Preliminary results of astroclimate parameters measurements at the Sternberg 2.5m telescope installation site

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Why to study optical turbulence and some other relevant site parameters

- Primary goal is the collection of the statistically reliable data on seeng and altitude atmospheric optical turbulence distribution at the Sternberg institute 2.5m telescope installation site.
- Additional goals – accumulation of information on clear nights frequency and measurement of the weather parameters at the site.

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Wavefront propagation through turbulent atmosphere

1. Refraction index fluctuations (optical turbulence) cause phase distortions of the lightwaves.
2. While propagating, phase distortions convert to amplitude distortions.
3. In the space scales 1cm to 10m (optical telescope sizes), these fluctuations obey Kolmogorov law.
4. The turbulence intensity at a given altitude is fully described by the refractive index structure function coefficient $C_n^2(h)$
5. The main parameter characterizing the integral influence of the turbulent atmosphere is the Fried radius:

$$r_0 \sim \left[\int C_n^2(h) \cdot dh \right]^{-3/5}$$

and the derived parameter – image quality (seeing):

$$\beta = 0.98 \frac{\lambda}{r_0}$$

What we know from optical turbulence measurement

- Seeing defines the efficiency of a telescope in a classical imaging mode at a given site
- Fried radius – the basic unit for modeling of the adaptive optics systems (AO), meanwhile not the sole one
- The layout and parameters of the optimal AO are determined by the knowledge of altitude turbulence distribution
- Altitude optical turbulence distribution defines the precision of photometric and astrometric measurements
- Statistical properties of these quantities help to develop the strategy of the telescope use
- Realtime turbulence data acquisition is used for prompt operative planning of observations
- General understanding of the phenomenon of the turbulent atmosphere behavior is crucial for well-directed site search for future large and giant optical telescopes

MASS – multi-aperture stellar scintillation sensor

Measured scintillation indices:

normal

$$s^2 = \langle (\Delta \ln I)^2 \rangle$$

differential

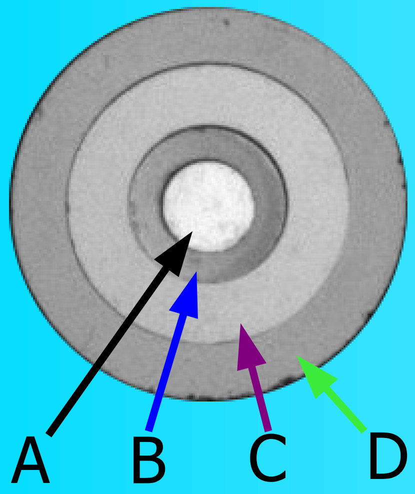
$$s_d^2 = \langle (\Delta \ln (\frac{I_1}{I_2}))^2 \rangle$$

