Università degli Studi di Torino
Tesi di Laurea Triennale in Fisica

AY 2019/2020
2021/04/14


Image by: S. Mackovjak, Slovakia, 2018/05/13

Automated data processing of AMON-ES

Student: Davide Dionese
Advisor: Mario Edoardo Bertaina
Co-advisor: Simon Mackovjak

Image by Tomas Slovinsky (slovinsky.art)

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What is airglow?

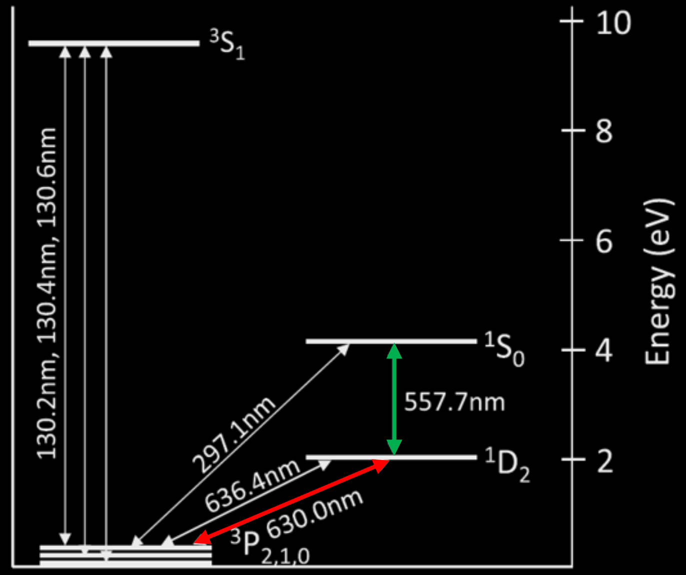
Non-thermal electromagnetic radiation emitted in Earth's middle and upper atmosphere.

Airglow observed from ISS (ESA)

It represents a background in the ground observation of celestial corps, including the EAS generated by UHECR.

How is it generated?

Sun radiation hits atmospheric particles → excited states
Transition towards less energetic states → electromagnetic radiation



Electronics energy level of atomic Oxygen, von Savigny (2017)

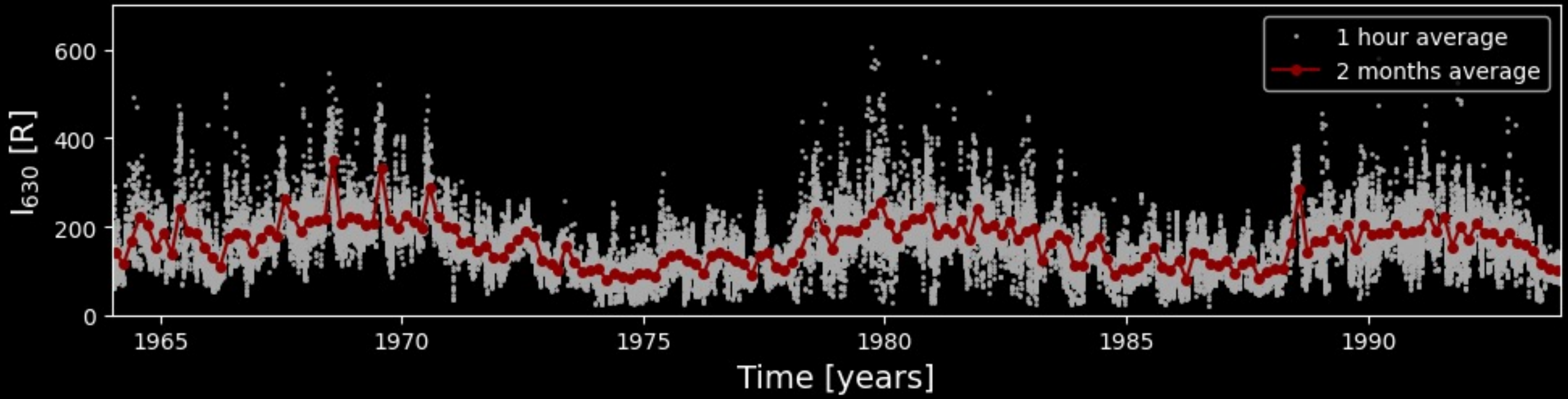
Green (557.7 nm) and red (630.0 nm) lines originate from two different atomic Oxygen transitions.

Different elements are located at different altitudes: the airglow is layered.

The airglow is a dynamic system: it changes over time and for different Earth locations.

It is influenced by many factors, such as:

- intensity of solar activity
- density of atmospheric species
- temperature
- earth's magnetic field



Variation of airglow intensity over a period of three solar cycles.
Image by: Mackovjak S.

When efficiently modeled, airglow will become a useful tool in the study of all those phenomena.

How can it be observed?


Green and red airglow (Chile), image by Yuri Beletsky

Airglow intensity should be higher during the day, but the Sun light overwhelms it.

It can be observed from the ground during the night.
AMON-ES was built with this purpose.

AMON – Extended Station

Airglow MONitor (AMON)

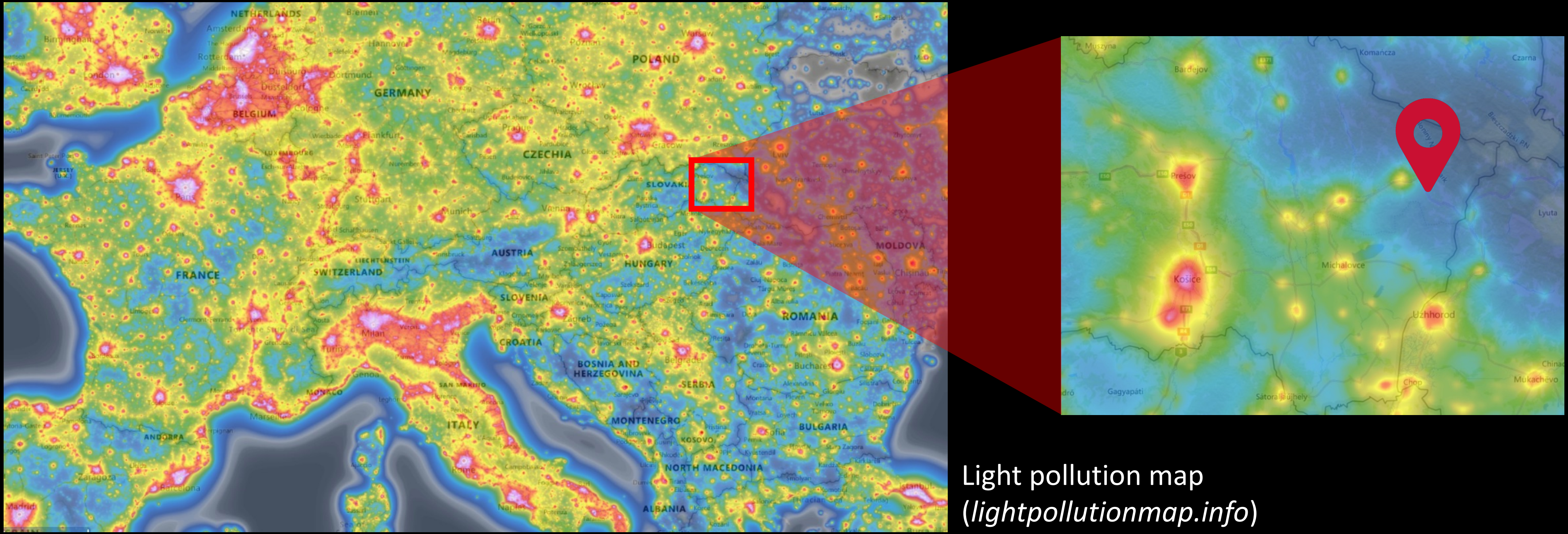
- µPMT sensor
- 1s time resolution
- 300 - 480 nm

Airglow All-sky Camera (AAC)

- CCD sensor
- resolution of 2062x2056 pixels
- time exposure set to 300s
- different filters can be applied to capture different airglow wavelengths

