A "NEW APPROACH" FOR TESTING OPTICAL TRAINS

4

Jul 04 2012 09:47 AM | MADRID SKY in Articles

Discuss this article in our forums

A "NEW APPROACH" FOR TESTING OPTICAL TRAINS:
Trying to corner a long-term concern in the astro-amateur world through "slanted edge" method
by Samuel de Roa & You Yourself

-September, 2010-

Part I: "Slanted Edge" method under loupe

Introduction (1/7)

Hi pal! My name is Samuel and you'll have to excuse my english. You will find weird expressions and bad english everywhere. So, I am afraid you'll have to put up with me. :)

This "solution" for measuring resolution/contrast has been used for a long time in labs worldwide since the compilation of the "algorithm". It could be tagged as "new approach" becouse as far as I know nobody has made public its usage in the amateur astronomy world. Today, maths behind it are used extensively under expensive hardware, costly analysis software and probably a pretty steep learning curve to test optics. Unfortunately, testing results have either been secretly kept by the manufacturers or, in case they are published, it is really difficult to get a sound comparison with other brands/models due to the different scales, collection of data and hardware each manufacturer uses upon testing them. It is only been recently, on the Internet, that reliable, comparable, data is beginning to be available on DSLR lenses (www.dpreview.com). In the astronomy amateur world there are some testers using high-tech hardware (http://rohr.aiax.de), but to my knowledge this "slanted edge" method has never been used at the very eyepiece to address *objective* testing practice.

Fair play, fair winner.

It is ironic. Right now, while you are reading these pages, there are ever-going heated discussions on astronomy forums –that will not end after this publication, becouse we so love them– about the worship you should pay to a certain eyepiece, scope, diagonal, mirror, camera, combination or mix of them. It seems what works for *Bill* does not make it for somebody else. People do not tend to agree except when it comes to top gear, which *usually* works nice for everybody. If for anything, we wish this report would prevent anybody in his right mind adore something not tested in a personal way. The importance of this method rests in data thad doesn't rely on your eye, brain, sky conditions, or mood –all of which are subject to change– but on mathematics, a computer and a CCD camera: if not a *perfect world*, we are dealing with *proven* scientific instruments. Better still, they are nowadays affordable: 20 years back this very amateur report would not have even been thought of! I am not saying visual "field tests" under changing "seeing conditions" are useless on a general basis, but I am trying to point to a more objective way of testing your optical gear. This methodology is intended as a tool to ease your quest of your *best*, which may be confirmed later doing visual field testing.

<u>So, what may I expect from this "slanted edge" method?</u>

a) Good news:

You won't need Ph.D. training, neither *special* hardware of the likes of spectroscopes, interfermeters, comparators or collimators. Forget about that. You mostly need *time* and *practice*...

You wil be able to finely pinpoint the best hardware you own for high resolution work, as you can obtain resolution *and* chromatic aberrations for any given lens/accesories combination across the whole FOV. Change one element at a time (for example, you just change eyepiece, or place a single filter, or you just change your camera), and you will be able to *compare* performance. Good news for deep space observers too: they may not be much interested in "high resolution", but they certainly look for light throughput. Our software has some modules for them too.

You will be able to test your optics from home, *inside* home. You can perform testing on a cloudy night. While pouring outside you are *inside*, *comfortable*, even *warm*, enjoying a reliable high resolution test. You can take your time and be relaxed in a controlled enviroment.

This testing bench procedure is NOT intended for wide angle stuff. It is more oriented to moderate and smaller FOV eyepieces (around <60º). *Why* should this be "good news"? Simple: Televue big boys and such must feel quite relieved now. I have *spared* them. Of course, you can test these big-body eyepieces, but it is difficult to get the right hardware to do so (it has to be custom-made). My main concern has been ultimate on-axis performance, and wide angle hardware is to give you overall pleasure while filling your whole retina. They are not intended for high resolution. I am not going to discuss this point further, but maybe you can argue it with *Chris Lord* anytime (if he is still alive on earth).

B) Bad news:

"Bill, buddy, you are a real fibber; your eyepiece/scope cannot perform the way you say it performs. You are a good boy, but you are just a deluded noobie. You better stop talking nonsense and start reading more astronomy books, will you?" Right, that's something you won't like to say after performing this test, becouse there is ONLY one way to prove *Bill* is a liar, and that is to get his very own optics and test them with the same method and under the same conditions *Bill* did the testing. Things get worse, as he could truly say he *likes* his optics more than yours, or he feels more *comfortable* and *happy* with them… and he is most probably absolutely right. To prove his claim is wrong, we would have to *test* his brain and eye first, mapping it all through, and then manufacture exactly the same brain and eye to have a reference to compare his claims with, to see if the results of both coincide and he is not lying to you. Scary, but you may get the point. In the real optics world, whenever there's a brain+eye set involved in testing, there is a subjective element (even this method has it!). In part, that's why we avoid dealing with *analog* USAF targets: there, too, there is a lot of space for *opinions*. You already know the optical train there is not only one piece involved in, but a whole array that starts in your brain and ends at the target, going all the way through eye, soul, optics, atmosphere, and target itself.

Invite *Bill* home, get a mug of hot chocolate, and perform the test under the same circumstances *and* set up as you did with your optics. You may get a friend and he may learn something, or maybe you yourself learn *Bill* was right!.

<u>Lesson one:</u> when you test the optics, do it under the same conditions: testing method (set up), hardware, light conditions and place (temperature). These last two are not mandatory, but the better you control them, the more exact your results will be.

<u>Lesson two:</u> we cannot claim that you will be able to get exactly the same results we got. You *might* get the same overall results: my *best* glass tested on yours could very well show off, but *absolute* results will not be the same as I got. Different hardware *leads* to different results. Different scope, everthing else the same, *does* lead to different results! Worse on, even if you used the same brand and catalog parts as we did, you will be *around* and *bording* our own results, but most probably not spot on.

The reason for this is the *analog nature* of the world. There are billions (infinte) of *optical combinations* –each of them being different and unique– due to the variables involved with optics and the way light behaves. Only through comparison under *more or less* controlled variables is that we are able to pin point that *sweet spot* we are so desperately looking for. To get *near-perfect* controlled variables you would need to spend more money you can probably afford. The analog nature of manufacturing doesn't help either. If you buy two brand new eyepieces, or scopes, same brand, same catalog part, it doesn't mean they are the same. Polishing, coatings, form or concentrity of lenses themselves will vary, though little, from one to another, even when taken out of the same batch… so they will not perform *exactly* the same.

Summing up, "slanted edge" (knife edge) method will allow you to talk *objectively* of your own hardware as tested under your own hardware. Maths *can* assort your glass, and you can trust them. But, what's behind it?

What is this "slanted edge" method?

Slanted-edge method consists in imaging an edge onto a CCD/CMOS detector, slightly tilted with regard to the rows (or the columns) of that detector.

Edge is located for each scan line, and so the slope can be calculated. Data of each line are projected along the edge direction and accumulated in 'bins' that have a width inferior to the pixel width.

The slanted edge method calculates MTF by finding the average edge (4X oversampled using a clever binning algorithm), differentiating it (this is the Line Spread Function (LSF)), then taking the absolute value of the fourier transform of the LSF. The edge is slanted so the average is derived from a distribution of sampling phases (relationships between the edge and pixel locations). For the maths geeks, the algorithm is described in detail in this internet link:

http://www.imatest.com/docs/sharpness.html#calc.

The slanted-edge method has several advantages. The camera-to-target distance is not critical, and it doesn't enter into the equation that converts the image into MTF response. Slanted-edges also take up much less space than sine patterns (another way into image analysis) and are less sensitive to noise. Our analysis software can calculate MTF for edges of virtually any angle, though exact vertical, horizontal, and 45° should be avoided because of sampling phase sensitivity (see Fig. 0).

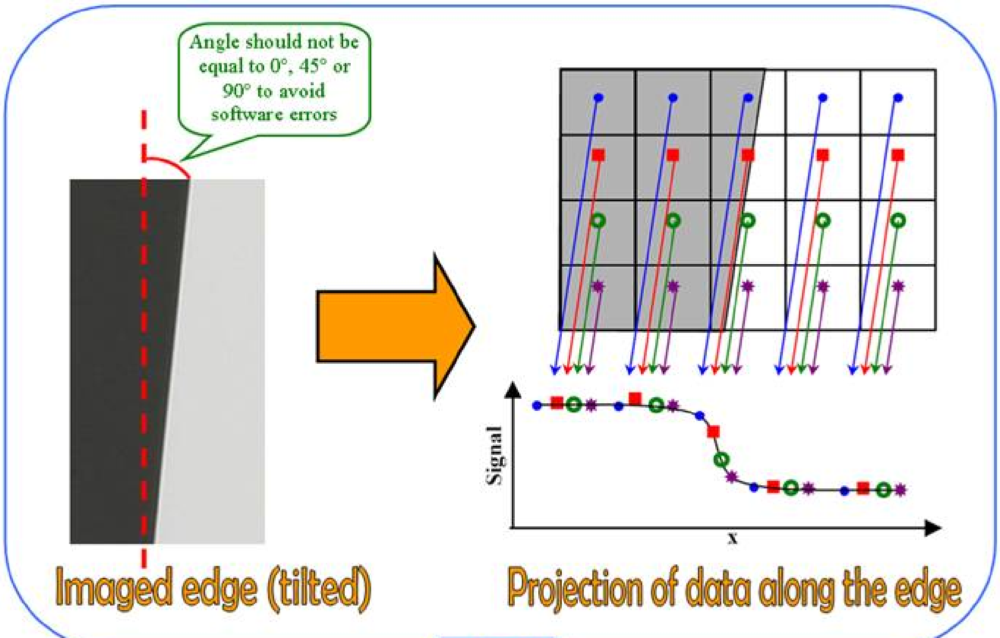


FIG. 0

Ok, enough of boring introductions and let's rock a little bit. There's a lot of fun and *maybe* some surprises ahead. Information is quite condensed and there are tips and hints here and there, so I recommend you to read it through if you are to engage in the adventure yourself.

The set-up (2/7)

Background

It is summer 2007 at www.cloudynights.com eyepiece forum. At that time my current observatory was being designed (now, as august 2010, it is being finished!). Many years before summer 2007 –at least 14 years before, at the beginning of expansion of the Internet–, I concluded I was going to do eyepiece projection to get high resolution planetary/moon work instead of going the "barlow projection" way. Therefore, I had to know what were the *best* eyepieces for my eyepiece projection set up. I needed as high resolution as possible at the on-axis area. That's how it all began.

In my search of the *best* eyepieces out there for high resolution work, I got in contact with some venerable eyepiece testers out in the Cloudynights community, and I got some nice answers and some scorn too, sometimes in the same package at once. The bad answers had at the tip some "grow up, and stop talking nonsense" attitude, but I have to confess those answers encouraged me to get into *unknown* territory –as it relates to a naive astronomy amateur as me.

I had been aware of *Norman Koren*'s work for some time now, and this software he had created in order to use a computer to analyze optical performance. The wealth of information he provided in his webpages (www.imatest.com and www.normankoren.com) was more than enough to begin and finish the bench set up, so I decided to give it a try. What interested me the most was the power of analyzing the final image at the eyepiece front lens, and by means of *relative comparison*, to reach reliable results. I am not going to get into optical theory. First, I am not an expert at all, and second, Norman's great job in making it available to the general public speaks for itself. I advise you to have a look at his websites, and learn a bit about MTF curves and optical theory, becouse his work comprises our theoretical testing background. Besides, I have to try to keep this as simple as possible. So, our software analysis is going to be Norman Koren's Imatest™, which has grown to become a world standard.

The need of an appropiate target

Now that I had chosen the method –eyepiece projection, CCD data capture and analysis through Imatest™ software–, the most basic and important problem then was to find a target that would fit the quest. I knew from what I had learned from book *"Telescope Optics: Evaluation and Design"* (Rutten & Venrooij) that the higher resolution was reached at the center of the field. You can learn a lot from that book. I also learned from it you can **match** eyepiece design with your scope design in order to counteract aberrations (and therefore, improve your on-axis resolution.) I learned from it that at 1.0 * D magnfication you are enjoying 95% of the maximum resolving power of your telescope (at *moderate* magnifications you can enjoy quite the sharpest and more contrasted views.)

Ok, now. What's the appropiate target to test a high magnification glass? Pal, this is not the same as testing low-magnification DSLR lenses. First you have to decide if you want to test indoors or outdoors. If you want to test outdoors –something which I would NOT recommend– you can just print out any of the charts with Imatest™ software on a glossy A4 sheet of white paper, stick it on a flat surface and place it at the appropiate distance –which could very well be at least 200 meters (220 yards)– and front illuminate it with a couple of lights. That would be cheap. However, and believe me here, that's a *lot* of space full of nasty air currents ready to ruin your testing sesion. Unless it is cloudy and cold, sun and heat are going to kick your backside. So, we really have to strive to test indoors, which provide us a small gap between target and optics and a more temperature controlled enviroment.
Now, if you decided to test indoors, before you clap hands and praise the Lord of Heavens for how lucky you are, you need to know your minimum focus distance. Just take your scope, put an eyepiece, and try to focus indoors. Make sure you have some focusing margin.
Hint: *I could focus my 70mm Televue Ranger at about 4,5 meters (15 feet) distance, and my 250mm Cassegrain focuses at about 9 meters distance (30 feet), at the very limit of my indoors available space. So, that's twice the distance. Minimum focusing distance is heavily scope-dependant. Test yours before embarking.*
Ok, if you really got your scope/eyepiece focused indoors, it is time to get the *appropiate target*.
An indoors target
Imatest™ measures sharpness/contrast based on the "slanted edge" method, which basically "sees" how many pixels extend at a highly contrasted frontier. Explained to common people like me, the less pixels it takes that black/white frontier, the higher the ability of your optical train to resolve detail (ie, the sharper it is). Imatest™ not only takes into account highly contrasted surfaces, as its algorithm is able to analyze the response of your glass to fine details and low contrasted surfaces too, all the way through. Even if we use highly contrasted targets, as is our case, you will be presented with a cute MTF graph letting you pinpoint your system's overall response all over the spatial frequency and contrast domain. We also get chromatic response and other data.
The best way to test a scope/eyepiece combo is to be able to test resolution all across the field of view, at any point of your FOV. For this unrestricted purpose, the best "slanted edge" target is a "star" –versus "square". Although "squares" are more easy to analyze, "stars" will give you a better analysis, as you can check the resolution of almost any point in your FOV ("squares" only allow you to analyze four lines across the fov, and if not placed correctly at the center, you could miss the on-axis performance).
Given the high magnifications involved with scopes, we need stars that would fit your whole FOV. This means we would need small stars that fill our FOV at the high magnifications involved in testing our telescopes. You cannot do this with normal printing technology. So, I found two solutions industry offers to our problem:
High resolution negative film: cheap and sharp enough at the black/white frontier.
Chromed plates: *very* expensive and perfect sharpness at the black/white frontier.
I had to go the "cheap" way becouse I am not rich. Where did I get it? Ivan Danes at www.DANES-PICTA.com did make for me a "custom" 50x50mm film chart (Fig 1). It costed 100€. Thinnest sharp line on the image is 50 microns; thinnest visible line on the image is 25 microns. That's sharp enough for our purposes. Ivan is a responsive person, and he would be able to sell you "my" custom chart if you just mention my name or send him a pic of chart below. He would remember that work.

