LRGB Imaging setup and acquisition

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This article describes my imaging setup and procedures for capturing deep sky objects using the following kit:

- A Celestron C11 scope with a f6.3 Focal Reducer;
- An EQ6 Pro mount (equatorial);
- Imaging via an Atik 314L CCD;
- LRGB filters via a ZWO USB powered motorised filter wheel;
- Guiding via an Orion Off Axis Guider with a ZWO ASI120MM CCD using PHD2 software utilising connection via EQMOD and pulse guiding;
- Capturing Bias, Dark and Flat images;
- Capturing LRGB images.

This article and others can be found on my website www.astroworkbench.co.uk.

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1 Setup Overview

Figure 1 below shows the main components of my imaging setup which consists of:

- A Celestron C11 scope;
- JMI Motofocus (connected to a HiTecAstro DC focus controller - not visible);
- Celestron F6.3 focal reducer;
- An Orion Off Axis Guider;
- A ZWO ASI120MM used with PHD2 (allows ST4 or pulse guiding);
- A USB powered ZWO filter wheel;
- An Atik 314L (Atik Artemis software used for capture);
- An EQ6 Pro equatorial mount (not visible).

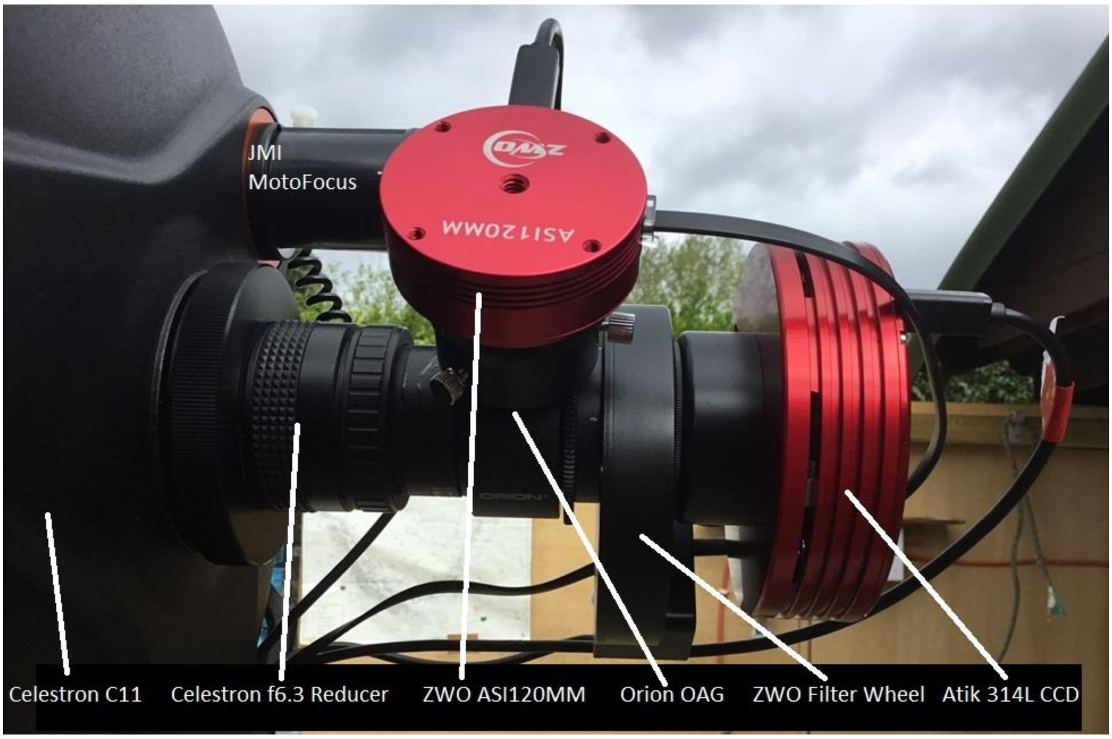

Figure 1 – Main imaging equipment setup

The following sections detail the components, the setup and the imaging procedure.

2 Details of Imaging Components

2.1 Setup of Initial Component Spacing in daytime

One of the biggest initial problems with an imaging setup using a main imaging CCD and a OAG mounted CCD for guiding is getting the spacing correct as the distance from the OAG pick off mirror to the guiding CCD chip needs to be the same as the distance to the imaging CCD chip; this is shown in Figure 2 below as *Distance A and Distance B*.

Note: The distance of the focal reducer to the CCD chip is also critical to get the correct working f-ratio for the focal reducer. For example, to ensure that a Celestron f6.3 reducer, which has a focal length of 285mm, is actually working at f6.3 it needs to be about 105mm from the plane of the CCD.

