Chapter 8
Own Weight Flexure and Figure Control of Telescope Mirrors

8.1 Primary Mirror Support Systems Against Gravity

8.1.1 Introduction

Foucault solved the problem of maintaining a mirror with a high reflective coating by introducing glass mirrors, which then can be easily re-silvered after chemical removal of the tarnished coating. This ended the era of speculum metal mirrors which required, when tarnished, a repolishing within a seeing limited – or diffraction limited – criterion. The chemical process was later replaced by the vacuum deposition process by J. Strong (cf. Sect. 1.1.5).

The next problems for the primary mirror of large telescopes were to minimize their elastic deflection under gravity – or own weight deformation – and also that resulting from thermal gradients. This latter problem was appropriately solved by the inventions and developments of low expansion materials such as Pyrex, Sitall, fused silica, vitrocerams, and silicon carbide.

8.1.2 Axial and Lateral Support System Concepts

The design of axial and lateral supports for large telescope mirrors necessarily act onto several mirror subareas which support a small fraction of the mirror weight. In addition to some reference subareas, an appropriate number of additional subareas are distributed all over the back surface and possibly on the edge surface of the mirror. Whatever the geometrical distribution where these forces act, the associated system of forces must be non-hyperstatic. In other terms, the set of the supporting forces must be in astatic equilibrium so the 3D-orientation of the mirror remains unchanged with respect to the reference zones.

Three small reference areas, generally located at 120° and near the mirror edge, allow us to determine its axial position whilst two or three small reference areas are required to define the lateral position. The number of these latter areas depends on whether the telescope is an equatorial mount or alt-azimuthal mount.
Let $P$ denote the weight of the mirror, $N_a$ the number of axial supports and $N_l$ the number of lateral supports. We shall hereafter refer to passive axial and lateral support systems as astatic systems that deliver reaction sets of equal forces $f_a$ and mean forces $< f_l >$ in the axial and lateral directions respectively; thus $N_a^2 f_a^2 + N_l^2 < f_l >^2 = P^2$ and these forces are

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f_a = \left( \frac{P}{N_a} \right) \cos z, \quad < f_l > = \left( \frac{P}{N_l} \right) \sin z,
$$

where $z$ is the zenith distance angle of the telescope axis.

In such passive support systems, the assumption of invariance of the mirror orientation is strictly valid only if the flexure of the cell structure remains axisymmetric in all orientations of the telescope. We note here that the telescope star-pointing error resulting from deviation from this hypothesis is easier to compensate for an altazimuth mount than with an equatorial mount. These corrections are achieved by the telescope control system.

Several types of passive astatic systems have been invented for axial support (Fig. 8.1) and lateral support (Fig. 8.2).

![Passive astatic systems for the axial support of large mirrors](image)

**Fig. 8.1** Passive astatic systems for the axial support of large mirrors. (A) Articulated stacked segments – ridges, triangles, or both – invented by T. Grubb [32] and known as whiffletree assembly. (B) Folded astatic levers invented by Lassel [40]. (C) Open-loop air pressure cushions introduced by Foucault [28]. (D) Open-loop hydraulic pads

The mirror support system with articulated stacked segments – or whiffletree assembly – was introduced by T. Grubb [32] for the axial support of the 1.8-m Lord Rosse telescope. Because of the difficulty to obtain such stiff and lightweight systems, these devices are limited to thin mirrors whose aperture diameter does not exceed 2 m, hence preventing resonance instability problems that are generated from wind buffeting. For instance each 1.8-m hexagon segment mirror of the KECK telescopes ($t/d = 1/24$) is supported by three whiffletrees acting on $3 \times 12 = 36$ pads,

![Passive astatic systems for the lateral support of large mirrors](image)

**Fig. 8.2** Passive astatic systems for the lateral support of large mirrors. (E) Direct astatic levers acting on rear apertures or on edge. (F) Perimeter bag filled with liquid of the same mirror density or narrow mercury bag. (G) Open-loop radial hydraulic pads acting on edge