Imaging Source DMK 21AF04.AS

Camera review for solar system imaging

Page 1 - Introduction

The DMK 21AF04 camera by Imaging Source became one of the most used cameras out of the range of "fast interface" cameras (IEEE1394 firewire or USB2) for planetary / solar system imaging including it's predecessor DMK 21F04 and and sister model DMK 21BF04. Originally intended for industrial vision and scientific purposes Imaging Source recognised the growing astronomy market segment like a few other competitors and offers this camera among other models as astrophotography versions as indicated by the .AS extension in the ordering code.

The Imaging Source astronomy cameras basically come in three flavours:

Monochrome CCD versions - DMK models
Color CCD versions with RGB output - DFK models
Color CCD versions with raw Bayer output - DBK versions

Currently each flavour is available as 640 x 480 1/4" CCD, 1024 x 768 1/3" CCD and 1280 x 960 1/2" CCD version, all equipped with Sony CCDs.

The 21AF04 models using the Sony ICX098 1/4" 640x480 CCD variants should be the most popular models. The CCD color variant 098BQ is well known from the famous Philips ToUcam Pro models and the monochrome version 098BL was often used to modify the ToUcam. 640x480 pixels are enough to image solar system planets, more pixels are only usefull for lunar and solar imaging. Compared to the ICX204 (1024x768) and ICX205 (1280x960) the ICX098 offers the highest pixel sensitivity in relation to pixel size. Unless a higher resolution than 640x480 is required the 21AF04 models are best planetary performers out of the range.

The "BF" models (not in the range of AS astrocameras) include external trigger capabilities not required for astro-imaging. The "F" models feature a longest integration/ exposure time of 1/30s - too short for most astronomical purposes, so that the AF models should be the astronomers choice. The longest integration/ exposure times of the .AS models has been extended to 60 minutes compared to 30s of the regular models so that extended deep sky imaging is possible although this should be limited in practise by the missing active cooling.

Monochrome, color or Bayer ?

Color CCDs contain a Bayer color microlens matrix - each pixel features a green, red or blue filter only, colors are arranged in the Bayer pattern. The missing two colors for each pixel are calculated from adjacent pixels having the required color. The DFK models do this debayer calculations in the camera, the camera output is complete RGB for each pixel. The DBK models output the raw bayer data to the host machine where the debayer calculation will be done instead of in the camera, the main advantage is speed: Only one third of the full RGB data has to be transfered and higher frame rates are possible.
The principles of the Bayer matrix limit the true color resolution to one third of the resulting RGB data since only one color is sampled per pixel. To aquire the full color resolution a monochrome CCD with a 3 pass RGB or CMY capture is required. Of course the capture using RGB filters and the processing of the data are more timeconsuming than a single color camera capture pass and might be critical for the recordings of a very short time window.

A monochrome CCD is more sensitive than the color equivalent since the color matrix is not present. Captures using special filters like IR-pass or UV-passfilters require a monochrome CCD without a color matrix for practical results.
Most solar system imagers should opt for the monochrome CCD variants of the cameras. Lunar and solar imaging is usually done without using color information (the usage of bandpassfilters is highly recommended, though). Imaging planets is recommended with mulltiple monochrome passes and filters unless the convenience of a color camera is favored - the Bayer models should be prefered then.

Why "fast interface" cameras ?

Cameras using a slow bus like USB1.X (e.g. the good old Philips ToUcam Pro) have to compress image data with lossy compression algorithms to deliver higher frame rates - the higher the frame rates the more image quality is affected. Solar system imagers try to gather as many raw image frames as possible in the recording time frame. The best frames affected least by seeing will be selected and stacked/averaged to minimize random noise of the raw frames and increase the effective bit depth. The more frames are used the better the resulting signal to noise ratio and the effective bit depth.
Cameras connected by firewire IEEE1394a (or even faster 1394b) or USB2 can deliver high frame rates without image compression - more raw frames with better quality can be captured.

