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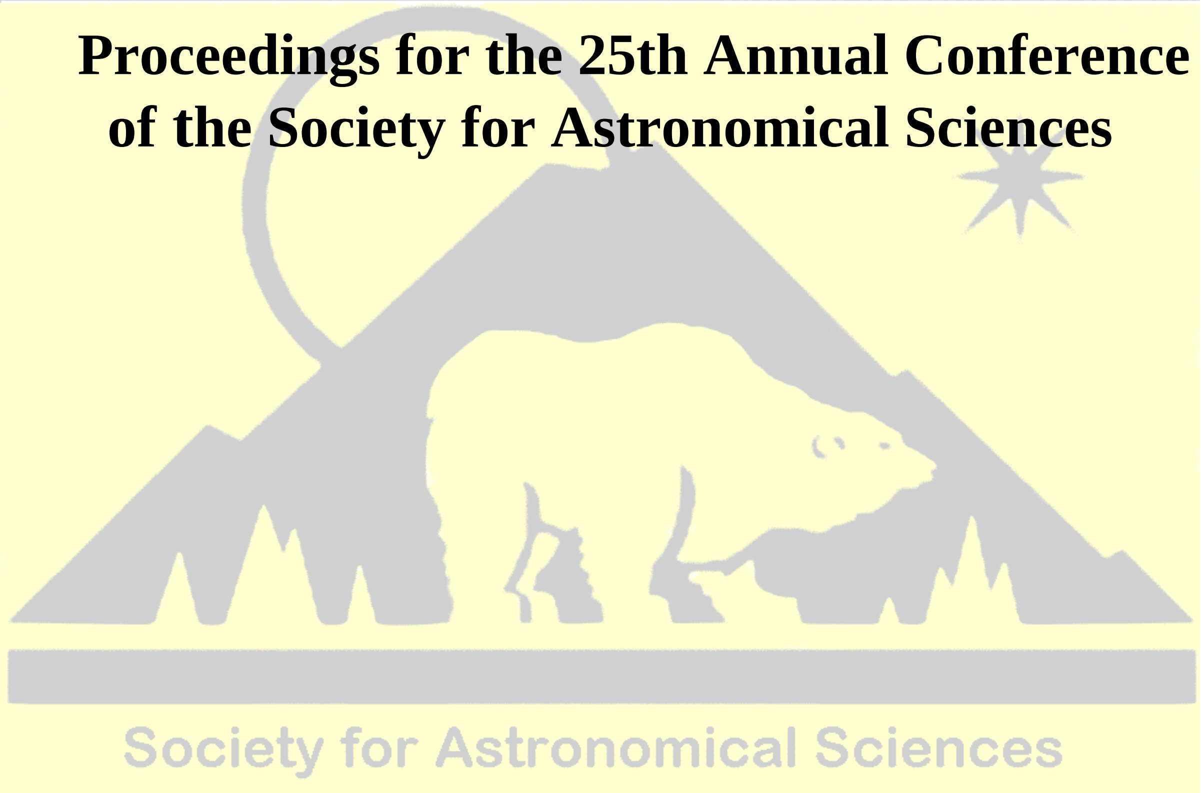

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Magnet Loader for Schmidt-Cassegrain Mirror Flop Reduction

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Abstract

The struggle with mechanical and optical issues in most commercially available Schmidt-Cassegrain amateur telescopes is exacerbated by the random flop of the primary mirror as it progresses beyond the meridian. Several retrofit techniques are available to reduce this problem, including lock-down screws and collars. Such approaches all require some modification to the optical tube. This paper discusses "work-in-progress" on a Magnetic Loader for the popular C14 optical tube that locates a rare-earth magnetic assembly on the primary mirror collar thereby continuously loading the sleeve bearing assembly. This technique requires no machined modifications or parts, can be accomplished by removal of the secondary mirror, and requires no operator intervention during focusing. While the initial data looks favorable, additional development and testing over a wider range of conditions is necessary.

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1. Introduction

The ever-present problem of mirror flop in most Schmidt-Cassegrain optical tubes creates some major limitations to the serious amateur. This mechanical problem arises largely from the necessary clearances between the inner stationary guide tube and the mating outer sleeve bearing that supports primary mirror. Secondary issues such as flexure and thermal instability in the mirror supporting structure also affect performance.

Expensive research optical tubes go to great length to eliminate this problem with more complex loaded bearing assemblies and/or locking schemes to eliminate the mechanical play and use of more thermally stable materials. Some newer amateur or research grade optical tubes offer built in mirror locks and at least one after-market locking collar is available to solve this problem. The later requires some machining and modification to the tube assembly.

