All Sky Camera, LIDAR, and Electric Field Meter for the ASTRI SST-2M prototype for CTA

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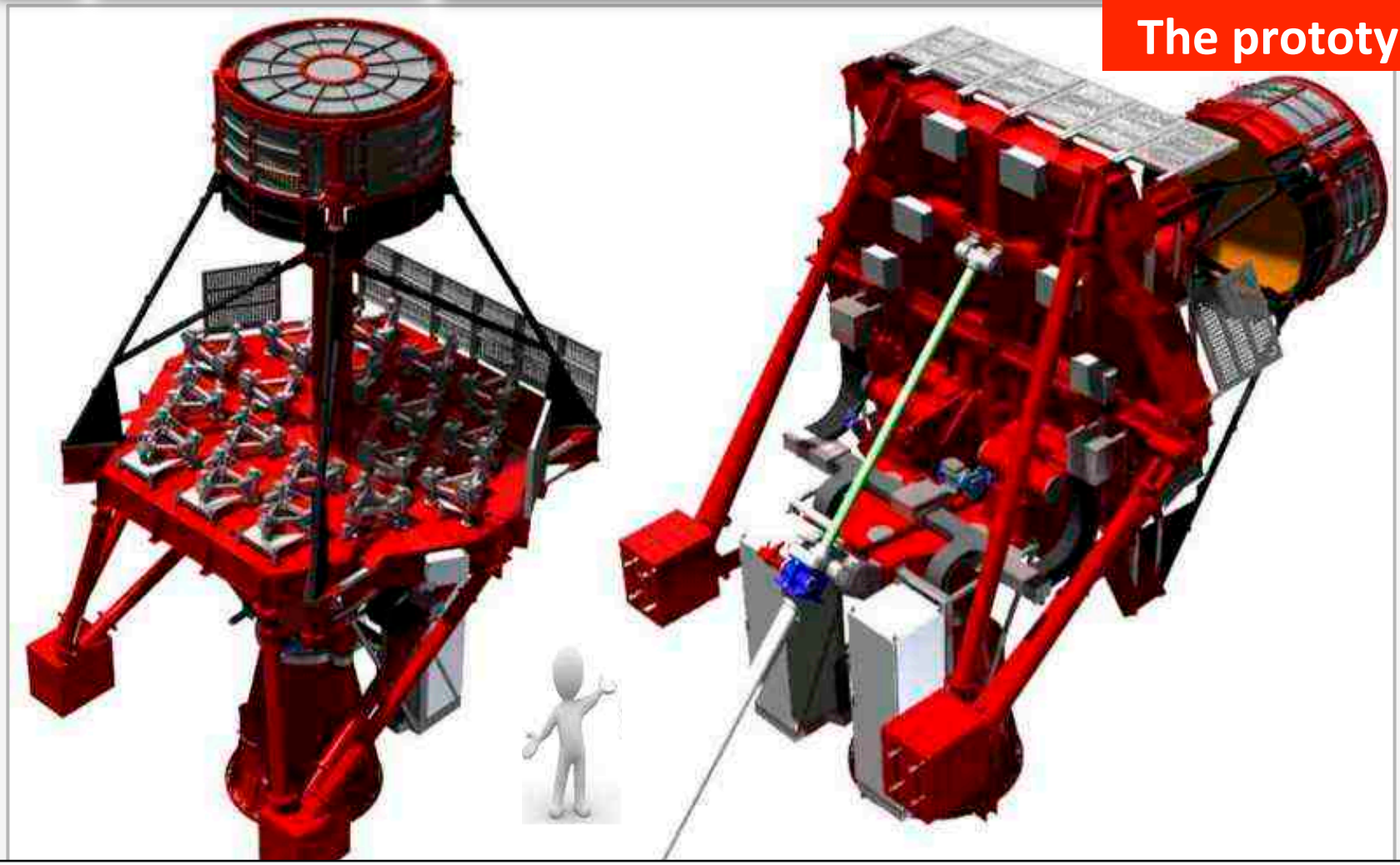
(for the ASTRI Collaboration and the CTA Consortium)

The ASTRI SST-2M telescope

The prototype

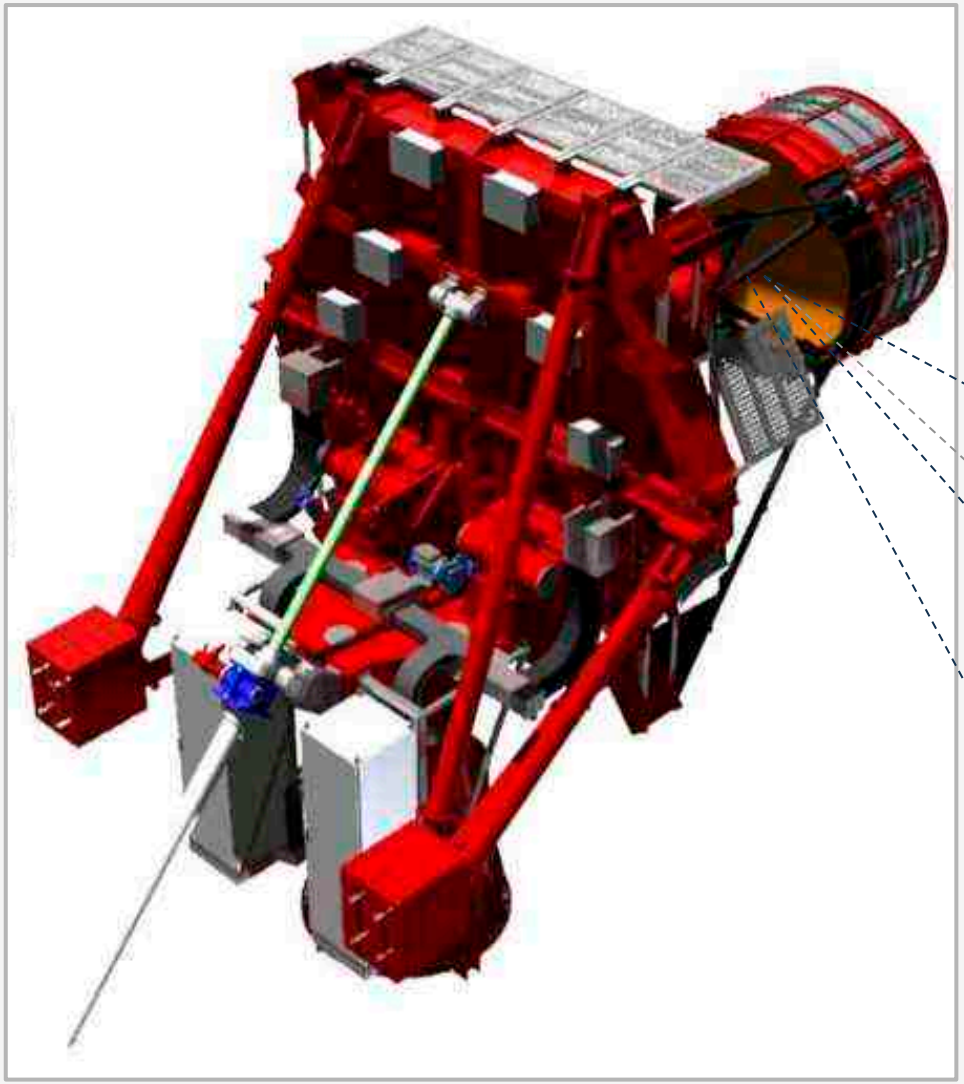


… devoted to investigate the VHE region, 1-100 TeV, in a wide field of view, 9.6° full FoV, making use of innovative technological solutions:

- a dual-mirror optics Schwarschild-Couder configuration,

The ASTRI SST-2M telescope

The prototype



… and:

- a compact focal plane camera (50cm x 50cm x 50cm) based on Si-PMs sensors
- managed by a specifically designed front-end electronics.

The site for the ASTRI prototype

Serra La Nave (SLN)

The ASTRI SST-2M telescope is an end-to-end prototype that will be tested on field.

The **ASTRI SST-2M prototype** will be placed, at the INAF "M.G. Fracastoro" observing station located in **Serra La Nave** on the Etna Mountain near Catania.

Latitude: ***37° 41' 05" N***

Longitude: ***14° 58' 04" E***

Altitude: ***1735 m a.s.l***

After the verification tests, devoted to probe the technological solutions adopted, the ASTRI SST-2M prototype will perform scientific observations on the Crab Nebula and on some of the brightest TeV sources …

Monitoring the atmosphere at SLN – Auxiliary Instrumentation

Auxiliary Instruments	Level Guards (Alerts)	Data Calibration (Analysis)	Forecast and Statistics
Weather Station	Yes	Yes	Statistics
Dust Monitor, Pludix	Yes	Yes	Statistics
Sky Quality Meter, SQM	Yes	Yes	Statistics
…	…	…	…
Electric Field Meter, EFM	Yes	Yes	Yes
LIDAR	No	Yes	No
All Sky Camera, ASC	Yes	Yes	Statistics
…	…	…	…

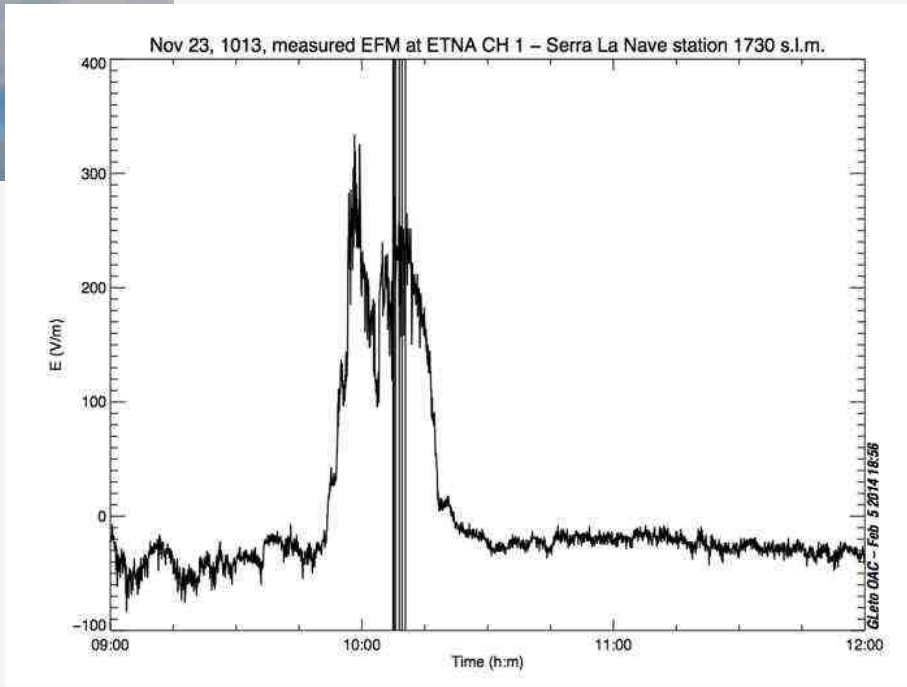
The Electric Field Meter, EFM

- Developed by the INAF Radio Astronomy Institute (IRA), contact Federico Perini
- Field-Mill sensor

Auxiliary Instrumentation at SLN

EFM at work

Etna Eruption 23 November, 2013



EFM – SLN output alarms

Jan 5 2014 storm

First derivative

Signal
+
Alarm bits

Alarm bits issued from software are weighted to create an alert to ASTRI SST-2M

- Can issue alarms
- NO distance/direction (3 EFM needed!)
- Can detect lightening distance > 7 km!!

