

CLOWN: A new tool for cloud detection for optimization of space- debris surveys

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Kessler Syndrome

- ◆ As far back as 1978, there has been a growing worry about the problem of space debris accumulation.

Today, we see the consequences of past work, in the collision of active satellites with pieces of debris, which will only escalate with the new mega-constellation projects.

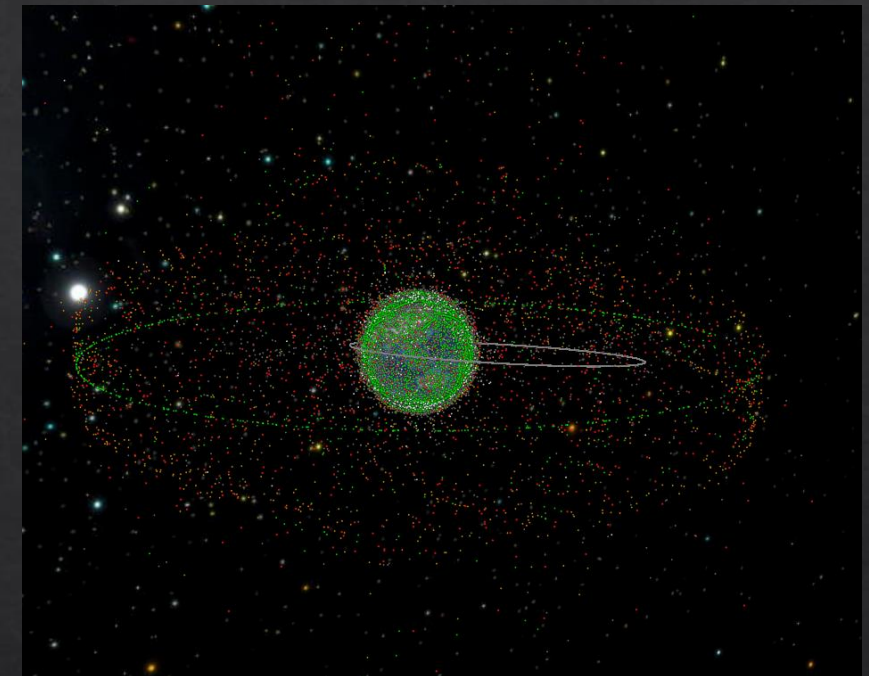
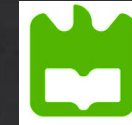
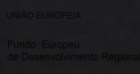


Illustration of satellites in orbit around Earth, taken from Celestrak; <https://celestrak.org/>.



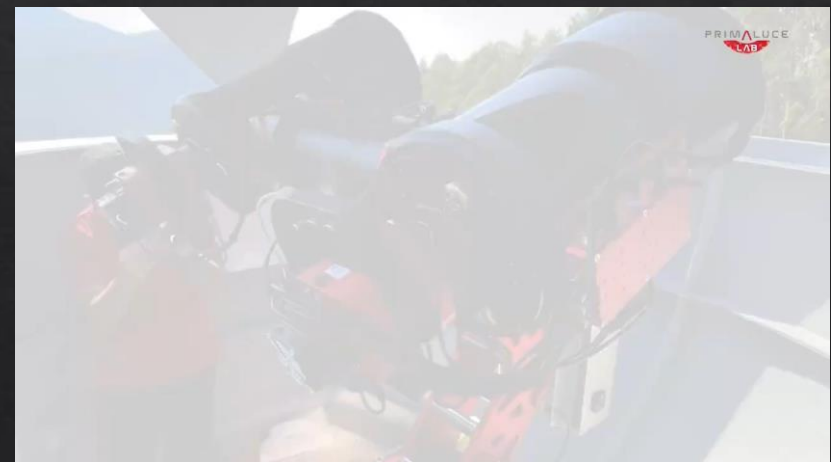
PASO – PAmpilhosa da Serra Observatory



Lat: 40.182524°, Lon: -7.873811°, Portugal
Observatory image, available at Google Maps.

