# The Differential Image Motion Monitor (DIMM) at ELOT


Prof. Yosry Azzam

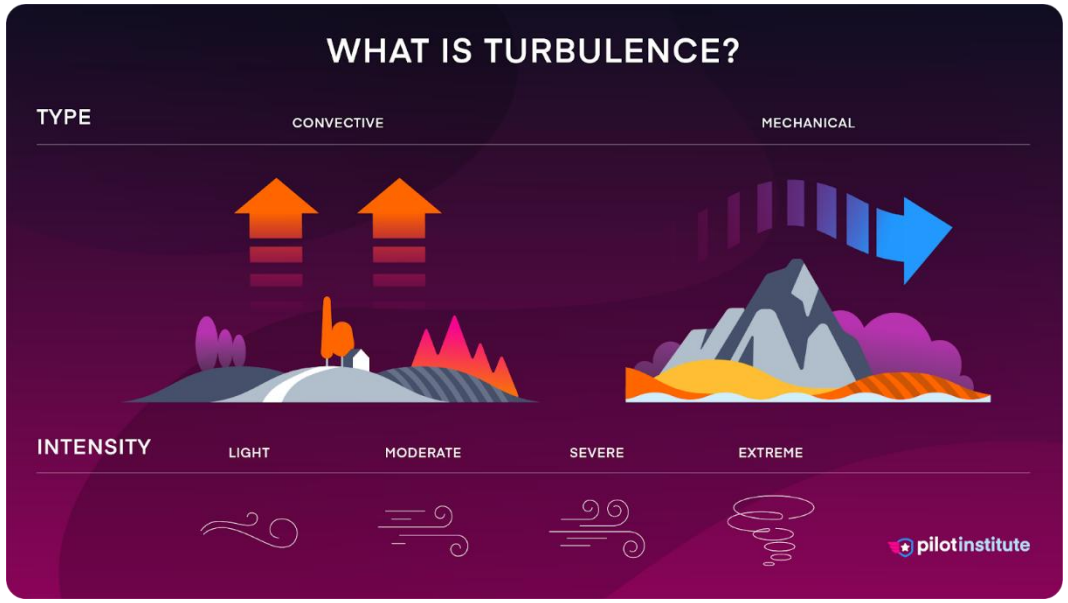
National Research Institute of Astronomy and Geophysics(NRIAG), Egypt

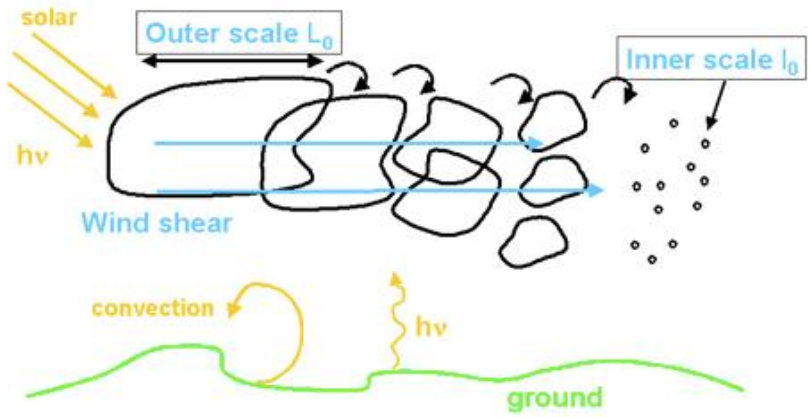
# How to find the best place for telescope?

- Optical Propagation through Atmospheric Turbulence (Optical Turbulence)
  - Mechanical and Thermal
  - Index of Refraction
- Integral Monitoring Techniques
  - Seeing Monitoring
  - Scintillation Monitoring
- Profiling Techniques
  - Microthermal Sensors
  - Scintillation Ranging

# What is the atmospheric turbulence?

- Turbulence across the Earth's atmosphere is the irregular motion of air resulting from obstructions to the airflow (mechanical) or vertical currents (convective/thermal)
- This causes a degradation of the image of an astronomical object.
- The origin of this effect is rapidly changing variations of the optical refractive index along the light path from the object to the detector.