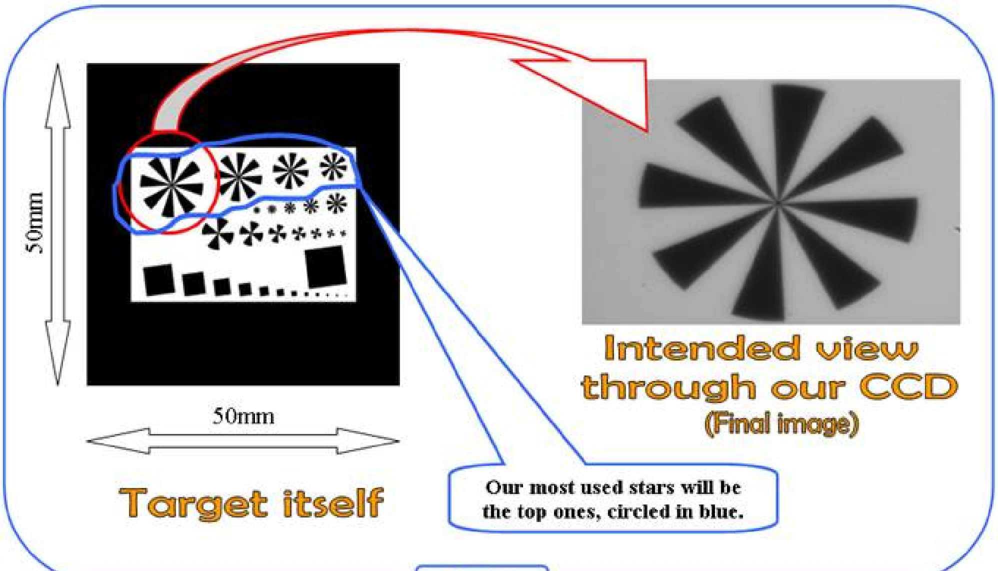


FIG. 1

As you see in Fig. 1, there are "squares" and "stars" of different sizes. We will mainly use "stars". But... why so many sizes? They are needed to acommodate for different magnifications. Biggest star is 10mm diameter (top left, upper row); smallest is 1mm diameter (top left, second row).

Hint: *if you are ever going to order from Ivan at Danes Pictas, tell him to rebuild this chart in order to acomodate 10 stars, each 1mm smaller than the previous one. You will have ten stars, the biggest would be 10mm, then 9mm... till you reach 1mm diameter. Later on you will know why this change in the custom chart design (10 stars instead of 9) would make your life easier. I also recommend to include bigger stars (wipe off squares and 4-segmented stars). More info later...*

Hardware needed

So, we've arrived at last to the most painful part of the story. What do I need and how much money do I need to invest? Let's go:

1) TARGET & OPTICAL WINDOWS: If you are to test indoors, I recommend you get special custom chart (from *www.DANES-PICTA.com* or similar). If you really want to protect it when mounting it to the back-illuminator, you will have to have it sandwiched into a couple of optical windows that you can get at Surplus Shed (http://www.surplusshed.com or similar). You can get those surplus optical windows, clean them and then mount the film target to the back-illuminator by means of pliers (Fig 3). Target is **100€.** Optical windows are about **25€**.

2) CCD CAMERA: We need a big CCD with small pixels. The reason for a big CCD is to cover as much FOV as possible, even if we suffer "vignetting". Explained briefly, the reason for small pixels is not restrict our optical system's resolution to our CCD's resolution. You can go the DSLR way, which is cheaper than dedicated cooled astrocamera (the ones that have the big CCDs). If you go the DSLR way –my camera is 15 million pixels, 5um pixel size– you will need a DSLR with "live preview" function that would help you with focusing. Even better if it has "zoom in" and "video output" on that "live preview". The most important step in our data collecting is the one that relies in our ability to check the best focus. It is not needed to get the absolute *perfect * focus to achieve reliable results (will explain this latter), but it is better to focus as perfect as possible. If we have "live-preview" with "zoom-in" function, we can focus easier in our DSLR camera. You will also need a DSLR with "mirror lock up" function to minimize camera shake (when the shutter buttom is pressed, the mirror pops up first to reduce camera shake while shooting.) I recommend the video output (to an external monitor) to allow for a more comfortable focus when higher magnfication is involved (around 200x or more). I got my Samsung GX-20 DSLR camera (new body only) at Ebay for around **350€.**

3) REMOTE SHUTTER CONTROL: Now you need wireless shutter. You don't want the image to be shaken when pressing the shutter button, so you need a wireless shutter. There are thousands of myriads of these on Ebay. I got mine for around **35€**.

4) BACKLIGHT + ILLUMINATOR. You have to mount the above film target on some hard surface that can be back-illuminated. It is recommended to back-illuminate instead of front-illuminate. A back-illuminated target allows for repeatable lighting conditions over time. A back-illuminator would provide even illumination and similar light condition from session to session. This back-illuminator should not heat up the target as we do not want any thermals coming forth from the target! So, you need a "fiber optics" back-illuminator plus the illuminator (Fig. 2 & Fig. 3), as those manufactured by Schott or similar. Second hand, I got both at Ebay for around **250€**.

FIG. 2

5) EYEPIECE PROJECTION ADAPTER. You need to put your eyepiece between your scope and the DSLR. The hardware needed has been historically called "eyepiece projection adapter". You would need a "variable eyepiece projection adapter" (from now on "VEPA"), one that allows you to move the eyepiece to and fro from the CCD. You can get these for around **90€**.
6) SEVERAL ADAPTERS. You need to attach your DSLR to the VEPA. You need a T-mount adapter that fits your DSLR model and outputs female T-mount. Then you need another ring that attaches that female T-mount and VEPA toghether. Depending on your VEPA output, you might not even need this adapter (for instance, your VEPA output is T-mount male, which would screw onto the forementioned T-mount female side). These are cheap and could go for around **40€**.
7) SOFTWARE & COMPUTER. You need Imatest™ software and an "average" computer to run it. By that I mean an Intel Pentium IV with 512Mb RAM and a 80Gb HDD. Imatest™ Studio version is enough for us, and it runs now at about **80€**. I am confident you already own an "average" computer. :)
8) MOUNT (ELSE, 2 AXIS STAGE.) You need to set your hardware on a mount with fine control adjustment (electrical or mechanical) to center target star. Otherwise, you would need to mount the back-illuminator into a 2 axis stage (x-y movement) with fine movement control. You can get these stages at Ebay at a nice price. I tried both approaches. Let's suposse you have your telescope on mount, so zero cost.
9) SCOPE WITH FINE FOCUSING MECHANISM. We need the scope to have fine focusing mechanism, the smoother and the most rigid the focuser, the better, as there is going to be some weight hanging over your scope. If your focusing mechanism is bad, you are going to notice (and suffer) it. This is supossed to be not an investment for testing, but your own equipment already in ownership, so let's say no cost to add up.
10) EYEPIECES, BARLOWS, ET AL. All the stuff to be tested in conjunction with the above scope. Remember all of our data will greatly vary in absolute numbers the very moment we change scope. So, let's test all of it with the same scope or else our results will be meaningless. Remember your eyepiece widest body measure cannot exceed your VEPA inner diameter (in my case, 45mm), otherwise the eyepiece just doesn't insert into it. A word here: although this is supossed to not be an investment for testing, if you are really looking for a high-resolution eyepiece-scope combo, I would recommend to test over the highest number of eyepieces as possible. This could mean your wife to divorce you, or it could be picking up from time to time used (or like-new) stuff here and there. This can mean "low cost" compared to what you can achieve IF you know where and what to look for. (This will be unveiled as we go on, so be patient.)
Total cost: **Very dependant on you previously owned equipment**, the investment is around **1,000€** for the European Union citizens (quite less if you live in the States). Fortunately, some of it you can use at other activities (like DSLR).
Hint: *This is the place where most of you would just stop and refuse to go further. Relax. You can go the cheap way and use whatever CCD device you may own, build yourself the illuminator with a desk-lamp and print a test chart through Imatest™ for outdoors testing. All of it for zero bucks. But remember this: the more money you invest now, the less frustrating, reliable and dynamic will be your testing. Maybe at the end of report you will be able to make your own choices about how much you want to invest.*

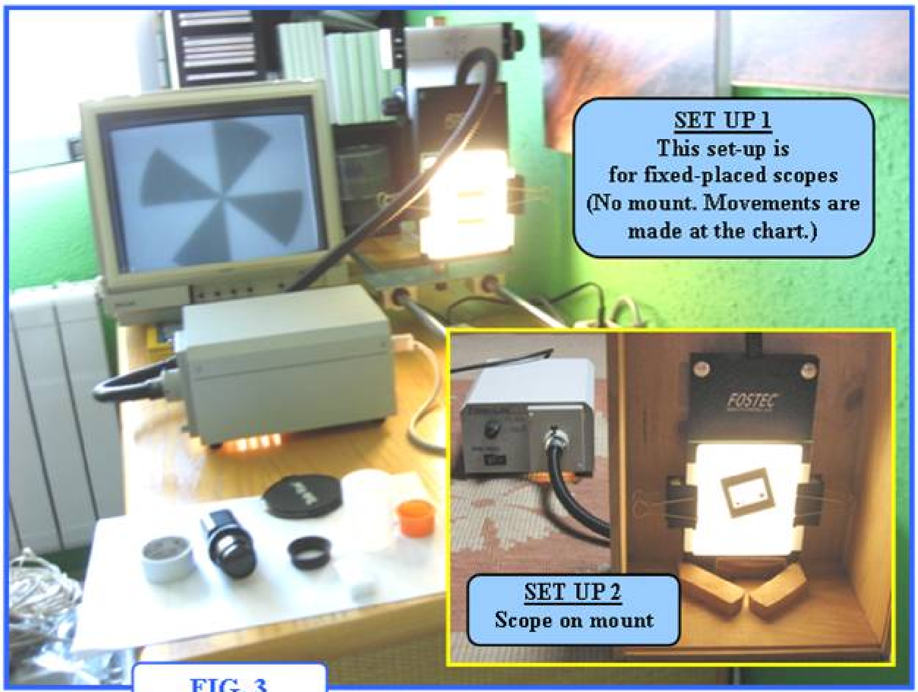


FIG. 3

Collecting data at the scope (3/7)
Time invested: **15' (time counted from point 3 and onwards), maybe more if you get very picky about centering and focusing.**
Now we come to the testing procedure itself. One word again here. I have outlined this procedure out of my own experience, but there is probably a LOT of room for improvement. Feel free to do so. The procedure itself is not much time-consuming once you get used to the steps. It is explained for a DSLR camera and back-illuminator with variable output control at the illuminator (light power knob), my custom chart, and a VEPA. Some steps could be taken before or after (for instance, anotation of eyepiece model and pic #.) With a little practice you will get the "idea" and do it yourself much better than I am explaining here.
Group eyepieces of similar focal length. This is just an organization measure, not really important (as you will later see). You do not have to be very strict about it. A 2mm margin could do (I made my test with 3mm variation groups). Take "X" group (for example, eyepieces with 4-5mm focal length), and just start with any of them. If you want to know your eyepiece fl using an indoors method, you may do a search in google for "eyepiece steroids" to find a complete report and excel worksheet I did along the way.

Next, **set up your hardware**. Place target and illuminator and scope-eyepiece combo in place, with our CCD camera behind your eyepiece. Quite an obvious step.

Set your illuminator at aprox. 70% light throughput (not recommended to work with light at more than 75% for thermal and bulb safety), and just keep that light power output mark (you can see the mark at power knob) throughout the whole testing. It is recommended your illuminator be placed BEHIND back-illuminator, so that any thermal currents emitted by bulb get behind your target and disturbs your captures as little as possible.

Place your eyepiece closest to your camera inside your VEPA. VEPA allows us to move the eyepiece to and fro the camera (the fixed eyepiece projector adapter does not). Doing so alters real working focal length, and therefore magnification. If you have worked with eyepiece projection at any time, you already know how this works. Be careful not to smack your eyepiece into your DSLR prism/CCD. You do not want to ruin your expensive camera, do you? What I did to avoid this was to rutinously place the eyepiece's front lens leveled with VEPA's back. That's a way to assure your eyepiece is not going to get in physical contact with your camera's innards.

Point with your scope to target and "center" a star from target that would fit into your DSLR screen (our "FOV" will be now what you see through your camera) This is the reason for different sized stars and squares. At my custom-made chart, the most complex object at the target is 8 segments stars, which are recommended over the other objects (4 segments stars and squares.) So, let's center a 8 segments star in your FOV. If you cannot make any star to fill your FOV, just center the biggest star in your FOV (low magnification), or choose a star that would just NOT overfill your FOV (high magnification). The idea is to have access to star's diameter (Fig. 4.) If you want to be picky with centering, you can take the center of the star as a reference, and mark a point with a marking pen in the camera (or monitor) screen and just overlap them. Be smart with these details.

