3

STEWARD-1538

PREPRINTS

of the

STEWARD OBSERVATORY

THE UNIVERSITY OF ARIZONA
TUCSON, ARIZONA 85721-0065 U.S.A.

No. 1538

EXTREMELY LARGE SPACE TELESCOPES AND INTERFEROMETERS MADE WITH FLAT PRIMARY MIRRORS

J.R.P. ANGEL, J.H. BURGE, AND N.J. WOOLF
Steward Observatory and Optical Sciences Center
The University of Arizona
Tucson, AZ 85721, USA

PROCEEDINGS, *Ultra Lightweight Space Optics Challenge Workshop*, **ON WEB SITE:**
http://origins.jpl.nasa.gov/meetings/ulsoc/
NAPA, CA, MARCH 24-25, 1999

Extremely Large Space Telescopes and Interferometers made with flat primary mirrors

J. R. P. Angel, J. H. Burge and N. J. Woolf

Steward Observatory, University of Arizona

Introduction

We have found designs for imaging telescopes and interferometers in which the primary reflecting elements are multiple flats. Such configurations may have been previously overlooked because their overall size is impractically large for ground based telescopes, and high quality flats to withstand gravitational and wind loading are not much easier to make than curved mirrors. But flats could greatly simplify the construction of large aperture space systems, built up as multiple spacecraft flying in formation. In space, large flat reflectors of high quality and extremely light weight could be simply made from thin stretched membranes. The requirements are that the membrane be of uniform thickness and that its perimeter be held in a plane. In practice, the surface would be defined by a discrete number of edge actuators, actively controlled from wavefront measurements to maintain flatness. The membranes might be formed on an optical flat of metalized plastic such as polyimide, or of metal alone. Already single membranes as large as 8 m could be made on glass flats from existing facilities, with existing vacuum coating systems.

Examples of optical systems based on flat primaries

a) 100 m filled aperture telescope

As a system example, consider a telescope with a concave 100 m, f/20 primary whose surface is approximated by 5 m flats, tangent to the desired conic of revolution. We can think of the primary as a single, continuous concave surface with a figure error in the form of quilt-like bumps of about 800 μm peak-to-valley At the quasi far-field focus, 5 m across and 2 km distant, is a secondary in the form of a concave field mirror which forms an off-axis, reduced size image of the primary. This concave collector might be built with with a curved glass membrane, rigidly supported by a two-dimensional field of actuators[1]. At the exit pupil is located a concave tertiary mirror that is made up of scalloped segments, each registered with the image of a primary flat. Think of this as a single, continuous surface with a compensating figure error in the form of dips. These correct the error of the wavefront reflected by the primary, in just the same way each instrument of the HST corrects the primary spherical aberration at a pupil image. A finite field of view is corrected, because the sine condition is obeyed to first order. Errors across the individual flat surfaces could additionally be corrected, by actively controlling the scalloped elements.

b) *100 m nulling interferometer for spectroscopy of extra-solar planets*

Our second example is a double, nulling interferometer suitable for finding Earth-like planets of nearby stars and searching their thermal emission for spectroscopic evidence of life[2,3]. Eight flats, each 8 m diameter, would be flown in formation in a line some 120 m long, perpendicular to the line of sight to the star under study. Each one would be oriented to reflect the starlight as before, into a single 8 m telescope some 2 km away. The telescope's field of view would be about 3 degrees, to catch the light from all the elements. Small scale optics near the focal plane of the collector would be used to interfere the individual beams as required. In this way, only one large precision telescope needs to be built instead of 8. The 8 flats should be much faster, lighter and cheaper to build than telescopes of the same size.

A test of a membrane flat with the HST

A useful early test of a stretched membrane flat in space could be made with the HST. A 2.5 m prototype could be readied in time for the Shuttle's 2003 servicing mission. It would be used to reflect starlight light into the HST some distance away, after it has been serviced and released. In order to eliminate vibrations, to which a large membrane will be sensitive, the prototype should also be released from direct connection with the Shuttle. The goal would be to demonstrate a steerable spacecraft with a 2.5 m flat reflector of comparable quality to HST, but weighing perhaps 10 kg, 10^{-4} of HST's mass. This degree of lightweighting would open a path to future space telescopes with 100 times larger diameter, ie 250 m.

Acknowledgements

Optical designs and details of flat construction are under study, and will be the reported elsewhere. This work is supported by the Air Force Office of Scientific Research under contract F49620-96-1-0036 and by NASA under NIAC grant 07600-015.

References

1. J.H.Burge, J.R.P Angel, B.Cuerden, H.M.Martin, S.M.Miller and D.G.Sandler, 1998 Proc SPIE **3356**, 690-701.
2. J.R.P Angel and N.J Woolf, 1997. Ap.J. **475**, 373-377.
3. N.J Woolf and J.R.P.Angel, 1997 in *Planets Beyond the Solar System*, D. R. Soderblom ed, A.S.P.Conference Series **119**, 285-293