Personally I prefer IEEE1394 to USB2 because cameras supporting the IIDC/DCAM protocol can be used with any capture software and operating system supporting the standard instead of requiring proprietary drivers.

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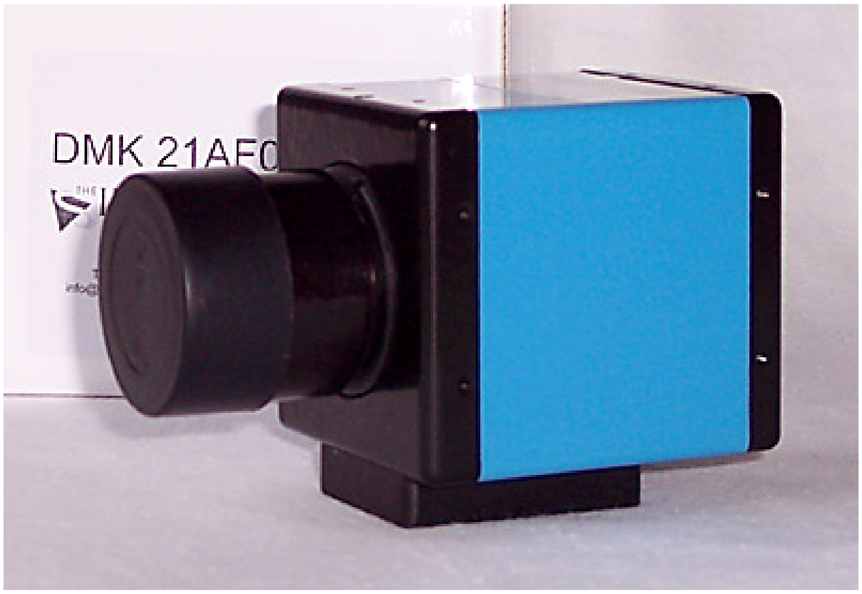
I've chosen the DMK 21AF04.AS to replace my previous cam since the latter had some severe issues with banding noise patterns in high gain settings.

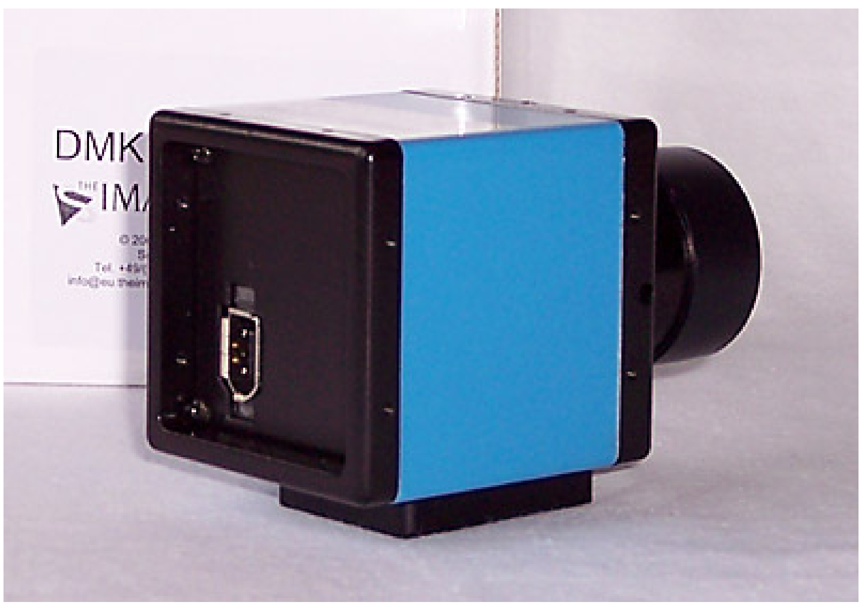
Lets look at some camera details first:

Camera model	The ImagingSource DMK 21AF04.AS
CCD model	Sony ICX098-BL (1/4" monochrome progressive scan)
Pixel size	5.6µm x 5.6µm square
Bus, protocol	IEEE 1394a (Firewire 400MBit/s), IIDC/DCAM 1.31
Max. usable resolution	640 x 480 pixels
Pixel depth	8 bit output (10 bit internal analog to digital conversion assumed)
Frame rates	60, 30, 15, 7.5, 3.75 fps
Integration/exposure times	1/10000s to 60min
ROI (Region of interest)	Yes
Binning	No
Lens mount	C/CS
Built-in filters	No
Power supply	8 V to 30 V DC via 6 pin firewire port (~200 mA @ 12 V)
Physical dimensions	Metal housing, 50.6mm x 50.6mm x 50mm, 265g



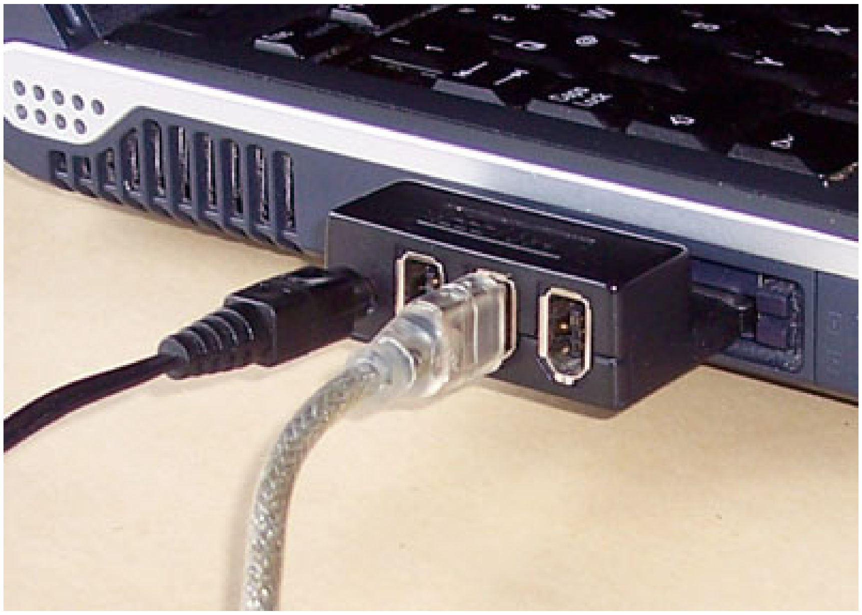
21AF04 with C/CS mount to 1.25" adapter attached

The compact enclosure of the DMK 21AF04.AS features a C/CS mount on the front. The camera can be adapted to a telescope or telescope equipment by 1.25" or 2" eyepiece adapter, T2 mount adapter or other adapters screwed into the C mount thread of the cam (adapters not included with the camera).



Back of 21AF04 with 6 pin IEEE1394 connector

The back of the camera holds a 6 pin IEEE1394/firewire connector jack. The cam can be powered via this connector only. 6 pin firewire interfaces of desktop computers usually power the lines but powered 6 pin connectors can only be found on very few laptop computers (e.g. some models from Samsung & Apple), most mobile machines feature the unpowered small 4 pin connector. Since most astronomers use laptops in the field the camera power has to be applied externally. This can be done by a Y-cable available from ImagingSource (4 pin plus additional power-jack to 6 pin, quite costly, though) or a PCMCIA firewire card with an extra power jack. I prefer the latter solution and power the camera with a lead battery powerstation since this will exclude any noise possibly introduced by a mains adapter. Choosing the correct voltage is totally uncritical since the cam operates between 8V and 30V DC to adapt to all practical scenarios (nominally 25V but can be down to 9V on some laptop ports).



PCMCIA IEEE1394a interface with external power connector

The bottom of the camera holds a metal base plate with 3 1/4" UNC tripod screw threads.