Auxiliary Instrumentation at SLN

Raman Lidar - AMPLE

•Build for the VAMOS SEGURO project by CNISM, Napoli (contact Nicola Spinelli)

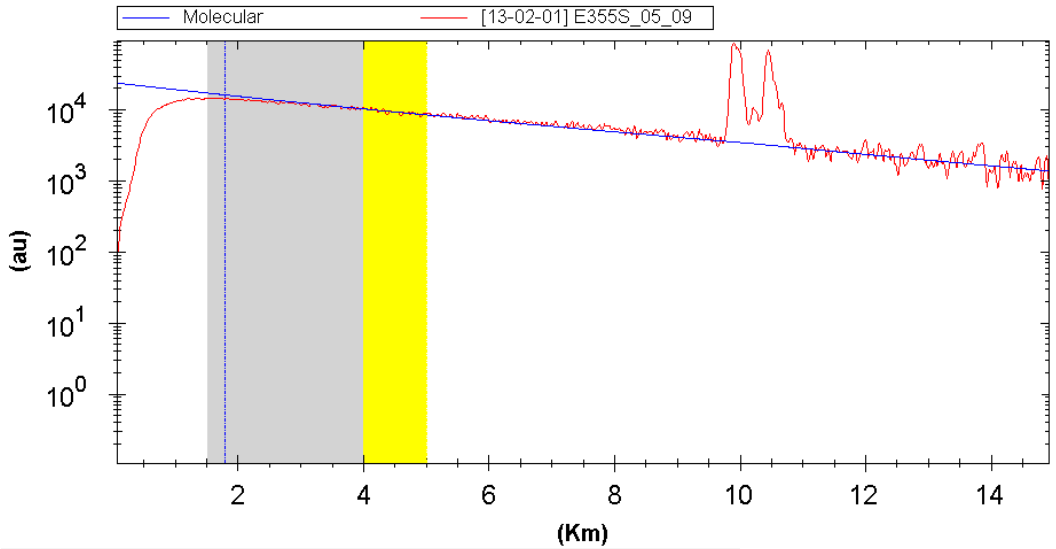
AMPLE main technical features:

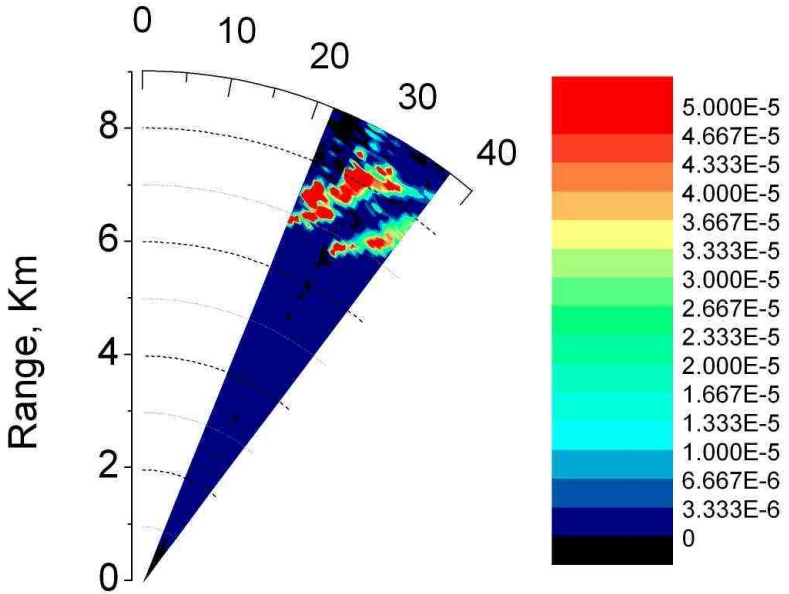
- Elastic channel at 355nm.
- Polarization measurements available.
- Raman channel at 386nm.
- Raw spatial resolution from 30cm to 30m
- Can be pointed from software

Auxiliary Instrumentation at SLN

Raman Lidar - EARLINET

- Part of EARLINET since 2013: atmosphere monitoring routinely carried out.



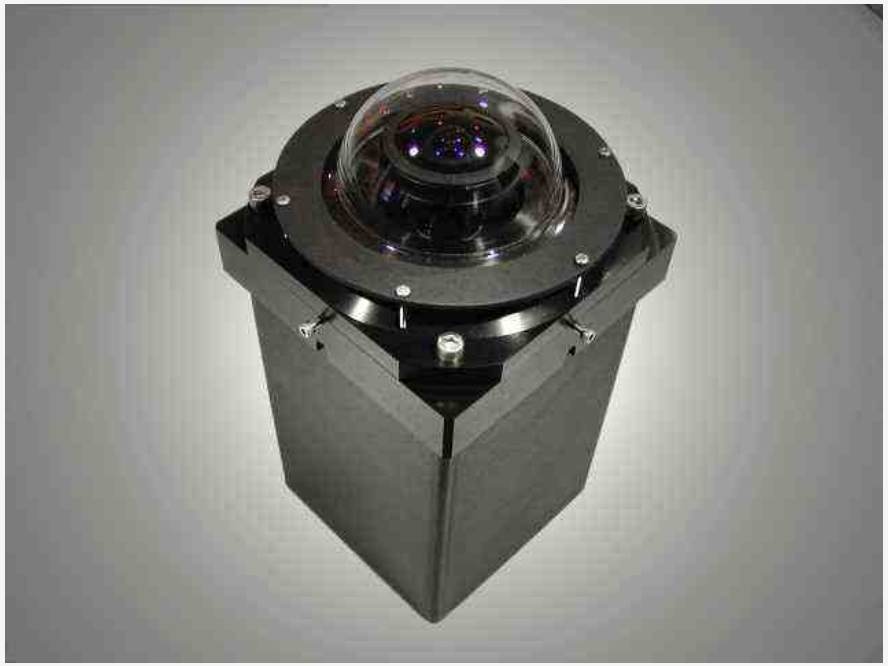


Particle backscatter, $m^{-1}sr^{-1}$

Elevation 14.4°

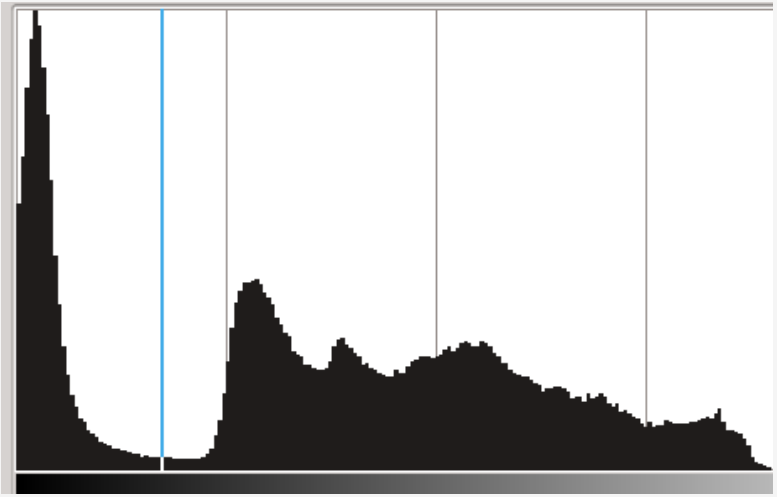
Auxiliary Instrumentation at SLN

All-Sky Camera, ASC



- SBIG All-Sky Camera 340C
- Kodak KAI-340 CCD 640x480
- Exposure time 50 microseconds to 180 sec
- One image every five minutes

ASC- Thresholding



- Usually the 3 RGB channels are turned into one: R-B (Heinle et al 2010) or R/B (Long et al. 2006)

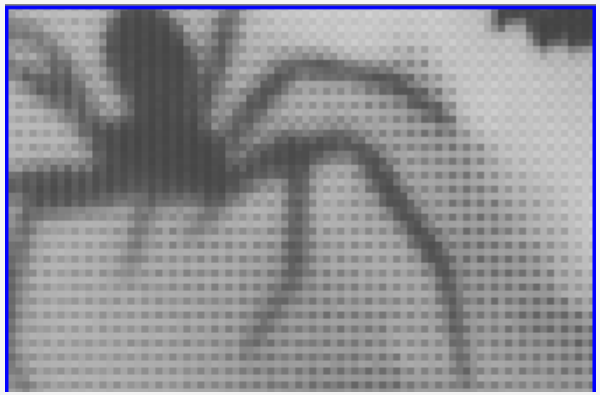
RGB turned into HSL and Saturation is used (Souza-Echer et al 2006)

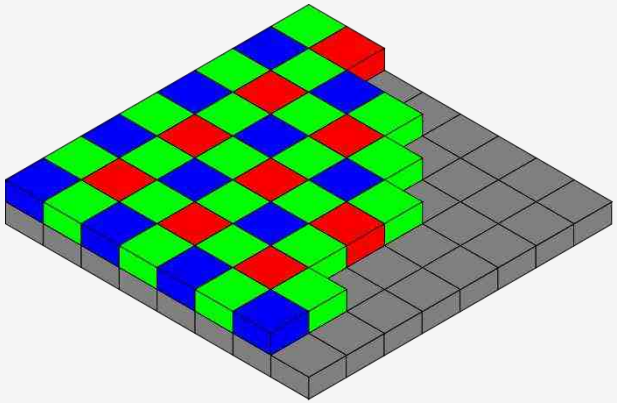
Euclidean Geometric Distance (Sylvio et al 2010)

