THE CALIBRATION LAB AT UNIS

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How to take color pictures of aurora

Fred Sigernes [1,2,3]

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[3] Birkeland Centre for Space Science (BCSS), University of Bergen, Norway

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How to take color pictures of aurora

Fred Sigernes

CONTENT

1. MOTIVATION – The optics revolution …
2. FORECASTS – Where is the aurora?
3. THE DSLR CAMERA – What is it?
4. SCIENTIFIC CAMERAS – What is new?
5. WHAT CAN WE DO WITH COLOR?

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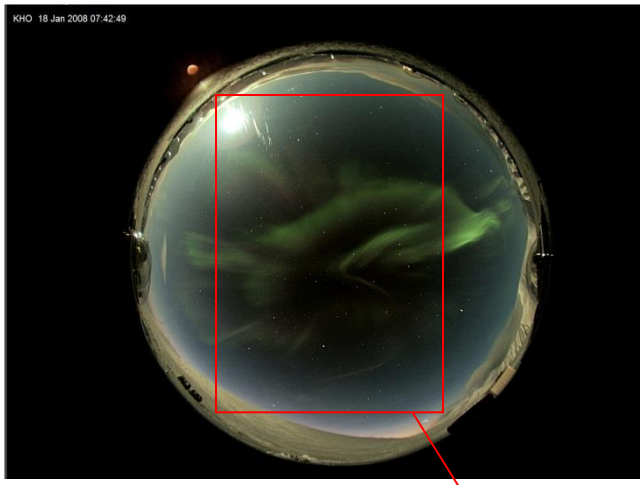
SXVF-H9C & D80 @ KHO



Starlight Xpress Fujinon F/1.4 (McWriter@UCL)<60s

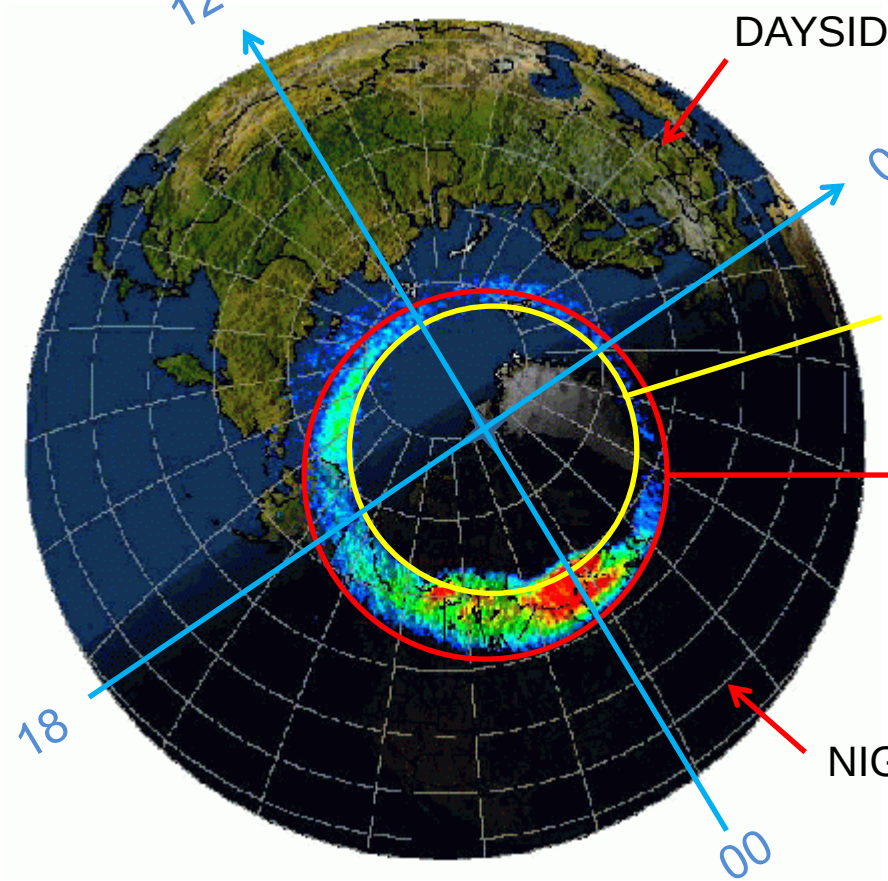
LYR, 17.01.2007, 08:22:28 UT
6 sec exposure ISO 1600, f/2.8

Nikon D80
ISO 1600
F/2.8 20s

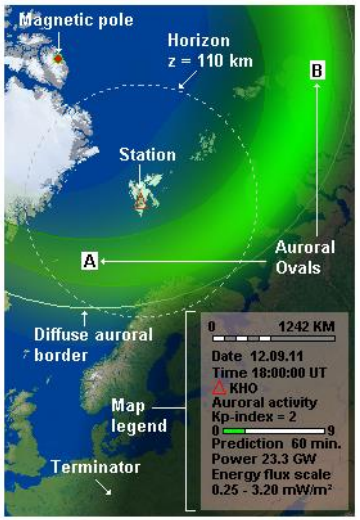
MOTIVATION

1. The cameras are low cost mass products
2. High spatial resolution (stars, satellites...)
3. Sensitivity (<25 000 ISO)
4. Simple optical design
5. The main auroral emissions (4278, 5577 & 6300 Å) are well colour channel separated
6. Colour classification of sky conditions (clouds, snow, light pollution & aurora)
7. Can operate in all types of light conditions including periods of full moon.
8. It is relatively easy to flat field calibrate and find mapping functions of lenses by the use of stars.
9. Useful in public presentations
10. The cameras are not intensity calibrated!

LOCATION: AURORA OVAL TERMS



Download Android forecast with Q-Code scanner



(A) Auroral oval by Starkov (1994)
(B) Electron energy flux Zhang & Paxton (2008)

F.Sigernes, 2011

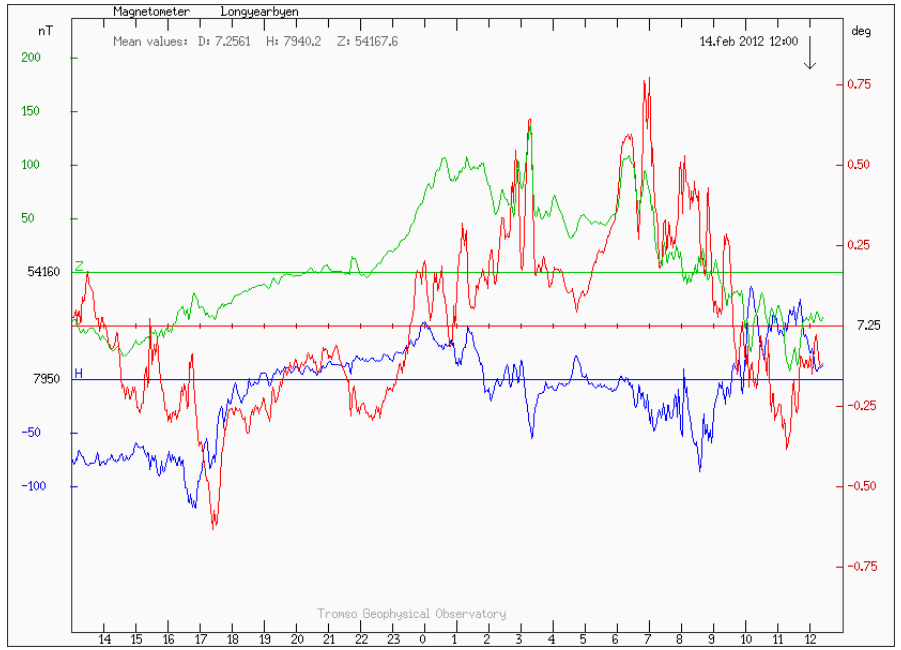
Note: Size and location depends magnetic activity or **Kp index**

GEOMAGNETIC ACTIVITY

K-index	Boulder, CO observatory measurement (nT)
0	0 - 5
1	5 - 10
2	10 - 20
3	20 - 40
4	40 - 70
5	70 - 120
6	120 - 200
7	200 - 330
8	330 - 500
9	>500

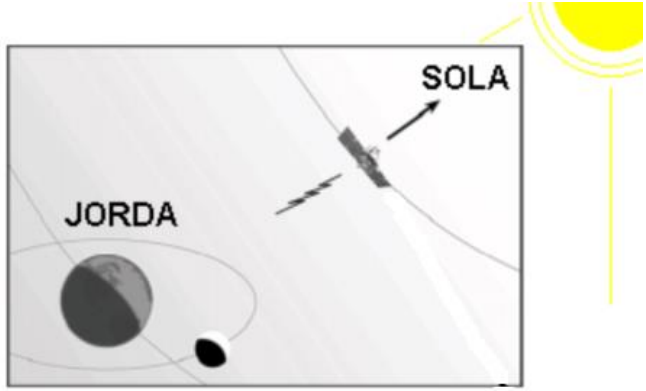
The **K-index** quantifies max disturbances in the horizontal component of earth's magnetic field during a 3 hour period.