Without attention to this problem the amateur is continually frustrated by variations in pointing, tracking, and difficulty in holding collimation across the full sky. Software approaches such as T-Point cannot correct for this problem since its magnitude and position are not predictable from run to run or night to night. The technique described in this paper was designed around the popular C14 optical tube but should be adaptable to other manufactures and mirror sizes where the secondary access hole is large enough to gain access to the inner support tube or, the corrector plate is removable.

2. Approach

The design objective was to find a method of substantially reducing mirror flop that could be accomplished without disassembly or modification of the optical tube and would accommodate some movement of the primary mirror using a remote focusing system.

Reviewing other references, it was decided to try a magnetic loading approach using very powerful rare-earth magnets[1, 2]. The magnets are available inexpensively in a wide variety of shapes and flux levels. This approach could potentially meet the design objectives and be compact enough to eliminate light shadowing issues. The initial concept was to place a narrow-strip steel pole piece within the central stationary tube and locate bar magnets on the outer movable tube. This technique was found to provide inadequate force between the sleeve bearing assembly. The separating tubes' permeability and air gap significantly reduces the force between the inner and outer tube.

Figure 1 shows a technique that provided substantially more force and could be scaled to higher force levels.

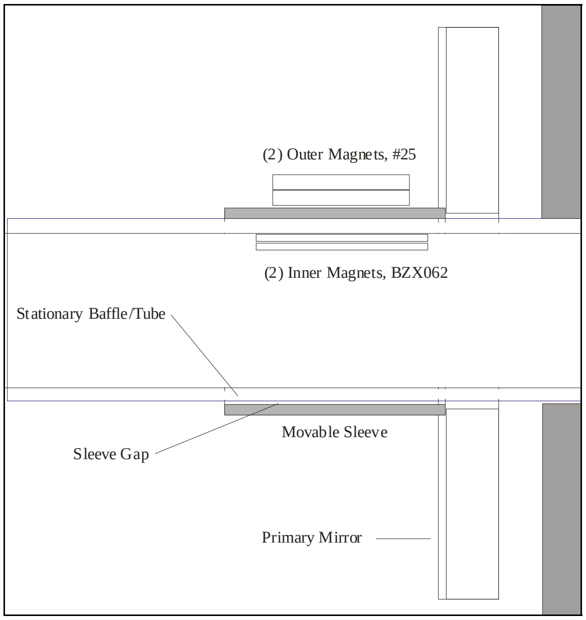

Figure 1, Magnetic Circuit Using Two Pair of Rare-Earth Magnet Assemblies.

Note that the inner and outer magnet's attracting force pulls the sleeves together along a line in the plane of the magnetic force. It is estimated that a force between 15 and 30 pounds is required to adequately load the sleeve bearing. An exact minimum value would require disassembly of the optical tube, which was not undertaken.

Changing magnet type, size, and number in the stack can easily scale the approach shown. For this study the internal assembly has two stacked, BZX082, 100x12x3mm magnets [3] each rated at 140 lbs force and two external, #25, 75x25x12mm magnets each rated at 150 lbs force [4]. The internal magnet projection into the light path is at its maximum for this optical setup. Scaling of this technique is easy: with one internal and one external magnet as the base force level, adding a third internal or external magnet doubles the force. Adding a forth magnet doubles the force again. The four-magnet assembly was used for all experimentation in this paper.

3. The Performance Data

A major issue with the existing C14 was holding collimation across the sky and 30+ arcseconds of random pointing error that could not be compensated by T-Point. Quantifying the amount of mirror flop proved to be a real challenge. The Software Bisque T-Point model of the non-loaded C14 was investigated to quantify mirror flop. Patrick Wallace had suggested terms PZZ0 and HZCH0 as candidates for isolation of the mirror flop magnitude. Analysis of the model was not conclusive due the interaction of un-modeled DEC axis flexure, HA gear errors, and other variables.

A new program by CCDWare, CCDInspector (CCDI), was tried to see if it could quantify the collimation level with the full optical train in place[5]. CCDI proved useful for measurement of both the level of collimation and the direction and magnitude of the resultant optical misalignment.

Figure 2 shows a sketch of the CCDI graphical output for each image. The output for each image includes the range of FWHM across the image, curvature, tilt of the X and Y image axes, collimation level, and the number of stars used for the calculation. Finding areas in the sky with adequate and uniform star counts that are about to cross the meridian proved a real challenge. The most reliable method was to follow an open star cluster for several hours as it passed through the meridian.

