Towards forecasts of atmospheric parameters and optical turbulence for ground-based telescopes *operations*

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(coll: Gaetano Sivo, Andreas Guesalaga, Florian Kerber, James Osborn)

Credit: ESO/S.Guisard

OUTLINE

- Forecasts of the optical turbulence and atmospheric parameters: news

  - Implementation on an *automatic and operational system* for the forecasts of these parameters at LBT: **ALTA Center**

- Can we use OT measurements from an AO system as a reference for our model ?

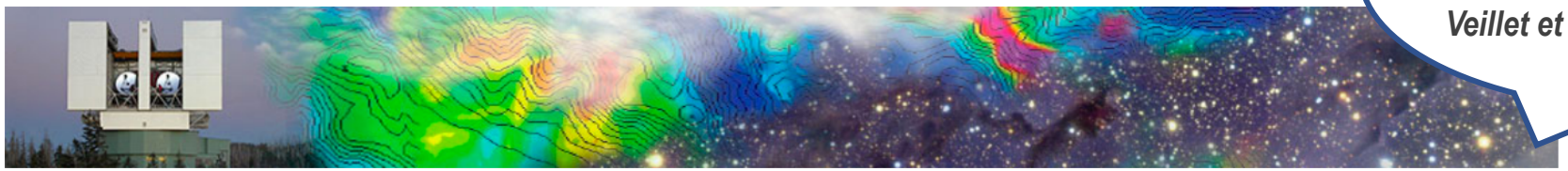
- Which kind of information can supply our model in relation to SR, V_{eq}, contrast, …?

- Conclusions and perspectives

ALTA is part of the LBTO Operational Observing Strategy see paper Veillet et al., 2016, SPIE, 99100S

ALTA Center

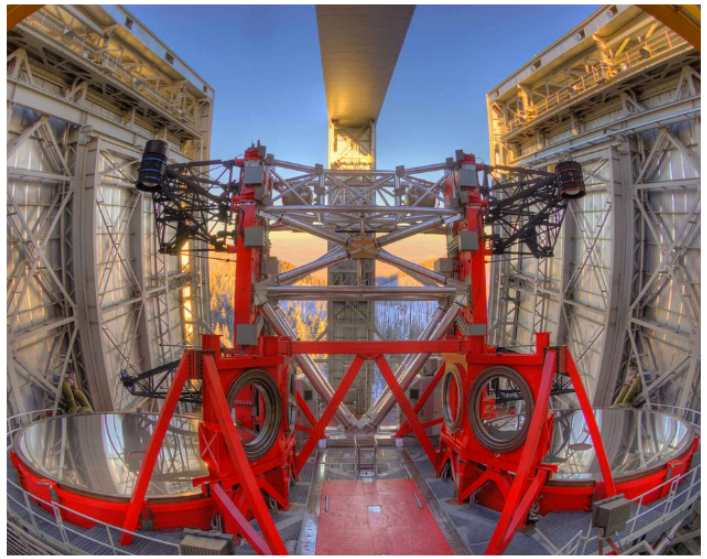
Advanced LBT Turbulence and Atmosphere

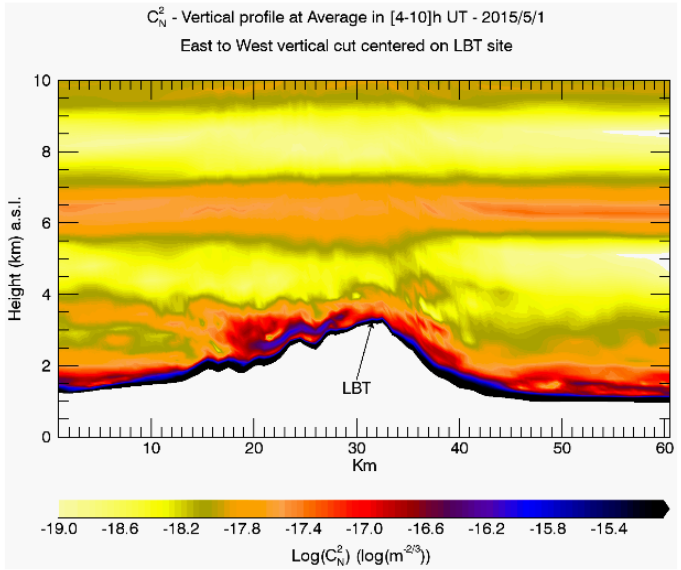


- Home
- Optical Turbulence Tutorial
- Forecasts Legend
- Forecasts
  - Next night
  - Previous nights
- Trends
- Team
- Bibliography
- Contact

The ALTA Center is a project aiming at forecasting automatically and nightly the optical turbulence and other integrated astroclimatic parameters as well as atmospheric parameters relevant for ground-based astronomical observations, mainly supported by Adaptive Optics systems. The project has been conceived for the Large Binocular Telescope (LBT) located at Mt.Graham, Arizona, US.

The project is lead by INAF - Arcetri Astrophysical Observatory.