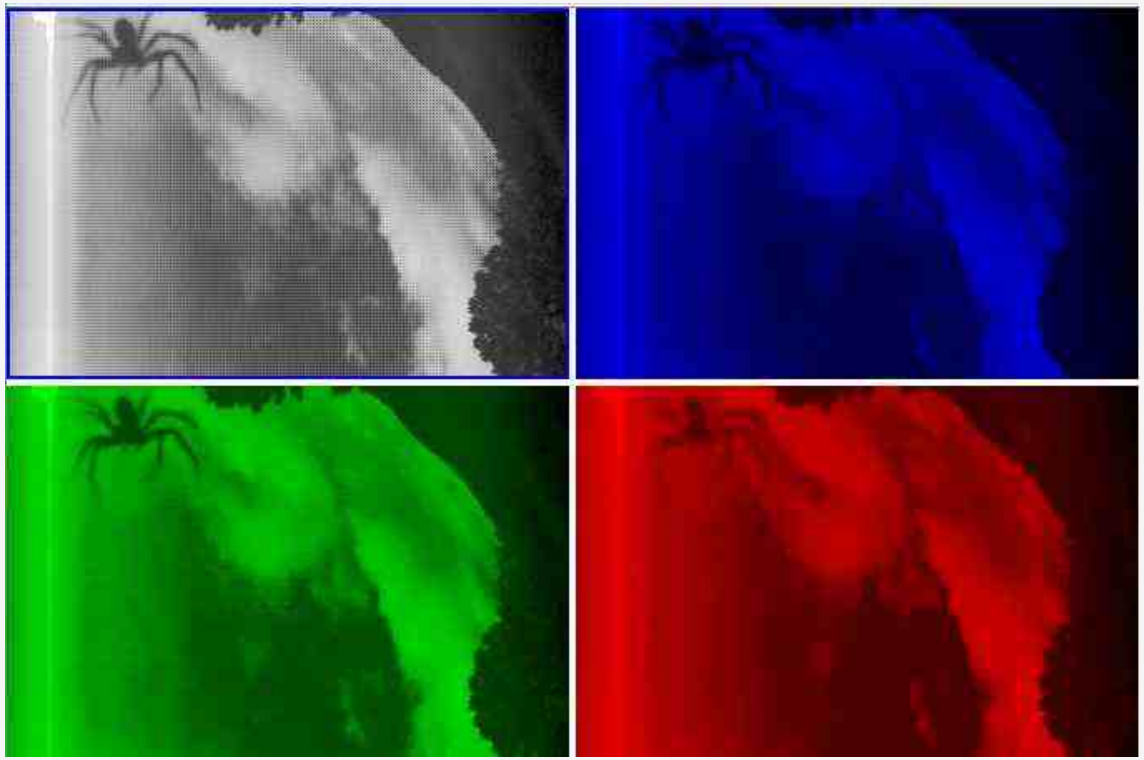
ASC: Cloud Detection

- What colors do we use for the night sky?
- Is it right to ignore the G channel.

