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How to convert a hybrid short tube Newtonian into an enjoyable RFT (Oct/2004)

I – Introduction:

Why doing such a conversion project?

I must confess: I'm not a reflector nut. During 38 years as an amateur astronomer, having owned a dozen or so telescopes in the meantime, I never really bought or built a simple Newtonian, until 2 months ago. Yes, believe it! From the very beginning until quite recently, all my scopes were refractors. During the last 6 years or so they got gradually replaced by SCTs and some new refractors (again). Of course, I have seen through many Newtonians in all those years, thanks to star parties and a few friends of mine, and really enjoyed most of the images I saw, mainly those of DSOs, but I never jumped seriously into the reflector bandwagon.

This state of affairs was unacceptable! How an amateur astronomer could fulfill its hobby demands without owning a Newtonian? Sometimes I felt like a sports car collector that has had dozens of dream cars, but none was a Ferrari or a Porsche!

Then, about 3 months ago, I decided to start changing this story. I made my mind: I would buy a small Newtonian RFT. Having many long focus scopes (all of them are slower than f/9), except for an Orion ST80 that usually gets very busy, there was no reason for a long focus Newtonian. Moreover, I was looking for a portable wide field scope that would easily travel to dark sky sites. My ST80 plays this role very often, but images of star fields and clusters usually get somewhat affect by the chromatic aberration inherent to such a short focus refractor. I was looking for a wide field portable scope that delivers true color images, at an affordable price, and only a small RFT Newtonian could fit the bill. Given that I already have more mounts than room to store them, I was looking for the OTA only. After browsing lots of astronomy-related web markets and vendors websites for months in a row, I finally realized that there is not a thing such as a small newtonian RFT OTA for sale (new or used), anywhere in this planet! Small RFTs always come with bundled mounts.

Meanwhile, I joined some web groups, the Meade-DS-Telescopes among them, and continued searching the net for bargains. Then, during a threaded dialogue in one of these groups, I got in touch with a guy who was selling a Meade DS-2114ATS OTA. I knew that it is not exactly a RFT, but it could be converted into one without much effort (Ok, it was not as easy as I initially supposed). I jumped onto this opportunity and bought it for US$40. I spent some additional US$40 in order to bring it to Brazil plus the equivalent to US$44 in materials used to convert it into a RFT.

II – The scope and the project:

In its original guise, the DS2114-ATS is a hybrid Newtonian. Its main mirror, a 114mm f/4 unit (actually a 111.5mm f/4.02, according the measures I made) with a spherical figure, has its native 448mm focal length stretched to nominal 1000mm by a Barlow lens built into the focuser drawtube. Meade uses to call it a "correcting relay lens", but it is just a Barlow as it will be demonstrated along this report.

Designers of these hybrid Newtonians put this Barlow in the hope that – by extending the focal length – they would bring spherical aberration (of the spherical primary mirror) down to an acceptable level. IMO, the final result at the eyepiece doesn't confirm this thesis. The Barlow "corrector" lens is incapable of coping with the huge spherical aberration (SA). In summary, a f/4 spherical mirror of this size, even barlowed to a final effective focal ratio of 8.8, delivers more SA at the eyepiece than a longer native f/8 mirror, also sporting a spherical figure. That's probably why most reports on the long tube f/8 "regular Newtonians" (from Orion, Celestron and Meade) are favorable, while their shorter barlowed hybrid versions are usually blamed as having poor optics or, at best, receive mixed reviews.

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In order to convert this scope into a RFT, I will have to remove the Barlow from the focuser, a procedure that will leave me with a spherical primary mirror, sporting a huge amount of SA in excess of 1.8 wavelengths. Of course I could replace it by a parabolic unit, but there are no 114mm f/4 parabolic mirrors for sale. You can find some good parabolic 108mm f/4 units (Apogee Inc. and University Optics), but their street price in USA is about US$90. If I add import (custom taxes and fares) and shipping costs, it would reach some US$260. Ouch!!!

The alternative left is to mechanically flex the original spherical mirror into a near paraboloid figure. I borrowed this idea from the excellent article in the November 2003 issue of Sky and Telescope (page 128). Authored by late Ernie Pffannenschmidt, and entitled "An inexpensive microflexed newtonian reflector" it explains, step by step, how to mechanically pull the back center of your spherical mirror so it shapes into something very close to a paraboloid. This article was inspired on another S&T report, authored by Alan Adler (Nov 2000 issue). Both Ernie and Alan were successful in their projects, but they have worked with primary mirrors sporting substantially slower focal ratios (f/6 to f/8).