Optical telescope

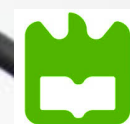
- ◆ In July 2022, it was installed a new optical double telescope in PASO, with a field of view of $4.3^\circ \times 2.3^\circ$.
- ◆ It will have the main objective of tracking objects in LEO, and also being able to track and survey objects in MEO and GEO.



Optical double telescope installed in PASO; video taken from 4
PrimaLuceLab YouTube Channel
<https://www.youtube.com/c/Primalucelab>.

All-sky camera

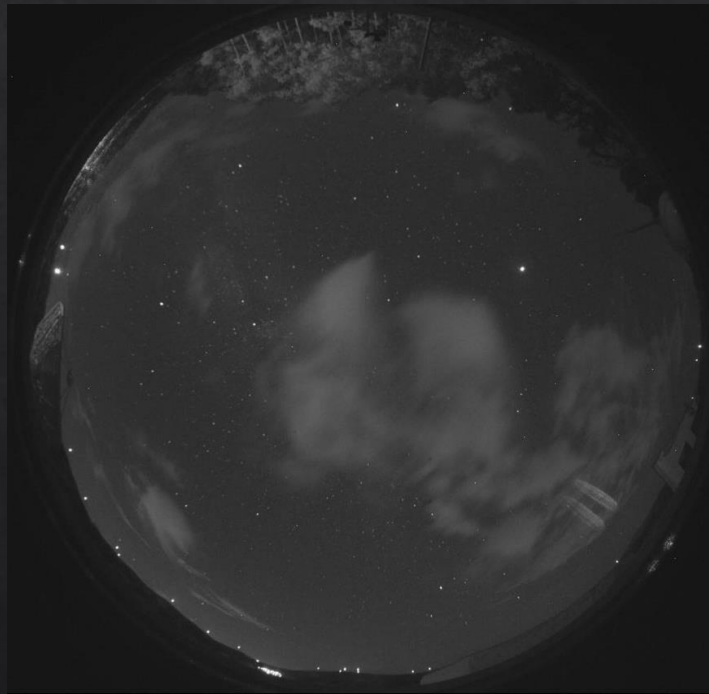
- ◊ An all-sky camera is a type of camera capable of capturing the entire sky in a single shot.
- ◊ This is achieved using a fish-eye lens, which can be equidistant, stereographical, equisolid angle, and orthographic.



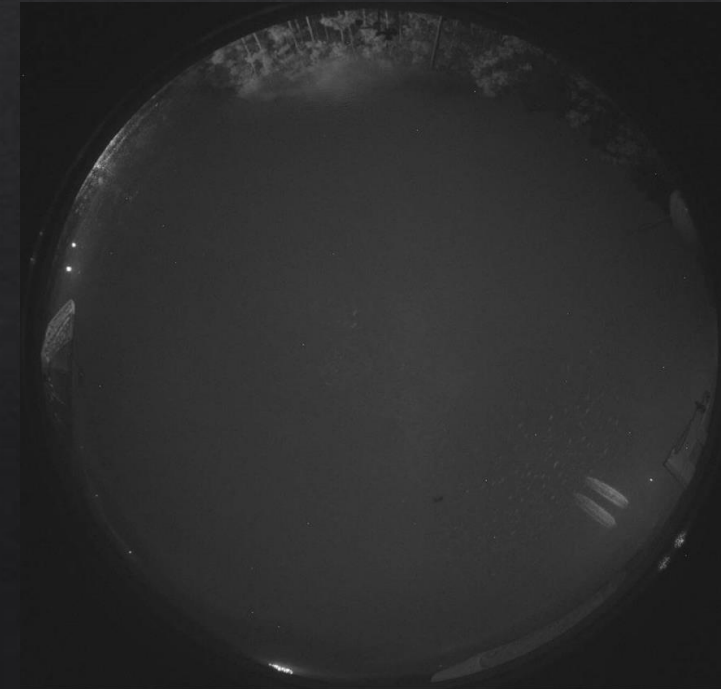
Occlus All-Sky Camera 180°

Cloud detection problem

- Clouds don't naturally emit light, and due to the remote location of observatories, they can be both visible or invisible to the camera. This originates a problem for normal image analysis software.