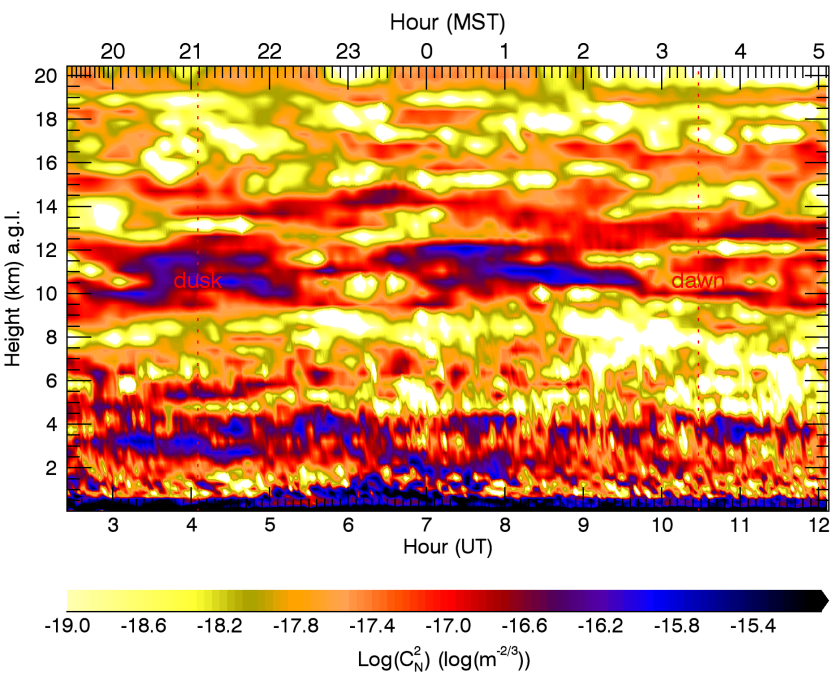


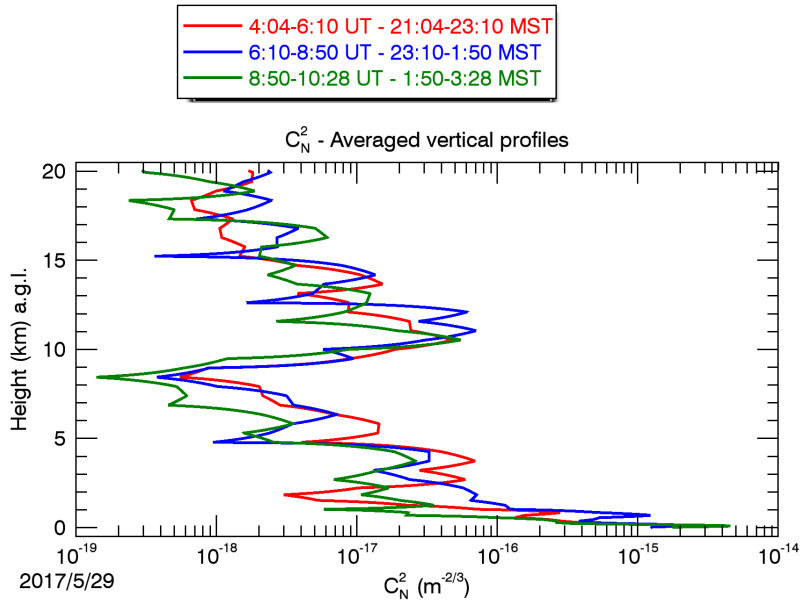


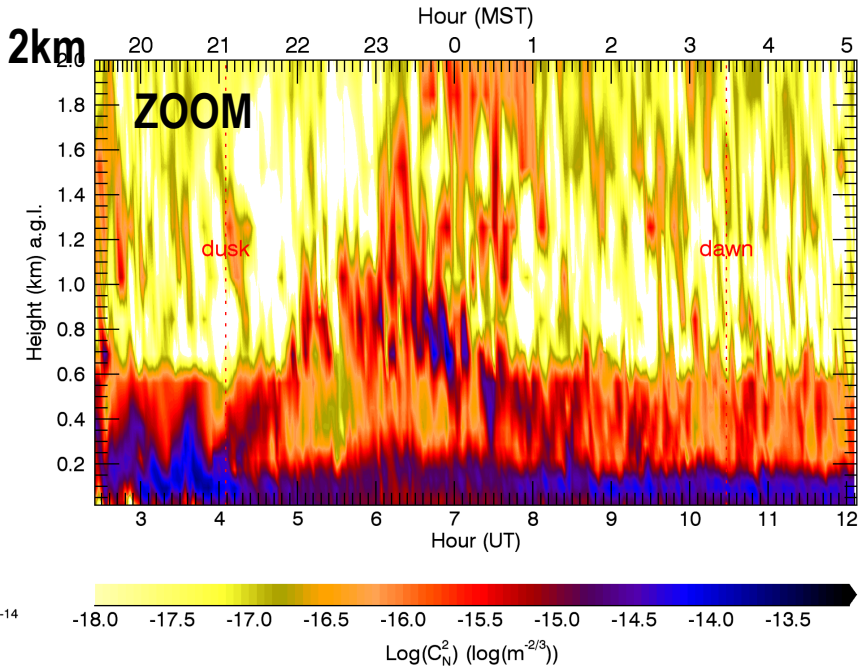
http://alta.arcetri.astro.it

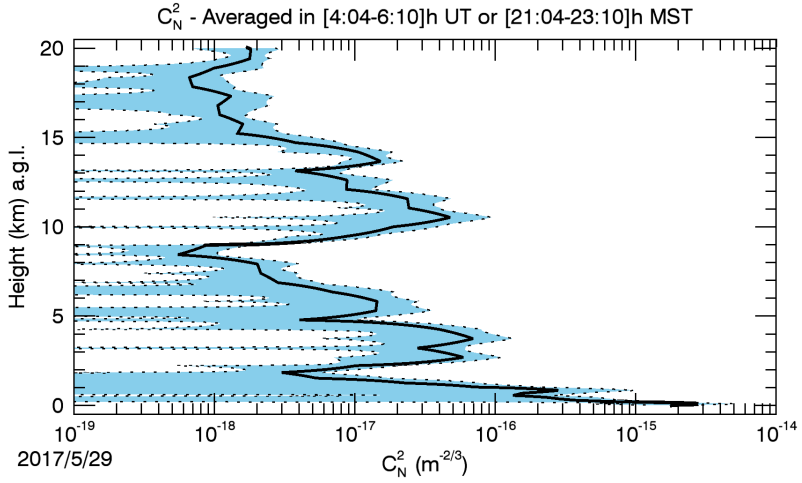
C_N^2: OPTICAL TURBULENCE

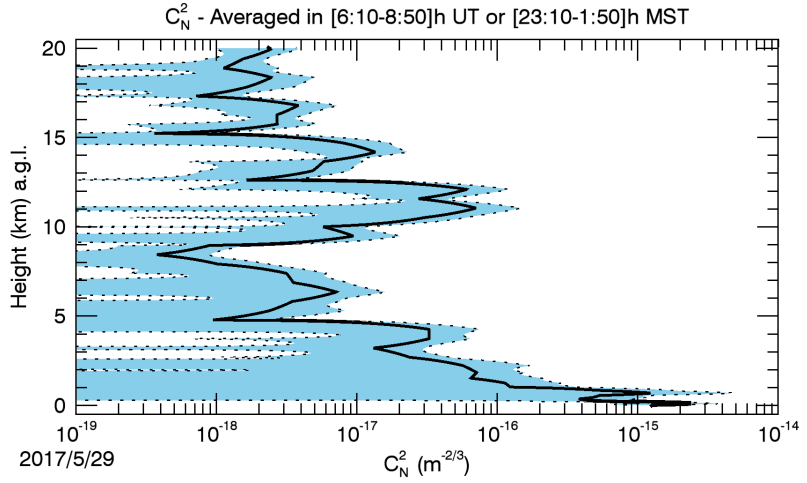
Masciadri et al., 2017, MNRAS

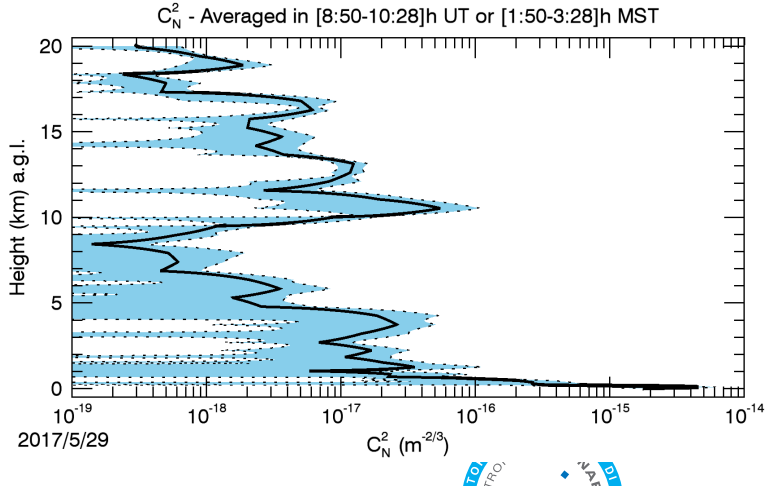






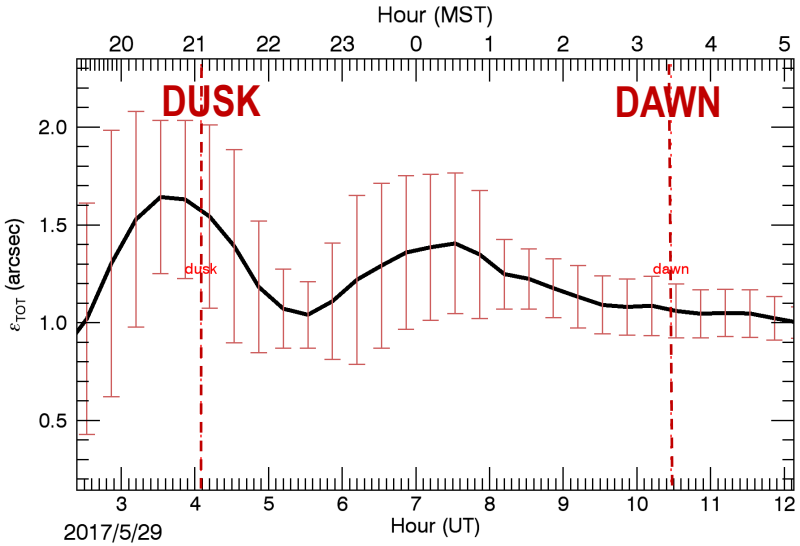




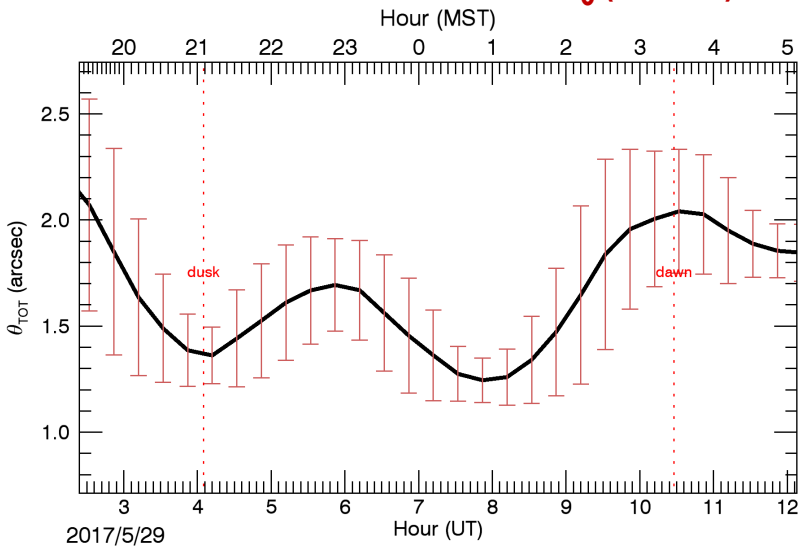


INTEGRATED ASTROCLIMATIC PARAMETERS

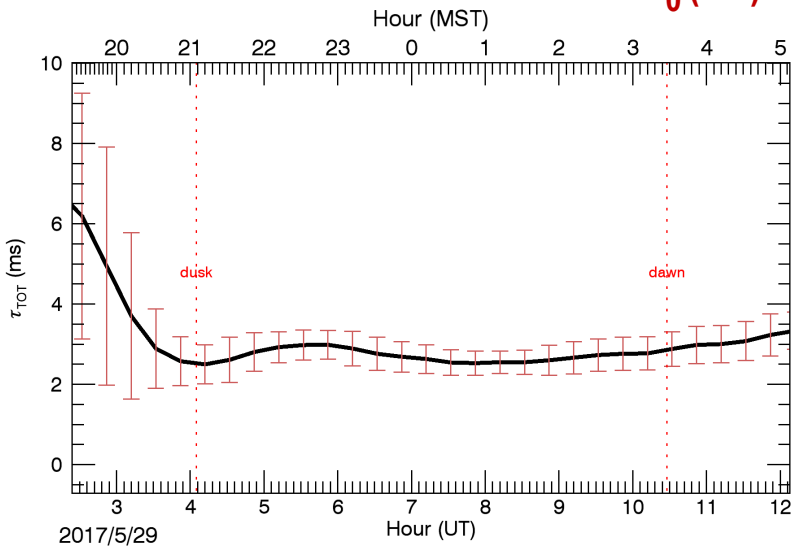
TOTAL SEEING ε_{TOT} (arcsec)

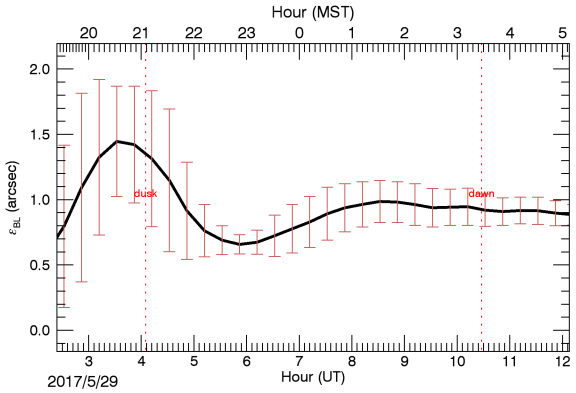


ISOPLANATIC ANGLE θ_0 (arcsec)

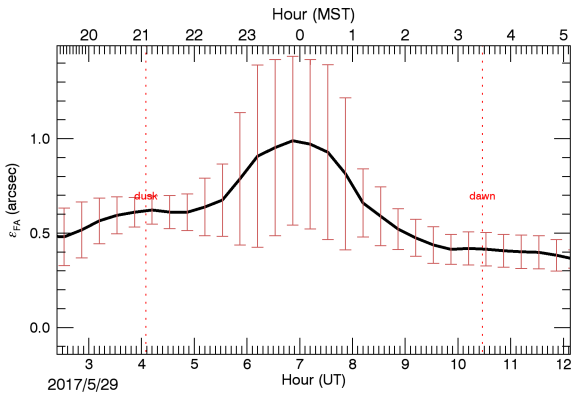


WAVEFRONT COHERENCE TIME τ_0 (ms)

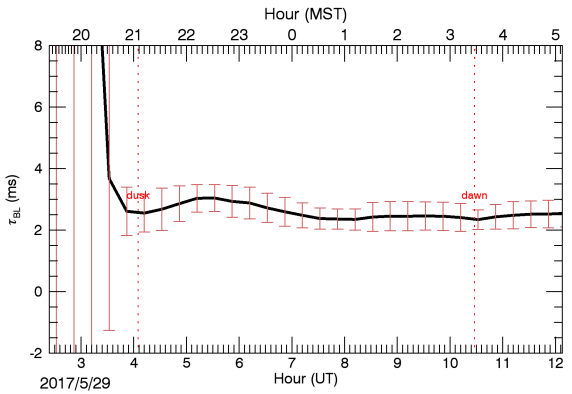




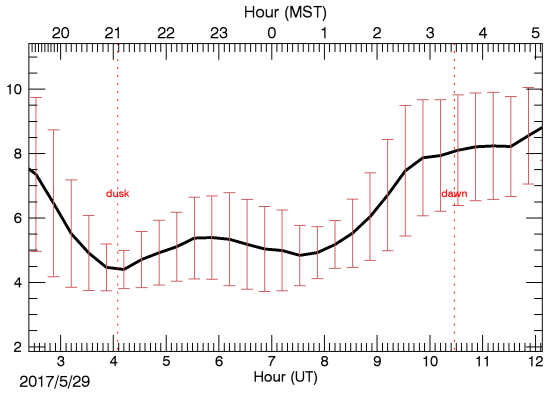
$\varepsilon_{[dome,600m]}$



$\varepsilon_{[600m,20km]}$

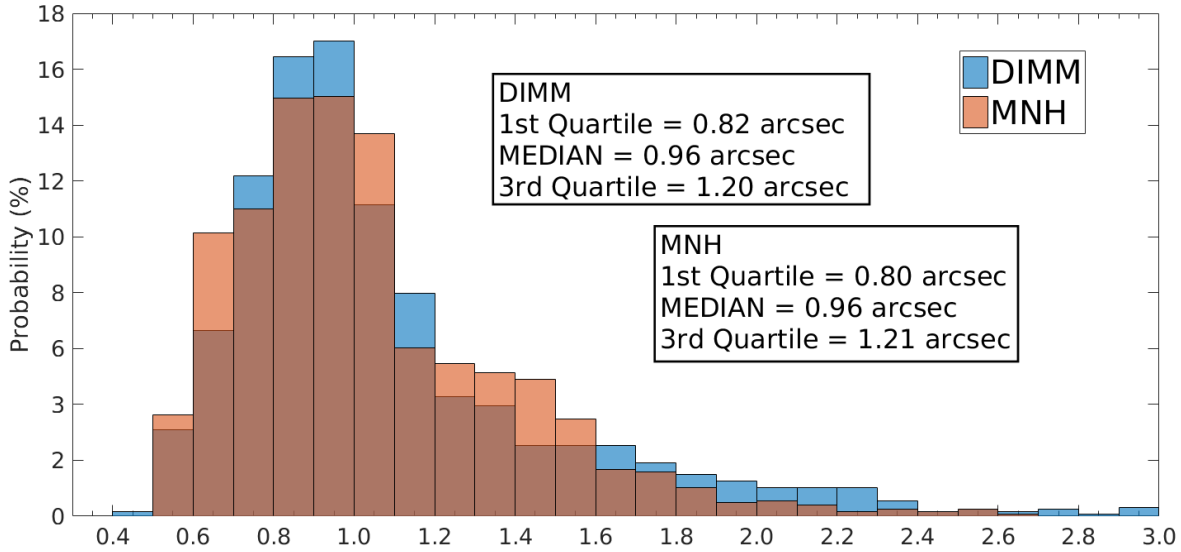


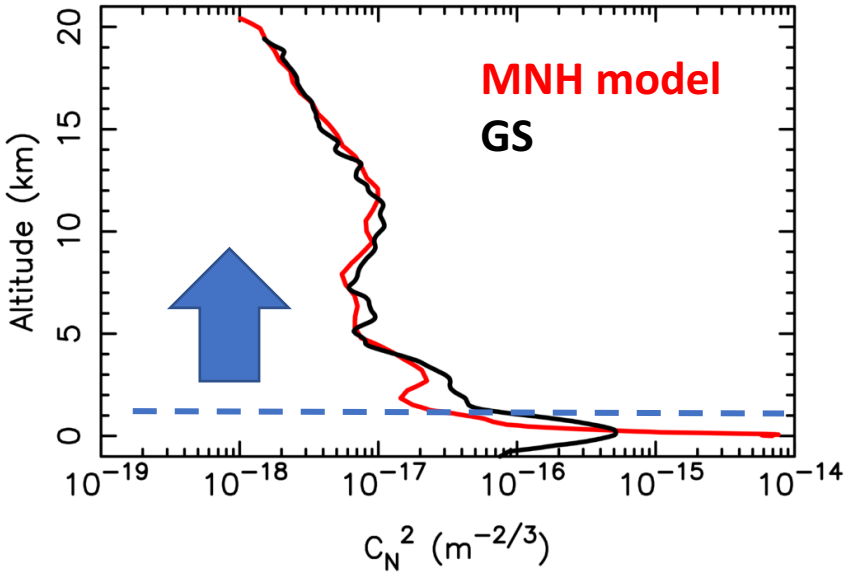
$\tau_{0\ [dome,600m]}$



$\tau_{0\ [600m,20km]}$

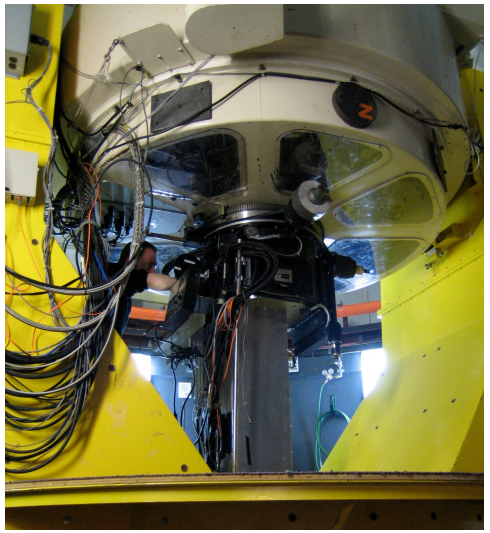
42 NIGHTS





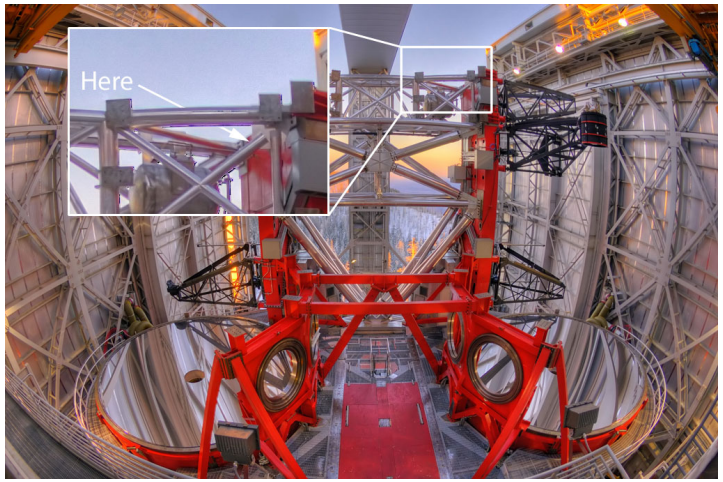
SEE (arcsec)