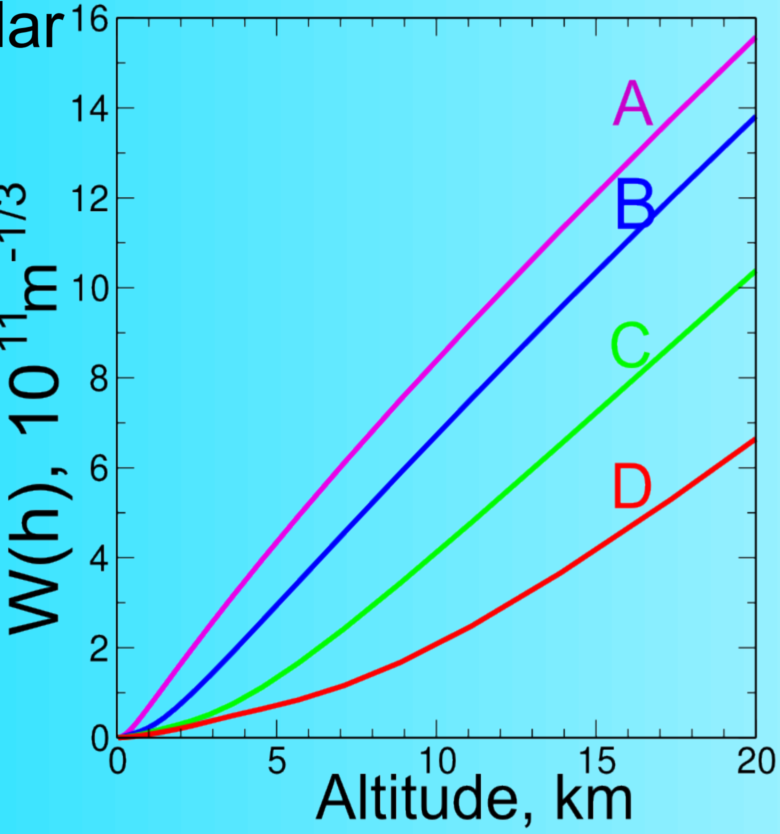
theoretical scintillation index

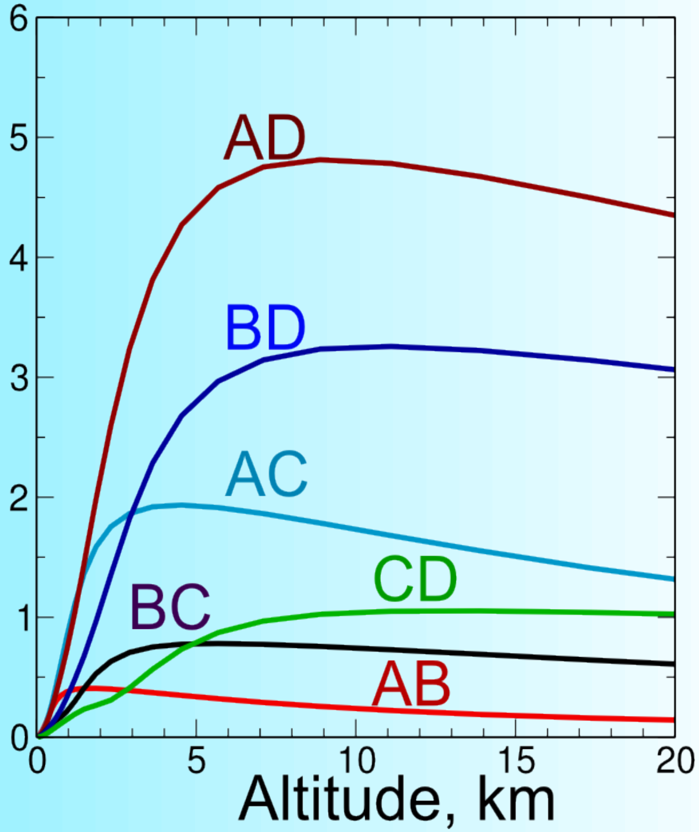
$$s^2 = \int C_n^2(h) \cdot W(h)\, dh$$

where $W(h)$ is aperture geometry-computed weighting function

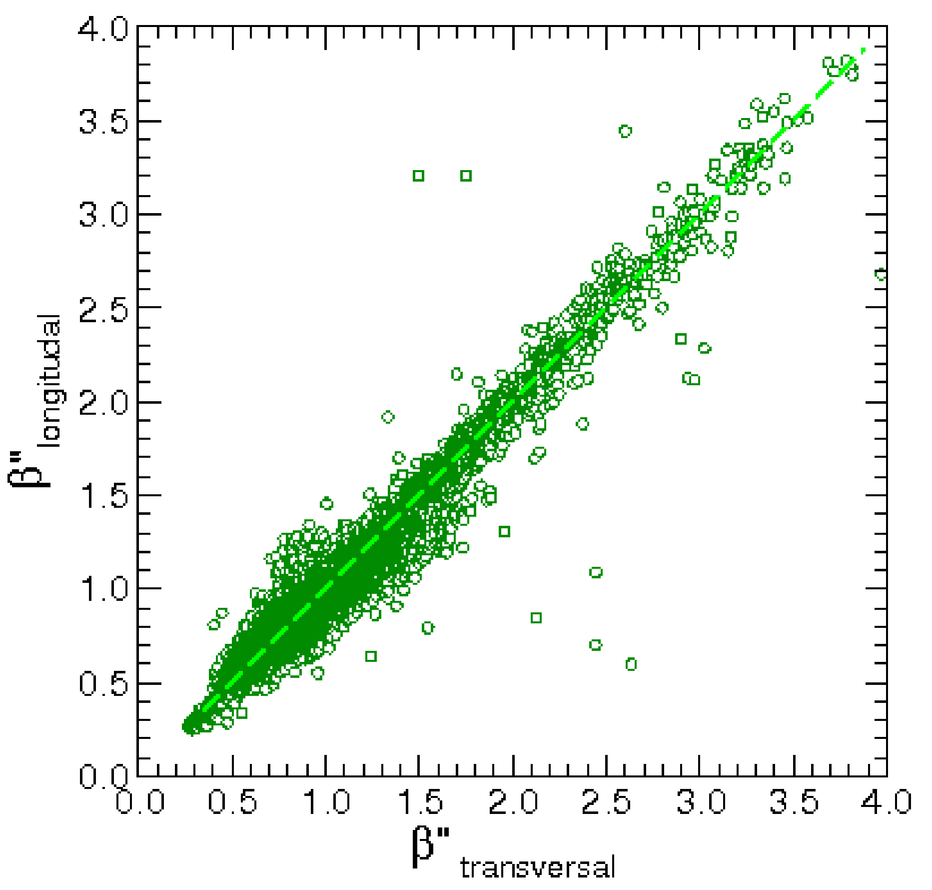
For the annular geometry:







DIMM – differential stellar image motion monitor



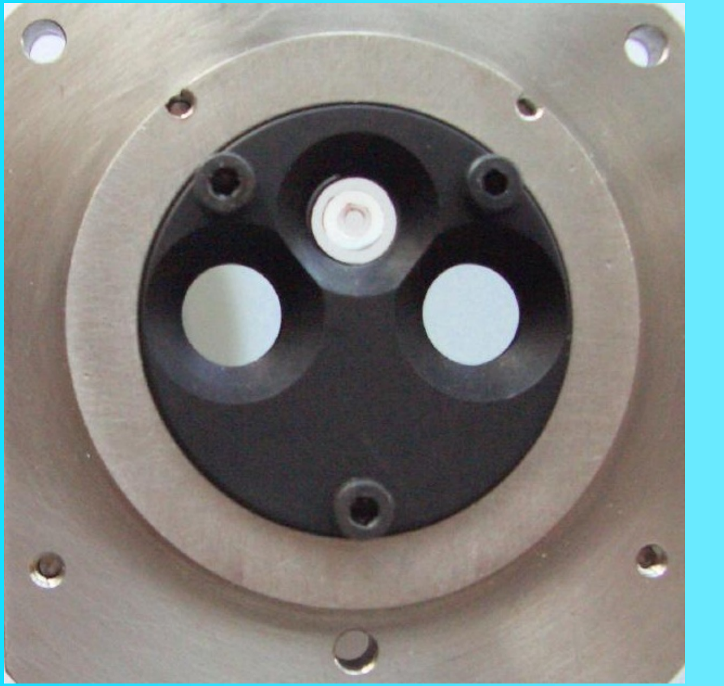
The basic relation which ties the measured differential image motion withe the Fried radius (i.e. with image quality or seeing):

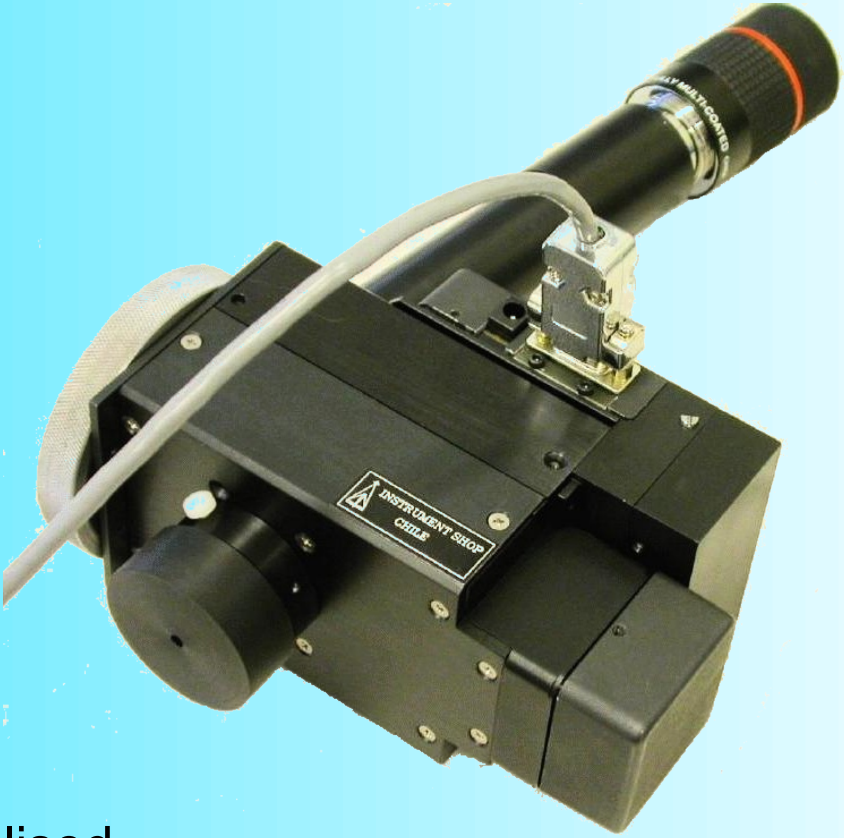
$$\sigma^2_{l,t} = K_{l,t} (\lambda / D)^2 (D / r_0)^{5/3}$$

Indices *l* and *t* relate to longitudinal and tangential wavefront distortions (random slopes).

Combined MASS/DIMM device

allows the turbulence study through all the atmosphere including the ground layer





1. the singe feeding telescope is utilised
2. the same line-of-site is involved in both device operations
3. the measurements are time-synchronised

These circumstances allow the combination of the two methods results for restoration of the complete altitude turbulence profile.

The current tasks in study of optical turbulence at the 2.5m SAI telescope site (on-going and finished)

- Setting up the MASS/DIMM device, development and testing of the data acquisition software
- Development and manufacturing of the automatic optical turbulence monitor (ASM – astroclimate site monitor)
- Setting up the ASM on site, testing
- Regular measremen performing during 2 – 3 years
- Final data processing and analysis
- Conclusions on the properties of atmospheric turbulence at the site, comparison with other observatories, development of the optimal telescope equipment and Adaptive optics system parameters

The demands to the ASM – automatic seeing monitor

- The monitor must be placed not far (30 – 40 м) from the place of installation of 2.5 m telescope near the southern slopes of the mountain.
- The monitor tower is about 5m, in order to place the ASM feeding telescope at the 6m from the ground.
- The pillar for the feeding telescope must not be mechanically tied with the tower to minimize the wind-caused vibrations of the instrument.
- The instrument enclosure has to have the least thermal capacity and well protect the instrument from the wind gusts and from rain or snow while being closed.
- Power consumption is minimized in order to allow the autonomous functioning of the ASM system
- The reliable line connection through Internet for instrument operation and data acquisition
- Hard- and software structure must allow robotic or remote operation
- The monitor must include a number of weather sensors including the cloud sensor.