ASC: Color = Bayer Filter

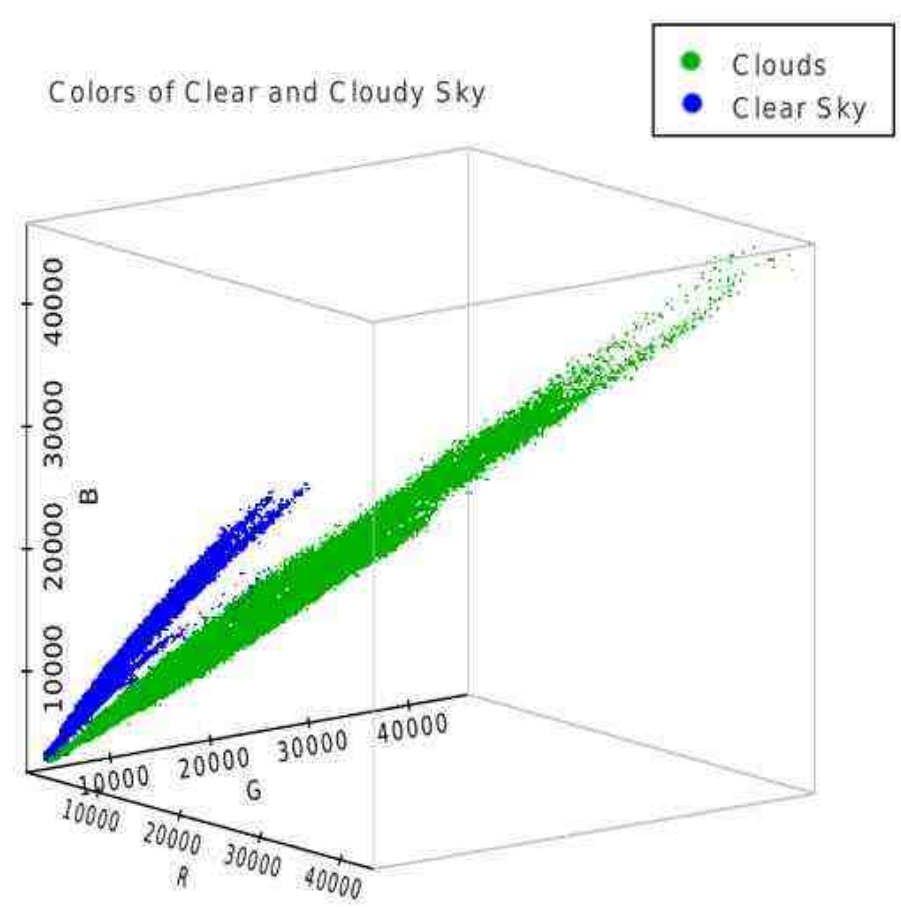






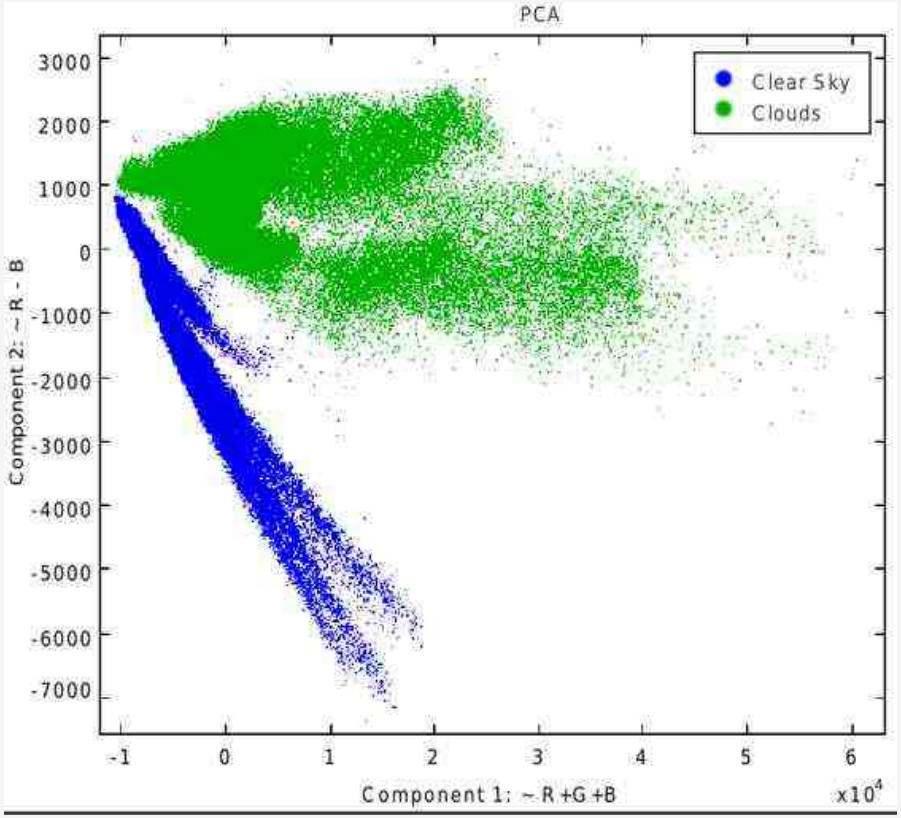
ASC - Thresholding

Principal Component Analysis



ASC - Thresholding

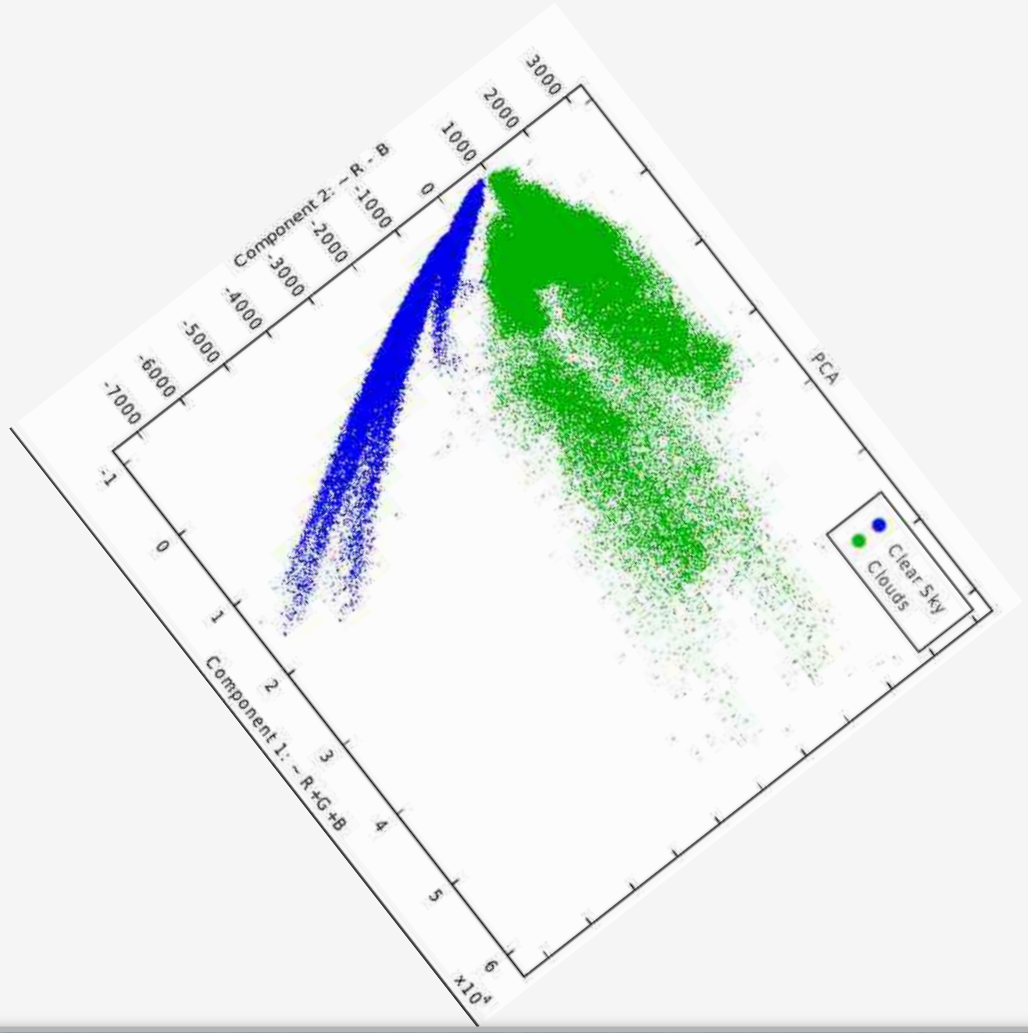
Principal Component Analysis



	Eigenvector		
Eigenvalue	**R**	**G**	**B**
9.2e7	0.5	0.6	0.6
1.6e6	0.7	0.1	-0.7
2.9e4	-0.5	0.8	-0.4

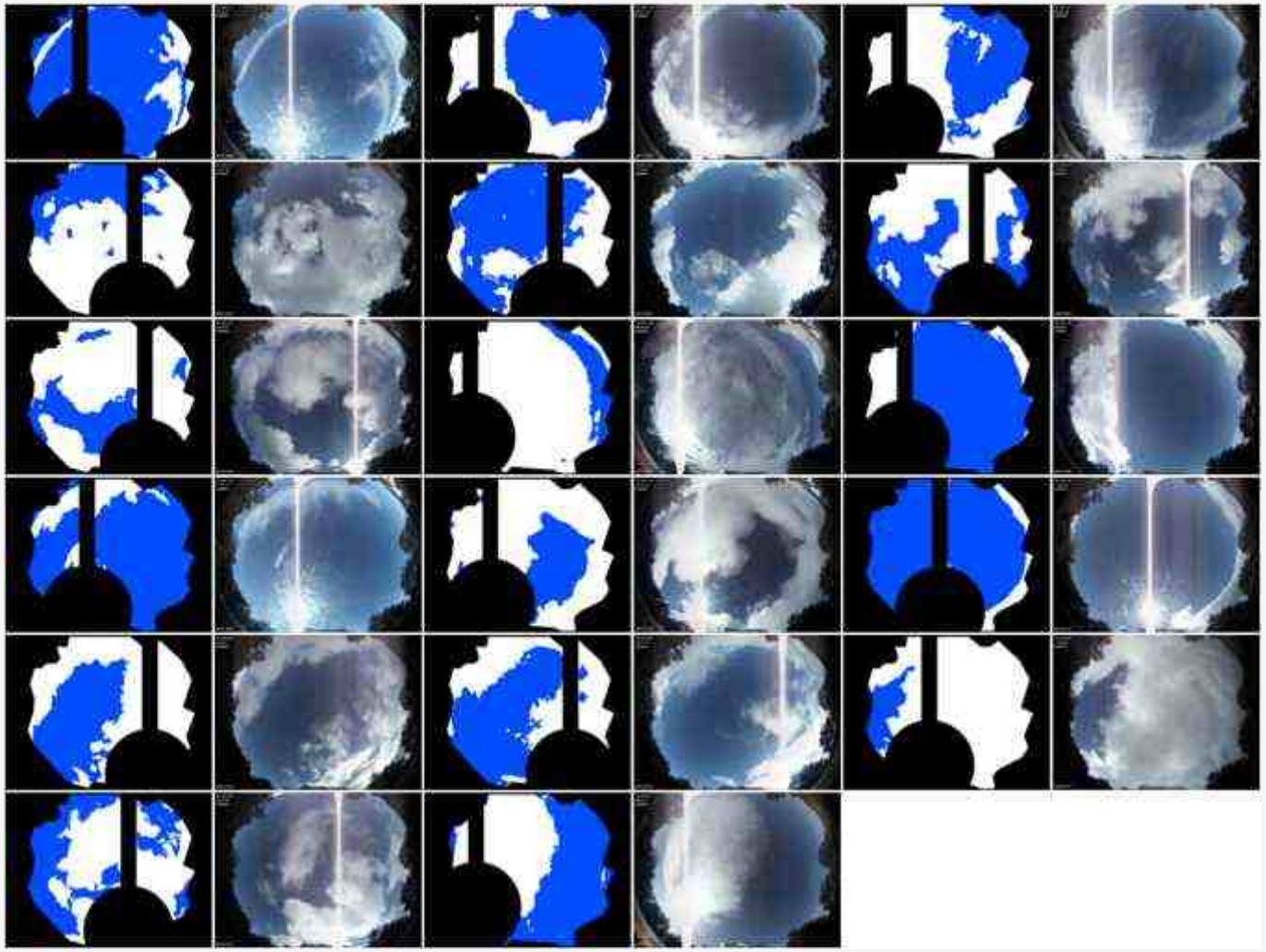
ASC - Thresholding

Principal Component Analysis



ASC - Thresholding

Ground Truth



ASC - Thresholding

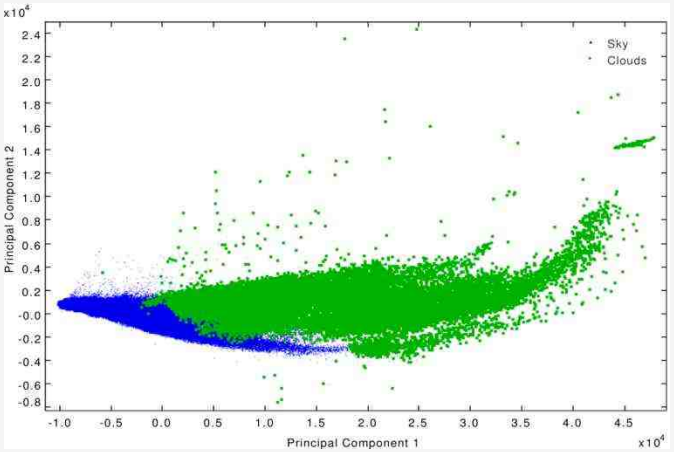
Confusion Matrix of Cloud Detection

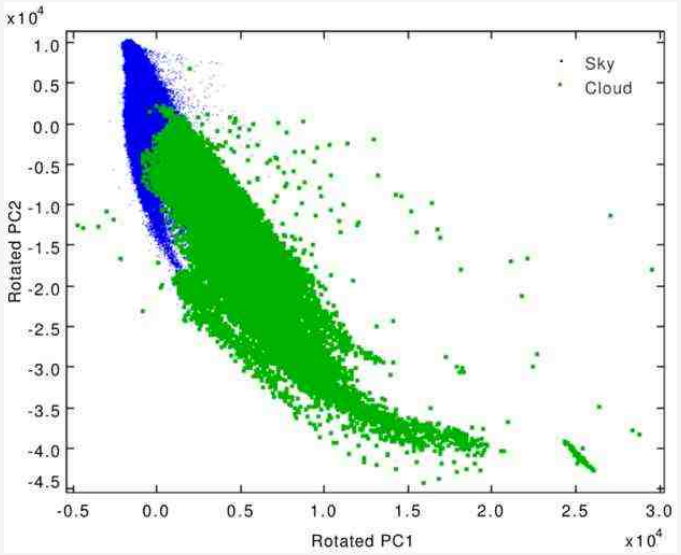
Detected \ Truth	Cloud	Sky
Cloud	TP	FP
Sky	FN	TN

