Small Refractor CCD Imaging

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Small Refractor CCD Imaging covers the equipment configuration, advantages, disadvantages, imaging session, image processing and imaging results of using the CCD Cookbook CB245 camera with an Orion ShortTube™ 80mm aperture refractor. Currently 70 Messier images have been taken with this configuration and they can be seen at http://www.stargazing.net/david/.

Equipment Configuration

The CCD Cookbook CB245 camera is used with the Orion ShortTube™ 80mm aperture rich-field refractor. The Orion ShortTube™ refractor focal length is 400mm. The Orion ShortTube™ refractor is mounted on top of a Celestron CG-11 Schmidt-Cassegrain telescope using Losmandy dovetail plate and rings. The Celestron CG-11 is used as a finder and as a telescope mount for the Orion ShortTube™ refractor with the CB245 camera.

CCD Camera
The CCD Cookbook CB245 camera is a build yourself CCD camera that is described in *The CCD Camera Cookbook* by Richard Berry, Veikko Kanto & John Munger. The CB245 camera is wrapped in plastic and foam to reduce temperature drift of the electronics in the camera head. The camera is water cooled by two 1/4-inch plastic tubes carrying water to and from the camera. White quick disconnect fittings prevent water draining out of the camera and hoses when disconnecting the hoses from the camera. A Compaq 486 desktop computer or Compaq 386 laptop computer is used to control the CB245 camera.

Shutter
A manual shutter from Spectra Astro Systems (Vibration-Free Shutter) is mounted on the CB245 camera and is used for taking dark frames.

IR Filter
An IR is needed to prevent bloated star images because the CCD detector is sensitive from visible light into the IR spectrum and the Orion ShortTube™ refractor does not focus at the same point in the visible spectrum as it does in the IR spectrum. The IR filter is from Santa Barbara Instrument Group and screws inside of the Edmund Scientific 48-mm T-mount extension tube that is mounted on the Spectra Astro Systems Vibration-Free Shutter.

CCD Camera Mounting
A ring clamp is used to hold the CB245 camera and to prevent stress on the Orion ShortTube™ refractor focuser. An Edmund Scientific ring mount clamps on the 48mm T-mount extension tube that contains the IR. The ring mount is attached to a Losmandy DA dovetail adapter using Edmund Scientific stainless steel mounting posts and a right angle post clamp.

Finders
Three finders are used: Daisy finder, Lumicon finder and the Celestron CG-11. First, the Daisy finder with magnification 1 X is use to position the telescope to the general area of the sky. The Daisy finder is mounted to the Orion ShortTube™ refractor finder bracket. Secondly, the Lumicon 80mm Super-Finder with a right-angle correct erect image and a 25mm cross-hair Kellner eyepiece (F = 300mm, magnification 12 X) is used to star hop to the desired object. If the object can be seen in the Lumicon finder it is centered in the Super-Finder cross-hair. If the object cannot be seen with the Super-Finder the Celestron CG-11 with Celestron f/6.3 focal reducer, 2 inch right-angle and Tel Vue 35 mm Panoptic eye piece (magnification 50.4 X) is used to find the object. Some faint objects can not be seen with the Celestron CG-11.

The CB245 camera with a 2 to 4 second exposure is used to find faint objects that can not being seen in any of the above finders. A 2 to 4 second CB245 camera exposure through the Orion ShortTube™ refractor can see fainter objects than can be visibly seen with the Celestron CG-11 telescope.

Telescope Mount

The Celestron CG-11 telescope mount is the Losmandy G-11 equatorial mount.

Short Focal Length Advantages

The Orion ShortTube™ refractor was originally acquired as a super finder to be used in conjunction with the Celestron CG-11 7x50 finder. At that time the CB245 camera was used on the Celestron CG-11 and it was challenging to use with it long focal length (2800mm (f/10) or focal length of 1764mm (f/6.3) with the f/6.3 focal reducer). The advantages of using the CB245 camera on the Orion ShortTube™ refractor are bigger FOV, large object imaging, finding the objects are easier, reduced affects of polar alignment errors and reduced affects of tracking errors.

Bigger FOV

The focal length and size of the CB245 camera CCD IC determines the field of view (FOV) that is imaged by the CB245 camera. CB245 camera has a 7.89 x 5.85 arc minutes FOV with the CG-11 focal length of 2800mm. It has a 12.52 x 9.29 arc minutes FOV with the Celestron CG-11 focal length of 1764mm (f/6.3) with the Celestron f/6.3 focal reducer. And, it has a 55.23 x 40.97 arc minutes FOV with the Orion ShortTube™ refractor focal length of 400mm.