Focus the star paying attention to the center of the FOV. The better focusing, the more reliable results. I found it easier to focus in my DSLR screen making some zoom to the center. Differences in focusing were more apparent that way. It is easy to see the "fuzzyness" all over the star once you defocus (particulary on the center of the star), so focusing is not that terrible

task if you keep your eyes on the center of the star. I repeat, a zoomed preview helps here, but it is not mandatory. Another way of making this easier is to take video output from your camera and cable it to a nearby monitor placed near your scope/camera set up. This also saves you eye strain over time.
Hint: *BE CAREFUL when focusing, becouse this is the most "human subjective element" in our data collection procedure. As I said before, we are not looking for *perfect* focusing (software can counteract bad focusing to some extent), but I consider focusing more important than centering. The better centering, the less work afterwards in software analysis, but I do my testing with "rough" centering becouse perfect centering is much time consuming, and I prefer to invest my efforts to achieve a good focus.*

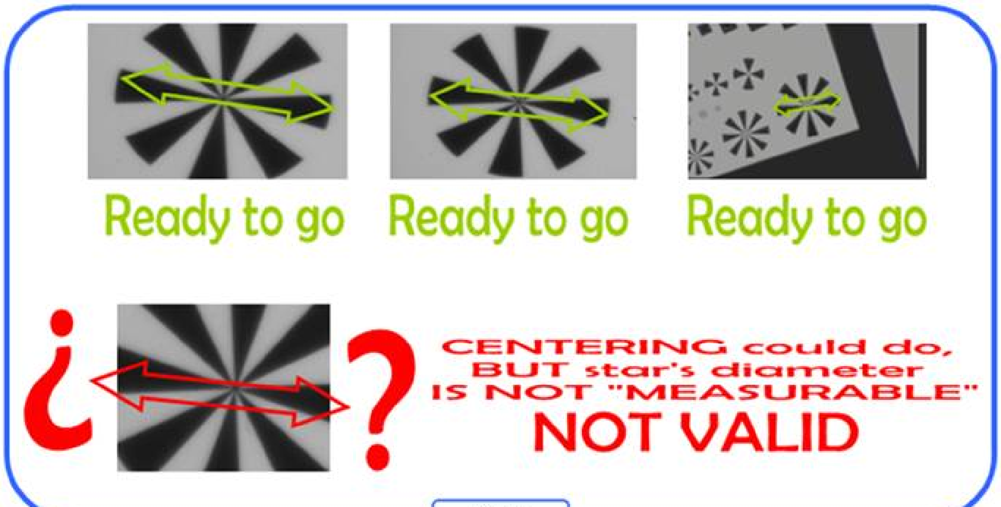


FIG. 4

White balance, exposure time and resolution at your camera's controls. We have to choose to go one or another way:

You want to give sharpness most priority: useful for high resolution work, mainly planets and moon observers or imagers, where you want to squeeze the last minute detail out of your image/view. Light throughput is not the main concern. This report focuses on this area. Imatest™ will compensate for us any light loss (due to lesser light throughput, for instance).
You want to give light throughput most priority: more useful for DSOs observers (eye will benefit more from greater light throughput than ultimate sharpness as such.) Imatest™ can make sensitivity measurements through its *Stepchart* or *Colorcheck* modules. This report is not focused on this area.
Exposure time:
Let your DSLR to automatically take the exposure time. Usually, DSLRs have 3 metering methods: *multi-segment*, *center-weighted* and *spot metering*. The first one takes into account the whole image and takes a "median", the second one emphasizes the center, and the last one only measures the center of the screen. I recommend to use a center-weighted metering method for most situations. This way it won't greatly saturate nor underexpose.
White balance:
According to Norman Koren's words, "good white balance is not required for chromatic aberration measurements because the three channels are normalized to maximum amplitude of 1 at a distance from the edge." Well, to me this means you set your camera to "automatic white balance" and forget all about it. Let's enjoy the power of Imatest™ and make not many questions here (thank you, Norman).
Resolution:
Your camera should be set to max. resolution and least compression. This is the "RAW mode" at your DSLR, which reaches max. resolution and no compression.
Oh, gee... let's press the capture button at once and for all! Wait for any bumping to dissapear, and with the remote control (previously) switched on, press it to shoot. Ideally, you should set your DSLR camera to make capture with "mirror lock-up function" (with delayed auto-fire if possible) and then fire. My Samsung GX-20 takes mirror up, waits for 2 seconds, and then shoots picture. Otherwise, the up-mirror movement in DSLRs will make the hardware to bounce a little and this will translate to your shoot. The "mirror lock-up function" minimizes any shaking due to mirror movement in DSLRs. Wait for the bumping to disappear (when the DSLR mirror gets down again, there is movement... you won't notice it at low magnifications, but surely you'll do at mid/high!). Take 3 more shots the same way. **I recommend you shoot 4 pictures**. If your indoor air current conditions are good, you will only need 3-4 shots. Otherwise, you could take up to 6 shots. I find 4 shoots a good mid-number.

Let's review your shoots in the "play mode" and choose the *best* one. We can do this job now or afterwards at the computer. I recommend you do it now and save yourself that job. Besides, this would keep you entertained doing a different thing. Get the DSLR in "play mode" (Fig. 4 bis) and zoom in towards the center of the star, and then swap from one pic to another. The greater the zooming in, the easiest discerning differences. You will notice that some of them are "sharper" or "cleaner" than others. If your indoor conditions are good, they will be almost the same, so it will be much difficult to judge any difference at all. In this case, just take the one you judge the best. The easiest way to review the pics is just to swap between PIC1 & PIC2 (for instance), and delete the worse one, and so on. At the end, you are keeping your sharper one. If you are very unsure, you can keep 2 pics and then let maths (software) decide which one is best focused, but I don't think you want to reach this kind of perfection. I tried it and I saw differences are so small they are not noteworthy for the task at hand.

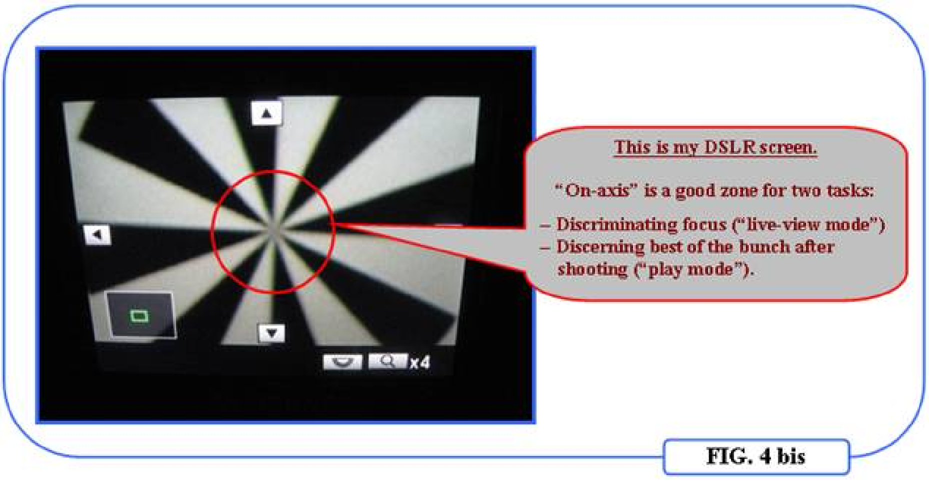


FIG. 4 bis

Have ready a sheet of paper to write down details (Excel, Word, or just hand-made) on which you anotate your hardware set up (scope, camera's details, date, etc.) and you have 3 columns where you place "eyepiece specimen", "star" you have centered and focused (for instance, you anotate "10mm star"), and "picture #" to identify your DSLR shoots with eyepiece. There are many stars on the chart, but you have to know WHICH ONE you are centered and focused on. For instance, it could be the 2nd bigger, or the 4th bigger, etc... I just used 3 stars (next to one another) to test my whole array of eyepieces on a given scope, and I found unlikely to change your star across any given eyepiece grouping (for instance, your 10-12mm eyepiece group will nicely fit under the same star). However, sometimes you have to change star when you "zoom in" (see next step.) Ok then, you have to anotate picture numbers as your DSLR records them on its memory card next to actual eyepiece model, so that we know "picture #xxxx" correlates to "x eyepiece". I got two pics per eyepiece (zoomed & not zoomed), but you do not need to anotate which one is zoomed or not, as this is visually perceived on the final pictures. You can do it if you wish, but not really needed. The important thing is to anotate your DSLR's pic number besides your tested eyepiece. This might seem a stupid thing, but I got messed up more than once and had to go back and do the process again just for not being careful with this.

Now, move physically "forward" the eyepiece –away from the camera– using your VEPA's mechanism. This will zoom-in the focused star. You just want to move in your eyepiece a little bit, around 25mm (1 inch). If your VEPA or hardware is flimsy at all, your star will get decentered. Even if it is good stuff, it will probably move off a little bit. Now, you go through steps 5, 6, 8, 9 and 10 again. Later on we will know this step is important.

Hint: *Ideally, you may like to take 3 different pics with eyepiece positioned in 3 different places at your VEPA... I did only 2 positions to save me time and work (Fig. 5) :*

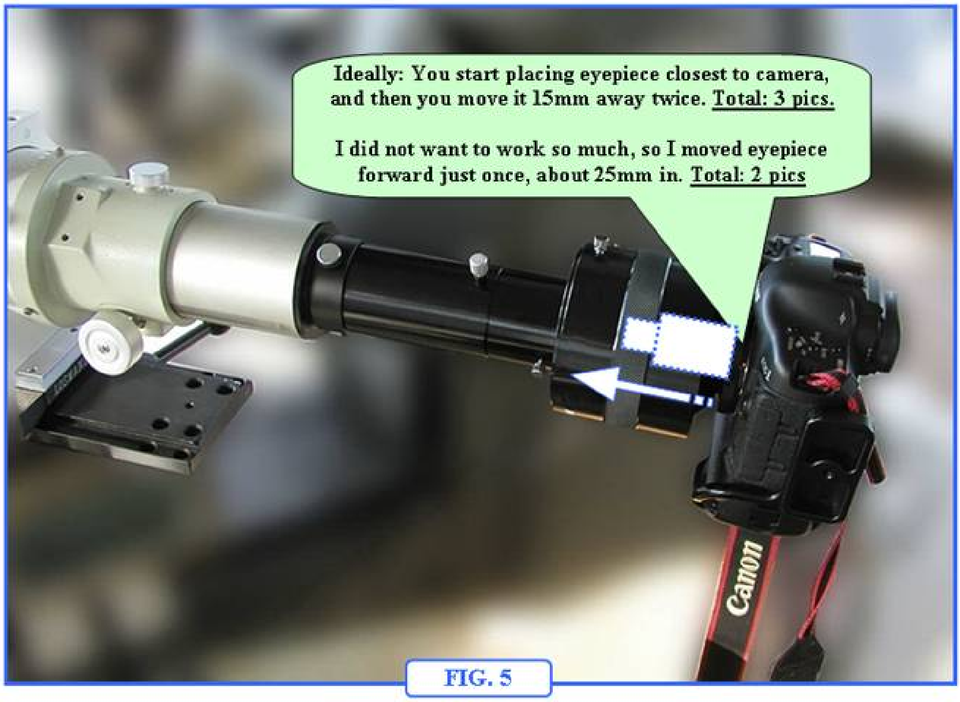


FIG. 5

Analyzing data with Imatest™ (4/7)

Time invested: **when you get used to procedure, you can "do" an eyepiece in about 4', depending on your CPU & HDD processing speed.**

We have to take our images to our analysis software for its analysis. I was given permission by Norman Koren (author) to publish captures from my Imatest™ version. I am running Imatest™ 2.3.8. Pro under Windows XP Proffesional (Imatest™ also worked nice for me under Windows 7 64 bits). Although it is an old and outdated version, I think the basis are the same against newer versions. You can take good advantage of these screen captures, but have in mind all of them belong to that (old) version. Imatest™ is in under constant improvement, so new versions probably will make your life easier.
Download your RAW DSLR images to some folder in your computer HDD. Do not change their names nor convert your RAW. Your eyepieces are identified by your camera's pic number, and Imatest™ can deal with DSLR's RAW images.

Let's open Imatest™. It opens up two windows. One shows internal processing under MS-DOS and the other is our Graphical Usar Interface itself. We will use this GUI (Fig 6).

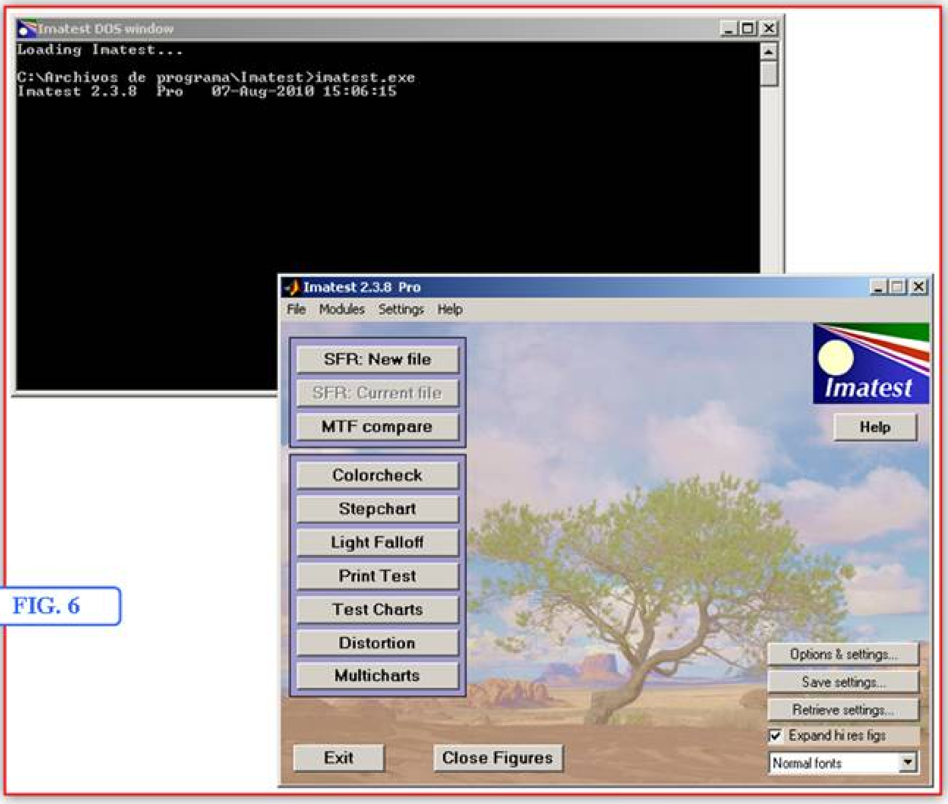


FIG. 6

Click "SFR: New File", and another window will pop-up (Fig. 7). I have 2 pics per eyepiece (remember ideally you may have 3 pics.) You may choose whichever you want. Double-click on it for Imatest™ to load it.