Bottom of 21AF04 - baseplate with 1/4" tripod threads

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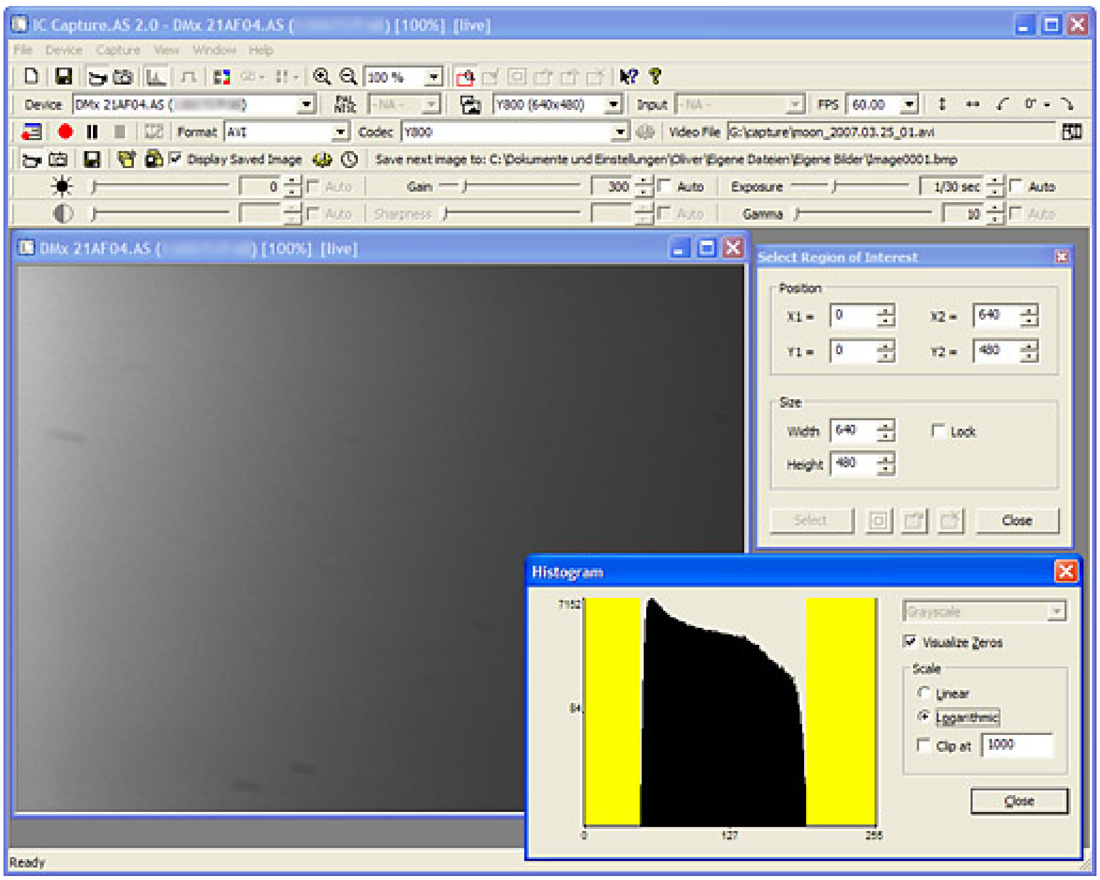
Page 3- DMK 21AF04.AS Software

All ImagingSource astrocameras come with drivers for Windows 2000 & XP (it's reported they work with Vista) and the capture software solution IC Capture.AS for Windows (currently in version 2.0) with a free license for ImagingSource cameras included. Nevertheless the IEEE 1394a & IIDC/DCAM 1.31 standard interface of the camera should make image & video capture with any software & OS supporting the standards possible (e.g. Coriander for Linux or Astro IIDC for Mac OS).



IC Capture.AS 2.0 main screen - click image for original size

IC Capture can show a live preview of the camera signal, record single images (BMP or JPEG), sequences of single images and movies as AVIs. AVIs can be saved with all codecs installed in the system, uncompressed lossless codecs like Y800 should be prefered for astro applications. All camera properties can be controlled within the software. The ROI (region of interest) properties can be controlled very comfortably. One highlight of the software is the very appreciated live histogram with different display modes, color channels can be displayed separately for color cameras.

The software offers a complete package for effective planetary imaging - much appreciated that the software is included with any ImagingSource camera.

