All-spherical Catadioptric system for 0.8 m F/4.5 astronomical telescope: can we compete with the Ritchey-Chrétien design?

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Abstract: Aspherical surfaces are difficult to manufacture, therefore we consider a possibility of using only spherical surfaces. Two optical designs for 800-mm F/4.5 seeing limited telescope are considered: Ritchey-Chrétien and a two-mirror Catadioptric system.

OCIS codes: (110.6770) Telescopes; (220.4830) Optical system design; (350.1260) Astronomical optics

1. Introduction

Ritchey-Chrétien telescope is a well-known design in astronomical optics. The manufacture, optical testing, and alignment of aspheric surfaces of this design are hard and expensive, but for large diffraction limited telescopes using aspheric mirrors is unavoidable. As a possibility of replacing aspheric surfaces, all-spherical Catadioptric designs can be used for telescopes with about 1m apertures. For such telescopes, using adaptive optics is not usually required and the quality of image is limited by atmospheric seeing. The atmospheric turbulence reduces the sharpness of the image of a point source and blurs the spot to the size of the seeing disk. For good seeing conditions the radius of the seeing disk is about 0.5 arcsec [1].

In this paper, two seeing-limited systems are presented and their optical performance is analyzed and advantages and drawbacks are discussed. The first design is a modified Ritchey-Chrétien with a hyperboloidal primary mirror and a planoid secondary mirror. An achromatic doublet is used as a field corrector near the image plane [2]. The second design is based on a modified Klevtsov system [3]. The design contains a spherical primary mirror, a doublet Mangin mirror as the secondary, and a triplet corrector which provides apochromatic correction near the image plane. These two systems have the same 800 mm aperture and 3600 mm focal length that corresponds to F/4.5 design. The optimization is done for wavelengths between 486 to 656 nm and 1.5x1.5 degree full field.

2. Designs

The optical layout of the modified Ritchey-Chrétien telescope and relevant fraction of enclosed energy diagram are presented in Fig. 1. The hyperboloidal primary mirror (conic constant -2.041) is combined with a secondary mirror, which has a planoid shape with its meridional profile show in Fig. 3 (a,b). An alternative all-spherical design, which is a modified Klevtsov system, and its optical performance is presented in Fig. 2.

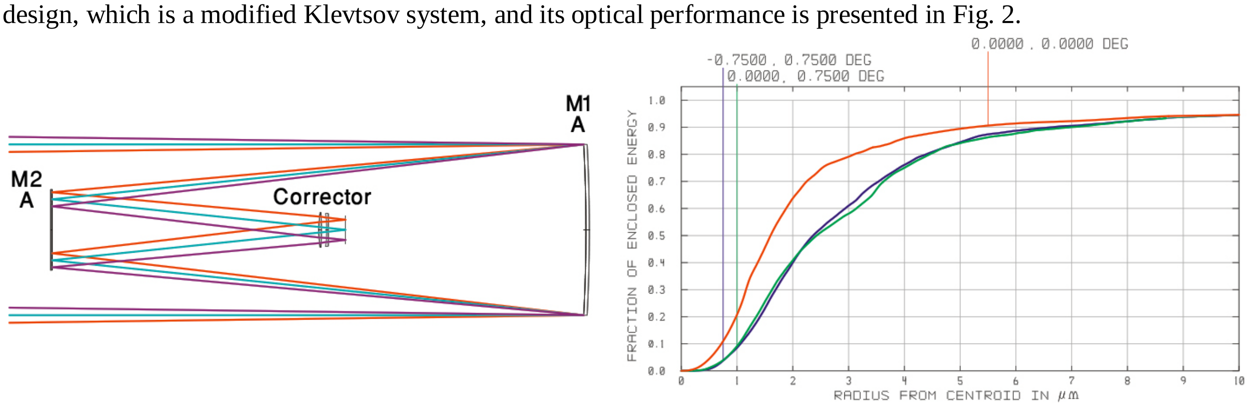

Fig. 1. F/4.5 800-mm modified Ritchey-Chrétien design with a doublet corrector; M1 hyperboloidal and M2 planoid mirror (left-hand side). The enclosed energy for 0 deg, 0.75 deg and diagonal field of view (right-hand side).