Installation of the ASM at the SAI summit

Top: N.Shatsky checks the alignment of the concrete formwork for the ASM telescope pillar

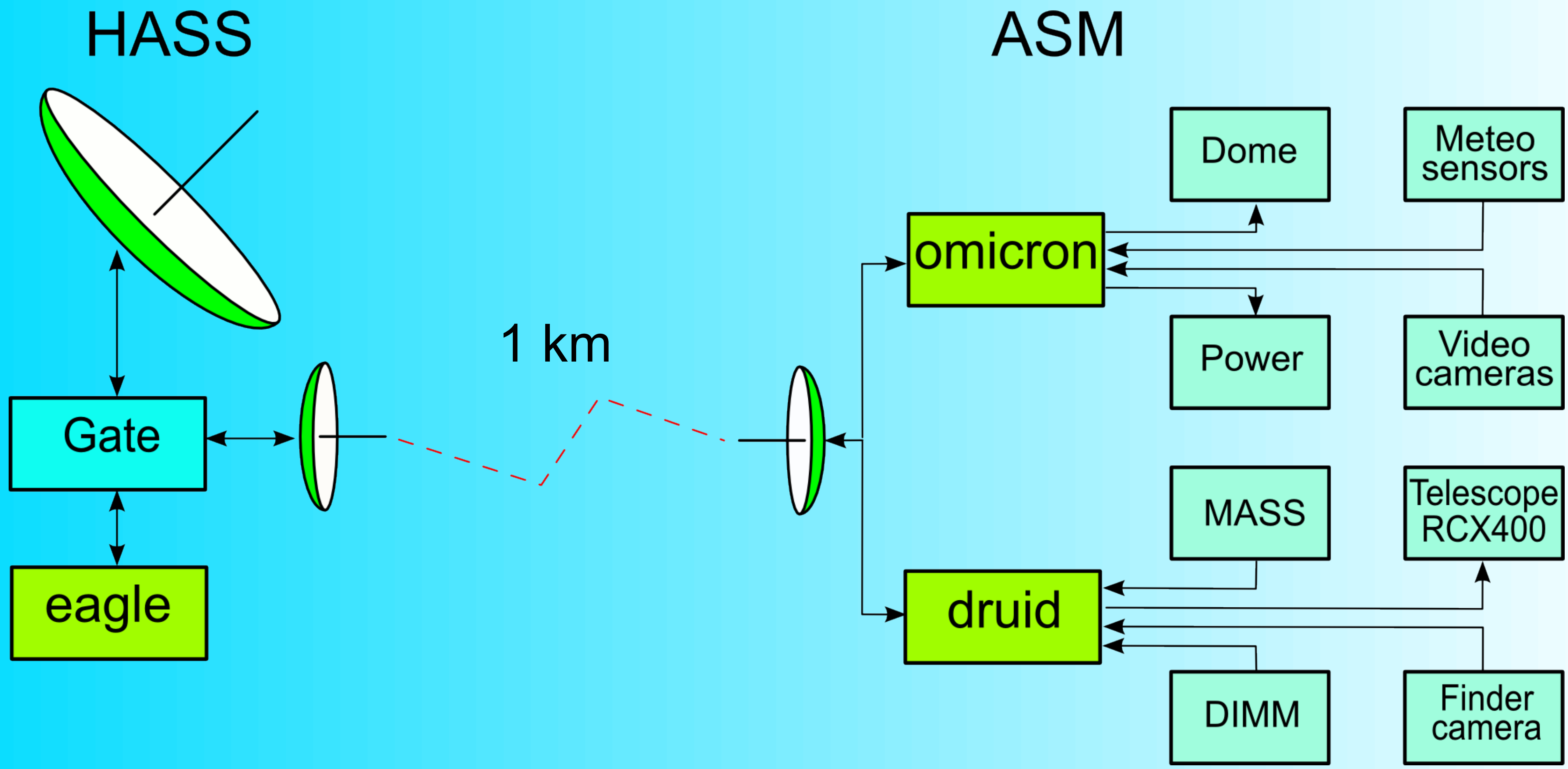
Left: Erection of the metallic tower for the ASM enclosure with help of the hand wrench and S.Potanin.

Everything is nearly ready (another 2 months of work will follow)

Enclosure space is 2.7sq.m.
V.Kornilov and equipped with
MASS/DIMM device the
Meade RCX400 telescope.

This box encloses two
computers, dome and
power control and the link
with extenal world

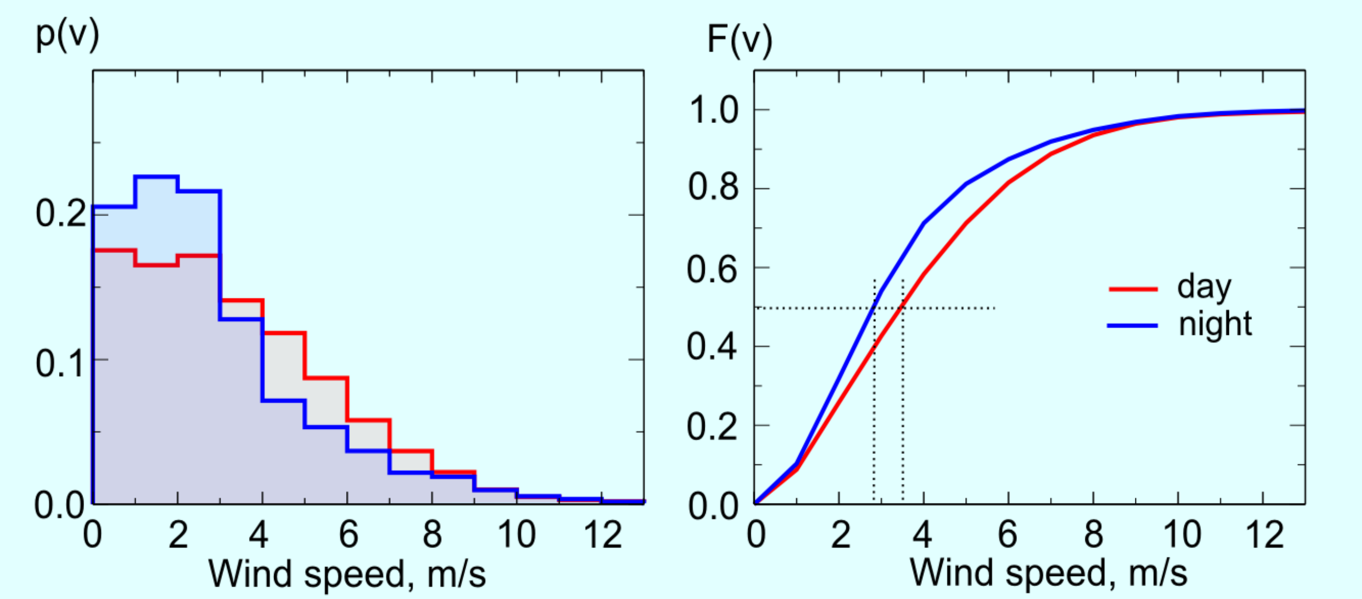
Data flow structure

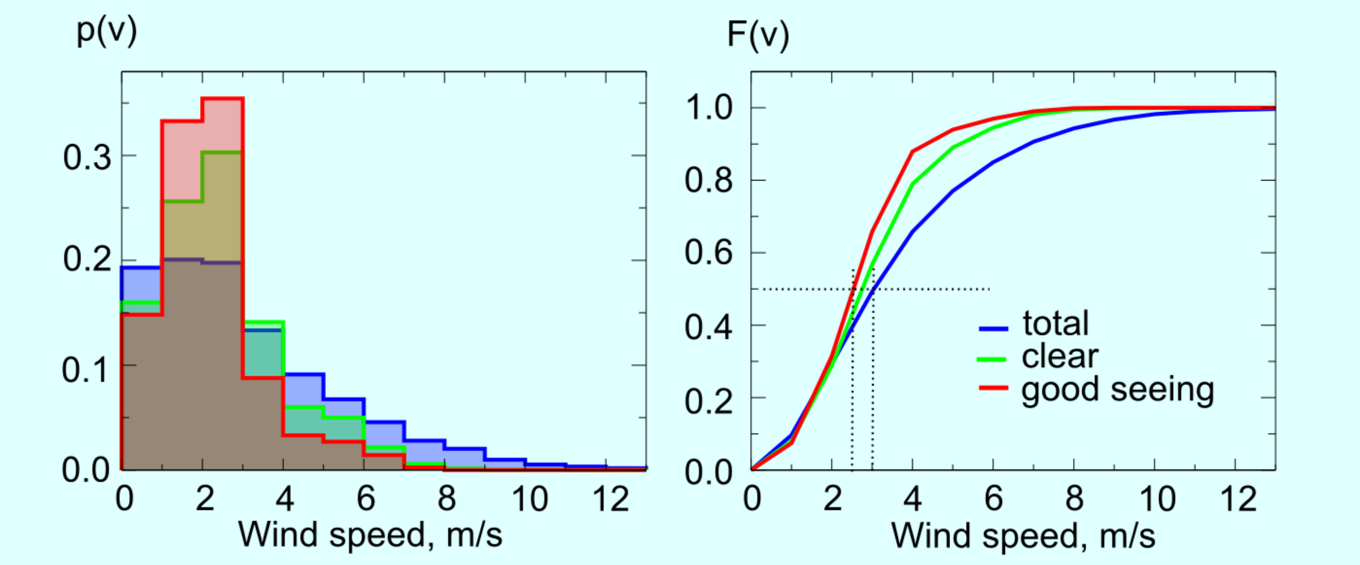


Computer eagle – system control, http-server, data storage
Computer omicron – link to KHSS, dome control, auxilliary web-cameras control, weather sensors, power control
Computer druid – telescope and MASS/DIMM control, data acquisition and primary processing