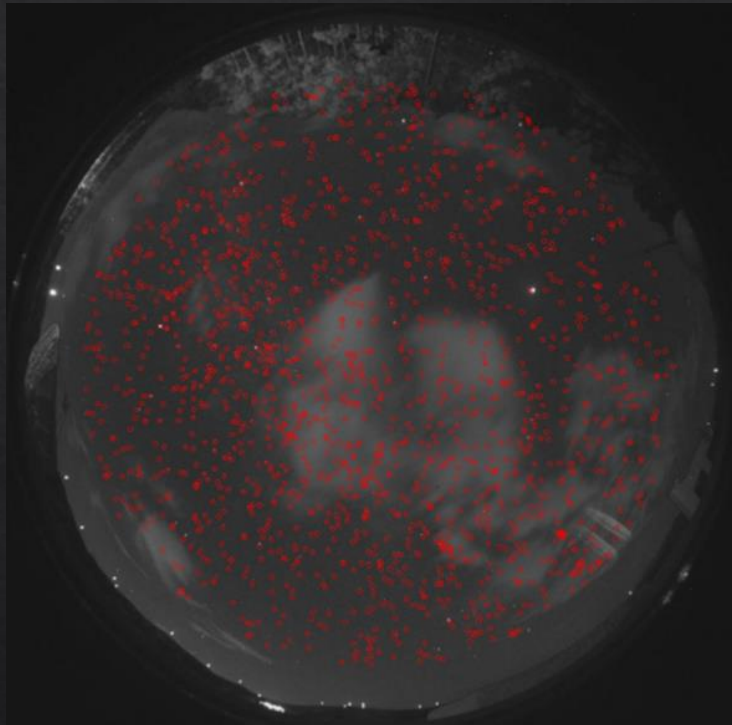
Visible cloud example, image from PASO all-sky camera.



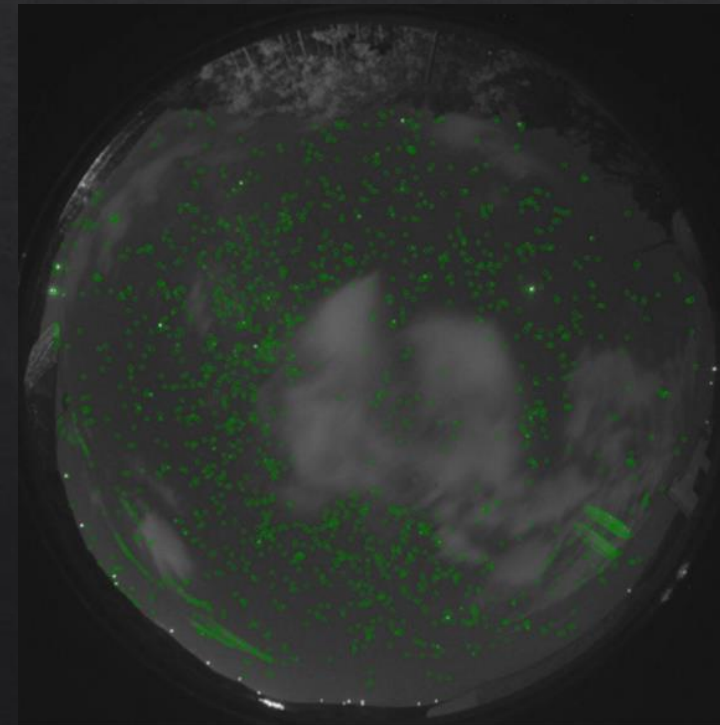
Invisible cloud example, image from PASO all-sky camera.