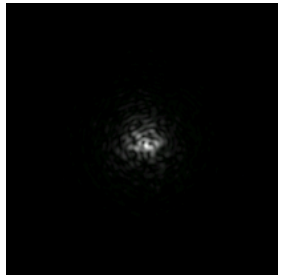


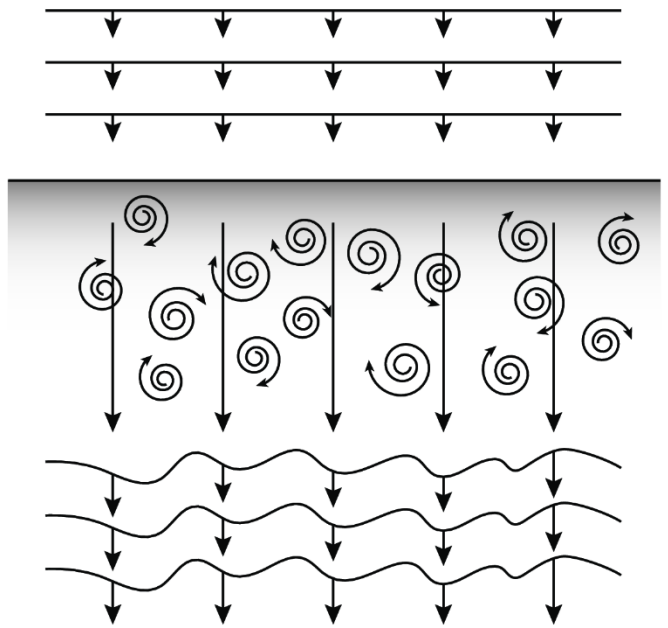



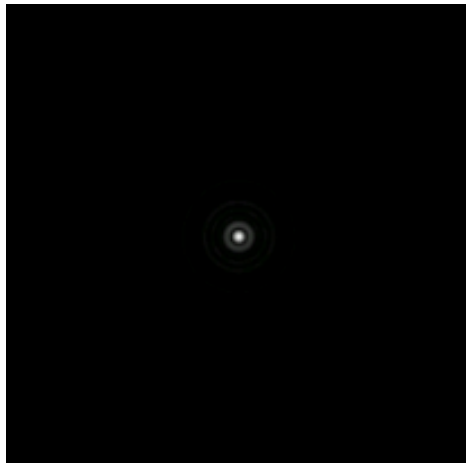
# Definition of atmospheric seeing

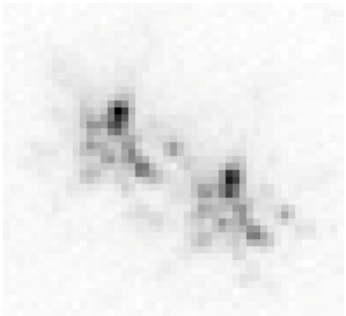
- Atmospheric seeing refers to image blurring caused by random phase distortion of the wavefronts entering a telescope. This blurring results from a combination of imperfect focussing of rays due to wavefront distortion, and random motion of the image due to varying wavefront tilt.

- It has the effect that causes the images of point source (like a star) which in the absence of atmospheric turbulence would be steady airy pattern produced by diffraction, to break up into speckle patterns, which change very rapidly with time.





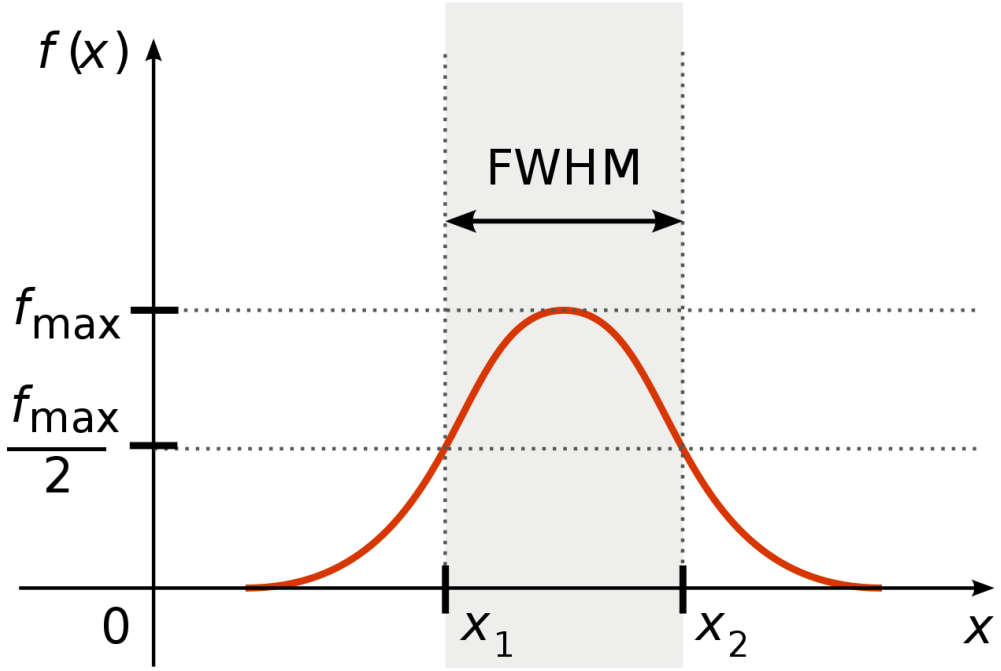


# Another definition of seeing

Seeing can be defined as the overall quality of an optical image and ***technically*** it is the Full Width at Half Maximum(FWHM) of a star image.

The power of a telescope is proportional to the primary collecting area divided by the solid angle formed by the image. So, a 2.5 - m telescope with 0.5" seeing might be equivalent to 5 m telescope with 1" seeing

This means that smaller telescopes situated at sites with good seeing is better than bigger telescope situated at sites with bad seeing.