Planetary estimated **Kp index** is derived by calculating a weighted average of K-indices from a network of geomagnetic observatories (US Air Force) and NOAA

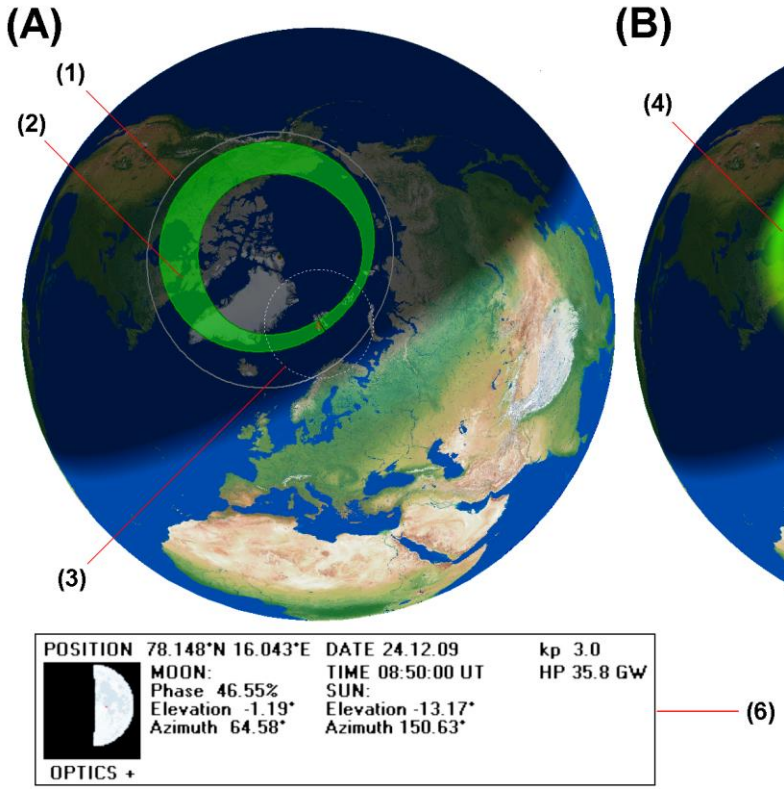


Using data from solar satellites, located 1 hour upstream in the solar wind, we get the **predicted Kp index**.

Prediction time ~ 60 minutes



VISUALIZATION



The twilight zone, night- and dayside of the Earth are projected with grades of shade on the Globe as a function of time.

The ovals are visualized with a stand alone 32-bit executable Windows program called

SvalTrackII.

The program is written in Borland's Delphi – Pascal and uses a Geographic Information system (GIS) unit called TGlobe.

Includes:

Method A

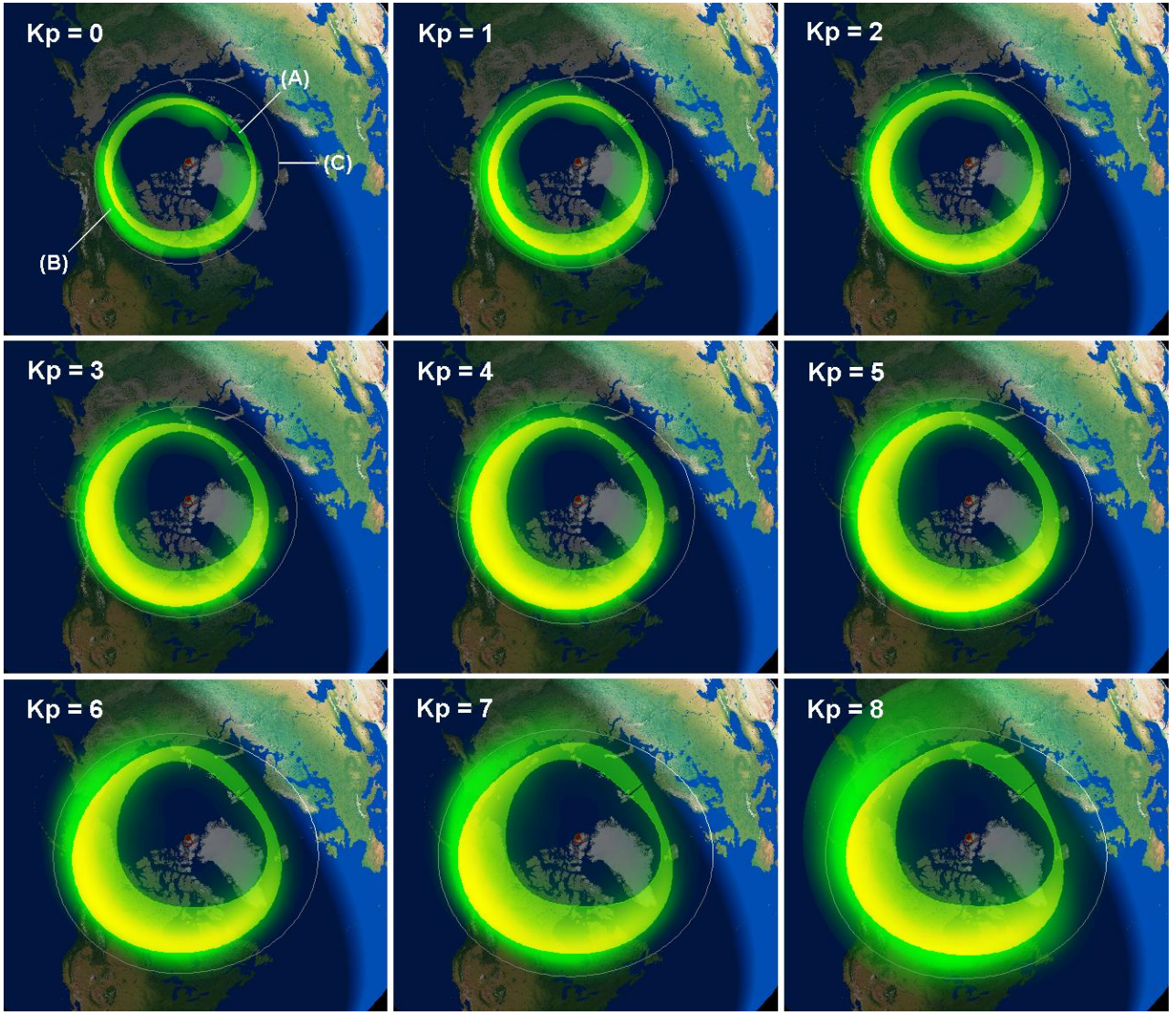
(1) Equatorward boundary of the diffuse aurora
(2) Feldstein & Starkov oval
(3) Field of view aurora observer

Method (B)

(4) Zhang & Paxton oval
(5) Observer location
(6) Moon and Sun information at local site

ANIMATION

Animated aurora ovals as a function of *Kp* index [0…8] at 08:50 UT, 24th December 2009



THE AURORAL OVAL FORECAST

KHO
The Kjell Henriksen Observatory

UNIS

Tel: +47 79 02 33 00 | post@unis.no

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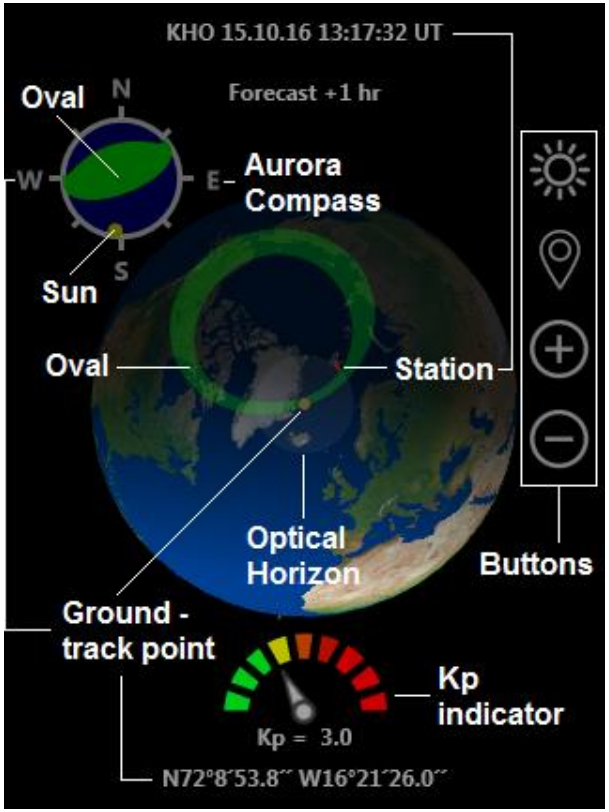
KHO Auroral forecast service