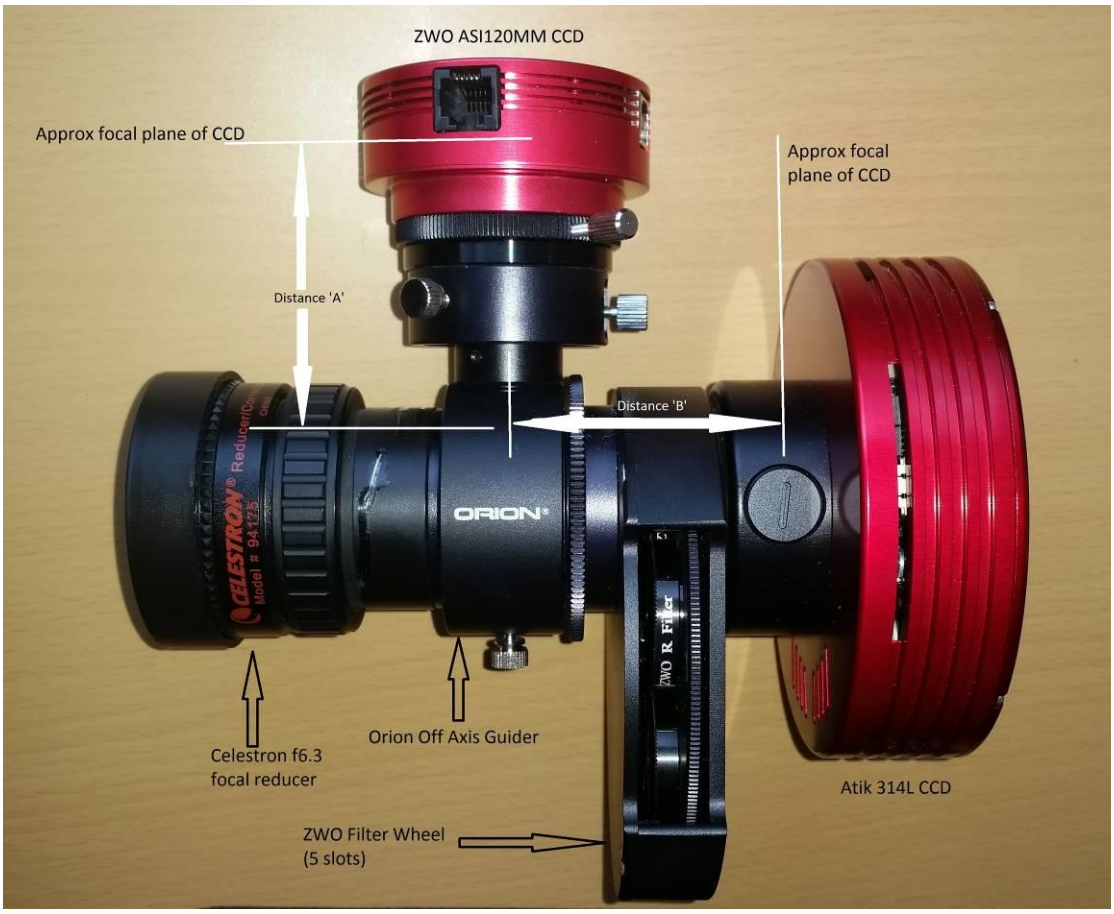

Figure 2 – Imaging setup spacing considerations

To get Distance A and Distance B to be equal usually involves trying out a range of spacers and any adjustment the OAG provides until you get the correct distance.

I have found that by far the easiest way to do this is to get the two focus points as close as possible during daylight hours so that only very fine final adjustment (using the OAG's built in adjustment) is required under darkness which makes life a lot easier.

This daylight procedure only needs to be performed once.

The Orion OAG gives you about 10mm of simple push/pull tube sliding adjustment to play with and the rest is all down to spacers.

To accomplish this, I used the following method:

- Attached the setup shown above to a scope during the daytime; I used my Celestron 102 for simplicity rather than my main Celestron C11 scope;
- Focus the Atik CCD on a distant object (I used a tree) by using the telescopes focuser and the Atik Artemis Capture software;
- Adjust the distance of the ASI120MM guide camera on the OAG by using different M42 adaptor rings and it's built in push/pull adjustment until both cameras are in focus at the same time (do **not** adjust the scope's focus while adjusting the AS120MM distance). I used PHD2 for capturing the ASI120MM image.

This is shown in the sequence of photos below:

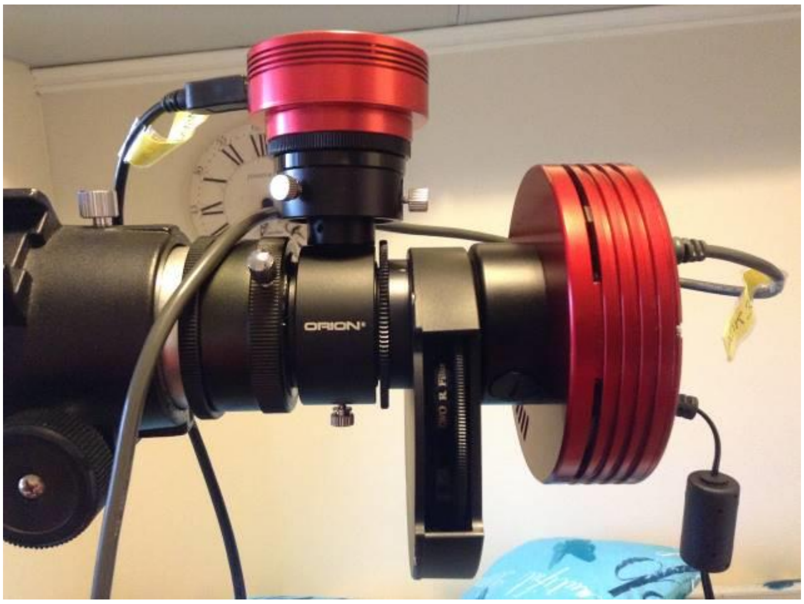

Figure 3 – Attach imaging setup to a scope for initial daytime setup

Figure 4 – Imaging setup focussed on distant tree

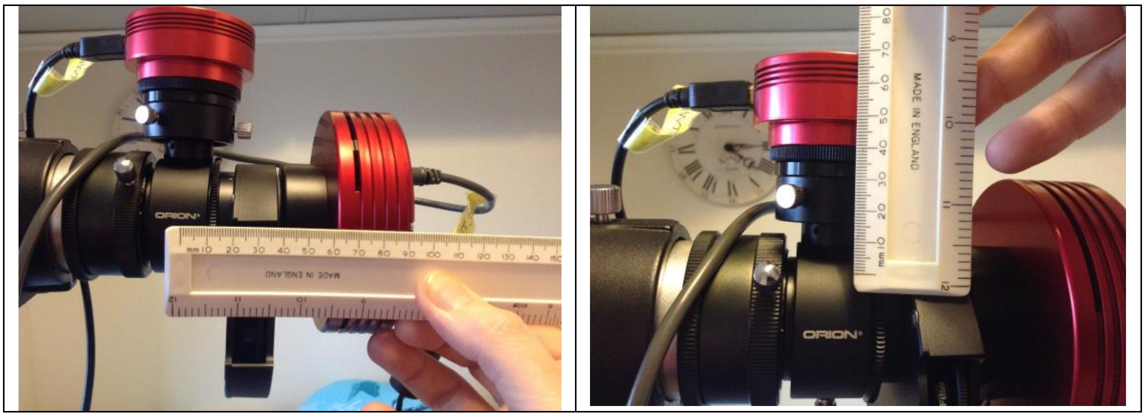

Figure 5 – Swap spacers until distance is approximately equal and both are focussed at same time

All spacers for this setup are the common 42mm variety and you can usually get them in 5mm, 10, 20mm etc. sizes. It is important however to keep the distances as small as possible otherwise you may find that you do not have enough back focus on your scope to achieve focus. This is particularly true if you are using a Focal Reducer as with the setup shown here.