Weather data

for the period August 2007 – February 2008

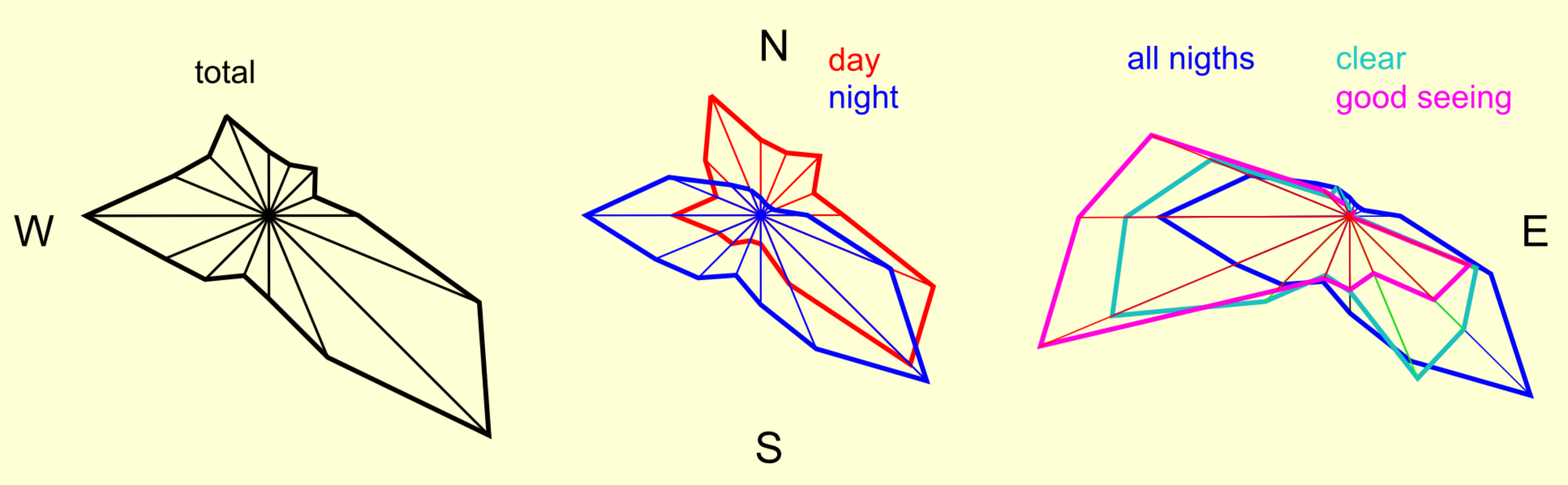




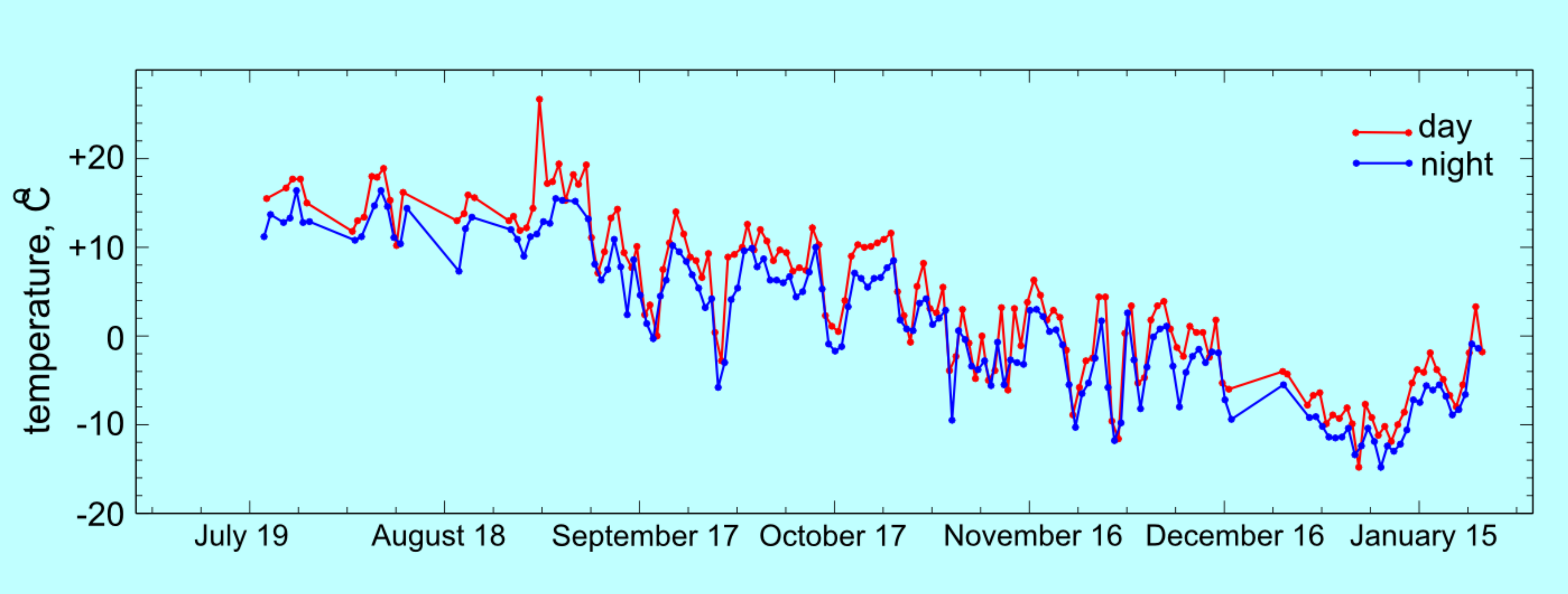
Wind speed distribution at the mountain at 6m elevation

Weather data

for the period August 2007– February 2008



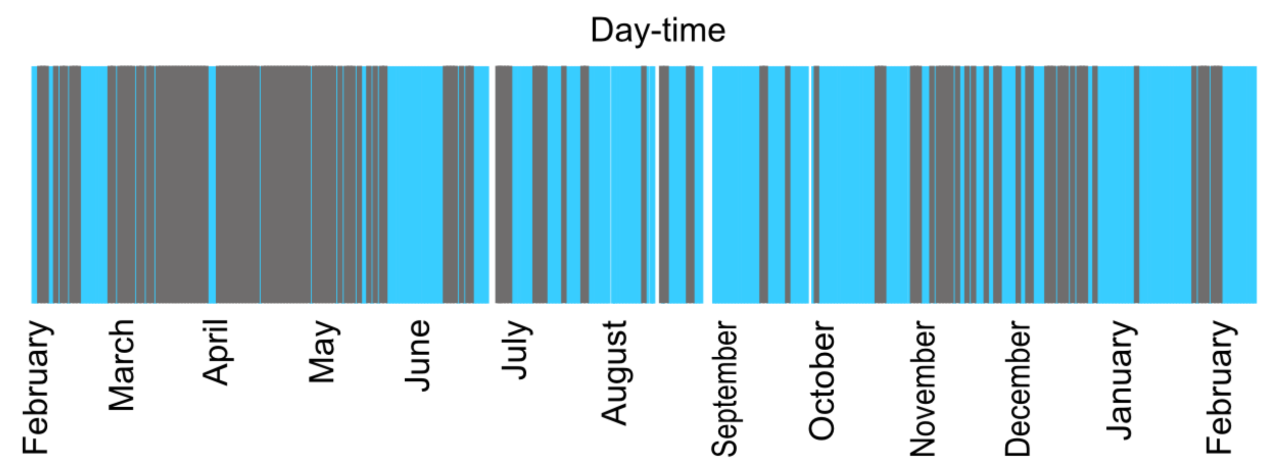
Wind direction for the different data subsamples