NEWS: THE AURORA OVAL FORECAST 3D



New cross platform application
iOS, OSX, Android and Windows

Forecasts: 0, +1 and +4 hours

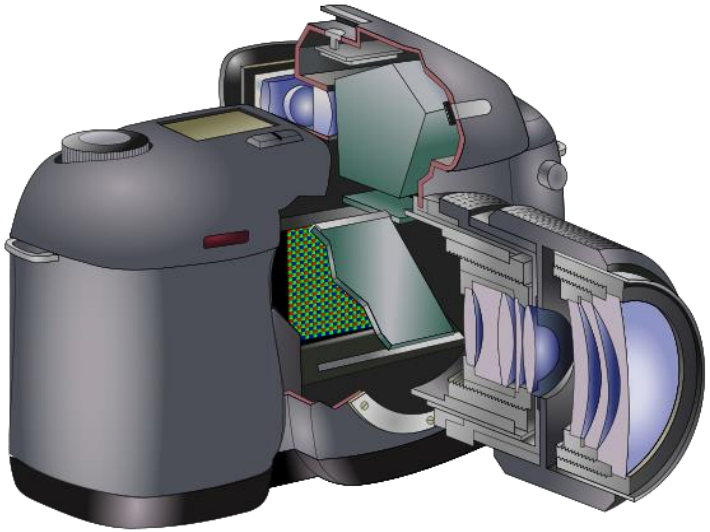
3D scaling and rotation of Globe

Not only predefined Stations. It forecasts anywhere on the planet using the location service of your phone.

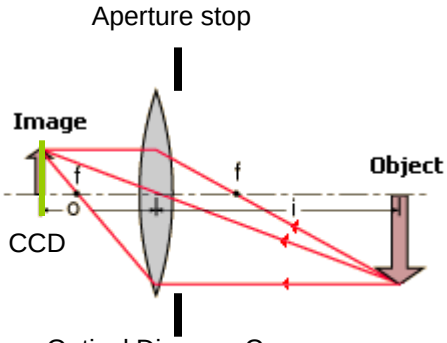
Current status: β – testing.
Will also include star and planet sky view.
Price: TBD

THE DSLR CAMERA

The Digital Single Lens Reflex camera



DSLR Cross section (Wikipedia)



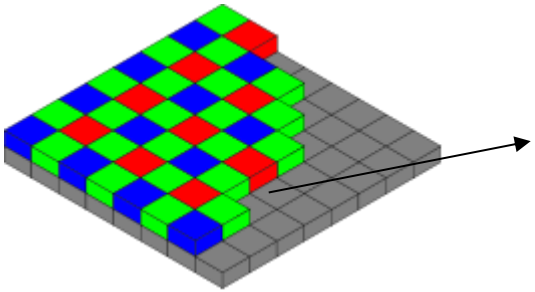
Optical Diagram Camera

Aurora

1) Look at the auroral forecast to find pointing direction.
2) Use a tripod and self trigger.
3) Open to maximum aperture (low F/number)
4) Set focus to infinity
5) Use detector (CCD) settings on?

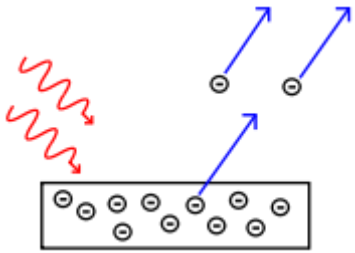
THE CCD

The Charged Coupled Device



CCD with Bayer color filter mosaic (Wikipedia)

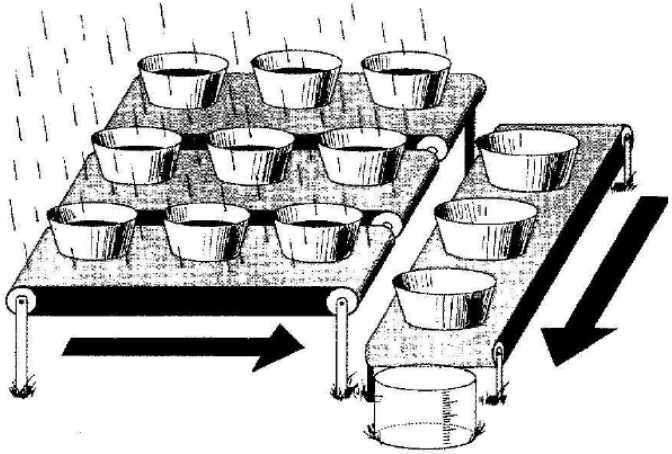
The photoelectric effect

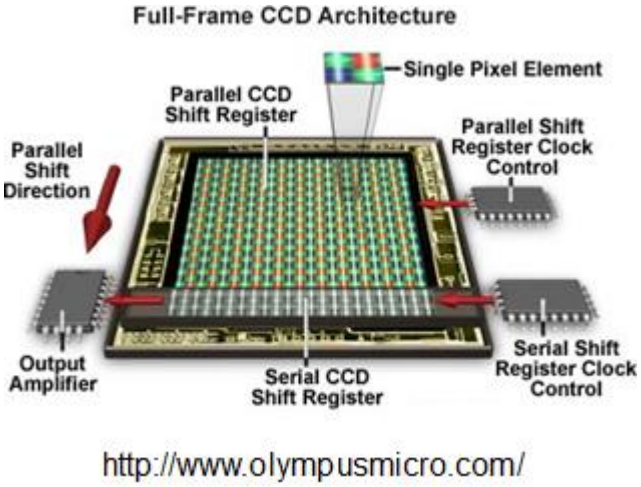


Metals or non-metallic solids like phosphorus doped silicon.

CCD Principle

Janesick et al. (1987)





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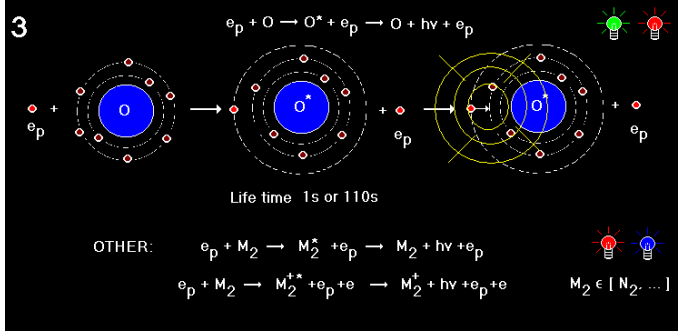
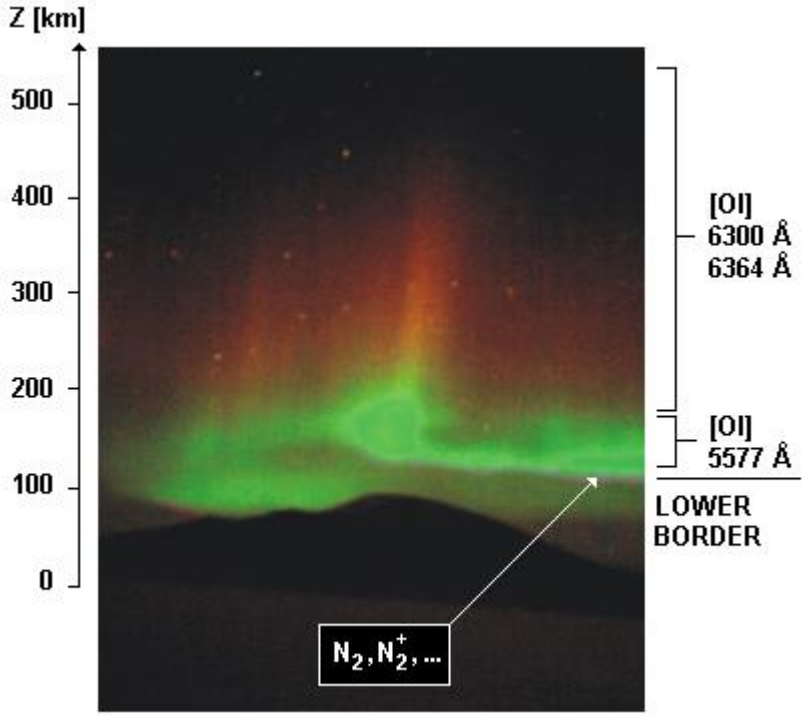


THE TARGET?

