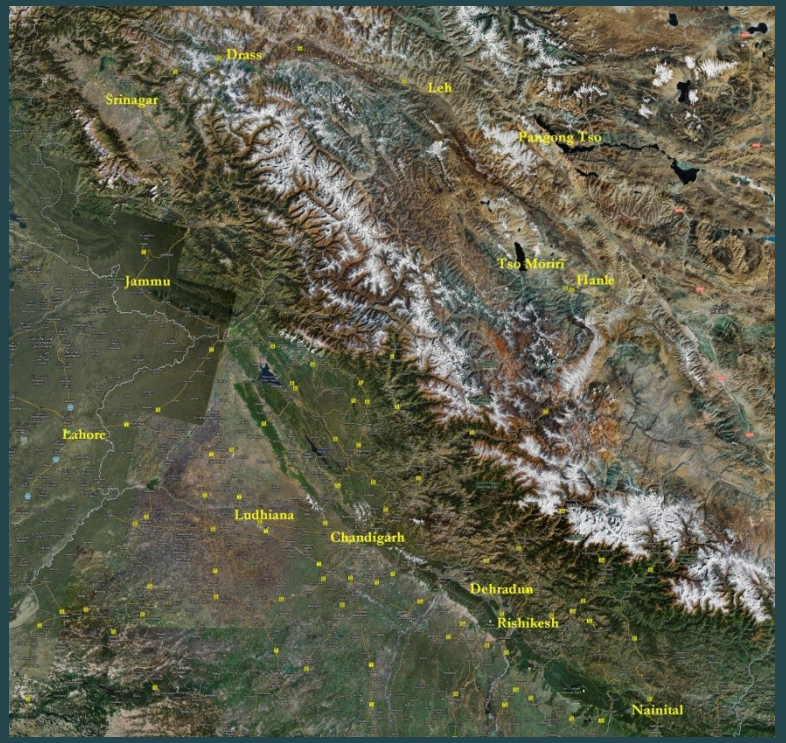
IAO 2m

DOT 3.6m

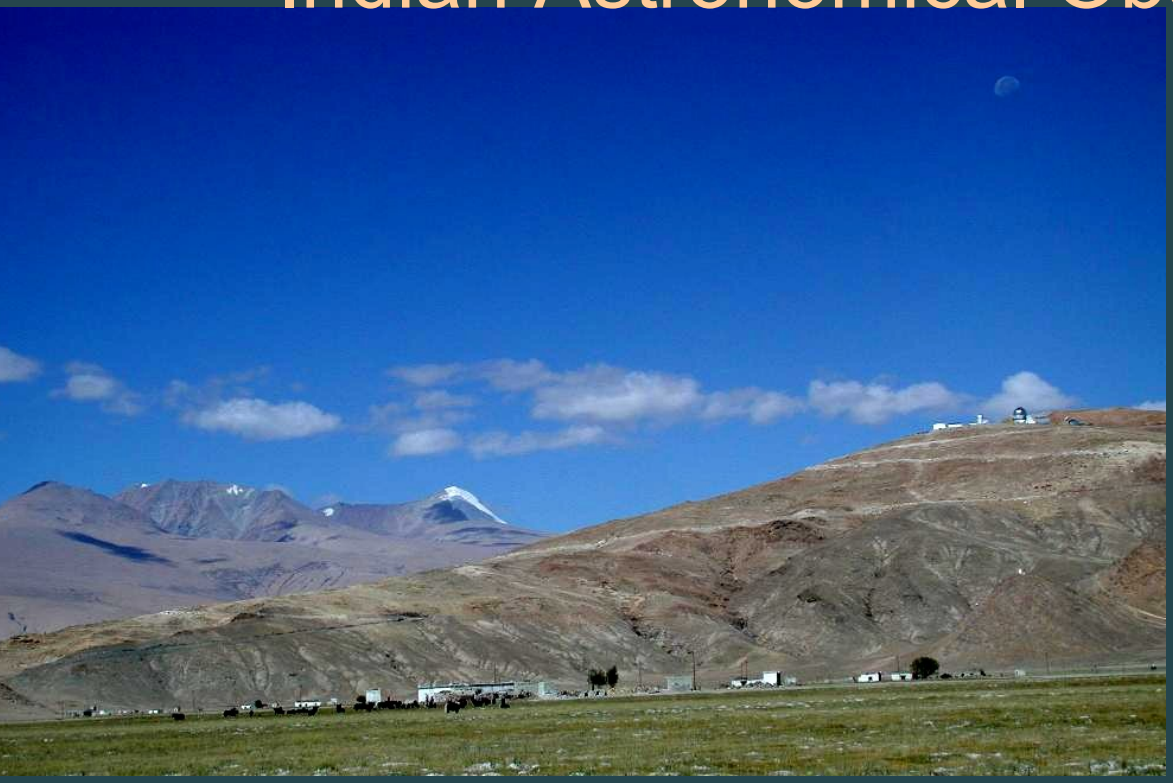


The potential sites for the NLOT: Trans Himalayan Region





Indian Astronomical Observatory



One 2m HCT telescope, operation remotely since 2000.

One 0.5 Robotic Antipodal Transient Observatory.

http://www.iiap.res.in/centers/iao

Coordinate	32:46:46s N 78:57:51s E
Altitude	4500 meters above msl
Wind Speed	Median 2.2 m/s at night
Wind Direction	Prevailing south-south-easterly
Rain & snow	< 7 cm
PWV	< 2 mm between October - April
Number of usable nights	~ 260 per year

The potential sites for the NLOT: Close to IAO Hanle

Place	Distance (road)	Distance(Aerial)	Latitude(m)	Longitude	Latitude
Leh	270km				
Hanle (base camp)	0		3500		
Hanle (IAO)	4.5km		4500	78:57:51.0	32:46:46
Kalaktartal	25km		5111	79:00:44.4	32:38:23.4
Raindong	20km		5055	78:55:20.4	32:50:46.92
Twin-lake	45km				

Status of the NLOT site characterization instruments

Meteorological parameters:

- Three Automatic Weather Station are acquired and in use.