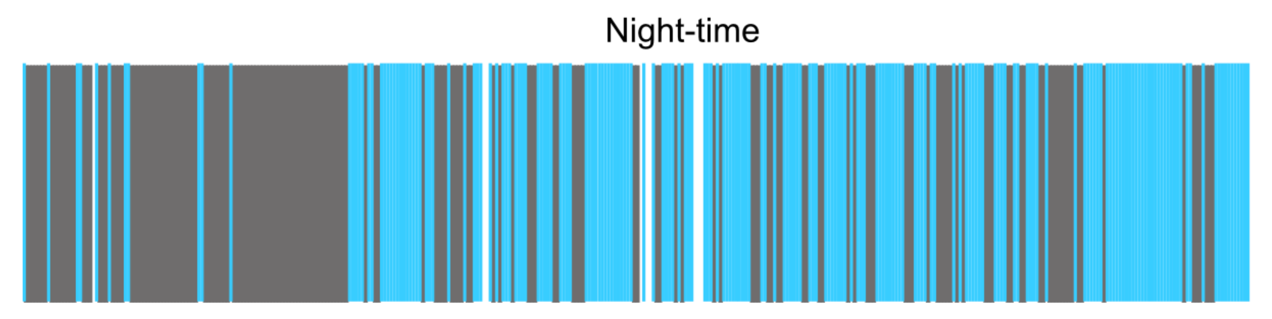


Half-year trend of the average night- and day-time temperature

Year-long record of the day- and night-time sky clearness data

by the cloud sensor data


Day-time


Night-time

October. Evening. Yard-space control camera

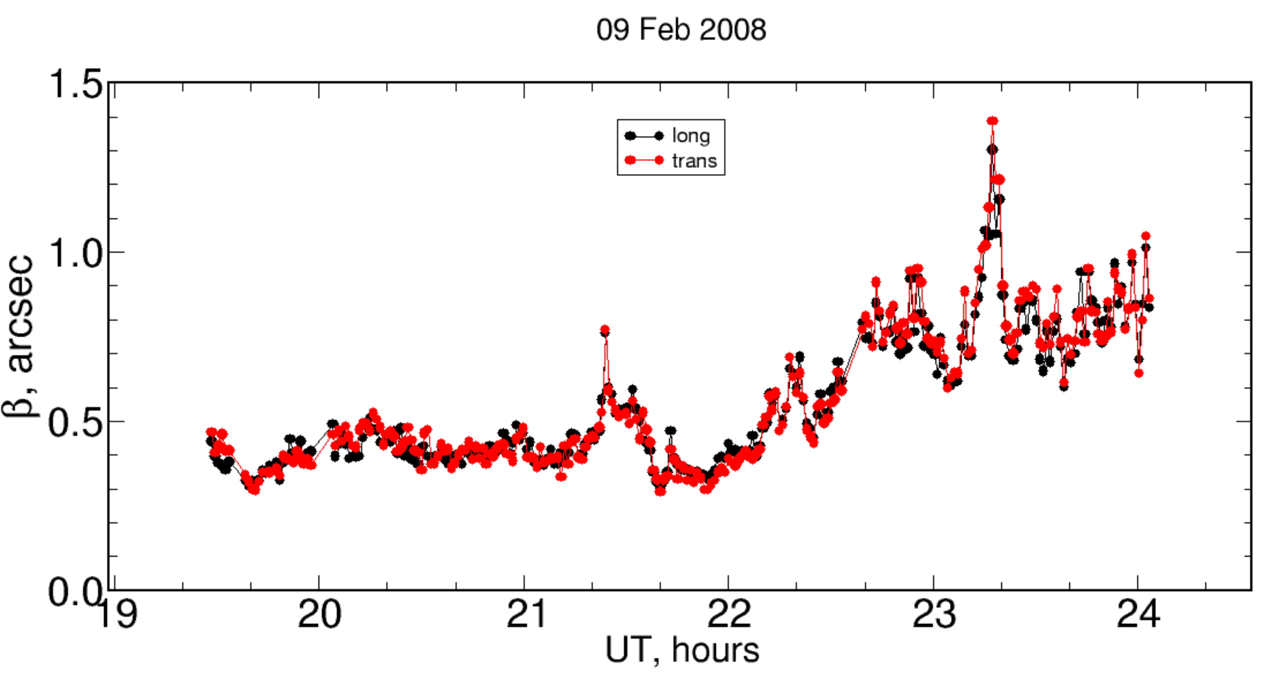
Measurement statistics

at 13 February 2008

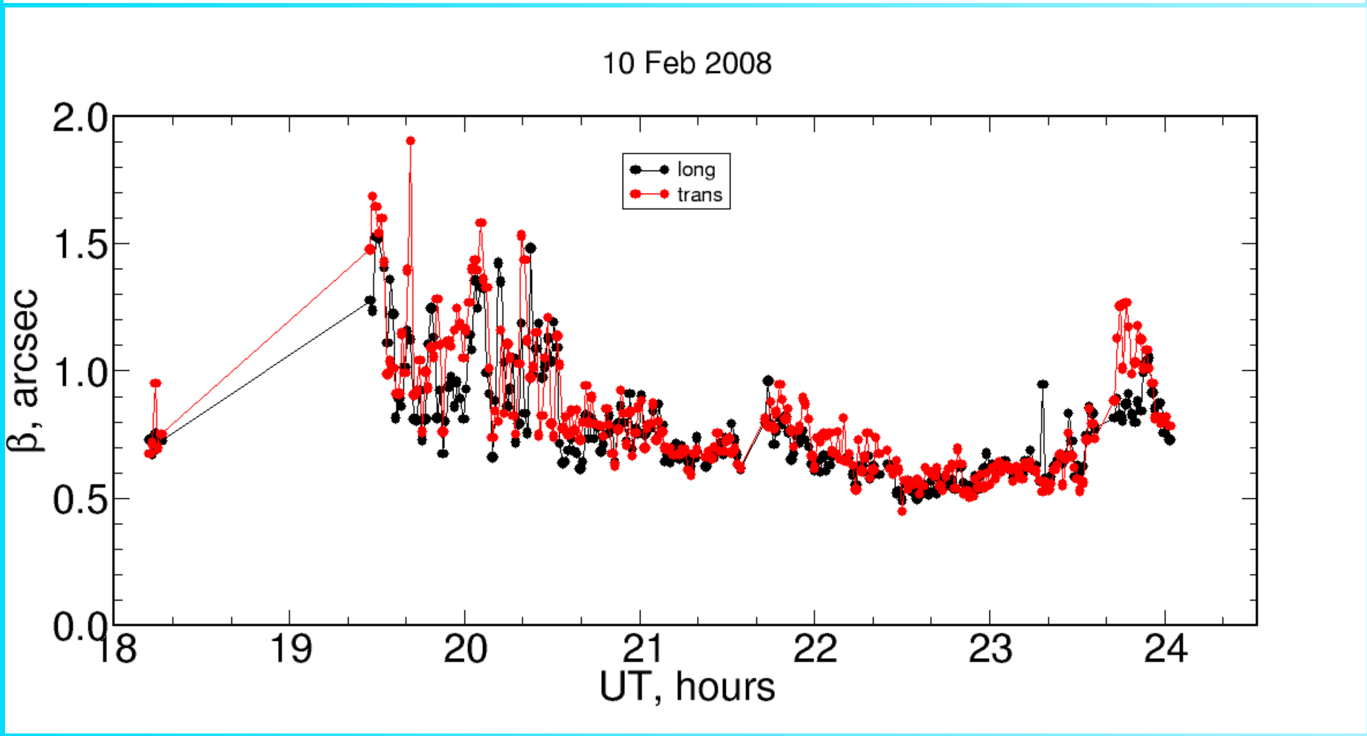
- September – 2 nights
- October – 10 nights
- November – 13 nights
- December – 11 nights
- January – 19 nights
- February – 13 nights

