April the 28th 2020

AZOTEA

MONITORING THE NIGHT SKY DURING AND AFTER ISOLATION

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0 - AZOTEA PROJECT

0.1 ABSTRACT

This citizen science project aims to monitor the brightness and color of the night sky using photographic cameras to evaluate variations in light pollution that may happen during the exceptional period of self-isolation we are living.

A decrease on human activity is normally associated with darker skies.

Anybody with a digital photographic camera who is interested in the project is welcomed to participate.

0.2 OBJECTIVES

1. Study of the impact of human activity on light pollution.
2. Evaluation of the brightness and color of the sky of our cities and towns.
3. Introduction to photometric measurement techniques with digital cameras.
4. Establishment of a network of digital cameras to monitor the brightness and color of the night sky.

1- INTRODUCTION

1.1 PROJECT OPPORTUNITY

Due to the self-isolation we are experience, astronomical observation activities are reduced to those that we can carry out from our home with the instrumentation we happen to have with us.

In this document, a study over time of the brightness and color of the night sky through measurements obtained at home with the help of DSLR cameras is proposed.

It is well known that the brightness of the night sky and its color depend on the amount, type and location of light pollution sources. For this reason, the study of the brightness and color of the sky allows light pollution estimation. Monitoring night sky brightness continuously provides data to study statistically if there has been evolution with time.

Keeping track of sky brightness can be used to study light pollution evolution. Part of the light pollution that lights up the sky comes from traffic, shops and offices. This contribution is expected to decrease considerably during the lockdown.

It is an exceptional opportunity to compare the values of these parameters during the self-isolation with the data when we recover normality. This will allow us to verify the effect on the night sky of a decrease on human activity.

In addition, the restrictions on travel and industry have produce an unprecedented fall in air pollution levels. This implies that there is a smaller amount of aerosols in suspension in the air, which improves the transparency of the sky.

1.2 PHOTOMETRY OF THE NIGHT SKY

The brightness of the night sky is measured with specially designed devices called photometers such as SQM and TESS. SQM type photometer is used in network monitoring stations such as the Red Española de Estudios de Contaminación Lumínica (REECL[1]), the Galician[2] and the Catalan networks. The European STARS4ALL project, on the other hand, has deployed TESS-W3 photometers for its network.

Only some stations equipment, such as AstMon all-sky cameras, allows to determine the color of the night sky, but these kind of devices are expensive and are not designed for the general public.

1 https://guaix.fis.ucm.es/reecl/SQM-REECL
2 https://www.meteogalicia.gal/Caire/brillodoceo.action?request_locale=gl
3 https://tess.stars4all.eu/map/

However, many people own digital DSLR cameras that allow to take images in native or RAW format that once calibrated, provide scientifically accurate data.

DSLR images are made up of pixels in three RGB colors corresponding to the red, green and blue channels arranged in a layout known as the Bayer matrix. This can be used to our advantage as RAW images can be decomposed into individual images of each color that allows to estimate the color of the sky.

The idea behind AZOTEA project is to analyze RAW photos taking from home by volunteers that ideally (although not necessarily) aim the zenith of the sky. Taking sequences of a photo every 10-12 minutes is enough for the study and allows not to generate an excessive amount of data.

These measurements should be taking every possible night, including cloudy ones and should continue when the lockdown is over so it allows to compare both situations.

Hopefully some of the monitoring stations will remain operational after AZOTEA project finishes and a network of digital cameras will remain monitoring the brightness and color of the night sky.

2 - OBSERVATIONS

2.1 OBSERVATIONAL METHOD

Each collaborator should use his or her DSLR camera to take photos of the night sky from home. The idea is to keep track of the sky brightness so measurements must be taken for along the night, everyday even on cloudy ones. The camera must be installed in a fix spot and protected from the weather producing a monitoring station. The statistical analysis of the data will allow to distinguish clear sky moments (in witch darker skies in urban environments are expected) from cloudy nights with brighter skies. **Please keep in mind that measurements during cloudy nights are just as important as those taken during clear ones.**

2.2 EQUIPMENT AND CONFIGURATION

The camera

Any digital camera that allows to obtain RAW images is useful for this project. To find out if yours is one of them it is necessary to look for this information in its menus. DSLR cameras are ideal ones, but there are compact cameras and smartphones with this feature. This project requires a dedicated camera, as photographs along the whole night trough several weeks will be needed. We recommend not to use your best camera, but one that you are not using as much. It is not necessary to use a full frame camera as APS-C and similar cameras work as well.