On this setup I have a 5mm M42 spacer to join the OAG to the FW and then a very thin M42 male to male ring to fix the FW to the CCD. I then needed another 5mm spacer plus a thin (4mm ish) locking ring between the OAG and the ASI120MM guide camera. This is about the smallest number of spacers it is possible to get away with and is as shown in Figure 2 above.

Now just keep experimenting until you get both CCDs to focus at the same time by checking the images via Artemis and PHD2 as shown below.

Try to have the OAG's built in adjustment about half way of its travel so that you have some adjustment left in both directions for fine tuning the focus when you performing an imaging session.

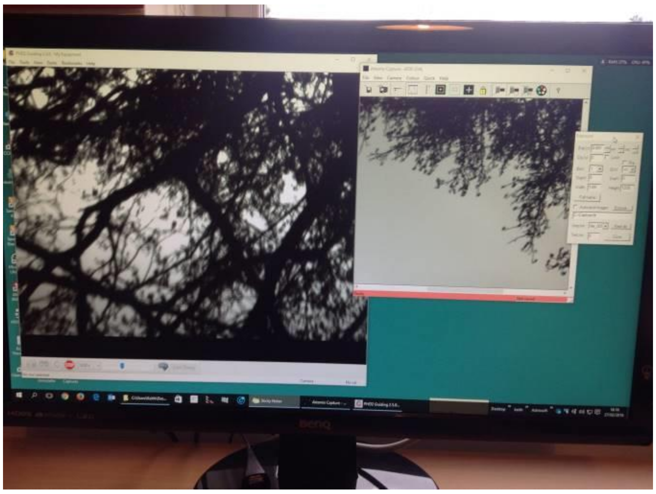

Figure 6 – Atik Artemis (right) and PHD2 (left) capturing the two CCD images simultaneously

As mentioned above it is also critical that the distance of the focal reducer to the CCD chip is also checked so as to get the correct working f-ratio for the focal reducer. For example, to ensure that a Celestron f6.3 reducer, which has a focal length of 285mm, is actually working at f6.3 it needs to be about 105mm from the plane of the CCD.

Now that this initial setup is completed the only adjustment required under darkness will be fine focus adjustment to the OAG to get the guide star focussed within PHD. You will need to focus your target on the main CCD first and then **without** changing the main focus, adjust the OAG focus to get a guide star focus correct.

3 Connectivity

3.1 Kit connectivity

The diagram below shows my imaging setup connectivity.

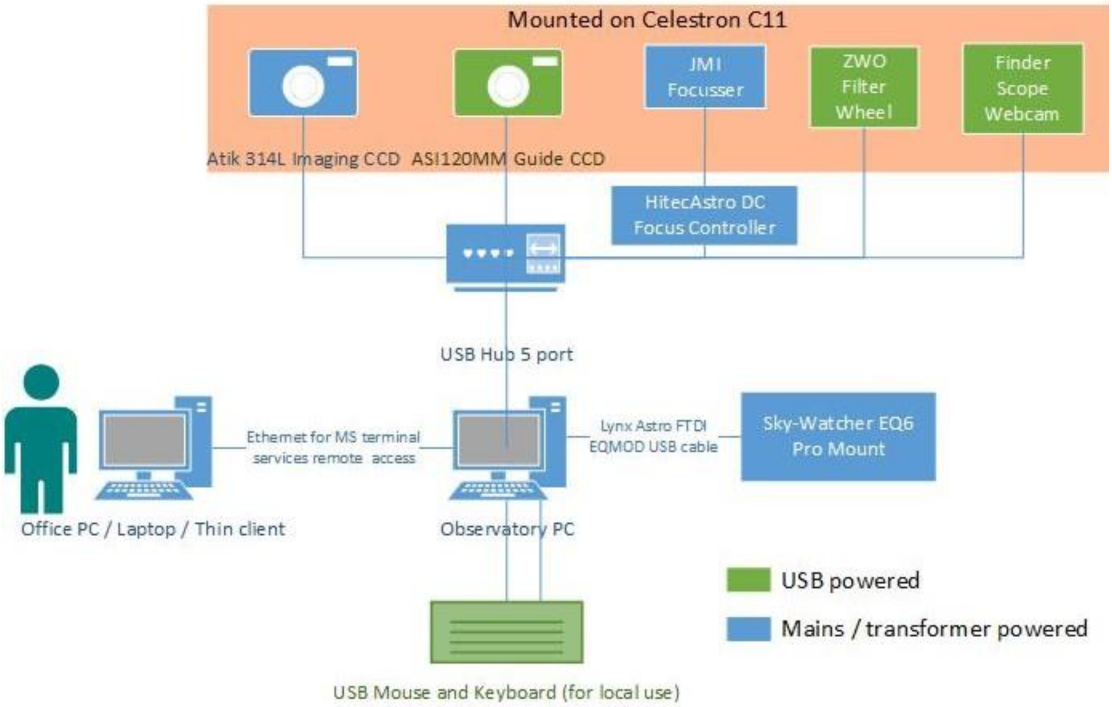

Figure 7 – Kit connectivity

The images of my observatory setup below show some of these components.