Before even starting the project, I knew that a f/4 mirror would require more flexing than a f/8 and the more you flex a mirror the greater are the chances of inducing astigmatism. In fact, the more intense is the pulling strength applied to the back center of the mirror, the harder it becomes to assure that the resulting tension will be distributed with perfect circular symmetry across the mirror's surface, given that even the slightest wedge in the mirror blank will "channel" more flexing tension onto perpendicular diameters, inducing rapidly growing astigmatism.

Anyway, I decided to put the idea to test. In the worst case, I could stop the flexing at any point, before astigmatism steps in, so at the end of the day I would get at least some SA correction.

During the process of planning and preparing the flexing device, I took the opportunity to apply some improvements to the scope, so the whole conversion project became a bit more than simply flexing the primary mirror and removing the built-in Barlow.

III – The conversion process, step by step:

After inspecting the OTA (which arrived in very good conditions – thanks Jerry!), I realized that this scope is a very wobbly thing indeed! The focuser drawtube wobbles as you rack it in and out. The secondary mirror wobbles in its holder and the spider vane (3 stalk model) wobbles in its slots on the scope tube. Ok, I have quite a challenge before me. There is much more to do than a simple "hybrid newtonian to RFT conversion". There are many enhancements+fixing procedures on my way.
Let's go to the conversion steps.

Step 1 - I nicknamed my new scope as "Wobby".

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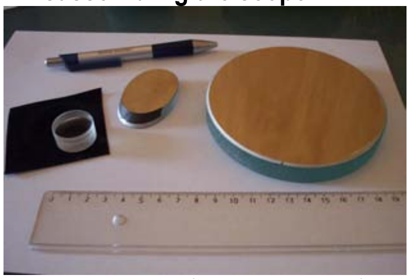
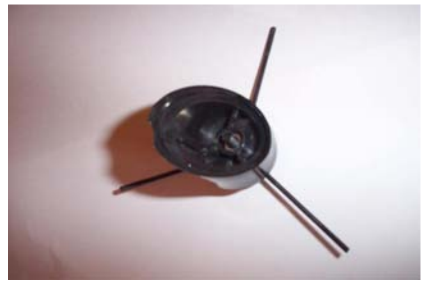
Step 2 – Disassembling the scope:


The optical train (mirrors and Barlow)


The disassembled focuser


The primary mirror (without a center dot) sitting loose on its cell (clips removed)

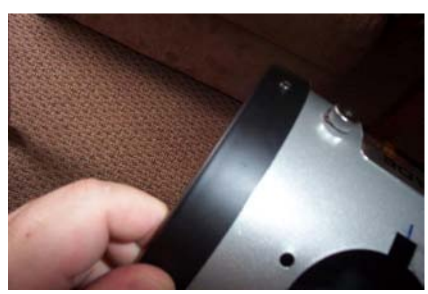

The spider and the secondary mirror holder

Step 3 – Fixing the wobbly spider vane and secondary: I used grommets to fill the gaps left by the spider stalk nuts in their 3 respective slots on the OTA, as showed in the following pictures. Meanwhile I realized that the secondary mirror wobbles into its holder, because the retention clip doesn't apply enough pressure. I was tempted to simply increase the clip's pressure, but it would probably pinch the mirror surface and induce astigmatism. I corrected this problem by removing the clip and its screw altogether. I glued the secondary to its holder using silicon adhesive. Now both the secondary mirror and the spider vane are rock solid, no wobbles. It will help a lot during collimation procedures (and also to keep it tuned).


The grommet (one of 3)


The squeezed grommet


The squeezed grommet fills half of the slot


Each of the three spider nuts fits tightly now

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Step 4 – Converting the focuser - part I: removing the Barlow.


Removing the Barlow's retention ring


Removing the Barlow (the element with the thinnest edge faces the eyepiece)


OK, it's really a typical Barlow – a negative doublet. Both external faces are concave, while the cemented interface is steeply curved. It's definitely not a relay lens (two opposed plane-convex doublets).


Removing the Barlow's housing from the focuser drawtube (step A)


Removing the Barlow's housing from the focuser drawtube (step B) – Just pull it with a passed-through finger. It won't put up a fight... Fortunately, it's badly glued to the drawtube.


OK, it's out!! Don't throw it away. It will become an important accessory in the near future. Believe it!

Step 5 – Converting the focuser - part II: Attaching the 1.25" eyepiece holder.

The 2" focuser drawtube comes with a 0.965" eyepiece holder standard. It can be removed to allow you to slip down 2" accessories (caveat emptor, since no retention thumbscrew or ring is provided for 2 inch barrels…). I do not have any 0.965" accessories and the only 2" ones are useless in a Newtonian (a mirror diagonal and a SCT laser collimator). Fortunately, I do have a surplus 2" to 1.25" adapter that fits well into the focuser drawtube (after removing the 0.965" holder). When I dropped the adapter into the drawtube I notice that – guess what – it wobbles!! Then I decided to epoxy the adapter into the focuser, in a permanent setup. I used a collimation eyepiece into the adapter during the cure period, in order to monitor the process and assure that the adapter's and the drawtube's axis are aligned.