AOK, Kolonica Saddle, Slovakia

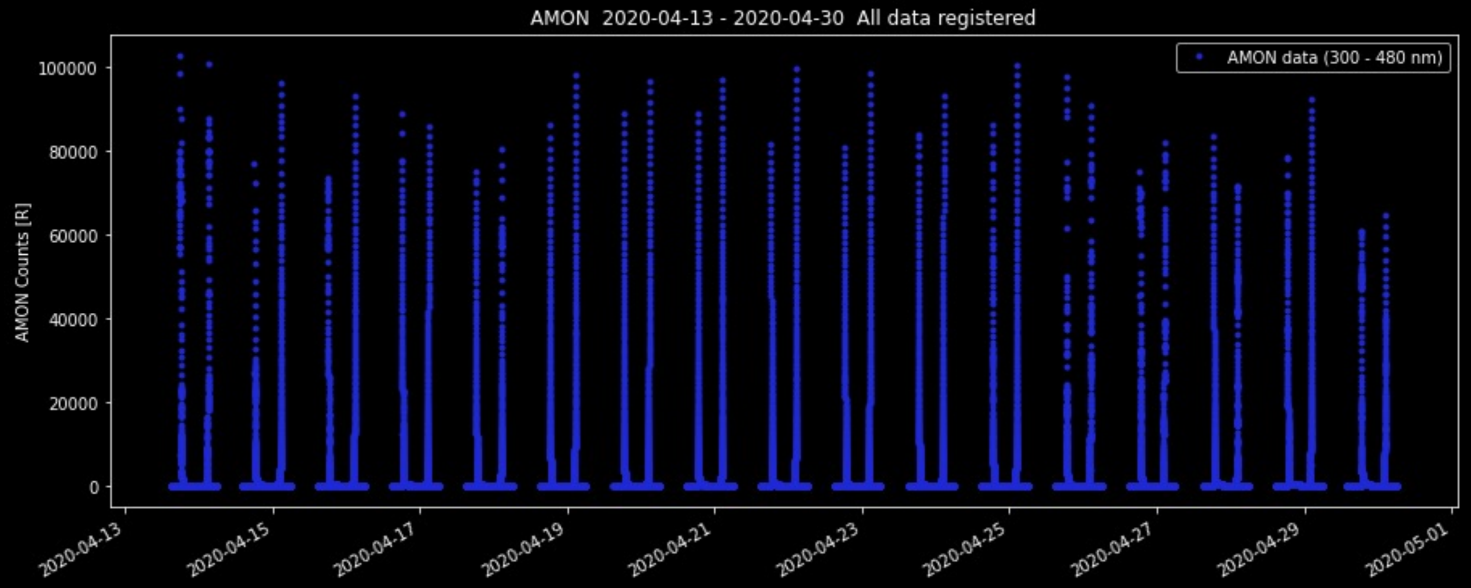
Kolonica Observatory



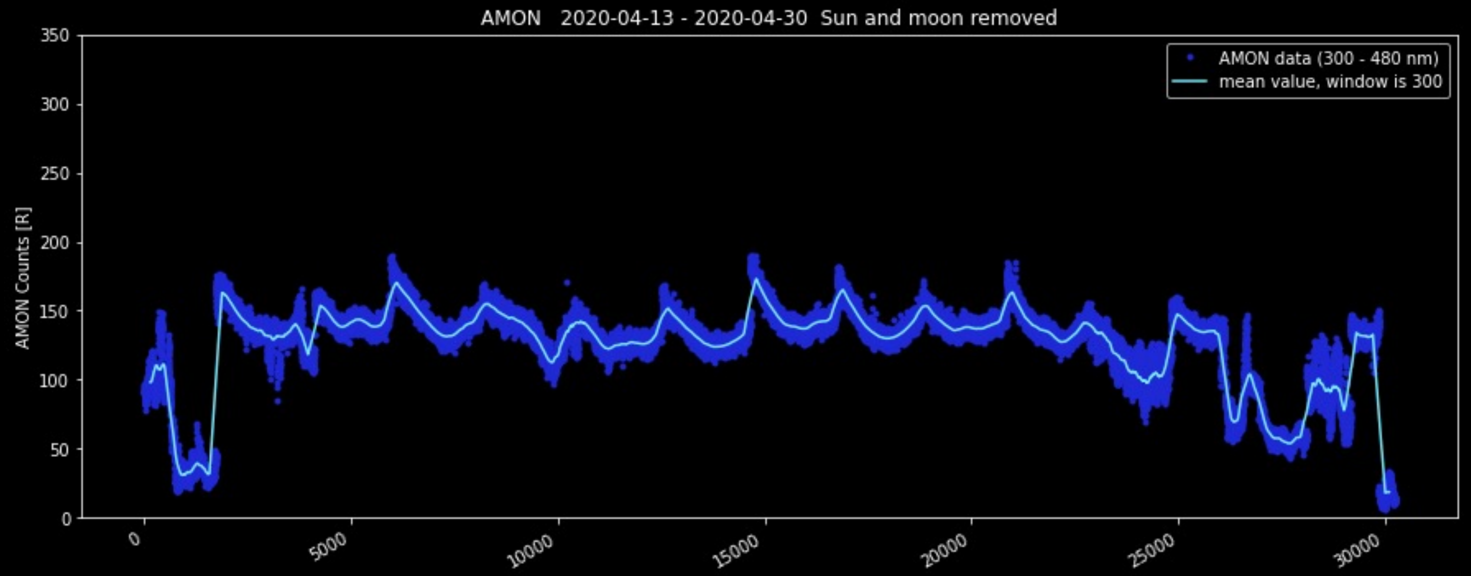
Light pollution map (*lightpollutionmap.info*)

AMON data processing

All AMON data (April 2020)



Isolation of dark hours by removal of Sun and Moon contribution.



Weather conditions

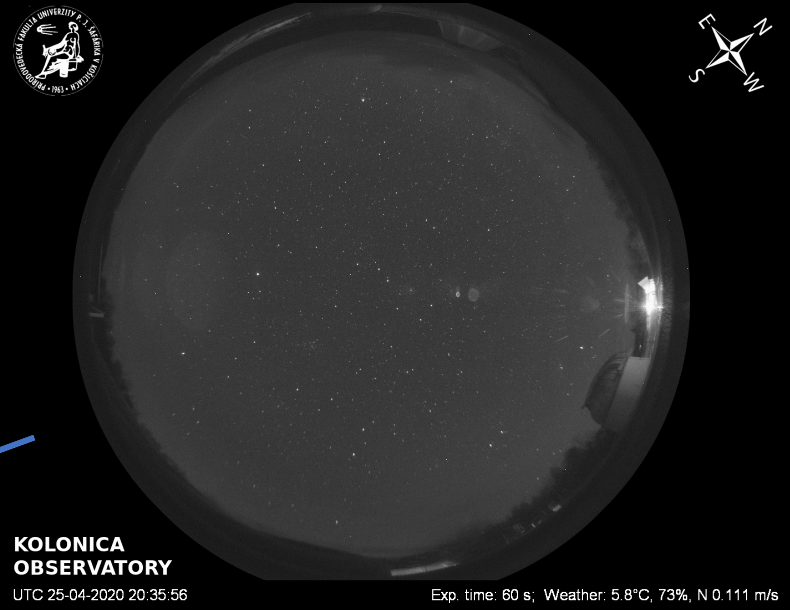
Different ways to isolate clear sky hours:

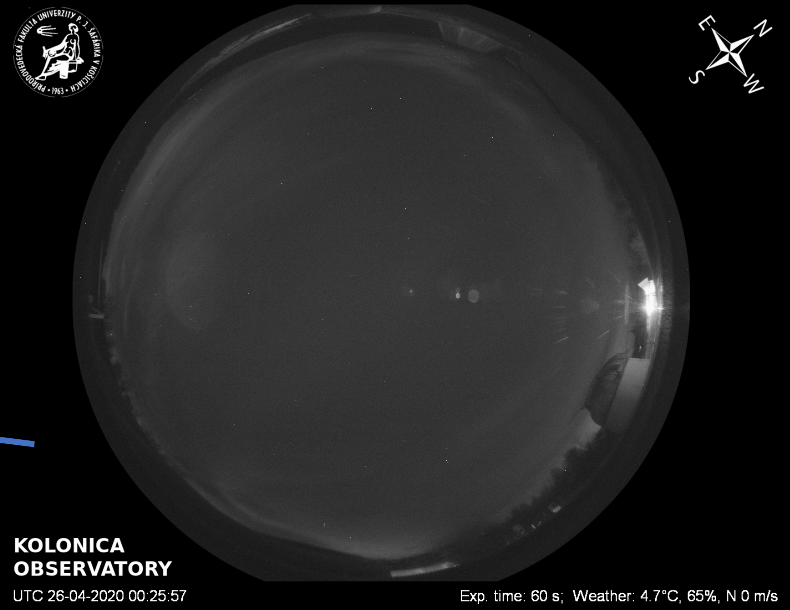
- **sky temperature**
  provided by an infrared sensor, 10-11.5 μm, inside Cloudwatcher instrument, situated in AMON-ES
- **photographs from Raspberry-Pi camera**
  situated in AMON-ES, resolution of 2592 x 1944 pixels
- **photographs from ALL-sky cameras**
  our AAC and one camera from UPJS University
- **rain value** (eventually)
  provided by a rain sensor inside Cloudwatcher