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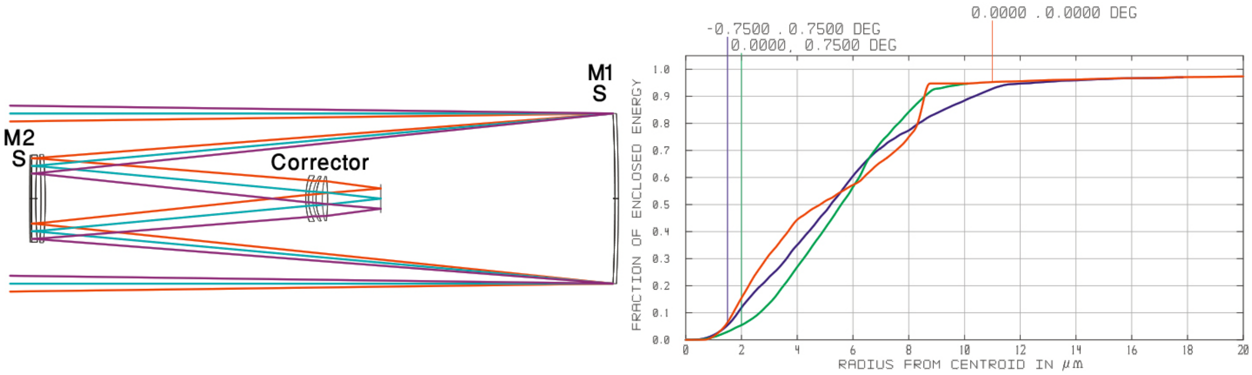

Fig. 2. F/4.5 800-mm modified Klevtsov design with a triplet corrector; All surfaces are spherical (left-hand side). The enclosed energy diagram for 0 deg 0.75 deg and diagonal field of view (right-hand side).

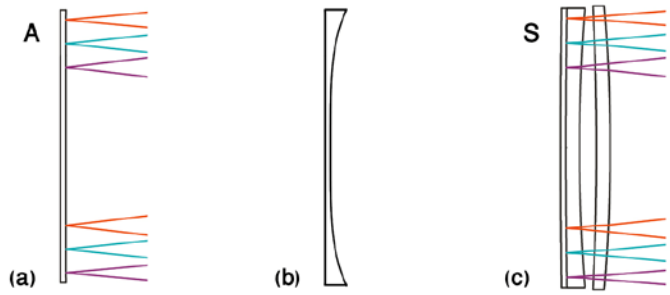

Fig. 3. Secondary Planoid in the Ritchey-Chrétien design (a). Exaggerated scheme of secondary Planoid in Ritchey-Chrétien design (b). All-spherical doublet Mangin mirror as the secondary in the Klevtsov design (c).

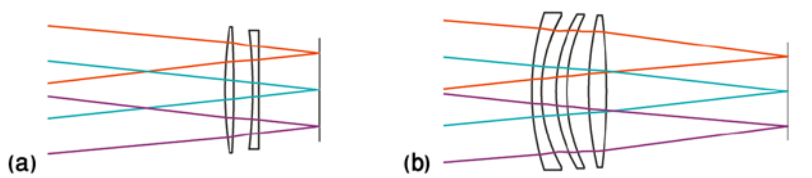

Fig. 4. Doublet corrector in the Ritchey-Chrétien design (a). Triplet corrector in the Klevtsov design (b).