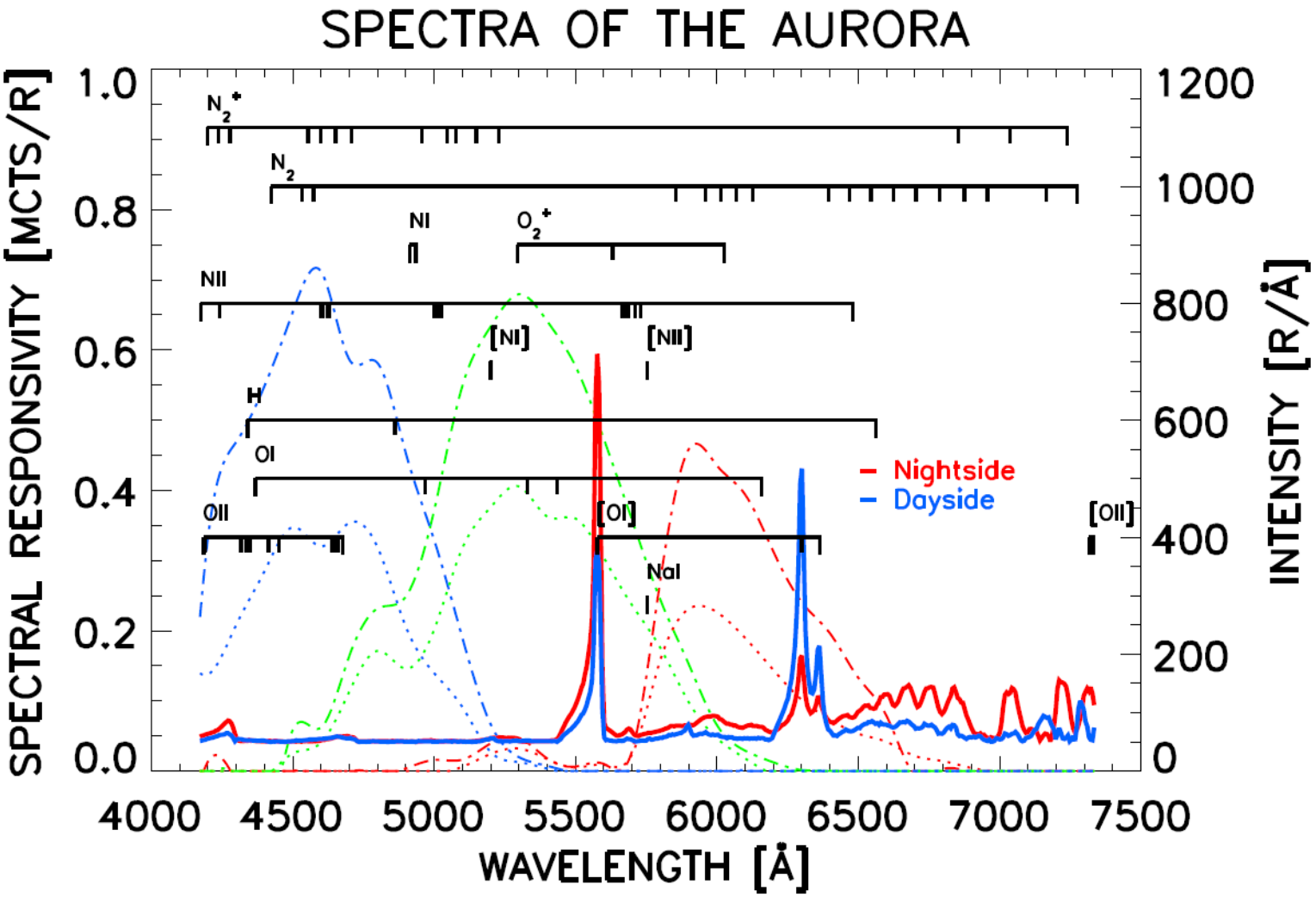


Fujifilm S2Pro, 30 s exposure ISO 1600, f/2.8

NOTE

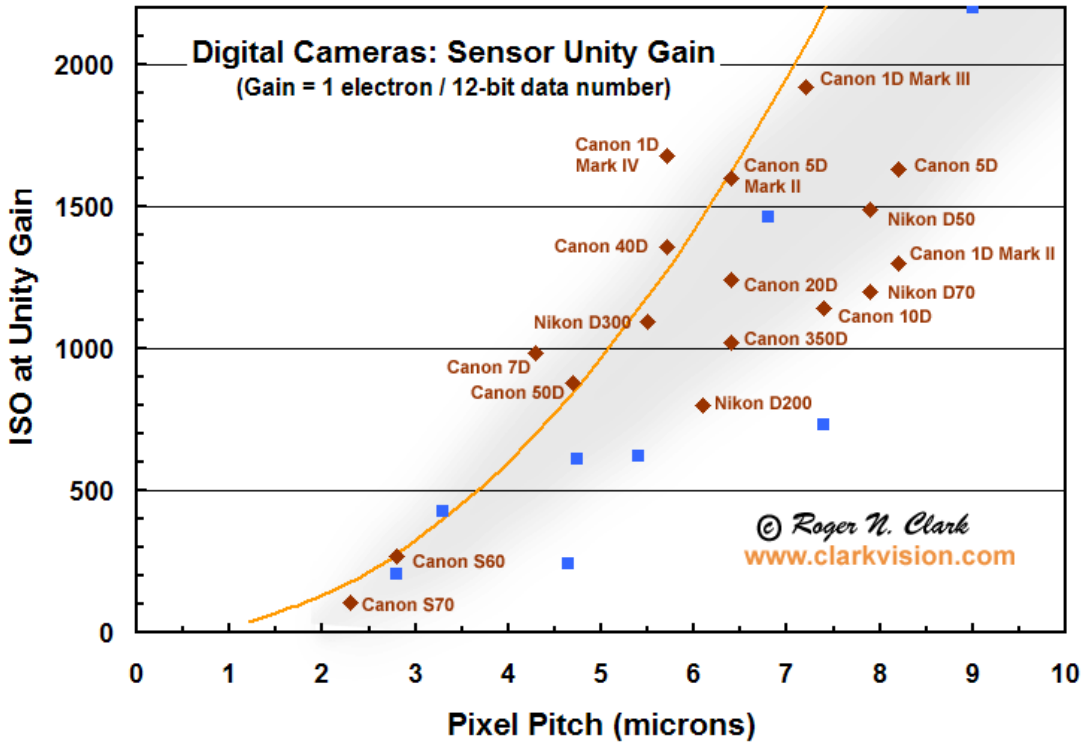
Upper red emissions from [OI] 6300 Å has a lifetime of 110 s, while lower green [OI] 5577Å only is 1s.

Fast moving emissions along lower border of the auroral arcs are produced by high energetic electrons exciting molecules N_2, N_2^+…life times<1s.


SPECTRA OF THE AURORA
SPECTRAL RESPONSIVITY [MCTS/R]
INTENSITY [R/Å]
WAVELENGTH [Å]
1.0
0.8
0.6
0.4
0.2
0.0
1200
1000
800
600
400
200
0
4000
4500
5000
5500
6000
6500
7000
7500
N2+
N2
NI
O2+
NII
[NI]
[NII]
H
OI
OII
[OI]
NaI
[OII]
Nightside
Dayside

THE UNITY GAIN ISO (g)

"The Unity Gain ISO is the ISO of the camera where the A/D converter digitizes 1 electron to 1 data number (DN). Since 1 electron (1 converted photon) is the smallest quantum that makes sense to digitize, there is little point in increasing ISO above the Unity Gain ISO" (http://www.clarkvision.com).