Sky transparency/brightness:

- One night camera and day night camera
- Extinction and sky brightness monitor is being developed and expected to see the first light by March 2011.
- NLST Skyradio meter is in operation since 2007.
- 220 Giga Htz radiometer is in operation since 1999.

Seeing monitors:

- One Differential Image Motion Monitor (DIMM) has developed and installed at Hanle 2010
- Other mobile DIMM will ready by April 2011

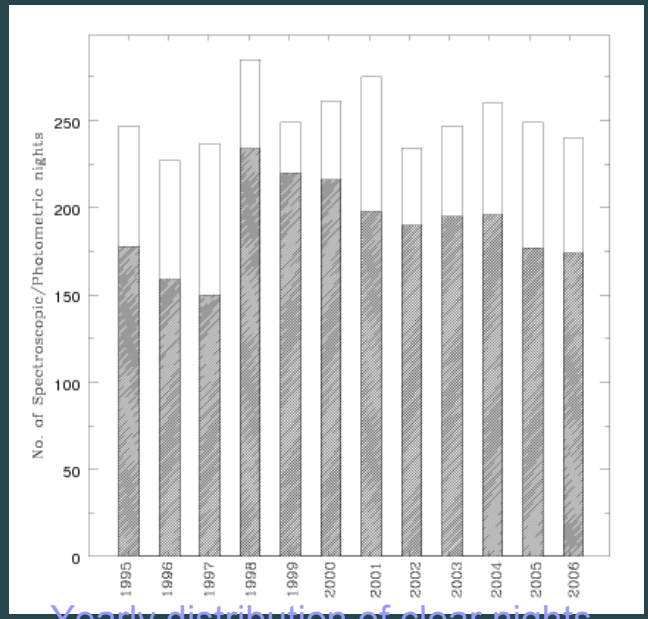
Atmospheric turbulence profiles $C^2_n(h,t)$:

- One microthermal measuring instrument being devloped
- A Lunar Scintillometer has been also proposed
- MASS (Multi-aperture scintillation Sensors) development work has been initiated

Statistics of the clear sky at IAO

Statistics of the clear sky can be obtained from following sources

- Hourly visual monitoring of the sky since 1995
- Observing log of HCT since May 2003
- CONCAM: All sky night camera since 2004
- Day-Night all sky Camera since 2010
- Satellite images

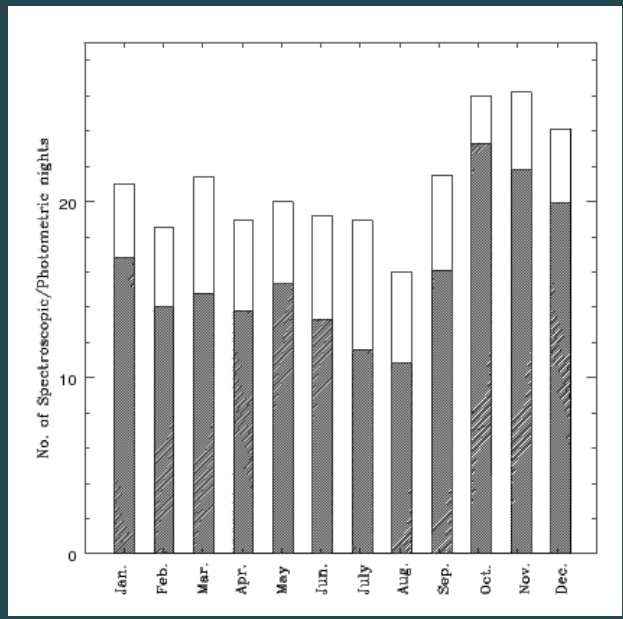


Yearly distribution of clear nights

I. Number of spectroscopic/usable nights = 263±17(72±5%)

II. Number of photometric/clear nights = 191±25(52±7%)

III. Usable nights trough out the year.



Monthly distribution of clear nights

The clear sky at best astronomical sites

Usable nights = 78-85% (Mauna Kea = 78%)

Clear nights = 69-83% (Mauna Kea = 69%)

All Sky Camera's

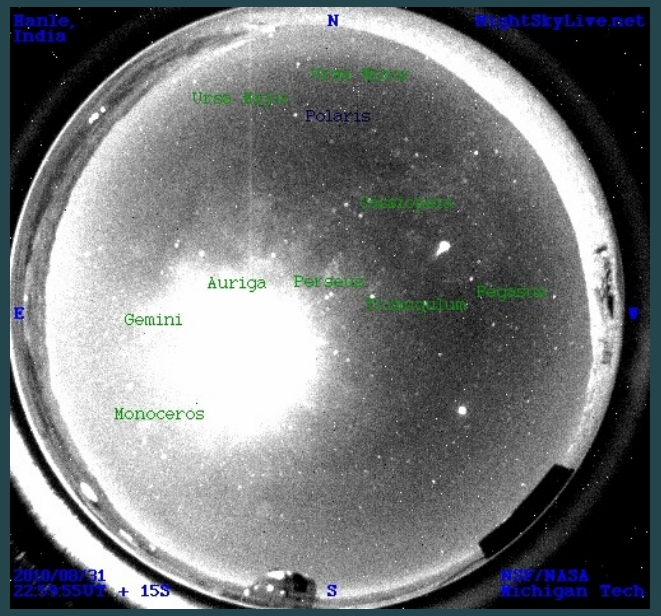
I. All sky day and night camera, operating around the clocks provides unbiased statistics of the clear skies.