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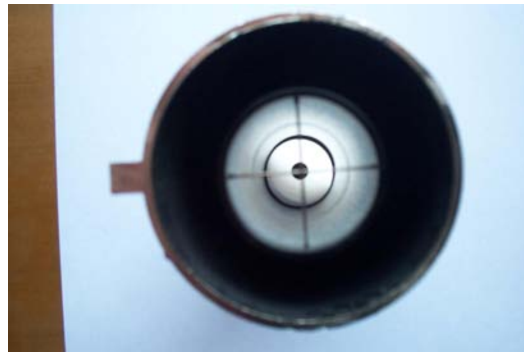
The focuser drawtube with the 2” to 1.25”adpter and collimation eyepiece on top.



The drawtube and the collimation eyepiece seen from bottom end, now pretty concentric. The adapter has already been epoxied and is now undergoing the cure process.

Step 6 – Converting the focuser - part III: Preparing the focuser to work without the Barlow. The built-in Barlow moves the original focal plane (primary mirror focal plane) further out of the optical tube. As it is now removed (so the focal plane moved inward), I must provide some additional inside focus travel, in order to reach focus with every single eyepiece. At the same time, I realized that there is no need for a generous outside focus travel anymore. After testing with many eyepieces and eyepieces+Barlows (regular Barlows, not the removed one) combos, I concluded that:

- I could cut off 27mm of the inner end (the one closer to the secondary mirror) of the focuser drawtube. Such procedure will bring two benefits. First, it would allow more inside focus travel without bumping onto the secondary mirror. Second, it will remove significant obstruction from the light path.
- I would need to cut a dent on the focuser housing, in order to allow some 12mm of additional inside focus travel.
- I need to remove the rack stops from the drawtube ends (the inner one was already removed when I cut off the drawtube’s end). This was necessary to allow easy removal of the drawtube and to get a bit more of inside focus travel.

Cutting off 27mm of the inner end of the drawtube

The dent cut on the right side of the focuser housing allows extended inside focus travel, by slotting the thumbscrew of the 1.25” eyepiece holder.

As the main result of these procedures, the focuser got transformed into a low-profile unit. Thanks to the modifications, the drawtube now rarely protrudes into the light path. Only when I use a long focus eyepiece on top of a short 2x Barlow, the inside focus travel is big enough to barely touch the light path.

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Step 7 – Converting the focuser - part IV: Improving the focuser movement and reducing its wobbly and sloppy behavior. :

- Wrapping the drawtube with a transparent plastic sticker significantly reduces the wobble and tilt behavior presented by the original focuser. I cut a 166,5 mm x 62,5mm sticker rectangle that was just enough to circle the drawtube, sparing the rack, of course.
- I removed the rubber pressure "dot" that came under the focuser locking screw, because it negatively interferes with the plastic sticker's surface (It causes a "bumping" feeling when you rack the focuser in or out). This way I lost the locking feature, something that I will probably never regret. Given that I will use only 1.25" barreled eyepieces and – due to the short focal length of the primary mirror – I will never use an eyepiece with F.L. longer than 25 or 26mm, this focuser will never need to withstand the load of a hefty eyepiece. Astrophotography with this instrument isn't in my plans, so there is no need to hold the added weight of camera or photo adapters either. The heavier accessory I will drop into the focuser is my Meade 8-24 zoom eyepiece, which poses no threat of a weight-induced focuser movement. Anyway, I kept the rubber pressure dot in my drawer, just in case I need to reactivate the locking screw.
- At last, but not at least, I lubricated the rack and the external surface of the drawtube (the plastic sticker surface, actually) with silicon spray. These procedures allowed smooth and steady racking movement of the drawtube.

I kept the locking screw in place, for aesthetic reasons only. It's now inactive since the rubber "dot" (which goes between the screw and the drawtube) is removed. It can be reactivated at any time, though I'll probably never do it…

Step 8 – Building the flexing device: After tinkering a lot with the focuser and secondary holder+vanes, it's about time to face the real challenge. Let's flex the primary mirror. I'll present here the best setup I achieved, although I came to it only after a lot of trial-and-error cycles.