Clear sky and clouds as seen by the Raspberry-Pi camera

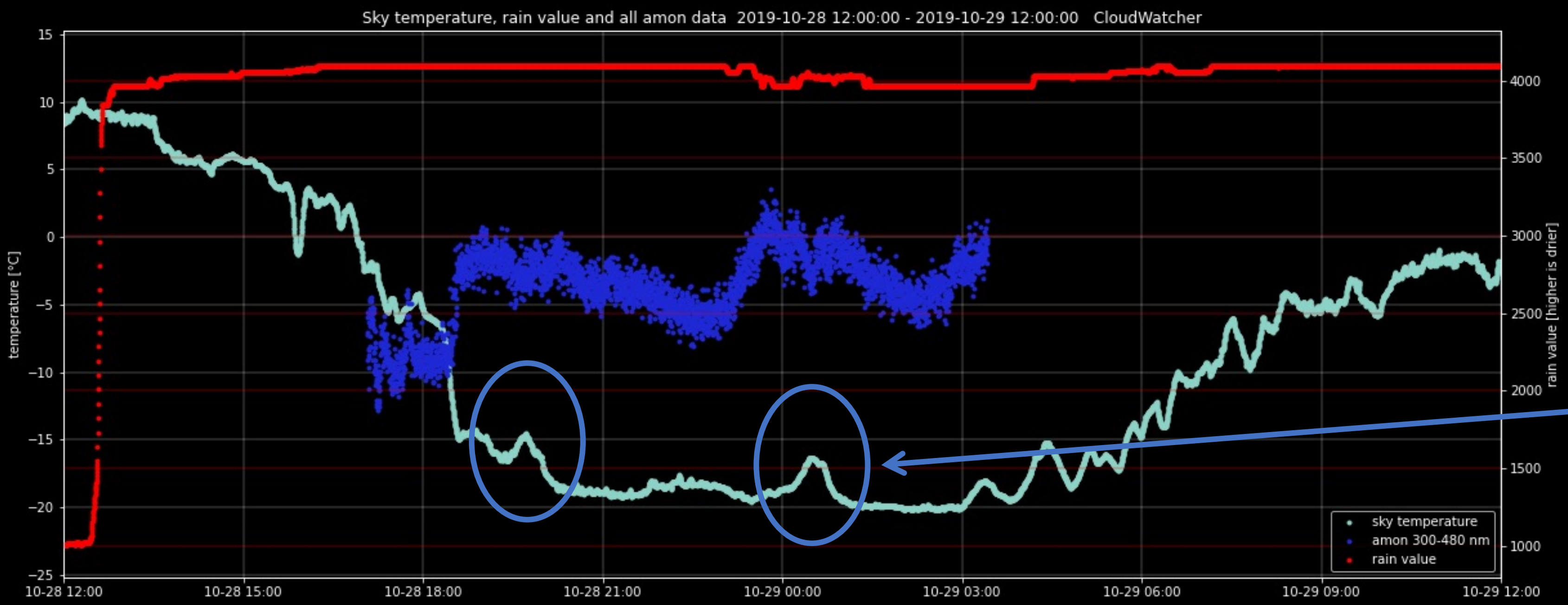
Sky temperature

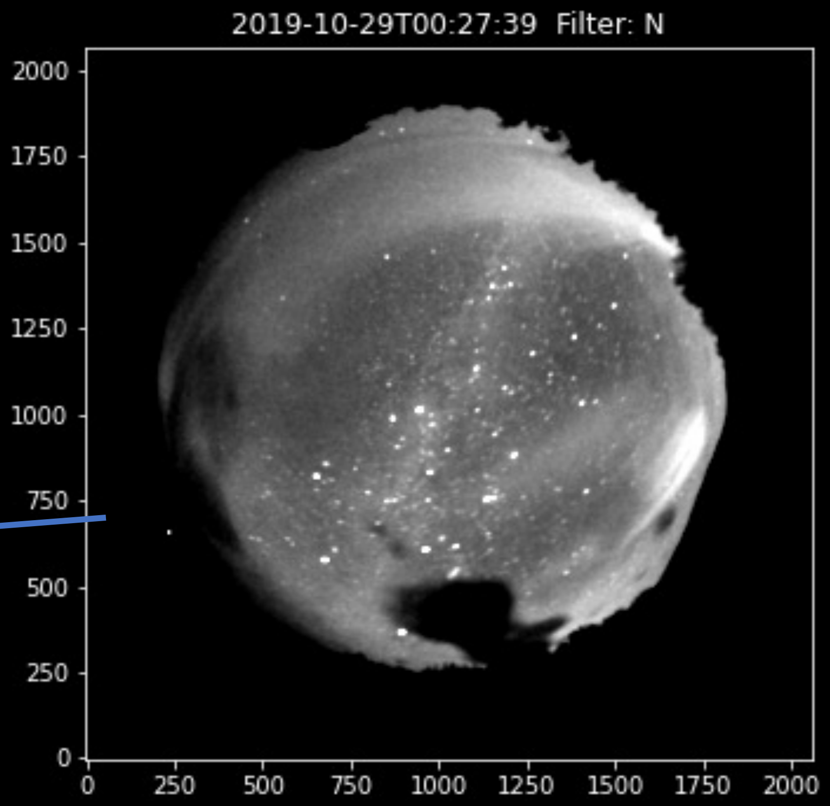
Higher sky temperatures mean presence of clouds.





Small peaks in sky temperature indicate transit of clouds and immediately reflect in fewer counts in AMON data.