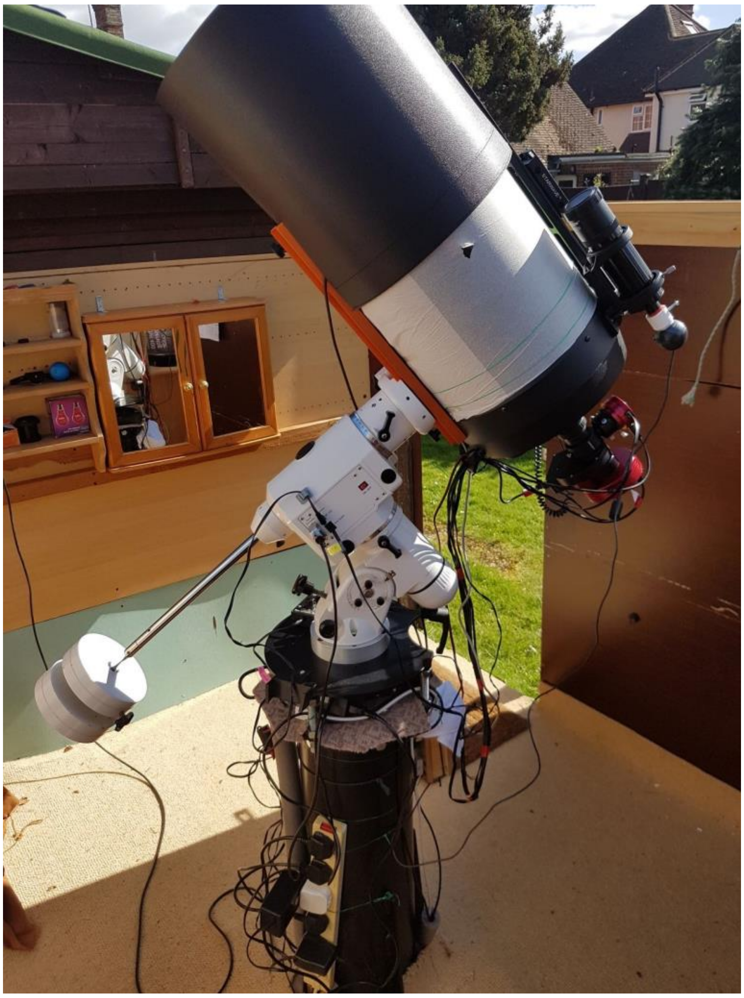

Figure 8 - Observatory setup 1/2

Apart from the jumble of USB and power cables one significant connection to note is the *Lynx Astro FTDI EQDIR USB* cable that can be seen plugged into the mount that allows EQMOD connection and control of the scope from a PC/Laptop. A closeup is shown below. Note that an ST4 cable is also shown but I prefer to use pulse guiding which is described in the section below.

Figure 9 - Observatory setup 2/2

3.2 EQMOD Connection to PHD and EQ6 mount

My setup described above allows for either ST4 or pulse guiding. I prefer pulse guiding as in my experience PHD seems to integrate with EQMOD better using pulse guiding that ST4. When using ST4 with PHD it has always worked without incident but the guide profile (PHD RMS errors and guide graph) seem smoother when using pulse guiding via EQMOD.

The following describes how to setup EQMOD and PHD to use pulse guiding.

3.2.1 Step 1 – EQMOD settings

After installing ASCOM and EQMOD for connecting your PC/Laptop to your mount via a suitable EQMOD cable (I use a Lynx Astro FTDI EQDIR USB cable which can be seen plugged into my mount in the mage above) run the 'Setup EASCOM' (from the Windows EQMOD program group) so that the following screen is presented. Ensure that the following are set as shown below:

- SideofPier is *Pointing (ASCOM);*
- Guiding is *ASCOM PulseGuiding.*

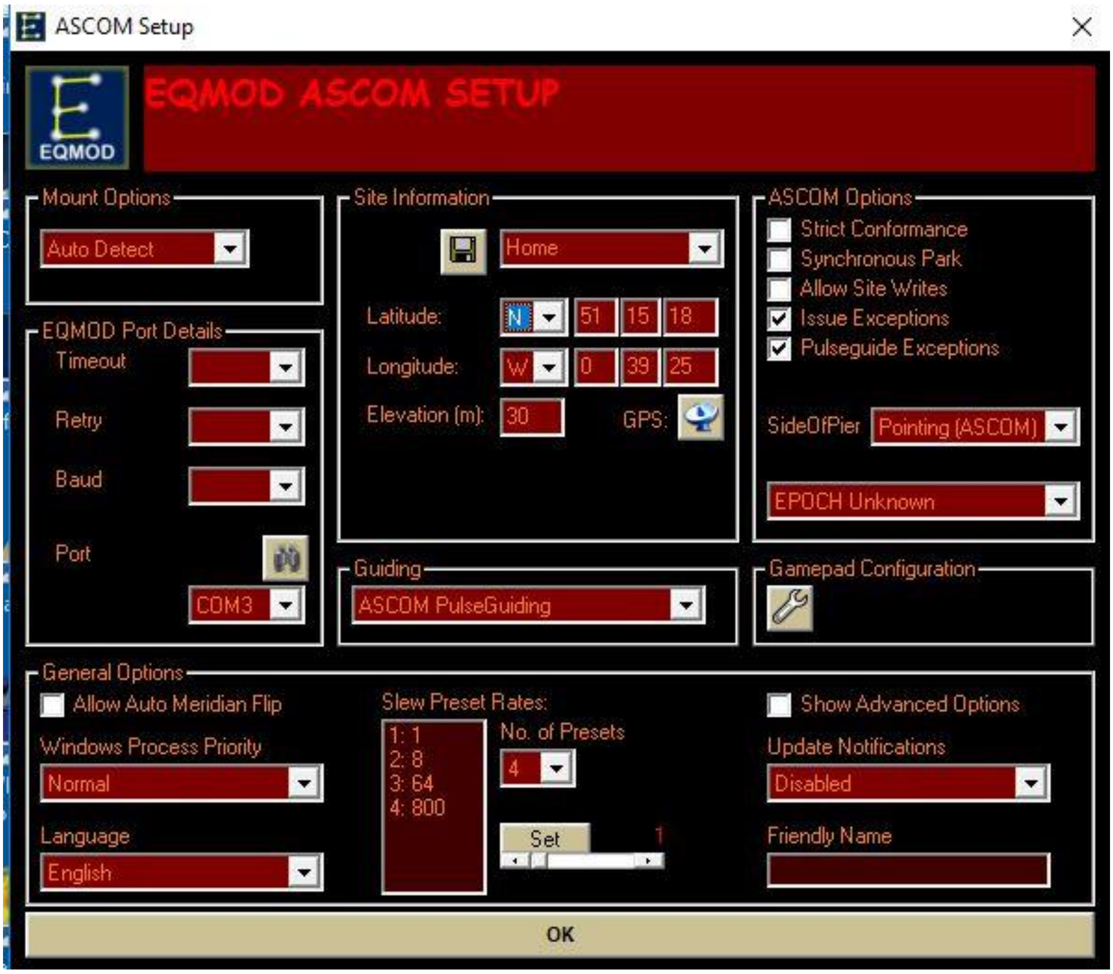

Figure 10 - EQMOD ASCOM setup

3.2.2 Step 2 – EQMOD connect and pulse guide settings

Connect EQMOD with the mount and using the resulting control screen that appears (as shown below) use the *ASCOM PulseGuide settings* section to ensure that the following are set:

- RA Rate is set to a high value – 0.9x is the example below;
- Dec rate is set to a high value – 0.9x in the example below;
- Minimum pulse is as low as it will go;
- Dec backlash is set to 0 (disabled).