II. They can also be used to get course extinction map of the sky and to detect cirrus clouds.

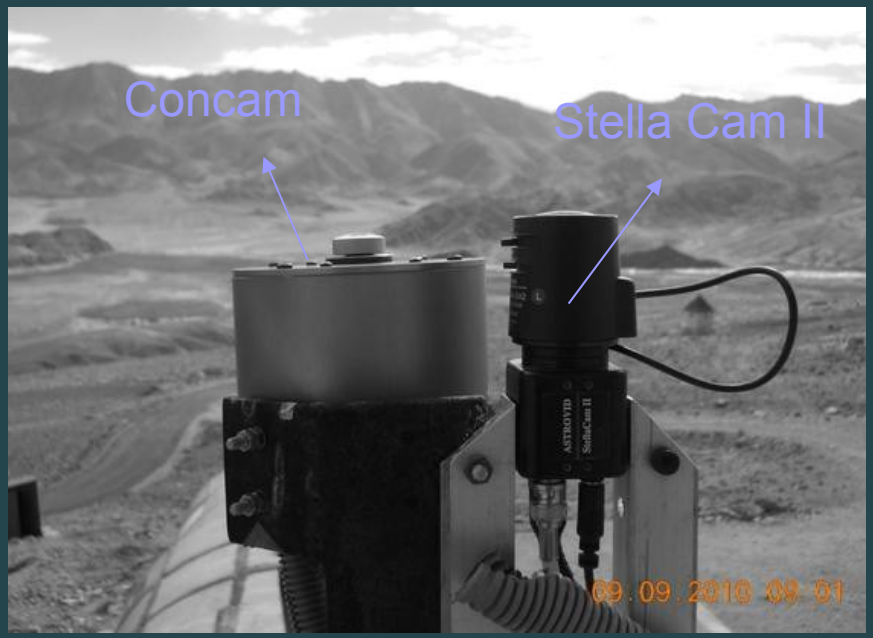
III. One night (CONCAM) and one day-night (StellaCam II) camera are used to monitor Hanle sky.

IV. CONCAM is in operation since 2005 and data is being used to get statistics of clear sky.

V. Two sttella Cam II has been tested and will be put in operation soon



All sky night camera: Concam



All Sky day-night Camera:

NLOT DIMM

1) The old DIMM was operational during 1998-2001. Nearly 1 arc-sec median seeing was obtained.

2) Development of new DIMM for the NLOT started in March 2009 and installed at IAO in Sep 2009.

3) Few more DIMM are planed to be developed, including one mobile DIMM.

Hard ware specification:

Telescope:

MEADE LX200GPS
- Diameter 0.35cm (F/10)
- GPS receiver
- Micro focuser
- Flip mirror
- ~4' RMS pointing error
- RS232 Serial Interface

CCD:

SBIG ST-5
- RS232 Serial Interface
- Maximum Baud Rate: 115kbps
- 320x240 array size
- Pixel size 10x10 micron
  - 0.59"/pixels
- TE cooling (-20 C)