- **Choosing the back plate**. If I'm going to flex the mirror, I need to pull its back center against some kind of back plate. After searching the shelves of a hardware store, I found a good candidate: A diamond coated circular saw used to cut stones (granite, marble, etc). A relatively inexpensive tool (BRL22.00, equivalent to US$7.90) it sports a diameter of 110 mm, while featuring a central hole of the right size. However it seemed too thin to hold the intended pressure without deforming too much (the idea is to flex the mirror against the plate, not the opposite). Therefore, I glued two of them to each other, using silicon adhesive, yielding a 2mm thick back plate, enough to assure proper mechanical strength.
- **The intervenient ring.** In order to give room for the mirror to flex down, I needed some kind of ring, made of a deformable material, to be sandwiched between the back plate and the back side of the mirror. After many tries, I settled with a 100mm external diameter rubber ring (Internal diameter=93mm)
- **The pulling screw.** This is the screw that will be glued to the back center of the mirror and will do the pulling job. After a few tries, I ended up with a flat head machine screw, 25mm (1 inch) long, with a thread diameter of 6mm (1/4 inch) standard threaded (18 turns per inch). Head diameter is 11,1mm (about 3/8 inch). A wing nut and two washers (25mm x 8,5mm and 17,8mm x 6,8mm) complete the "bill of materials" of the flexing setup.

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- **Gluing the screw head to the back center of the mirror.** After performing surface preparation (using household ammonia, following Ernie's recommendation), I went for the (irk!) gluing job. One of the circular stone saws was used as a template, to help on centering the screw (see pictures below). About the cement: Ernie Pffannenschmidt did it using regular two part epoxy adhesive (24 hour type) and waiting for a 48 hours long cure. It didn't work in my case. The resulting bond broke before completing the second tightening turn in the wing nut. I think that the main difference lies in the back surface of the mirror. While Ernie's blank had a smooth back surface, mine is pretty rough (completely unpolished). I tried many other types of adhesives. Those of the conspicuous "instant" cyanacrylate type seemed to work well in the first hours after cure (I wait for 1 hour cure, although they are supposed to reach full cure in less than a minute). They showed strong enough to sustain some 4 tightening turns on the wing nut. Nevertheless, after 12 hours or so, the bond seemed to weaken and the screw popped out. I went back to the epoxy bonders, but now I tried a 15 minute type, while keeping the 48 hours curing period. And wow! It worked. The bond is now capable of sustaining full 5 tightening turns of the wing nut without breaking up (at the end of the day, I settled down to about 3 turns).
- **Gluing everything.** Silicon adhesive's galore! I glued the back plate (double circular saw, previously glued to each other) to the mirror cell. Then I glued the rubber ring on top of the back plate, Finally, I glued the back side of the mirror to the rubber ring. As a fringe benefit of all this gluing process, I got rid of the infamous mirror clips, a common source of pinched optics, astigmatism and/or additional diffraction patterns. Now my little scope has no mirror clips at all.

The bill of materials for the flexing device (rubber ring, diamonded circular saw (2 units needed), wing nut, washers and screw.

Using the back side of the circular saw as a template to help centering the screw on the back side of the mirror

Gluing job is almost done. One step left: binding the mirror to the rubber ring (silicon adhesive again…)

Mirror (now center dotted), sits higher on the mirror cell, thanks to back plate, rubber ring and silicon bonding layers. Notice that mirror clips were removed.

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The view from the back side of the mirror cell (reassembled to the optical tube)

Complete, with the wing nut and washers (also glued together, but with instant cyanacrylate adhesive)

- **A few additional comments on the flexing device:** Besides its main purpose (flexing the mirror) and the benefit of providing a nice way of holding the mirror against its cell without clips, the flexing device brings another desirable side effect. Thanks to the added subduing layers (back plate + rubber ring + silicon adhesive films) the primary mirror got a lift, and is now sitting some 12mm higher on its cell. It also means that it is now 12mm closer to the secondary mirror, moving focal plane 12mm further out of the optical tube. This effect, added to the extended inside focus travel (see step 6) will allow reaching focus with nearly every 1.25" eyepiece, or even Barlow+eyepiece combo. In fact, after performing collimation, I measured the distance of the focal plane to the secondary (the so called "L" distance). It gave out a generous 138mm length or 30,8% of total focal length. Dividing L by the f ratio (4.02) I got 34.33mm as the minimum size acceptable for the secondary mirror's minor axis (m.a.). I measured the actual length of the secondary m.a.: ooff! 34.5mm. Just barely enough to assure full illumination on the center of the field (and only there…). No chance of replacing the secondary mirror by a larger one. Central obstruction is already at whooping 35.4% (The secondary holder's diameter is 39mm). Although the main purpose of this scope is to observe DSO's, I wouldn't like to put it to shame when taking casual looks at moon and planets. In order to assure full illumination in most of the eyepiece field, I would have to use a secondary spanning some 46mm in its m.a. or a prohibitive 41% central obstruction. An alternative approach would be to replace the focuser and the primary mirror cell by ultra-low profile units, thereby decreasing "L" (increasing F-L, the distance between the center of the primary and the center of the secondary). This way I could keep the secondary's current size while enjoying full illumination in most of the focal plane, but it would require some huge investment. Decision: Let's stay put with full illumination on the center of the field only. It' not the ideal situation for a RFT, but it is acceptable.