$$\text{Accuracy} = (TP+TN)/(TP+FP+TN+FN)$$

ASC - Thresholding

Principal Component Analysis





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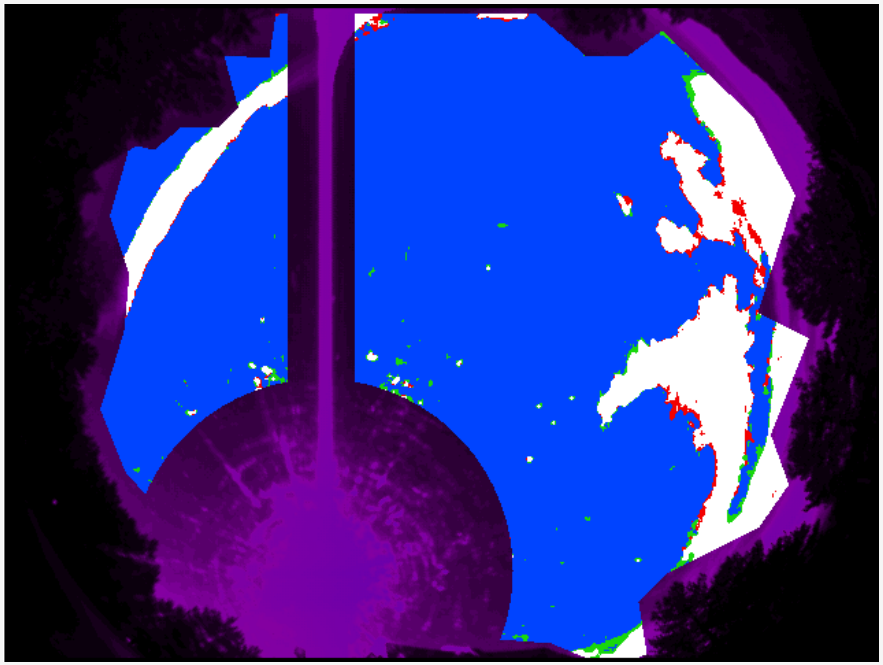
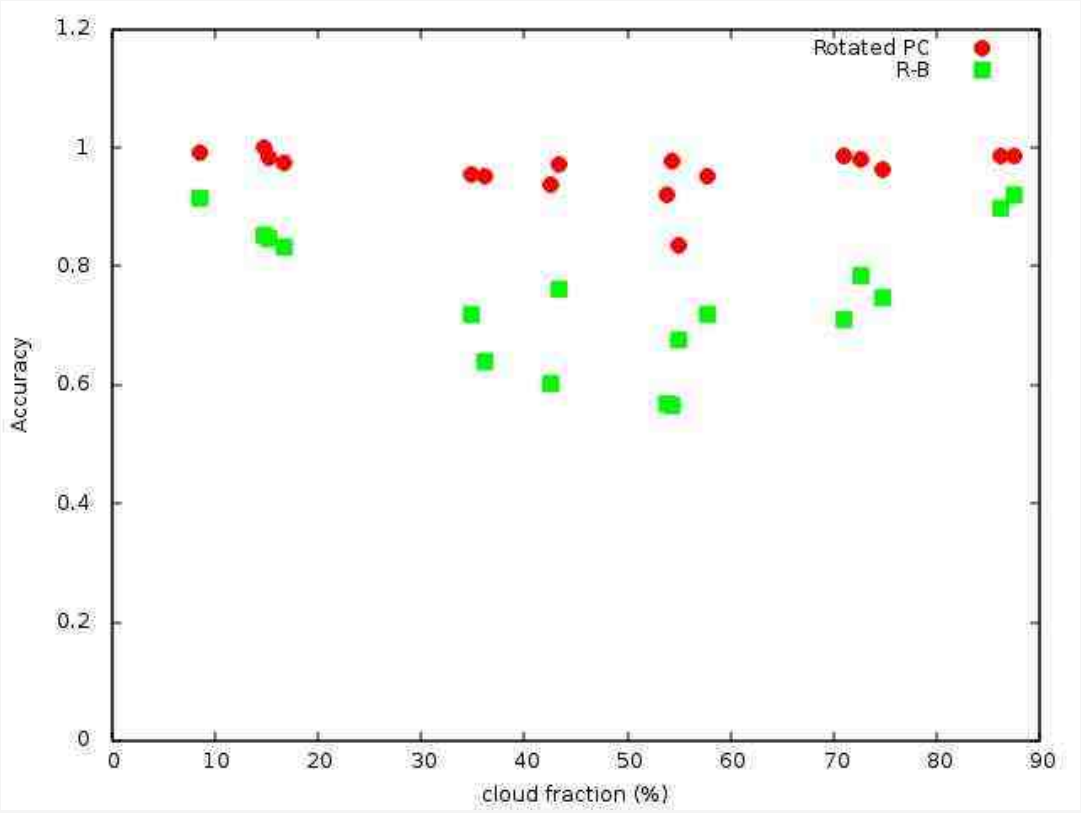
Principal Component Analysis