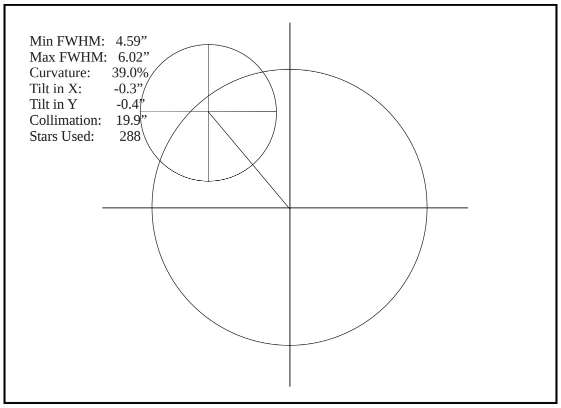

Figure 2, Drawing of the CCDInspector Output Showing the Mechanical and Optical Centerline Misalignment

Figure 3 shows collimation as the standard C14 approaches and crosses the meridian. The meridian crossing occurred at image 14. East of the meridian the collimation was misaligned and averaging about 20 arc-seconds. The flop resulted in an increased collimation error of approximately 15 arcseconds. The data scattering in all cases is due to the poor Michigan sky conditions. Collimation deterioration for the later images is due to focusing shifts and mechanical shifts from temperature change.

The most useful data for assessing performance proved to be the X-Y optical tilt data. Collimation was useful but you could have mirror flop and still have the same collimation level when the misalignment moved same amount to another quadrant.

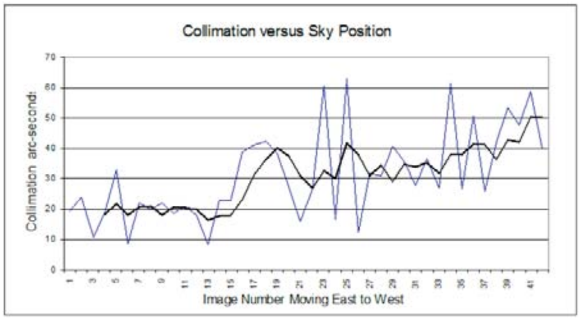

Figure 3. Standard C14, Collimation as the Telescope Crosses the Meridian.

Figure 4 shows an example of tilt as the telescope passes through the meridian using the same images as Figure 3. In this graph the X-tilt shifts approximately 1.1 arc-seconds (black curve) and the Y-axes approximately 0.9 arc-seconds. In all the graphs a rolling average line for analysis purposes augments the scattered data lines. It is important to note that the flop is highly variable; it does not always occur near the meridian and its magnitude varies with sky position, temperature, etc.

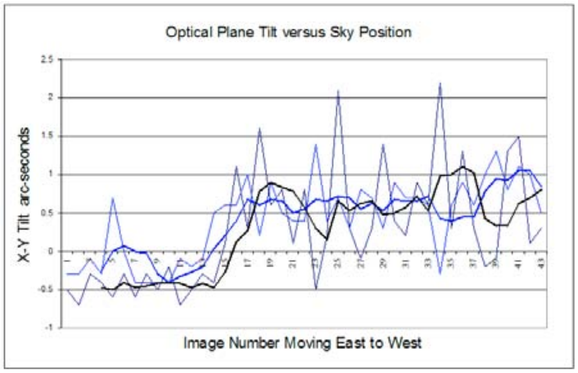

Figure 4. Tilt Each Side of the Meridian for the Same Image Data of Figure 3. No Magnetic Loader. Black is X-axes.

The two-pair Magnetic Loader was attached per Figure 1 with the magnetic force vector in the DEC plane. Figure 5 shows the X-Y tilt following an open cluster for 267 minutes passing the meridian at image 111. This graph shows that the total flop magnitude was reduced substantially with no obvious step changes. The gradual shift in tilt is likely thermal instability, deteriorating focus, and other mechanical instabilities. Figure 6 shows an additional run with the loader attached. Here there is very little change versus sky position with a total lapsed time of 107 minutes.

Other runs were conducted and a few showed some residual flop. It is likely that the estimated 15 plus pounds force provided by the two-pair Magnetic Loader is still marginal. Additional trials will utilize the same two internal magnets and 3-external magnets to provide approximately a 30% force increase. Other circuits for trial are the same two internal magnets with a two to four stack of larger 100x12x6mm BZ084 series magnets.

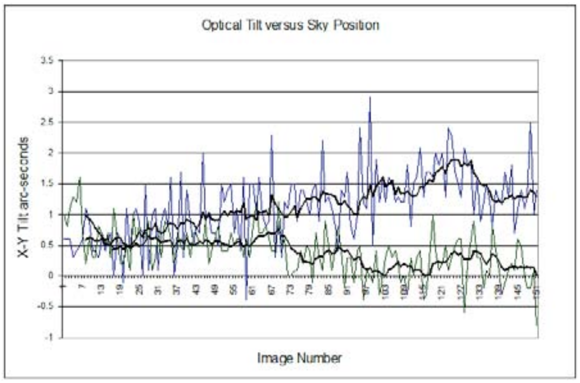

Figure 5. X-Y Tilt with Magnetic Loader as the Telescope Crosses the Meridian. Black is X-axes.