Method: Star detection

- ◆ In both cases, the presence of clouds will block the light coming from a star. Analysing which stars are missing from the image, we can then detect invisible and visible clouds.



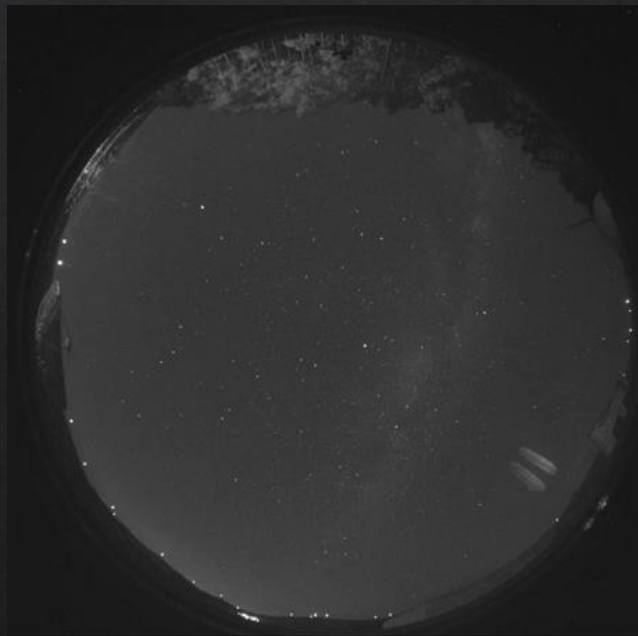
Expected objects from the Hipparcos catalogue [1], illustrated with red dots.



Detected objects in the image, illustrated with green dots.

Calibration with Stellarium

- ◆ To correctly compare coordinates between found and expected objects, we need to know in which direction is North in the image, as well as the pixel corresponding to the zenith.
- ◆ This is achieved, by utilizing “Stellarium”, which is a program capable of simulating the night sky for a desired time and place.