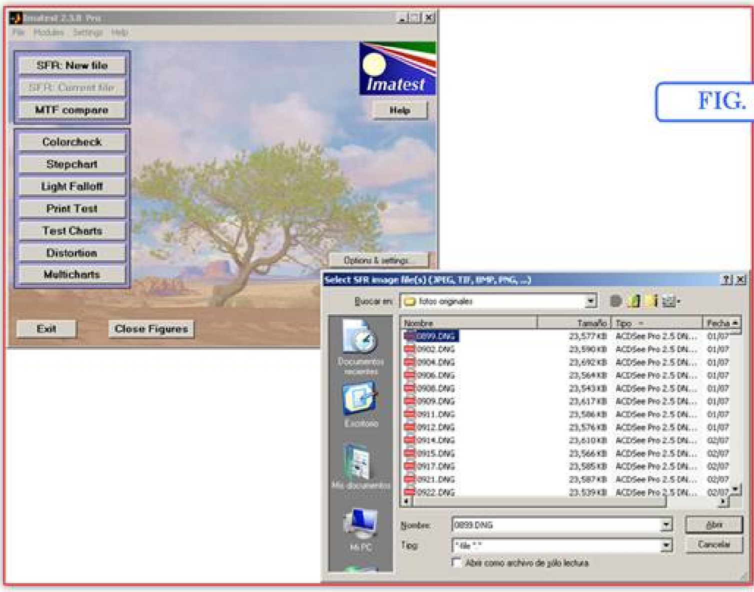


FIG. 7

Another window will pop-up (Fig. 8). Imatest™ uses "Dcraw" to convert your RAW image to universal TIFF format. Here you set White Balance setting to "Camera, if available". You also tell Imatest™ your DSLR's color space (see your camera's manual to know this information, mine was "sRGB"), and 24 or 48bits conversion. My camera's RAW bit depth is 48bits, but you can check this out trying to open your RAW image with any photo editor (Photosop, ACDSEE, etc..) and have a look at "image details" or "properties". If you choose 48 bits, make sure you set Gamma to 1 in next screen (see step 6).

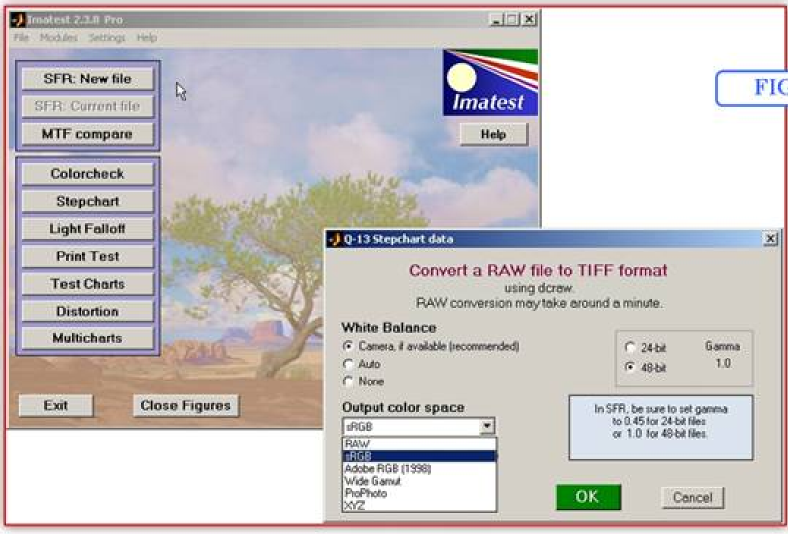


FIG. 8

In next window, Imatest™ asks for points of analysis, each named by Imatest™ after "ROI" ("Region Of Interest".) When low magnifications are involved –depending on scope and eyepiece being tested– centered "star" does not cover all of our FOV, so you can only choose analysis points up to the central star diameter size, whatever that is. This means it would be a good idea to modify this custom-made chart to include bigger 8 segments stars if you are interested in analyzing off-axis performance (Fig. 9 VS Fig. 10). Moreover, as Fig. 12 "hints", ideally we should ALWAYS have our centered star filling FOV.

Hint: *If you introduced points earlier, Imatest™ "remembers" them and it asks if you want to use same ROIs as previous image. You can only use them in some situations. If you carefully centered your star throughout the data collection process, and magnification is not much different from previous image, points will match closely. However, I advise you too introduce new ROIs on each new picture to be analyzed.*

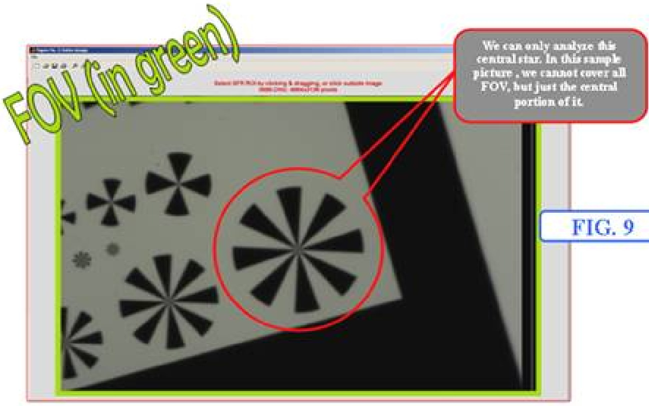


FIG. 9

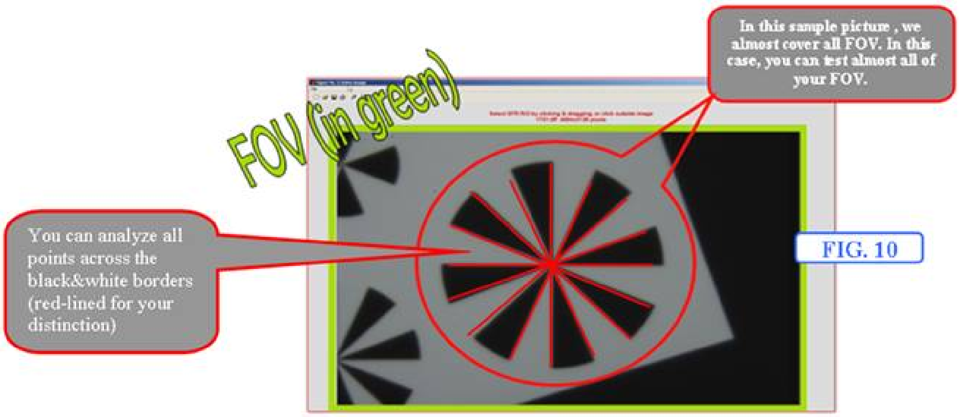


FIG. 10

If your sampled picture lets you analyze the entire FOV (star fills all FOV), here it comes your decision. What portion of your FOV do you want to analyze? You want to analyze the overall response of your eyepiece? Choose dozens of points, all over the FOV. Do you want to analyze off-axis, middle-axis and on-axis behaviour? You can do that too, doing 3 separated analysis procedures, for example. Your analysis can be so broad as your imagination. Now you may understand why 8 segments star is preferred over a 4 segments star or square: you just have more points to analyze. But as I said throughout this report, my main concern is not off-axis system's performance, but on-axis performance in order to reach the highest resolution for eyepiece projection planetary work. So, I will choose on-axis points for Imatest™ to analyze them.

We get analysis points this way: take mouse and click&drag rectangles all around the black&white frontiers of the central star's segments. Place them all around, aprox. at the same

distance of the center of the star, following a "circle" (Fig 12). As you can see, I placed them at "middle" distance from the center for all of my tested stuff. This is not really "on-axis", (but it is less time-consuming). For subsequent image ROIs, keep this same distance regardles AFOV. The idea is to "study" the same points at the same distance from the center, regardless magnification/eyepiece involved. To properly keep the same distances in your whole eyepiece lot, you could print concentric circles in a transparent paper film, which you place –physically– on your your screen over the star's center, as a guide. This way you would always follow the same circle(s) perimeter to choose your analysis points, and those points would be placed at the same distance of star's center, regardless of magnification.
The rectangles should be drawn so that black&white borders are placed within them (Fig.11). If you do not choose them correctly, Imatest™ will usually not admit it, and it make you repeat the rectangle. Each time you draw a rectangle, a zoomed window pops up which lets you refine rectangle position and size. It also lets you discard actual point ("no, try again"), discard all process ("cancel"), keep on choosing points ("yes, select another region"), or finish our choosing process ("yes, continue".) Do NOT hit "yes, continue in express mode."

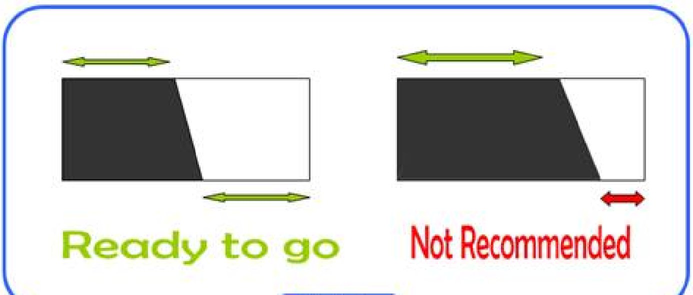


FIG. 11

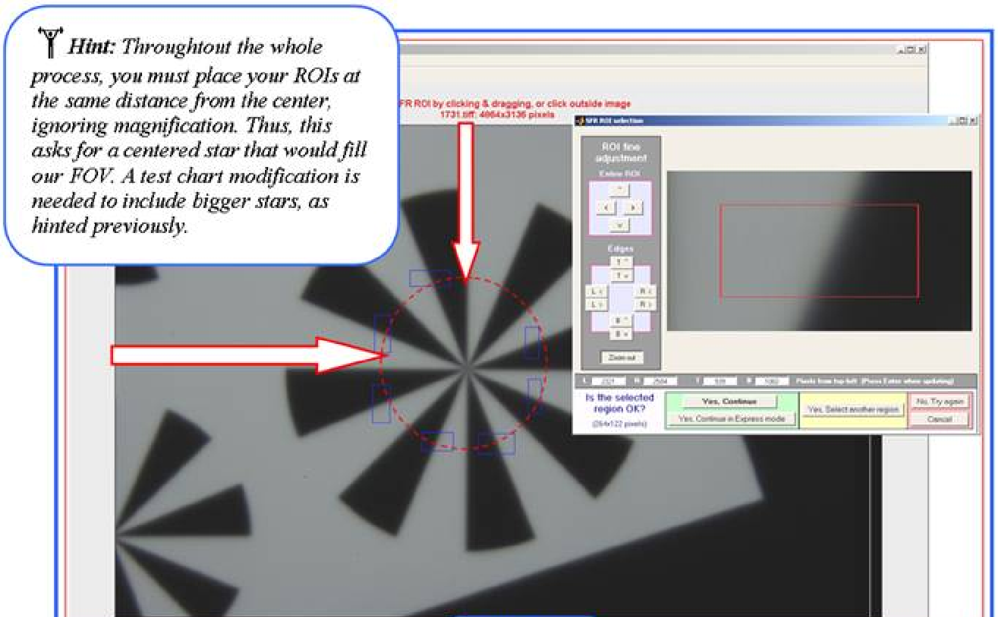


FIG. 12

In next window, we must introduce some data (Fig. 13):

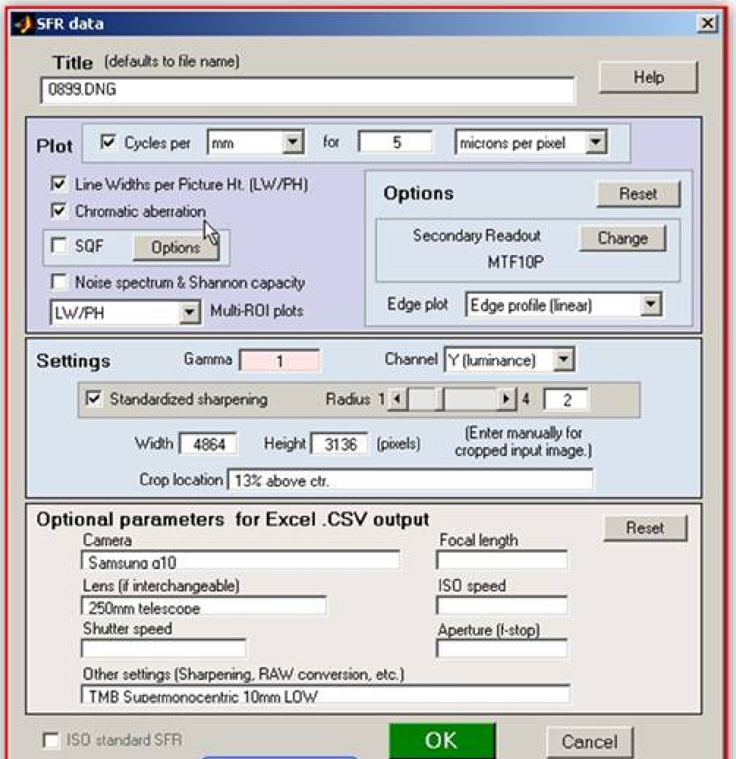


Fig. 13

Plot: Introduce the size of your CCD's pixels. I chose plot scale as "cycles/mm", and secundary as "Line Widths per Picture Ht". The later one lets you compare images taken with different CCDs. Check "chromatic aberration" analysis if you want to know how good your glass deals with colours. You can also play around with some other options, but I want to keep it simple. Click "change" under "options" tab and choose your secondary readout. Imatest™ can give you detailed data all across the spatial frequency domain. I chose just to deal with data at MTF50 (resolution at half the contrast domain) and 10% Peak MTF frequency (a good indicator of contrast levels and fine detail correlation, Fig. 14)

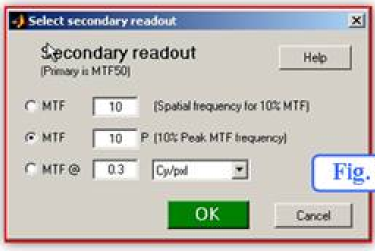


Fig. 14

Settings: Set Gamma to 1 if your raw image was converted to 48bits. Check "Standarized sharpenig." This allows to Imatest™ to compensate for loss of sharpness due to any camera's processing engine or bad focusing. We will later know the percentage of improvement your system can achieve through this digital technique. My camera's processing engine did some serious softening.