# Seeing Calculations

Seeing:
(radian, ∝λ^-0.2)

$$FWHM(\lambda) = 0.98\frac{\lambda}{r_0}$$

Fried parameter: (
meter, ∝λ^6/5)

$$r_0(\lambda) = \left[0.423\left(\frac{2\Pi}{\lambda}\right)^2 \sec(\varsigma)\int_0^{\infty} C_n^2(h)dh\right]^{-3/5}$$

$r_0$ quantifies the size of the atmospheric cells or regions of turbulence that cause distortions in the wavefront

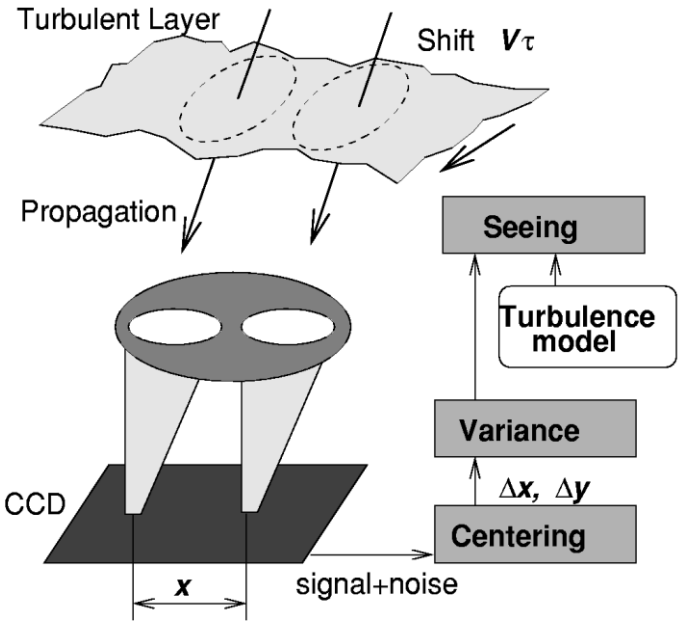
$C^2_N$ is the refractive index ***structure constant***
is considered as a measure of turbulent strength

# DIMM Principle

- The variance ( σ2) of the two-dimensional image position is:

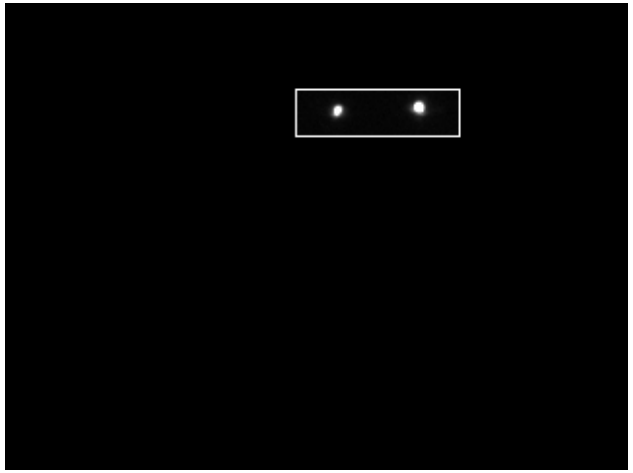
$$\sigma 2 = 0.373\ (\text{FWHM})^2 \left(\frac{r_0}{D}\right)^{\frac{1}{3}}$$

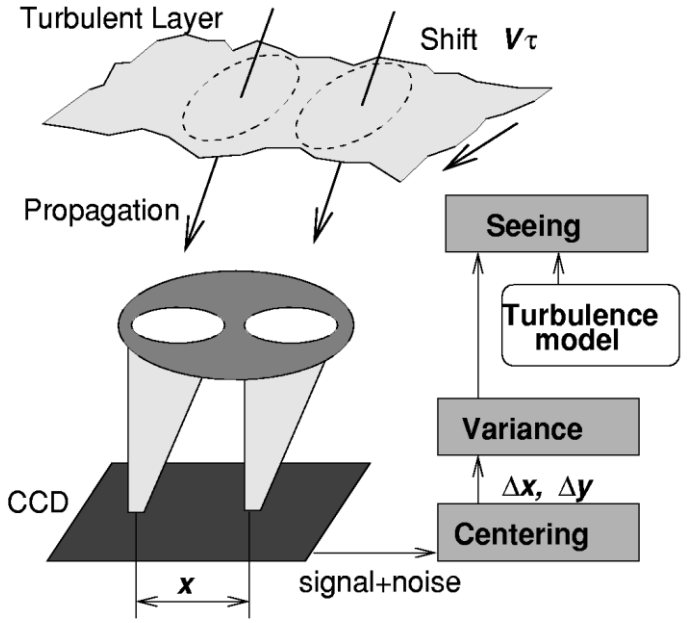
Thus, measuring the image motion with a fast camera at the focus of a telescope of aperture D and at wavelength λ, the Fried parameter $r_0$, the seeing can be deduced.