Step 9 – Preparing to test the converted scope: After reassembling the modified primary mirror's cell and the focuser to the optical tube, time has come to collimate the scope and start flexing the mirror. But there is some preparation work to be done. First, this new baby needs a cradle. I bought the OTA alone, with no rings or dovetail bracket. My very intention was to have it sitting on my Celestron CG3 equatorial mount (equivalent to Orion's EQ-2), that came bundled with my 5 inch Celestron SCT. Now I need to build some kind of cradle that interfaces the OTA with the CG3 mount. It's time to visit the hardware store again…

I bought 2 steel rings that are used to hold 4 inch pipes against walls and ceiling. I removed the lock link from each ring and opened their arms a bit wider (in order to fit the 133mm outer diameter of the OTA). Now the rings became "tube clips" (after attaching 10 felt lined disk pads to the inner surface of each clip). I attached them to a small (15mm x 45 mm x 160mm) MDF board (black painted) using screws and epoxy adhesive. I drilled 3 more holes on the MDF board in order to match the ones on the CG3 mount's bed plate. The 45mm width of the MDF board will allow it to fit into the dovetail slot in my Meade LXD55 equatorial GOTO mount, a second - and a bit oversized - alternative to hold this little scope.

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The cradle. Please notice the felt pads sticking to the inner side of the “tube clips”

Viewing the bottom side of the cradle. The additional holes drilled on the MDF board will match the ones in the CG3

Well, given that I will use the star test to measure and tune up the effects of mirror flexing, I will need to point the scope at a star. Therefore, a finder scope would be very convenient. Since I bought the OTA alone, it came with no finder. Fortunately, my “surplus astro stuff drawer” came to help again. An old 6x30 finder is back on work.   It has a glossy white finish, and its bracket has a too low profile to use in a Newtonian. Therefore, some tinkering is needed again. I painted it silver (a notch whiter than the OTA hue) and made a small pedestal (a simple blackened block of plywood) that lifted the finderscope about 105mm.

The white surplus finder and its low profile bracket

The finder after receiving a silver finish and a 105mm tall plywood pedestal (notice the focuser drawtube without the built-in Barlow in its end). The scope is already sitting on its cradle, on top of the CG3 mount.

A drawer pulling knob attached to the OTA turns into a “rotating knob” that, thanks to the felt pads stick to the inner side of the clips, allow easy and smooth rotation of the OTA, bringing the eyepiece to a comfortable observing position.   It also works as a “safety stop”, by not permitting the OTA to slip down the cradle clips and dropping onto the floor.

The shortened drawtube hardly protrudes into the light path, regardless the eyepiece or eyepiece+Barlow combo used, thereby reducing diffraction and improving image contrast.

The scope, sitting on the Celestron CG3 mount, a good match for this OTA, is ready for collimation and flexing

Need GOTO features? Just sit it on the LXD55 (OK, I must admit – it's a bit too overmounted…)

Step 10 – Flexing the mirror: After performing full alignment with a collimation eyepiece (an easy task, now that there is no wobbling components or intervenient Barlow in the way), I aimed the scope at Canopus and got a nice star image at the center of the field (using a 7.5mm Ultima eyepiece at nearly 60x). No focusing issues. A lot of trouble with the sweet spot issue. As the star drifts across the field, coma quickly steps in and the bright dot gets an ever growing tail. Hey guy, it's a f/4!!
After tweaking the focus in and out, spherical aberration (SA) showed up clearly. By using Ronchi gratings (100 and 150) and the defocused star images (compared with patterns calculated by Aberrator 3.0 freeware) I found a 1.8 wave undercorrection. It's a bit better than I was expecting from a spherical 111.5mm f/4 mirror, but it's still an unacceptably huge amount of SA. Then I started tweaking the wing nut, applying increasing pulling tension to the back center of the primary mirror. After each half turn I stopped turning the nut, fine tuned collimation (the increasing pulling action slightly affects the tilt of the primary mirror) and rechecked both Ronchi and defocused star patterns. As a magic trick the patterns start showing less SA. After a bit more than 2.5 tightening turns of the wing nut, SA is somewhere between ½ wave and ¼ wave, closer to last figure. A half turn tighter and it drops to a bit better than ¼ wave, but the patterns start to show a slightly oval shape, that flips 90 degrees when you go to the opposite side of focus. Astigmatism stepped in…..Checking the infocus image of Canopus, some easy doubles and a crescent waxing moon image, I found that the last tweak brought no improvement. The upcoming astigmatism completely offset the 1/12 gain in SA. I opted to undo part of the last move, unscrewing the wing nut less than half turn stopping the tensioning process (final number of tightening turns nearly 2.7). The mirror is now about 1/3 wave undercorrected, a 85% SA reduction from initial conditions, a final figure that is good enough for low power views of DSO's (I'm used to mags between 30x and 60x when observing these objects) and solar system targets.