Figure 11 - EQMOD pulse guide settings

3.2.3 Step 3 – PHD connection to EQMOD

Now run PHD and connect as shown below:

- Select the *EQMOD ASCOM HEQ5/6* mount option

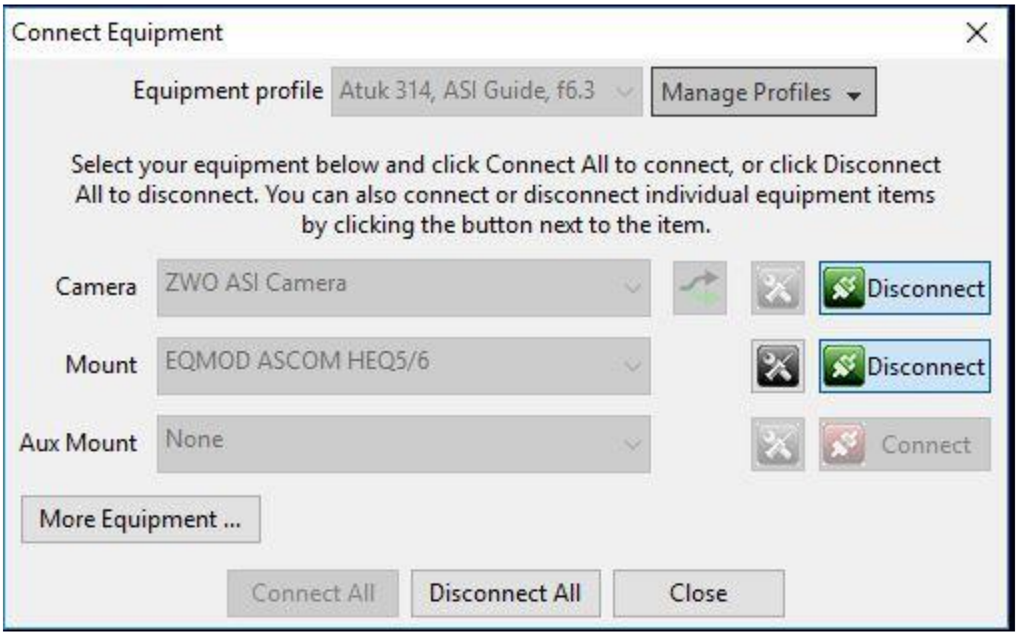

Figure 12 - PHD EQMOD connection

You can now start using PHD to guide (after calibration) as usual. PHD will use EQMOD to send corrections to your mount using pulse guiding.

4 Imaging

4.1 The Imaging Process

As my scope is mounted on a permanent pier and polar aligned so I just use the following procedure to orientate it before I start my evenings imaging:-

1. Ensure that the scope controller (or your PC clock if using EQMOD for example) is set to the exact date and time (to within a couple of seconds) and exact location. The more accurate the better.

2. If you have previously parked your mount then in theory no star alignment is required (depends on your mount's accuracy). For my EQ6 I usually do a modified three-star based alignment anyway as its quick and easy and gives reasonable results, the procedure is:

   If using the good old traditional hand controller and eyeball method:

   a. Start from the Park Position (Scope up and weights down);
   b. Enter the first star and let the mount slew to it but **do not** use the hand controller to centre the star – undue the RA and Dec clutches and manually move the scope to centre the star (either in a reticle eyepiece on in the CCD).
   c. Select the second star and use the hand controller to centre it.
   d. Select the third star on the other side of the meridian (e.g. East if first was West) and use the hand controller to centre it – with the EQ6 this three-star alignment should also mitigate any cone error.

   If using EQMOD and planetarium software:
   a. Start from the Park Position (Scope up and weights down);
   b. Pick a star on the software, slew to it, centre it in the CCD FOV;
   c. Sync the star – which also automatically adds the sync data to the EQMOD software;
   d. Repeat for a few stars including on the other side of the meridian.
   e. Ensure that one of the star syncs is close to the (deep sky) object you want to image and ensure that a slew successfully goes back to that star.

3. Goto the (deep sky) object required. I find that with my EQ6 mount, about 8 times out of 10 after performing the alignment procedure above the GoTo slew will get the object in the CCD field of view as long as you have set a star sync and checked its slew accuracy on a nearby star.

I can now start imaging which involves the following process. Note that I don't intend to re-produce instructions from the Atik Artemis software manuals or from PHD, as I have found the instructions produced by Atik and Stark Labs to be excellent and both sets of software are very intuitive.

1. Fire up the Atik Artemis software.
2. Fire up the PHD2 software and connect to the ZWO guide camera and mount (I use EQMOD and pulse guiding as described in the section above but you can also use the ST4 port connected to the ZWO guide camera in which case the mount to choose on the PHD2 connection dialog screen is the 'On Camera' option).
3. Set the temperature for the CCD cooling (I normally go for about 20 degrees below ambient – many CCD's will do more than this but you don't want to set it to something unachievable).
4. Focus the Atik CCD using any star of suitable brightness as you don't want a star that will swamp the CCD readout. Using a looped short exposure, along with the sub frame and

tracking (focus) features of the Artemis software which makes the focus process easier. I also sometimes use a Bahtinov mask on a bright star.

5. GoTo slew the scope to the object I wish to image and centre it. If the object is faint then the fact that the scope is already focussed means that you have more chance of seeing it at this stage. It's also good if the focus star was close to the object to mitigate any focus shift during the slew – otherwise you may have to re-focus.
6. Find a guide star in the OAG field of view to guide on. This rarely involves rotation of the OAG but generally does require some slewing the scope slightly. The ZWO ASI120MM guide camera sensitivity and PHD2 means you can usually pick up star with a 2-3 second exposure. I quite often find that as the OAG guide star pick off mirror is towards the edge of the scopes light cone the star shape is a bit elongated (coma on my C11 at the edge I guess). Remember that if the OAG focus needs changing **do not** use the scope focus, use the OAG focus adjustment.
7. Check that the object to be imaged is still framed o.k. within the Artemis software as it may have moved when locating a guide star. This may involve repeating the last step and this step until the object and a guide star are reasonably framed in their respective CCDs.
8. Re-check and ensure the Atik CCD image is focussed as precisely as possible (you may have to re-focus at this stage) and that still has PHD has a reasonable star image.
9. Start (pulse) guiding the scope with PHD2 and let it guide for a minute or so just to make certain that all is working well.
10. Make certain the Atik CCD has reached the specified working temperature.
11. Start imaging via the Artemis software.
12. Take a set of L, R, G and B images as described in the section below.