Hole size = 57mm Hole separation = 272mm

Spot separation = 30 arc-sec

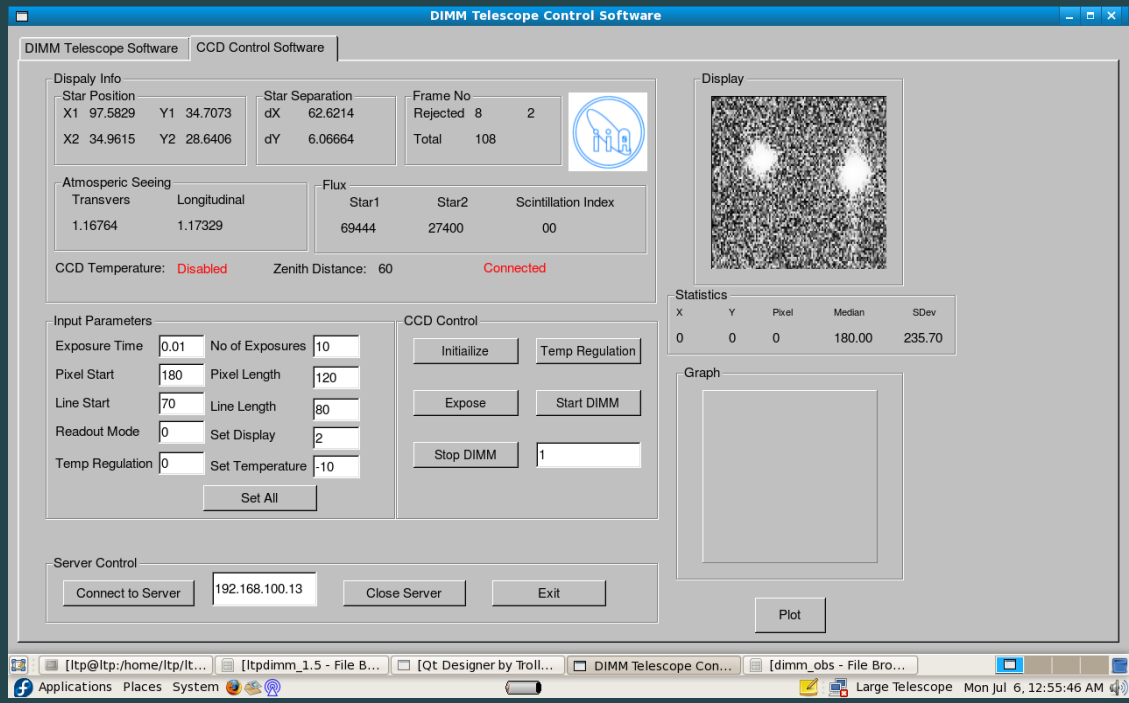
The Control Software

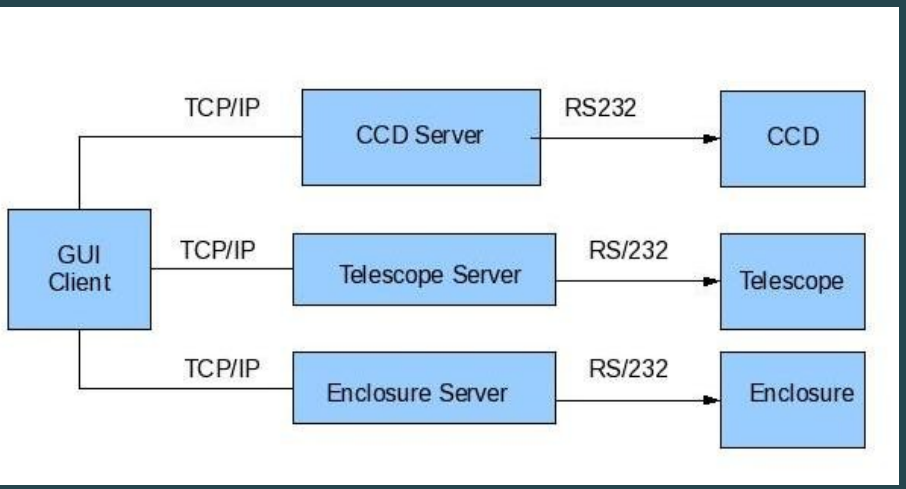
The Software :-

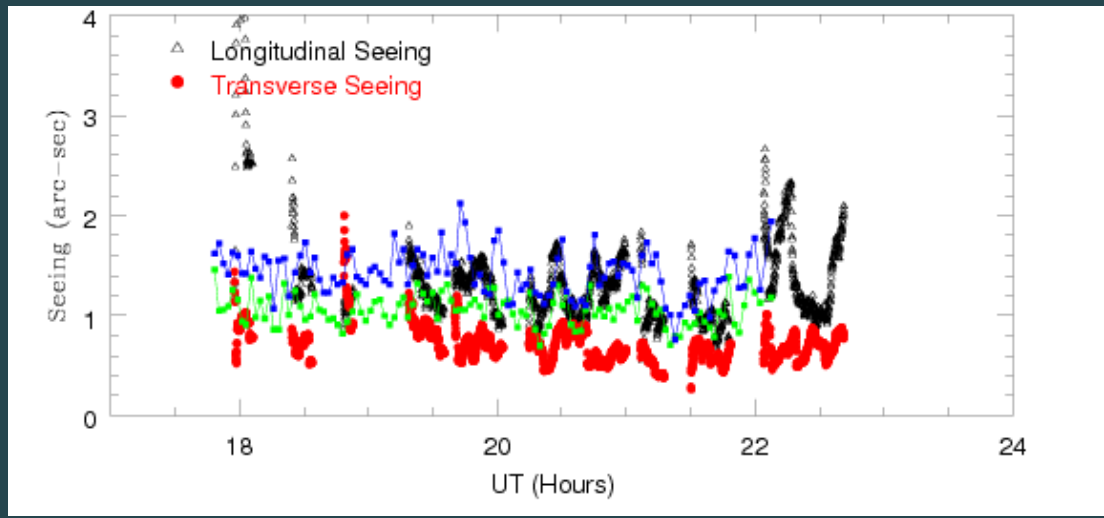
We have chosen client- server mode of operation using socket programming and all hardwares are controlled by servers.

All CCD and Telescope control software functions are written in C++ in Linux platform. The GUI is in QT.

The DIMM control software will be shortly linked with the weather station and the web.

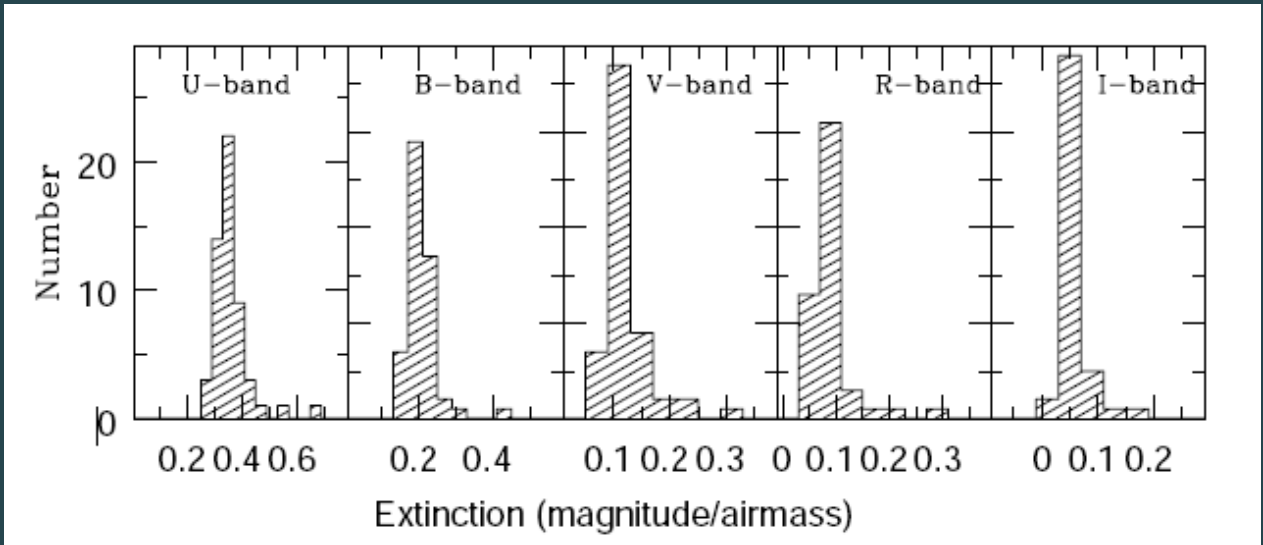






Atmospheric Extinction and sky brightness at IAO Hanle

Over more than 60 nights, 2m HCT was used to get extinction and sky brightness.



Distribution of atmospheric extinction at IAO.