Generalized SCIDAR @ VATT

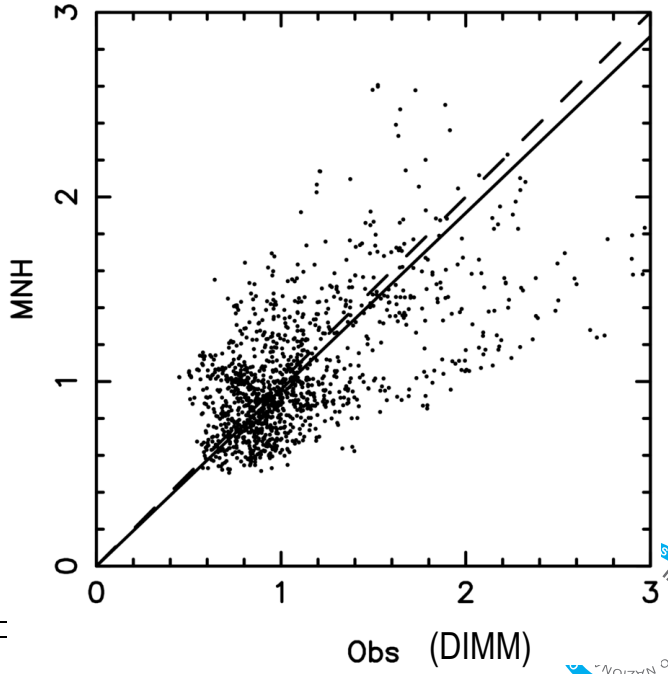


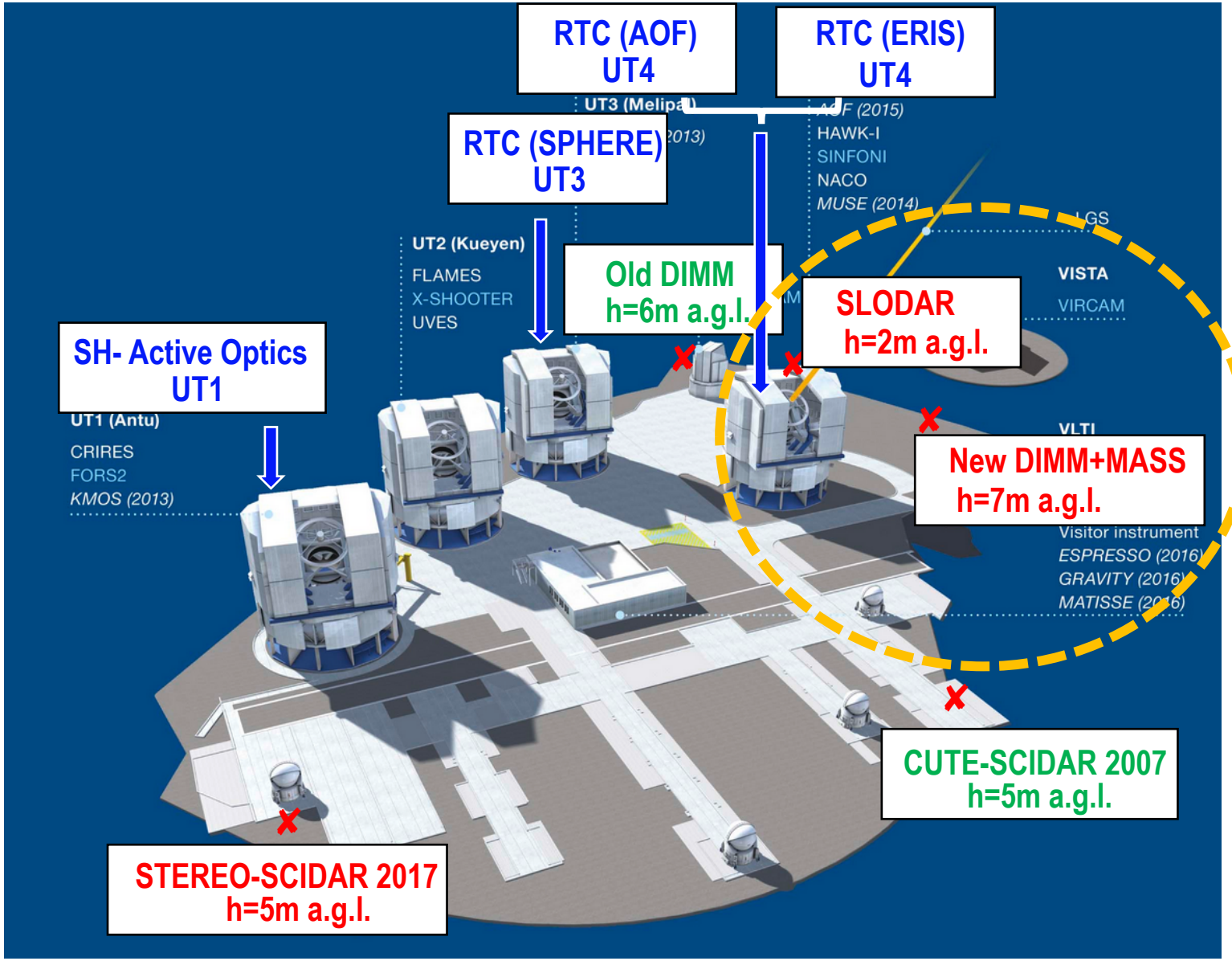
2005-2008: 42 nights

DIMM



2016: 42 NIGHTS





WHICH INSTRUMENTS FOR MODEL REFERENCE ?

ESO archive available since April 2016

Instruments dedicated for OT measurements

De-commissioned instruments dedicated for OT measurements

AO instruments providing OT measurements

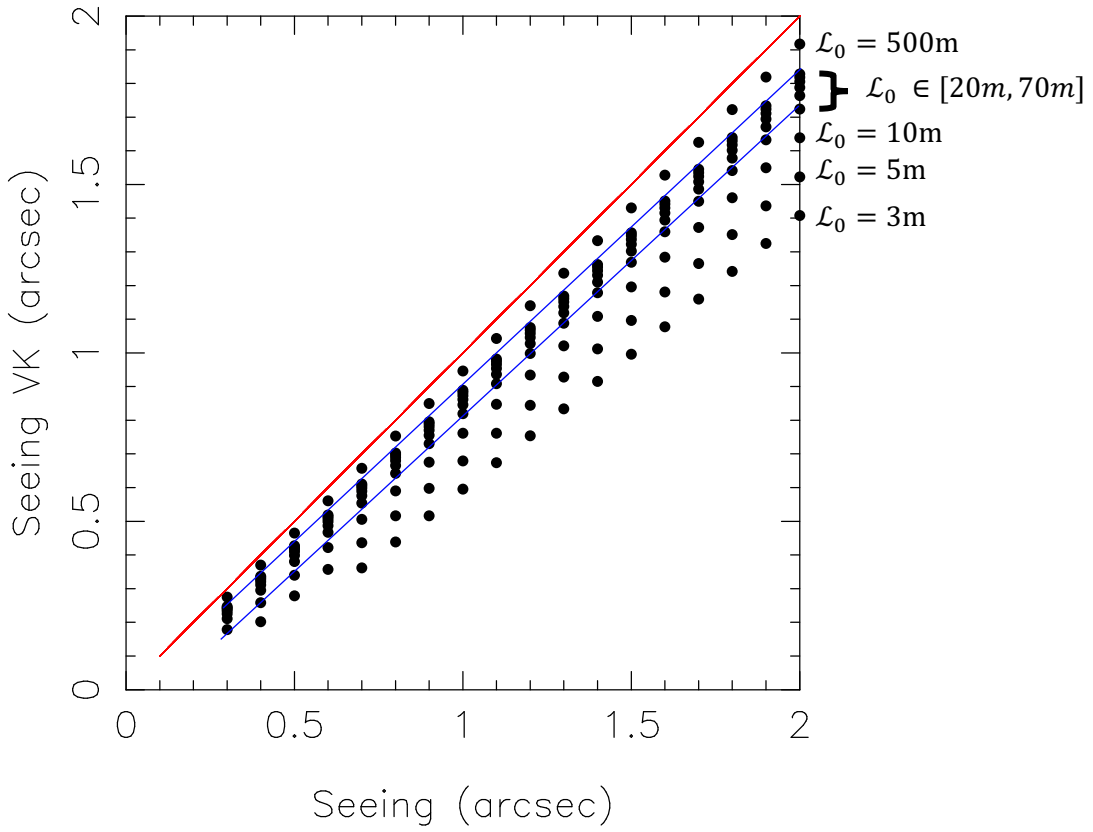
To be used for the MOSE demonstrator

SEEING

$$\varepsilon_{VK} = \varepsilon_K \sqrt{1 - 2.183 \left(\frac{r_0}{\mathcal{L}_0}\right)^{0.356}}$$

Valid for $\frac{\mathcal{L}_0}{r_0} > 20$

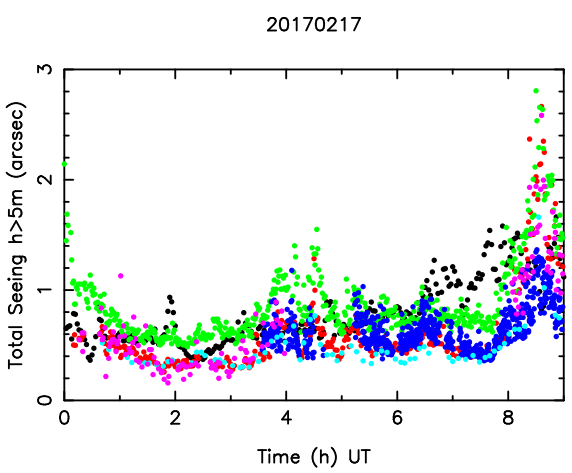
COMPARISON OF OT MEASUREMENTS FROM INSTRUMENT AFFECTED AND NOT AFFECTED BY L_0

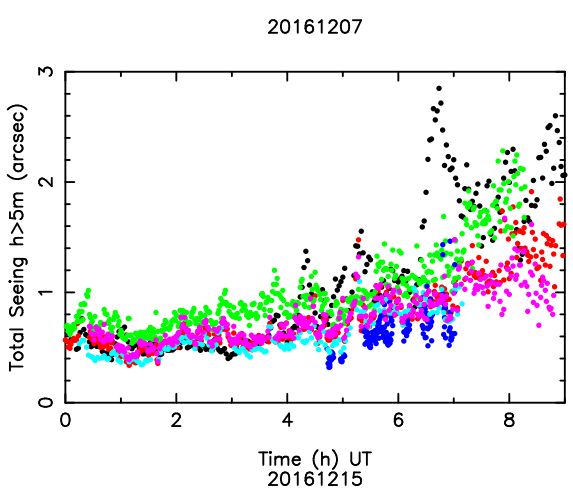


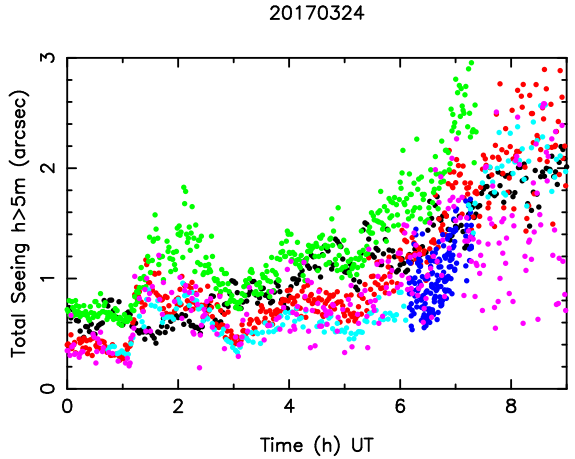
if $\mathcal{L}_0 \in [20\text{m}, 70\text{m}]$ ➡ $\Delta\varepsilon \sim 12\%$

if $\mathcal{L}_0 < 20\text{m}$ ➡ $\Delta\varepsilon \; up \; to \; 30\%$

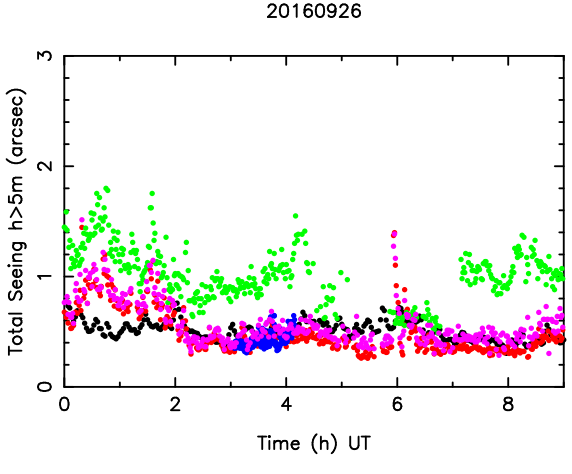
$$\mathcal{L}_0 = 25m$$

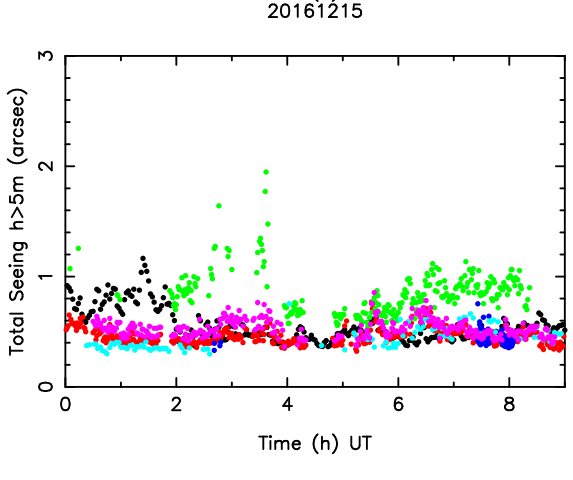


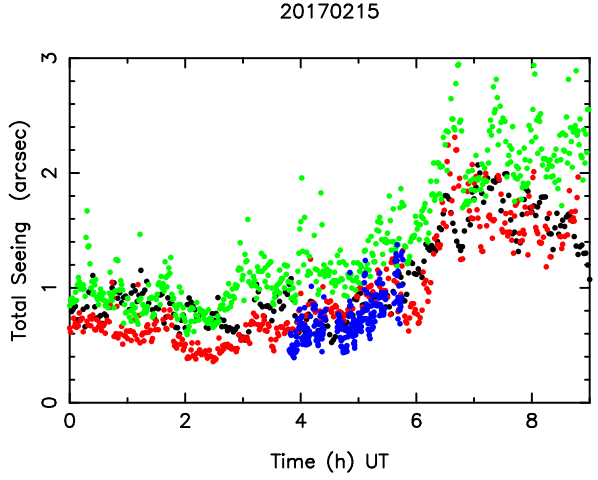


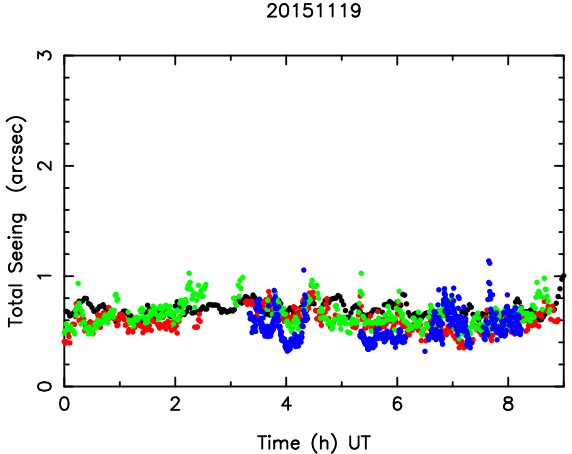


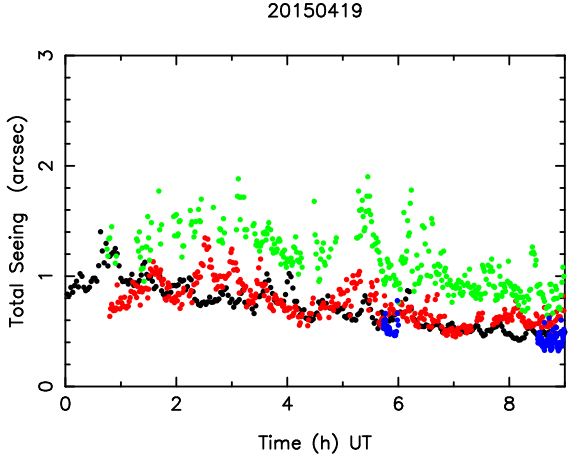
SEEING WITH DIFFERENT INSTRUMENTS/MODELS WITH CORRECTION L_0=25m











MNH Model

MASS-DIMM

DIMM new

SLODAR above UT

AO-RTC (SPHERE)