Photographic lens

The photographs must frame a wide area of the sky vault, not necessarily all of it. During the processing only the central region of the field of vision will be measured although seeing the rest of the sky is interesting as well. If you have a vision of the horizon, the use of a fisheye lens or a wide angle lens would be appreciated although we understand these kind of objectives might be not available to the volunteer, so we accept photographs taken with any available lens.

Please do not change the objective nor its configuration during the project. This is particularly important if you are using a zoom lens that offers a range of different focal lengths. If this is your case, please select the maximum or minimum focal length available to be sure that it is always the same. For example, if you are using an 18-50mm zoom, please configure it to be 18 or 50mm and not another focal length in between.

Data format

RAW is a native to the camera file format that captures all image data recorded by the sensor when you take a photo.DSLR cameras have a panoramic detector that is linear so twice the light outcomes twice the signal. When you shoot in JPEG format, the camera does it’s own processing to convert the RAW information into a JPEG. This process

prevents the original data from being recovered and linearity (a crucial feature when calibrating measurements) is lost. We would appreciate the date and time of the data collection to be added to the names of the files. This would facilitate the processing of the data, although the information can be recovered later in the metadata of the photos that normally use an EXIF format.

The camera or the computer that controls the shooting should be set on universal time (UT) but the study is still doable if local time (TL) is selected. The measurement of the images is linearly related to the flow of photons that have been received as long as we subtract an average value of some dark frames taken in a given moment.

A dark frame (DARK) is an image captured with the sensor in complete darkness (i.e. with a closed shutter). **Please take several DARKS at the beginning of any sequence of photographs**. For the purposes of this study we will not take into account that every DARK contains a base level of read out noise (BIAS) that depends on the temperature of the camera and the exposure time. To make the decision of not including BIAS in this study we have taken into consideration that we will be working with constant exposure times and that if the temperature changes throughout the night, the dark current and the DARK value will change as well.

