Properties of a two–mirror three–reflection space telescope

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ABSTRACT

Some solutions for the case of two–mirror three–reflection telescope assuming to use really two mirrors (first reflection on a surface strictly equal to the one related to the third reflection) are briefly described. This work is a by–product of the efforts of a larger team for the conceptual design of wide field UV space mission.

1. INTRODUCTION

Ultraviolet sky–surveys from space requires all–reflective solutions able to cover a moderate to large Field of View (FoV hereafter). The quest for wide–field ultraviolet Astronomy is long standing. In the past years, indeed, there have been more proposals to space agencies and assessments study about wide field telescopes than substantial realization.

Among endehavour, at international level, of exploiting of wide fields from space systematically, it may be recalled the accomodation study of UTEX on SpaceLab (ESA, 1976), the assessment study of SWAT (NASA, 1979) and Space–Schmidt (ESA, 1979) and proposals ASCHOT on MIR (USSR, 1988), UTEF on Space Station Freedom (ESA, 1990), the SMEX–type mission UVSE, now renamed JUNO[1], to NASA, $\mathcal{MOUSE}$[2,3] to ESA.

Meanwhile UV astronomy aimed at single light sources in the spectroscopy or photometric mode as been having its glorious days with OAO–A2, Copernicus, ESRO–TD1, ANS, IUE and the Hubble Space Telescope, not to mention the early sounding rockets (1964) which discovered the mass loss from stars. The concept of wide field UV observations has not been so far successful at large despite reccomandation of IAU commissions.

A major difficulty in the past was clearly the lack of suitable UV detectors of large dimensions other than emulsions.

As technology is rapidly developing and in consideration of the success of UIT flown on the Shuttle recently[4], times might become ripe to give finally astronomers large fields also in ultraviolet light which is the last windows to be exploited for studies of mainly statistical nature.

However, a survey, in order to be effective nowadays, has to be deep which necessitates a telescope with a sufficently large mirror. In order to be feasible over an interval of a few years, a survey requires a large FoV which, in turn, in the case of respectable telescope aperture, demands a large detector if we want an angular resolution not too worst than provided by the Palomar Sky Surveys.

In the end, in order to be affordable, the cost of a survey cannot exceed the available resources for a single project.

2. SOME OPTICAL SOLUTIONS

Two–mirrors, three–reflection telescopes are a suitable way to employ a compact, wide field, all reflective solution for a small space mission. In spite of this considerations a limited number of optical solutions can be found in the literature. A crucial point that is to be pointed out is the complexity of the required surfaces of the two mirrors. Solutions adopting strongly aspheric surfaces, and constraining the primary-mirror/first-reflection to primary-mirror/third-reflection only to the radius of curvature. In this way the number of free parameters grow up and can reach, following certain authors[5] remarkable good, practically diffraction–limited, solutions.

In these case, otherwise, it is difficult to think to some their practical realization for space purposes in a near future: apart from the difficult of realization of such a mirrors, a 600 mm aperture telescope, with ° FoV and diffraction–limit at 300 nm requires a $\approx 36000 \times 36000$ pixel detector in order to be fully exploited.

Much more relaxed solutions can be found assuming as a rule the adoption of two mirrors with only moderate aspherics (pure conics, without additional terms).

A sample of the results obtained are summarized in Tab.1 and sketched in Figs.2 to 4.