SCIENTIFIC CAMERAS

EMCCD

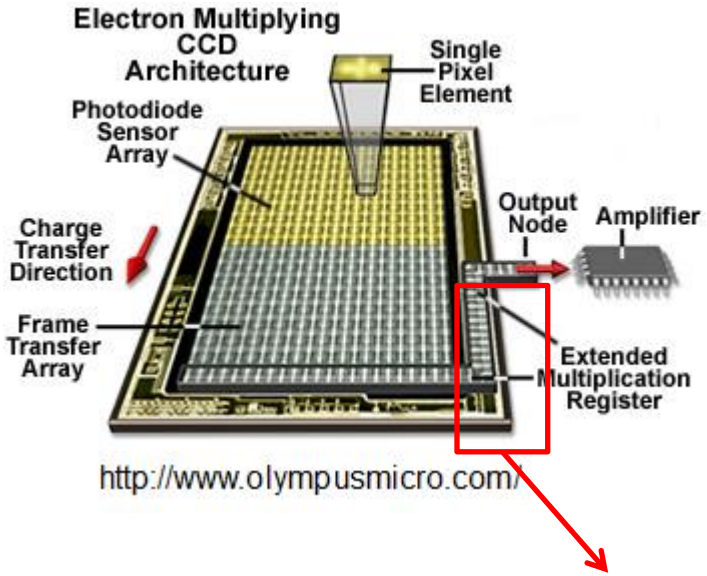
Color matrix EMCCD (Electron Multiplying Charged Coupled Devices) image detectors have become available to the auroral community to a reasonable price. The latter is due to increased surveillance and the astronomical use of this technology.

ICCD

The sensitivity of the EMCCD is close to the Intensified CCD (ICCD). Monochromatic all-sky ICCD's cameras have been used for decades to study auroral morphology with no emphasis on image segmentation based on color.

THE EMCCD CAMERA

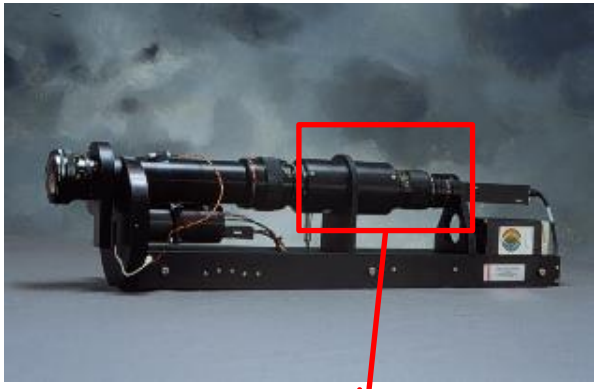
Electron Multiplying Charged Coupled Devices

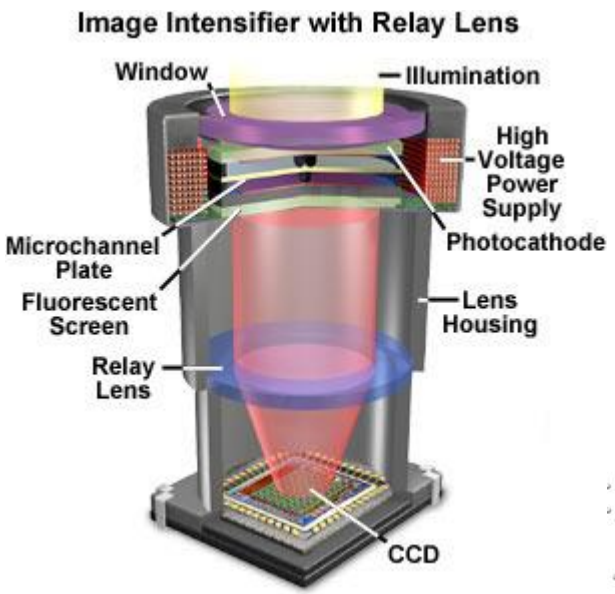


Photoelectrons from the CCD are amplified by impact ionization through a high voltage serial register.

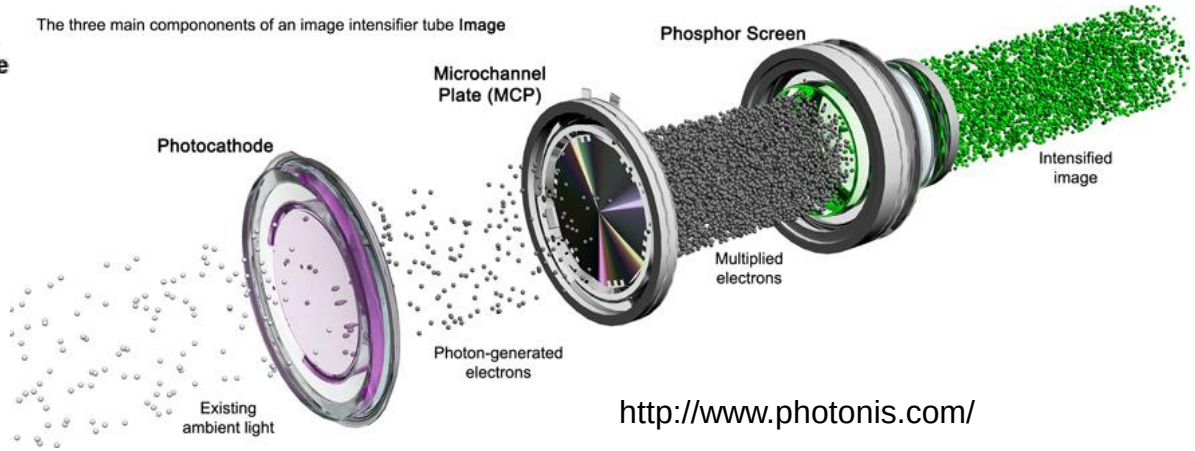
THE ICCD CAMERA

The Intensified Charged Coupled Device





http://www.olympusmicro.com/

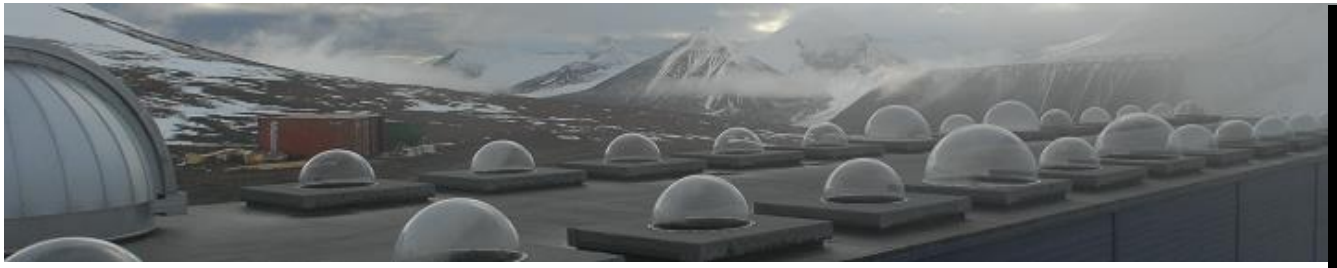


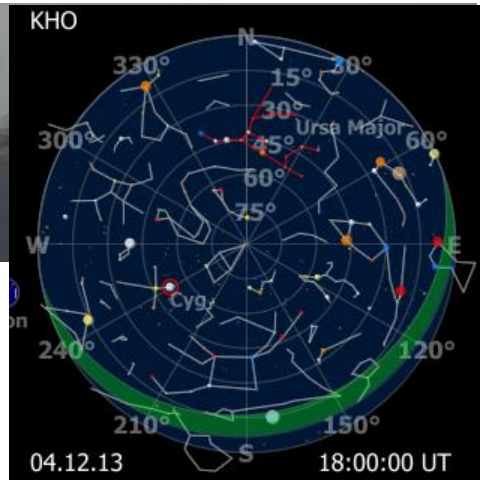
http://www.photonis.com/

Next: What can we do with color data?

