MASS 2-pager

Andrei Tokovinin

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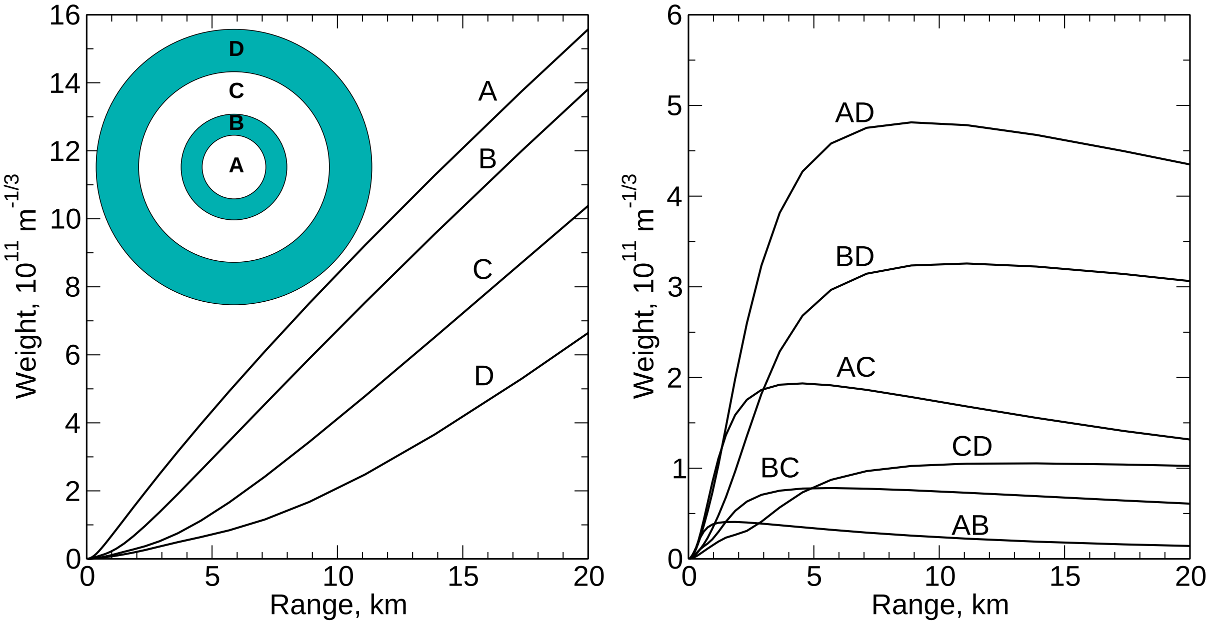

Figure 1: Apertures A, B, C, D of MASS and the weighting functions for the normal scintillation indices (left) and for the differential indices of pairwise aperture combinations (right).

Principle of operation. The MASS instrument is based on the analysis of stellar scintillation. The light from a single bright star is received by a system of 4 concentric apertures – the inner aperture A of 2 cm diameter, and the annular apertures B, C, and D surrounding it, with the outer diameter of D about 8 cm. Photon counts in each aperture are detected with photo-multipliers with 1 ms exposure time. Series of these counts are processed statistically to determine a low-resolution turbulence profile. The apertures and their combinations act as spatial filters, isolating details of certain size. The characteristic size of scintillation pattern is of the order of Fresnel radius $\sqrt{\lambda z}$ (λ – wavelength of light, z – propagation distance), $\sim$ 10 cm for a 10-km propagation. We distinguish contributions from different altitudes by spatial filtering.

A MASS instrument is attached to a feeding telescope with a clear (unvignetted) aperture of at least 8 cm. The beam splitting between annular apertures is done by internal optics (Kornilov et al., 2003). Most MASS instruments in use now are combined with DIMM and utilize an off-axis part of telescope's aperture (Kornilov et al., 2007). MASS needs only a small telescope, it is insensitive to pointing errors and well suited for turbulence monitoring using single stars of $V = 2.5^m$ or brighter. MASS does not sense the near-ground turbulence and does not work under strong scintillation.

Data products. After each 1-min. accumulation time, the MASS software, *Turbina*, calculates 10 *scintillation indices* – 4 normal and 6 differential (Tokovinin et al., 2003; Kornilov et al., 2007). The relation between turbulence strength, propagation distance z, and index s^2, is called *weighting function* (Fig. 1): $s^2 = \int W(z) C_n^2 \mathrm{d}z$. The data are modeled by 6 thin turbulent layers at fixed altitudes h_i of 0.5, 1, 2, 4, 8, 16 km. The MASS data products are 6 turbulence integrals $J_i = C_n^2(h_i)\mathrm{d}h$ in these layers. To compare these numbers with a real, continuous $C_n^2(h)$ profile, we assume that J_i correspond to trianlular response functions centered on the respective layers. The altitude resolution of MASS is $\Delta h/h \sim 0.5$. Turbina automatically accounts for the air mass, spectral type of the star, finite exposure time, and photon noise. Deviations from the weak-perturbation theory are also corrected up to a certain limit (Tokovinin & Kornilov, 2007).

The atmospheric time constant τ_0 is estimated from the temporal bandpass-filtered scintillation in the smallest aperture A. This method is only approximate and goes not include the ground-layer turbulence. Secondary data products of MASS are the free-atmosphere seeing calculated from the sum of J_i and the isoplanatic angle θ_0. The 1-min. average flux can be used for cloud detection and extinction measurement.

Calibration of MASS consists in determining the optical magnification factor, hence the size of the apertures projected on the pupil. The noise parameters of the detectors are determined with an internal light source inside the instrument. The spectral sensitivity curve must be known for correct calculation of $W(z)$ (Kornilov et al., 2007). The sensitivity of MASS data products to the errors in calibration parameters has been studied by Els et al. (2008). They find that the error in the free-atmosphere seeing is less than $0.05''$, the integrals J_i are measured to within $\pm 10^{-14} \mathrm{m}^{1/3}$ (with a smaller error for high layers). In the model-fitting processes, the integrated atmospheric parameters such as seeing are well constrained, but the individual J_i may be re-distributed between adjacent layers under the influence of random errors and small calibration errors.

Common mistakes in the use of MASS are: pointing stars fainter than $V = 2.5^m$, incorrect setting of calibration parameters or time in the computer, vignetting of the apertures caused by optical mis-alignment. The data quality parameters recorded in the MASS files can help in detecting some (but not all) of those errors. Regular detector checks with internal light source are strongly recommended.

References

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