Only some minor complaints from my side:

- Changing the AVI capture file requires navigating through 2 subwindows, the target file cannot be changed quickly in the main window
- No overlays like a crosshair, grid etc. in the preview window

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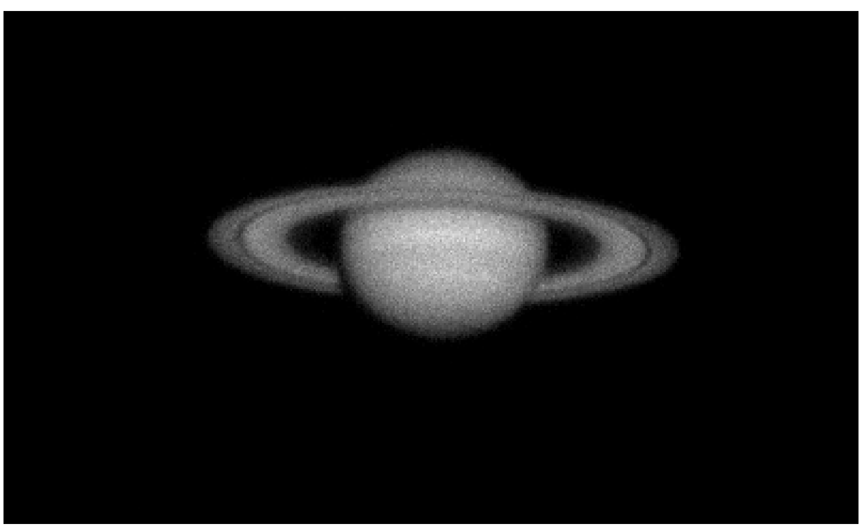
Here some practical sample captures with the camera to demonstrate raw frame and final results qualities.

Saturn 2007.03.11

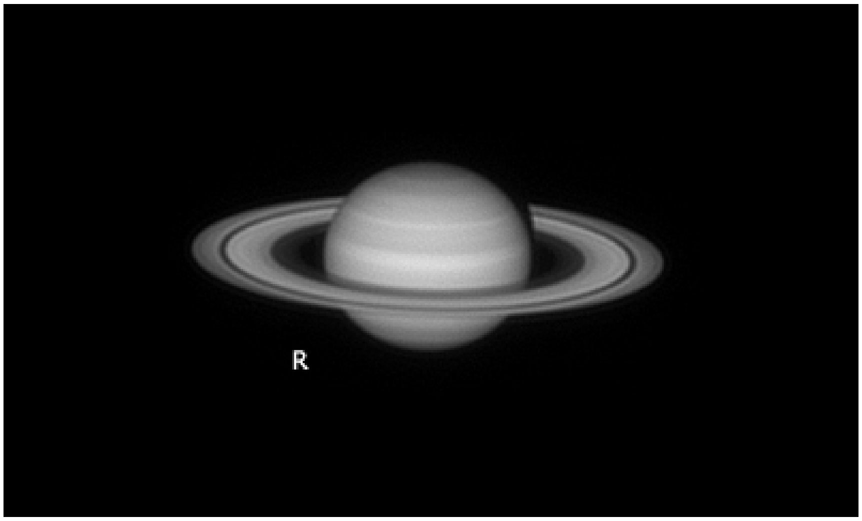
One of my best Saturn captures so far. Seeing was good but not very good. Choosing shorter exposure/integration times to the disadvantage of higher gain settings = more noise helped to freeze the seeing.