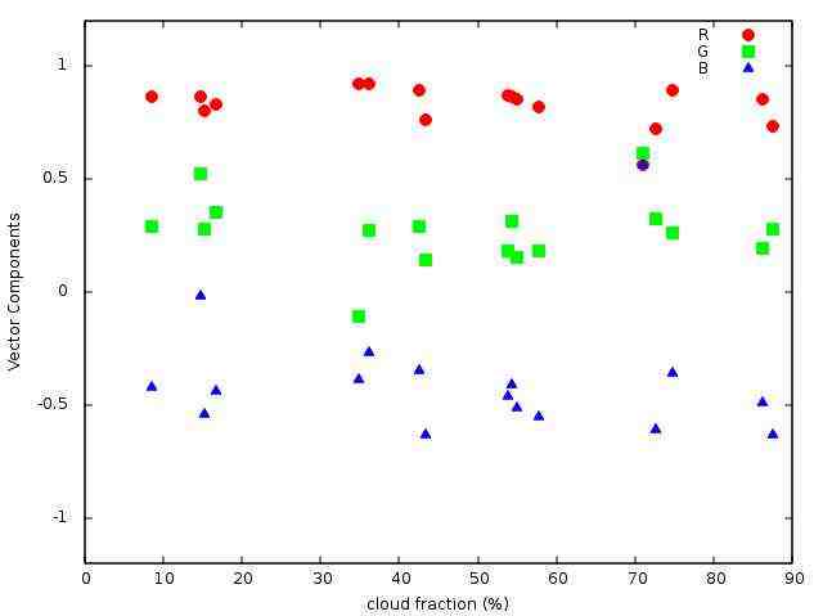
ASC - Thresholding

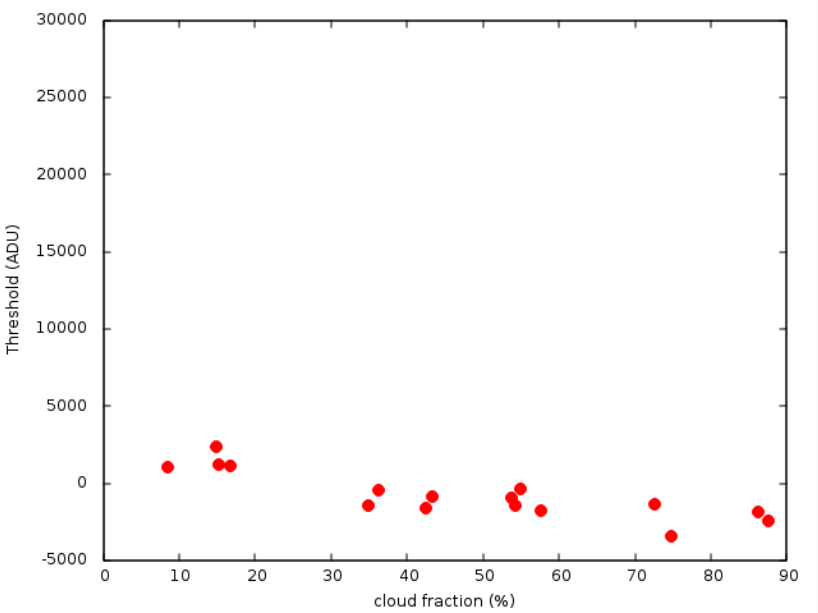
Accuracy
Rotated PC Vs. R-B



ASC - Thresholding

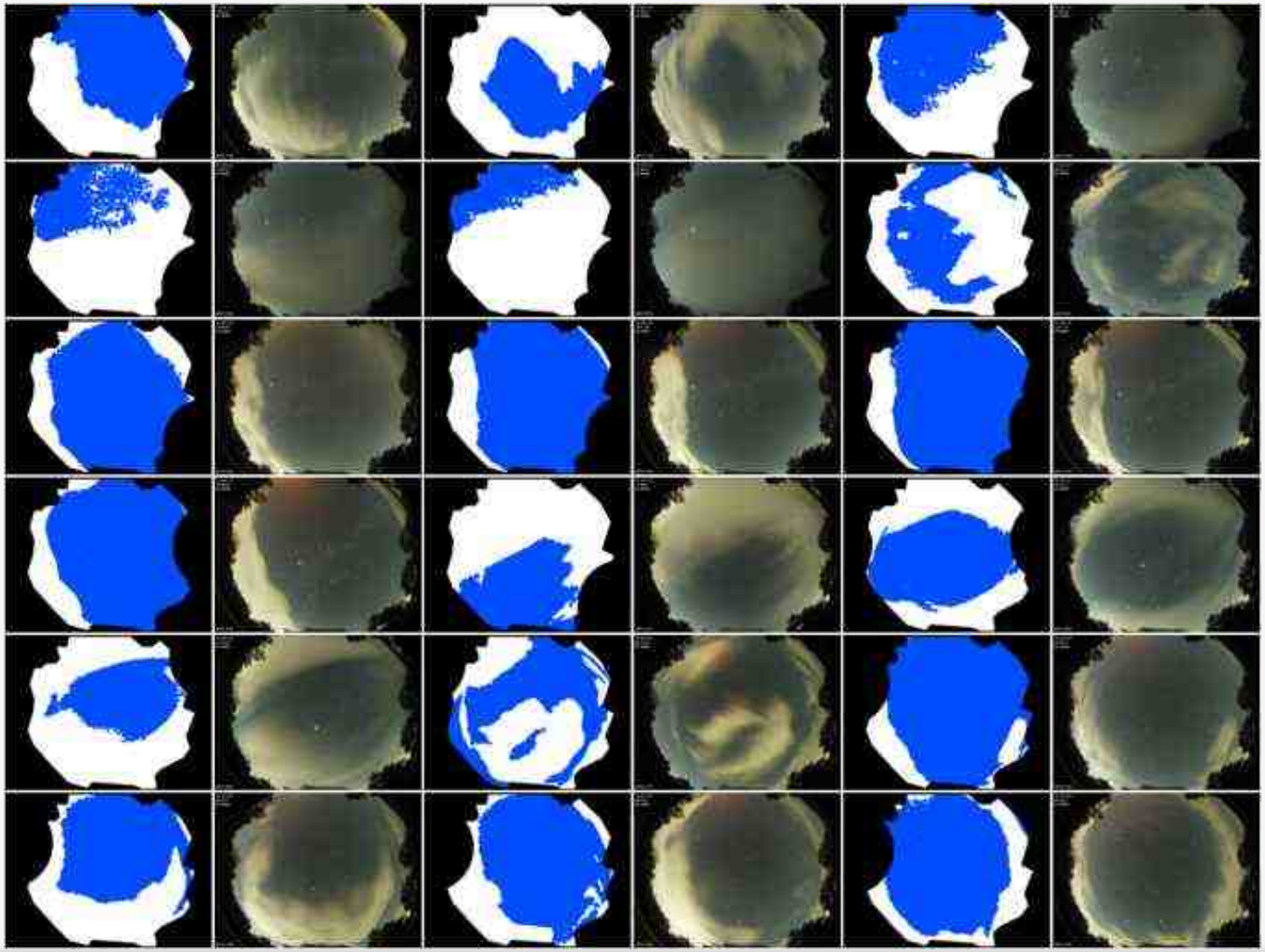
Final Mix of Colors
And
Threshold





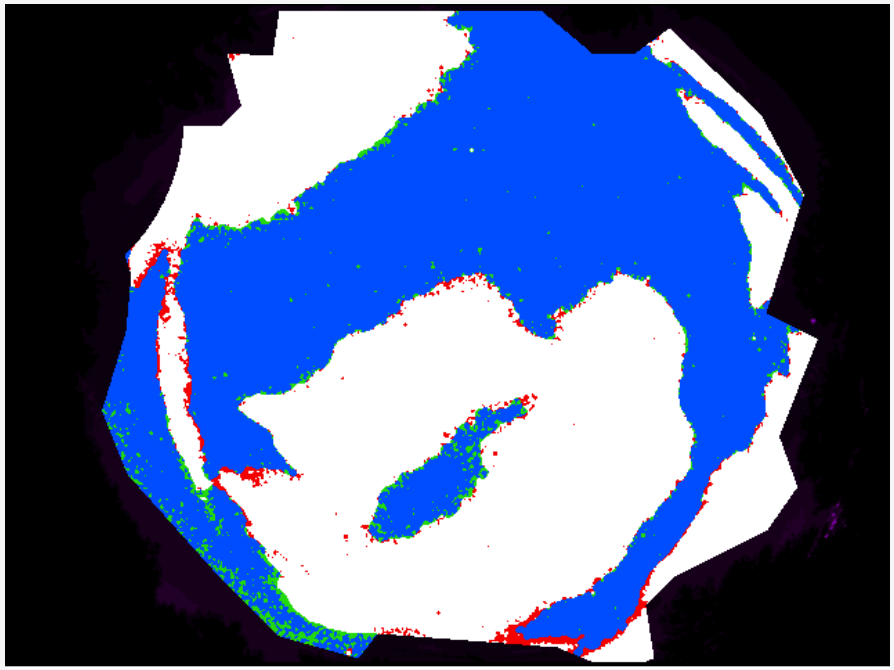
ASC - Thresholding

Ground Truth



ASC - Thresholding

Principal Component Analysis



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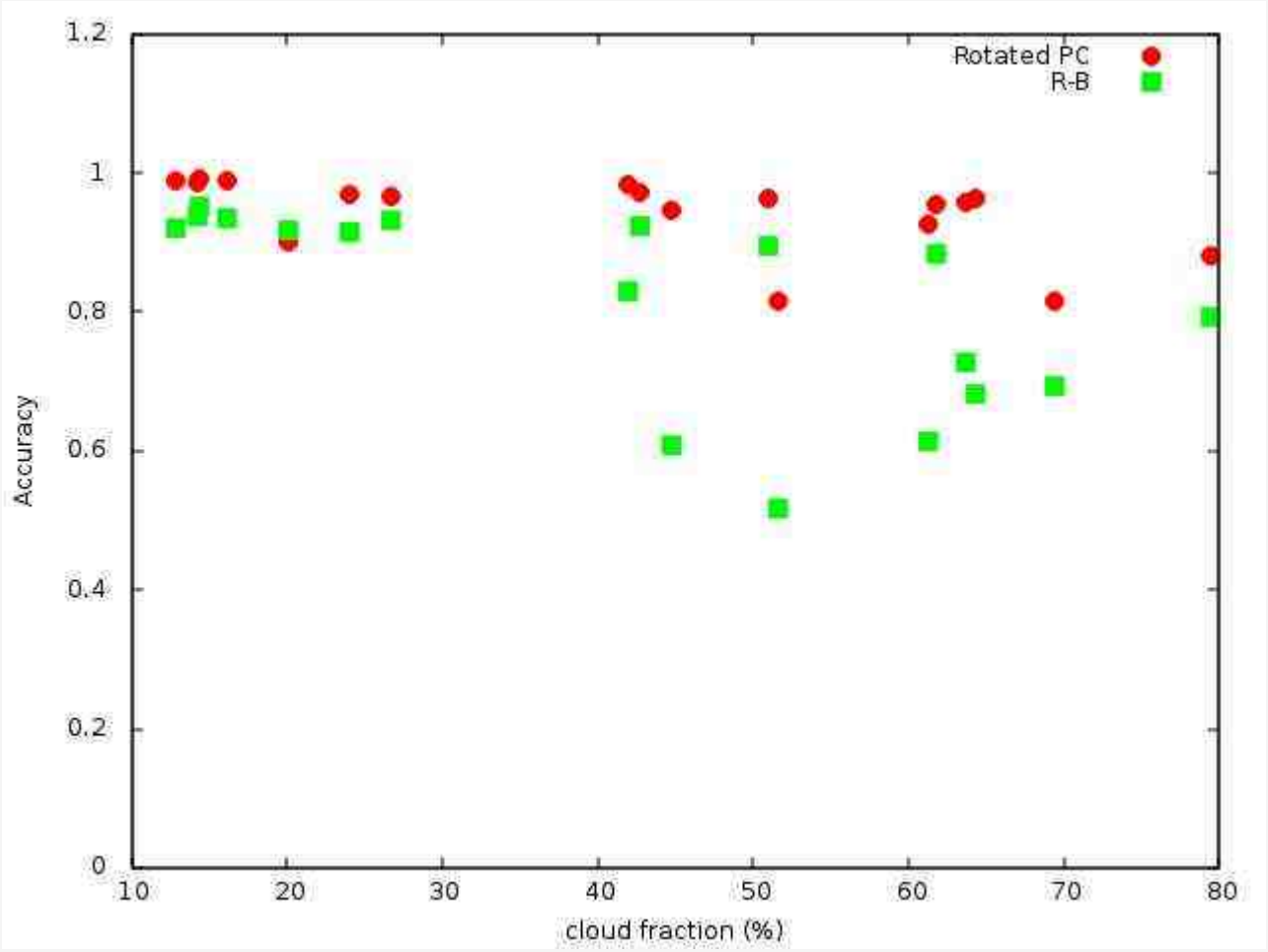
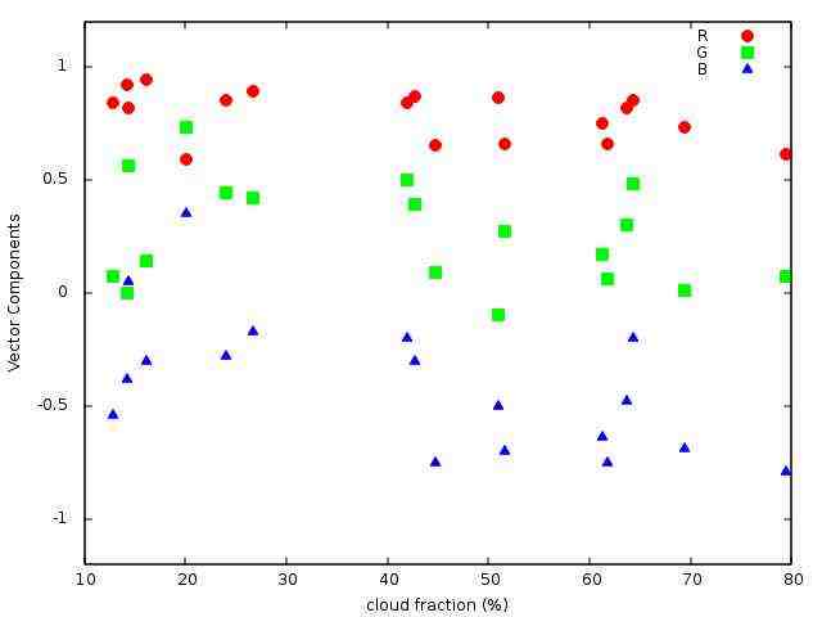
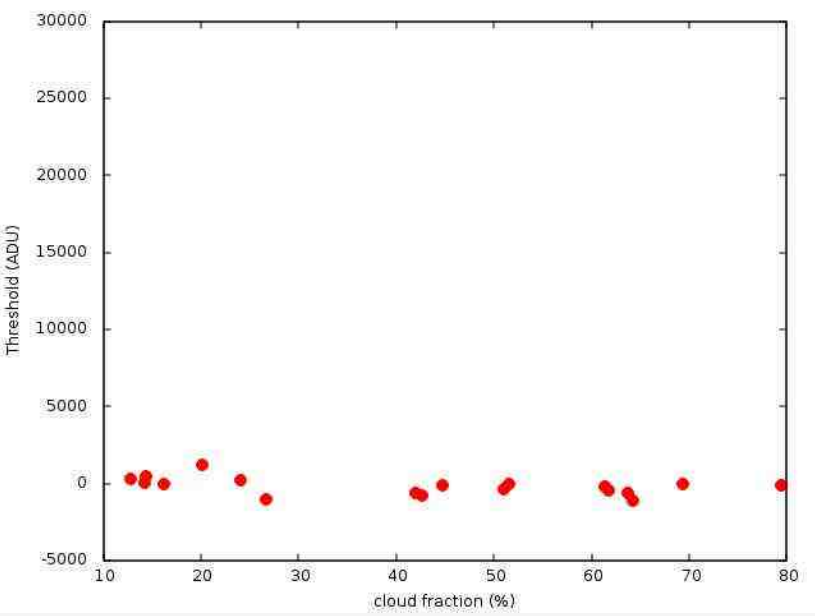