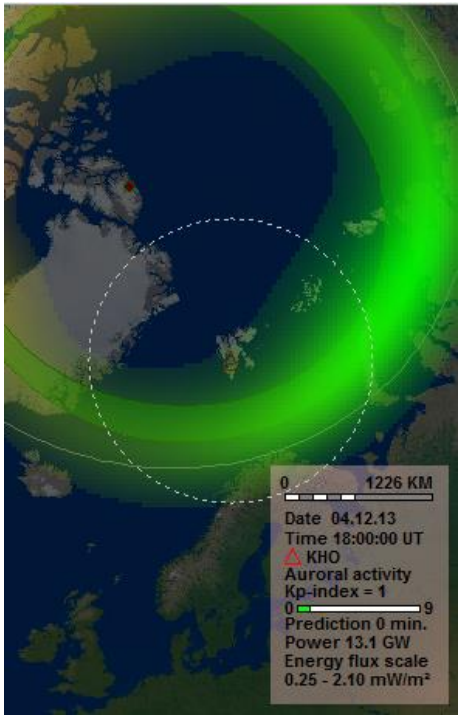
A relatively low cost color all-sky EMCCD camera has been assembled and tested at the Kjell Henriksen Observatory (KHO). The camera is able to automatically detect aurora based on color matching at high frame rates. The results are compared to corresponding images from a Digital Single Lens Reflex camera (DSLR).

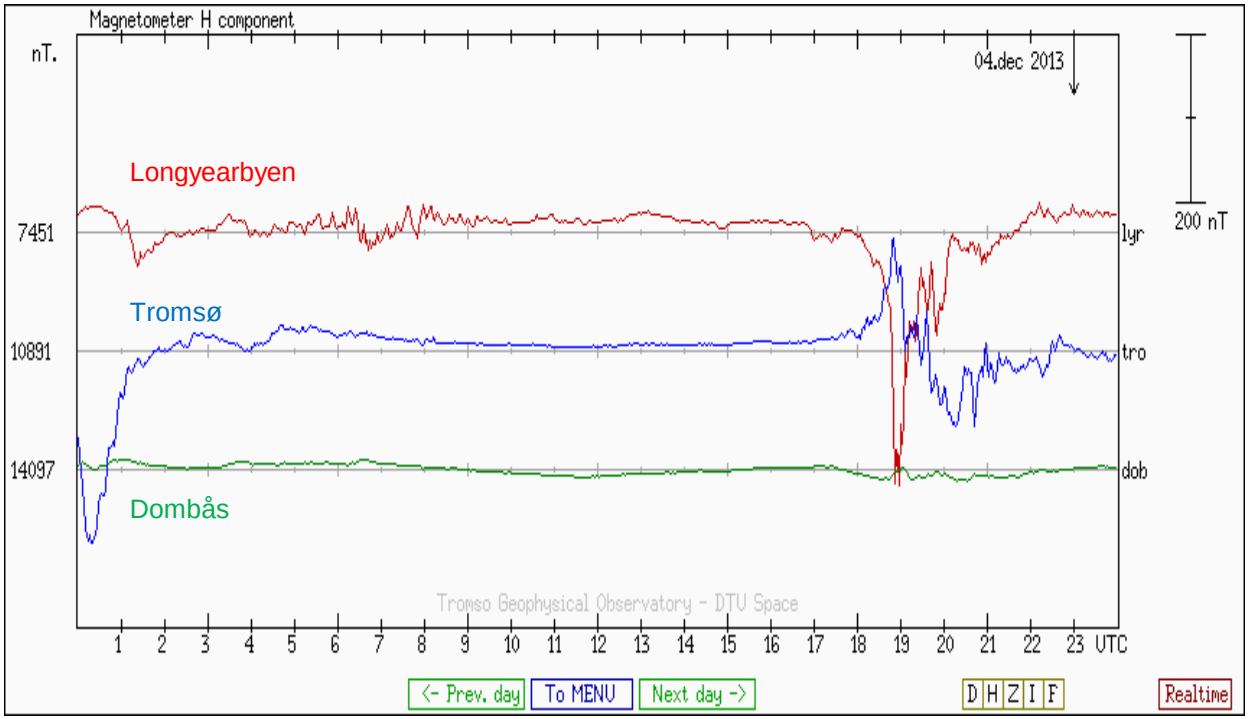
Raptor Hawk EM-246
Color EMCCD camera
Electron Multiplying Charge Coupled Device
Fujinon F1.4 Circular Fisheye 185°
Time resolution: 25 msec (real time)
PAL 25 frames / second
Color matrix: CYMG
Frame accumulation ~1s
Dimension: 43 x 43 x 50 mm^3





The Substorm of December 4, 2013

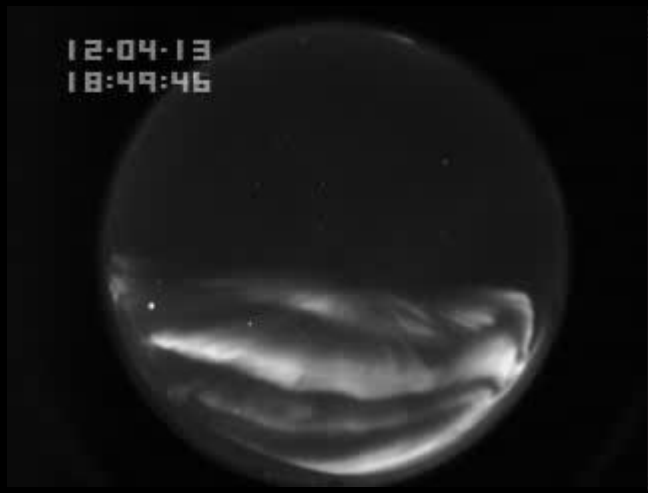


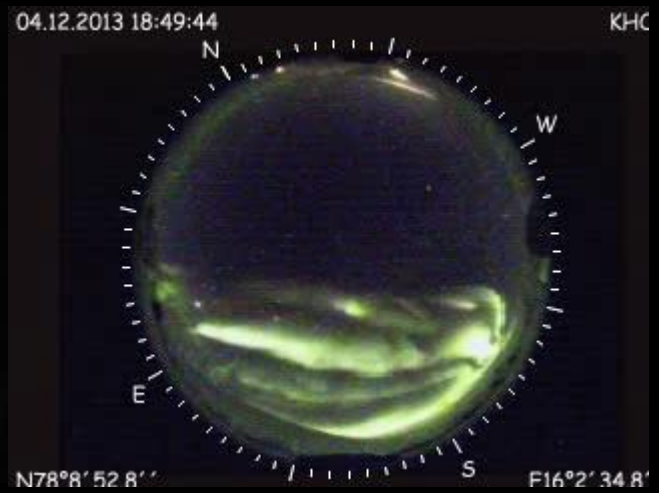


Estimated Kp = 1

An ordinary aurora that was associated with a co - rotating interaction region, CIT, in the solar wind. Originate from coronal holes on the sun.