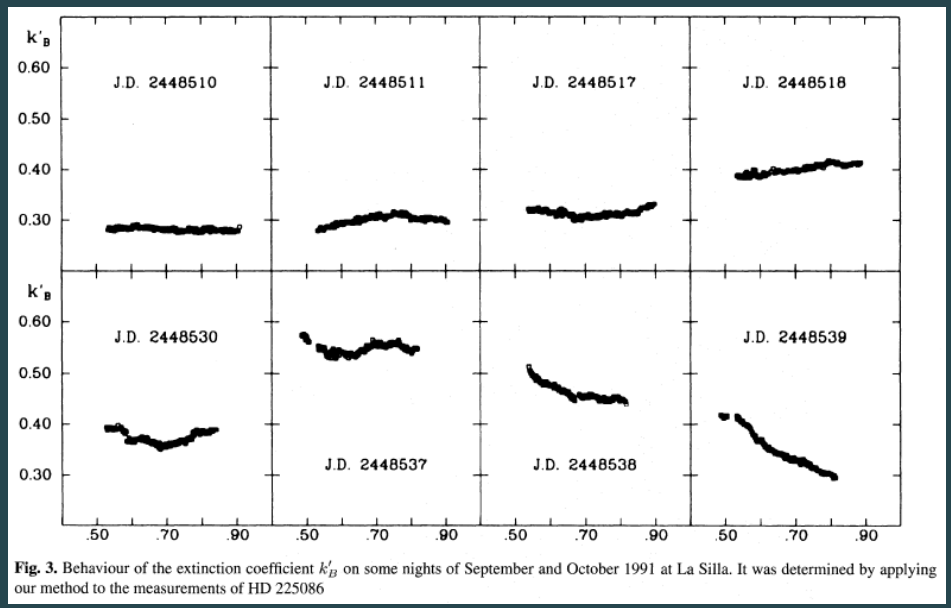


Fig. 3. Behaviour of the extinction coefficient k'_B on some nights of September and October 1991 at La Silla. It was determined by applying our method to the measurements of HD 225086

Inra-night extinction variation in LaSilla

Extinction

	IAO	Mauna Kea
U	0.36±0.07	0.36
B	0.21±0.04	0.20
V	0.12±0.04	0.12
R	0.09±0.04	0.10
I	0.05± 0.04	0.05

Sky Brightness

	IAO	Paranal
U	22.14±0.32	22.35
B	22.42±0.30	22.67
V	21.28±0.20	21.71
R	20.54±0.37	20.70
I	18.86±0.05	19.20

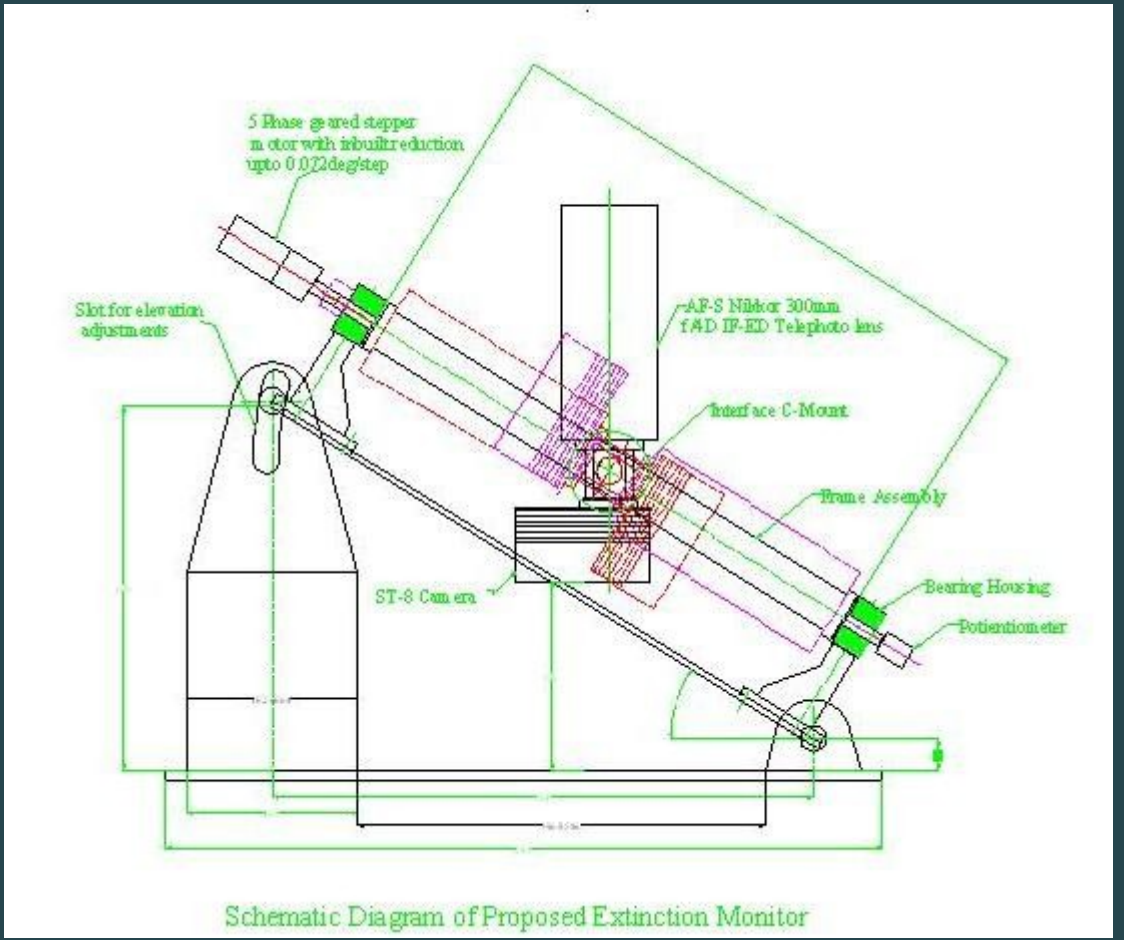
Development of Automated Extinction and Sky Brightness Monitor

Motivation

1) Very accurate measurement of atmospheric extinction in single band.
2) Statistics of clear sky (photometric nights/hours).
3) Instantaneous measurement of extinction.
4) Measuring the sky brightness.

Hardwares

1) Equatorial Yoke mount
2) Driven by 5 phase stepper motor and custom made controller.
3) Optics is a Nikon Telephoto lens F/4, D=75mm
4) ST-8 Thermo electrically cooled CCD camera.
5) FOV 2.6x1.7 degree.