DIMM old (de-commissioned)

Selection of nights done looking at the ESO archive

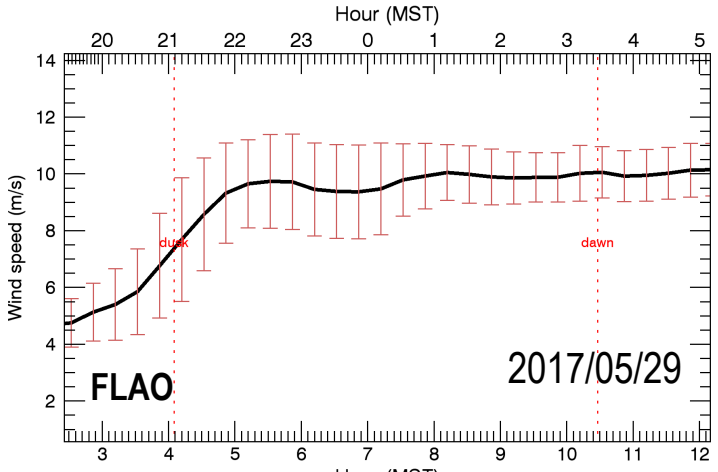
V_{eq}: EQUIVALENT WIND SPEED

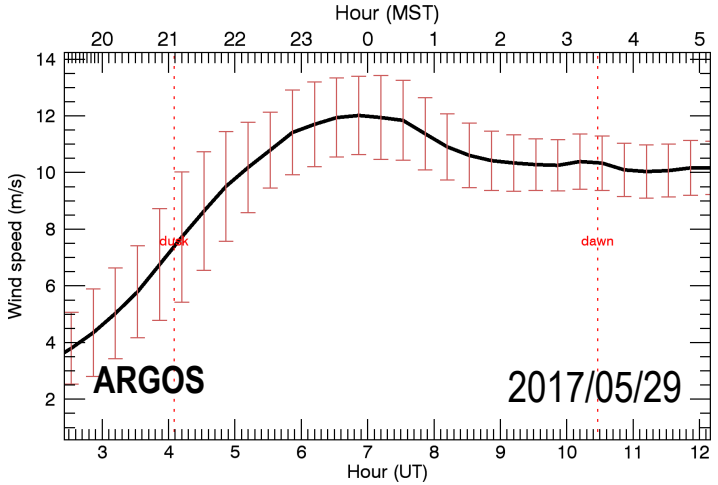
It tells us how fast the AO has to work …

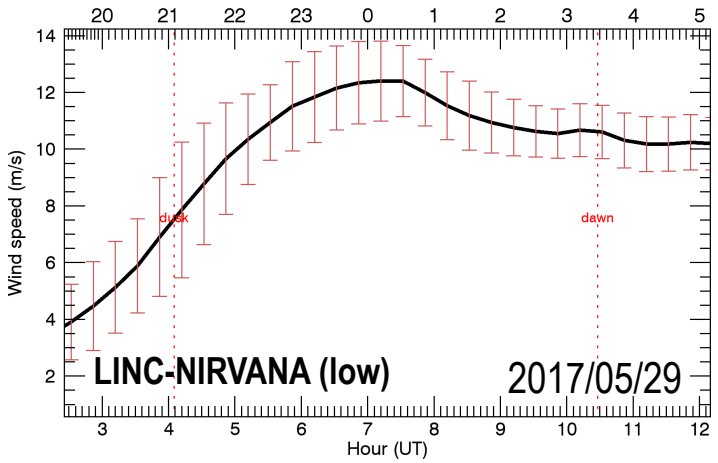
$$V_{eq} = \left(\frac{\int_0^{\infty} |V(h)|^{5/3} C_N^2(h) dh}{\int_0^{\infty} C_N^2(h) dh} \right)^{3/5}$$

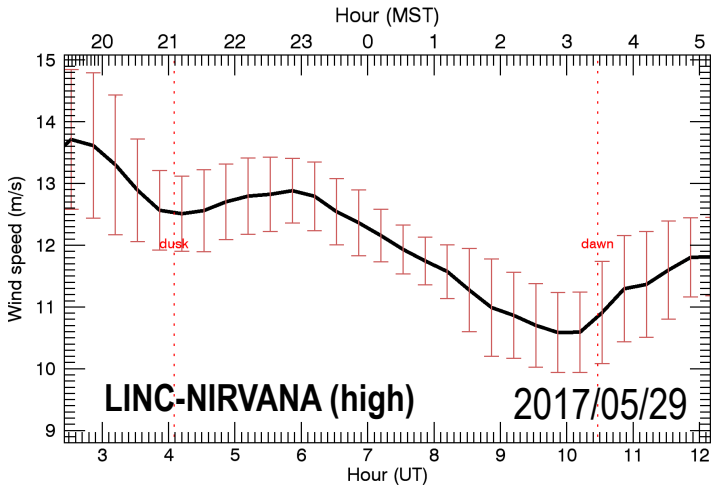
$$\begin{cases} V_{eq} = \left(\dfrac{\int_{H_{min}}^{H_{max}} |V(h)|^{5/3} C_N^2(h) dh}{\int_0^{\infty} C_N^2(h) dh} \right)^{3/5} \\ \Delta H = H_{max} - H_{min} = 2 \cdot \dfrac{d}{\theta} \end{cases}$$

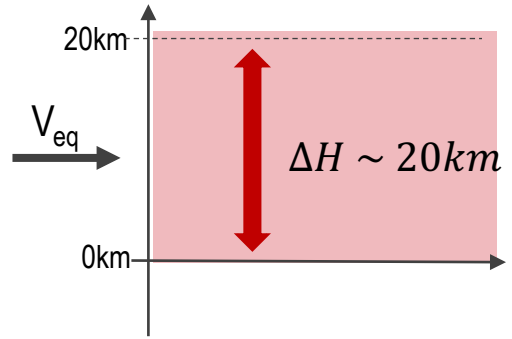
optical field depth

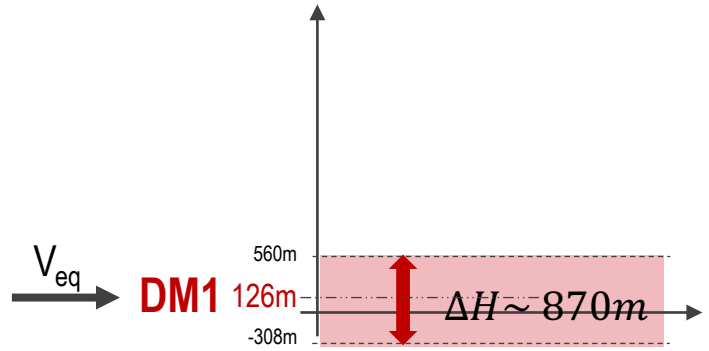


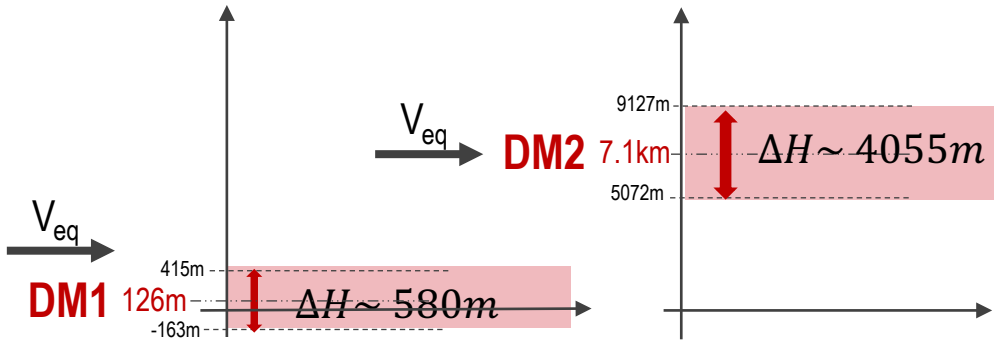








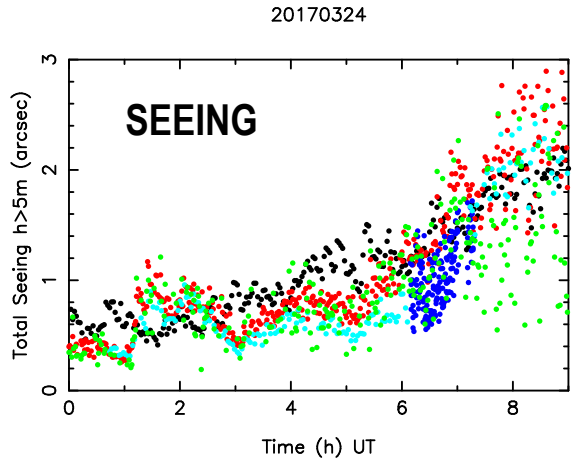


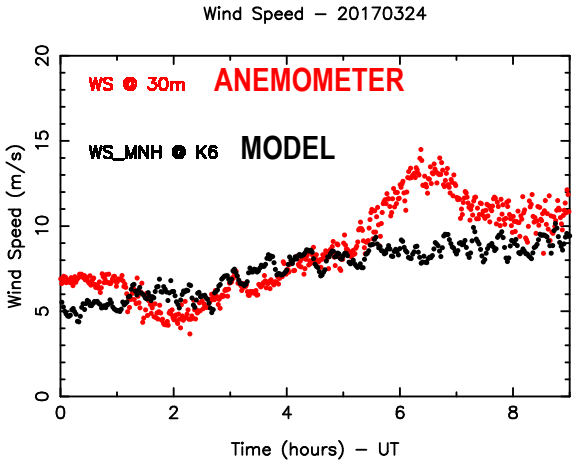


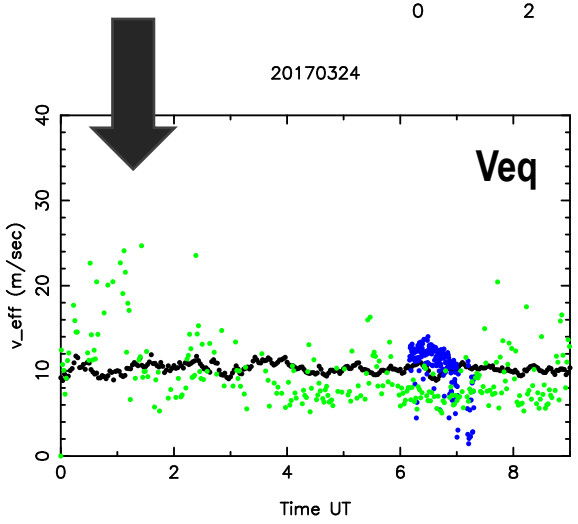
@ CERRO PARANAL (VLT)

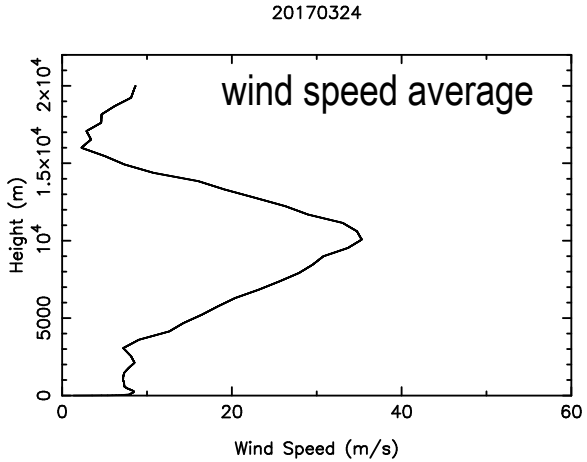
24/03/2017

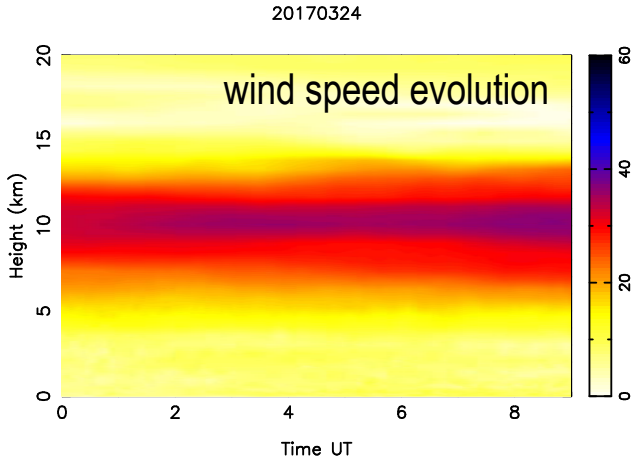
$$V_{eq} = \left(\frac{\int_0^\infty |V(h)|^{5/3} C_N^2(h) dh}{\int_0^\infty C_N^2(h) dh} \right)^{3/5}$$