4.2 Bias, Darks and Flats

As well as the 'master' light frame images you may wish to acquire bias, darks and flats for subsequent image processing.

The aim is to create a master bias, master flat and master dark that can be applied to your light images.

4.2.1 Bias

A single master bias image needs to be created that will be used to compensate for the electronic noise present in any CCD. The same master bias is fine for each filter (as you are not recording any light).

1. Cover scope – absolutely no light must get into the scope of imaging setup.
2. Set the CCD exposure to the fastest shutter speed possible.
3. Set the CCD to the same temperature as your imaging.
4. Focus does not matter.
5. Take loads to frames, as your shutter is as close to 0 seconds as possible you can shoot a couple of hundred easily.
6. Stack all frames to a single master bias frame.

4.2.2 Flats

A master flat is required to compensate for dust and vignetting. A separate master flat is required for each filter (as you are recording light and hence optical characteristics and dust marks).

1. During daytime – leave you setup exactly as it was when you finished your imaging run.
2. Cover scope with a white t-shirt or sheet of fine stich.
3. The Imagining kit orientation must be exactly the same as your light imaging run.
4. Park your scope and check that it is facing an even bright sky.

5. Set the CCD exposure so that the histogram is not flat topped (i.e. CCD is not swamped).
6. Set the CCD to the same temperature as your imaging.
7. Focus must be the same as your imaging run.
8. Take 15 to 20 frames.
9. Subtract you master bias from each flat frame (how you do this depends upon what imaging software you have – Atik Dawn does this easily).
10. Stack all frames to a single master flat frame.
11. Divide your master flat from your light frames (how you do this depends upon what imaging software you have – Atik Dawn does this easily).

4.2.3 Darks

A master dark is required for each combination of light image exposure time and CCD temperature. To compensate for hot pixels. The same master dark is fine for each filter (as you are not recording any light). Take at the start or end of your nights imaging run. Some CCD's have so little noise that you can get away without needing darks.

1. Cover scope – absolutely no light must get into the scope of imaging setup.
2. Set the CCD exposure to the same as the light images.
3. Set the CCD to the same temperature as your light images.
4. Focus does not matter.
5. Take 10 to 20 images.
6. Stack all frames to a single master dark frame (for the given exposure and temperature). Do **not** need to subtract bias.

4.3 LRGB Imaging

My procedure for LRGB imaging is as follows.

4.3.1 RGB Exposure Ratio

I use a default RGB ratio of 1.00:0.74:0.77. Object altitude also makes a difference due to light extinction, but I don't go down that route and this is a good average to start with. The table below shows exposure times based upon this ratio. You can also just take RGB images all of the same exposure time and balance them later in software.

Before taking the RGB images take as many and highest quality as possible images through the Luminance filter (a clear IR filter).

Remember to name your (fit) image files with L, R, G, B so that you know which ones are which when it comes to processing them.

Exposure	Red	Green	Blue
30s	30	23	25
60s	60	46	50
90s	90	69	75
120s	120	92	101
150s	150	115	126
180s	180	133	138

Table 1 – RGB ratios

5 Imaging Software

The software that I use to achieve image acquisition is as follows:

- Atik Artemis for Atik CCD image capture;
- PHD2 and EQMOD for pulse guiding;
- EQMOD and Cartes du Ceil for scope control;
- HitecDCFocus software for JMI Motofocus control;
- My AWB ASCOM FW Control software for USB filter control (see my website www.astroworkbench.co.uk).

5.1 Atik Artemis

For my image capture I use Atik *Artemis Capture* for the initial capture of the LRGB images (as .fit files).

The screen capture below is during a sequence of 120 second red filter images of M76.

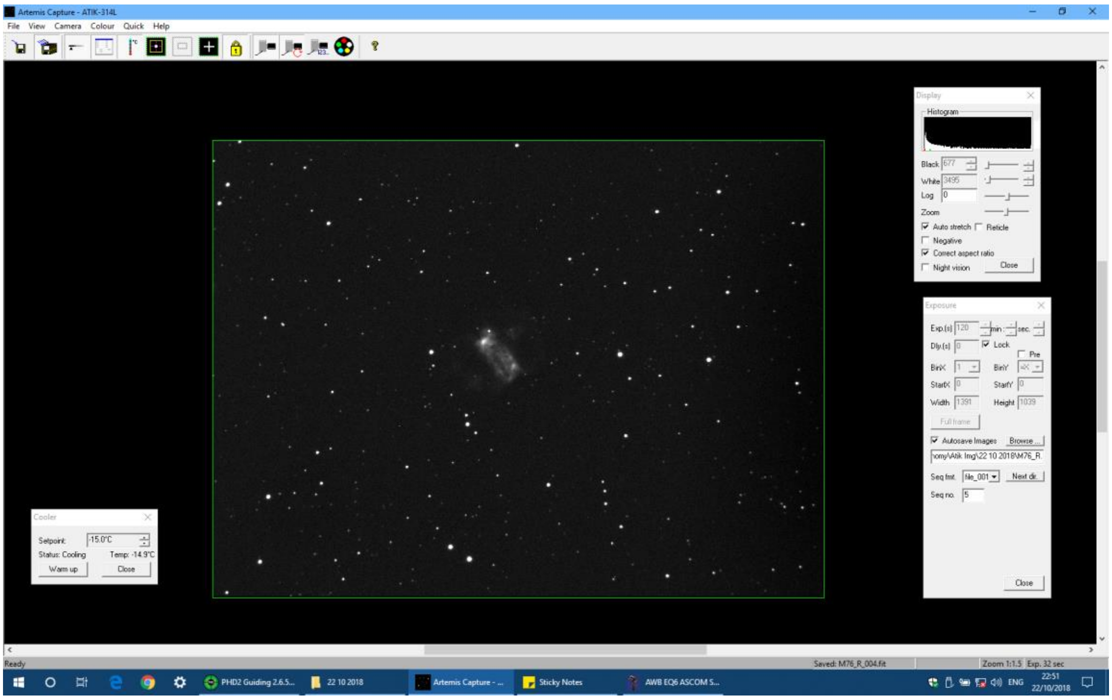

Figure 13 - Atik Artemis software

5.2 PHD2

For guiding I use PHD2 and pulse guiding via EQMOD as described above.

