CT Scan of a Meade 2045D SCT

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Introduction

One of us (DWR) has owned a Meade 2045D 100 mm schmidt cassegrain telescope (SCT) for about ten years. This scope, shown in Figure 1, hadn't been used much since it was purchased new. The scope is a typical Meade design and moves the primary mirror to achieve focus. Collimation (alignment) of the optics is performed by tilting the secondary mirror via three small screws.

Figure 1. The Meade 2045D on its optional wedge and tripod. The scope also has three small legs so it can sit on a table top.

DWR recently renewed his interest in astronomy and decided to get it working again. Unfortunately the image quality wasn't what he expected it should be. After reading the book on star testing by Harold Suiter, it was obvious that the scope's optics were out of alignment (collimation). Removing the eyepiece and looking into the scope confirmed that things were indeed not right. The secondary mirror looked as if it was off centre from the tube that the primary mirror slides on. Unscrewing the entire tube from the scope (see Figures 2 and 3) confirmed that there was no obvious problems, but it was hard to tell if the mirror tube and central tube were aligned. Looking into the scope is very confusing because of the reflections from the two mirrors.

Figure 2 Here is the scope without its tube. You can see how the primary mirror slides on a central tube.

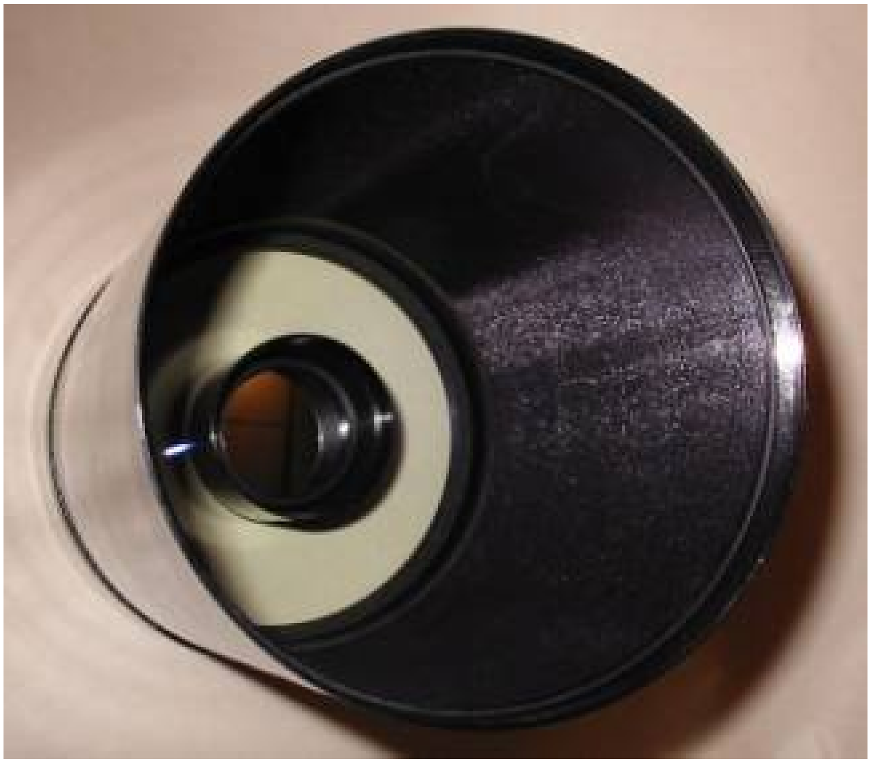

Figure 3 This is the inside of the tube and shows the curved secondary mirror, which sits down inside of a cup. Note the colour change resulting from the coated corrector lens.

Methods

To see if there was any misalignment of the mechanical components we decided to image the scope in a CT scanner (note that many people refer to “CT” by its old name “CAT”). This scanner uses x-rays to make cross-sectional images. The scanner is shown in Figure 4 and is typical of instruments used to scan patients. Figure 5 shows how the scope was positioned on the table. Figure 6 shows the scope in the bore of the scanner. Two scout views were acquired 90 degrees apart. A total of 56 cross-sectional images 2 mm thick were acquired with a centre-to-centre spacing of 2 mm. An energy of 140 kVp was used to minimise beam hardening artefacts from the metal components. The 56 images were combined to form three-dimensional image and this was viewed with a program (MacCubeView) written by one of us (DWR).