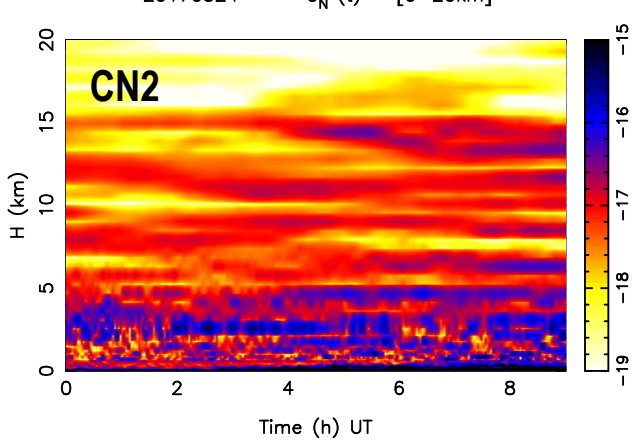


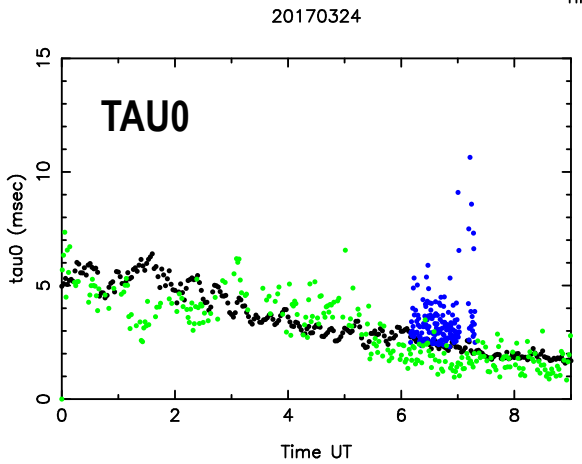












MNH Model

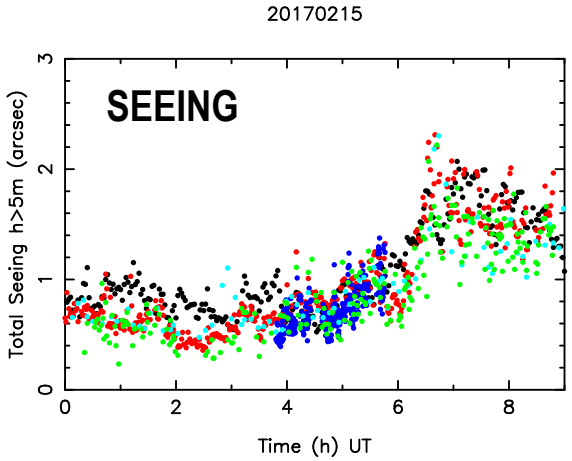
DIMM new

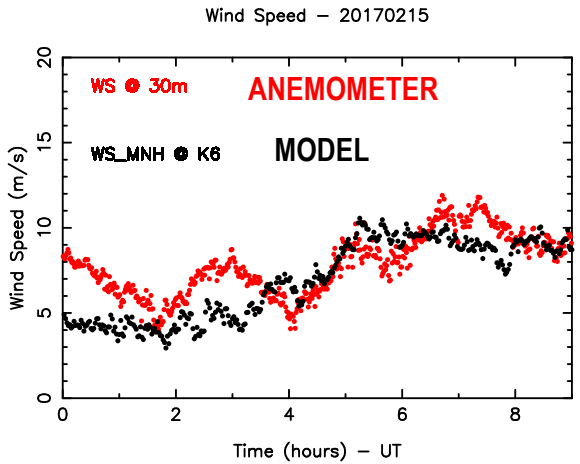
SLODAR above UT

AO-RTC (SPHERE)

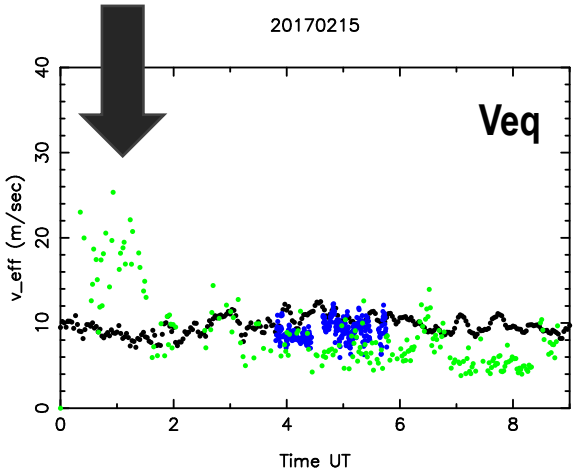
MASS-DIMM

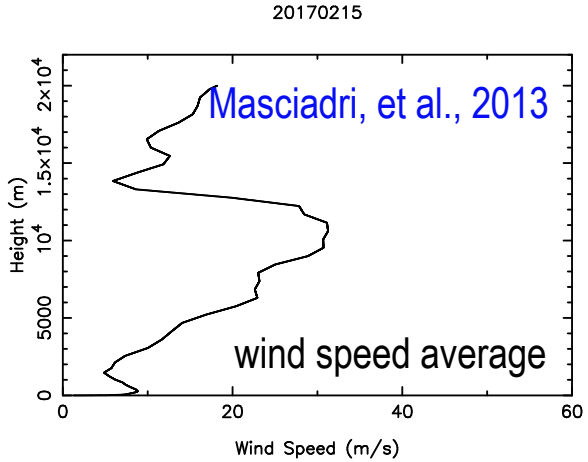
$$V_{eq} = \left(\frac{\int_0^\infty |V(h)|^{5/3} C_N^2(h) dh}{\int_0^\infty C_N^2(h) dh} \right)^{3/5}$$

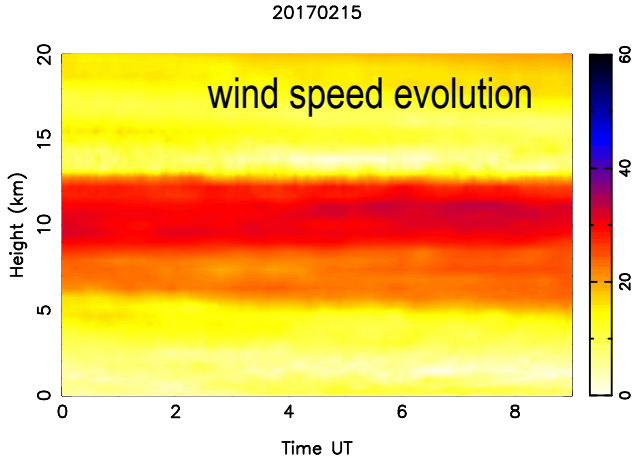


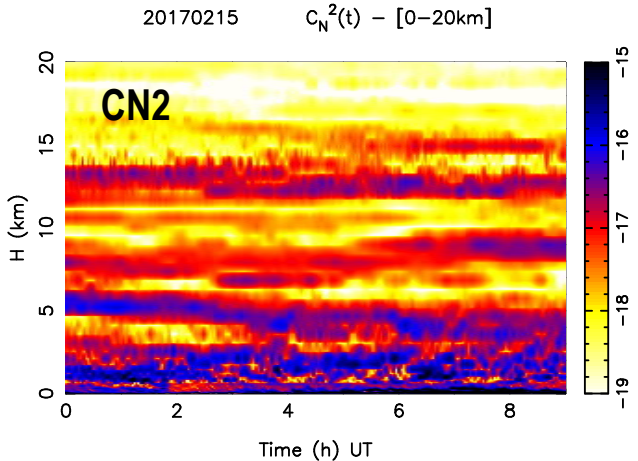


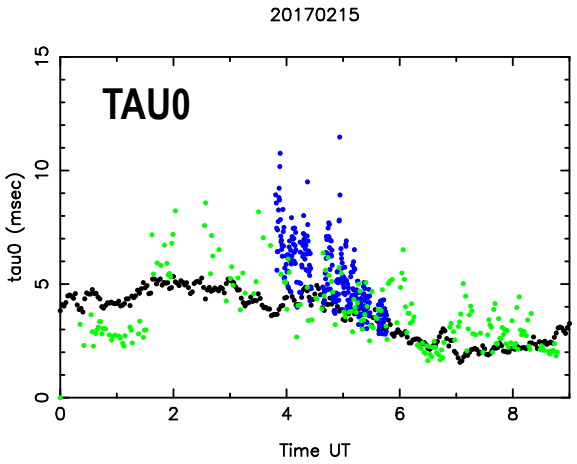
15/02/2017







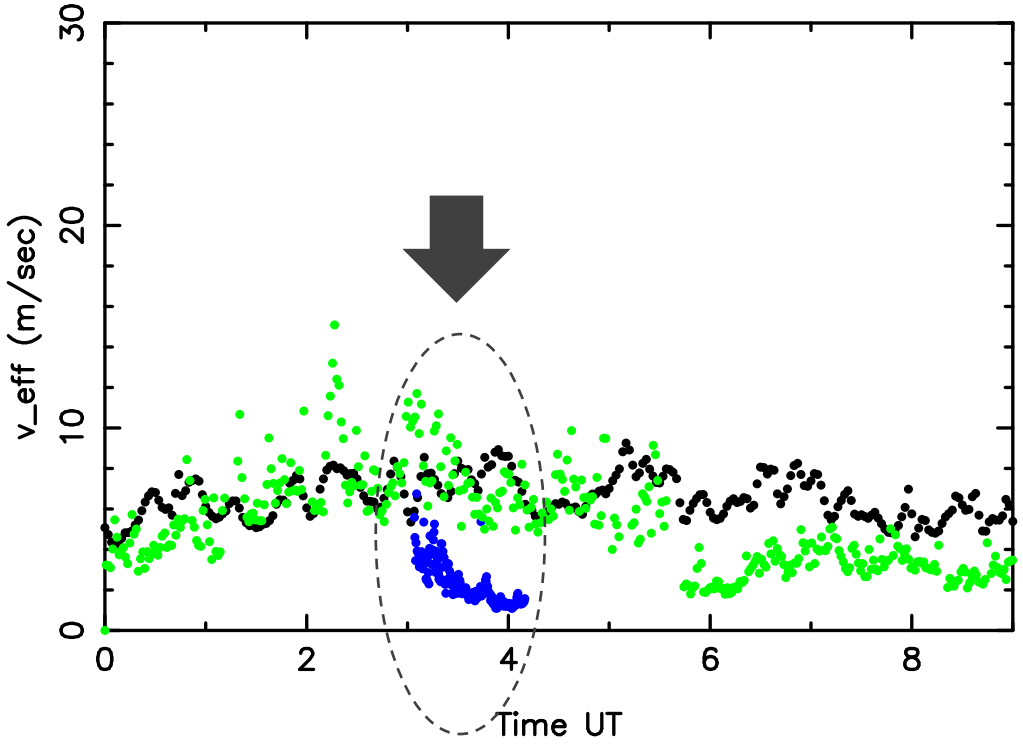




MNH Model
DIMM new
SLODAR above UT
AO-RTC (SPHERE)
MASS-DIMM

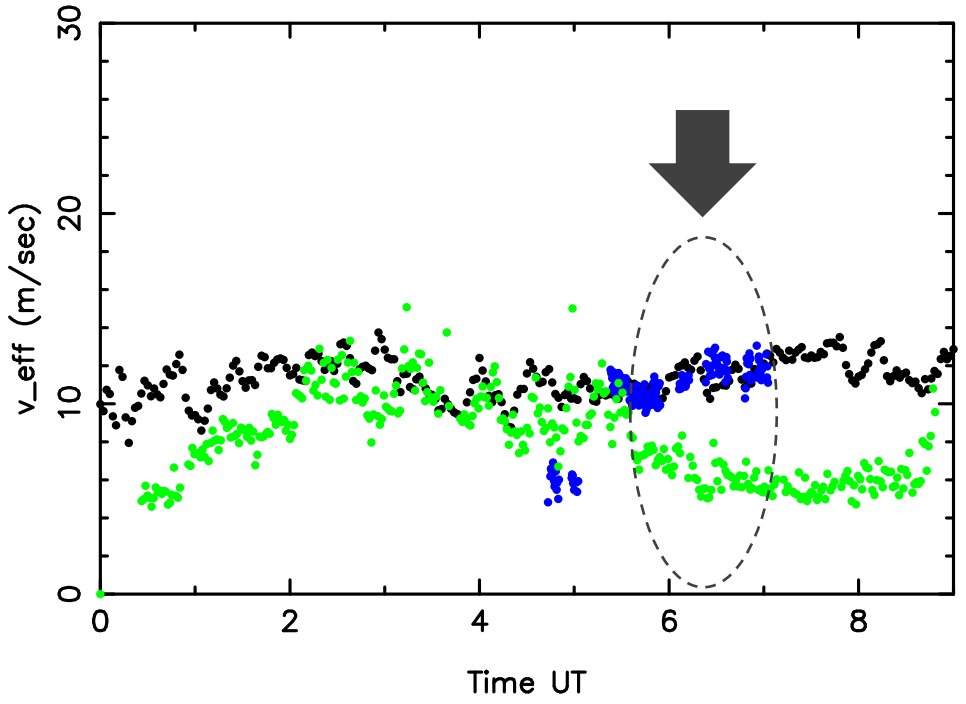
Meso-Nh model + simultaneous measurements from independent instruments can be useful to discriminate between the correctness of measurements provided by different instruments (here an example for the V_{eq})

20160926



AO-RTC (SPHERE) seems the "anomalous" one

20161207



MNH Model

AO-RTC (SPHERE)

MASS-DIMM

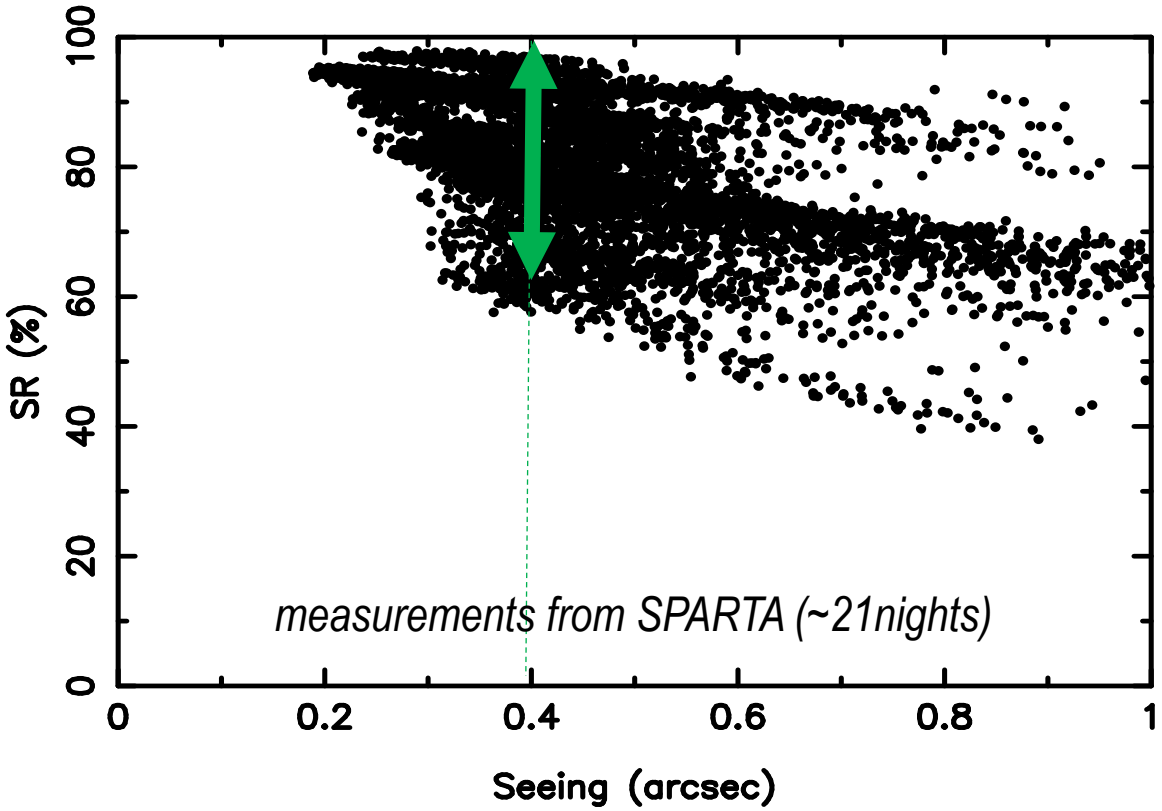
MASS-DIMM seems to be the "anomalous" one