# DIMM Principle

- Differential Image Motion Monitor (DIMM) is the site testing standard tool which delivers integrating seeing through the entire atmosphere.
- Two images of the same star are created on a CCD, corresponding to light having traveled through two parallel columns in the atmosphere

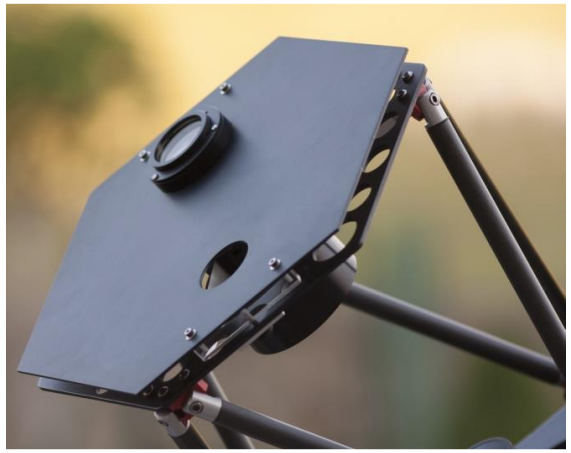


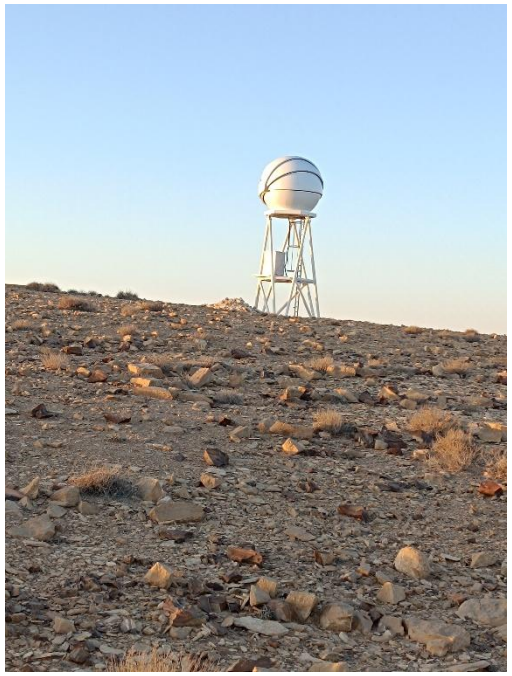


# ELOT's DIMM seeing monitor

**ASTELCO universal mount NTM-500 with its control unit and its 12" RC DIMM telescope and camera.**

**DIMM mask mounted to 12" truss OTA** →



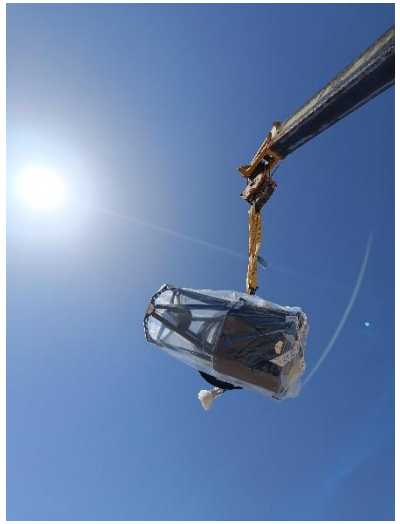


# DIMM Telescope OTA

**Is a 12” OTA F/8 aperture (Ritchey-Chrétien Astrograph) with carbon truss tube.**

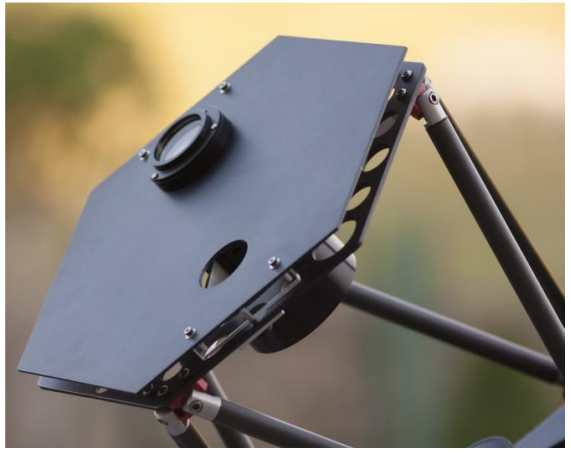
**Optical Parameters**

| | |
|---|---|
| Clear aperture | 304mm |
| Focal length | 2432mm |
| System focal ratio | F/8 |
| OTA mass | 24kg |
| OTA diameter | 485mm |
| Mirror material | low thermal expansion fused quartz glass |
| Coating M1, M2 | dielectric Al protection coating; $R_{max}$ ~ 98% |



# Mask with prism

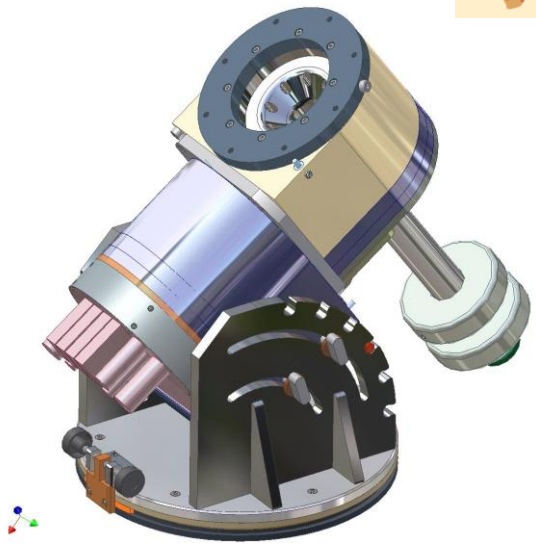
- One of the mask holes remains empty, the other one is equipped with two adjustable prisms in their support cell, allowing to adjust the two images of the same star at a given distance, to fit as best the field of view of the camera.
- Hole and prism location are separated the maximum possible to utilize the optical aperture of the OTA.