The screen capture below shows a 2.5 sec exposure loop with approximately 1 arc second (less than 1 pixel) RMS which is fairly representative of what I get with my setup described in this document (Celestron C11 on a Sky-Watcher EQ6 Pro mount, pulse guide via EQMOD).

Figure 14- PHD2 software

5.3 HitecDCFocus

This is proprietary software that comes with the Hitec DC focus controller that I use to control my JMO Motofocus.

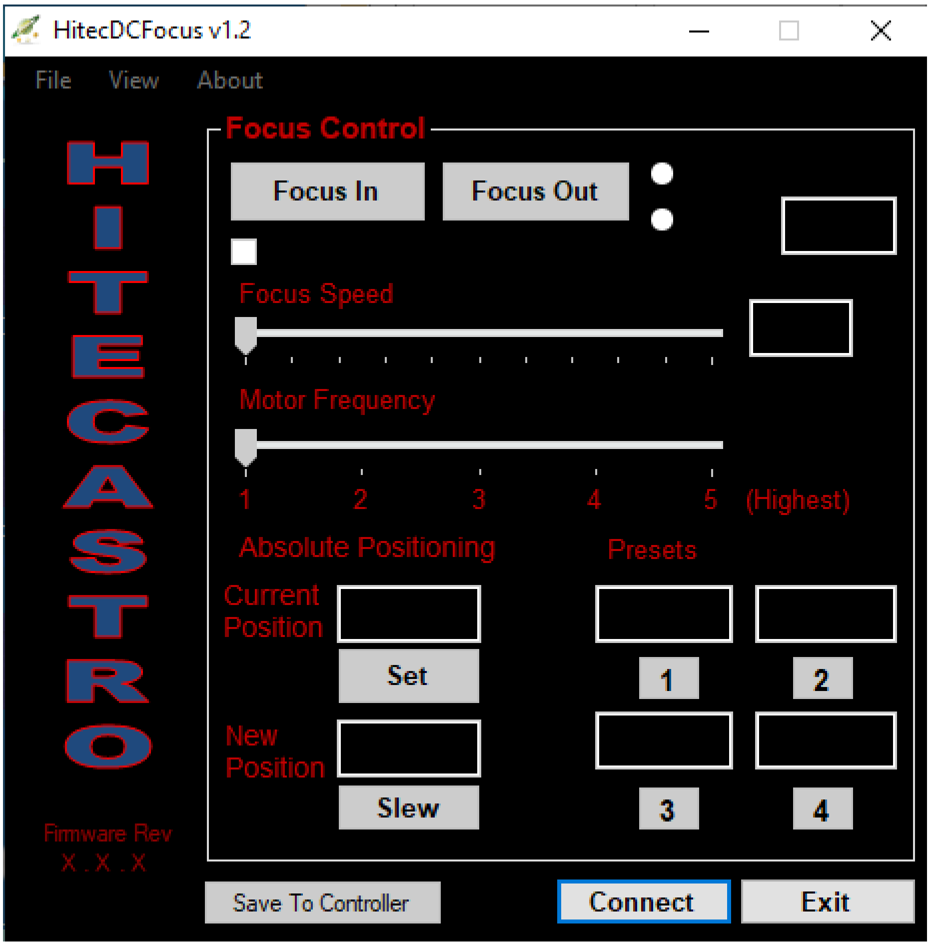

Figure 15 - Hitec focus software

5.4 AWB ASCOM Filter Wheel Control

This is my software for USB filter control (see my website www.astroworkbench.co.uk)