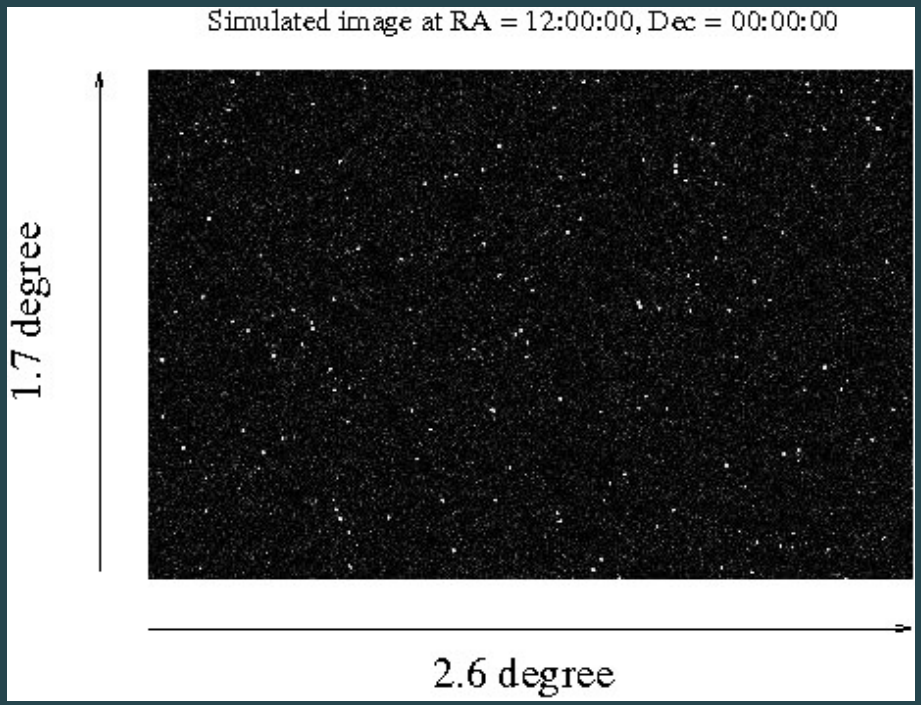


Schematic Diagram of Proposed Extinction Monitor

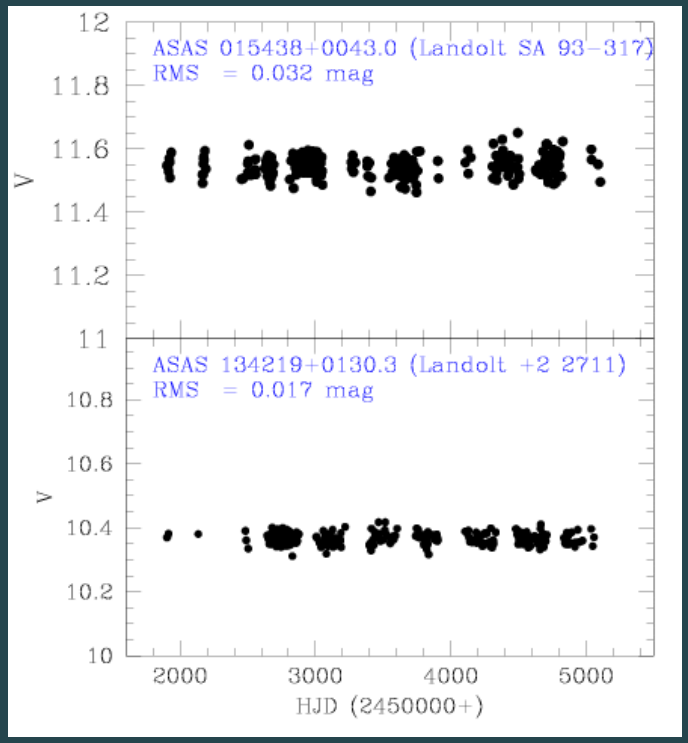
Extinction and Sky Brightness Monitor

1) All 100-200 stars not found to be variables will be used to determine extinction.
2) There is no filter wheel in the present design, so initially extinction will be recorded in single R broad band filter.
3) In the classical mode extinction monitor will observe any chosen filed ±45 degree around the meridian at variable airmass.
4) In instantaneous mode, pre-calibrated filed will be observed and instrument will start delivering reliable extinction within 10-20 minutes .
5) The pre-calibrated field with very high binning will give very accurate sky brightness.

Simulated FoV



ASAS observations



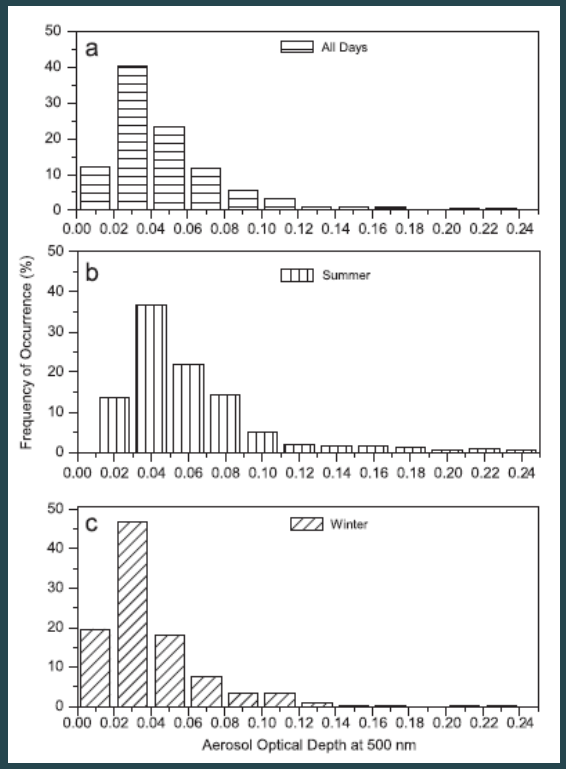
Optical Aerosol Monitor: NLST Radiometer

