Artificial Antares
(or the story of a poor man's, low tech artificial star)
by Carlos Nogueira click to email author

I) Introduction:

As every amateur astronomer, I got somewhat tired of performing collimation on my SCTs immediately prior to or – even worse – in the middle of an observing session. You know, when you got under the stars, your spirit is pulled high by them, and mundane duties, such as collimation procedures, become a hell of a burden. This is why many times I just set up my nice AR5 instead of my superb 8 inch SCT so to skip collimation and cool down times at once.

But there are many other times when you simply cannot resist the appeal of putting your best optics through their paces such as on that multiple shadow transit on Jupiter or on a beautiful Saturn occultation.

The solution is to fine tune collimation in a regular basis, taking some benefit from cloudy nights. Of course, I can also make use of sunny days, by employing the time tested glint reflection on pole insulators (I have hundreds of them pretty accessible in a power station a third mile away from my terrace), but I don't have much availability during daytime.

Therefore I decided that I should buy or built an artificial star. A first glance at the prices (plus some 180% on duties and shipping fares needed to bring it down to Brazil) of the cheapest model quickly convinced me to build my own device. But at the same time, I was also pretty convinced that this small project should be kept simple and inexpensive, otherwise I would soon find myself browsing the web again after commercial units.

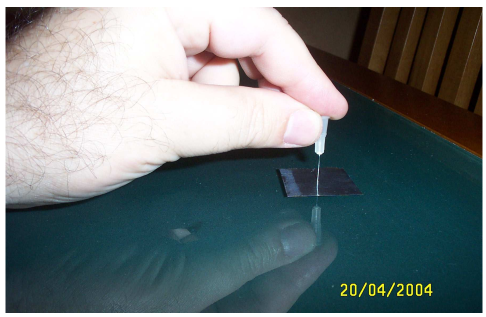
After thinking, web-surfing and reading for a whole evening, I made my mind: I would build the poor man's, low tech, no frills, pinhole artificial star. Forget about lasers, powerful white LEDs, microscope objectives or extra-thin fiber optics. I decided that I would use only whatever I could find at home, in my home-office or my car. The bill of materials came out as the following:

1. A 6 Volt conventional light-bulb flashlight (borrowed from my car).
2. A 14,5cm x 14,5cm x 21cm cardboard box (the type used to ship 20 CDs).
3. Two colored front flaps of CD cases - blue and amber – of the sanded type that will act as “diffusion plates”.
4. Aluminum foil – that conspicuous kitchen type.
5. Syringe needle - 13mm x 0,3mm size.
6. Scotch tape.
7. Black card (surplus left from a prior project – an aperture mask).

Given that items 2 and 3 were “to-be-trash” ones, my total investment was precisely zero.

II) Punching the pinholes:

Use the syringe needle to punch many pinholes on a strip or square of aluminum foil, against a hard, smooth surface (glass, polished granite or flat metal plate). This way you will be sure to obtain holes that will be less than 0.5mm across. Change the pressure applied when punching each pinhole, in order to produce samples with different diameters.



Check the holes diameters, using the slide projector method suggested by Suiter (*) and choose 2 of them that have diameters under 0.3mm. I chose one of 0.19mm (to be my “Artificial Antares”) and another one of 0.28 mm (to be my “Artificial Arcturus”).

III) The box - Putting things together:

Now make holes on each of the two smaller opposite sides of the cardboard box. They should be punched in an off-center position, in a way so – when the flashlight is switched on into the box - the hole would be illuminated by the “bright ring” produced by the flashlight beam. This procedure, combined with the diffusion plates (the CD case colored front flaps), will assure diffraction rings with beautiful circular uniformity. These holes don’t need to have precise edges, since the aluminum foil with its pinhole will take care of this issue.

Now it's time to cover the holes punched in opposite sides of the cardboard box with the square pieces of aluminum foil that bear the pinholes (use scotch tape or glue). I've also framed the aluminum foil squares with black cardboard, so to create a contrasty dark background when viewing it through the scopes. The following pictures show the "Antares" side at left (0,19mm pinhole) and the "Arcturus" side at right (0,28mm pinhole). I've added some black card strips to block light that would eventually come from a central vertical slit in the cardboard box. A top cover made of black card finishes the not so handsome artificial star box.

Now just place the "Antares" amber diffusion plate (former CD colored case front cover) and cap the box, so it's ready to use. In order to use the Arcturus side, just flip the flashlight, so the light is directed toward the box opposite side (with the wider pinhole) and replace the amber diffusion plate by the blue one (more about it follows).

IV) Will this low techie approach work at all? – Putting Artificial Antares to test:

Ok. Now it's time to stretch ugly duck's legs. In order to have success in collimating my SCTs (a 5 inch and a 8 inch, both f10) with such a tool, I would need a somewhat lengthy test field, since the scopes should be a minimum 60 meters from the 0.19mm pinhole ("Antares") or about 87m from the "Arcturus" 0.28 pinhole (**). This could be worse if I didn't have a Crayford focuser attached to the rear cell of my scopes, so I don't have to focus using the standard SCT focuser (which moves the primary mirror, thereby changing the scope's focal length).

