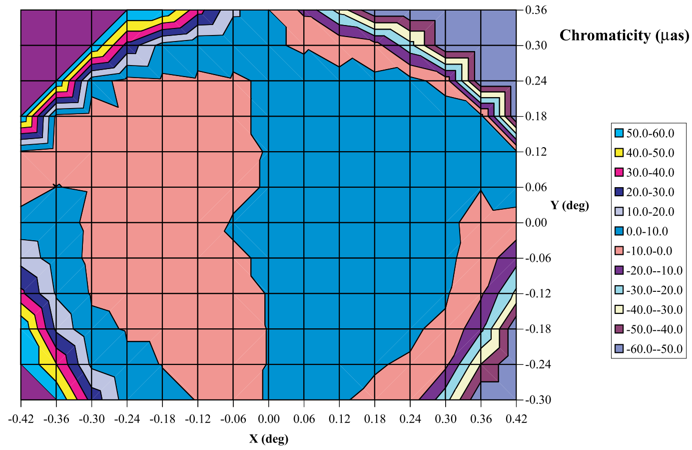

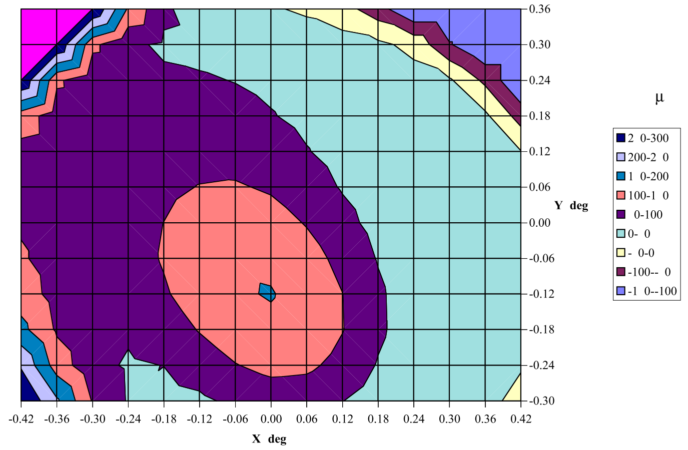

Above: Chromaticity map for the nominal system of an early Gaia telescope design.
Below: Chromaticity map when all sources of wave-front errors are included.

Although the Gaia optical design only employs mirrors, diffraction effects with residual (achromatic) aberrations induce a small chromatic shift of the diffraction peak. This effect is usually neglected in optical systems, but was relevant for Hipparcos and becomes even more critical for Gaia. The chromatic image displacement depends on position in the field, and on the star's spectral energy distribution, but not on its magnitude. The overall system design must either reduce these chromatic displacements to levels below those relevant for the final mission accuracies - which proved to be impossible for Gaia's selected flight design - or ensure that they can be calibrated as part of the data analysis. One purpose of the photometric instrument is to provide colour information on each observed object in the astrometric field to enable the chromaticity bias calibration on ground.

For a rough quantitative assessment of the effect of chromaticity, a chromaticity measure can be defined which corresponds to the relative displacement (in μas) of the diffraction peak between two stars of extreme spectral types (say B3V and M8V). This measure can be calculated by means of a simple formula for any WFE (wave-front error) map. WFE maps for different points in the field of view can thus be transformed into a 'chromaticity map' showing the variation of the effect across the field of view for a given set of alignment and polishing errors.

A chromaticity map for the nominal system of an early Gaia telescope design is given in the top figure above. In the field of view, where the RMS optical-design WFE is assumed to be $\lambda/30$, chromatic shifts reach $\sim$30 μas. However, the actual chromaticity error will include all sources of WFE, i.e. including optical misalignments and residual polishing residual errors. The lower figure shows an example of a chromaticity map obtained by including all sources of WFE, assuming that polishing errors are $\lambda/30$ RMS for the primary mirror and $\lambda/50$ RMS for the secondary. For constructing this map, the polishing errors were arbitrarily distributed over 3-rd and 5-th order Zernike polynomials. This is a worst case scenario, since the actual polishing error will be distributed over a much larger number of polynomials (the actual spectrum depends sensitively on the polisher and the polishing technique), and since high-spatial-frequency wavefront errors contribute marginally to chromaticity. Nevertheless, this example shows that chromatic shifts of several hundred μas should be expected. This is confirmed by recent simulations of the EADS Astrium Gaia flight-model design. With the aid of the photometric data these shifts can be accurately calibrated by the data processing on ground, thus not impacting the final mission performance.