Optional parameters for Excel .CSV ouput: you just write down here details of your hardware which will appear later in an Excel file Imatest™ writes for us. Do not worry much about this.

Imatest™ analyzes the first ROI, and then pops up a window asking for data to be saved, its placement and main file name (Fig. 15). I have played around with these results, and I just checked what you see. It is what I found useful and not recurrent. Choose your results directory and leave "results root file name" as default. Imtests names it after picture #, and that's what we need (remember we have a sheet of paper with picture # along with eyepiece being tested.) The first 4 rows must be checked to save plots for each point. The last four ask is raw (numeric) data to work in worksheets. Unfortunately, my Imatest™ version do not save "averaged" plots or "averaged" data, so each of the ROIs has his own plot, independently, and later on you have to combine data to calculate the average of those ROIs we selected earlier (new versions may vary!). You also check "close figures after save". When you are finished, hit "Yes", and Imatest™ will begin to make same calculations for rest of ROIs.

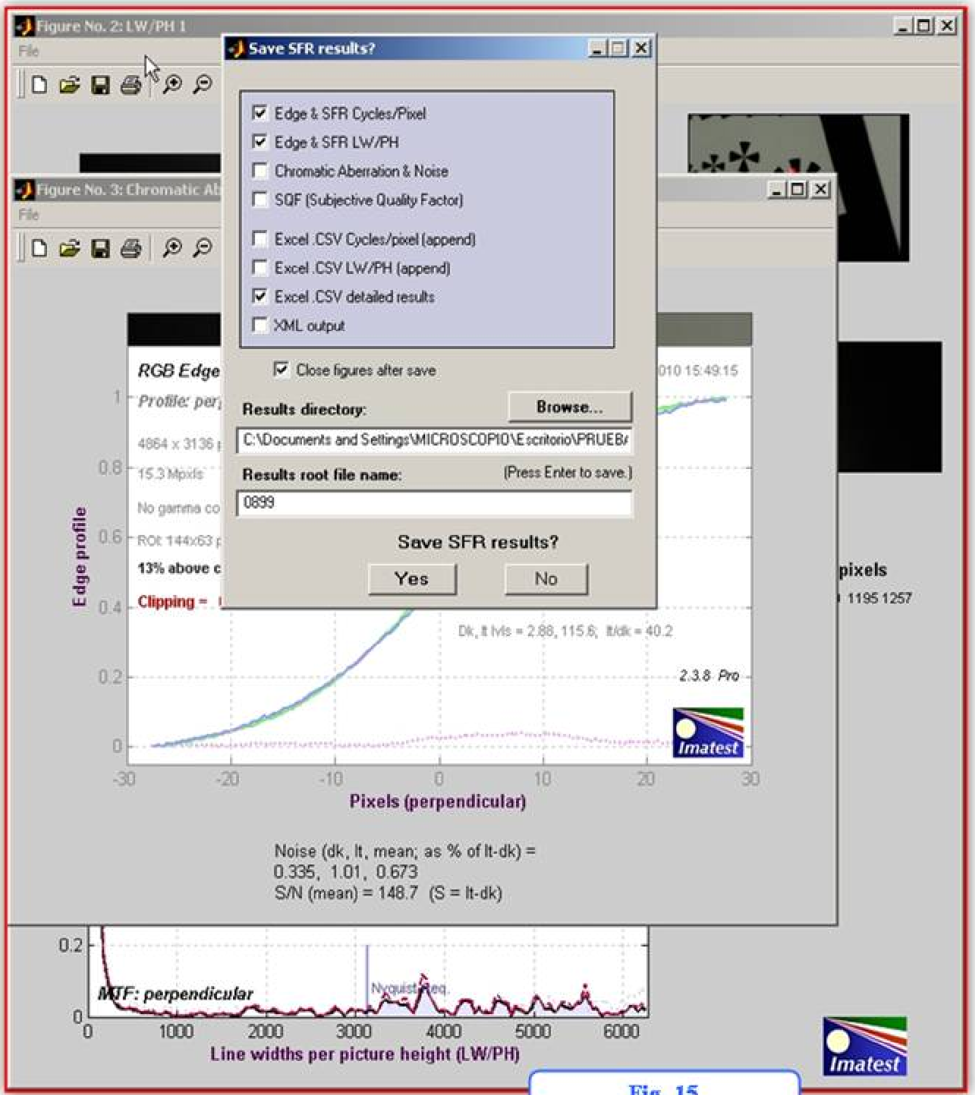
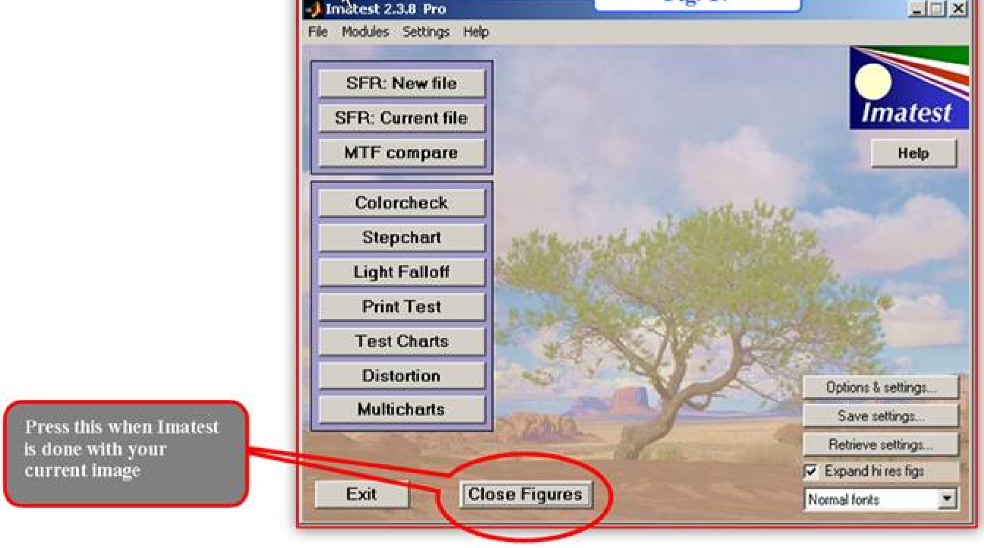


Fig. 15

When done, Imatest™ will present you a new window asking for further saving possibilities (Fig. 16). Just check the last one, “Excel .CSV multiples ROI summary” and click on “Yes”.

Click on “Close Figures” at the main Imatest™ window to begin new image analysis (Fig. 17). Go on with the rest of images (doing steps 3-8 with each image till you are done.)

Fig. 17



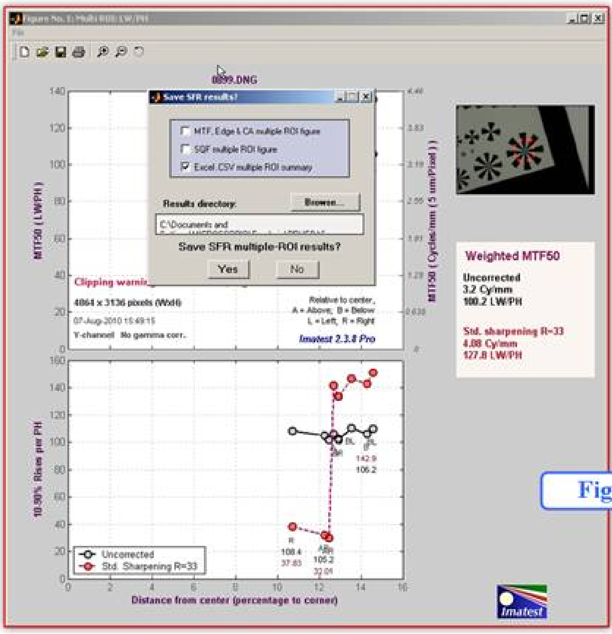


Fig. 16

Compilling and organizing data in Excel (5/7)

This is quite weary by itself, and I think Imatest™ latest versions can make your life much easier here. I am telling you how I did this data compiling with my old Imatest™ version and Microsoft Excel.

We open our "results" folder. Get into "detailed view" mode ("view" menu), you just click on "modified date" top column header and "file type" top column header to arrange our data files to find and open them the easiest way. This sorting out allows us to separate Imatest™'s figures from raw data and arrange them in numerical order (numerical order keeps same numeration as our DSLR picture #). Then we scroll down till we reach data files (*.csv files), and we select all those files that belong to the same image (in our sample, all files starting with "0899", see Fig. 18). Then we open them by hitting ENTER keyboard key once. Microsoft Excel opens them.

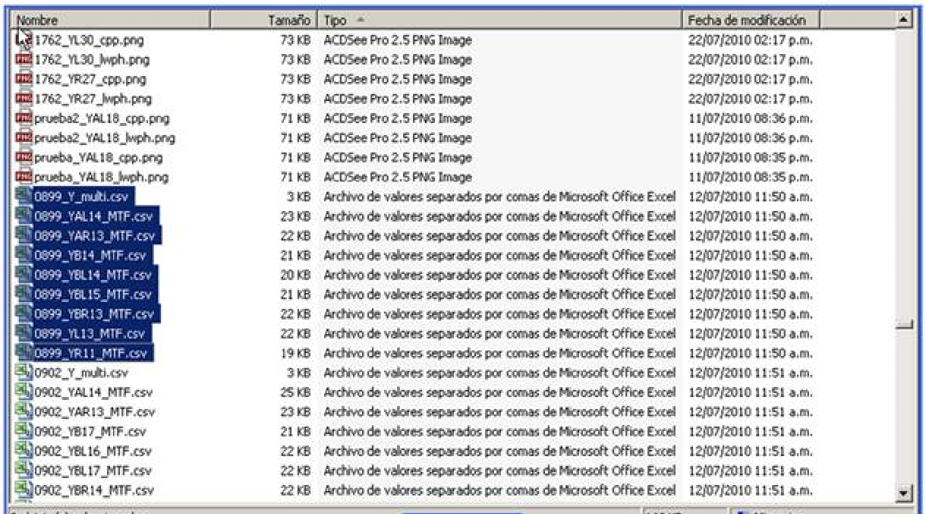


Fig. 18

We have to copy our intended data from these (now opened) files and paste them on a new Excel file. As you have noticed, just one of the *.csv files has the word "multi" on its name. The rest of them is detailed data from EACH point (each ROI) that we selected. Usually, we would have 9 files (multi + 8 detailed ROIs). Sometimes Imatest™ cannot correctly analyze ROIs becouse of bad angles (anything getting near to 45º would make Imatest™ go crazy, and ignores that ROI), so you may find only 7 detailed ROIs *.csv files (multi + 7 detailed ROIs), and maybe even less. Don't worry about this.

On the "multi" file you opened, you will find something like Fig. 19. Copy those cells, close the *.csv file, and paste data into your empty Excel file.

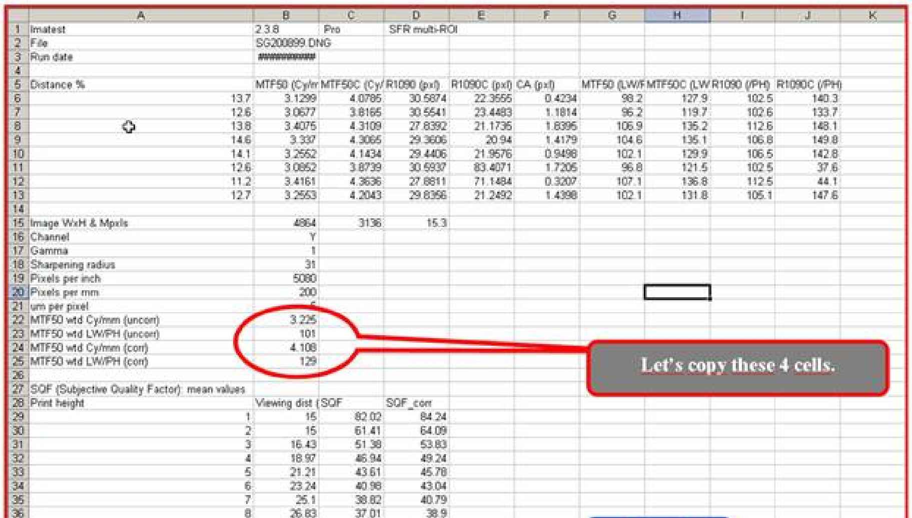


Fig. 19

Let's go, one by one, to the individual detailed *.csv files.Go to the end of each worksheet and you will find something like Fig. 20. Copy those cells, close the *.csv file after copying it, and paste them on a different empty temporal worksheet on your Excel file. Do this for each ROIs *.csv, and you will get something like Fig. 21. At the end of of this data copying process, we will have what we may call "8 columns" (I coloured the bottom, in total that's 24 excel columns). We need to do the "arithmetic mean" of those values, and present them at the end which you can see in Fig. 21 at the right end, in green highlight.