I was lucky enough to find the right place right under my feet (although some 22 floors downstairs). I use to observe from a terrace, on the 20th floor of the building where I have my home-office, which – by its way – is conveniently located at 160 yards from home. I use to keep my instruments in this home-office. In the same building, there is a huge 2 floor underground garage. Since the building isn't a residence-type one (it's a mix of flat+office service), the lowest garage floor happens to be very empty during workday's evenings, from 7PM to 7AM. It's also almost completely quiet and empty during weekends and holidays. Therefore, it's quite common to find there long straight alleys, free of cars, spanning full 100m, where I can use my artificial star without any disturbance. Moreover, there are many other advantages of using a quiet underground garage. Since the sun exposed ground is some 3.5m (almost 12 feet) above the garage ceiling, and there are no cars getting in or out during these quiet periods (there is no heating or air conditioner either), the whole place (floor, ceiling, walls, pillars and most important – the enclosed air) is at almost perfect thermal equilibrium, so there is no convection, no obtrusive turbulence in the diffraction pattern. Ok, there are the fluorescent lamps, but they don't add much heat, and they are attached to the ceiling, so there is still no convection.

An extra bonus is that, being an indoors test field, it can be used even when it's raining or windy out there. These are benefits that city dwellers can't find in often recommended test fields, such as city parks. In fact, given the current amount of urban violence, São Paulo's city parks are forbidden places at evening, specially if you show up there lugged with expensive+attractive equipment.

Moral of the story: I strongly recommend underground garages as testing fields for scopes aimed at artificial stars. I just can't imagine where else I would find a quiet&stable 100m x 60m x 3m weather-proof (and safer) layer of air.

I took all the stuff downstairs, as follows:

- OTAs - Both SCTs (to be collimated) plus the AR5 (to be star tested)
- Artificial star box set.
- Mount 1: My CG3 (where my 5 inch SCT usually sits) to support the artificial star
- Mount 2: My LXD55 that will be shared by the 3 OTAs, once at time.
- Eyepieces: A 26mm Meade super plossl and a 7.5 mm Celestron Ultima
- An extension tube (an old Barlow with its lens removed) so I can reach focus with the AR5.

The following picture shows the artificial star attached to the CG3, by a double sided Velcro strip.

An alternative to Mount 1 is a low-tech support. I've been using a household floor wiper in replacement of the CG3 as shown below. It's much lighter and more portable than the CG3.

V) Under the stars (or should I say, underground, in front of the stars?):

V.a) Using Artificial Antares:

The artificial star is switched on, with the smaller pinhole (0,19mm) directed to my scopes, 65m away (angular size = 0.60 arcseconds), having the amber diffusion plate between the flashlight and the pinhole.

In focus, both SCTs show a bright yellow-orange star (it reminds me Antares, so that's why I nicknamed it so). Inside and outside focus, both scopes show sharply defined diffraction rings, brightness is circularly uniform. Collimation becomes child's play with such a "sitting ugly duck" target. I spent less than 15 minutes to accomplish precise collimation on both scopes (OTA setup time included). In the meantime I've also performed full blown star tests, which shown that my SCTs still remain optical gems. No difference from the last actual-star test I've performed 6 weeks earlier. Now it's time to perform a star test in the AR5. Diffraction rings are quite symmetrical and round inside and outside focus. The inside focus pattern show a bit blurrier, due the ¼ wavelength overcorrection I've identified in prior actual-star tests.

Total elapsed time to precise collimate 2 SCTs besides fully start testing them plus the AR5: less than 25 minutes.

V.b) Using Artificial Arcturus:

Now I flipped the artificial star box, so the larger pinhole (0,28mm) - having the blue diffusion plate between it and the flashlight – is now beaming at the scopes. I moved the whole setup 26m farther, so the artificial star and the scopes are now 91m apart (pinhole angular size = 0.63 arcseconds), Given the output spectrum of a conventional light bulb (much more intense in the yellow-red region), the interloping blue diffusion plate doesn't make the pinhole looks blue (it simply blocks much of the red). In fact, the final result is a white-yellow bright star (so the nickname Arcturus).

The tests in the SCTs and in the AR5 show nearly the same outcomes as the ones of the Antares-based test. The diffraction rings are brighter with this setup, making it easier to identify the ¼ wave overcorrection in the AR5.

V.c) Wrap up:

My conclusion is that it's possible to make a low-tech, inexpensive, though useful and satisfying artificial star using household materials, virtually for free. It took me less than 40 minutes to build the whole thing, plus some 15 minutes to get together the raw materials.