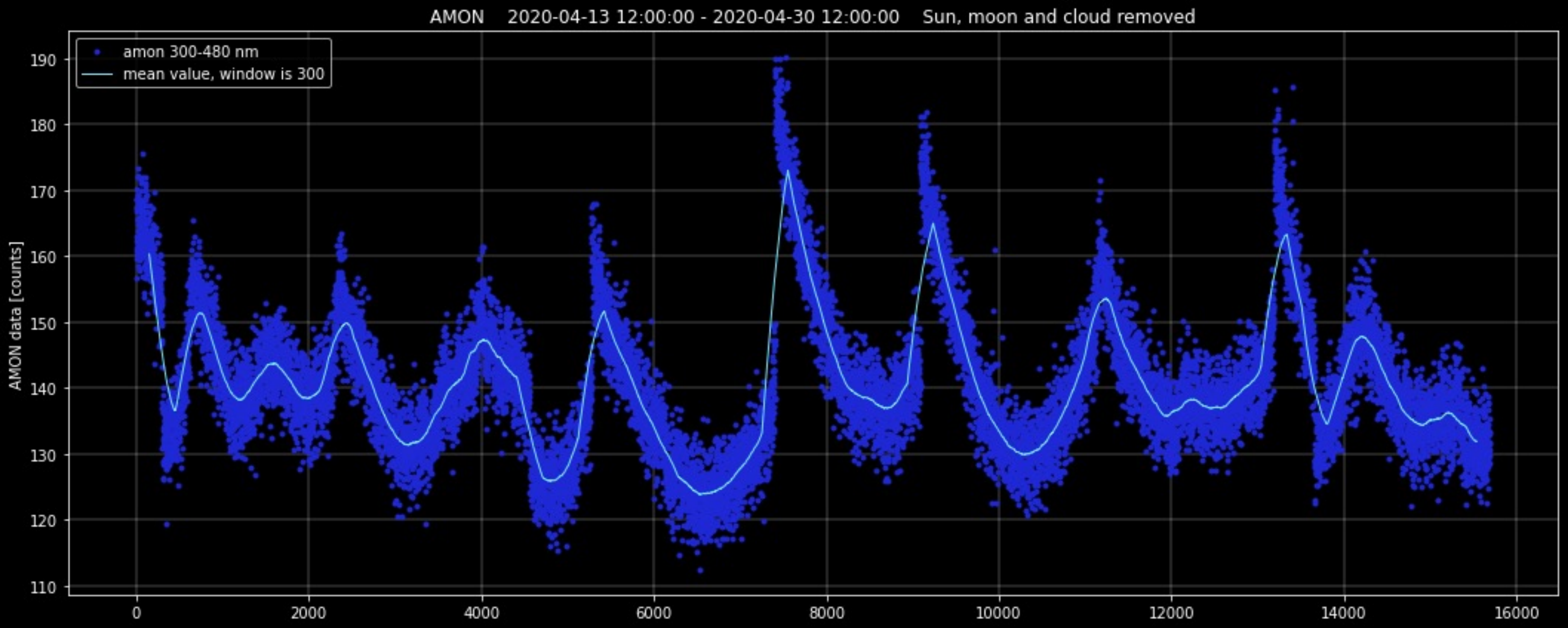




Key points of weather analysis

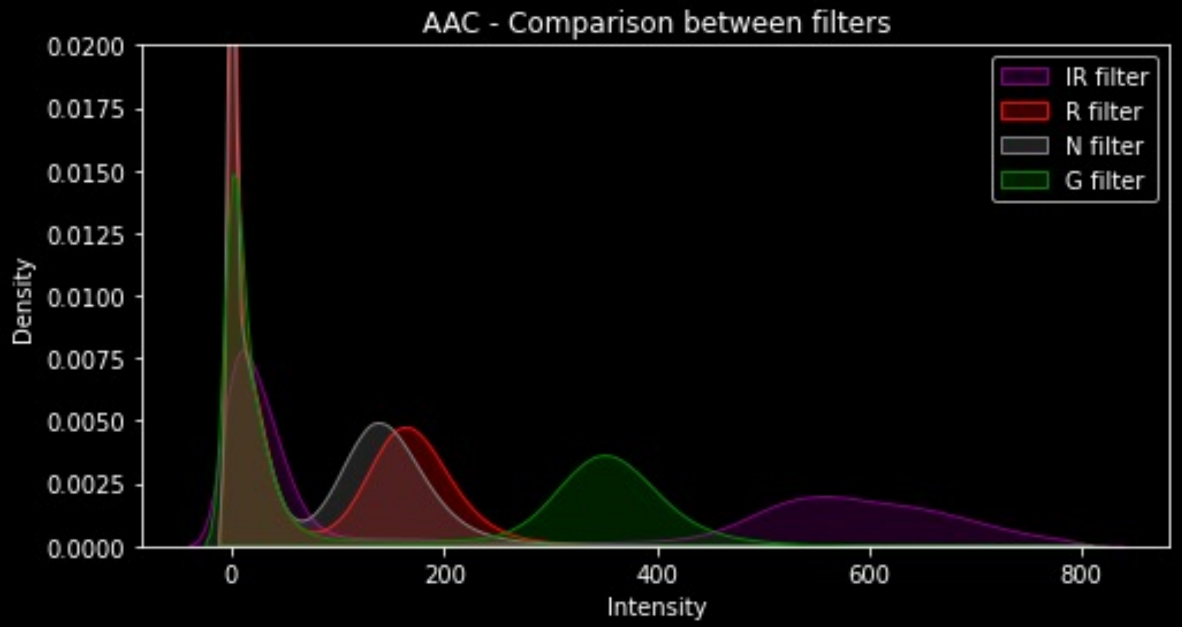
- Just establishing a threshold in the sky temperature is not enough
- The most reliable method is looking at ALL-sky cameras and Raspberry-Pi camera pictures
- Checking the sky temperature can help speed up the analysis

Final plot of AMON data for the desired period.

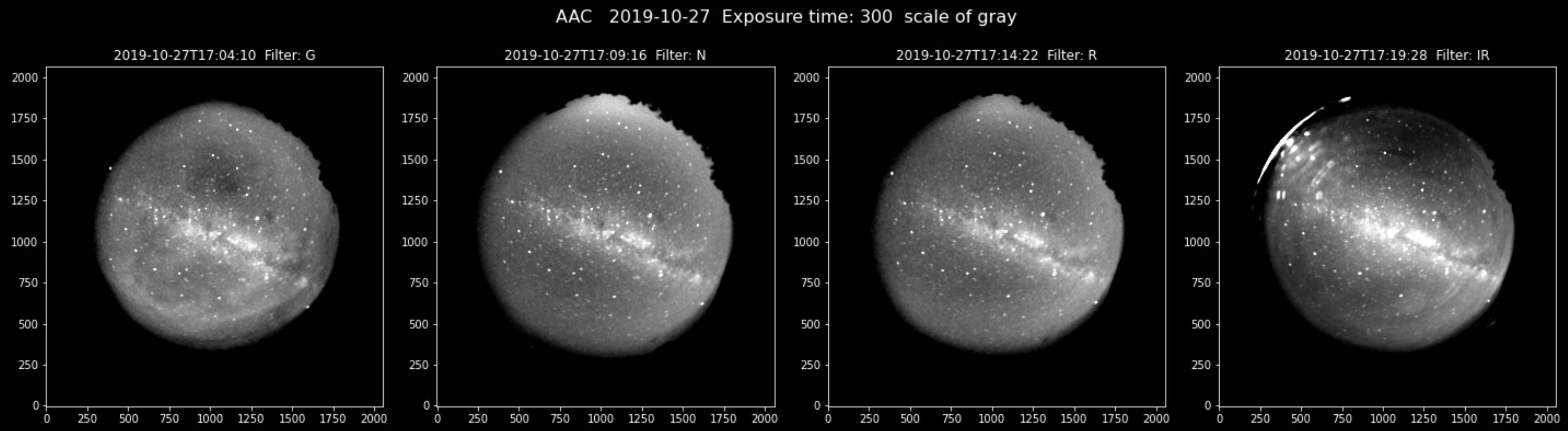


AAC images

The different filters capture different wavelength ranges.
The N filter covers a range where no airglow light is emitted, therefore the image taken is the least bright.



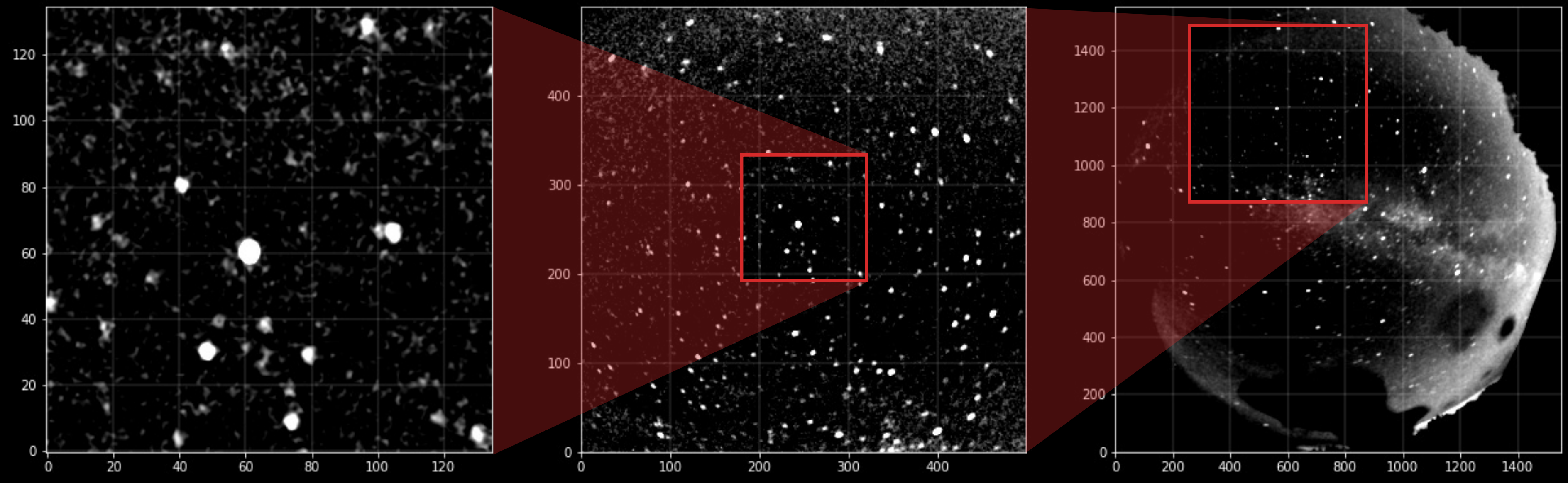
Images from the night 10/27 – 10/28 are shown below.