<u>About the views (most obtained during early October)</u>: I dropped my Meade 8-24mm zoom eyepiece into the focuser and started real observing. DSO's like Orion Nebula, M6, M7 and M31 look great at 45x (zoom at 10mm). A quick peer at the 8 day old moon (at 56x, zoom at 8mm) show good contrast and crisp images of Plato rim, Appenines, terminator and limb, except when they are far from the center of the field. Whenever these objects get closer to the field edge (above 60% of the field radius), their images loose sharpness, but this effect is surely due to coma, not to the 1/3 wave undercorrection. I tried my Celestron 7.5mm Ultima, on top of a Meade 2x APO Barlow, so I can see the Moon at 119x. Image is still acceptable. I can see Copernicus' terraces, rubble and central peaks without effort, but I don't think this scope will take significantly more magnification before images start to break down. Using the same eyepiece+Barlow combo, I took a quick look at epsilon lirae pair of doubles. It's not an easy test for telescopes located in mid-southern latitudes, since Lira isn't above 35% in the sky, and seeing is quite unstable in Sao Paulo (lots of turbulent air). I could split the easiest pair (epsilon2, with stars of nearly equal magnitude) most of the time. The epsilon1 pair (just

as tight, but more uneven) was split only in fleeting moments. None split was clean, but given the current seeing conditions, the low altitude in the sky, and the 1/3 residual undercorrection, a better split would depend on a miracle. Saturn was still quite low in the morning sky, so it didn't make a fair test for a small RFT sporting 35%+ of central obstruction. Anyway, rings A and B showed up clearly, as well as Titan. Rhea and Dione were visible only briefly in steadier moments. Equatorial zone just hinted, as well as Cassini division in the ansae. I didn't even try my Meade 6.4mm superplossl or the Pro-optic 6mm wide field (eyepieces noticeable inferior to the 7.5 Ultima). The fact that this scope won't take magnifications above 60% of its theoretical limit of 223x is probably an outcome of the combined effects of the residual SA, short f ratio (small sweet spot) and the large central obstruction. The very fact that my eyepieces are average-quality plossls – no specialized oculars for RFTs neither for planets – also sets some limit for high powers in this short focus scope.

Step 11 – Revamping the removed Barlow: As I said in step 4, the formerly "built in" Barlow will find some usefulness. After blackening its edges, I reassembled the Barlow in its housing, which can now be attached to the drawtube inner end at any time, so now it turned into a useful accessory. As a consequence of steps 5 and 6 (I cut off 27mm of the drawtube and replaced the eyepiece holder), the distance between the Barlow and the eyepiece "field stop" decreased from 96mm to 63mm, so the magnification produced by the Barlow isn't 2.2x anymore. After measuring exit pupils with and without the Barlow for a bunch of different eyepieces (see "Measurements and calculations" section in this document), I found the current magnification to be 1.45x. Given the fact that I removed the rack stops from the drawtube's rack, now it's pretty easy to add and to remove the Barlow, as the following pictures show.

The Barlow, after getting blackened edges, before being reassembled into its housing

Need a boost in magnification? Start removing the drawtube (remember: no rack stops)

Inserting the 1.45x Barlow in the drawtube's inner end (please notice that I cut a triangular dent on the drawtube edge, in order to allow easy removal of the Barlow).