Total: 68 nights

Telescope view during measurements taken with internal dome space control camera

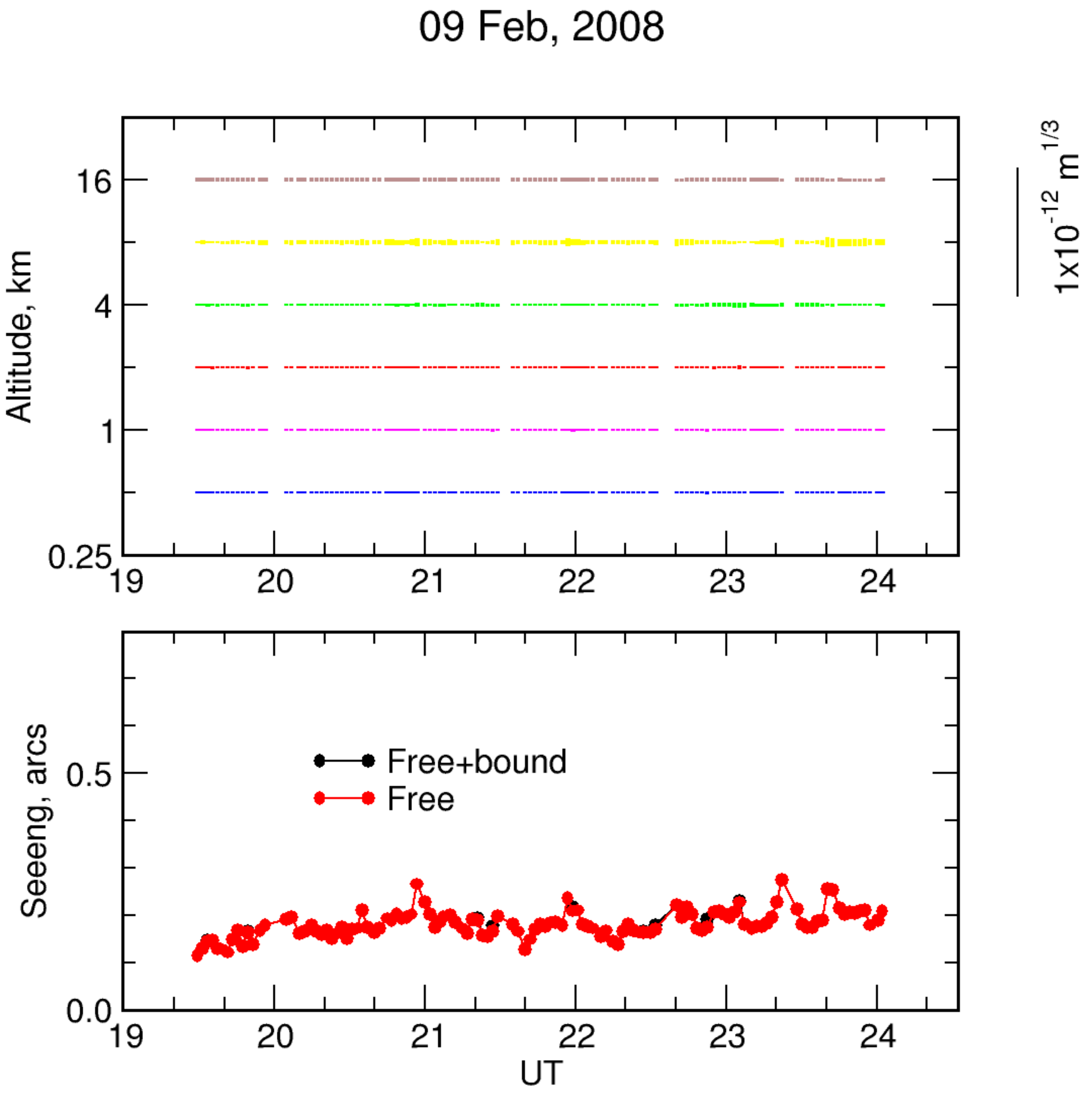


Data example from DIMM channel: seeing (integral turbulence) in 9 and 10 February 2008.



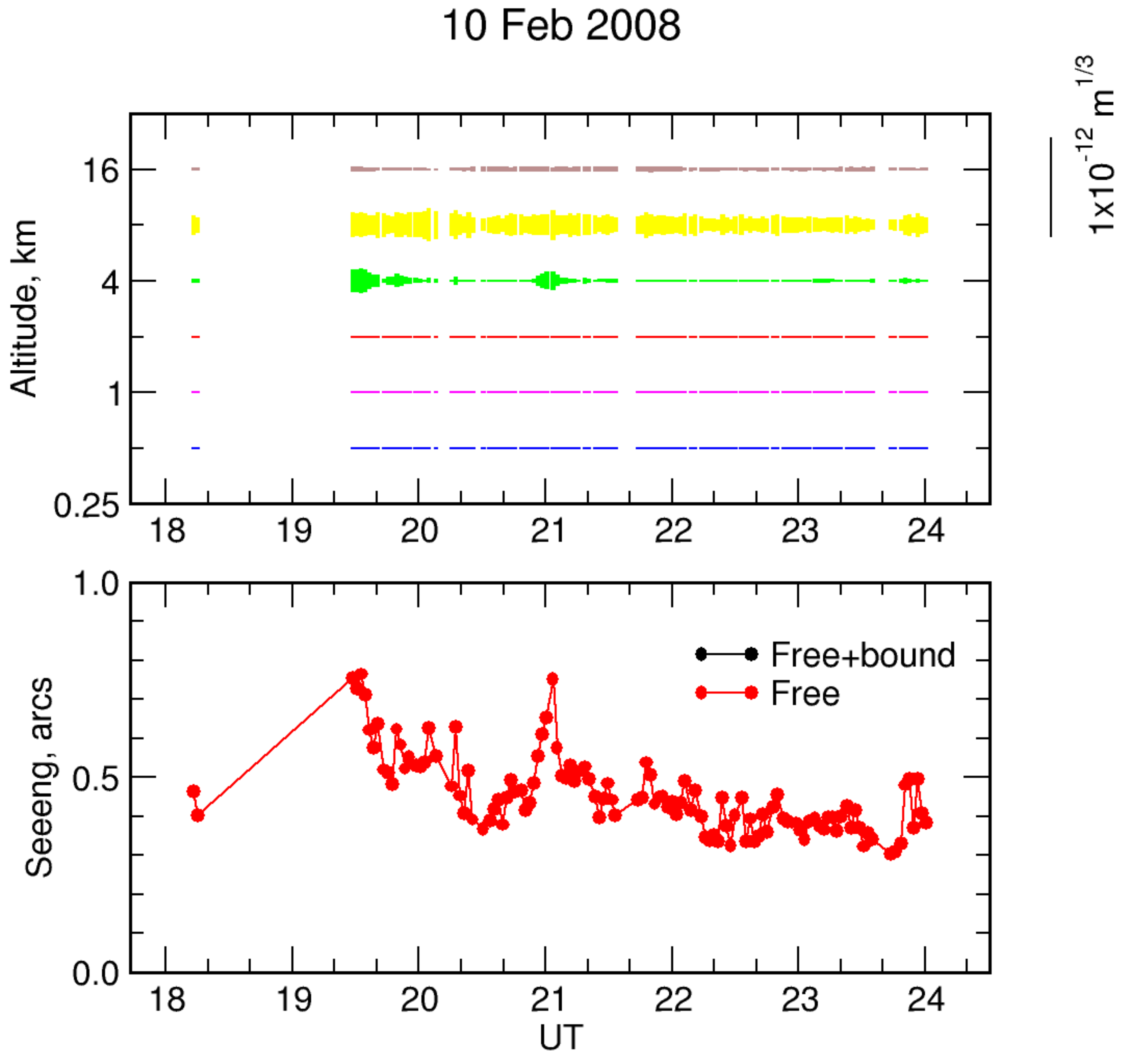
Black points: longitudinal image motion seeing.

Red points: transversal motion seeing.