- Normally, the mask will be mounted onto the OTA such that the orientation of the axis hole-prism will be horizontal, when the OTA is pointing to the North horizon.
- The prism assembly is made of two ~75mm Ø prisms with AR coating (400-750nm optimized), mounted together, conveniently tunable from 1' to 25' beam deviation.

# DIMM Telescope Mount

- **Universal German type mount NTM-500 which was developed with ESO for the "ELT Design Study Site Testing" project.**
- **Can be installed either as equatorial, Alt-Az or Alt-Alt mount.**
- **Use high dynamic torque-motors for pointing and tracking that ensures absolute backlash-free direct drives without any gears.**
- **Guarantee precise pointing and tracking with its high-resolution encoders.**
- **Contains internal brake-system that ensures the necessary safety during operation at all speeds and also during emergency cases (e.g. power failures).**
- **From a home-position (park-position) targets will be positioned automatically. After the observing run the home-position will be repositioned.**



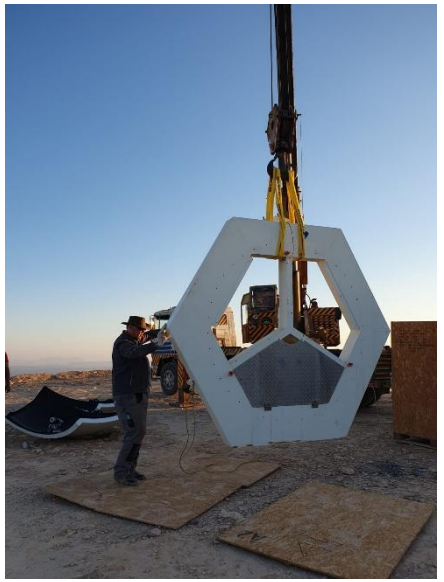
**Slewing, Pointing und Tracking**

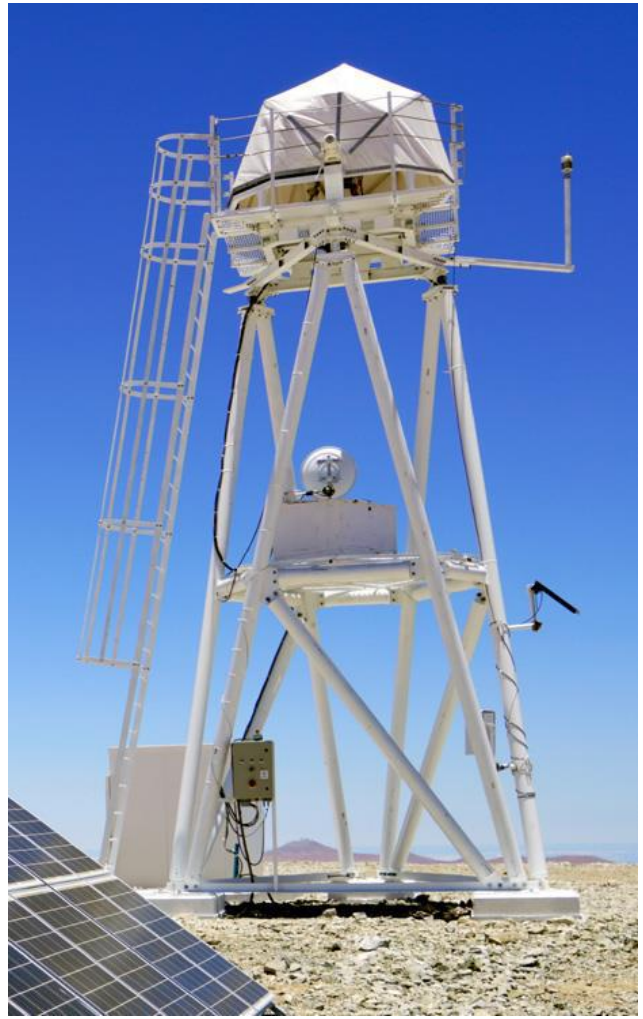
| | |
|---|---|
| Slewing Speed* | 20°/sec |
| Acceleration and Deceleration | ≥ 2°/sec² |
| Absolute positioning accuracy** | < 5 arcsec RMS ("Full Sky Blind Pointing") |
| Differential positioning accuracy*** | < 1 arcsec RMS |
| Tracking accuracy without autoguider | < 1 arcsec/60 min RMS |
| Tracking accuracy with autoguider**** | < 0,3 arcsec RMS |

* Typically used positioning speed, up to 50°/sec possible
** With established pointing-model
*** Within a field of 1.5° radius
**** Depending on CCD pixel size

# Tower and enclosure

- The mount, OTA and related optical equipment are mounted on top of a 6-m high tower, to escape from ground turbulences and enable measurements on roughly the same height as later the large telescope.
- The 6-m tower design is based on the ESO DIMM tower designs at Cerro Paranal and La Silla Observatories in Chile.
- The tower is a reinforced version of the modular DIMM tower, with enhanced stiffness and low vibration in high wind speed environment.