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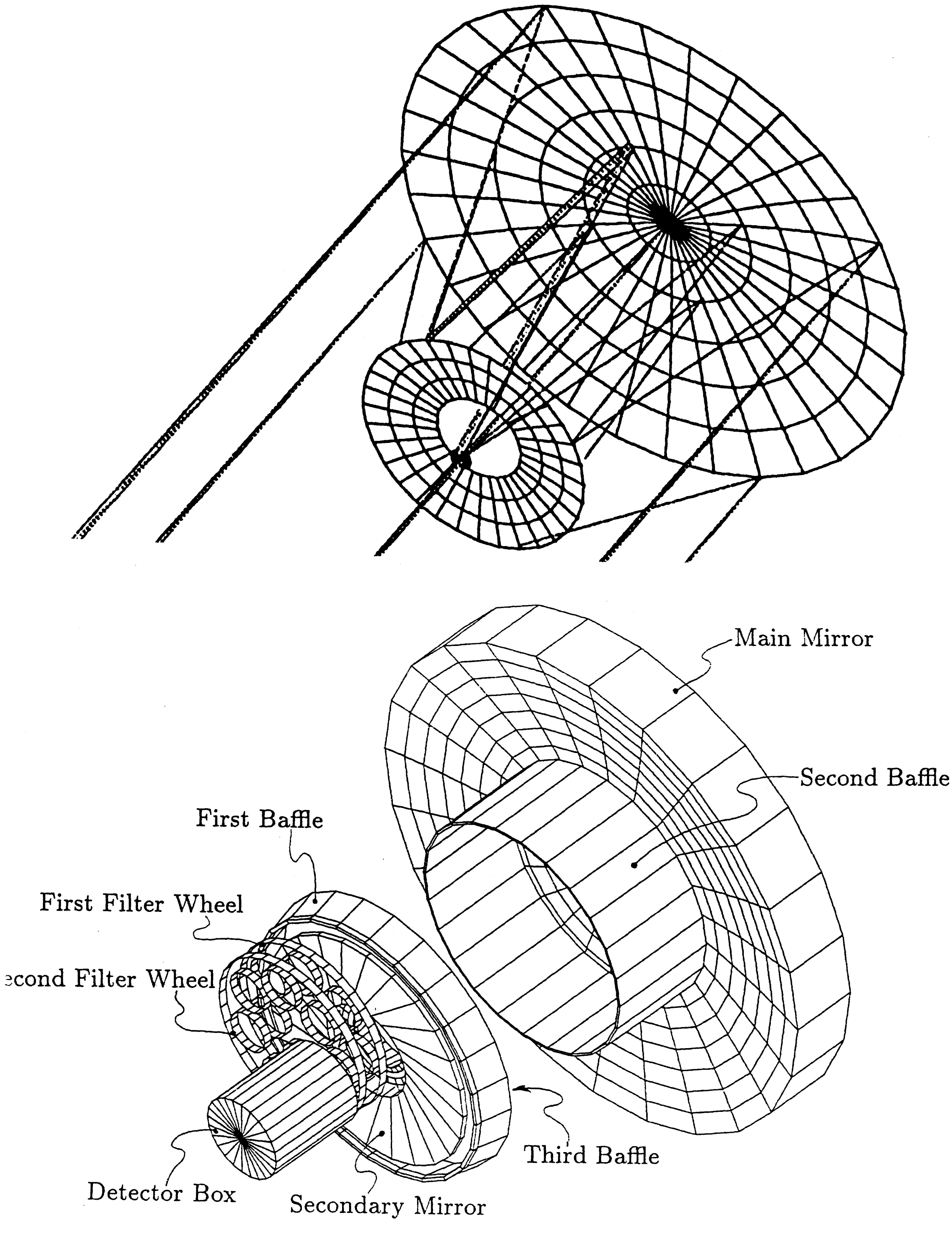
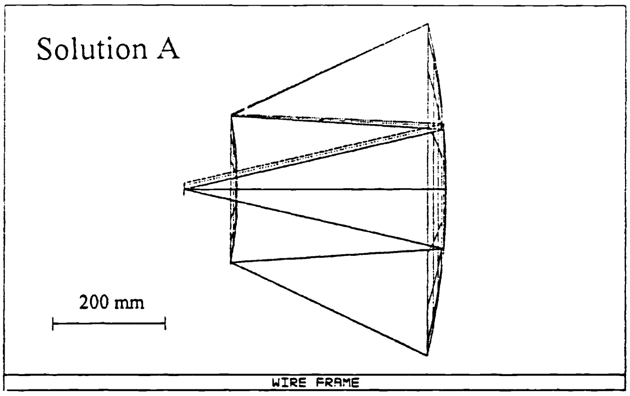
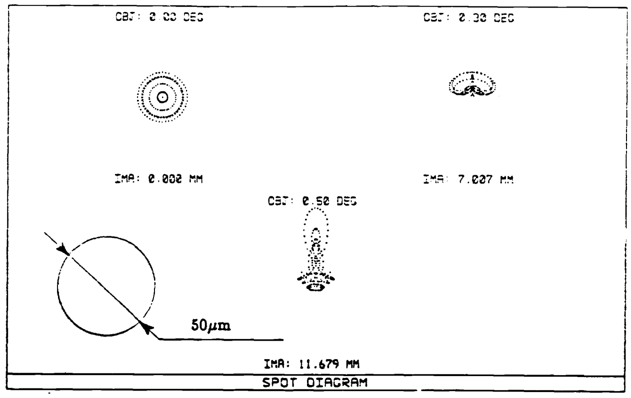


Figure 1: Top: The optical layout of a two–mirror three–reflection telescope; and Bottom: a CAD realization for the space observatory *MOUSE*.