STREHL RATIO

$$SR = SR(\varepsilon, m, V)$$

magnitude of the star

wind speed



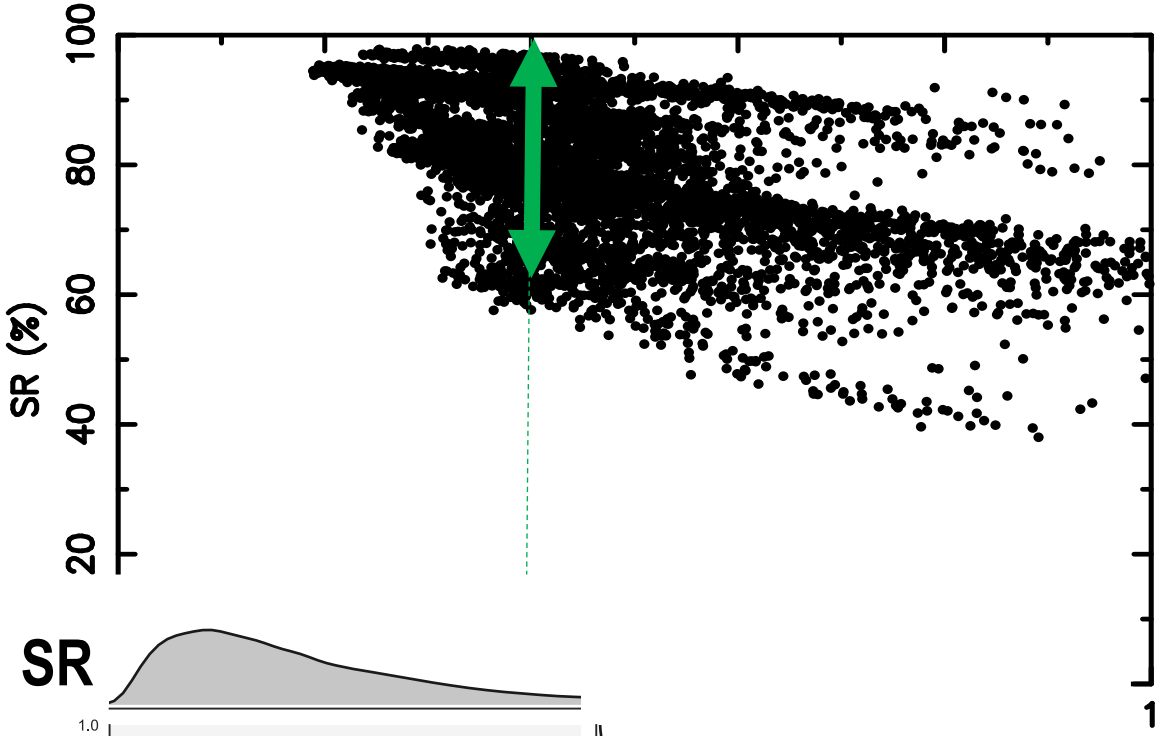
Strehl Ratio is not the IDEAL parameter to summarize the optical turbulence conditions because it does not depends **only** on optical turbulence