# Clamshell Dome

- **Clamshell dome is a 3.7-m dome designed as rigid and stiff self-supporting structure, consisting of movable hinged shell segments to open the dome for observations.**
- **Fabricated from fiber-reinforced polyester material which is UV-resistant, heat-reflecting, weather heat- and cold-resistant and light-tight.**
- **Closed dome can withstand wind speeds of up to ~200km/h.**
- **Remote control is established via Ethernet, through ASCOM compliant driver.**
- **Equipped with a rain sensor, closing the dome in case of rain and also automatic close in case of winds >20m/s.**

**The main specifications:**

- Almost completely openable to enable free air flow and to avoid "dome seeing effects"
- Two motors
- Survival wind speed ≥50m/s
- Opening / closing time ~90s
- Total weight of enclosure: Approx. 600kg
- Operable in the temperature range of -40°C to +55°C
- Limit switches, two emergency-stop buttons
- Power consumption of dome: Max. 200W


# Detector, electronics and electronic focuser

- **A Prosilica GC650 camera with GigE interface.**
- **A temperature compensated electronic motorized focuser (OPTEC TCF-Si) is connected to the computer control system which controls focus to maintain the desired Strehl ratio.**



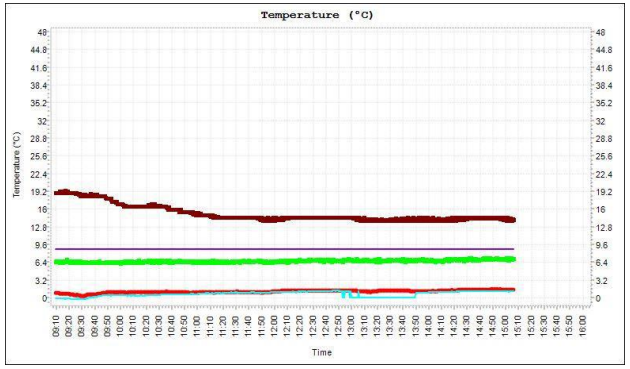

- **Protection cabinet for control unit(s)**

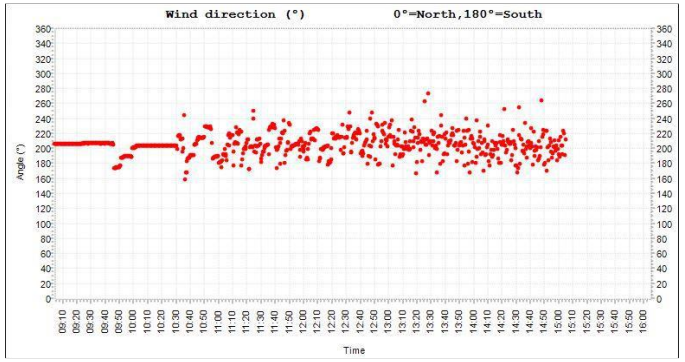
| | |
|---|---|
| Sensor pixels | 659 x 493px |
| Sensor size | 4.8 x 3.6mm |
| Pixel size | 7.4 x 7.4µm |
| Frame rate | 90fps |
| Integration time | 10µs – 60s |

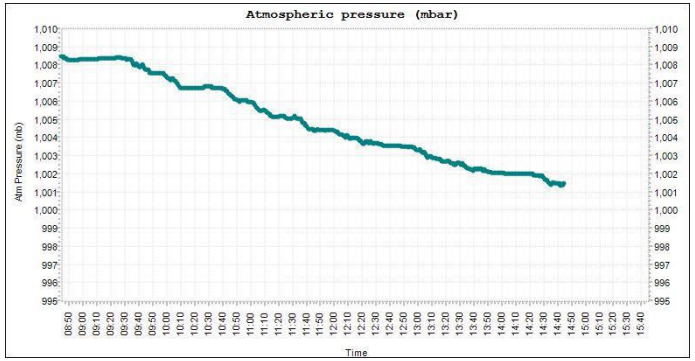
# All Sky camera

| Name | Sensor | Fisheye circle "Illuminated" pixels | Detector resolution | Field of view | Pixel Scale | Daylight imaging |
|---|---|---|---|---|---|---|
| OMEA 9M | Mono-chrome | 31.7 Million px | 9575 x 6380 px | 180° x 180° | 1.6 arcmin/pix | Yes |