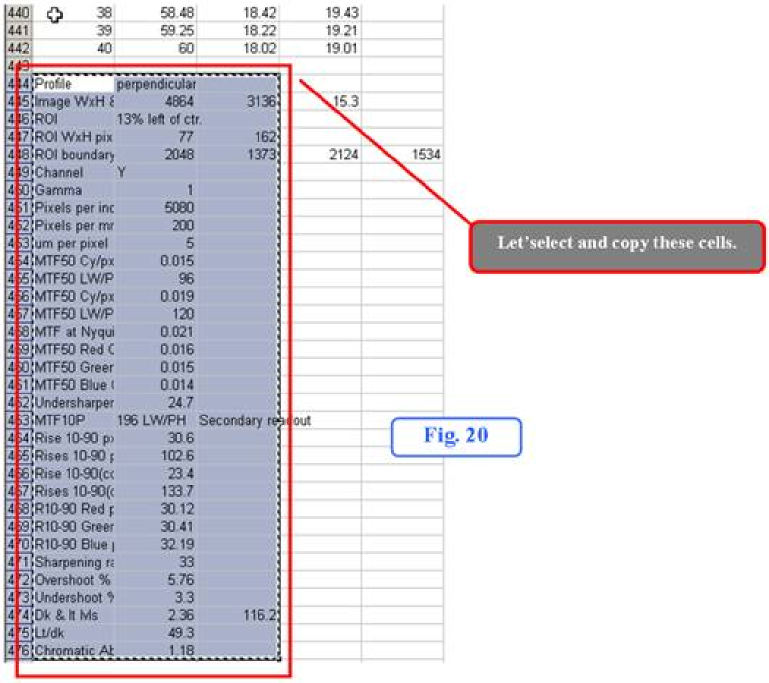


Fig. 20

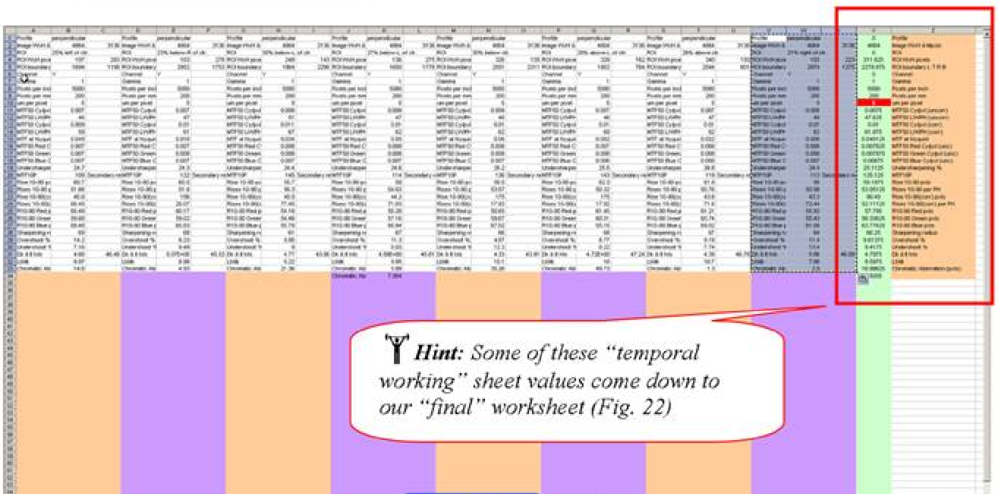


Fig. 21

For space-wise reasons, I will just say I made "internal links" in Excel to collect all data, so that those cells in Fig. 21 worksheet would automatically be copied over to other worksheets and all fit nice. This is not an Excel guide, so please, understand this summing up. You have to do your homework and learn to use basic Excel notions. At the end, I have this FINAL worksheet:

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	EYEPIECE MODEL	EYEPIECE fl METHOD 1 (LONG)	PIC #1	ZOOM TAMAÑO ESTRELLA	MTF 50 cy/mm	MTF 50C (lw/ph)	MTF 50 cy/mm corregido	MTF 50C (lw/ph) corregido	MTF 10P MEDIA PIC #1	MTF NYQUIST PIC #1 (x100)	CHROMATIC ABERRATION Meaning (now obsolete): Under 0.5: insignificant. 0.5-1: minor; 1-1.5: moderate; 1.5 and over: serious.	RISE 10%-90% (THE MORE THE BETTER) (MEDIA COR-UNCOR) PIC #1	UNDERSHARP (MEDIA) PIC #1 & 2 + DIGITAL IMPROVEMENT ROOM
2	Authorized eyes-only	32.00	906	21	7.134	224	8.807	276	289.25	1.45%	0.78	129.23	24.36
3	Authorized eyes-only	32.00	904	29	6.614	207	8.236	258	442.25	1.45%	0.16	238.14	26.21
4	Authorized eyes-only	26.00	1022	36	7.309	229	9.714	305	549.63	3.06%	0.53	276.96	26.74
5	Authorized eyes-only	40.00	1034	39	5.070	159	6.627	208	504.25	3.27%	0.67	183.02	27.74
6	Authorized eyes-only	26.15	908	43	3.625	114	4.580	144	243.13	2.09%	2.04	117.25	24.94
7	Authorized eyes-only	26.00	1026	44	6.505	204	8.884	279	556.88	2.37%	0.56	229.97	27.60
8	Authorized eyes-only	20.83	1036	46	6.437	202	8.413	264	554.71	1.23%	0.10	240.40	26.64
9	Authorized eyes-only	40.00	984	47	5.215	164	6.765	212	347.00	1.41%	1.68	194.91	24.35
10	Authorized eyes-only	39.65	922	48	4.693	147	6.112	192	319.13	1.99%	0.65	177.52	27.29
11	Authorized eyes-only	30.97	988	49	5.699	179	7.615	239	466.00	3.04%	0.38	202.18	27.36
12	Authorized eyes-only	38.52	917	50	5.457	171	7.391	232	513.13	2.18%	1.30	211.47	27.60
13	Authorized eyes-only	24.22	1017	51	5.587	175	7.383	232	470.38	1.66%	0.78	212.55	26.88
14	Authorized eyes-only	25.66	1196	51	4.626	145	6.050	190	372.71	1.54%	0.98	164.95	25.96
15	Authorized eyes-only	35.85	914	52	4.770	150	6.200	194	351.63	1.64%	0.87	170.91	25.78
16	Authorized eyes-only	26.15	909	52	4.439	139	5.595	175	261.13	1.06%	0.95	146.93	25.91
17	Authorized eyes-only	25.84	1203	54	4.168	131	5.507	173	334.00	1.69%	0.57	150.82	27.29
18	Authorized eyes-only	24.72	1130	54	5.108	160	6.659	209	464.88	2.01%	0.18	192.28	26.41
19	Authorized eyes-only	25.17	971	54	5.043	158	6.642	208	444.13	2.14%	0.23	190.93	26.88
20	Authorized eyes-only	40.00	986	55	4.394	138	5.643	177	318.63	2.20%	2.25	166.03	26.69
21	Authorized eyes-only	25.35	1175	56	4.866	153	6.380	200	457.13	1.25%	0.16	172.40	26.83
22	Authorized eyes-only	24.43	1144	57	4.552	143	6.006	188	439.63	1.63%	0.21	174.63	26.97
23	Authorized eyes-only	26.32	1072	57	4.804	151	6.431	202	466.06	1.93%	0.14	183.39	26.16
24	Authorized eyes-only	25.00	1108	57	5.400	169	7.200	226	505.66	1.30%	0.40	204.56	26.95
25	Authorized eyes-only	20.83	1039	57	5.046	158	6.639	208	462.14	1.04%	0.14	191.26	26.41
26	Authorized eyes-only	24.00	1112	57	4.407	138	5.764	181	366.00	1.30%	0.21	145.99	26.45
27	Authorized eyes-only	24.86	1029	58	4.635	145	5.979	188	392.86	1.01%	0.22	167.73	25.91
28	Authorized eyes-only	25.15	1049	58	4.974	156	6.476	203	419.38	1.98%	1.02	158.97	25.78
29	Authorized eyes-only	39.85	925	58	4.964	156	6.562	206	403.25	2.28%	1.47	188.64	26.47
30	Authorized eyes-only	24.13	1168	58	4.840	152	6.352	199	419.88	1.36%	0.20	183.53	26.86
31	Authorized eyes-only	24.79	[illegible]	59	4.709	148	6.356	199	465.00	1.66%	0.44	179.65	24.94
32	Authorized eyes-only	31.13	934	59	4.249	133	5.358	168	289.63	1.83%	0.34	140.37	27.14
33	Authorized eyes-only	31.96	942	60	3.097	97	3.941	124	187.63	2.10%	1.24	97.85	26.17
34	Authorized eyes-only	24.16	1091	60	4.396	138	5.856	184	391.71	2.23%	0.33	159.10	27.13
35	Authorized eyes-only	38.52	921	60	4.979	156	6.560	206	359.50	1.39%	1.24	190.83	27.75
36	Authorized eyes-only	30.97	994	61	4.997	157	6.660	209	437.00	2.13%	0.82	186.13	26.69
37	Authorized eyes-only	24.80	1064	61	3.786	119	5.110	160	435.57	1.79%	0.36	138.37	26.38
38	Authorized eyes-only	23.18	1225	61	3.703	116	4.898	154	301.86	2.04%	0.77	125.11	24.93
39	Authorized eyes-only	41.31	911	62	2.821	88	3.625	114	172.25	2.70%	1.32	90.88	12.48
40	Authorized eyes-only	24.31	1085	62	[illegible]	[illegible]	[illegible]	[illegible]	373.38	1.59%	0.70	155.91	26.93

Fig. 22

Data at columns goes as follows:
A: Eyepiece model.

B: Eyepiece focal length

C: Hyperlink to TIFF picture file on your HDD, which will be opened by your photo edition software. Useful to have a peek at any time at your original file!

D: Centered star diameter size, as measured with a ruler on your monitor screen. This needs further explanation, and this step is crucial. In order to keep eyepieces on an equal ground, and minimize as much as possible the effects of eyepiece focal length (see next chapter, "general conclusions", point 1), we must give priority to magnification. Thus, data must be assorted by "relative magnification." That's why we took 2-3 shoots of each eyepiece placed at different distance from CCD. We get "relative magnification" by opening each of our TIFF files with our photo edition software (I use ACDSEE) and be inspected under same "zoom" (for instance, 80% zoom), and then measure with a ruler or caliper ON THE SCREEN (physically, literally) the diameter of our centered star. I measured it in milimeters, but you can use whatever measure of length. Write those measures down some place in your Excel worksheet. There is a problem here: we know that stars imaged are not the same size all across our eyepiece collection. No worries... as we know which star you were imaging on (you remember?). If we know the real size of the centered star, we can compensate for different star sizes taking a "reference star" (Fig. 23).

Practical example: Let's say the biggest star pictured in all our testing procedure across all of our eyepiece collection is 10mm REAL SIZE (as measured on the chart).

Formula used is:

Magnification (column D) = Caliper * (Big / RSz)

Caliper= Measured diameter of star as taken with caliper on our screen computer
Big= Biggest star size used across all procedure as measured on chart
RSz=Real star size as measured on chart.

Eyepiece model	Measured diameter of star as taken with caliper on our screen computer	Real star size as measured on chart.	Magnification (Column D) Results rounded off!
Eyepiece A	20 mm	8 mm	20 * (10 / 8) = **25**
Eyepiece B	20 mm	6 mm	20 * (10 / 6) = **33**

You understand what we do? We have to think all images are taken under the same star. As this is not true –becouse we have used different stars– we have to compensate with a reference star. For easy calculation, this could be the biggest (or the smallest one.) Remember results are rounded off.

In our example, as measured on our screen, both eyepieces show 20mm centered star diameter size, but they show different stars! As you have guessed, Eyepiece B is magnifying our optical train more than Eyepiece A. If we do not "compensate", it would be like comparing oranges to apples.

Fig. 23

E, F,G,H: data from "multi" csv file that we talked about in step 3). These are MTF50 values at two different measuring units (cy/mm and lw/ph), "raw" (not digitally sharpened), and "corrected" (digitally sharpened to partially overcome bad focusing and camera's engine processing). According to Imatest™ web site, lw/ph units would allow us to get similar results if we test same hardware under different CCD sensor. I have NOT experimented with this, as I have always used the same camera.

I,J,K,L,M: all of these are extracted from the "arithmetic mean", that column highlighted in green you see in Fig. 21. Each of them is an "average" of our 8 ROIs.

I: "MTP10P" cell.

J: "MTF at Nyquist". This is the contrast reached at "Nyquist point" (which is the max. resolution that can be reached with your specific camera), and I did 100x. Not very useful maybe, but I just wanted to have more data at hand.

K: "Chromatic Aberration" values, very useful to know how your glass copes with colors. The higher, the worse. In more recent versions of Imatest™ this analysis is improved.

L: "Rises 10-90 (corr) per PH". The more, the better (for theory behind this, visit Imatest™ web site.) There are available several measures of this. I chose "digital corrected" and "per PH" out of personal choice.

M: "Undersharpening %". I chose this analysis value becouse it gives you a hint of the % improvement in resolution you can achieve in your "digital room". It mainly talks about your camera's softening internal processing engine.

Repeat steps 1-6 for your next image, whether it belongs or not to the same eyepiece (remember we take several images for the same eyepiece).

Once you are done with all your glass, to pinpoint your winners you have to rearrange (sort out) your whole Excel worksheet by "column D" (standarized star diameter as measured with calipers). This column is our "grouping reference", becouse we can only compare eyepieces of similar standarized star diameters (at this point you should know it means same absolute magnification / focal length). As a rule of thumb, I found the greater the number at "column D", the lower the resolution (at "column E", for instance). If we come up with a unexpected raise up in resolution, we have a "winner". We can establish "winners" taking "column D" groupings (for instance, 20-30, 30-40, 40-50, or whatever numbers you have there) As you can see in Fig. 22, I highlighted in strong green (E-H columns) those eyepieces that really stand out ("winners"), and in light green the "excellent" ones.

Congratulations! We are finished...

Dealing with data: summing up & useful conclusions (6/7)

***Huh... what are you doing here, pal? I knew you were going to jump off to this section at once.* :)**
For those blessed people who read this report through and lastly reached this point, hats off to you; let me make you a polite reverence and invite you to write an email to me telling me how much painful that was to read all those **beep** boring pages to come this point.

Details of my hardware

I tested almost all of my actual glass collection through 3 different telescope designs (Televue Ranger 70mm air-spaced doublet refractor, Meade ETX 105mm Maksutov-Cassegrain reflector, a Meade Smith-Cassegrain 10" reflector and a microscope Navitar 6000 Zoom design. I started off to test under the Navitar macro lens with printed chart, but methodology has evolved with years, and at this point I can only speak with confidence of my last testing benchmark for reasons already detailed in procedure iteself. This testing was made on the freshly collimated Smith-Cassegrain 10 inch design. It took me about 10 days of dedicated hard work –I had to literally get into bed at sometimes to rest– to achieve the goal of collecting and extracting results, so I recommend you never do that youself. Get this easy, slow, and enjoy yourself. If you test 15 eyepieces you will be happier than me, frankly. Now, smile: here it comes *the secret*...