AAC and AMON data comparison

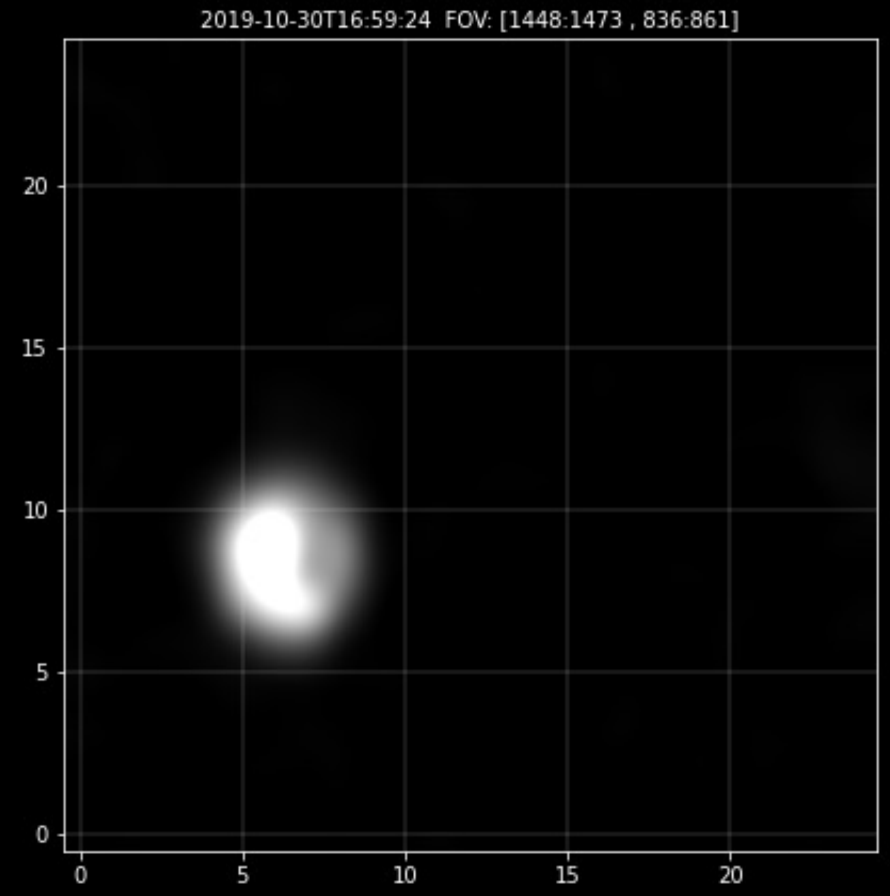
In order to compare the data collected by AMON and those collected by AAC, it is necessary to highlight the AMON FoV in the AAC images.
Only intensities from this region will be used as AAC data.

The Polaris star is visible at the center of the first and second images.
(This images were taken with G filter mounted on AAC)



AMON is observing the sky around the North Celestial Pole.
We located it considering the rotation of the stars during the night.

In our AAC images the North Pole is approximately around the pixel (y = 1460, x = 848).

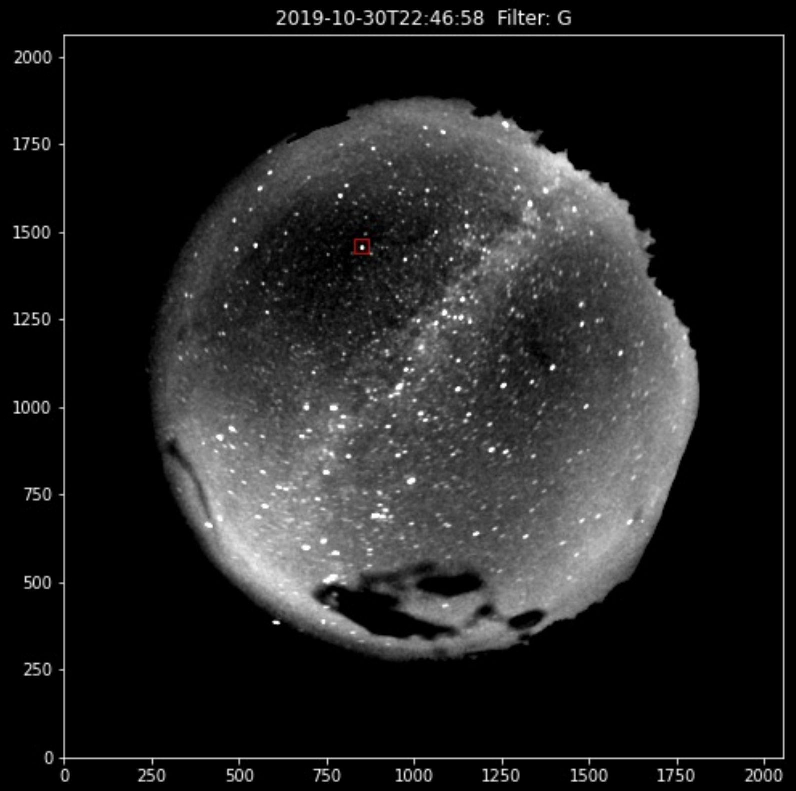


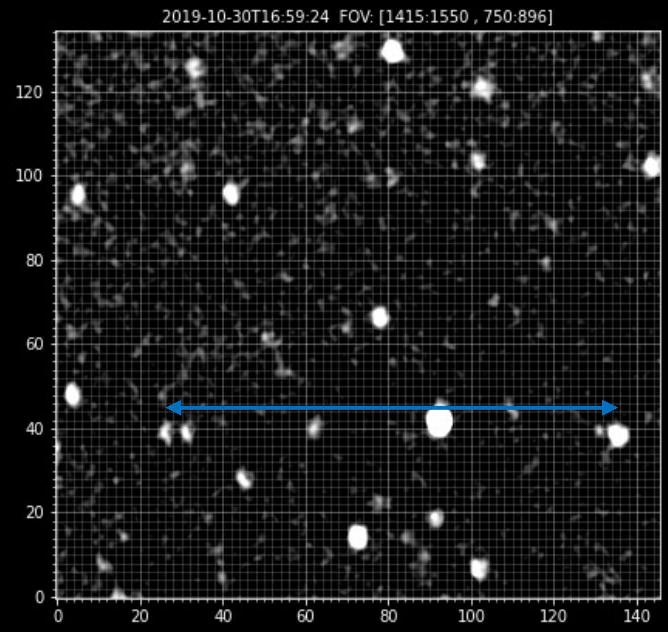
The Polaris star rotating around the North Celestial Pole, during the night 2019-10-30.
(These images were taken with G filter mounted on AAC)

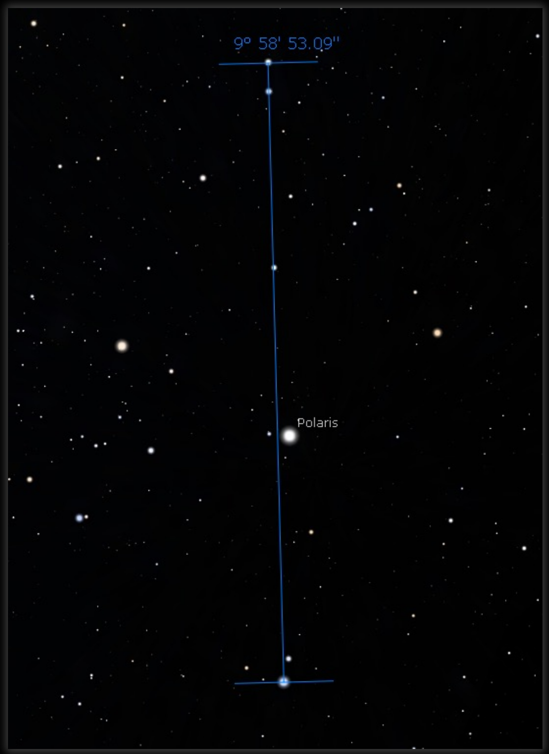
AMON Field of View

We know that the FoV has an elliptical shape with size: 4.09° x 1.35°.