Figure 4. This is the SCT on the table of a clinical CT scanner. Note that this is not a diagnostic scanner, so no patients were denied treatment in order to scan a telescope.

Figure 5. This is a better view of the scope on the table.

Figure 6. This is the scope in the bore of the CT scanner. The dark ring on the scanner is the location of the x-ray tube and detectors. The scan only takes a couple of minutes.

Results

When performing a CT scan, the first images acquired are scout views. These are a lot like normal x-ray films and are used to show the location of each CT image. Figure 7 shows a scout view of the scope projected top to bottom. This scout view very nicely shows the location of the scope's innards. In order to orient the reader, the components in this image have been labeled and the result shown as Figure 8.

Figure 9 shows the scout view obtained 90 degrees with respect to Figure 7. Keep in mind that this is a scout scan for CT, not a proper radiograph (x-ray). Thus, this image is a bit confusing because of geometric distortion. Because the x-ray tube and detector are close together, objects closer to the tube are magnified more than objects closer to the detector. This is true of most x-ray images. For example, about one third of the way up from the bottom of this image, one can see the two forks that support the scope. In this image they appear to be different sizes even though they are the same: the fork that was closer to the x-ray tube appears larger in the image. Another problem is that because the object (SCT) is scanned linearly in one direction (top to bottom in these images), the magnification is only in one axis. Thus circular object appear elliptical: in this image, the two setting circles appear as ellipses.

Figures 10 and 11 show cross-sectional images (coronal and sagital) obtained by slicing through (multi-planar reformatting) the three-dimensional image. These images show very nicely the internal structure of the scope. They also show that the mechanical assemblies are aligned, i.e. nothing is bent. Keep in mind that the relatively thick (2mm) image slices have introduced some artefacts into these images. For example, the secondary mirror looks too thin compared to the scout view.

A volume-rendered view is shown in Figure 12. This shows the relative location of the internal components. The wood-grain "look" is an artefact introduced by the rendering software. The chunky-looking setting circles are a result of the 2 mm thick slices.