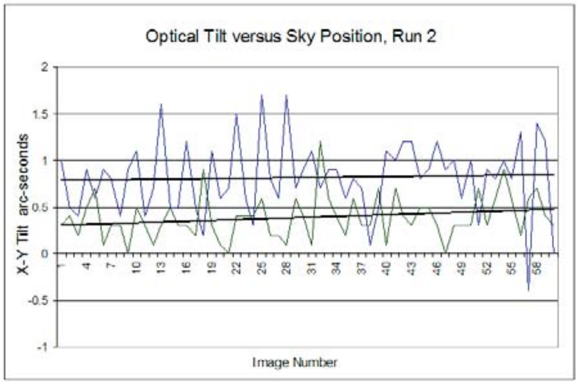

Figure 6. Run 2, X-Y Tilt with Magnetic Loader as Telescope Crosses the Meridian at Image 30. Black is X-axes.

4. Some Practical Considerations

This paper is provided as a "work-in-progress" report and idea starter. Numerous other magnetic circuits are possible and may work even better. Additional experimentation is the key.

A few notes on how to proceed. The references note two good sources for the rare-earth magnetic material. Be extremely cautious in working with these materials. The forces involved are very high and you can be easily pinched or hurt. Experiment on a bench with all ferromagnetic materials removed. To checkout various configurations use an aluminum tube about 1 inch square with 1/8 inch wall, clamp it over the edge of the bench, and tape one magnet set to the bottom and place the other on the top. This allows testing of various configurations with forces that are scaled down to less than you'll experience inside the optical tube. Also, be extremely careful when mating two magnets. Slide them together being careful not to pinch you or allow them to snap together since they are extremely brittle and will fracture.

Second, once you are familiar with the magnets, remove the optical tubes' secondary mirror. If your arm is not small enough you may have to solicit help or build a wooden placement tool to allow entry and placement. Identify any ferromagnetic materials that you will want to avoid when introducing the magnet assembly into the optical tube. Next, set the primary mirror to the nominal focus position for your setup. It is not a problem with plus or minus several knob turns from this position. The C14 configuration used for testing had a second external Optec TCF-S for fine focusing with the primary mirror focus used during large temperature changes and setup modifications.

Third, before installing the magnets, spray with a flat black paint or cover the non-contact areas with black masking tape. The latter works better due to poor paint adhesion to the magnetic material. The setup described had the Magnetic Loader installed so the direction of force was in the mounts DEC plane. Other mounting configurations were not tried.

To install, be sure you know the magnet surfaces that will attract. Place the inner magnet into the stationary tube using a stiff wire or long thin screwdriver and center along the movable sleeve. The magnet will slide using the outer magnet to properly center. With the second magnet's polarity identified, move the magnet through the secondary mirror hole, keeping away from the central tube until the correct position is reached. Keep fingers away from contact and place against the tube. The assembly can now be wiggled to its final position. If the mirror is going to be moved more than three or four turns attach the outer magnet to the tube to keep it stationary. A Ty-Wrap works well for this purpose. Figure 7 shows the external magnet pair of the Magnetic Loader installed on the C14.

5. Conclusion

From the initial data of the two-pair Magnetic Loader in a C14 application, the approach looks promising as a technique for substantially reducing mirror flop. However, the loader's force is still insufficient for the wide range of operating conditions experienced. A 50-100% increase in force is necessary. An additional number, more powerful, and longer external magnets will be tried to improve the robustness of the approach. Application to additional C14 optical tubes and other manufacturer tube types will be needed to confirm the full effectiveness of this technique. Ideas and results from others interested astronomers will also help solve this illusive problem.

Figure 7, Two-Pair Magnetic Loader Installed on C14 Optical Tube

6. Acknowledgements

Paul Kanevsky, Designer/Writer of CCDInspector, for continuous assistance in using the software and techniques for gathering data.

Patrick Wallace, Tpoint Software, for his assistance in identifying mirror flop within existing T-Point models and general encouragement on the subject.

7. References

1) Schmidt-Cassegrain Mirror Stabilizer, Chris Vedeler, www.isomedia.com/homes/cvedeler/scope/mirrorlock.htm.

2) Software Bisque, C-14 Locking Collar and Installation Service, http://www.bisque.com/Products/Collar/Default.asp.

3) K&J Magnetics Inc., 2110 Ashton Dr. Suite 1A, Jamison, PA 18929, www.kjmagnetics.com. Inner Magnets: (2) BZX082, 100x12x3mm, N42, #140 force each.

4) Gaussboys Super Magnets, PO Box 55401, Portland, OR 97238-5401, Tel: 866-840-4400, www.gaussboys.com/default.php?cPath=3.
Outer magnet: (2) Block #25, 75x25x12mm, N38, #150 force each

5) CCDWare, CCDInspector v1.1.4, www.ccdware.com/products/ccdinspector/