KHO
4th of December 2013





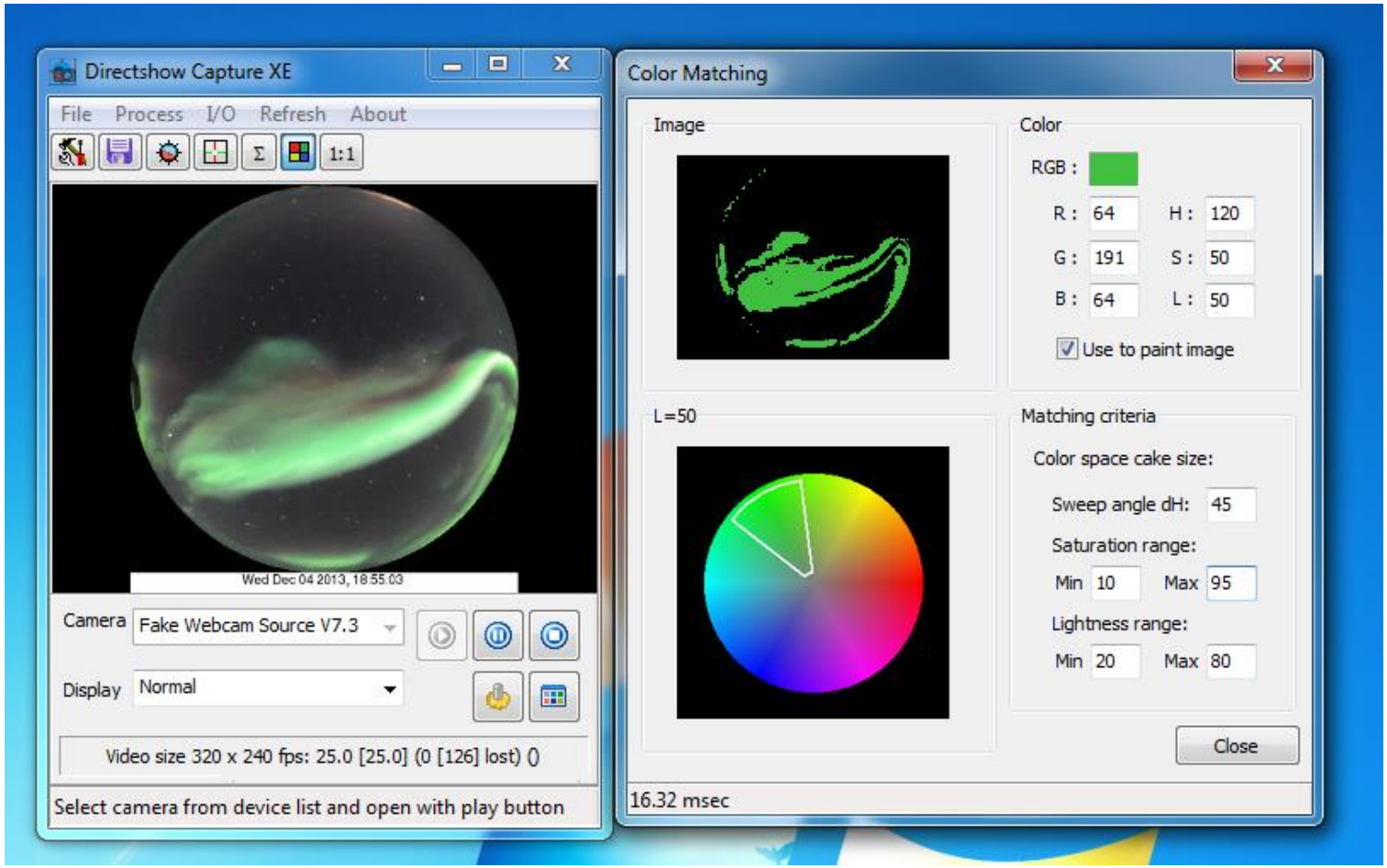
DSLR
Digital Single Lens Reflex
Circular Fisheye 180°
Time resolution: 5 - 30 s
Camera: Nikon D7000
Lens: Sigma 4.5mm f/2.8
Nikon D7000 -16M pixels
Color matrix: RGB

INTENSIFIED CCD
4th Gen Light intensified vacuum tube
Circular Fisheye 180°
Time resolution: 25 msec (real time)
Camera: Video CCD
NTSC: 30 frames /second
Monochrome
Frame accumulation ~1s (30 frames)

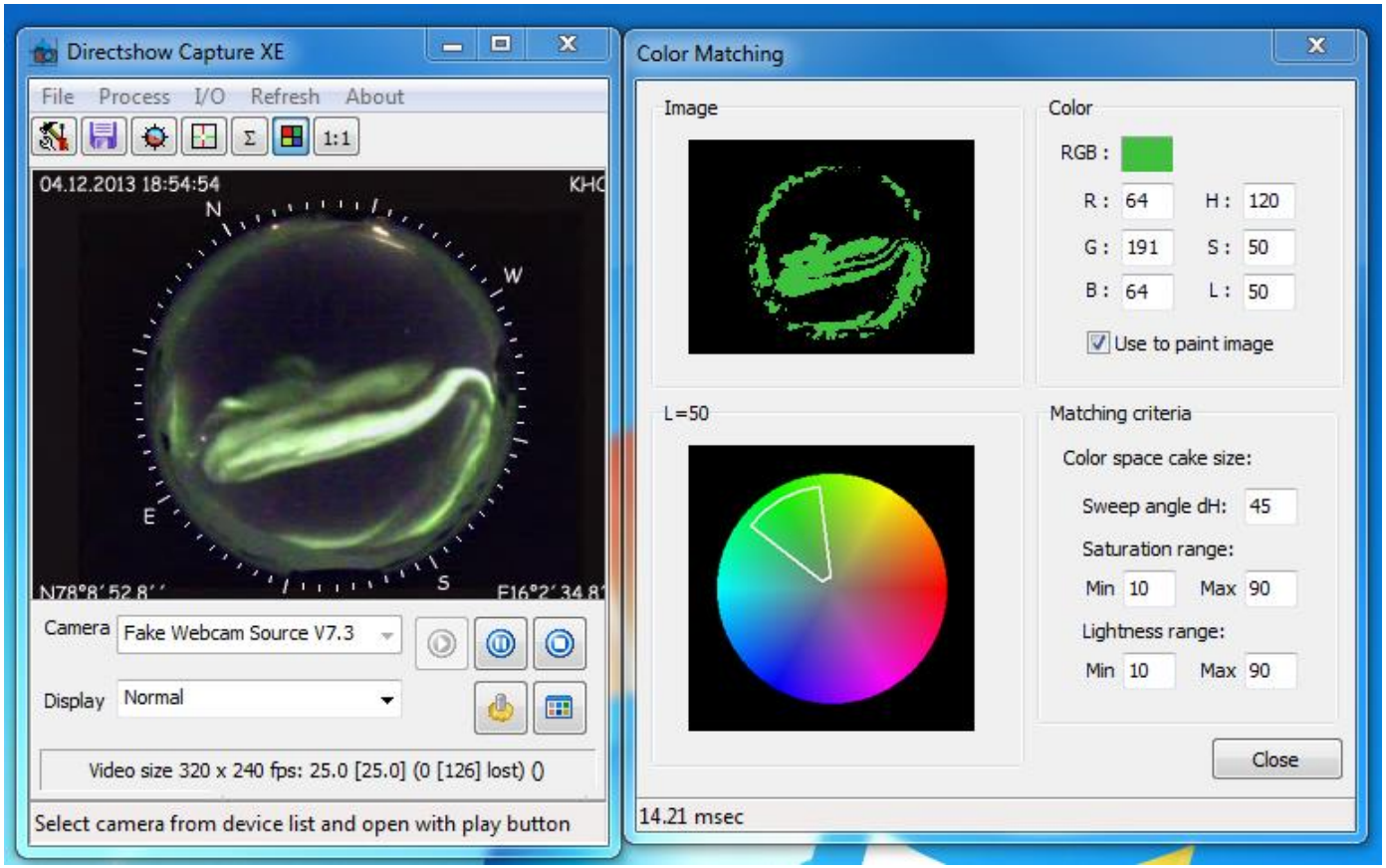
Color EMCCD camera
Electron Multiplying Charge Coupled Device
Circular Fisheye 185°
Time resolution: 25 msec (real time)
Camera: Raptor Hawk EM246
PAL: 25 frames / second
Color matrix: CYMG
Frame accumulation ~1s (25 frames)