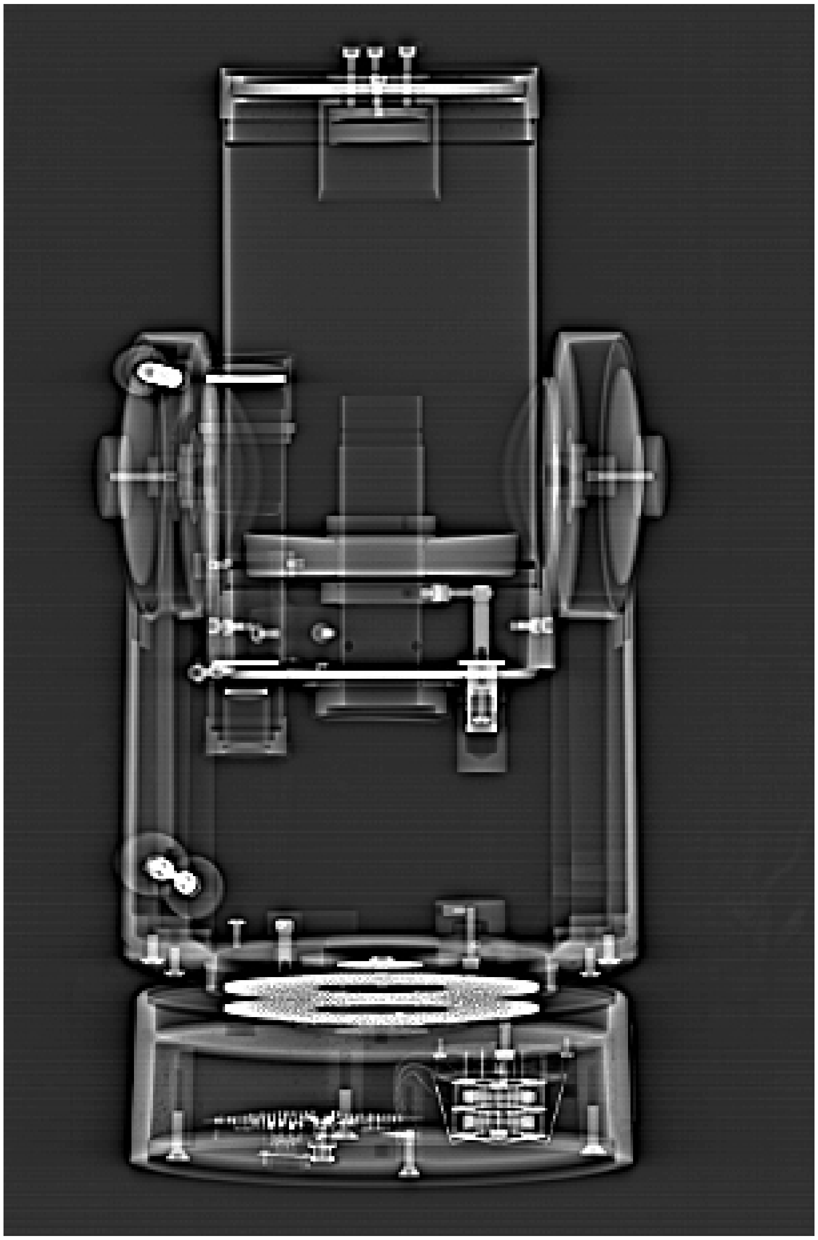

Figure 7. Scout view of the scope showing the location of the scope's innards.