Field of View (FOV) Table

Photosite (mm)	Focal length (mm)	Resolution per Photosite (arc seconds)	Objective Diameter (mm)	Focal Ratio	Total FOV Resolution (Pixels)	Total FOV (arc min.)	
0.0255	400	13.15	Orion 80	5	252	55.23	Horizontal
0.0197	400	10.16	Orion 80	5	242	40.97	Vertical
0.0255	1764	2.98	CG-11 279	6.32	252	12.52	Horizontal
0.0197	1764	2.30	CG-11 279	6.32	242	9.29	Vertical
0.0255	2800	1.88	CG-11 279	10	252	7.89	Horizontal
0.0197	2800	1.45	CG-11 279	10	242	5.85	Vertical

Field of View Table Notes:

1. The CB245 camera uses the Texas Instruments TC245 CCD IC that has a photosite dimensions of .0255mm wide by .0197mm high.
2. Focal length of the Orion ShortTube™ refractor is 400mm.
3. Focal length of the Celestron CG-11 with the Celestron f/6.3 focal reducer is 1764mm
4. Focal length of the Celestron CG-11 without the Celestron f/6.3 focal reducer is 2800mm
5. To calculate resolution per photosite in arc seconds
   (Resolution per photosite in arc seconds) = (Photosite size in mm)*(206,265)/(Focal length in mm)
6. Objective diameter of the Orion ShortTube™ refractor is 80mm.
7. Objective diameter of the Celestron CG-11 is 279mm.
8. The CB245 camera uses the Texas Instruments TC245 CCD IC that has grid of 252 horizontal photosites by 242 vertical photosites.

Large Object Imaging

Large objects such as M8, M33, M39, M42, M44, M78 require a larger FOV than the Celestron CG-11 with the Celestron f/6.3 focal reducer can produce. Dark nebula imaging like B112 is possible. Also, a large FOV make it possible to imaging multiple objects such as M65/M66 and M81/M82.

Finding the Objects Easier

Finding an object with the Orion ShortTube™ refractor 55.23 x 40.97 arc minutes field of view (FOV) is easier than finding an object with the Celestron CG-11 with focal reducer (f/6.3) 12.52 x 9.29 arc minutes FOV.

Reduced Polar Alignment Errors
The affect of the telescope mount's polar alignment error is reduced when using the Orion ShortTube™ refractor. The Orion ShortTube™ refractor resolution per photosite is four times less than the resolution of Celestron CG-11 with the f/6.3 focal reducer, see Field of View Table. Unguided exposures over four minutes of are possible just using the Celestron CG-11 polar axis finder for polar alignment. Longer exposures start to show polar alignment errors as drift in the north or south direction.

Reduced Tracking Errors
The affect of the telescope mount's tracking error is reduced when using the Orion ShortTube™ refractor. The Orion ShortTube™ refractor resolution per photosite is four times less than the resolution of Celestron CG-11 with the Celestron f/6.3 focal reducer, see Field of View Table. The Celestron CG-11 Right Asection (RA) worm gear takes four minutes to make one complete revolution. The mount has Periodic Error Correction that is not used. Over four minutes of unguided exposures are possible with polar alignment error being the largest source of error.

Short Focal Length Disadvantages

Small objects like M57, M72, M75, M76 are very small and do not image very well. Also, the Orion ShortTube™ refractor 80mm aperture is a small aperture for deep sky objects.

Imaging Session

Reducing Time Setting up for a Imaging Session
The challenge of enjoyable observing is to reduce the telescope setup and tear down time to a minimum and maximizing the imaging time. In the past telescope setup time was 1.5 to 2 hours when setting up the Celestron CG-11 and the CB245 camera. Much of this time was unpacking the Celestron CG-11 telescope parts and assembling the telescope. Also, a lot of time was spent setting up CB245 camera. Currently I have reduced setup time to about 30 minutes and tear down time is about 15 minutes. The following techniques reduced the setup and tear down time:

- First, leave the Celestron CG-11 assembled with the CB245 camera and set it on a moveable dolly that can be rolled into the house. The Celestron CG-11 is on a home made platform made with wooden 4"x4" boards with wheels. The Celestron CG-11 is stored in the house and is wheeled out of the house on a ramp to the observing site on the driveway. The Celestron CG-11 is positioned north for polar alignment using a compass. Then the dolly is lifted one wheel at a time and three 8"x8" concrete blocks are slid under the dolly's 4"x4" boards right under where the Celestron CG-11 tripod sits on the dolly. Thin aluminum plates are put between the concrete blocks and the wooden dolly to level the telescope. Final polar alignment is done with Polaris star using the Celestron CG-11 through the polar axis finder on the telescope mount.

- The CB245 camera power supplies, computers and 12 Volt power supplies are setup in the red trailer next to the driveway ready to be plug into the Celestron CG-11 and CB245 camera.

- An observing chair, water cooler for the CB245, CB245 water pump, computer, power supplies, etc. are in the red trailer 10 feet from the telescope observing spot on the driveway. The blue and white cooler is filled with water to provide cooling for the CB245 camera.

- An observing table on wheels with remote computer monitor, keyboard and mouse is stored in the garage ready to be wheeled out next to the telescope. The operator's table is a folding table with a homemade nylon cover on the table top to prevent due on the remote computer monitor, keyboard, mouse and other stuff. The nylon covering has a flap to cover the opening to stop the computer monitor display light from affecting astroimaging with the CB245 camera. Also, the computer monitor has a red plastic (.106 LEE primary red from Hollywood Lights, 503-232-9001) over the display to cut down the glare.