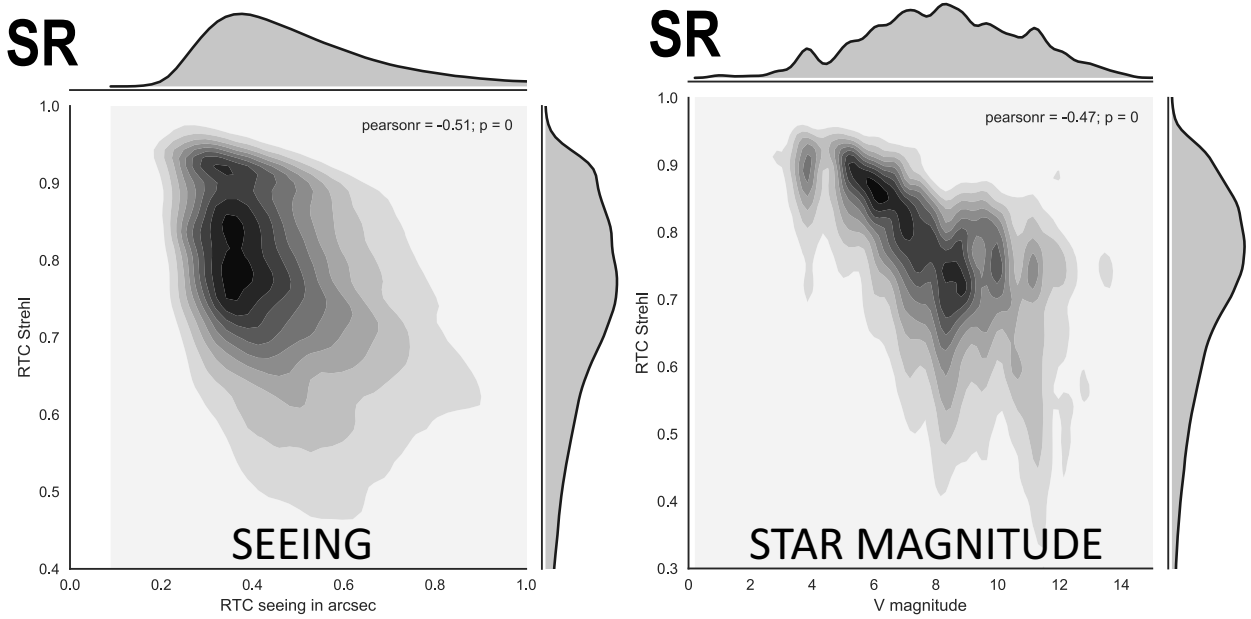
STREHL RATIO

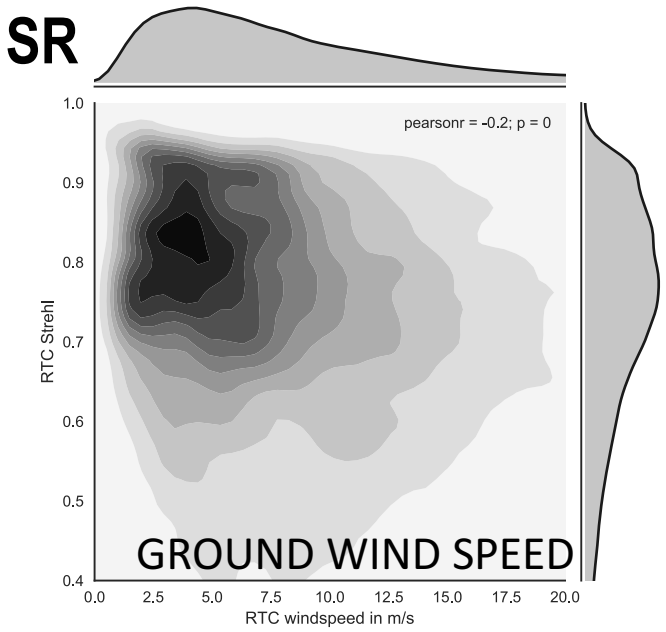
$$SR = SR(\varepsilon, m, V)$$

magnitude of the star

wind speed

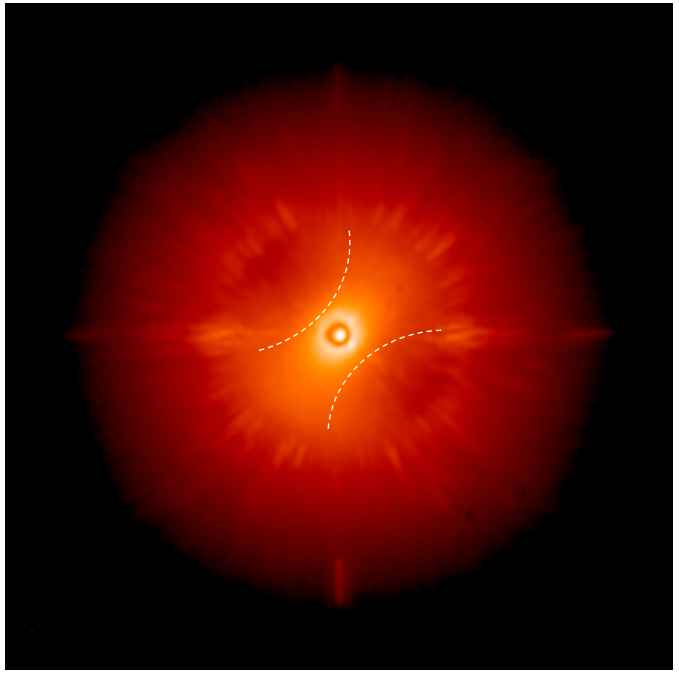




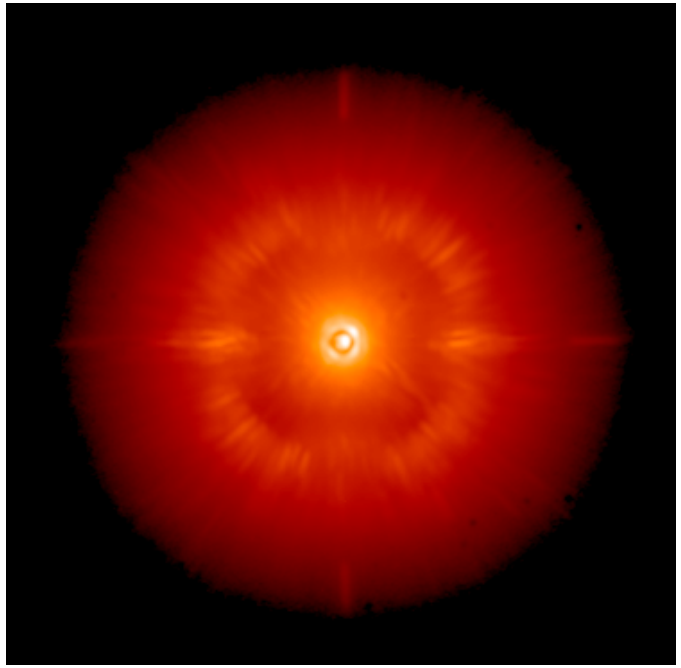


Julien Milli [p3046]
Thursday

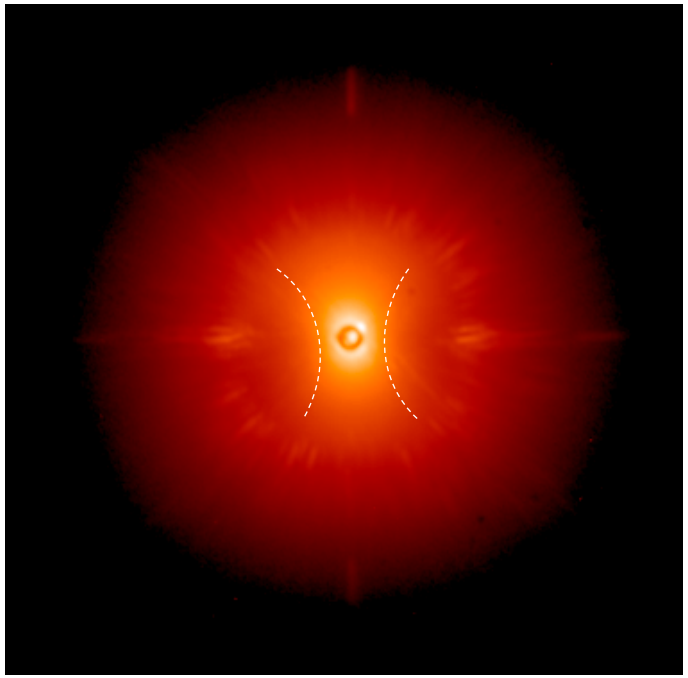
2015/09/17 SR=61.9%



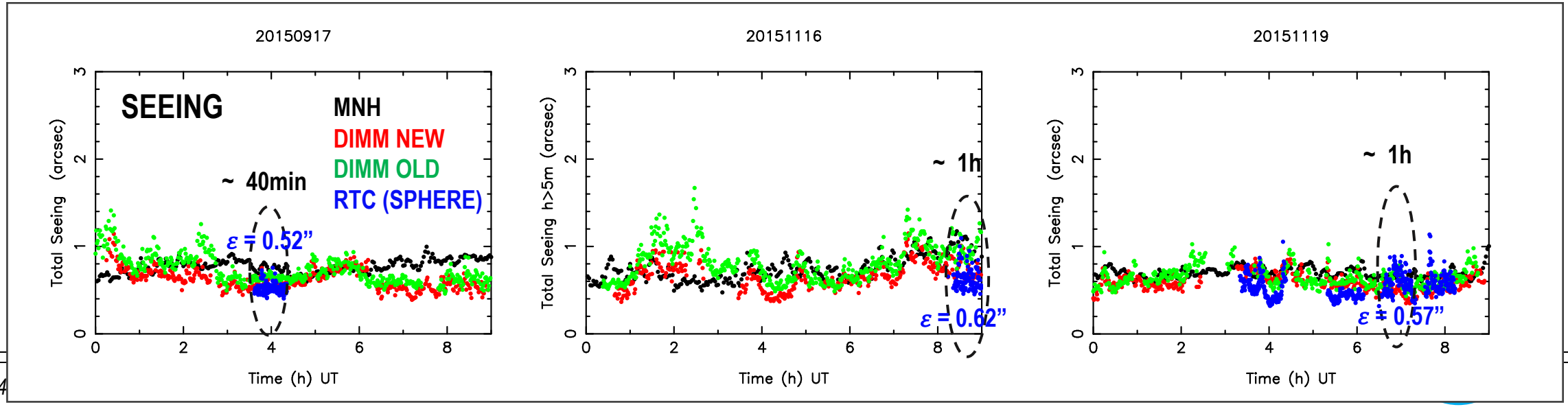
2015/11/16 SR=68%



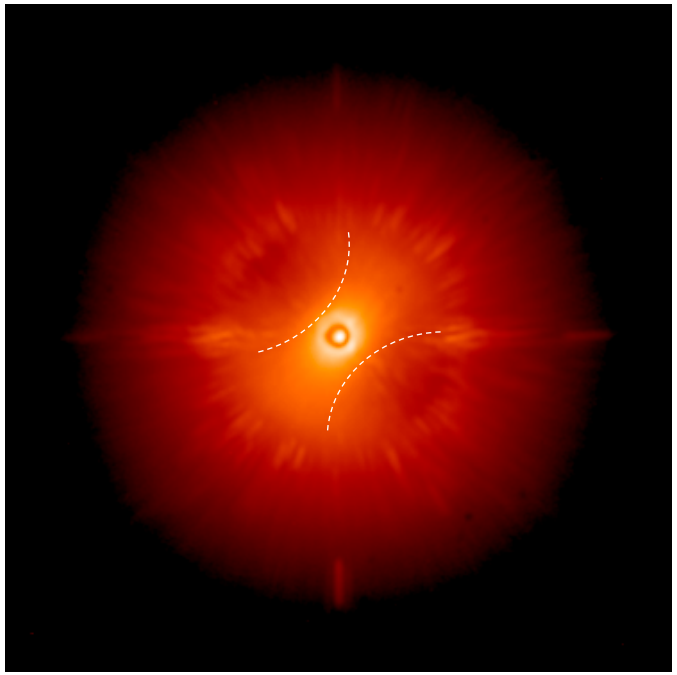
2015/11/19 SR=54.6%



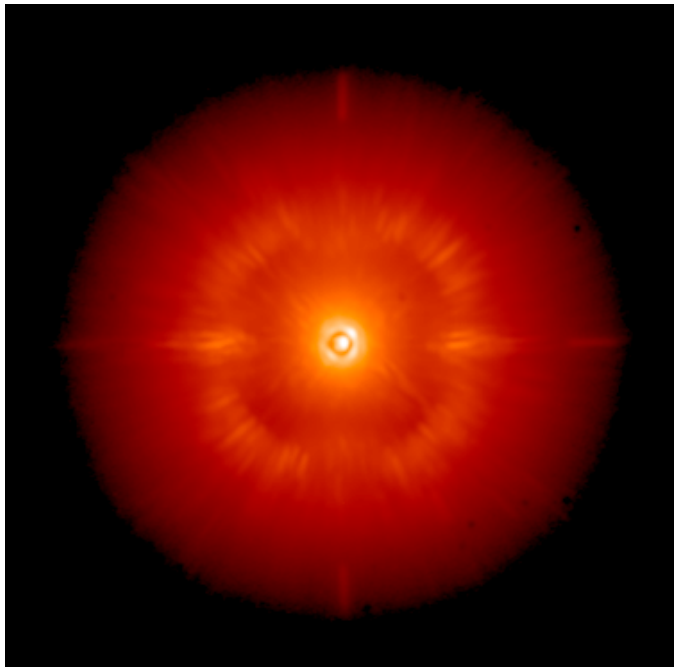
Courtesy of J.F. Sauvage , T. Fusco



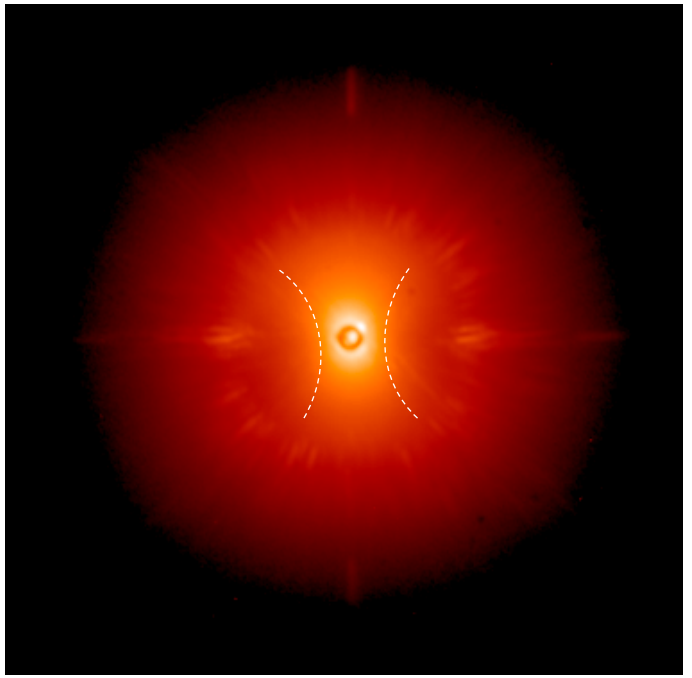
2015/09/17 SR=61.9%



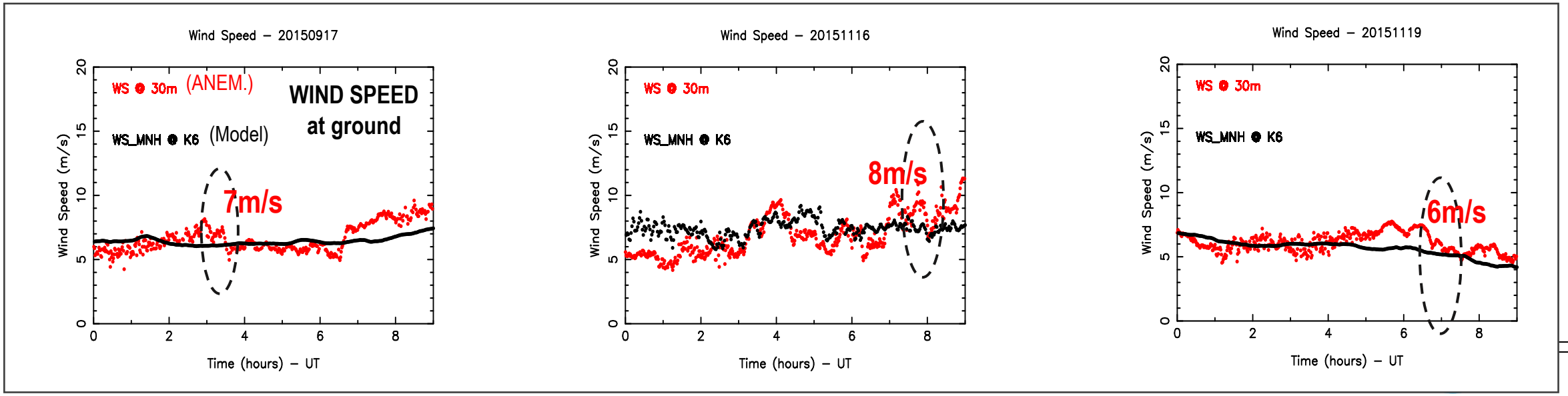
2015/11/16 SR=68%



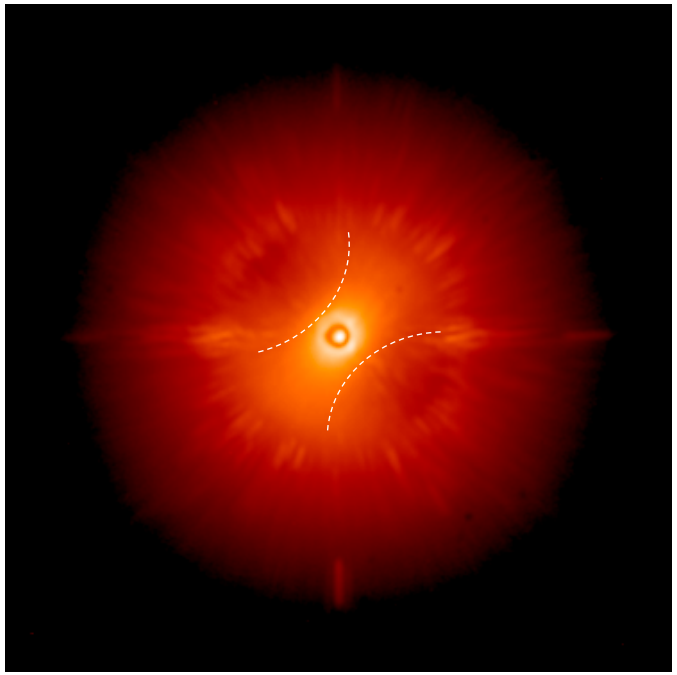
2015/11/19 SR=54.6%



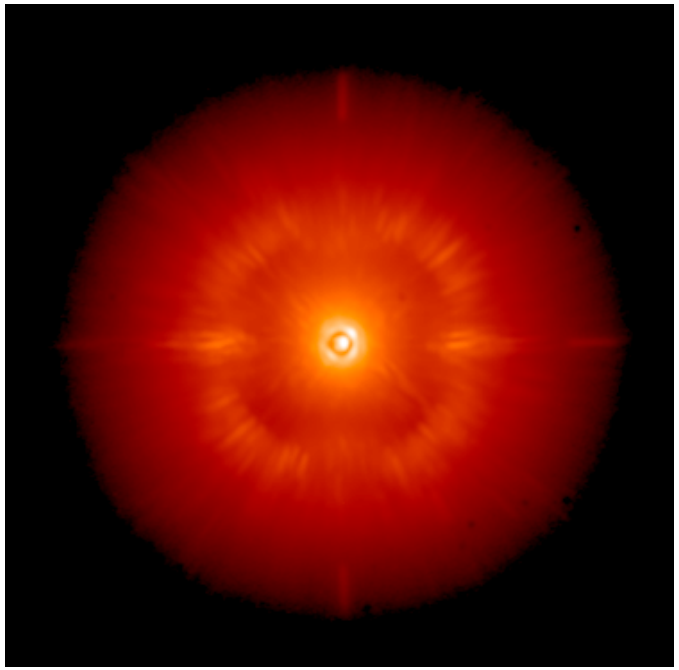
Courtesy of J.F. Sauvage and T. Fusco



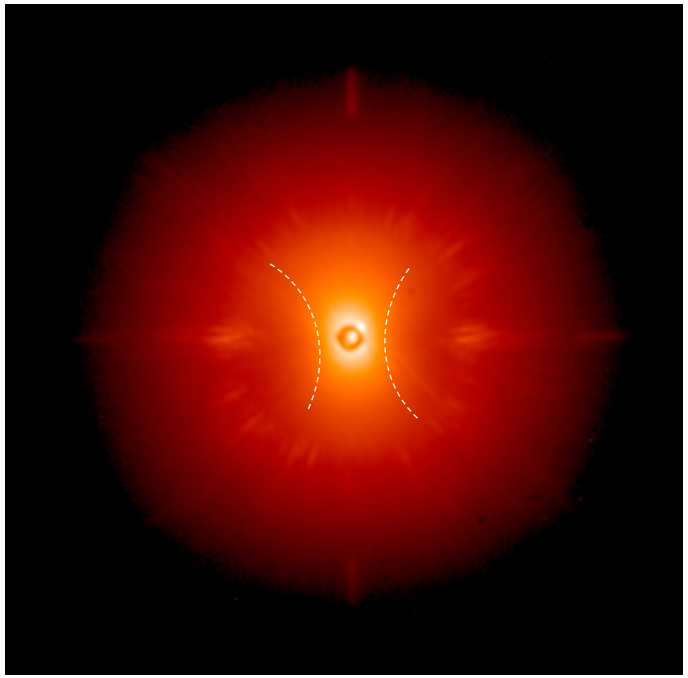
2015/09/17 SR=61.9%



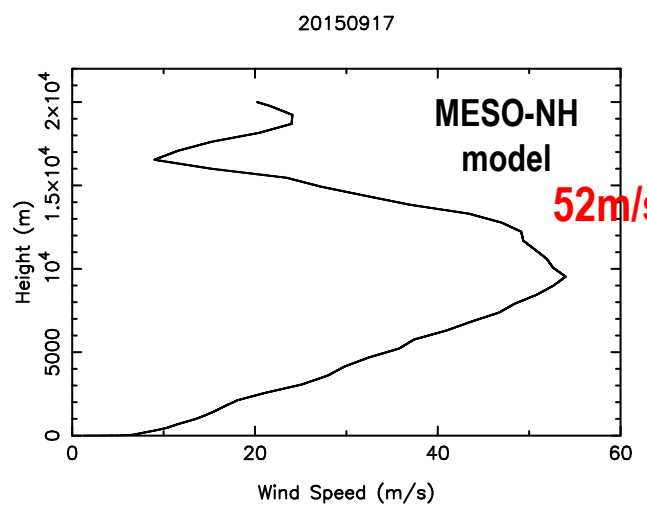
2015/11/16 SR=68%

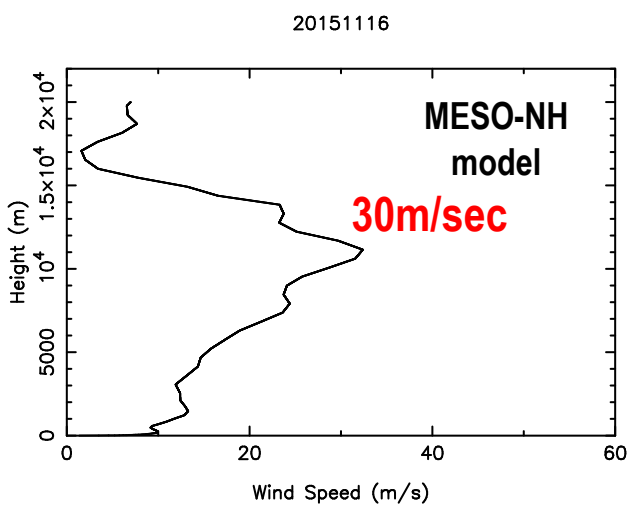


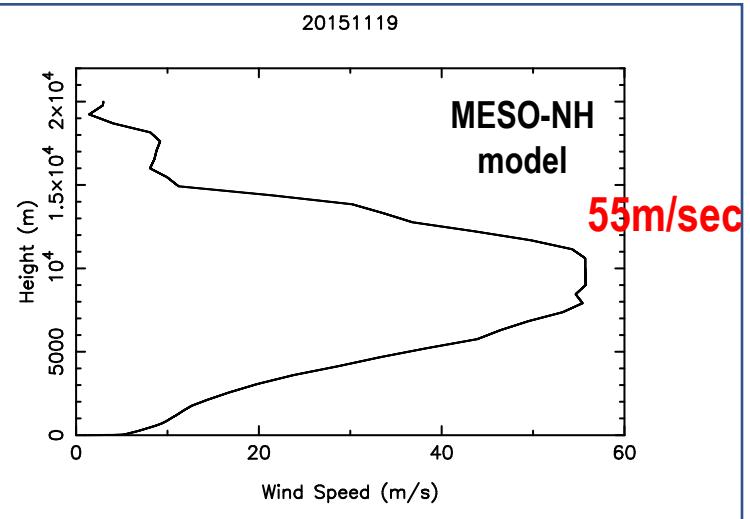
2015/11/19 SR=54.6%



Courtesy of J.F. Sauvage and T. Fusco





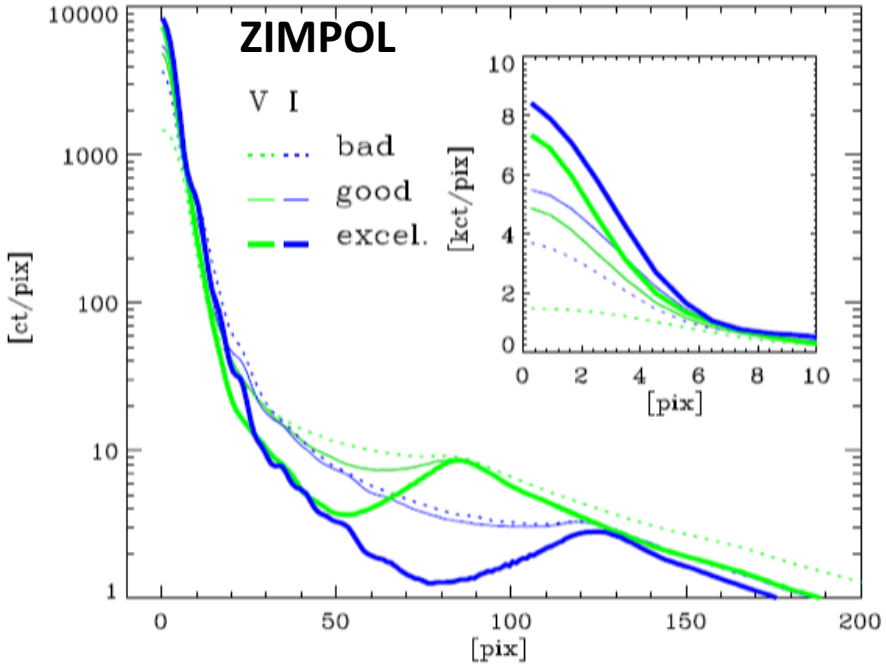


CONTRAST

Which are the conditions that determine such an excellent contrast ?

