Problems with telescopes

SIR—I should like to comment on the problems with the Hubble Space Telescope (HST).

The primary mirrors of large modern telescopes are tested in autocollimation at their centres of focus, the error being determined by interferometric or Hartmann type analysis. Because primaries of short focal length are strongly aspheric (slightly hyperbolic for Ritchey-Chretien telescopes), the autocollimated image suffers from strong aberration, which is compensated during the test by a 'compensation' or 'null' system. This technique was invented by the English amateur Horace Dall in 1947[1].

The null system must be correct to very high precision, not only in its design and manufacture but also in its position in the test set-up, otherwise a systematic error arises which is spherical aberration in its classic form.

The testing of convex secondary mirrors, which cannot form real images, is a subject in its own right[2], but all test methods have tolerances which, if they are not respected, will lead to similar spherical aberration. But there is one test of secondaries (together with the whole system) which effectively ensures that matching error cannot occur: this is the Pentaprism test. The Pentaprism test is essentially a one-dimensional substitute for the autocollimation test against a plane mirror. The Pentaprism deflects small parallel beams about 90° and has the property that the deflection is unaffected by inevitable rotation errors of the Pentaprism as it is moved across a diameter of the pupil. The Pentaprism test will ensure only that the two mirrors will in combination produce an image free of spherical aberration at the nominal Cassegrain focus. Various other tests exist[2] for faults such as astigmatism and high spatial frequency errors ('ripple'). The Pentaprism test was probably first invented by Wetthauer and Brodun in 1920[3], and has been systematically used by a few manufacturers, for example REOSC of Paris[4] or Korhonen in the recently completed 2.5-m Nordic Optical Telescope. It was used in the United States in 1939 by Hendrix and Christie[5] for Schmidt systems, and was described by Hochgraf in 1969[6].

It seems surprising that this test, which is simple and cheap to set up (the telescope axis can be vertical or horizontal) was not applied to the HST; it would certainly have revealed the error.

But its use is by no means general in telescope-making, which explains why matching error, often very large, has been a common technical error. It affected the Canada–France–Hawaii Telescope, for which the spherical aberration was successfully corrected by bending the secondary.

The ESO New Technology Telescope (NTT) also had a matching error, which was provoked by a systematic error in the positioning of the compensation systems used to test the primary. Although this error was small (1.8 mm in a test distance of ~ 15.4 m) the wavefront error caused by the spherical aberration thus introduced was ~ 3,000 nm. This produced an image containing 100 per cent of the light in 0.71 arc seconds. Although this was outside the NTT's passive specification, we were able to correct it completely — to less than 0.1 arc sec, the general 'noise' level of the system — by the first (fixed) level of the active optics system[7].

The Pentaprism test had been proposed by ESO to the manufacturer, Carl Zeiss, but was dropped by mutual agreement because a double test system (visible and infrared) gave a cross-check of the individual mirror tests. Had a matching error existed outside the dynamic range of the NTT;s active optics system, it would have been revealed by this comparison. Further details will be given in the *ESO Messenger*, September 1990.

The HST, by contrast, has a very stiff, lightweight, egg-crate type of primary, and the dynamic range afforded by the 24 actuators is far too small to be able to correct an error in the primary of the magnitude found. Because the HST is effectively a passive telescope as far as correcting the primary is concerned, the Pentaprism test would have been the best guarantee against matching error. It is reliable, simple and cheap.

It has been said that the current performance of the HST is as good as the best ground-based telescopes. This is certainly not true. Apart from the NTT, which because of its active optics routinely produces images smaller than 0.5 arc second at the excellent site in La Silla, Chile, there are several passive telescopes, including the William Herschel Telescope in La Palma, capable of producing sub-arcsecond images under favourable seeing conditions. By contrast, the HST has an image size of at least 1 arcsecond from the spherical aberration alone.

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Foreign aid

SIR—The British Natural History Museum (NHM) can apparently no longer find the necessary £20 million or so annually to fund its present level of activities, much less pay for needed renewals and expansions. Yet it is an institution "of great international importance", its collections belonging "to the world, not just to London or the British Isles" (Adam Urbanek and Michael Novack; *Nature* **345**, 656; 1990). This suggests a solution to the present crisis. If the United Kingdom is now too poor to finance the NHM adequately, let us rename it the International Museum of Natural History, and arrange to support it with funds from the International Union of Biological Sciences, the Smithsonian Institution and any other international or national organizations and individuals who recognize the necessity for such action at the present time.

Meanwhile, Britain feels that it *can* afford Trident missiles, a sad indication of where its priorities lie today.

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Correction

In the opening paragraph of his letter about the Natural History Museum, Des Griffin (*Nature* **346**, 99; 1990) was referring to commentary on the subject in general rather than to Sir Walter Bodmer's Commentary in *Nature*. □

Need for religion

SIR—The effort expended by scientists to prove God to be a myth and religion to be a superstition would be more fruitfully spent in finding out why belief in transcendental power is so widespread: just about every culture includes a religion. I can think of two reasons:

(1) Religion helps societies to function more effectively, giving them a competitive edge over atheists.

(2) Some humans are dimly aware of another dimension of this Universe, or even of some other continuum, that they call God. This awareness helps them make more constructive decisions than those of people lacking such a faculty.

A simplistic view indicates that, in the struggle for survival, atheists should have prevailed, as religious practices are a drain on resources. Yet it is the atheistic societies that failed to survive. Religion must have something going for it. Instead of pretending that it does not exist, we should try to see what makes it tick.

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