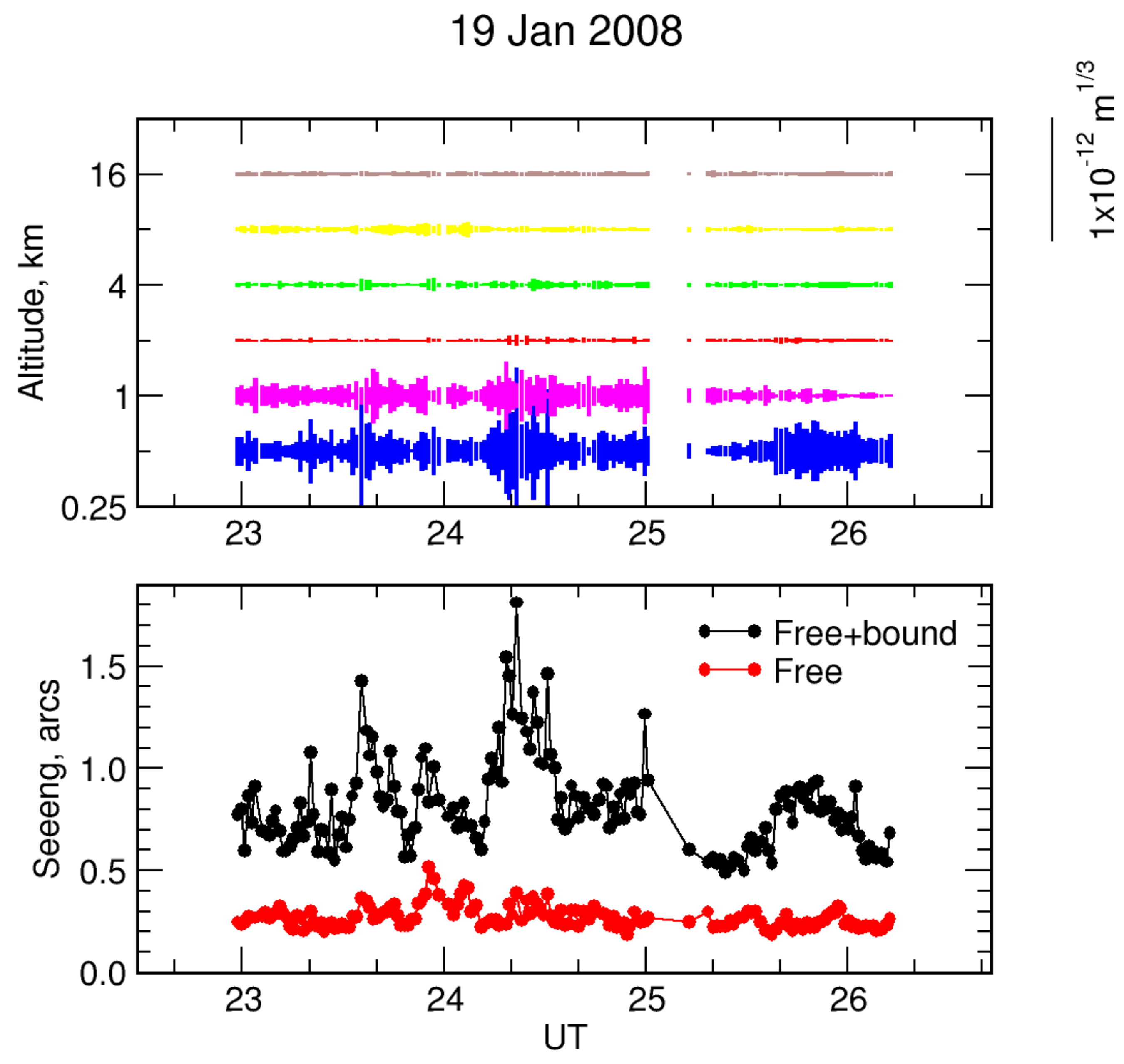
Free atmosphere turbulence (bottom) and altitude distribution of turbulence intensity for 9 February 2008 night.

In case the ground layer influence removed, the seeing would be 0"2.



The same for 10 February night. The predominant turbulence at 8km altitude is seen (tropopause) and some bursts at 4km.

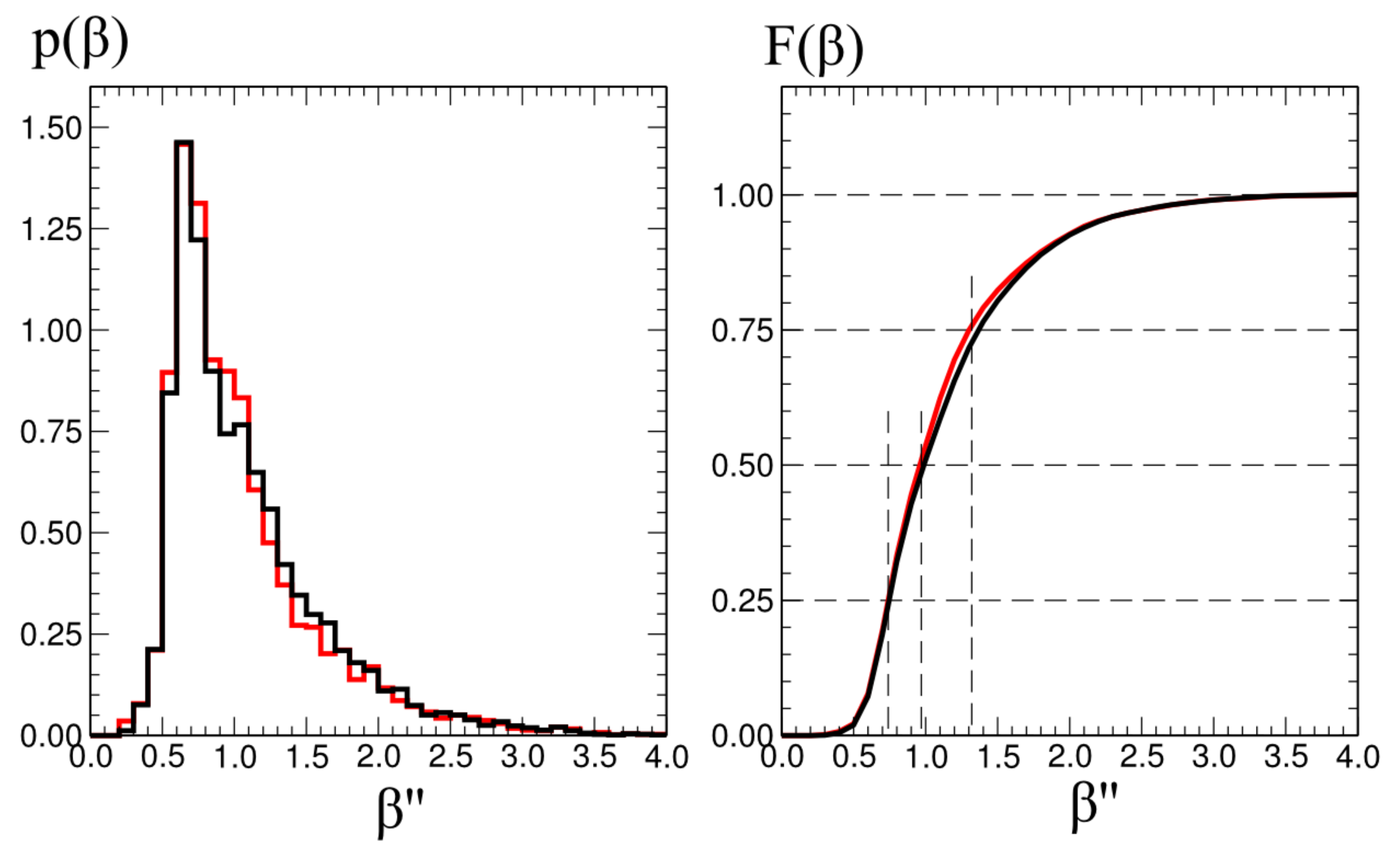
For this night, the influence of the free atmosphere is about 0''4 – 0''6 which is much more than 9 February.



The opposite case example – night 19 January 2008 г. The free (above 1km) atmosphere influence is only 0"2 – 0"3. Majority of turbulence is located in the ground and boundary layers (below 1 km).

Mean seeing by DIMM data for this night is 1"5.