ASC - Thresholding

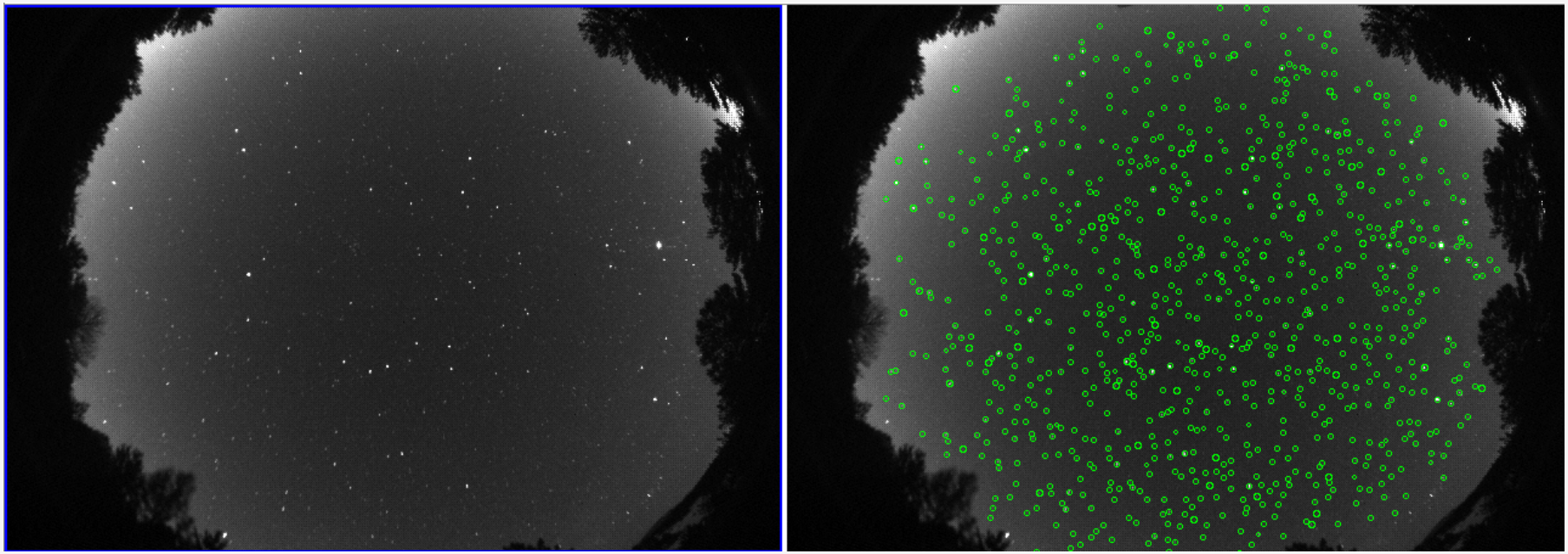
Final Mix of Colors
And
Threshold





ASC - Star Counting

Find stars

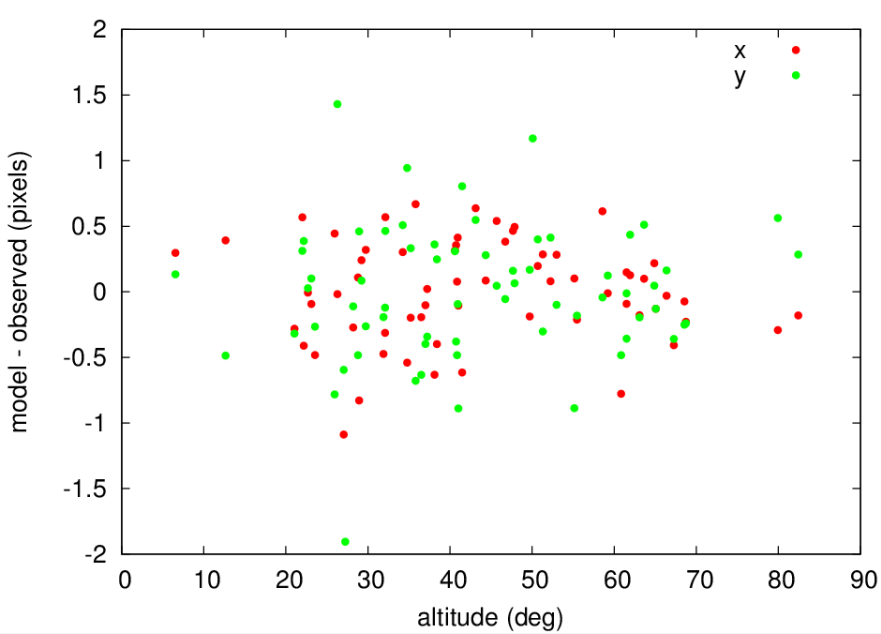


ASC - Star Counting

Confront with a catalog

We need an accurate transformation between pixel and celestial coordinates

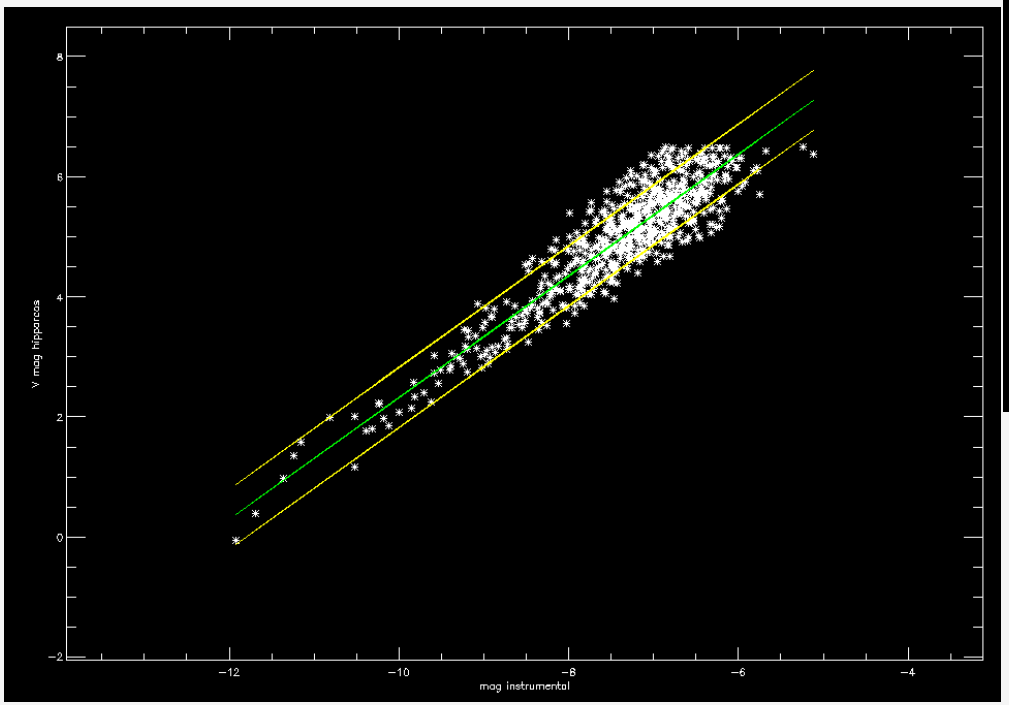
Zenithal Equal Area (ZEA) projection
Distortions modeled with 6 order polynomial series