Capture settings for the red channel:

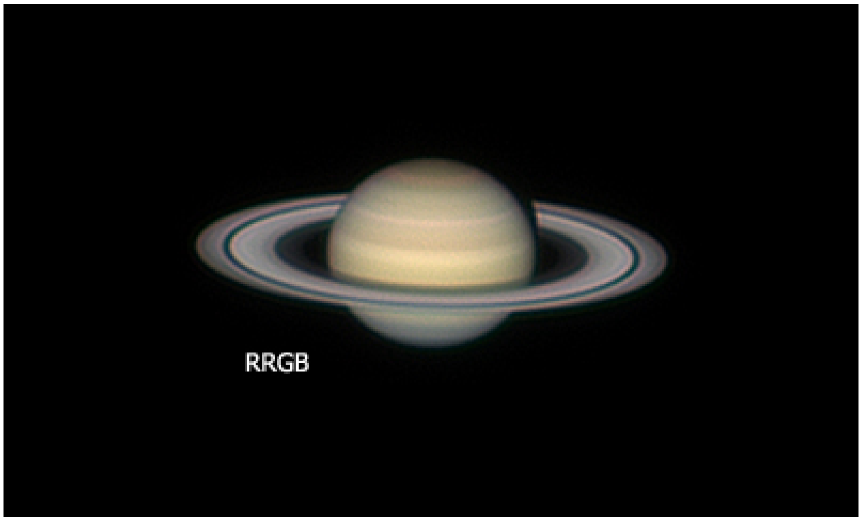
Exposure/integration	1/23s
Gain	820 (max. is 1023)
Black level / brightness	0 (slider all left)
Gamma	10 (slider all left)
ROI	400 x 240
Frame rate	15 fps



Best red channel frame - click image for lossless BMP



Processed red channel result with 1500 frames used - click for full details



Processed RRGB result - click image for full details

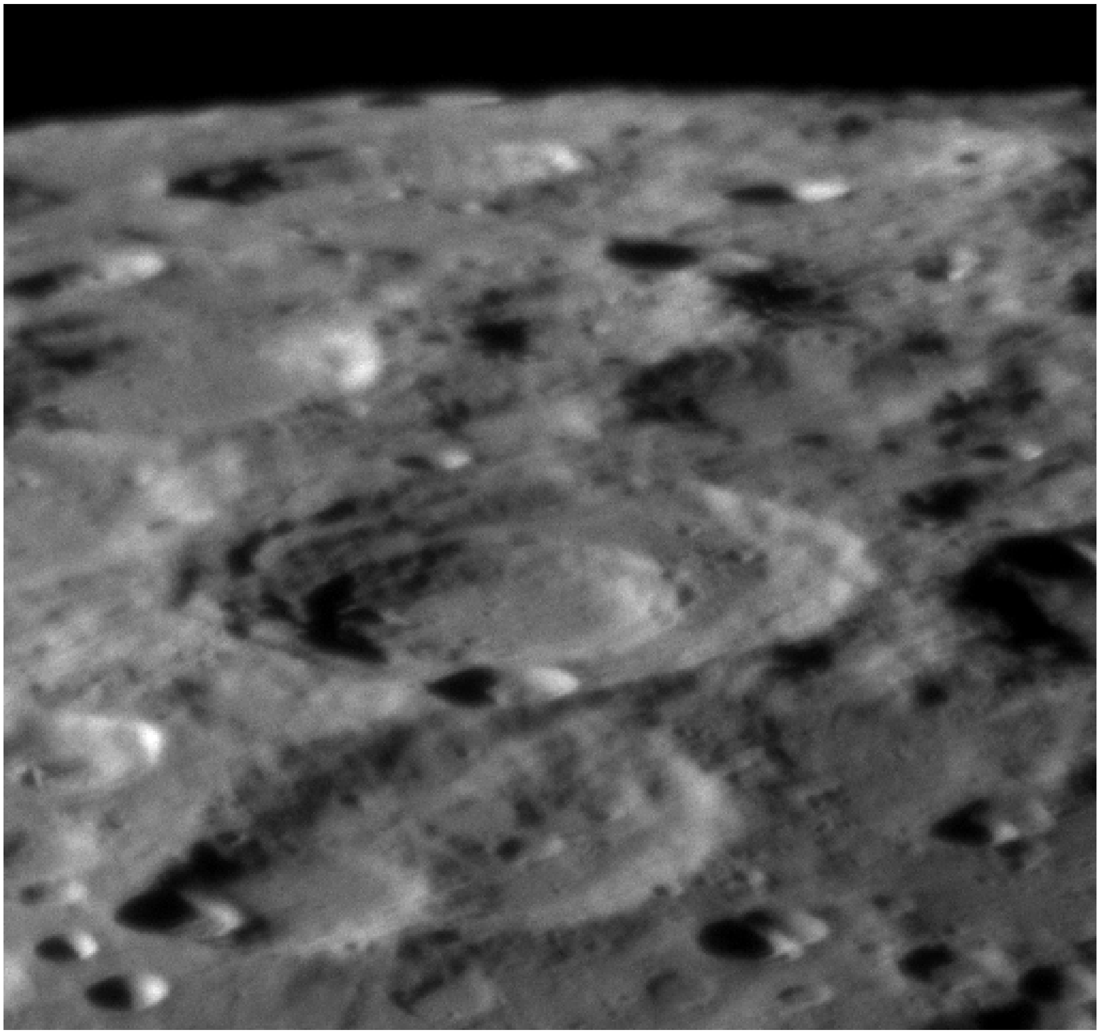
The raw frames show noticable random noise, no surprise since a very high gain setting has been used for the capture to freeze seeing with short integration times. Stacking 1500 frames eliminates the noise and allows sharpening details without enhancing noise. No sytematic noise patterns are visible even with heavy sharpening pointing out a good signal processing quality of the camera even at high gain settings.