AAC 2019-10-30 Exposure time: 300 AMON FoV in red







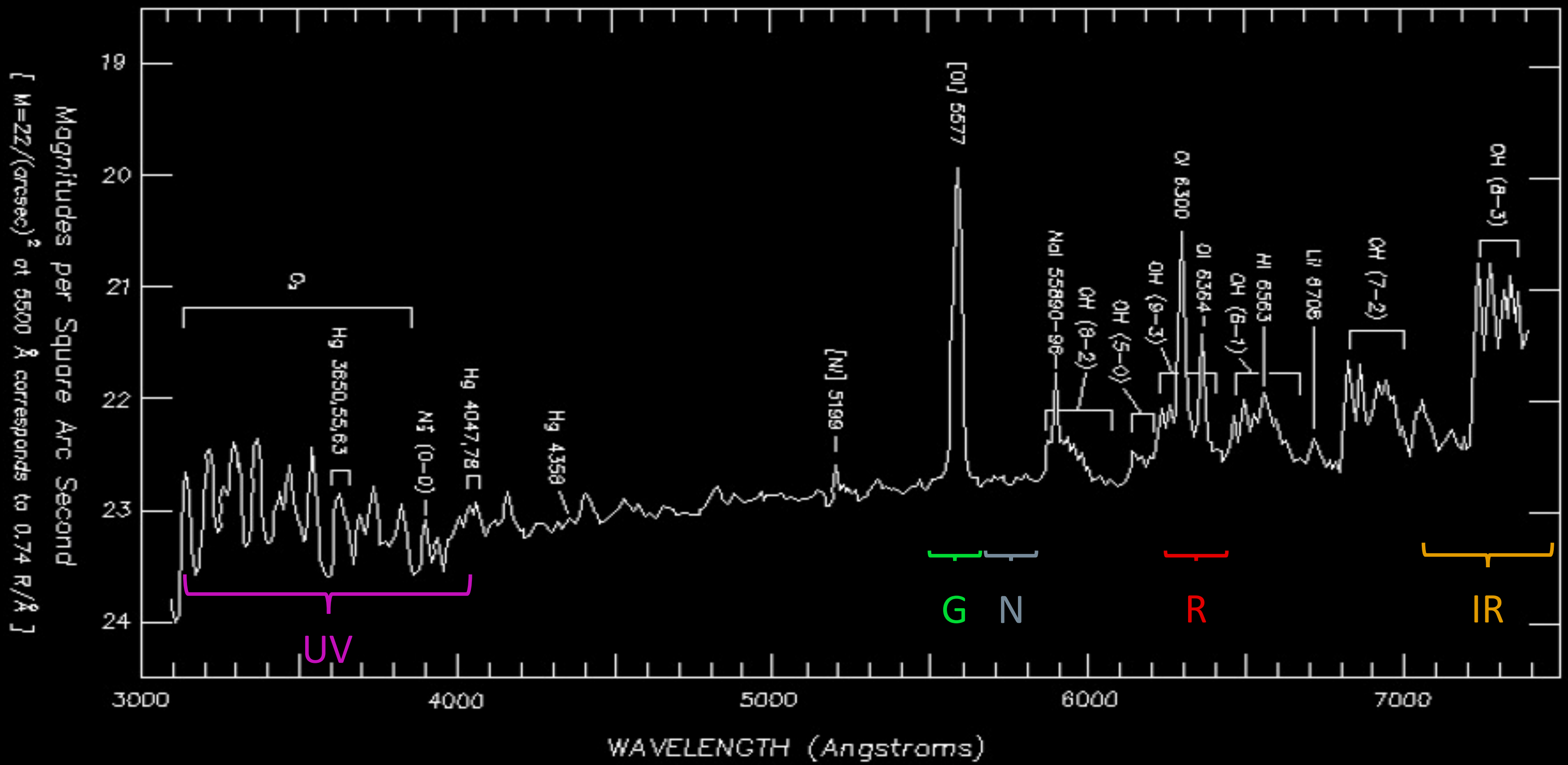
We obtained the conversion from degrees to pixels by measuring the distance between two stars.

The selected region is: [1439:1481, 830:872] (42x42 pixels).
It should include entirely AMON Field of View.

Background subtraction from AAC images

We can subtract the image in the N filter from the other images. With this operation we can:

- leave out the contribution of the stars
- have a better visualization of airglow variations



Typical spectrum of visible night sky emission at Mauna Kea (Paul Hickson and Alan Stockton)

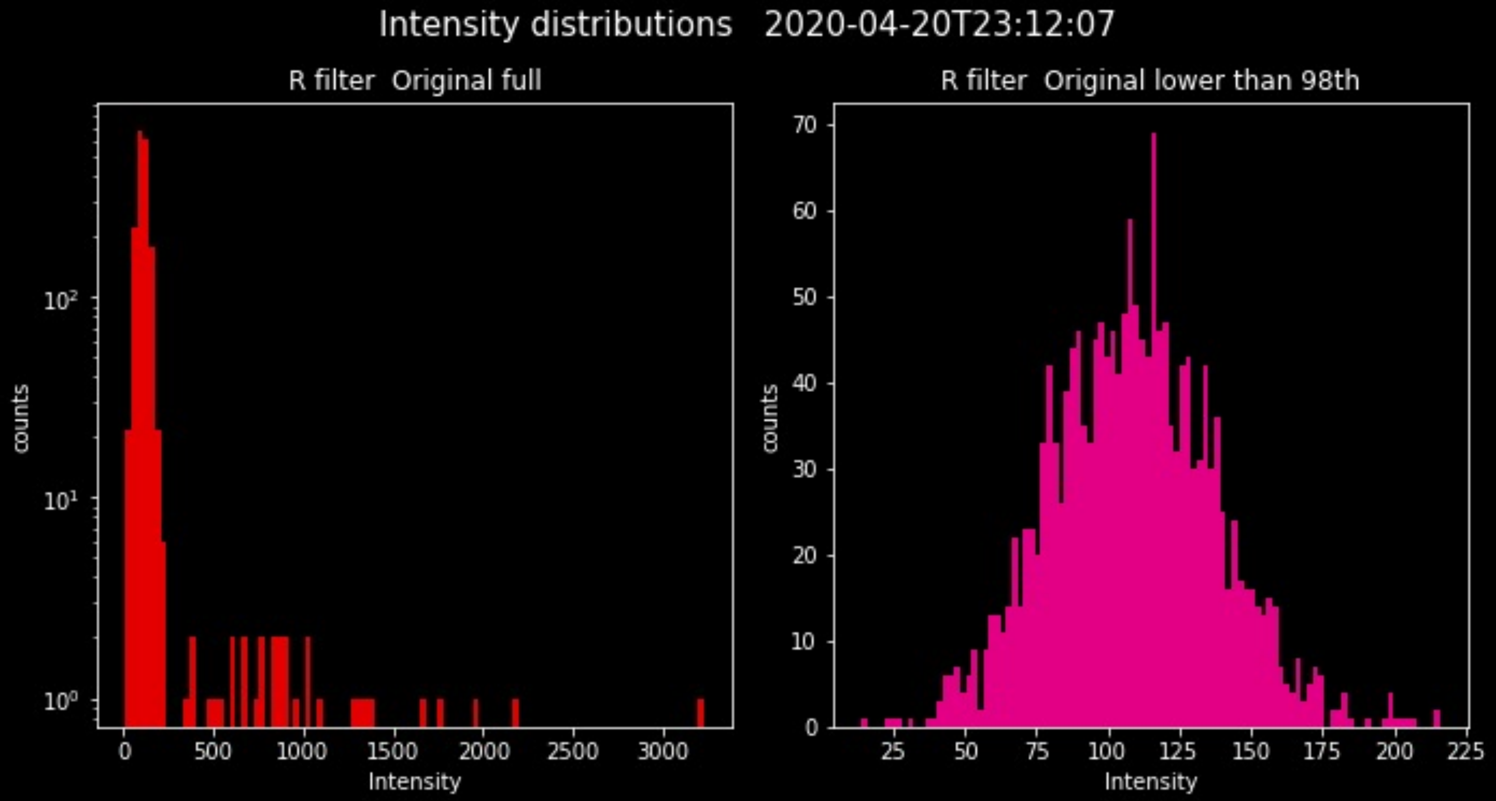
Due to the delay between the images, they must be rotated before the subtraction.

To obtain a better visualization we applied a median filter to the subtracted image.