Imaging Session Set up

The following activities are involved for setting up for an imaging session:

- Roll the telescope out of the house and on to the driveway.
- Remove lens caps, and eye piece caps to let optics cool to ambient temperature.
- Plug in 120 VAC to the utility trailer next to the driveway.
- Set up water cooler with water and connect water pump hoses to the CB245 camera on the telescope. Start the water pump to cool the CB245 camera.
- Plug in the power and computer cables from the utility trailer to the CB245 camera.
- Run CCD date bat file to create image directories and copy 245plus settings file to image directories.
- Start cooling the CB245 camera its steady state temperature and then start taking dark frames.
- Record date, time, air temperature, water temperature, CCD IC temperature, CB245 camera reset value and CB245 camera reference value.
- Align telescope dolly to north with compass.
- Lift and level telescope dolly on concrete blocks.
- Roll out remote monitor, keyboard and mouse table from the garage to next to the telescope and connect them to the computer switch box in the utility trailer.
- Polar align the Celestron mount using the polar axis finder on the mount when it is dark enough to see Polaris.
- From the utility trailer Plug in 12 VDC to the Celestron mount and dew heater.
- A dew shield to the Celestron CG-11.
- Check alignment of the finders: Daisy finder, Lumicon finder and the Celestron CG-11.
- Focus the CB245 camera on a bright star using star blooming method of focusing.
- Check north alignment of CB245 camera and adjust if necessary.
- Check CB245 camera CCD temperature and start taking dark frames for calibration.

Imaging Session

The following activities are typical for an imaging session:

- Record date, time, air temperature, water temperature, CCD IC temperature, seeing conditions, CB245 camera reset value and CB245 camera reference value.
- Collect dark frames until end of twilight.
- Record date, time, air temperature, water temperature, CCD IC temperature, seeing conditions, CB245 camera reset value and CB245 camera reference value.
- Use the TheSky to display a star chart of the object.
- Use binoculars to survey general area of the sky and to locate bright stars
- Use finders to move telescope to find object visibly or where the object should be. Tighten telescope mounts RA and DEC. Use hand control at 16X to fine tune telescope positioning.
- Use the find mode of 245plus CB245 control software to find and center object.
- Record date, time, air temperature, water temperature, CCD IC temperature, seeing conditions, CB245 camera reset value and CB245 camera reference value.
- Typically take a 4 minute image and check image for star blooming, object centering, focusing, tracking, etc.
- Make any adjustments and set up 245plus to take four 4-minute exposures. Use Messier or NGC numbers as part of the image file names.
- While imaging use the TheSky to display a star chart of the next object and use binoculars to learn it area in the sky.
- At end of imaging session, cap lenses, eyepieces, turn off telescope mount tracking, dew heaters.
- Record date, time, air temperature, water temperature, CCD IC temperature, seeing conditions, CB245 camera reset value and CB245 camera reference value.
- When morning twilight or clouds comes start collecting a 1 hour worth of dark frames.
- Record date, time, air temperature, water temperature, CCD IC temperature, seeing conditions, CB245 camera reset value and CB245 camera reference value.

Image Processing

The M42 Orion Nebula imaging processing is used as an example. Because of star blooming 31 M42 images were taken on 12-21-1998 at 01:07:57 to 01:20:06. One image was not used because it was blurred. 31 15 seconds images were stacked and calibrated with an average of the 16 15 seconds dark frames.

The imaging processing starts with Richard Berry's Multi245 version 40d for averaging 16 dark frames to create a master dark frame to be subtracted from each of the 31 raw images to produce 31 calibrated images. Using Multi245 the 31 calibrated images are register and stacked into one single calibrated image. This process is very simple and easy using Multi245. About five Multi245 commands are run to complete this task of creating a single calibrate image. Multi245 ML & AL commands are used for creating a master dark frame and the ML, TS & SA commands are used for creating the single calibrated image.

The calibrated image is processed with Richard Berry' CB245 imaging processing software using Kunihiko Okano's Digital Development functions. Next Software Bisque CCDSoft CCD Astronomy Software version 4.00.018 is used for brightness adjustment, contrast adjustment, rotating image, resampling the image to correct aspect ratio, and saving the image as a JPEG file for Web pages. JASC Inc. Paint Shop Pro version 4.12 is used for cropping the image to 187 pixels wide by 214 pixels high.

Imaging Results

Using the CCD Cookbook CB245 camera with an Orion ShortTube™ refractor is very fun and exciting to see what a CCD camera and small refractor can image. Today 70 Messier objects have been imaged, processed and can be seen on http://www.stargazing.net/david/.

The Imaging the Sky ’99 presentation will show a wide range of images that include small objects such M57 and NGC7331, medium size objects such as Horsehead Nebula, M17 and M51, large objects such as M8, M31, M33, M39, M42, M44, and M78, and multiple objects such as M81/M82.