Moon 2007.03.25.

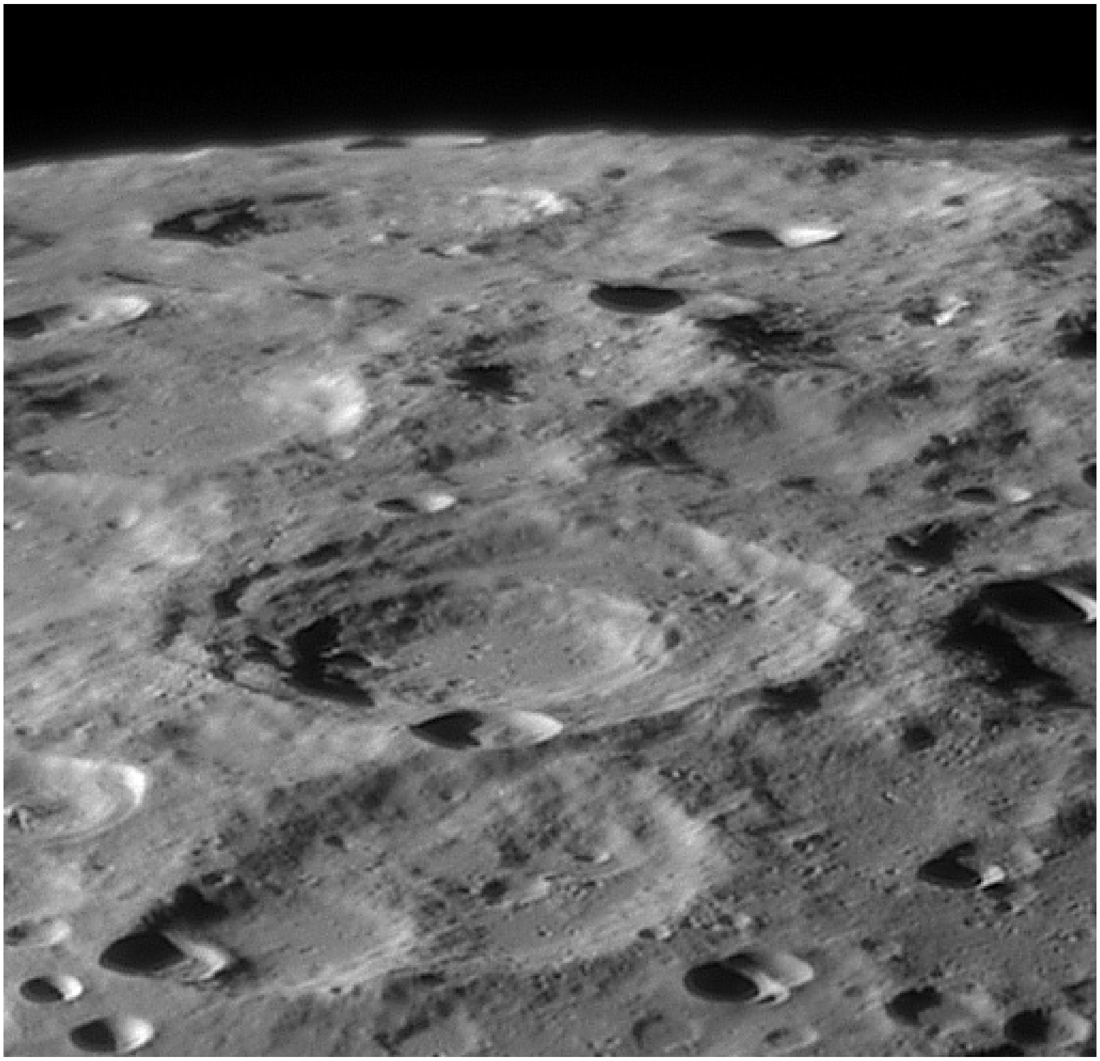
Seeing was slightly above average but not yet in the range I would call good. Again I used more gain to shorten exposure times. Random noise in the raw frames is quite low considering the gain is used at ~60% of the maximum gain. 380 stacked frames have been enough to have an almost noise free result after sharpening.