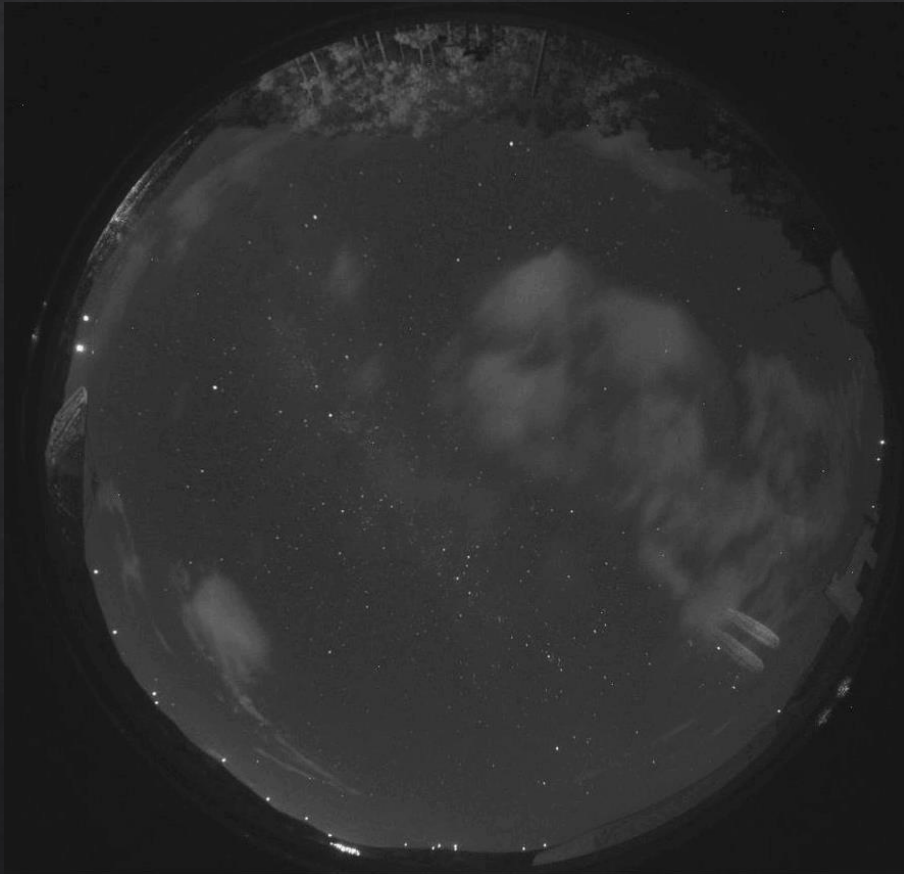


Clear sky image from PASO all-sky camera.

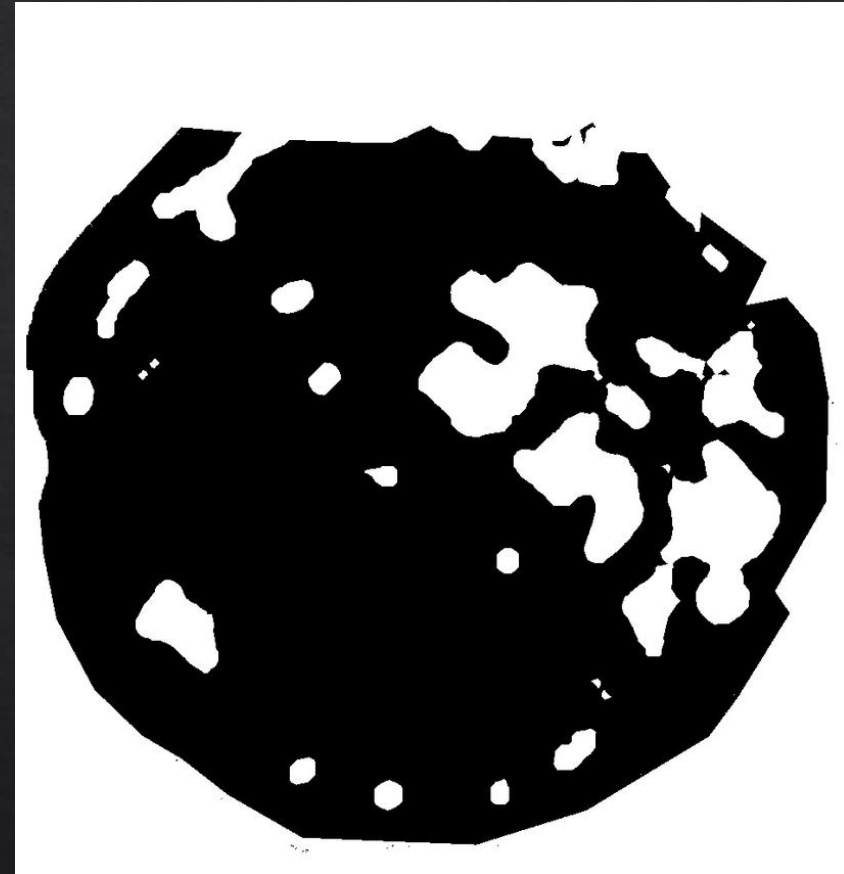


Stellarium [2] simulation for the same time and place, oriented according to the PASO image.

Cloud mask - PASO



Animation with all-sky images from PASO (~30 min).



Animation with corresponding cloud masks obtained with CLOWN.