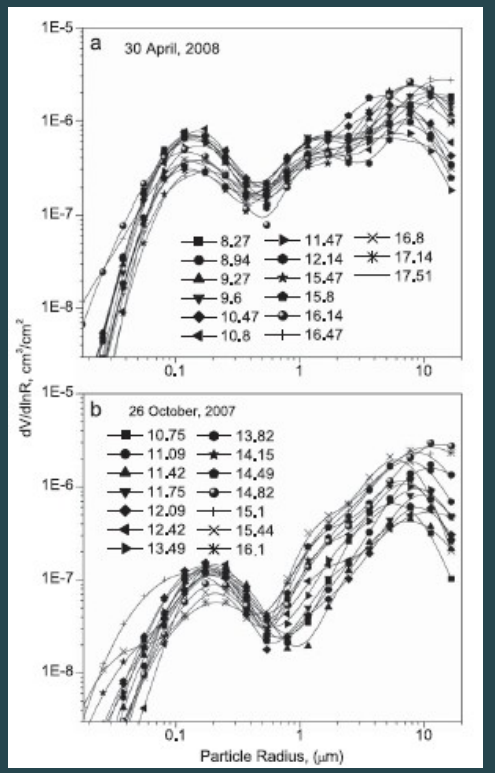
The atmospheric extinction due to Aerosol scattering is given by the formula

$$\tau_a(\lambda) = \beta\lambda^{-\alpha}$$

Where τ_a is aerosol optical depth (AOD) ,
α is Angstrom's exponent and β

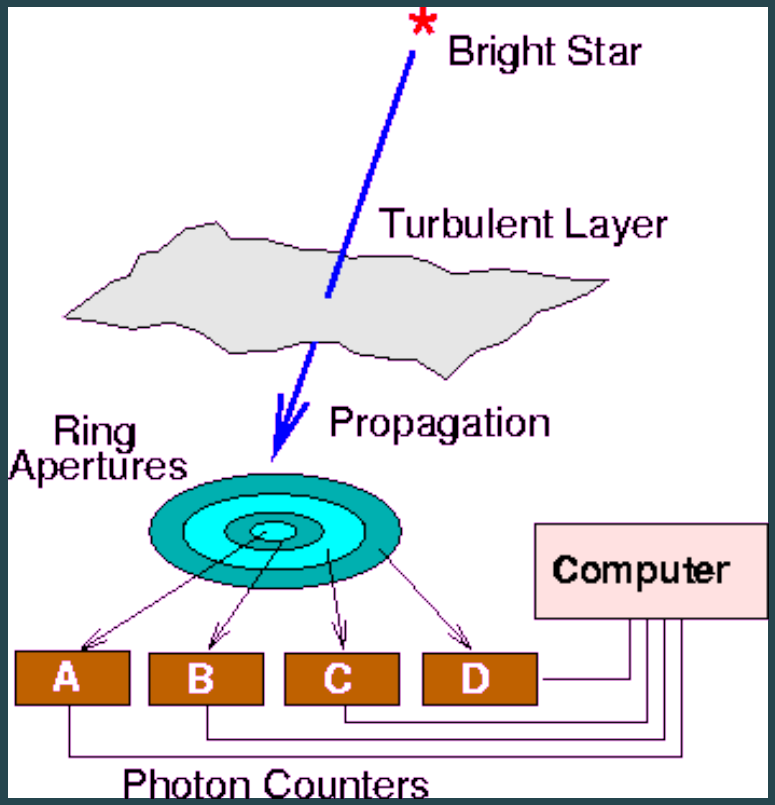
1) The aerosol scale height can vary by factor of 2 at any site.
2) The median AOD is about 0.035.
3) No strong seasonal variation has been found.
4) The α, is found to be ~0.8.
5) Aerosol particle size distribution peaks near 0.2 micron and 10 micron.





MASS-DIMM

1) Till date no measurement of the turbulence profile of upper atmosphere .
2) Missed an opportunity to obtain a MASS-DIMM when it was produced in bulk.
3) Now with help of Prof. Kornilov and his team plan to develop a MASS-DIMM within a year time.
4) Any improvement in the hardware-software may be included .



Micro-thermal measuring instrument

1) Differential temperature sensor is made of thin (25 micron) copper wire wound on a hylem sheet and the resistance is chosen close to 1 K Ohm. The The separation between two sensor are 1 meter.

2) The transducer (AD590J are used to measures the absolute temperature and hey are placed at middle of the differential sensor.

3) The signals coming from both sensor are amplified and a differentail temepratuer signa is fillter using broad band pass filter.

4) The Keithley PCI Data Acquisition Card (KPCI 3102) has been used to digitize the analog signals with the 12 bit resolution.

Temperature structure function:

$$D_T(s,h) = < |T(P_1) - T(P_2)|^2 >$$

where two probes placed at same height h and horizontally separated by s:
Temperature structure constant:

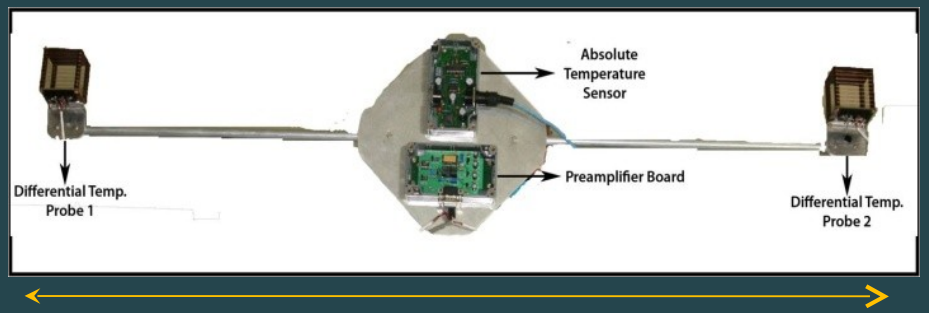
$$C_T^2 = D_T(s,h)s^{-\frac{2}{3}}$$

Refractive index structure constant:

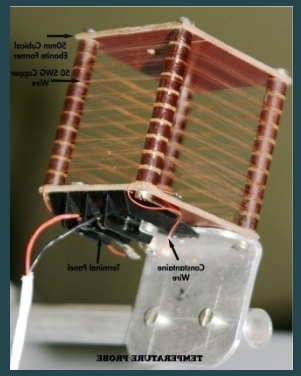
$$C_n^2 = \left(\frac{80 \times 10^{-6}}{T^2(h)}\right)^2 \times C_T^2$$