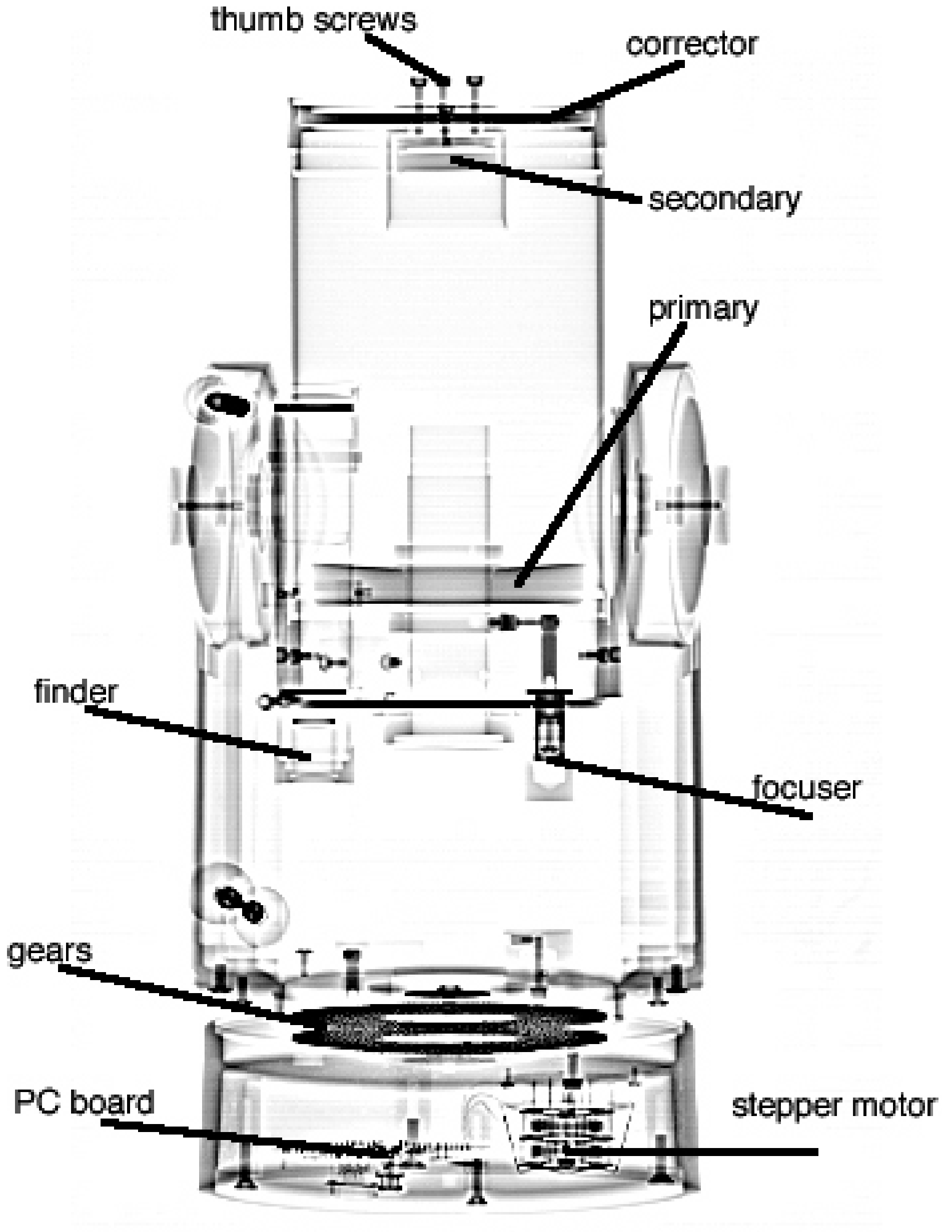

Figure 8. This is the same image as Figure 7 except that some of the components have been labeled. At the very top of the image are three thumb screws used to collimate the secondary mirror. You can also see how off-centre the focuser is: no wonder SCTs have problems with mirror shift!

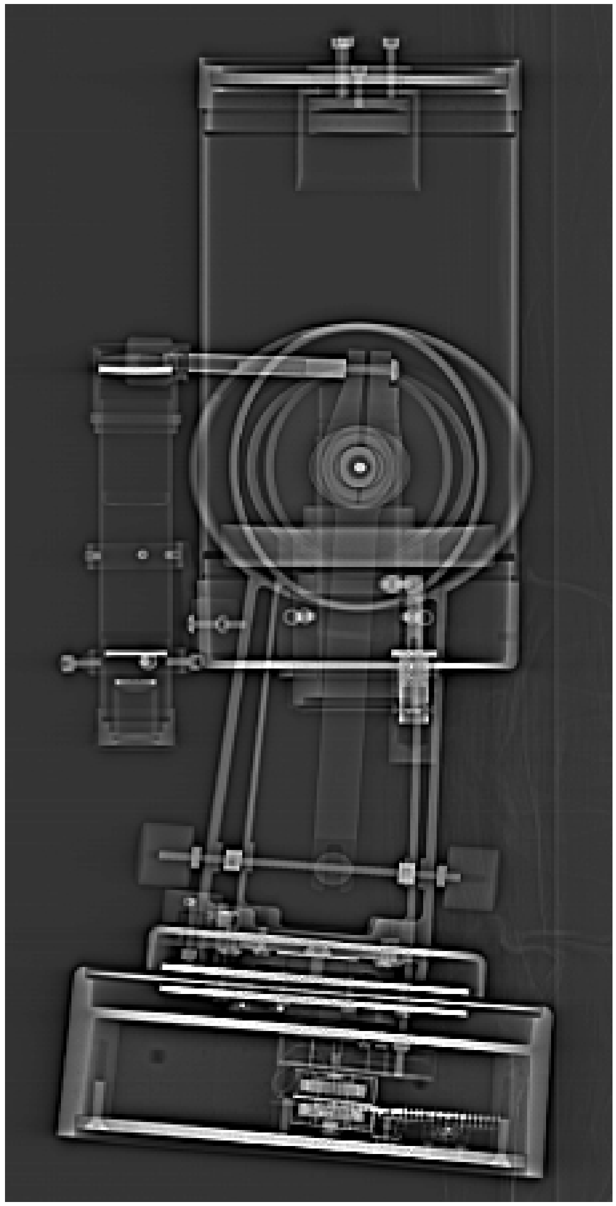

Figure 9. Scout view obtained 90 degrees with respect to Figure 7. In this image, the finder scope is on the left.

Figure 10. This coronal image was formed by slicing through the three-dimensional image.

Figure 11. This sagital image was formed by slicing through the three-dimensional image.