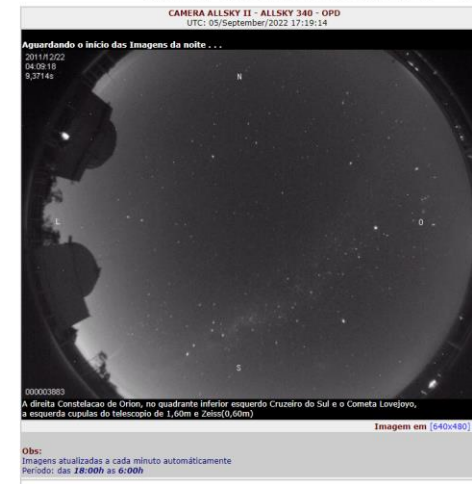
Observatório Pico dos Dias (OPD)

- OPD, part of Laboratório Nacional de Astrofísica (LNA), updates their all-sky image every minute from 18:00h to 6:00h (Brazil Time).
- We used their image to test our program without knowing camera specifications.
- Lat: -22.53444°
Lon: -45.5825°
Brazil

O P D - Estação Meteorológica

- [Estação Meteorológica](#)
- [Sensor de nuvens](#)
- [AllSky I](#)
- [AllSky II](#)
- [Monitor de seeing](#)
- [Boletim](#)
- [Ajuda](#)
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Brasopolis-MG Altitude: 1864 m Latitude: 22° 32' 04" S Longitude: 45° 34' 57" W
 Data: 05/09/22 - 14:15 UTC: 05/09/22 - 17:15 Amanhecer: 6:09 Por do sol: 17:54 Lua: Waxing Gibbous

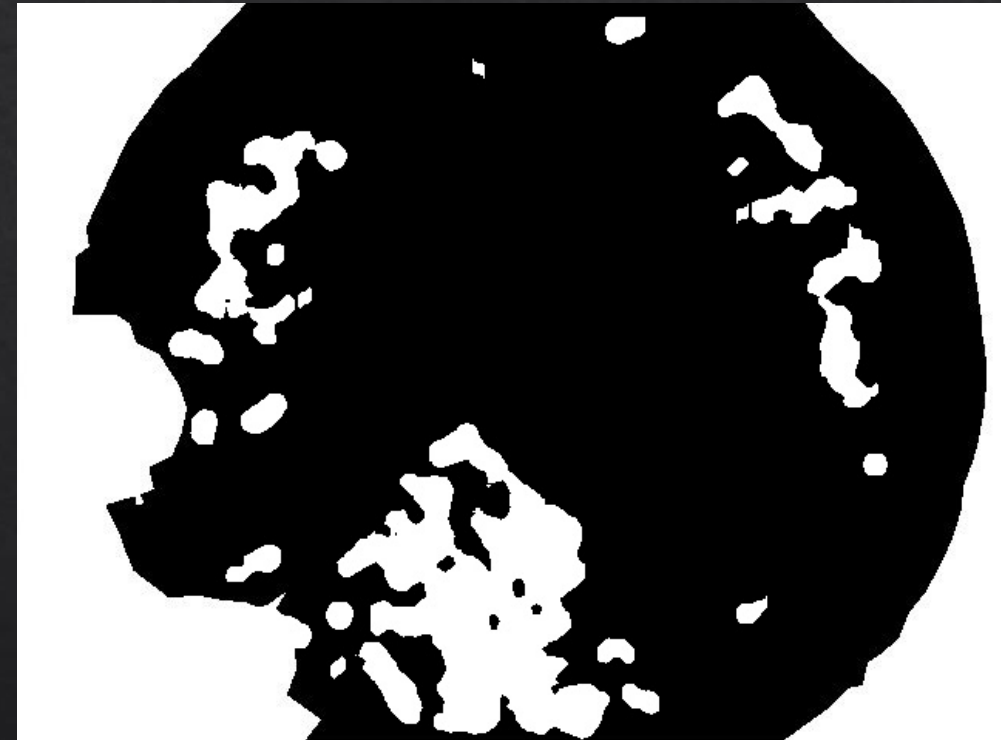


OPD weather station website, where their all-sky camera images are available:
<http://200.131.64.207/allsky/centralclima.html> .