What about the eyepieces themselves?

My eyepiece collection is composed mainly of microscope eyepieces. Here and there through the years I picked up "word" that some experienced observers used microscope eyepieces for high resolution work, and that some of these were "top performers", even in contrast with top dedicated eyepieces in the telescope world. Why not trust on their word? I just saw this as an opportunity to clutch my "poor-man" hands on high resolution glass, as I could not afford to pay $3000 for Zeiss Abbe Orthoscopic collection, but I could pay $60 for *microscope* Zeiss glass. As I wanted to test them against some telescope stuff, I got some telescope eyepieces on the way making a total of 20 telescope eyepieces vs 85 microscope glasses, just to be able to have *some overall* comparison ground. Do not be fooled: highly regarded telescope vendors on Germany sells these "microscope eyepieces" with custom-made 1.25" adapters for high $$$, so they *seem* to work and sell. Using microscope eyepieces on telescopes dates back from dinosaurs age, but I do think microscope glass is seriously under-rated and disregarded as such. The good stuff provides an amazing *performance VS cost* value. Just a word of caution here... 50º is "wide angle" in the microscope world. If you are for wide angles, ask Al Nagler, but this was not a handicap for me, being my main interest "ultimate on-axis resolution."

Where can I get my microscope eyepieces, and what price do I have to pay?

99% of my assorted glass is branded either Zeiss, Olympus, Nikon or Leica (Leitz). So, I am not "brand" envious. I have the result of the best coating and polishing technology at the tips of my fingers. I got most of them through Ebay within about a 4 years span time. Online auctions let you find new, like-new, nice used and badly used stuff, but I never paid really high $$$ for any unit –I stuck myself to "limits"–, and that's before present economic downturn. As now (May 2012), you can get real bargains. You could be getting $500 performance for $50 a piece!

Conclusions not statistically meaningful

These are MY results and they are strictly limited to my experience and hardware. I got into testing to find sharp glass for high resolution eyepiece projection. So, these conclusions MAY NOT fit yours AT ALL, nor being your field of interest.

These results are limited to my small collection, and they could very well be *shifted* becouse my gross eyepiece collection is not statistically meaningful at all. Read again that part, please, and bear in mind that I mean it.

This method you just read is subject to a lot of refining, and I wholeheartedly invite you to do so (and share it with me when you have time.)

General optical system's behaviour conclusions

Resolution *usually* gets lower as we increase system's focal length, be it decreasing eyepiece's fl, or increasing CCD-eyepiece distance. That's the reason to get two or three measures with different Relay Ratios (R_{ratio}= (D – $Eyepiece_{fl}$) / $Eyepiece_{fl}$). It allow us to compare eyepieces in a more reliable way, as we can play with same eyepiece over different magnifications (not comparing "oranges" to "apples"). Even though the general rule is lower resolution as we get CCD away from the eyepiece (increased CCD-eyepiece distance, increasing magnification), *some* eyepieces gave greater potential the other way (this ocurred on 13% of eyepieces.)

Whether you are a *believer* or not, you may like to asset with your eyes if software results correlate to visual results. In my opinion, maybe software could "splits hairs" beyond human acuity, but I have visually checked out differences 3% in relative sharpness at two different eyepieces. It is said human eye to perceive about 1% contrast difference under average "mesopic illumination" (such as planetary observation, http://www.telescope-optics.net/eye_spectral_response.htm), even less under photopic conditions. If our software sees some differences, our eye will also perceive them under ideal conditions (almost perfect seeing) almost 100% of times. Even though visual aspect is not my main concern for bench-testing, I could assert differences are real.

Refractors are much sharper than reflectors, and the "sweet spot" was found at *low-moderate* magnification, where you can enjoy some of the sharpest and more contrasted views.

Specific stuff-related conclusions

Be careful with barlows. Not all barlows seem to be intended for high resolution work. My optical train performance was **** through my crystal clean brand new Celestron APO barlow (no eyepiece in it), which is a "median level" barlow. Resolution was quite bad, but chromatic aberration was a pain in the neck. I know there *must* be some right barlow hanging over there, but it hadn't the privilige of being tested by me yet (ha!). It could be an AP Barcon barlow is all you ever needed, but I had not the opportunity to meet such a highly $$$ stuff in all of my life.

My brand new TMB 2nd run 10mm Supermonocentric was *not* sharp. However, I found amazing its light throughput and their *pure-clean* view. This means I found it much suitable for DSO observers. If I were a galaxy hunter, I would run for the longer fl units and get a pair of each and be a happy man –which is exactly the market tendency, by the way. I don't think my specimen was a "lemon", but just the way it is. Anyways, somehow it balances its lack of sharpness (probably due to improper polishing?) with their great light throughput. Small scopes and refractors could take better advantage of them than reflectors.

My like-new ortho Zeiss CZJ 16mm (not the ZAO nor the Monocentric one) performed nice. Not top-winner, but nice. This could mean the other series perform nice too. At least the medium $$$ glass do not "lemon" the on-axis view out and they stand by its reputation.

Some "ball lens" could be the ultimate weapon for on-axis performance. Besides, they snap focus like a charm. You may have followed that word spreaded recently over these in CloudynightsTM forums and the way some *fanatics* built their own specimens out of pure, uhhh... fanaticism. Well, they were proved right according to my tests. My brand-new 10mm Edmund Optics sample worked *best in its class* and the ball-mania could be an all-around solution to get cheap glass and obtain top performance at the same time... which is something really hard to achieve.

The seriously under-rated Olympus GSWH microscope series are really nice on-axis performers at those "wide" (50º) angles. You cannot go wrong with these for planetary usage. As stacked up against my collection, I found them this way:

Olympus 12,5mm (GSWH 20x): great	Olympus 25mm (GSWH 10x): great
Olympus 6,7mm (GSWH 15x): good	Olympus 8,3mm (GSWH 30x): good

Possibilities in testing optics with Imatest™ are endless... just do it!!

My Assorted Jewels: "Enchantment Under the Glass" dance (7/7)

Huh... what are you doing here, pal? I knew you were going to jump off to this section at once. :)

Given my *weird* non-statistically meaningful eyepiece list (see page 28), I will only detail my top performers... and let you do your homework. You may not agree with this and get mad at me, but I find it completely irrelevant to publish my eyepiece list details. You should take up the banner to objectively assort your glass yourself, and then share your results with the amateur community.

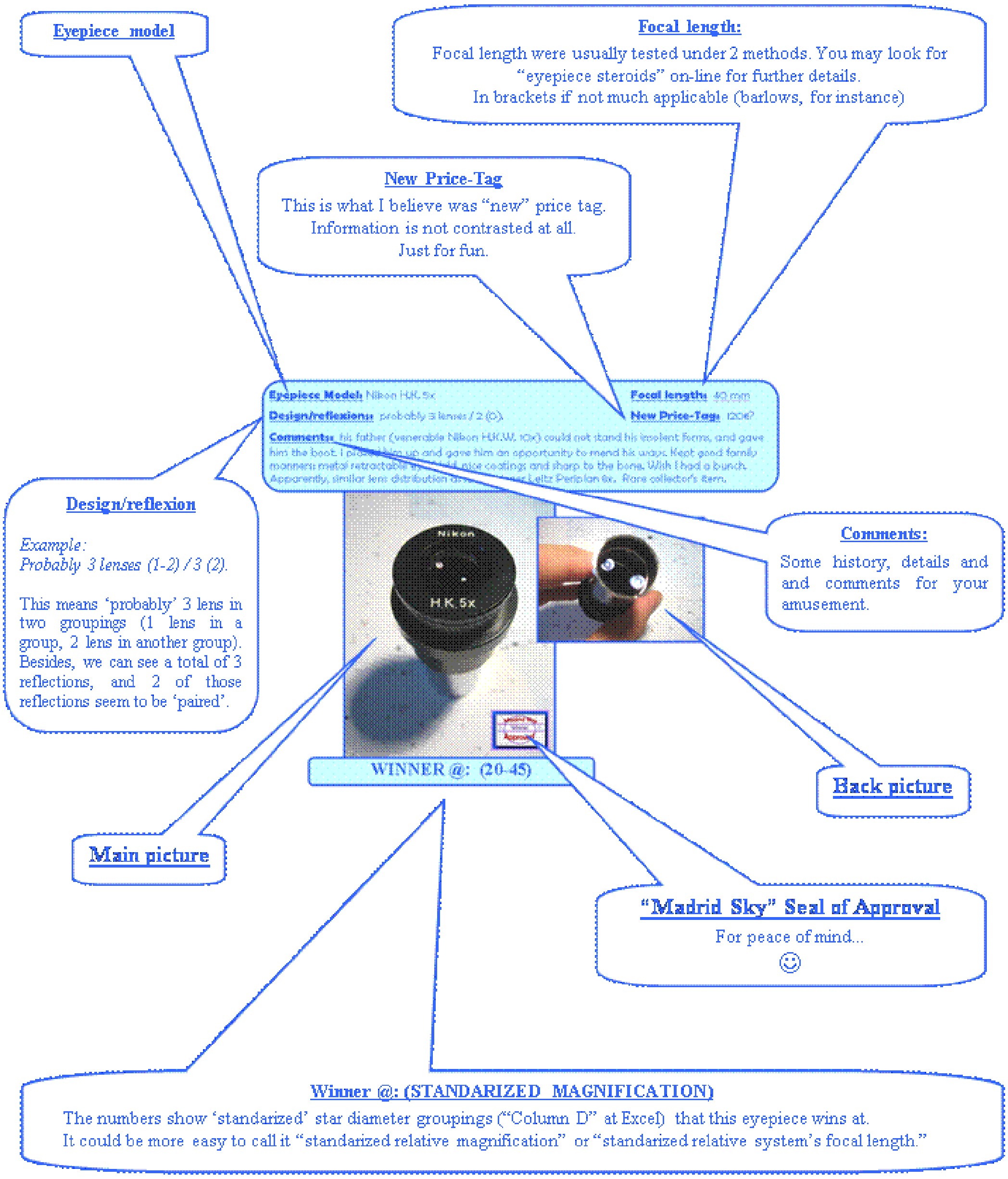
The ball is in your court.

List of contenders (winners in blue)

B&L 10x WIDE F	Nikon SMZ-U UW10x	Olympus WHK 10x/20 L
Baader 7.5mm Plössl	No-Brand (Nikon?) BW10x	Olympus WHK 15x L
Celestron 6mm Plössl MULTICOATED	No-Brand 4mm BAD PLASTIC	Olympus WHSZ 20x
Celestron 9mm Plössl MULTICOATED	No-Brand Huygenian 10x	TMB Supermonocentric 10mm (2nd run)
Celestron BARLOW 2x APO	No-Brand Huygenian 15x	Vixen ORTHO T 9mm
Edmund Optics BALL 10mm	No-Brand HUYGENS 9mm	Zeiss A10x/14
Edmunds Optics BALL 8mm	No-Brand KELLNER 10mm WIDE ANGLE	Zeiss 1026-548 PL10x/23 HighPoint
JML BALL 10mm	No-Brand KELLNER 12.5mm	Zeiss 12.5x / 15
JML BALL 7mm	No-Brand KELLNER 17.5mm	Zeiss 12.5x OPMI SERIES
Leica/Leitz 10x	No-Brand KELLNER 18mm	Zeiss A16X/12.5
Leica/Leitz 10X/21B	No-Brand KELLNER 25mm WIDE ANGLE FC	Zeiss A8x/16
Leica/Leitz 6X B	No-Brand KELLNER 6mm	Zeiss CPL W10x/18 HighPoint 464023
Leica/Leitz Periplan 10x	No-Brand ORTHO 6mm	Zeiss CZJ 10x 319770-9110.00 CZB 4879K99
Leica/Leitz Periplan 10x HighPoint	No-Brand RK 20mm	Zeiss FK10x
Leica/Leitz Periplan 6,3x M	Olympus P7x Bi	Zeiss Jena Ortho. CZJ O-16mm
Leica/Leitz Periplan 8x B	Olympus 10x	Zeiss JENA P10x/18 HighPoint
Leica/Leitz Periplan 8x HighPoint	Olympus 3M 24x BARLOW (Projector)	Zeiss JENA UNKNOWN 9.53mm
Leica/Leitz Periplan GF 12.5x	Olympus CWHK10x-T/18L	Zeiss K15x
Leica/Leitz Periplan GF10x	Olympus FK 6.7x 125	Zeiss K7x
Leica/Leitz Periplan GF25x	Olympus FK3.3x 125	Zeiss KPL 10x/16 464020-9902
Meade 25mm MA	Olympus G10x	Zeiss KPL 12,5x/12,5 HighPoint 464123-9902
Meade 32mm SP	Olympus G20x 12.2	Zeiss MF-PROJECTIV K 10:1
Meade 5000 SP26 Plössl	Olympus GSWH10x/22 HighPoint	Zeiss MF-PROJECTIV K 3,2:1
Meade 9mm MA	Olympus GSWH15x/12.5 HighPoint	Zeiss MF-PROJECTIV K 4:1
Meade SP 6.4mm	Olympus GSWH20x/12.5 HighPoint	Zeiss MF-PROJECTIV K 5:1
Nikon 10x/21	Olympus GSWH20x/12.5 HighPoint NO BARLOW	Zeiss MF-PROJECTIV K 8:1
Nikon 15x	Olympus GSWH30x/7-H HighPoint	Zeiss Ortho. 12.5x
Nikon 15x/14	Olympus NFK 5x L 125	Zeiss P25x / 8
Nikon 20x/12	Olympus P15x Bi	Zeiss PK10x/15,5
Nikon 33x	Olympus PE 3.3x 125	Zeiss PK16x/12
Nikon CF PL5x	Olympus PHOTO EYEPIECE 10x VEC	Zeiss PK20x

Nikon CFW 10x (RETICLE)	Olympus SWH10X-H/26.5 HighPoint	Zeiss PK32x/6,3
Nikon CFWE 10xA/18	Olympus SWHK 10X L	Zeiss PL 10x/20 HighPoint 444032
Nikon CFWE 15x/12	Olympus WF10x Bi	Zeiss PW 6,3x/25
Nikon CFWN 10x/20	Olympus WH10x/22 HighPoint	Zeiss W10x/21 455042
Nikon HK 5x	Olympus WH10x-H/22 HighPoint	
Nikon HKW 10x Bi	Olympus WH12.5x/16 HighPoint	

A short guide:



Eyepiece Model: Nikon H.K. 5x **Focal length:** 40 mm

Design/reflexions: probably 3 lenses / 2 (0). **New Price-Tag:** 120€?