Finally the ground layer Seeing:

$$\epsilon_{FWHM} = 5.25\lambda^{-\frac{1}{5}} \left(\oint_0^\infty C_n^2(h)dh\right)^{\frac{3}{5}}$$



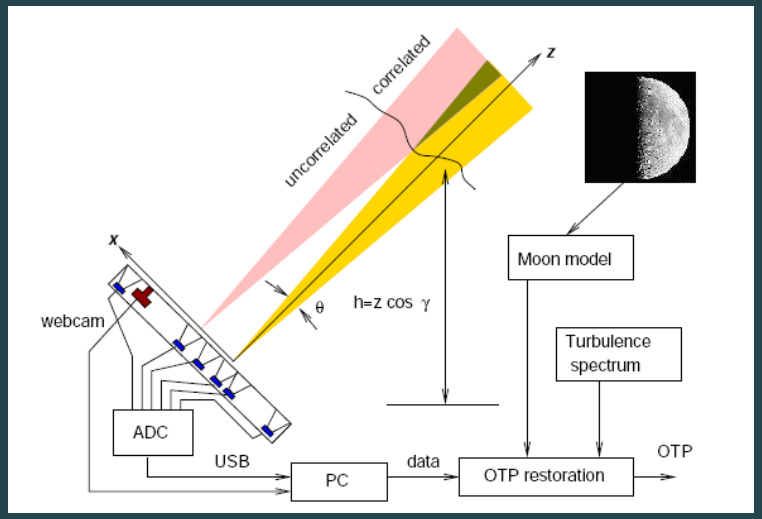
Separated by 1m



Differential sensor

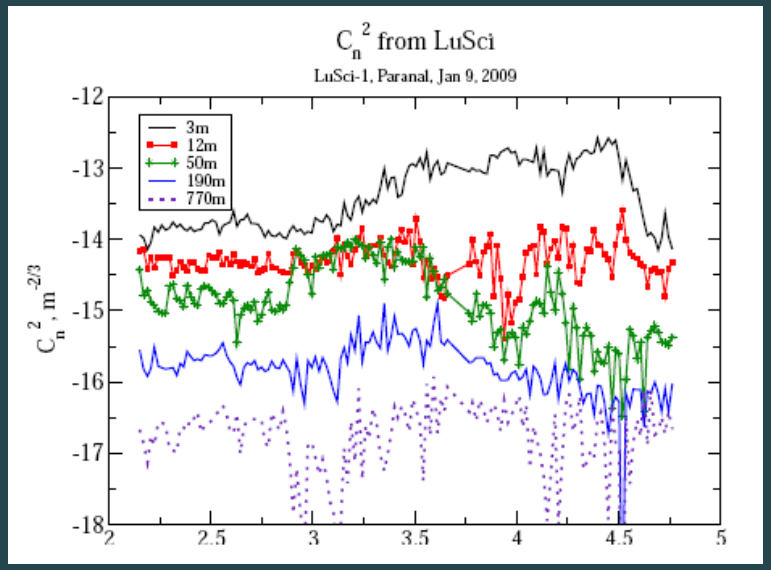
Lunar Scintallometer

1) Started working to develop a LuSci.
2) Need a support from the community operating LuSci..
3) Aiming to complete this project with 5-6 months.

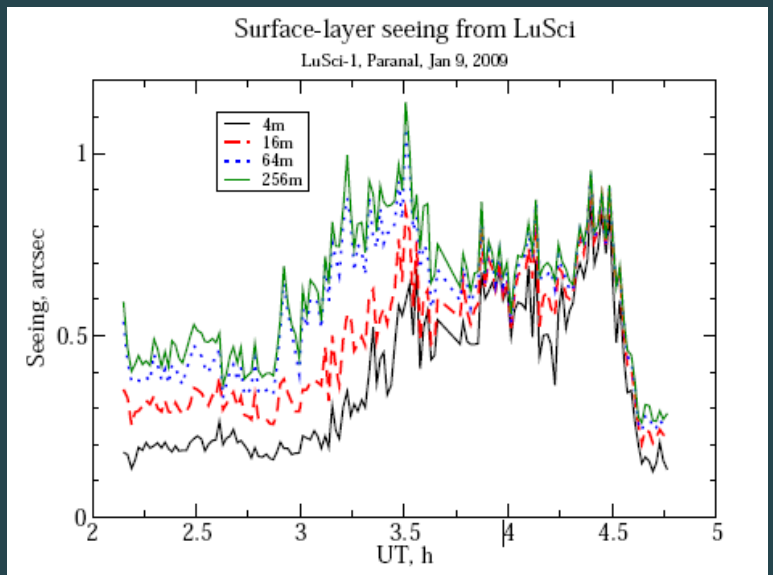


$$B_{i,j} = \frac{1}{K}\sum_{k=1}^{K}(\zeta_i\zeta_j)_k,$$

$$B(r) = \int_0^\infty \mathrm{d}z\; W(r,z)\; C_n^2(z).$$



Tokovinin et al (2010)



The hardware

Component	Vendor	Model	Qty
Photo-diode	thorlabs.com	FDS1010	6
Amplifier	Linear Technology	LT1464	6
8-channel ADC	cyberresearch.com	UMDAS 0802HR	1
Web camera 1/4"	logitech.com	Quickcam Pro 3000	1
Lens F=25mm	edmundoptics.com	NT56-776	1
Mount	celestron.com	NexStar 130-SLT	1

Thanking You

Several instruments are required to evaluate any astronomical sites. Few of them are listed bellow :

- Meteorological parameters:
  - Automatic Weather Station (AWS),
  - High altitude dust from satellite (for example TOM)
- Sky transparency/brightness:
  - All Sky day-night Camera(ASC)
  - Satellite images
  - Extinction and sky brightness monitors.
- Seeing monitors:
  - Differential Image Motion Monitor (DIMM)
- Atmospheric turbulence profiles $C^2_n(h,t)$:
  - Microthermal measuring instruments
  - Lunar Scintillometer
  - Generalized Scidar(GS), Single Stars Scidar (SS)
  - Multi-aperture scintillation Sensors (MASS).