I'll not waste time looking for commercial artificial stars anymore. The US140 or so that I would pay for the simplest off-the-shelf unit, are now saved to fund a small portable dob, which I'll buy during my next business trip to US.

Carlos Nogueira
May, 2004

(*) Suiter – Star Testing Astronomical Telescopes – Section 5.2.2 – see following addendum.
(**) Suiter – Star Testing Astronomical Telescopes – Sections 5.2.2 and 5.3.4 - see following addendum.

Addendum

For those who don't have easy access to the excellent Suiter's book, a summary of the referred sections follows:

I - About the slide projector method of measuring pinhole diameter:

Suiter suggests to place the pinhole foil in a slide frame (you may otherwise simply attach it with scotch tape), then measure the image "average diameter" using a rule. From then on you can calculate the actual pinhole diameter using the formulas from geometric optics, based on the known focal length of the slide projector lens. I used a slightly modified and simpler version, in order to save calculation time. I just measured the mean diameter of the pinhole's projected image using a rule. Let's call it D. Then I projected an empty slide frame and measured its image's smallest side (the height of the bright white rectangle). By knowing how long is the smallest side of the actual slide frame – the smallest side of the rectangular hollow in the frame (24mm) - I got the magnification produced (32x, for example). Then I calculated the actual pinhole diameter as the result of the division of D by 32.

Suiter rightly stresses the fact that the aluminum foil builds up a lot of heat while in front of the projector's light beam, so you must avoid a long exposure time, otherwise the frame may melt and/or burn. You may simply shorten the projection time, as suggest by Suiter, but this way you will be under time pressure when measuring the image. A viable workaround is to make a quick sketch of the pinhole image on the wall (or on a blank paper attached to it). Then you can switch off the projector and take your time – no stress - to measure the average diameter. Another way is to use a digital camera to take pictures of the images projected (both pinhole and empty frame), making sure that you don't move the camera in the meantime. Then you upload the images to your computer and use any photo viewer to compare sizes.

If you don't have an old fashion slide projector in your private museum, you can also use an overhead projector, which can do the same trick, and it's a bit less obsolete, this way also avoiding the frame-burning risk. You can project the pinhole and a transparent rule (with a millimeter scale) side by side.

II - On the pinhole size x distance issue:

The recommendations found in Suiter's book plus my own experience on applying them can be summarized as follows:

1-The distance to the artificial star and the pinhole diameter should be such so the apparent diameter of the artificial star will be equal or less than the resolving power of the instrument (Rayleigh criterion, or 139/D, for green light, where D is the objective diameter in mm). This way, the artificial star will be optically equivalent to a point source (its "average" diameter will span half the diameter of the instrument's Airy disc) so you can relax about obtaining a pinhole with a precise circular shape. Just check for a "reasonable roundness" to make sure that the pinhole isn't just a slit. In my setup, none of the holes is more round than a pretty irregular octagon. Anyway, in case you need to fine tune the roundness of a pinhole, use a thin copper hair, cut from an electric wire, passing it through the pinhole.

2-The distance between the pinhole and the telescope to be tested should be a minimum of 20 times its focal length, so to avoid inducing spherical aberration above 1/8 wave and vignetting (focus in a close target requires a lot of travel outside focus, which may cause vignetting of the image). If you are going to star test a SCT or MCT, using the standard move-the-primary focuser mechanism (which changes the focal length of the system), you will have to work with longer distances. Suiter recommends using a pinhole to telescope distance of 24 times the nominal focal length.

Telescopes with really big mirrors and short f ratios (say, a 30 inch f4) will require much longer test fields, some of them impractical, since the multiplier factor grows exponentially (157.5 focal lengths, or nearly 0.5km, for the 30 inch f4 example).

Taking a 6 inch, f8 refractor as an example, the minimum recommended distance would be 24m. The diameter of the pinhole at such a distance, considering green light for the resolving power calculation (giving 0.91 arcseconds for a 152mm objective), should be about 0.11mm (or 0.107 to be more precise). I personally found hard to produce a pinhole smaller than about 0.17mm in an aluminum foil (by using the mentioned household tools alone), so you can simply double or triple the scale, working with a pinhole 0.22mm across at a distance of about 48m or a 0,33mm one at 72m. I use to attach a light green filter (Wratten #56) to the eyepiece when performing a full blown star test, so to remove the effects of chromatic aberration (that blurs a bit the diffraction pattern inside or outside focus).

I used greater distances in my tests due to the fact that I was also testing my 8inch SCT, which requires a smaller pinhole apparent size. Resolving power (Rayleigh criterion for green light) of my 5 inch scopes (AR5 and Celestron G5 SCT) is about 1.09 arcseconds. The one of my 8 inch Meade SCT is 0.68 arcseconds.

The setup described above is the one I use to perform full blown star tests. When using the artificial star for collimation purposes only, I found that I could reach precise alignment with distances about 30% shorter.

Discuss in the Cloudy Nights Forums