Comments: His father (venerable Nikon H.K.W. 10x) could not stand his insolent forms, and gave him the boot. I picked him up and gave him an opportunity to mend his ways. Kept good family manners: metal retractable eyeshield, nice coatings and sharp to the bone. Wish I had a bunch. Apparently, similar lens distribution as lady-winner Leitz Periplan 8x. Rare collector's item.

WINNER @: (20-45)

Eyepiece Model: Ernst Leitz Wetzlar Periplan 8x / Highpoint **Focal length:** 30,97 mm

Design/reflexions: probably 3 lenses / 5 (2). **New Price-Tag:** 150€?

Comments: This shy slender lady is probably a Kellner, but she smiles at me and wants to remain a mystery. Robust and overall quality feeling. Internal field stop (between lens). Multicoated and very high eye relief. Gave also top results in earlier tests with other scopes. What a mysterious girl! Hum...

WINNER @: (46-52)

Eyepiece Model: Olympus Taiwan CWHK 10x-T / 18L **Focal length:** 25 mm

Design/reflexions: probably 4 lenses / 4 (2) **New Price-Tag:** 200 €?

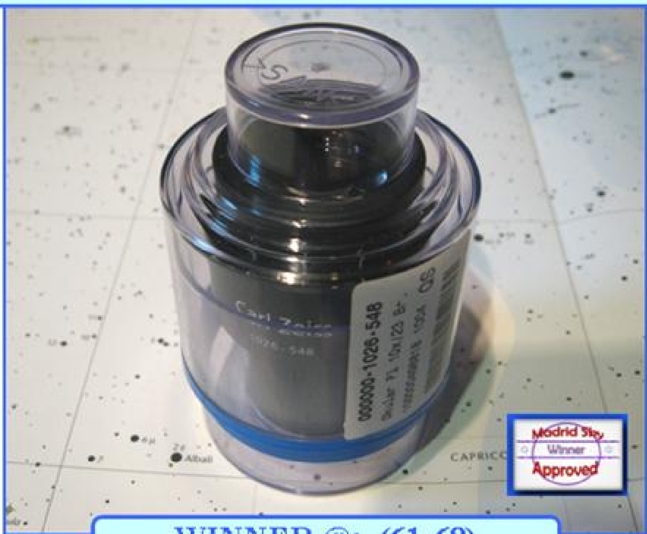
Comments: Very few "wide angles" (40-50º) slipped by, and this is one of them. This youngster is "Taiwan made", but that doesn't seem to really matter here. Quality feeling is Japan-made all through. Nice modern coatings and good eye relief. Pic made with eyecup off. This is a rare specimen and probably quite hard to come by. I got it off-line.

WINNER @: (53-60)

Eyepiece Model: Carl Zeiss 1026-548 PL10x/23 **Focal length:** 25mm

Design/reflexions: probably 3 lenses (1-2) / --- **New Price-Tag:** aprox. 1,000 €

Comments: This one here shows up you *sometimes* get what you pay for. I didn't pay 1,000 € for it, but this modern hi-tech glass has a kind of spell on it becouse it seems to dissappear when you look through it. I sound like Zeiss salesman, but I this one is just impressive. The lion king roars...

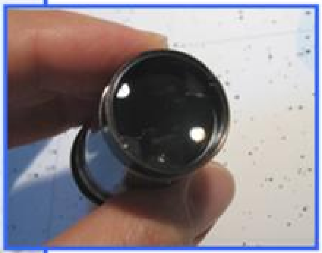


WINNER @: (61-68)

Eyepiece Model: Carl Zeiss Jena K7x **Focal length:** 31 mm

Design/reflexions: probably 2 lenses / 2 (0). **New Price-Tag:** Gift?

Comments: This dramatic piece of junk really surprised me. Definitely, this is Ramsden or Hyugens design. It seems to be laughing at you right in front of your nose. *How could it be...?* As it seems, chromatic corrected (K stands for that) enough to perform quite of a miracle.



WINNER @: (69-72)

Eyepiece Model: Leitz Wetzlar Germany Periplan GF 10x **Focal length:** 25.38 mm

Design/reflexions: probably 3 lenses (2/1) / 3 (2) **New Price-Tag:** 120 €?

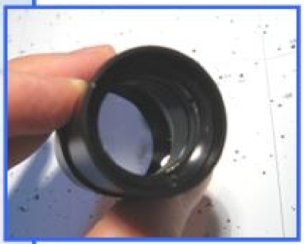
Comments: Vintage "wide angle" oldie that someone lost at the auction circuit and I rescued out of a bargained lot shipped from the USA. After carefully cleaning it, I had a hunch it would work at the scope. Seems to be a modified Kellner. Nice coatings too and very generous eye relief.

WINNER @: (73-77)

Eyepiece Model: Nikon 10x/21 compact **Focal length:** 24.09 mm

Design/reflexions: probably 2-3 lenses / 2 (O). **New Price-Tag:** 150€?

Comments: Not "Nikon" branded as such, vendor assured me this one belonged to a '90s Nikon microscope he had owned. Seems multicoated with modern coating. Internal field stop.



WINNER @: (78-88)

Eyepiece Model: Carl Zeiss MF-Projektiv K5:1 microscope barlow **Focal length:** (21,61 mm)

Design/reflexions: probably 3 lenses / 3 (O). **New Price-Tag:** 200€?

Comments: All of the Zeiss Projektiv series I own work nice, but this one had the chance to get out of its shell. Focal length is just a way to express its magnification. Definitely this is not working as 5x barlow, in which case it should have magnified out much more. Ugly-to-Disgusting coatings.

WINNER @: (89-99)

Eyepiece Model: Zeiss West 464123-9902 Kpl 12,5x/12,5x Highpoint **Focal length:** 18.82 mm

Design/reflexions: probably 4 lenses / 3 (0) **New Price-Tag:** 200 €?

Comments: I just couldn't help but crying when I got this one at a good bargain price. From the very beginning I knew there would be something special about it. Her innards are black-velvet and her body seems to be fashioned to give pleasure. High-tech coatings, manual focusing and West-Germany certified, you just get dizzy at this cute ebony lady. Drool over her, pal...

WINNER @: (100-112)

Eyepiece Model: Olympus Tokyo FK6.7x microscope barlow **Focal length:** (17,43 mm)

Design/reflexions: probably 3 lenses / 2 (0). **New Price-Tag:** 200€?

Comments: I have a good assortment of flirting microscope barlows, and sometimes you must get your socks off. I have quite a good assortment of them. Definitely, high quality Olympus stuff showing off everywhere. Nice coatings. What a luxury to behold...

WINNER @: (113-120)

Eyepiece Model: Carl Zeiss Jena K15x **Focal length:** 16,63 mm

Design/reflexions: probably 2 lenses / 2 (0). **New Price-Tag:** Gift?

Comments: The creepy K7x's aunty… Believe me, it just could NEVER cross my mind this old fossil could ever dare to show off. Surprise! Could K30x grampa be waiting for them at the junkshop? Following his nephew's ways, this one has poor coatings, which don't shy away against coated glass.

WINNER @: (121-139)

Eyepiece Model: Olympus Japan GSWH20X-HR-2 / 12.5 Highpoint **Focal length:** 10.49 mm

Design/reflexions: probably 5 lenses (1/2/2) / 3 (2) **New Price-Tag:** 300 €?

Comments: A "wide angle" that got podium. The very fact that a wide angle slipped by talks tons. What else to say about the brilliant GSWH series? Quality drowns you. I tested it with/without barlow, but the final punch was given in its original form (barlowed). High-tech coatings, bottom barlowed, focusable and nicely eyecupped. Dark-velvet views, this is Japan stuff that really shines forth. Despite being quite disregarded glass, you cannot go wrong with them.

WINNER @: (140-144)

Eyepiece Model: Carl Zeiss Jena PK20x / 8 microscope eyepiece **Focal length:** 11.99 mm

Design/reflexions: probably 3-4 lenses / 3 reflex. **New Price-Tag:** 90 €?

Comments: Little dwarf here is not slouch! "K-ompensated" for colour correction, could be Kellner or Plossl. Coatings are quite good and the feeling is 'Gimli-robust' and well-executed.

WINNER @: (145-159)

Eyepiece Model: Nikon 20x/12microscope eyepiece **Focal length:** 11.87 mm

Design/reflexions: probably 3 lenses / 3 (2) **New Price-Tag:** 150 €?

Comments: Seems newer Orthoscopic or Plossl or design. I got these in nice optical condition, with nice coatings and dark innards. Little but feisty Nikon stuff. I think Nikon is one of the best eyepiece microscope eyepiece makers out there. Quality really shines through in every piece.

WINNER @: (160-175)

Eyepiece Model: Carl Zeiss Jena PK32 / 6,3 **Focal length:** 7,63 mm

Design/reflexions: probably 4 lenses / 3 (0) **New Price-Tag:** 180 €?

Comments: The story of this gentleman is a sad story with happy ending. I paid for it more than I thought it deserved. It was a costly piece. When it arrived home, wearing necktie and impolute dressed, I just stared at him and said: "What went wrong at the carnaval?" Preliminary tests would make it get second place, always. Once the testing procedure got polished, the party just began. Nice coatings, clean and bottom barlowed.

WINNER @: (196-216)

Eyepiece Model: Carl Zeiss P25x / 8 **Focal length:** 10 mm

Design/reflexions: probably 6 lenses / 5 (4). **New Price-Tag:** 180€?

Comments: This penaut head pimp with a misguided sense of fashion could very well go unnoticed in the auction world. Manual focusing and bottom barlow. Nice coatings and overall quality feeling too. His head is built to withstand a nuke impact on it, head on...

WINNER @: (176-195)

Eyepiece Model: Nikon 33x/5 **Focal length:** 7,57 mm

Design/reflexions: probably 3 lenses / 3 (2). **New Price-Tag:** 120€?

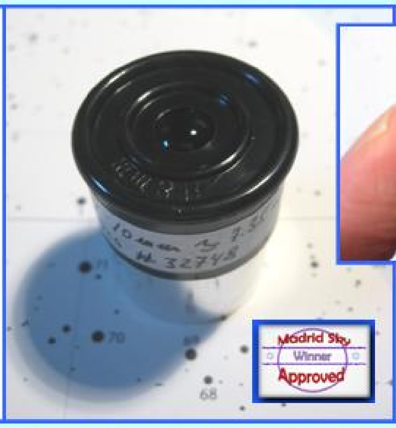
Comments: This one is *really* hard to find and a *rare* collector's item. It works like a champ, and it is a shame you don't have one of these. Seems to be a family matter when you find his shorter focal length father-in-law to also get top marks. Ahmadineyad should hire the whole lineage as his personal guard, and you should get a bucket to collect your tears...

WINNER @: (217-250)

Eyepiece Model: Edmund Optics 10mm BK7 Ball Lens **Focal length:** 7,35 mm

Design/reflexions: 1 lens /1 (0). **New Price-Tag:** 30 €

Comments: Reborn and baptized in Cloudynights™ on-line forums, this *SLINA* custom-made *couture*™ ('smelly ball') eyeball has incredible on-axis performance and good color correction on that highly corrected central area. If you overcome the shame of the "ball syndrome" (feeling like a nerd with a ball stuck into your eye), then you have a performer here for a penny. I had too few contenders in the high-magnification side, so I can only recommend this 10mm diameter ball, not the rest of the line. My 10mm ball was the absolute winner at the high-magnification courtroom. Non-coated. EO cat. # 32748.



WINNER @: (251-350)

Final words and acknowledgements

A "free offering"

I am curious about the performance of the high regarded planetary performers, and I would like to see them stack up against my "winners". I will only discuss results with owner. You may want to send me some eyepieces to be tested. I will freshly and carefully test them in a Meade 80mm 3-element APO scope. I will do this work for free, unless I get flooded with glass or stress myself, in which case I don't know if I will take a fee or just reject anymore of them. I cannot accept at this time eyepieces whose max. width surpasses 35mm (1.40 ") For details, get in contact with me at any time at: samuelderoa@gmail.com

Near future of my eyepiece collection

I do not stop getting new eyepieces, and I renew my collection selling some stuff to fund new one. I may offer some of my assorted glass from time to time through Ebay, Astromart and the like.

Acknowledgments

Due to the present nature of things, we humans stand on the backs of others. Genius of the like of Newton, Einstein or Ramanujan were probably inspired by the work of other people. Our corrupt nature decays, and "someone has to take the banner of those who preceeded us." I am not genius at all, but I want to thank all of those whose dedication and work has made possible this "amateur report". From ancient greeks to the latest teacher in school that passed on the

banner of science for childs to pick up and develop at later stages. Not being a scientifc nor expert myself, I am probably in debt with them all. The matrix of human history is indeed all-encompassing and the lines cross all over.

Special thanks to *Norman Koren* for his brilliant software and kind attention, to *Ivan Danes* for bearing with my test chart requirments, to *James Witt* for his pics and long-endurance, to *Richard Low* for his endurance, to *Paul Van Slyke* for his patience and workmanship, to *Cloudynights community* (each of you, specially the administrators and moderators whose work is so often ungrateful) for your encouragement and their *freakiness*, to *my family* for bearing with my weirdness, to the beloved *family of God*, and above all to ***Him***, the Christ, the Lord of All that holds all Knowledge, Wisdom and Power, keeping this miracle of life running day after day despite our very blindness.

Science is not rivaled with spirituality. Men are spiritual beings, atheists and believers alike. For a wealthy christian-based spiritual (but practical) 'database' you may visit: www.shulamite.com. You can't get out of there empty-handed. "All & Only" and "Adoration" manuscripts are a *must-read* for those of you in this great adventure which is living this Life.

Telescopically,

Sam

Part II: A Visual Assessment

You yourself are the author.
So... just be part of it!

Author in his present observatory placement in Madrid area (Spain mainland)
to be placed at Canary Islands sooner or later

:)

george tatsis, fissauer and Chistos papanicolaou like this

0 Comments