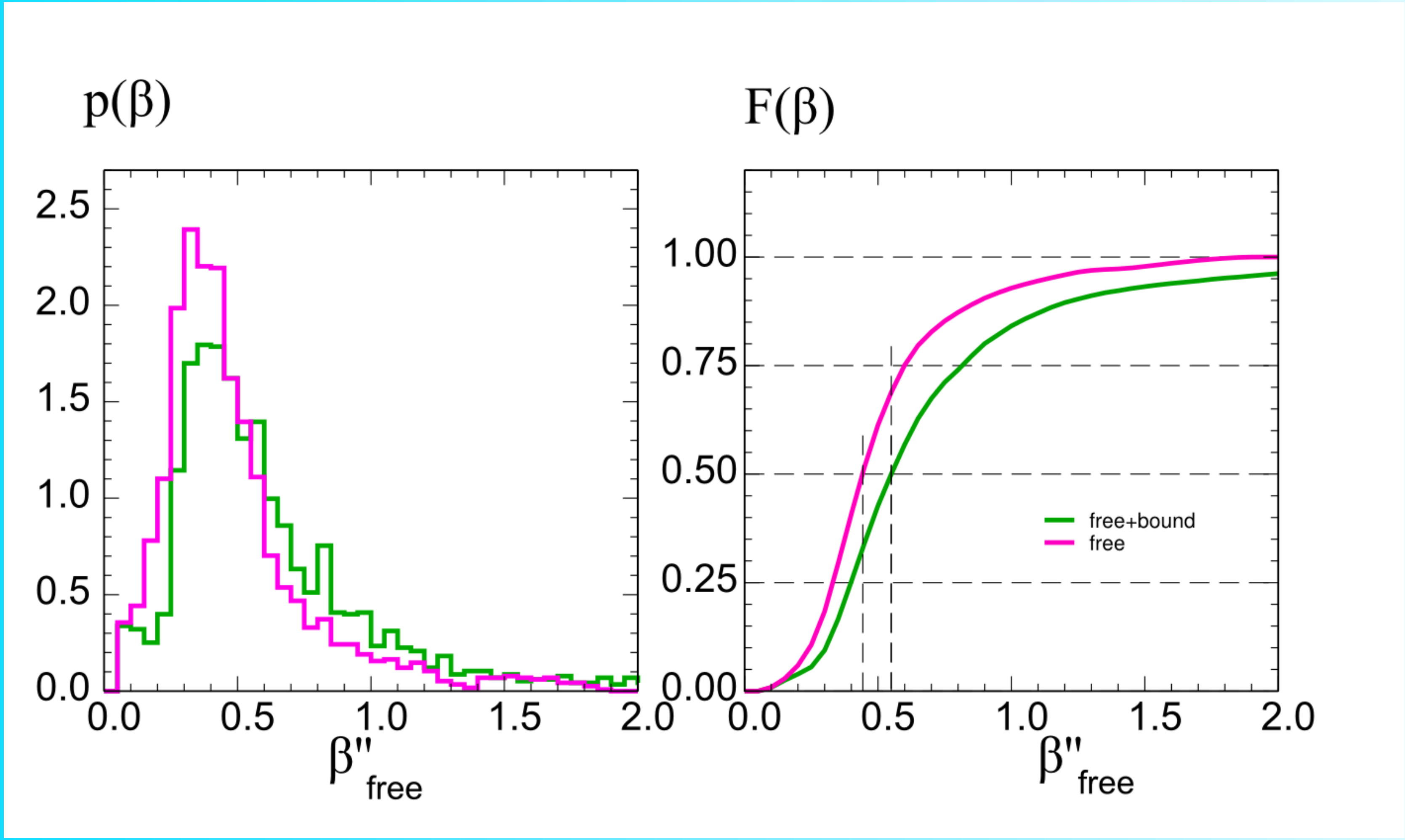
Three 2007 months statistics



Probability distribution and integral distribution of the image quality (seeing) by DIMM measurements:

median – 0.96", lower and upper quantile – 0.74" and 1.32"

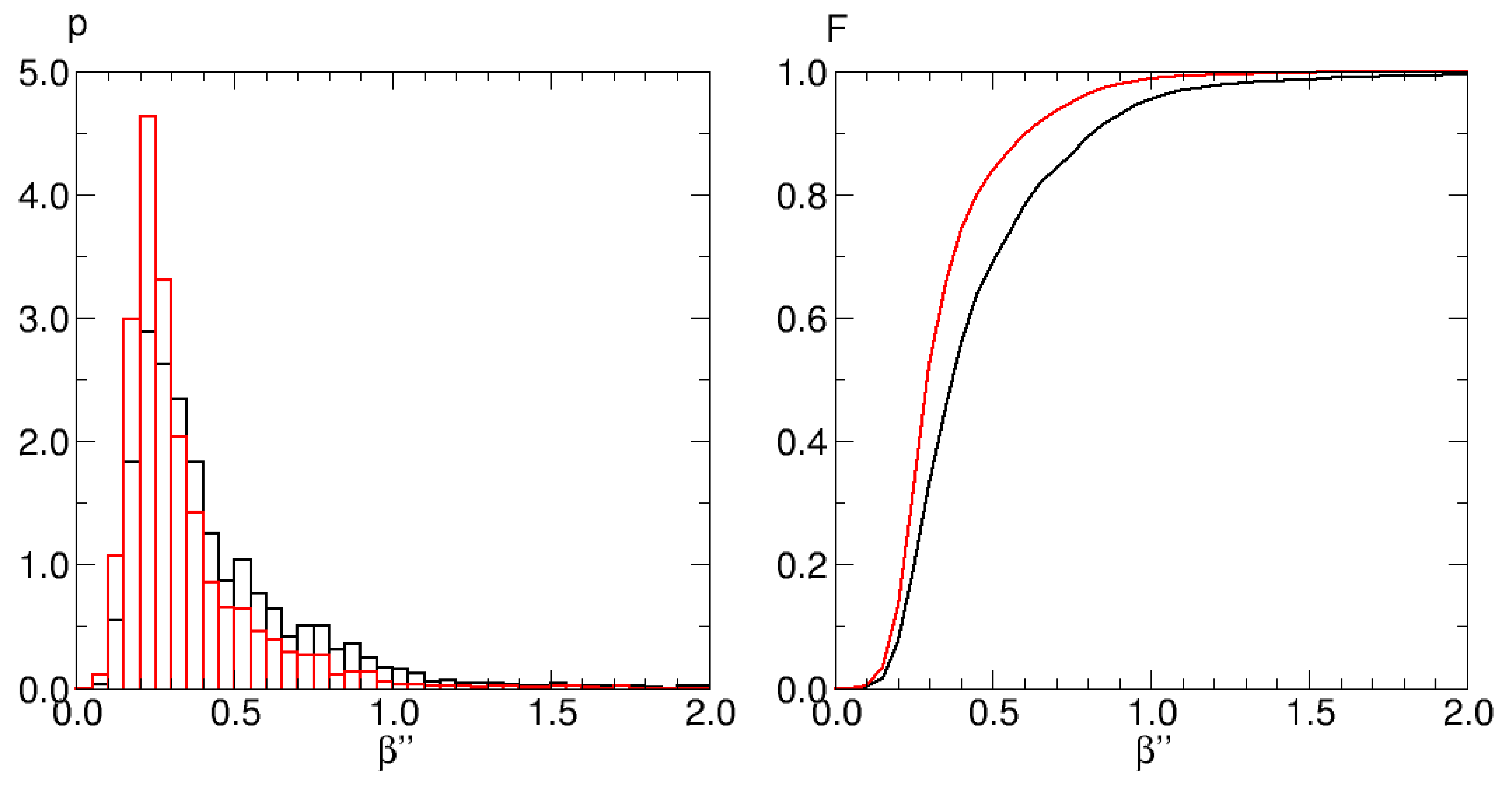
Three 2007 months statistics



Probability distribution and integral distribution of the seeing in free atmosphere from the MASS data:

median – 0.44" (above 1 km) and 0.55" (including 1km layer)

January-February 2008 statistics



Probability distribution and integral distribution of the seeing in free atmosphere:

median – 0.29" (above 1 km) and 0.37" (including 1 km layer)

See you in one year!