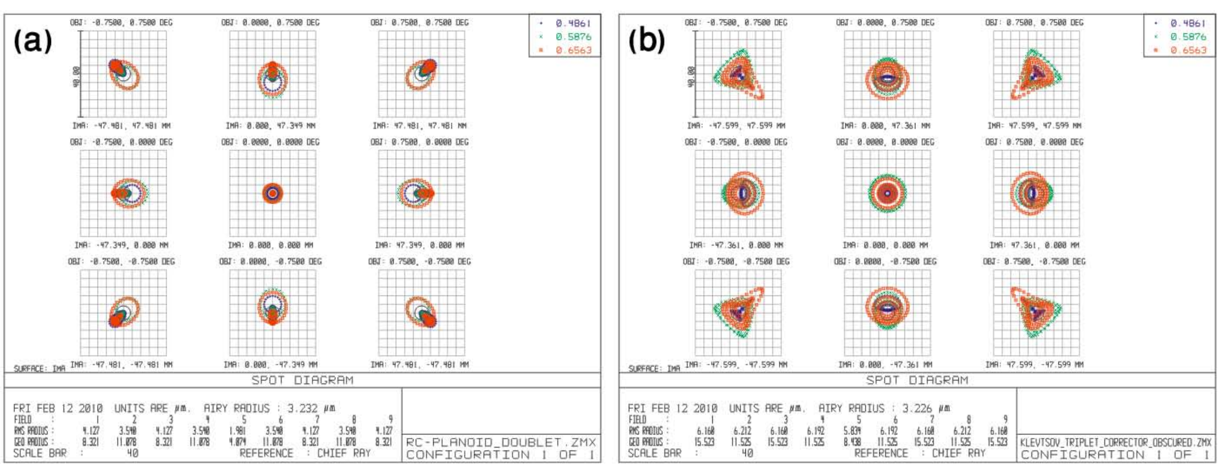

Fig. 5. Spot diagrams for the Ritchey-Chrétien design (a). Spot diagrams for the Klevtsov design (b).

Figure 3 (c) shows the detailed view of the Mangin mirror with a meniscus corrector placed near it; these components are relatively thin (with a diameter of 400 mm and a 20 mm central thickness for each approximately). It means that the secondary group is more compact compared to other Catadioptric designs [4].

A triplet corrector is used near the final focus, which helps to reduce chromatic aberrations and also field aberrations. The central obscuration is due to both the secondary Mangin mirror and the triplet and it is worse than RC system. Figure 4 shows both correctors for modified Ritchey-Chrétien and modified Klevtsov systems. The modified Klevtsov system needs two extra optical components, but there are no aspheric surfaces.

We can see from the table 1, presented below, that the optical performance of the all-spherical Catadioptric design is comparable to the Ritchey-Chrétien system. Figure 5 give spots diagrams for the two systems.

Table 1. Optical features for the Ritchey-Chrétien and Klevtsov designs.

	Modified Ritchey-Chrétien	Modified Klevtsov
Primary Mirror Diameter (mm)	800	800
Focal Length (mm)	3607	3600
F/#	4.5	4.5
Primary Mirror F/#	4.8	5.5
Total Length (mm)	2500	2744
Loss due Obscuration (%)	23	30
Airy Disk Radius (µm)	3.2	3.2
Seeing Disk Radius (µm)	8.7	8.7
Amount of Energy in Seeing Disk (%)	93	90

3. Conclusion

From the data presented above we conclude that for telescopes having up to 1-m apertures, Ritchey-Chrétien design can be avoided in favor to an all-spherical Catadioptric design for seeing-limited observations. Under such conditions using the Catadioptric design might be more cost effective than using a Ritchey-Chrétien design with a similar (f/4.5) speed. Unfortunately we cannot scale up Catadioptric designs to larger apertures, in view of physical limitations in the size of lenses and the need for higher image quality of the telescope system when using adaptive optics correction.

What is remarkable about the modified Klevtsov system is that there are a large number of variables available. It means that in general finding the global optimum is not straightforward and multiple solutions with similar image quality are possible. Our future work is to find a systematic approach to the optimization problem, so that one can select solutions, which offer better optomechanical performance. It would be interesting to explore the family of the modified Klevtsov designs by using global optimization and find other possible configurations.

4. Acknowledgment

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5. References

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