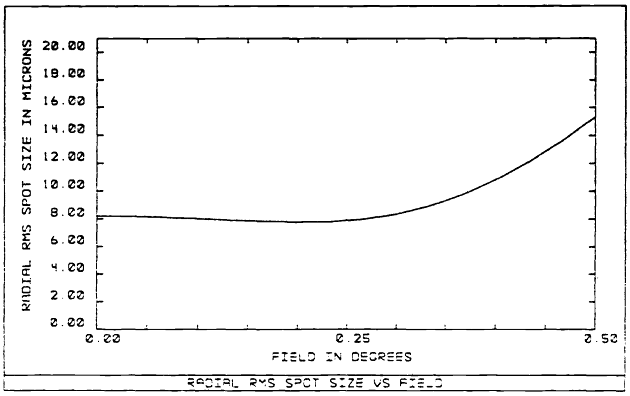
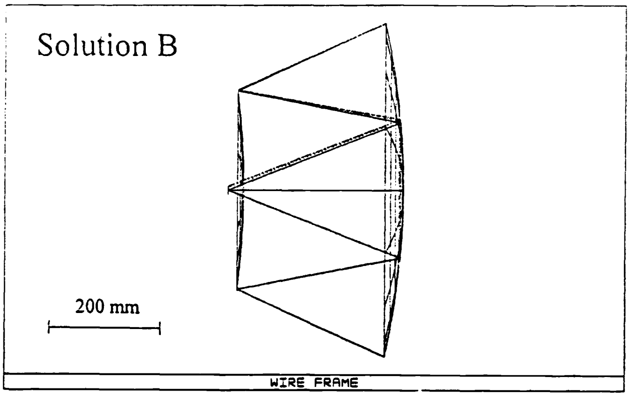
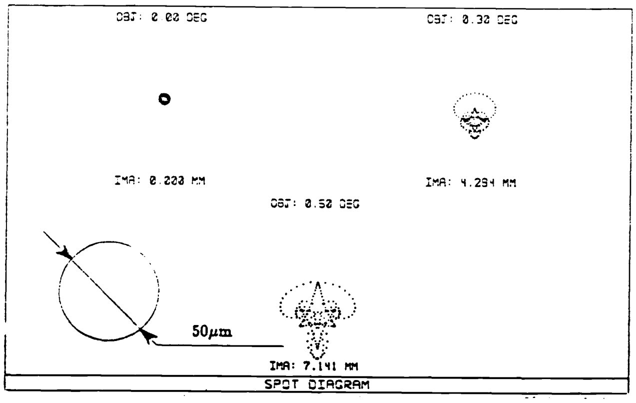


Figure 2: This solution retain slightly conical surfaces and a focal length of $f \approx 1340$ mm. A corrispondent scale of $\approx 6.5\mu\text{m} \cdot \text{arcsec}^{-1}$ on a FoV of one degree lead to the adoption of a detector with 1024×1024 to 2048×2048 pixel in order to exploit the capability of such an optics.