**By default, the camera records relative humidity and external temperature.**
**A module, attached to the camera measures other weather parameters such as wind speed, wind direction, and pressure.**




# ASTELCO DIMM Server (ADS)

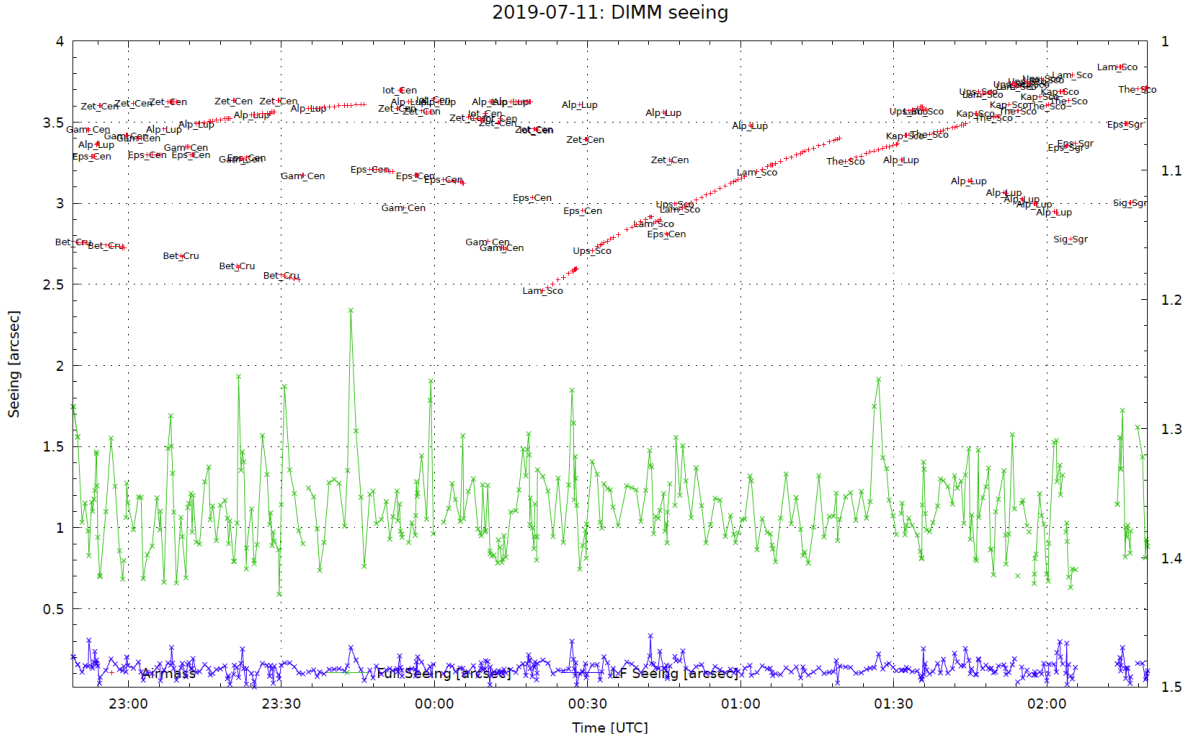
- A DIMM station control for automated and robotic observation runs, data acquisition, weather emergency procedures and complete control of the DIMM telescope, camera and enclosure.
- Is based on the well-known thoroughly tested "Kornilov algorithm" and has been extended and optimized for automatic application in robotic environments. ADS provides a way to analyze images produced by DIMM monitors and derive the seeing values from them.