Exposure/integration	1/30s

Gain	600 (max is 1023)
Black level / brightness	0 (slider all left)
Gamma	10 (slider all left)
ROI	Full frame
Frame rate	30 fps



Part of a better raw frame - click image for full lossless BMP



Part of processed result - click for full lunar limb mosaic

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Page 5 - Resume

The DMK 21AF04.AS is great value for money and a good performer for solar system imaging. Many top planetary imagers use the cam successfully, there's no bad surprise in the camera's behaviour.

Signal processing of the device is ok - I didn't experience any noticable systematic noise like banding patterns for high gain recordings unlike the camera I used before. Personally I consider the Sony ICX098 CCDs a good trade off between sensitivity and pixel size. Pixels are small enough to obtain small FOVs per pixel even with newtonian reflectors and 5x focal length enlargement and still offer a viable noise characteristic and good sensitivity considering pixel size.

One may ask the question if a higher analog to digital conversion depth than the camera offers can deliver better results. Basically a higher bit depth allows fewer frames to be stacked to reach the same effective bit depth as a result created with lower bit depth raw frames. Additionally a higher bit depth can lead to identical results with slightly underexposed frames compared to correct exposed frames with a lower depth - nice in low light situations and sessions where short exposure times are required to beat seeing. The number of frames required to obtain a certain signal to noise ratio enhancement is not related to the bit depth, though.
The DMK 21AF04.AS outputs 8 bits per pixel, I assume the internal A/D conversion is 10bit. Competitors cameras (e.g. Lumenera SKYnyx 2-0) offer 12bit output but usually use CCDs with larger pixels like the ICX424 instead. To evaluate if a bit depth > 8 pixels is usefull at all with the ICX098 the full well capacity of the CCD in electrons and the read & dark noise of the system is required to determine the optimal A/D depth. Since both parameters are not available to me I can't comment on the potential usefulnes of more than 8bits with this CCD.
Last but not least one should consider that the mentioned competitors products cost more than two times the price of the DMK 21AF04.AS.

The camera comes with a good and practical software package which is not too common for other cameras of this segment. The long exposure capabilities of the cam are fine to make a start into deepsky photography but the missing active cooling and only 8 bit A/D conversion don't make it a specialist for this task. The DMK 21AF04.AS is currently quite unrivaled in the price segment, some potential rivals may show up soon. The camera is highly recommended to solar system imagers looking for a solid & well known performer who don't want to invest in the range of 1000€.

Oliver Pettenpaul - July 2007

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