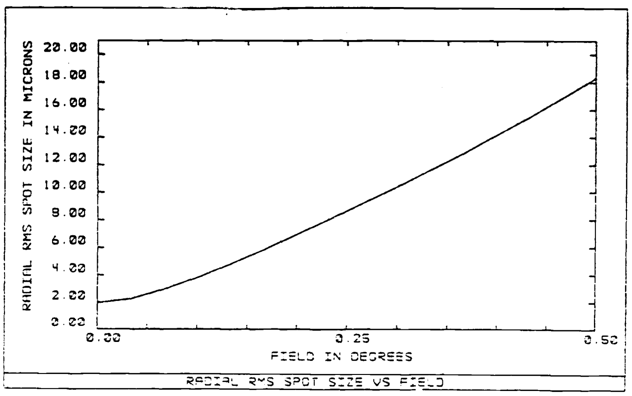
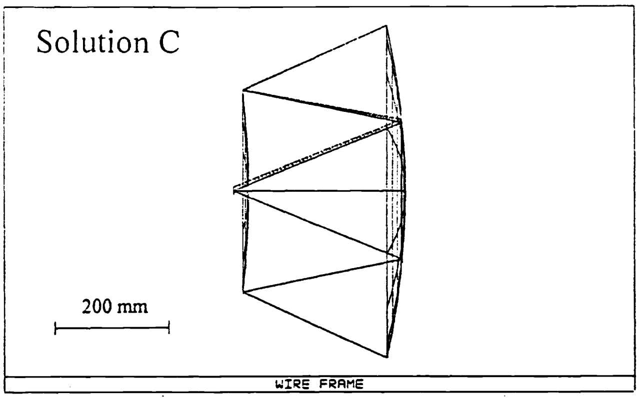
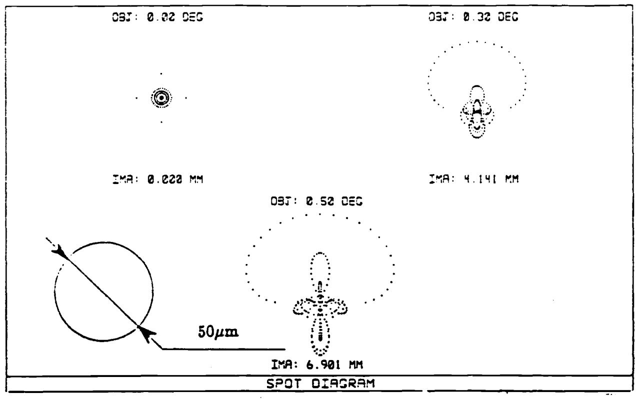


Figure 3: In this solution, obtained through global optimization ($\approx$ 12 hours on a 486/66Mhz machine) a smaller focal length, $f \approx 820$ mm has been required. The scale of $\approx 4\mu\text{m} \cdot \text{arcsec}^{-1}$ translates into a poorer resolution. The advantages are the much more compact solution (paying with some larger central obstruction) and the relaxed requirements for the detector, being a 512×512 to 1024×1024 pixel the optimal choice.

Solution	R_1	K_1	R_2	K_2	d	s
A	1314.87	−1.2722	658.88	−2.6155	374.15	470.00
B	1314.87	−2.5710	1282.5	−18.691	285.39	313.93
C	1314.87	−2.7442	1360.4	−22.633	278.80	306.68

Table 1: Optical parameters for the solutions described in the paper. R and K are the radius of curvature and the conical constant of the two mirrors; d is the distance between the vertex of the two mirrors and s is the distance from the vertex of the primary mirror and the focal plane.





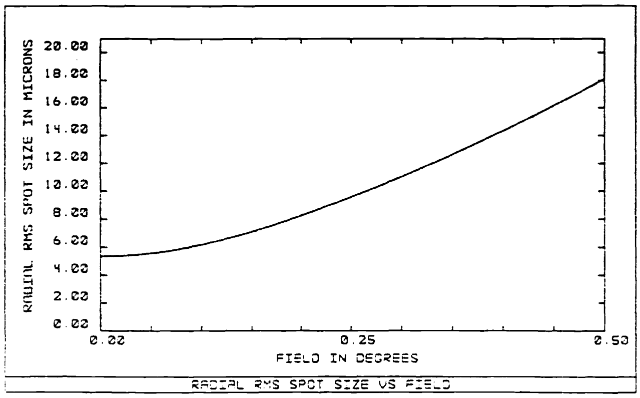


Figure 4: The short focal length of this solution ($f \approx$ 790 mm) leads to a very fast camera (F/$\approx$ 1.3) making this solution marginally interesting for detection of very large faint structures in the UV sky. A 512 × 512 pixel detector, also taking into account the poorer optical quality in respect to solution B, is reccomended.

3. CONCLUSIONS

The optical solutions here presented doesn't reppresent a final choice for any type of space wide field mission. On the other hand the required optical surfaces doesn't requires the development of new and/or quite exotic technologies; moreover the optimal detector is in the range of what is available as space–qualified.

A 600 mm aperture telescope is able to reach the magnitude $V = 25$ for hot sources ($T = 40 \times 10^3 K$) at $\lambda = 150$ nm without reddening and for half an hour exposure. Reasonable reddenings moves this limit down to $V = 21$. Very low resolution spectroscopy can bealso easily implemented.

The main goal of this paper, that we think has been reached, is to demonstrate that, near term moderately wide field UV missions are possible in the framework of the today technology.

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