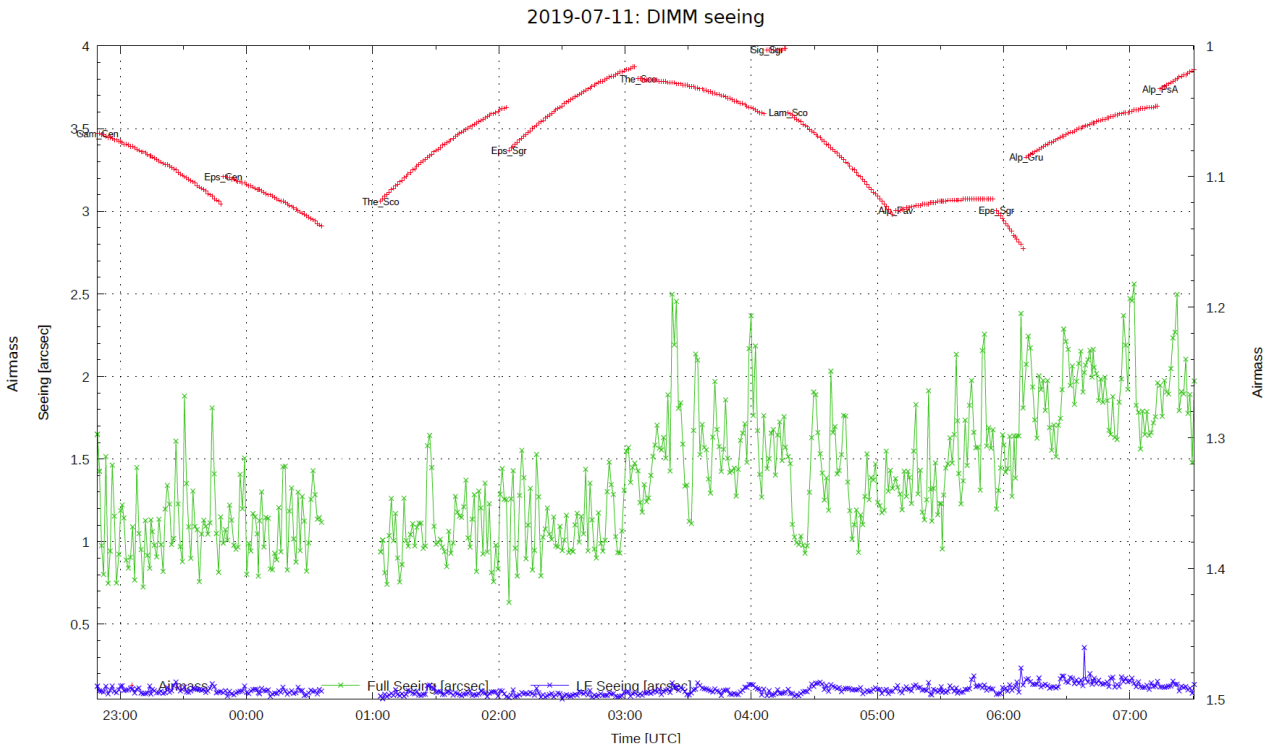
# ADS Features

- **DIMM robotic control**
  - ➢ Remote and automatic operation
  - ➢ Pointing and tracking control
  - ➢ Pointing accuracy control
  - ➢ Image quality control (re-focusing)
  - ➢ Automatic rejection of unsuitable targets
  - ➢ Avoidance zone around the Moon
  - ➢ First target after 180sec; time between targets < 90sec
  - ➢ Enclosure control
  - ➢ Power control
  - ➢ Manual mode capability (command line)
  - ➢ Remote re-boot capability
  - ➢ Access via Ethernet

- **Outputs, available in real-time**
  - ➢ Seeing values
  - ➢ Plots
  - ➢ Image quality Strehl ratio
  - ➢ Last image taken
- **Easy recovery after power loss**
- **Status reporting and log files (data and telemetry logging)**
- **Interface to easily use data from customer weather stations**

# ADS Seeing Plots



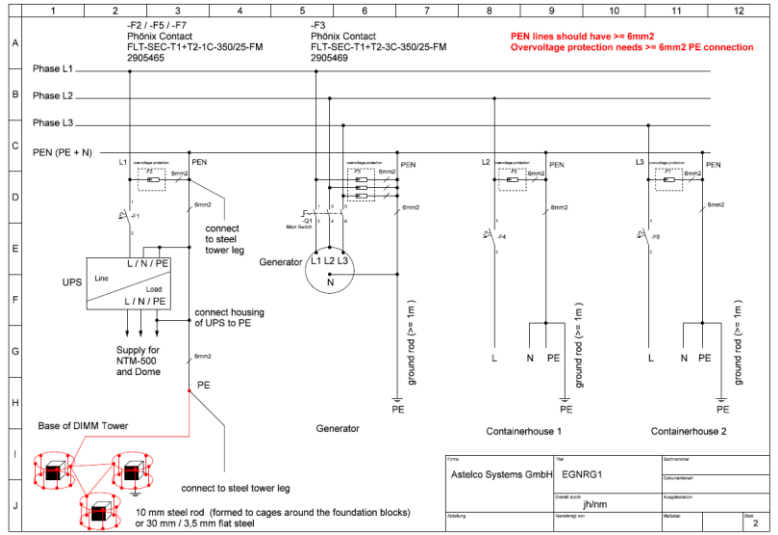
# Separate Automatic Weather Station

- **ClimaVUE™50 all-in-one meteorological sensor that fulfills all weather monitoring needs.**
- **The sensor reports air temperature, relative humidity, vapor pressure, barometric pressure, wind (speed, gust, and direction), solar radiation, precipitation, and lightning strike (count and distance).**
- **Has a built-in tilt sensor that assures long-term data integrity.**


- **Uses CR1000 as Data Logger**

# Technical Issues (Very Important)

- **Grounding is very important for local electricity generator.**
- **Lightning current and surge arresters have to be used for lightening protection**



# Conclusion

- DIMM is the starting instrument to be used for site testing campaign along with the AWS and ASC.
- Astelco DIMM system is a robust package which uses well proven existing algorithms established by the community over the past decades (Kornilov, ESO, …).
- It has been extended and put together into a nice package with modern hardware (telescope, mount, camera, computer) and state-of the-art software, which is easy to use and reliable in performance.
- All data captured by the ASTELCO DIMM system is fully available to the user for further processing, analysis or any other usage.
- A lot of work has been done and still a lot of work needed to match between ELOT optical design, its attached astronomical instruments and site optical characteristics.

# *Thank you for your attention.*


- y.azzam@nriag.sci.eh