Now just insert the drawtube back into the focuser

But why use this Barlow when I can use a regular 2x unit (as I used during part of the tests)? The simplest answer is: why not? My tests showed that, although inadequate as a relay and simply nonexistent as a corrector, this lens is a very nice Barlow, after all. To be more precise, it's a quite well figured negative cemented doublet, coated with MgF2 on both air-to-glass surfaces. Its dimensions (25mm in diameter and 12mm thick) are convenient (given the angle and entry-diameter of the incoming light cone) and its long focal length (nearly 140mm, according my measurements and calculations) is almost ideal for using in a RFT. It delivers only 1.45x magnification, but I really don't mind. As I said before, this scope is intended to low-to-medium magnification. When combined with my nice 7.5mm Ultima eyepiece, it will give about 87x, good

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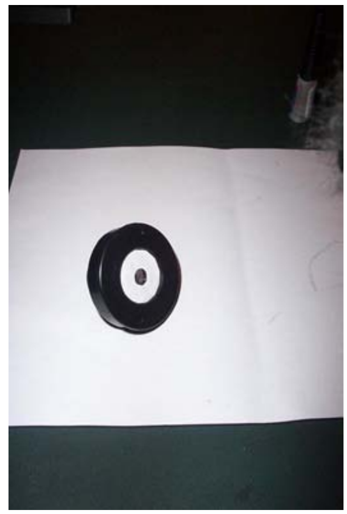
enough for DSO's and pretty acceptable for casual views of Moon and Planets. This way I can spare my regular Barlows to use in other scopes. Need more power? Ok, I can combine this Barlow with a 6mm eyepiece (yielding 108x) or simply switch to a regular 2x Barlow. Eager to observe Martian surface detail at 280x or above? That's what my SCTs and AR5 "get paid for"! Not this tiny RFT… After a few nights enjoying this little scope, I concluded that I can do all the intended observations with just my 8-24 zoom, plus a 6mm eyepiece and this revamped 1.45x Barlow. No additional eyepieces or Barlows needed.

Another useful application of this Barlow is as an accessory to a regular laser collimator, barlowing its beam. A makeshift screen for projecting the returning beam can be easily made with a piece of white card glued to a 25mm x 8.5mm washer, as depicted below.


The Barlow in its housing, a 25mm x 8.5mm washer and its white card counterpart (to be cemented to the washer with instant glue)


The screen can be easily attached and removed from the Barlow housing. A good device for converting a conventional laser collimator into a "barlowed" unit

Conclusion:

I would say that this project reached a happy end. My objectives are completely fulfilled. Now I do have a portable wide field reflector, capable of delivering nice images of DSOs (and decent low power views of Moon and planets) and it happens to be my very first Newtonian. My "lack-of-Newtonians" saga and frustration met its end so I can save the money I would spend with psychologists….

When compared with my Orion ST80, also a RFT, I must admit that the small f/5 refractor is a better overall scope. Besides pleasant DSO images, it also takes magnification very well. With the aid of a 3x Barlow and a "Minus violet" filter, it is capable of delivering decent views of planets and moon up to 180x, a bit above its theoretical power limit. But when it comes to see the pure colors of star clusters and/or stars embedded/behind nebulas, the converted Wobby is the winner.

Measurements and calculations:

All measurements cited in this document were made through the use of a dial caliper with 0.05mm precision. I rounded the measures to 0.1mm up or down for calculation purposes.

Exit pupil measurement procedures were supported by a magnifying glass (unfortunately my naked eyes don't feature 0.05mm precision anymore…).

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The primary mirror's focal length was measured by using two independent methods. The first (and more precise one) was to project a distant landscape (a tall building, about 1.2 km away) onto a paper screen at a controlled distance from the mirror's center. I called it "direct measure", since it doesn't depend on any other parameter or measurement. This procedure gave me the 448mm figure for the primary's F.L. A 2mm error margin must be accounted for due the very small tilting angle between the line of sight (connecting the center of the mirror to the center of the landscape) and the optical axis. So we have 448mm for F.L., give or take 2mm.

The second method was to measure the exit pupil's diameter floating at the top of each of 5 eyepieces, with different focal lengths. I took the opportunity to measure the exit pupil delivered by each eyepiece with and without the Barlow, so as a side benefit, I could calculate Barlow's magnification and focal length. The following table summarizes the findings.

	eyepice F.L. (mm)	Exit pupil diameter (mm) without Barlow	Exit pupil diameter (mm) with Barlow	Barlow magnification	Calculated Primary mirror's F.L.	Calculated Primary mirror's f ratio	Magnification (based on aperture and exit pupil diameter)	Magnification (based on measured primary mirror's focal length and eyepiece focal length)	Deviation
	32	8.2	5.7	1.439	435.122	3.902	13.60	14.00	-2.96%
	26	6.8	4.6	1.478	426.324	3.824	16.40	17.23	-5.08%
	25	6.6	4.5	1.467	422.348	3.788	16.89	17.92	-6.07%
	18	4.1	2.9	1.414	489.512	4.390	27.20	24.89	8.48%
	12.5	3.2	2.2	1.455	435.547	3.906	34.84	35.84	-2.86%
Average				**1.450**	**441.771**	**3.962**			-1.70%
Std Dev				0.025	27.286	0.245			
Error margin				1.74%	6.18%	6.18%			