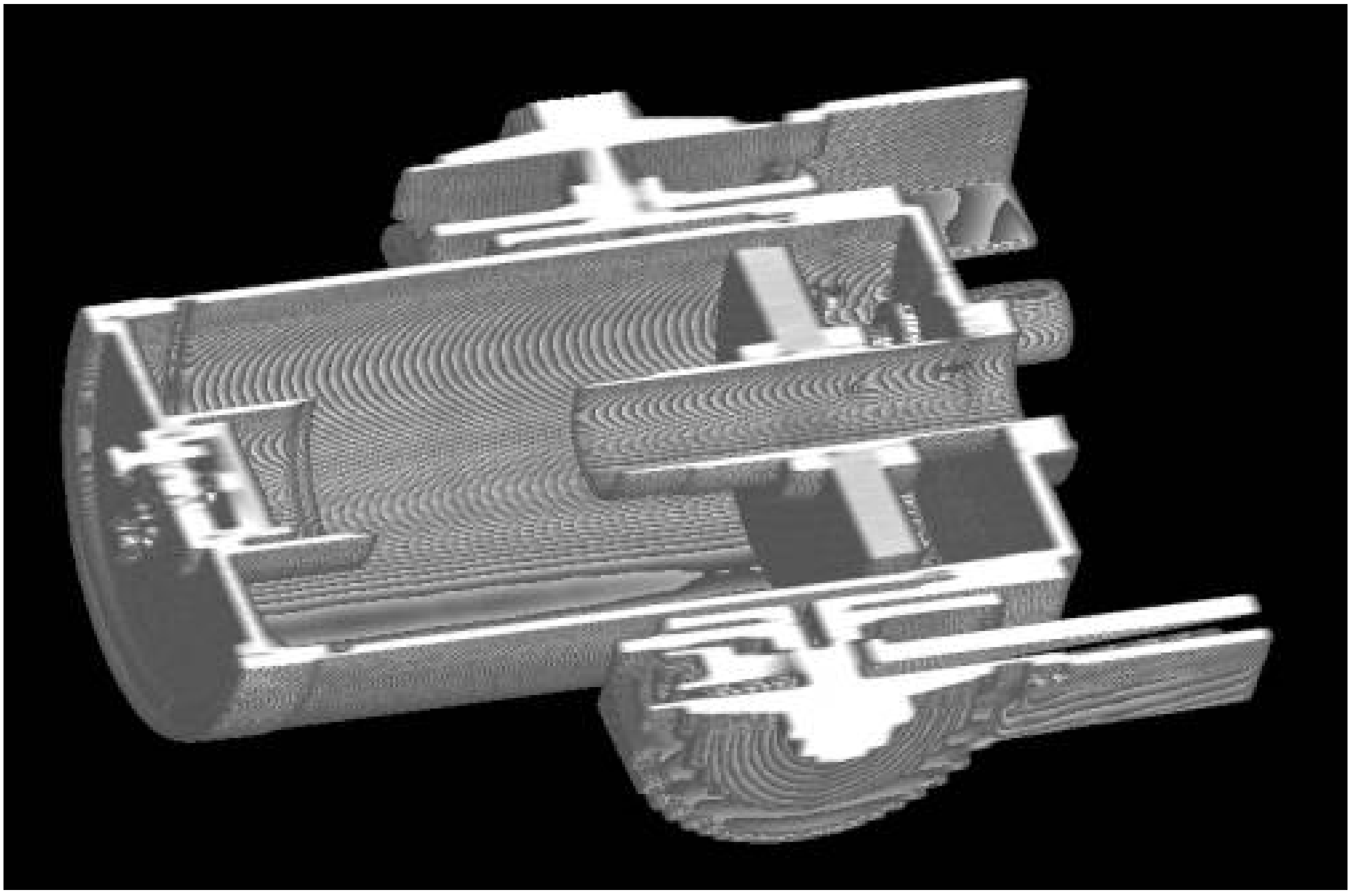

Figure 12. This is a rendered view of the scope showing its internal structure.

Conclusion

The images shown here demonstrate that a clinical CT scanner can be used to image the internal components of a telescope. The metal components did introduce some streak artefacts but these were minor. The worst streaks were from the steel screws used to align the secondary mirror. Clinical CT scanners are designed to image soft tissue and bone - not steel screws. The images shown here also show how the focuser exerts an off-centre force on the primary mirror cell. In addition, Figures 10 and 11 illustrate a large central obstruction (secondary mirror support) that is typical of SCTs. In conclusion, it’s kind of fun, but not really useful.

In the end, the image quality was found to depend strongly on centering the secondary mirror in the corrector plate. The hole in the corrector plate is quite a bit larger than the secondary mirror support, so the assembly can easily shift around. Getting it centered and keeping it there is not as easy as it should be. A 100 mm round disc with a hole in the centre would enable quick and accurate perform the centering. However, this scope has since been sold in order to make room for a larger one.

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