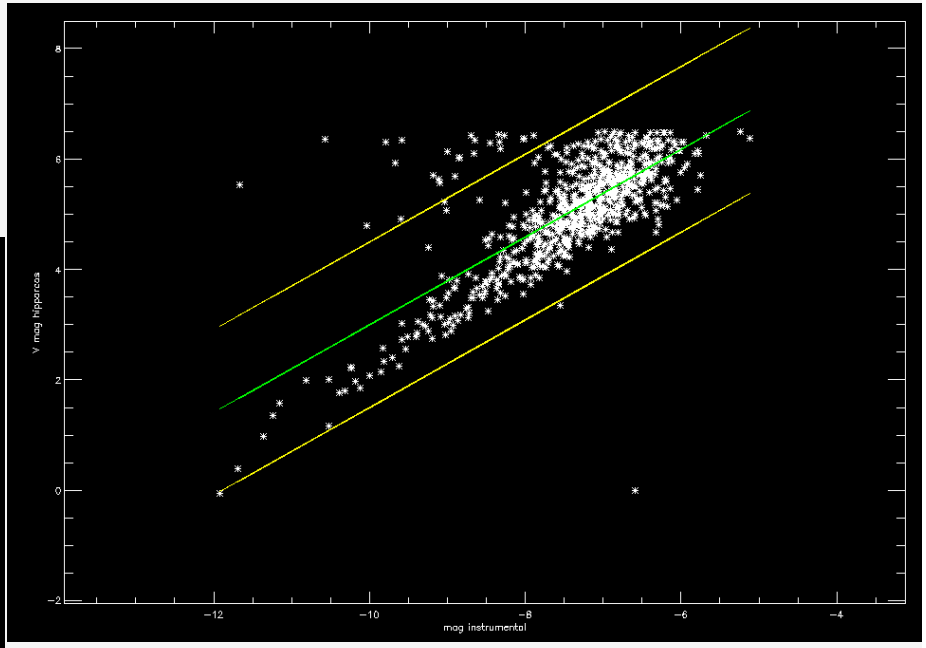


ASC - Star Counting

Discard Outliers

Fit for the magnitude transformation

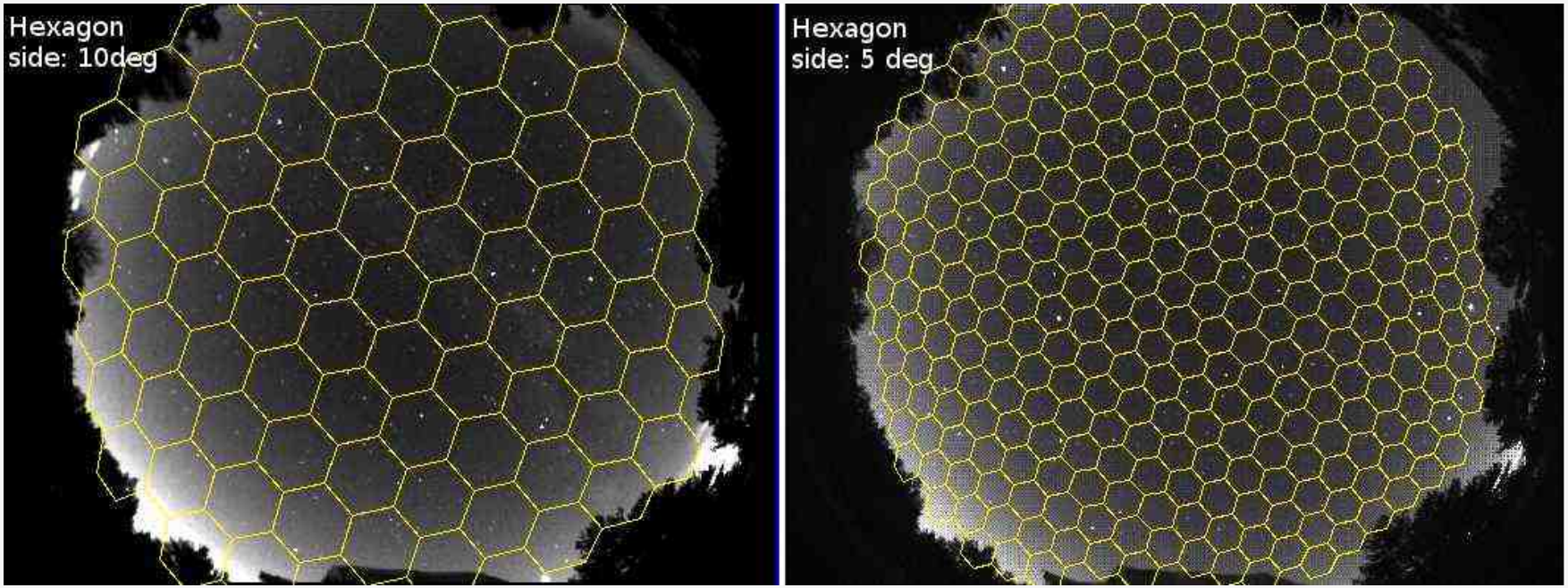




zeropoint	12.7+-0.2
slope	1.04+-0.02

ASC - Star Counting

Tiling



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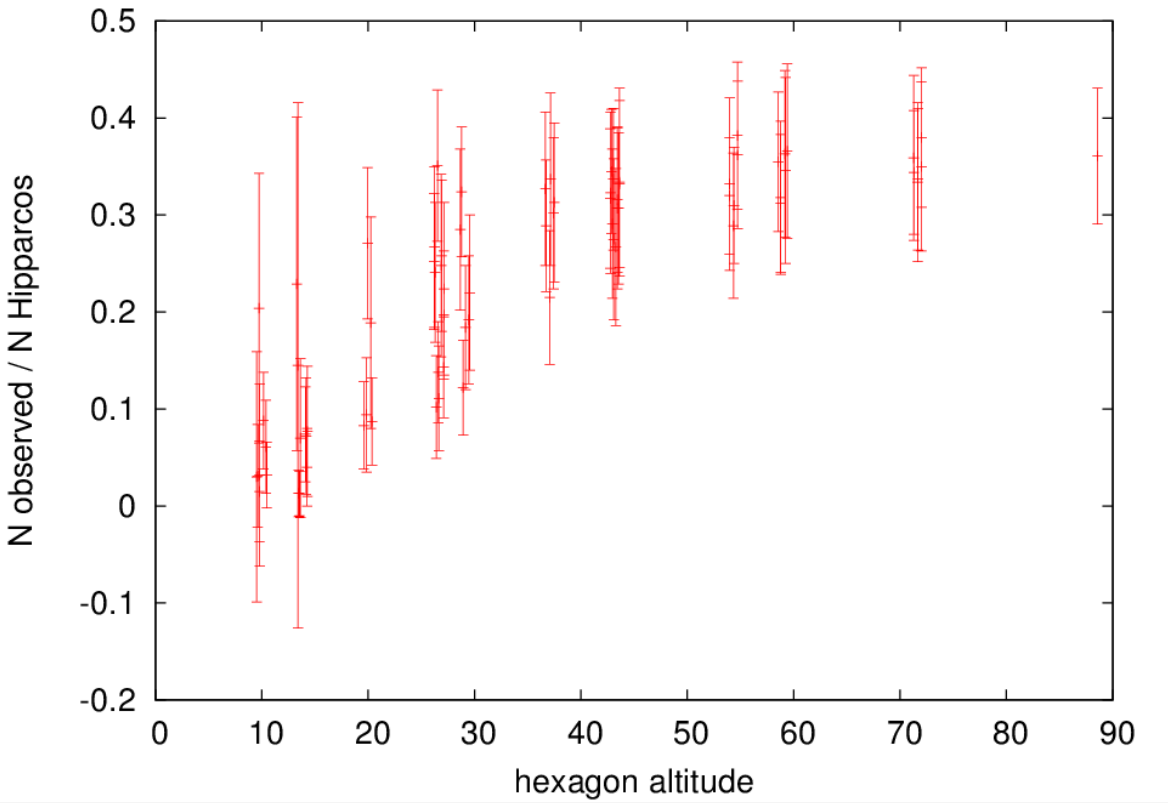

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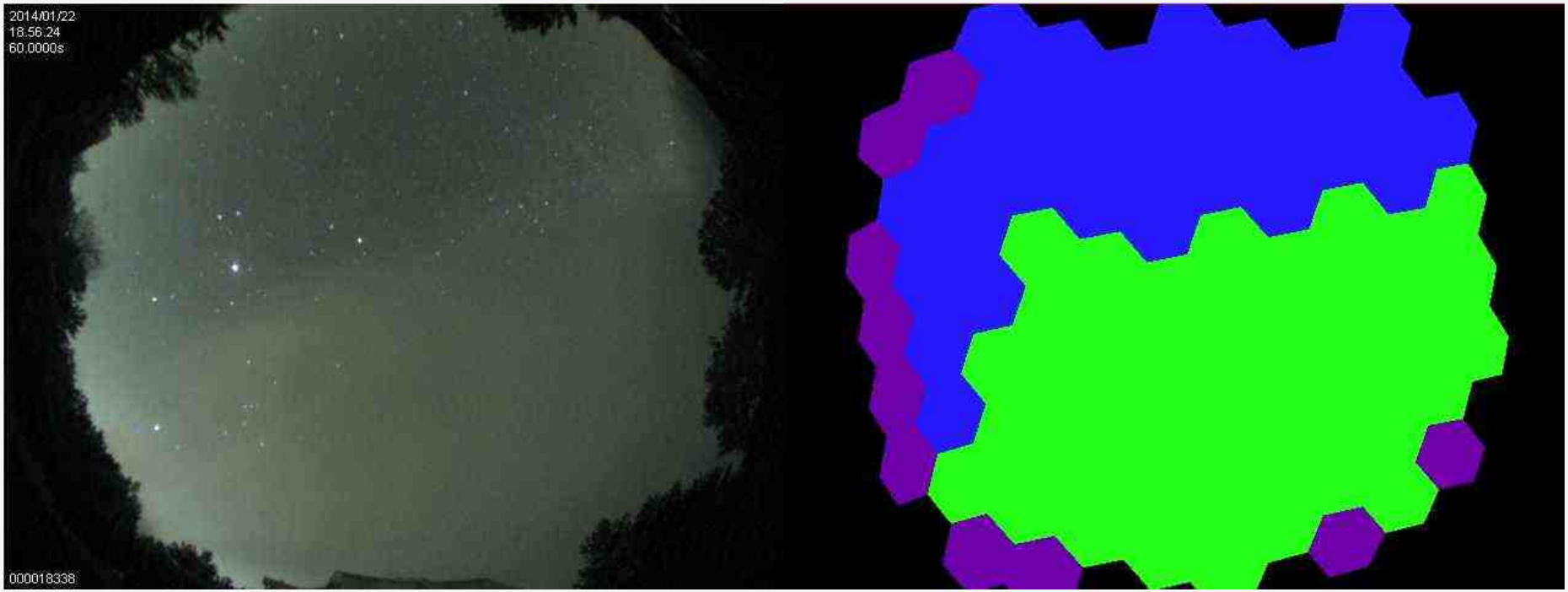

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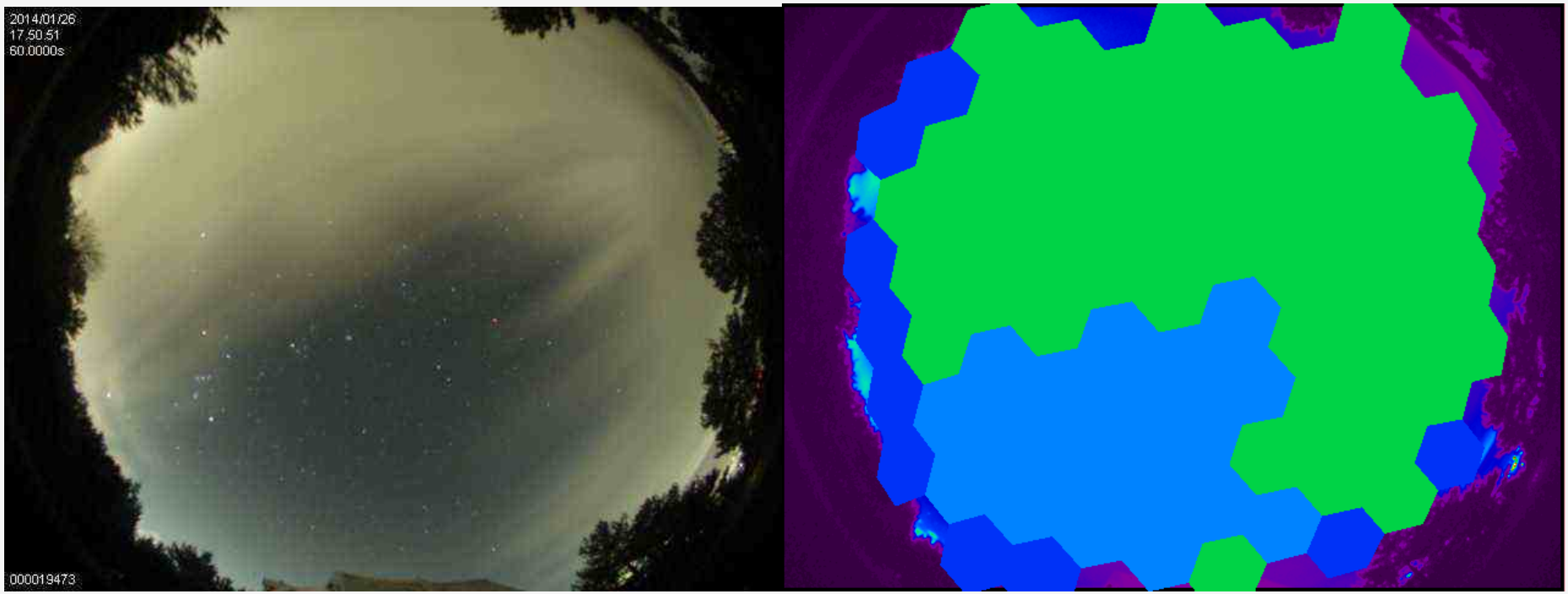

Conclusions and Future Work

All Sky Camera: Thresholding

- Increase statistics with more ground truth images
- Find a fixed threshold
- Work cases with the moon in the sky
- Sunset and sunrise

All Sky Camera: Star counting

- Build our own catalog

EFM:

- Deliver real alerts to ASTRI SST-2M software (dummy software already implemented)
- Calibrate it against a standard LINET instrument

Lidar:

- Data taken during ASTRI SST-2M observation will be available to define the real sky condition

The ASTRI Program

http://www.brera.inaf.it/astri/