Cloud mask - OPD



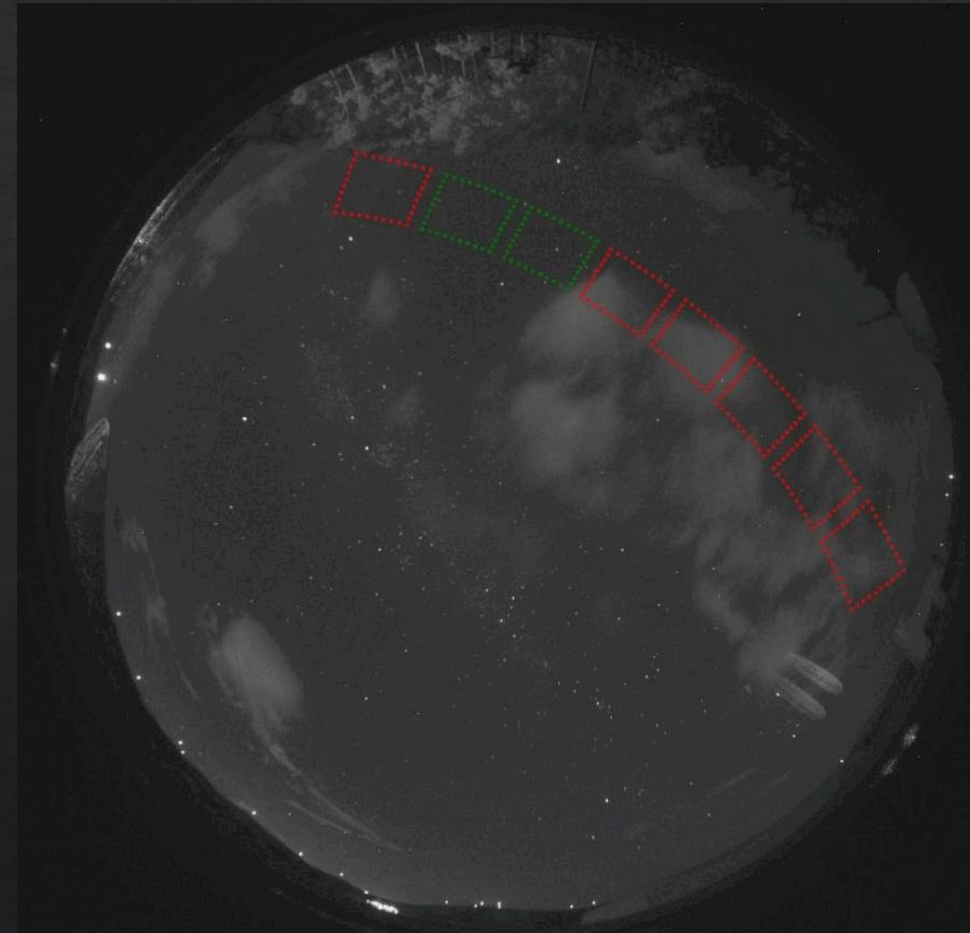
Animation with all-sky images from OPD (~30 min).



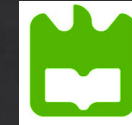
Animation with corresponding cloud masks obtained with CLOWN.

Application Example

- ◆ Each night, the telescope will have a set of objects to observe, in a determined order.
- ◆ This could lead to the waste of time, due to observing in a cloudy area which can be avoided by the use of CLOWN.



Application example for PASO images, non clouded areas are illustrated in green and cloudy areas in red,



Conclusion

- ◆ CLOWN is a tool with the ability to detect the presence of clouds in the sky, automatically and in real-time.
- ◆ It can be used in already mounted cameras.
- ◆ For future work, the images obtained by this program can be used to train a machine learning algorithm, so that it can reach even better results or be used for a meteorological study.

Merci!

Any questions?