Removal of outliers

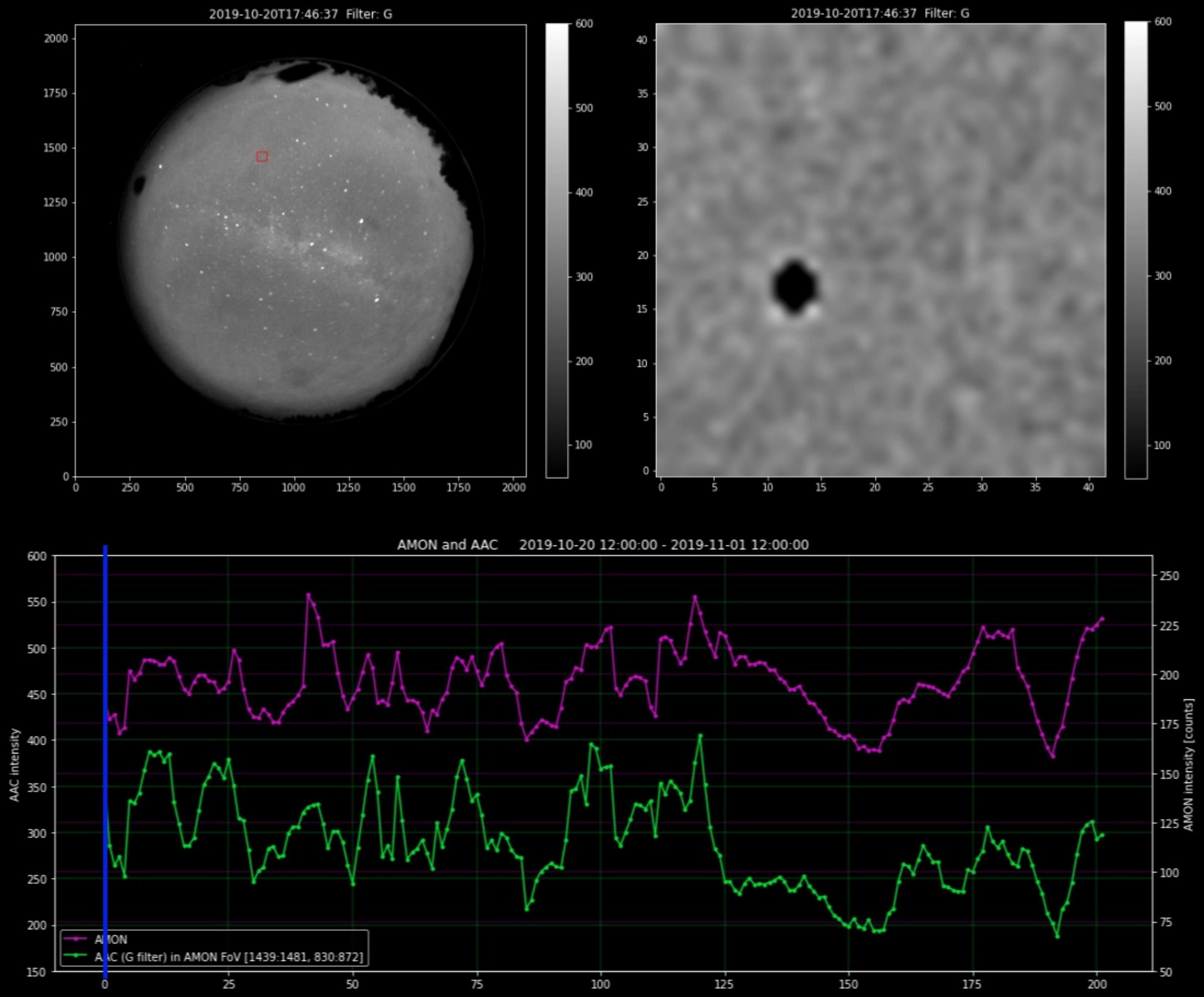
In the AAC images, some pixel intensities are located outside the distribution.

We removed those outliers by cutting off the tail of the distribution, keeping only 98% of the data.



Visualization of short-term airglow variations

Variation of intensity in the green filter throughout the period 2019-10-20 – 2019-11-01. The quadrant upper right shows the AMON FoV.



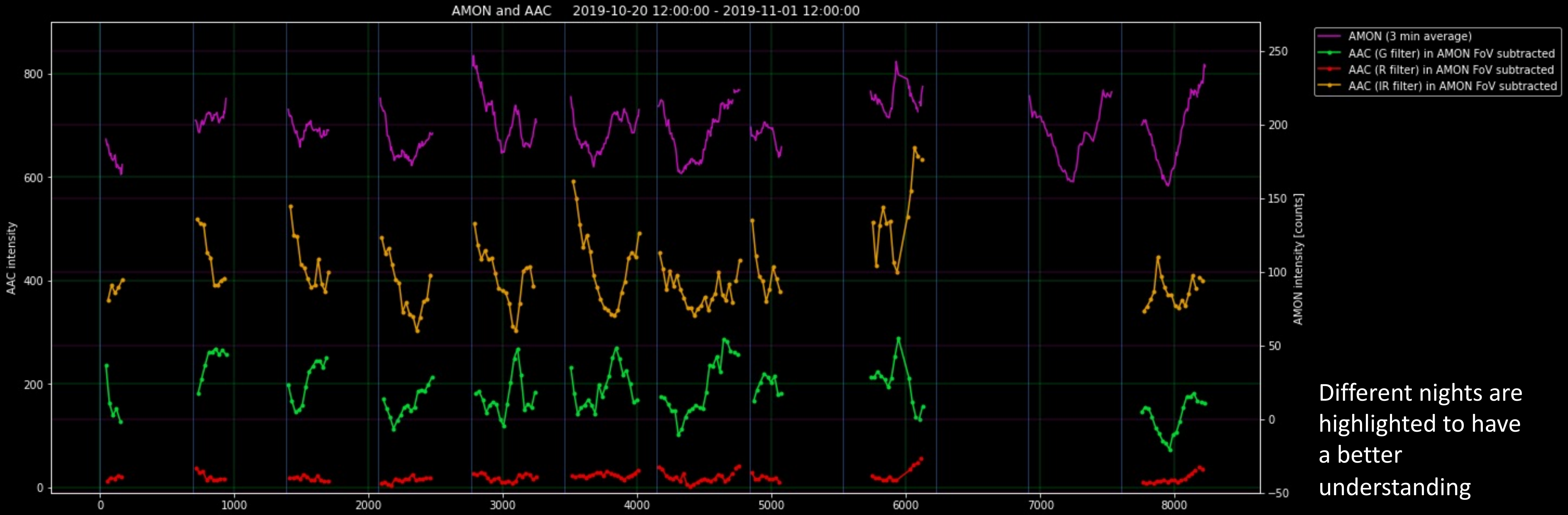
Analyzed periods:

- October 2019
- April 2020

Observed airglow emissions in:

- UV
- Green
- Red
- IR

October 2019



Different nights are highlighted to have a better understanding

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- October 2019
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- UV
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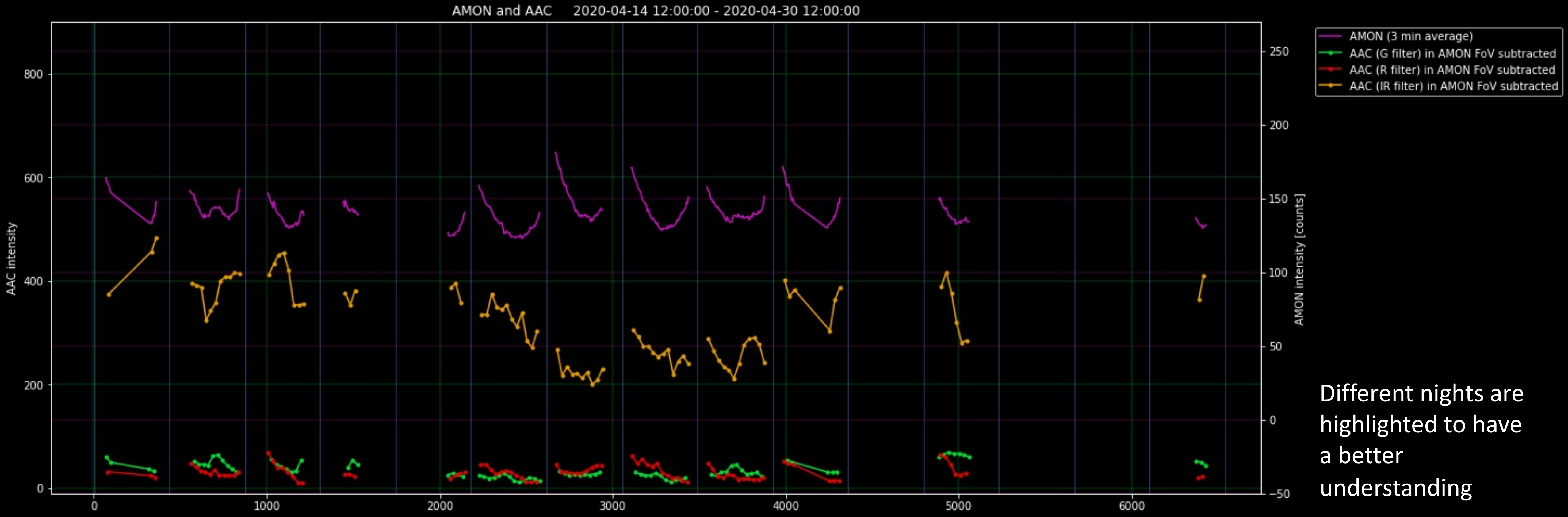
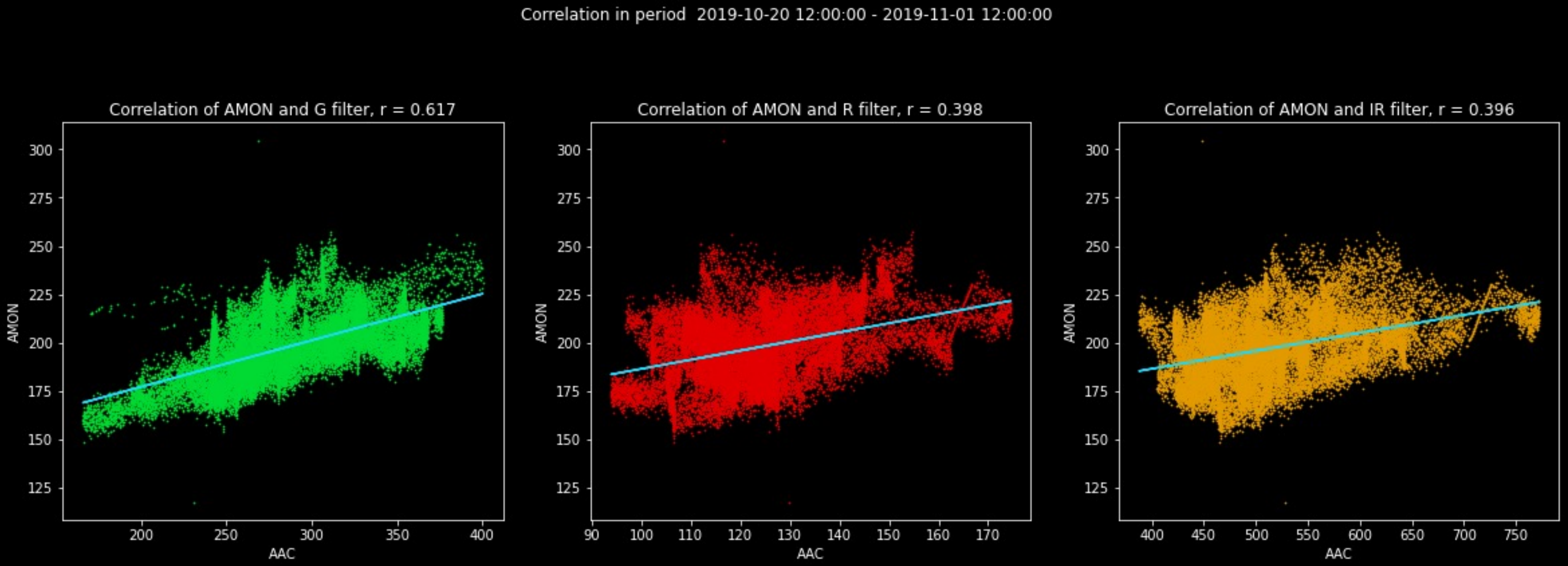
- Red
- IR

April 2020



Different nights are highlighted to have a better understanding

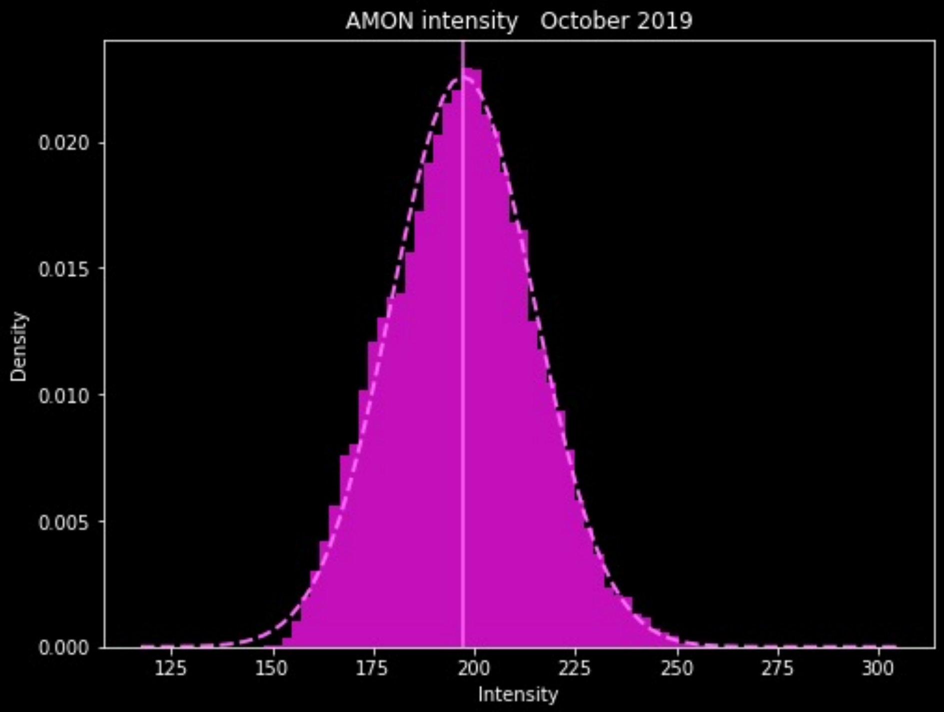
Correlation index between AMON and the different filters

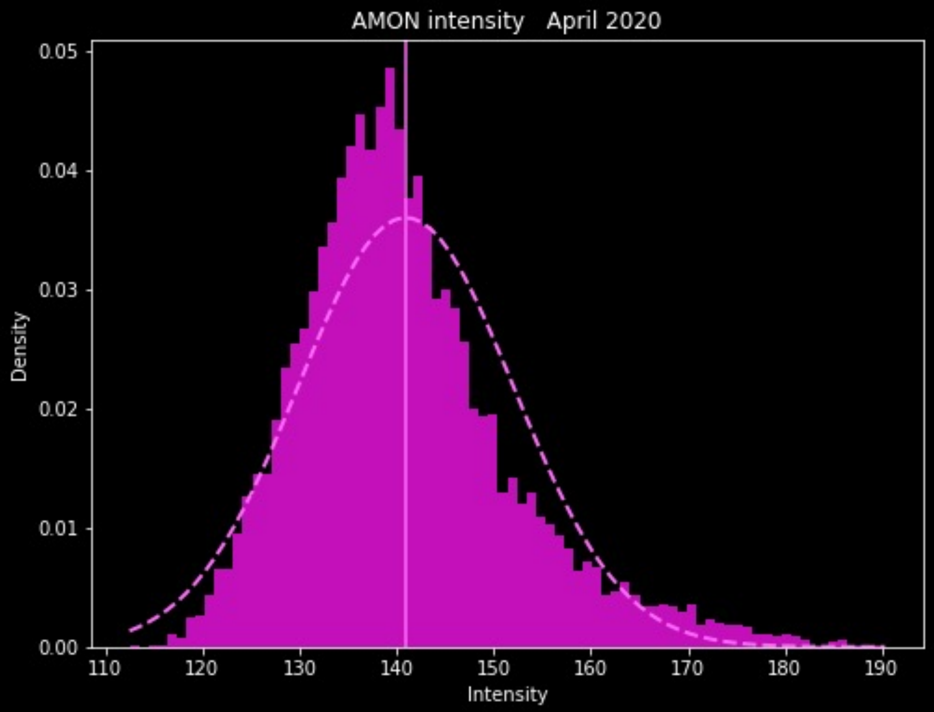


There is quite a good correlation between the AMON data and the intensity in the G filter.

Distributions of AMON intensity

	Average intensity (counts)	Average intensity (photons m^{-2} sr^{-1} ns^{-1})	Variation (standard deviation)	Variation ((max - mean)/mean) ((mean - min)/mean)
Oct 2019	197.1	1170.1	± 8.95 %	+ 25.6 % - 19.5 %
Apr 2020	140.9	836.4	± 7.87 %	+ 28.6 % - 12.8 %





Conclusions

- Reading and representation of AMON data
- Leaving out all the unwanted contributions (Sun and Moon, clouds)
- Processing of data from AAC (background subtraction, removal of outliers)
- Development of different methods to visualize airglow variations
- Comparison between airglow intensities at different wavelengths
- Observation of both seasonal and short-term changes in airglow intensities

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