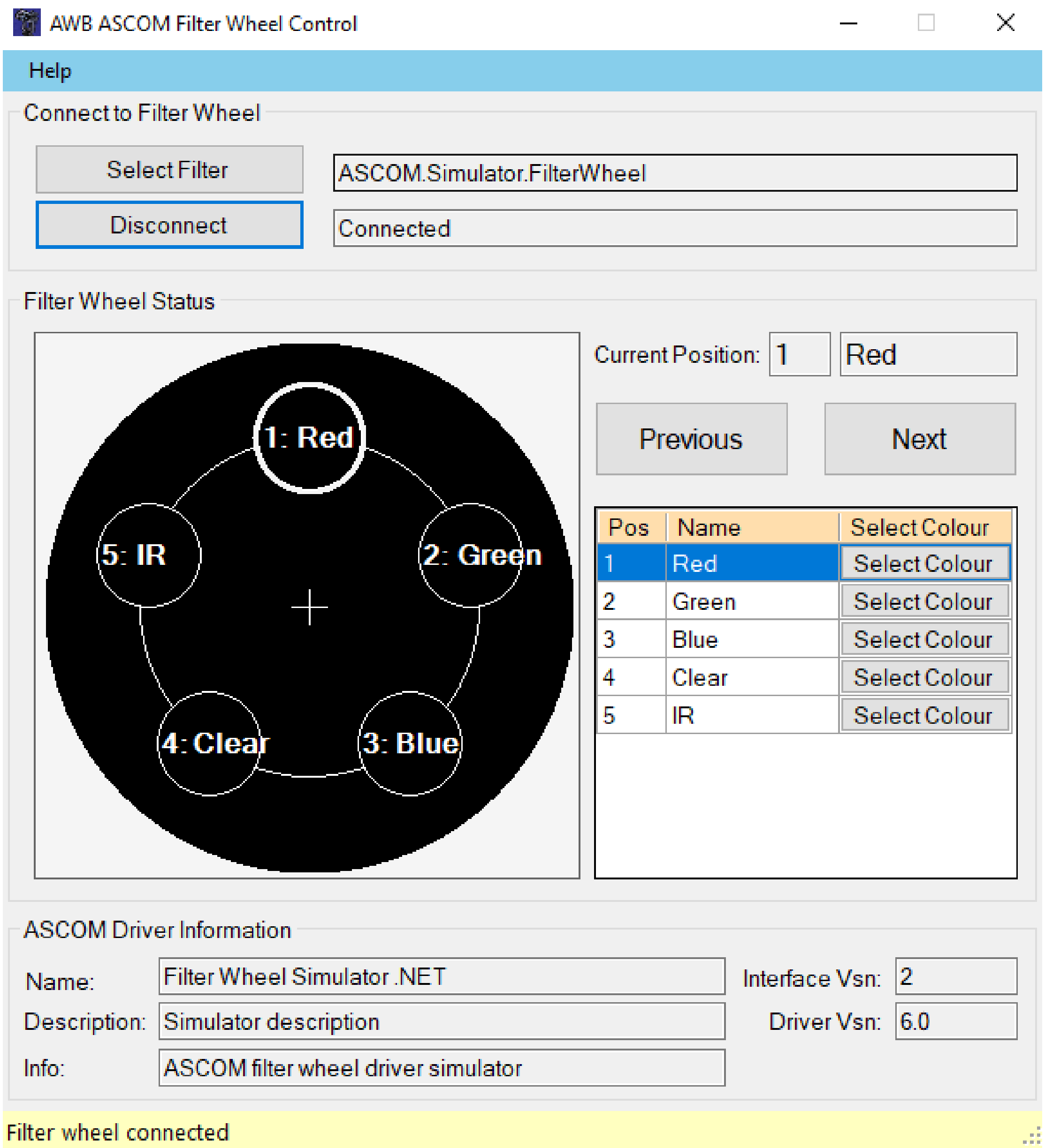

Figure 16 - AWB ASCOM filter wheel software

5.5 Post capture processing

Phew – that's enough for this document, if you have read this far then thanks very much.

See the separate document *LRGB imaging Process Procedure* which will be available on my website www.astroworkbench.co.uk.

6 Results

The image of M27 below is pretty typical of a 'quick' image with minimal post processing using the setup and techniques described in this article. This image comprises of only six 60 second images for each of LRGB, has no bias, flat or dark frames and minimal processing. I believe this therefore gives a representative example of what is easily achievable following the techniques described in this article.

Stars to about mag 18 are visible on the original which is not bad for six 60 second exposures for each LRGB.

Figure 17 – M27

7 Appendix A

7.1 Scope and mount Setup considerations

The relative benefits of the considerations below will differ depending upon your setup and hence I am not going to deal with them in detail here. The following five points are those that I have found as the most significant in my experience.

Collimate your optics: Collimation is essentially ensuring that your optical path is aligned to give the best images possible. If your scope is not collimated then your images will suffer. Some scopes cannot be easily collimated as their optical components are fixed during manufacture (e.g. refractors), but scopes such as Newtonians, Dobs, Cassegrains, RCs will have facilities to collimate your optics. There are numerous tools for achieving this as well as the good old method of using a defocused star. Please refer to your telescope manual and judicious use of Google! I have a document on my website www.astroworkbench.co.uk which explains how to collimate a typical SC scope..

Polar Align your scope: By Polar aligning your scope the rotation of the Earth can be compensated for by the RA (Right Ascension) drive. Errors in Polar alignment can be compensated for in the guiding process, but as with PEC training (see below), I believe the more sources of errors that you can eliminate the better. I have a document on my website www.astroworkbench.co.uk which explains how to achieve accurate Polar alignment. Many software packages (e.g. PHD2) also include polar align utilities. I have found that it's a bit pointless to get obsessive over this and that every software package will very in their results. Its obviously good to get polar alignment as close as possible, but If you can get polar alignment to within a few arcminutes then you are probably onto a winner.

PEC Train: If your scope's drive has a PEC (Periodic Error Correction) training facility it will reduce potential guiding errors by compensating for the inherent variability that exists in any drive. You may wonder why to bother as the guiding software will correct anyway. Well, to a certain degree this is true; however why leave in a potential source of error when it can be mitigated. See your telescope manual. Be careful that if you use mount PEC that it does not conflict with any software you use that may also be attempting PEC correction otherwise you may the two fighting each other.

Counter Balance: Having your scope balanced for your setup is important to stop any 'flop'. It's best to have a slight load on the opposite direction of your scope movement (i.e. some weight to the East while tracking to the West) so that the RA drive has a slight load to work against. Similarly, in reality unless your polar alignment and drive are spot on, you will also require declination compensation during guiding and hence a slight load in the declination is also desirable. Fork mounted scopes allow for 3rd party weight kits to be fitted to achieve this.

Backlash compensation: Backlash can cause erratic guiding compensation as a guide command may cause no movement if backlash causes the gears not to engage for the duration of the guide movement command from the software. This can cause the guiding software to produce erratic and possibly 'jerky' movements. Many scope controllers allow for backlash compensation; check your manual. Be careful that if you use mount controller backlash compensation that it does not conflict with any software you use that may also be attempting correction otherwise you may the two fighting each other, e.g. PHD also calculates backlash.

7.2 Facts, Figures and Considerations

My Celestron C11 is f10 has a focal length of 2800mm. With a 0.63x Celestron Focal Reducer this equates to about 1760mm. The actual reduction factor will depend upon the distance from the FR to your CCD and the focal length of the FR which varies for every type of FR.

This setup gives about one arc seconds per pixel on the Atik 314L. The formulae is: (206.265 / focal length in mm) *(CCD pixel size in microns, which with the Atik 314L pixel size of 6.45 equates to (206.265 / 1760) * 6.45 = 0.75.

A rough rule of thumb is that the arc seconds per pixel should be about half your seeing, so this means that 0.75 equates to <u>theoretically</u> capturing detail of about 1.5 arc seconds seeing (if your seeing conditions and tracking etc. can also accommodate it).

The chip on the Atik 314L+ is reasonably small by todays CCD standards (just under half an inch with 1392 x 1040 pixels and a 6.45um pixel size). For large chips chip you may have to be careful for image quality issues such as coma at the edges (depends upon your scopes optics and use of a field flattener) and vignetting due to the reduced light cone coming out of the reducer. Once again, it’s worth Googling these subjects and understanding them for your setup.

The Field Of View on my Atik CCD for my setup is about 17’ by 13’.

8 Further Information

Please visit my website www.astroworkbench.co.uk for further documents and articles.

Thanks.

Keith.