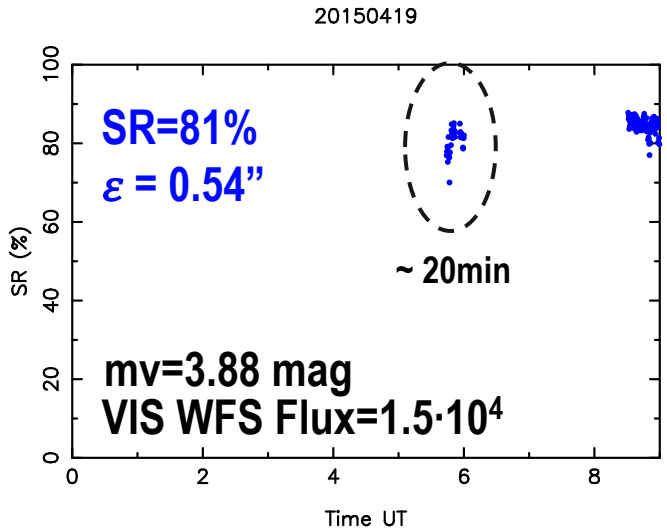
Is the model able to identify the conditions with the best contrast ?

Julien Milli courtesy

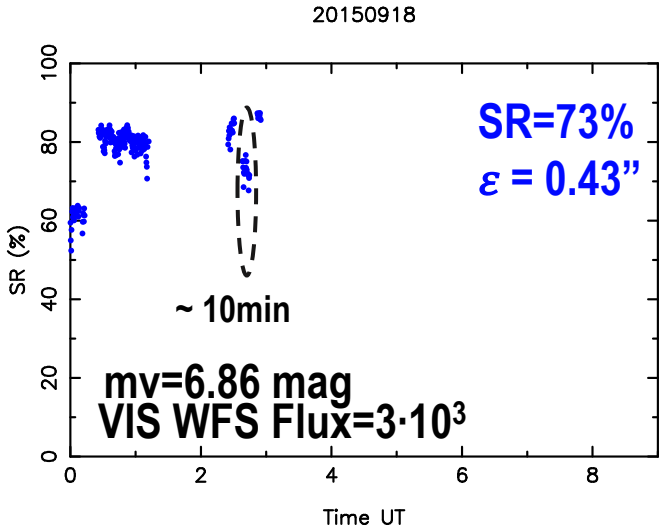


Observations in the visible are particularly sensitive to turbulence conditions changes

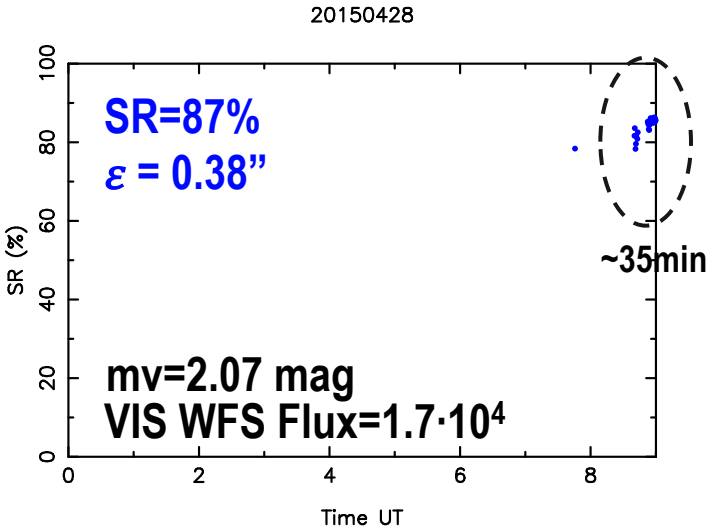
BAD [5:30-6:30]



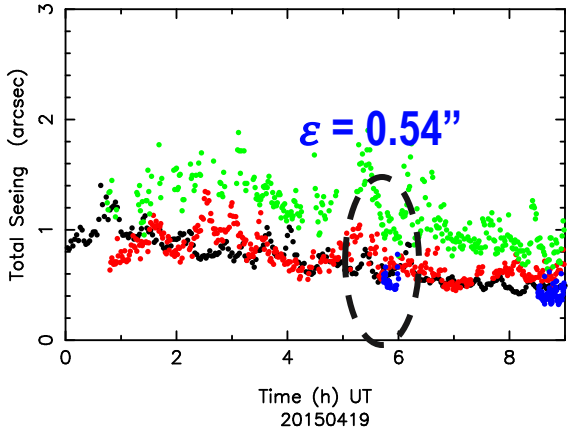
GOOD [2:37-2:47]

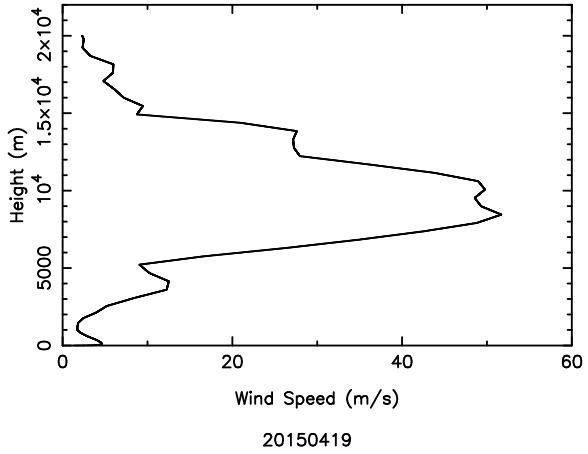


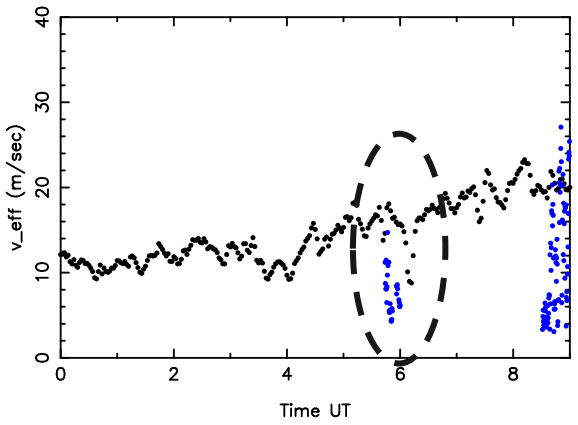
EXCELLENT [8:38-9:13]



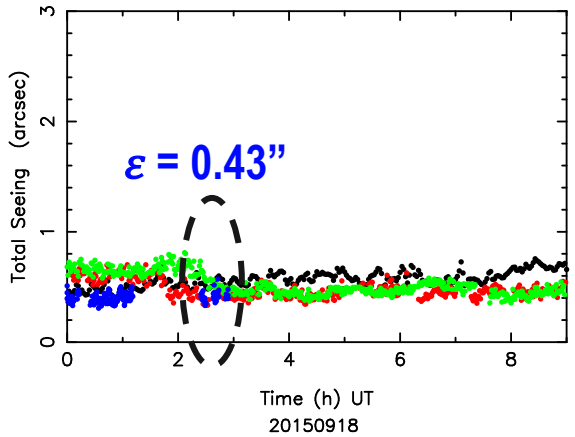
BAD 20150419

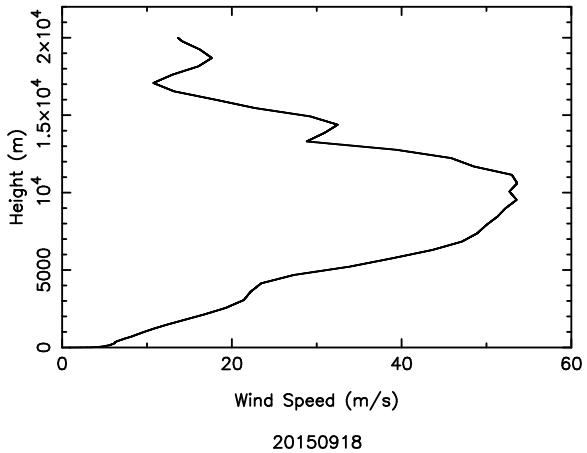


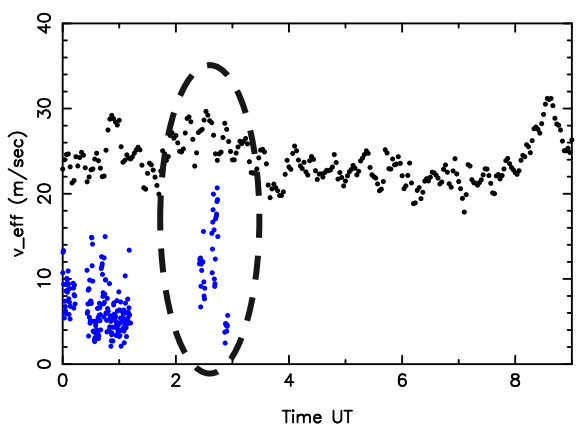




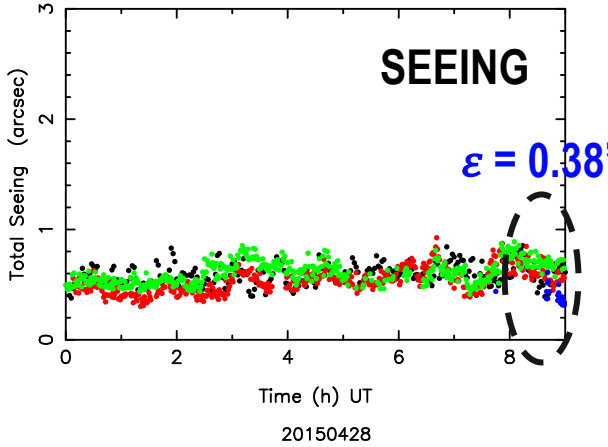
GOOD 20150918

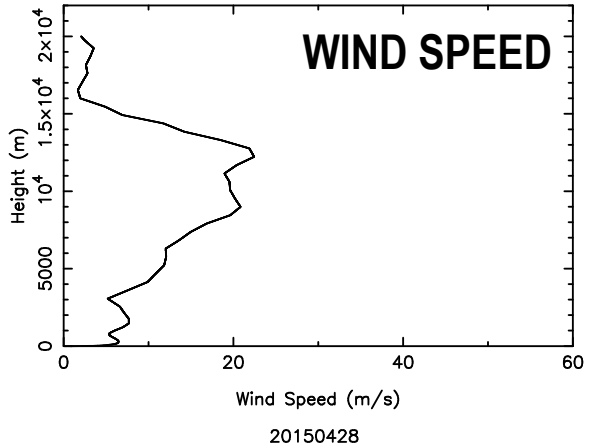


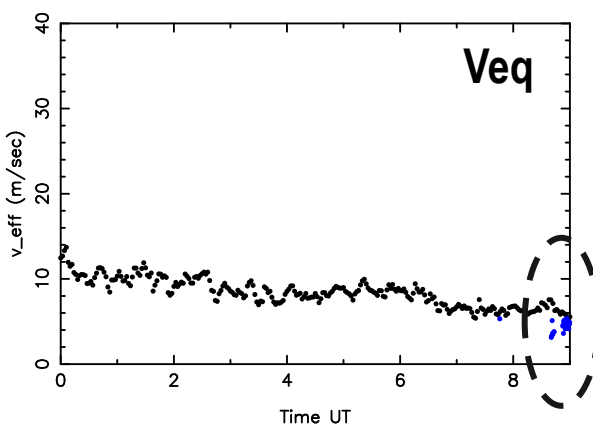




EXCELLENT 20150428







MNH Model

DIMM new

DIMM old

AO-RTC (SPHERE)

CONCLUSIONS

Night 2015/04/28 with excellent contrast has the weakest seeing and Veq and the model reconstructs coherently these conditions

Good info for SPHERE !

CONCLUSIONS

ALTA Center is now available ! Science Operation Team of LBT is starting to use it

ATMOSPHERICAL PARAMETERS: - extended model validation (144 nights uniformly distributed on a solar year) with excellent performances (**Turchi er al., 2017, MNRAS - Turchi et al. [p3013]**)

OPTICAL TURVULENCE: - We set-up a new model calibration that use GS and DIMM ➔ new perspectives for applications to other sites (new model calibration permits better model performances close to the ground)

- We verified that the procedure works and we obtain good model performances in reconstructing $\varepsilon, \theta_0, \tau_0$

OT measurements from AO system are very useful but further investigations are required, particularly for the Veq and Tau0

In spite of the fact that the model calibration we performed for VLT has been done with measurements of only 20 nights of 2007 and we changed in the meanwhile model versions, the model seems to reconstruct reliable OT measurements

We are waiting for the STEREO-SCIDAR measurements to be able to calibrate the model for the winter time for the MOSE demonstrator