Primary mirror's effective (measured) aperture	**111.5**
Distance between Barlow and combined focal plane (mm)	**63**
Barlow focal length (mm)	**139.9**
Primary mirror's focal length (direct measure) in mm	**448**
f ratio - direct measure	**4.02**

- **Magnification (based on aperture and exit pupil)** equals the measured(or effective) aperture (111.5mm) divided by the exit pupil diameter (without Barlow)
- **Magnification (based on primary and eyepiece focal lengths)** equals the measured primary's F.L. divided by eyepiece's nominal focal length (the number imprinted on the eyepiece's barrel).
- **Calculated primary mirror's F.L.** equals Magnification (based on aperture and exit pupil) times eyepiece nominal F.L
- **Deviation** equals the percent deviation between the two different calculation methods for magnification.
- **Barlow magnification** equals exit pupil without Barlow divided by exit pupil with Barlow.
- **Calculated primary mirror's f ratio** equals Calculated primary mirror's F.L. divided by effective aperture (111.5mm)

The second method thus gives the 441.77mm (give or take 27mm) figure for the primary's focal length; an outcome pretty consistent with the 448mm obtained though the "direct method".

It also gave me the Barlow's magnification. The result is 1.45x (give or take 0.025x).

I calculated the Barlow's focal length by using the well known Barlow formula:

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d/f = M-1 or ***f=d/(M-1)***

Where:

- "d" is the distance between the center of the Barlow and the combined focal plane (focal plane of the primary mirror+Barlow system)
- "M" is the magnification
- "f" is the barlow's focal length

I obtained 63mm for "d" by directly measuring the distance between the center of the Barlow (center of both diameter and thickness) and the eyepiece "field stop" (nearly 0,5mm above the top of focuser's eyepiece holder for the eyepieces used during the tests).

Discuss this article in the forums

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Addendum in November, 26th 2004:

Dear colleagues, I must confess. I was pretty unfair when I said that my ST 80 is a better overall scope. I wrote down it in the conclusion section of this document based on a half an hour look under light polluted and turbulent air. In more favorable conditions, things are quite different.

Last Saturday (Nov, 20th) I took my new DS2114-RFT for its first trip to a dark skies site (besides my 8 inch SCT and my ST80 refractor). The site, some 100 miles from Sao Paulo is usually good for looking at DSOs, but that night the air was also very steady, very little turbulence, so I had a good time also observing the 9 day old Moon and Saturn.

During the beginning of the night, all attention was concentrated on the SCT, given that in such good conditions, the bigger aperture delivered views of the Moon that simply blown away anything we could get on the smaller scopes. For the first time I saw the biggest 3 craterlets on the floor of Plato as really craters, with circular rims, not simple points of light. It was a sign that the air had to be frozen-steady.

After Moonset, at some 2:00 A.M. local summer time (4:00 a.m UT), already on Sunday morning, we were pretty tired of looking at Saturn (wonderful views for an hour or so, but even Saturn gets a bit boring after a while), so we switched to the DSOs. I found that the moment was perfect for a contest between the two RFTs, the newtonian and the small refractor. Putting it simple and straight: There was no contest! My new reflector won hands down! I was expecting better images through the little newtonian, thanks to the 68% of additional light gathering power, but the impression at the eyepiece was of some 100% or more. With my Meade zoom eyepiece at 8mm (56x) the view of the Orion nebula through the DS2114-RFT was the best I ever got from a scope under 6inch, period (including my AR-5). 4 Trapezium stars (A,B,C,D) were crystal clear, nebula filaments extending far west. Encouraged by this first views, I pumped some magnification, by adding a 3x Meade Barlow (168x), and I could resolve the E component in Trapezium (sometimes I thought that I glimpsed F, but I'm not sure)

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Finally, I pointed the DS2114-RFT to Saturn, now near zenith. Rings A and B popped easily into view. Cassini division very discernable in the ansae, while equatorial zone was also very clear. I switched to the ST80, using the same combo (zoom at 8mm and 3x Barlow, yielding 150x). To my very surprise, the small refractor wasn't delivering a better image of Saturn. In fact, the reflector, despite its 35.4% central obstruction, gave out at least as much sharpness and contrast as the refractor, plus a brighter image, allowing much easier views of Rhea and Dione.

On November 23rd now back to my light polluted city, I took a brief look at the waxing gibbous moon with the small reflector. I easily see the walls of Gassendi's internal rim very impressive on the Mare Humorum side, the two central peaks very clear, plus the hill besides them.

Therefore, let me correct my previous mistake. The DS2114-RFT is a better overall scope than the ST80. And since it's also quite portable, It will become my preferred grab-and-go scope whenever I travel to dark skies sites.