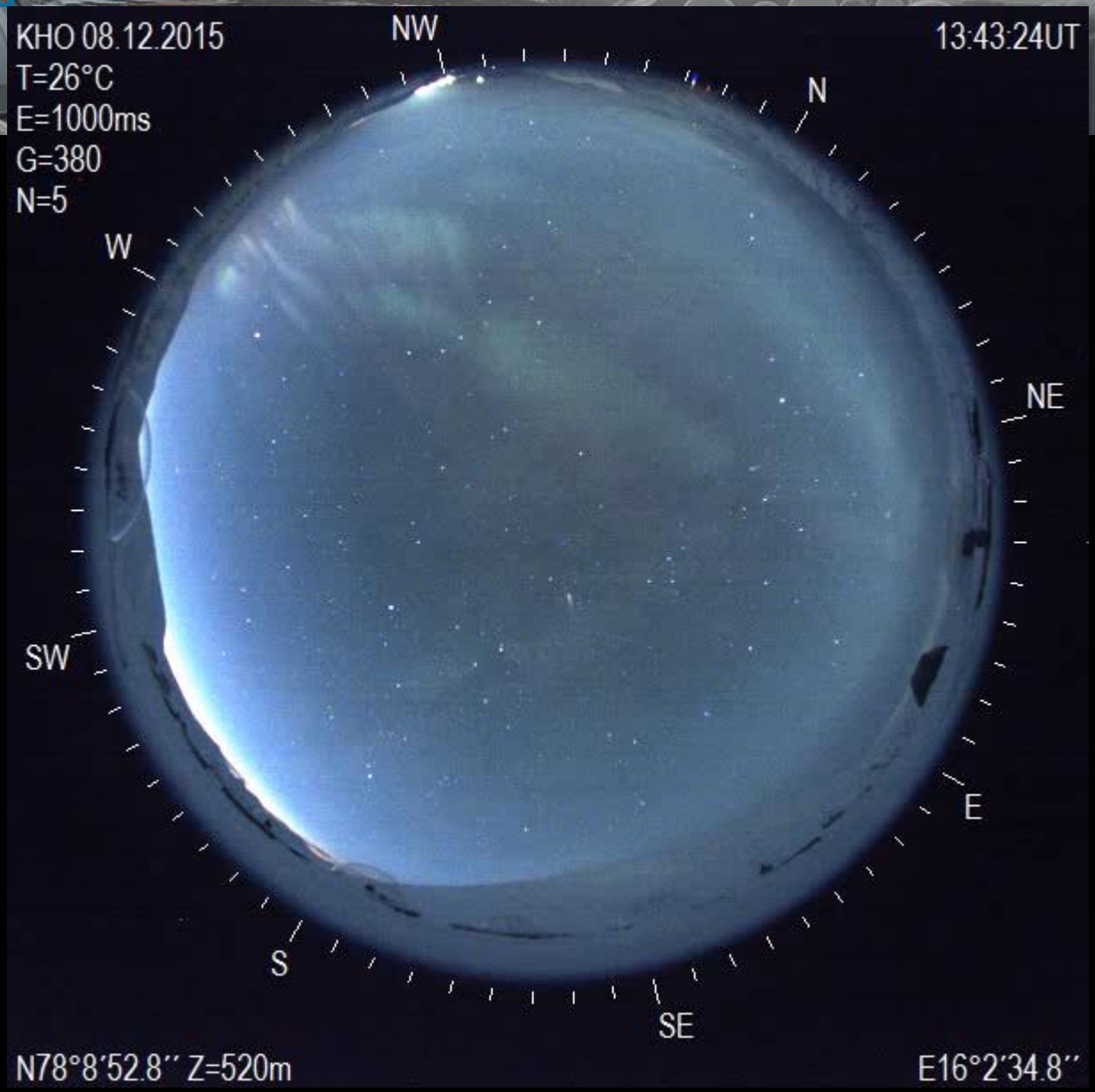
Price (US $) : ~ 1K ~ 2K ~ 60K 60 - 90K ~9K

DSLR Sample

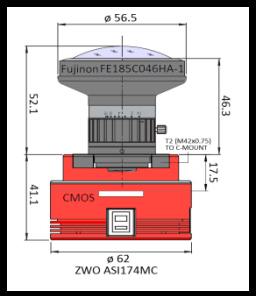

Directshow Capture XE
File Process I/O Refresh About
1:1
Wed Dec 04 2013, 18:55:03
Camera
Fake Webcam Source V7.3
Display
Normal
Video size 320 x 240 fps: 25.0 [25.0] (0 [126] lost) ()
Select camera from device list and open with play button
Color Matching
Image
Color
RGB :
R : 64
H : 120
G : 191
S : 50
B : 64
L : 50
Use to paint image
L=50
Matching criteria
Color space cake size:
Sweep angle dH: 45
Saturation range:
Min 10
Max 95
Lightness range:
Min 20
Max 80
Close
16.32 msec

EMCCD Sample





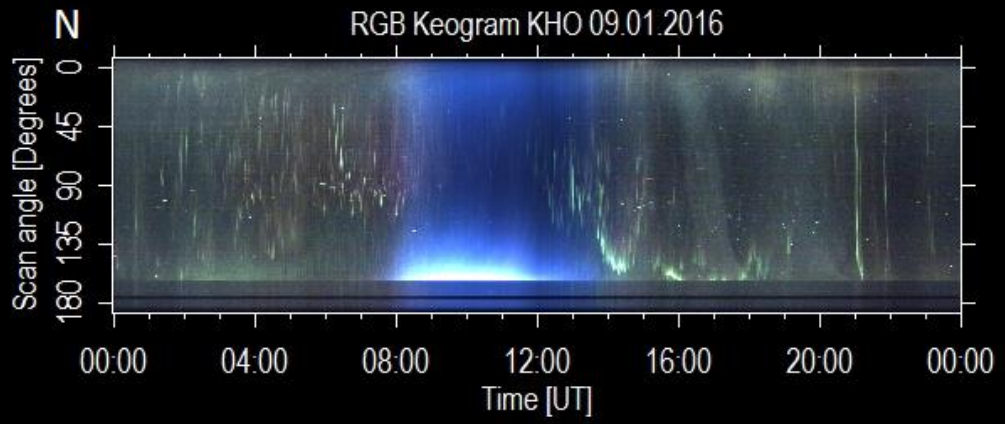
5. Post noon Dayside aurora



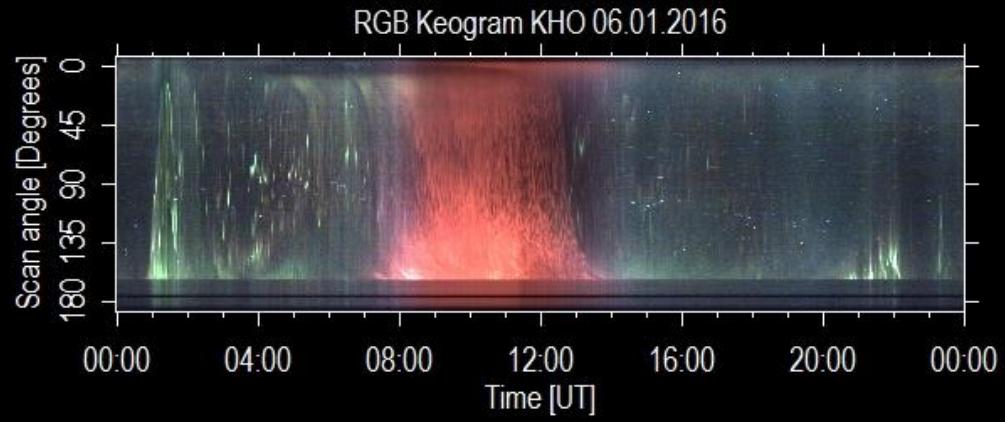
IMX174 SONY Pregius

- Resolution: 2.3 MP, 1920 x 1200
- Manufacturer: Sony
- Frame rate [fps]: 164.5
- Sensor technology: CMOS
- Shutter type: Global shutter
- Pixel size [µm]: 5.86 x 5.86

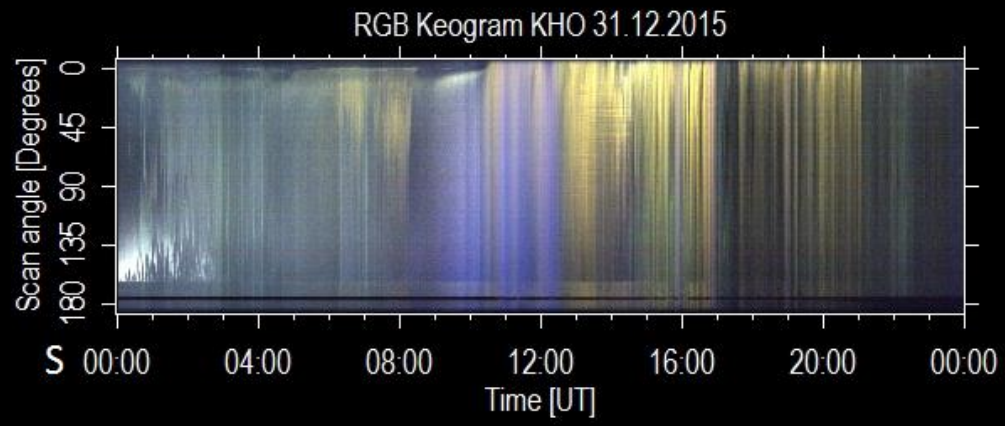
ZWO All-sky color camera keograms



Normal clear sky



The Red Sky Enigma



Cloudy day

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What to remember from this talk ?

1. For the auroral DSLR photographer it is important to:
   - Use available auroral forecasts to estimate pointing direction
   - Use a tripod with a self trigger
   - Use maximum aperture (lowest f/value)
   - Set focus to infinity
   - Find the camera Unity Gain ISO value for maximum sensitivity settings.
   - Take as many images as possible at different exposure times and ISO value, since the intensity of the aurora depends on wavelength and life time of the emissions.

2. Camera / Detector types:

- CCD – Charged Coupled Device
- ICCD – Intensified CCD
- EMCCD - Electron Multiplying Charged Coupled Devices

3. New high speed color detectors will enable us to explore the opportunities of image processing techniques such as color segmentation and classification.