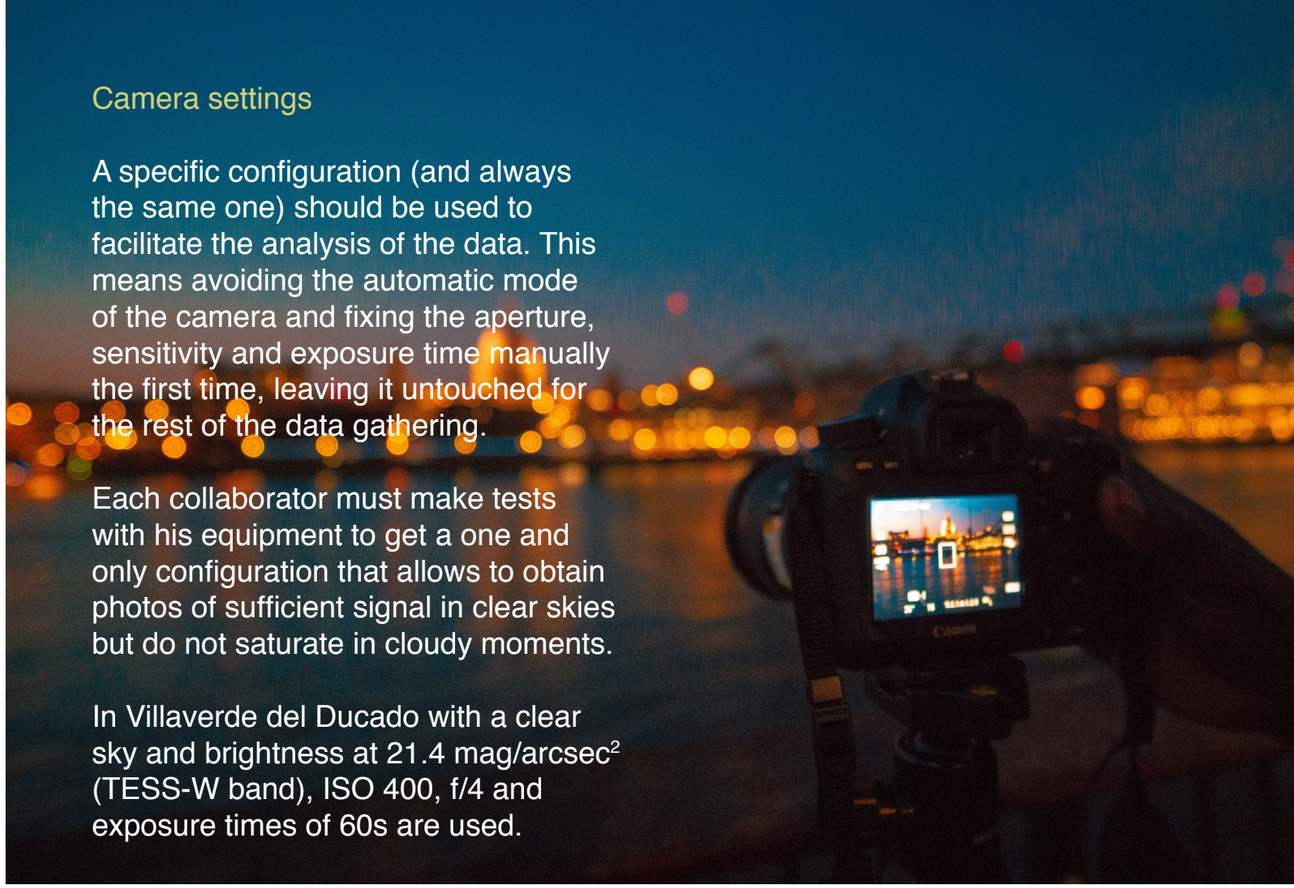
Obtaining sequences

To obtain measurements throughout the night, we will need to take a sequence of frames at set intervals time lapse like. To do so, you can either use an intervalometer or connect the DSLR camera to a computer that controls the shots. For Canon cameras the EOS Utility camera software can be used, although there are much more software available on the internet that can be used to this purpose.

Ideally, taking a photo every minute allows to isolate periods of clear and cloudy sky more effectively. However, the shutter of a regular camera is designed to take about 100,000 shots, so a sequence of one photo every 6-12 minutes (10-5 photos per hour) would be more convenient.

In order not to collapse our volunteers' disks, we are working to create an image collection and storage. Please remember that some DARK images (taken with camera covered, so no light reaches the detector) are needed to be taken at the beginning of the sequence. All camera settings, especially the exposure time, must be the same for every picture.

Take as an example the Villaverde del Ducado station, that is equipped with a Canon EOS 450D camera and produced 580 images of about 16 Mbytes on the night of 3/22/2020 producing a total of 7.44 Gb of data. This camera is taking 60s exposition photographs with 5s of interval between pictures needed for the The Canon Utility program to download the data to the computer. In Jaime Izquierdo's configuration a Canon EOS550 camera is set up in Madrid and it takes 60 images with a 10-minute interval. The data taken during 2020/04/06 night took up1.4 Gb of space.



Camera settings

A specific configuration (and always the same one) should be used to facilitate the analysis of the data. This means avoiding the automatic mode of the camera and fixing the aperture, sensitivity and exposure time manually the first time, leaving it untouched for the rest of the data gathering.

Each collaborator must make tests with his equipment to get a one and only configuration that allows to obtain photos of sufficient signal in clear skies but do not saturate in cloudy moments.

In Villaverde del Ducado with a clear sky and brightness at 21.4 mag/arcsec^2 (TESS-W band), ISO 400, f/4 and exposure times of 60s are used.

Diaphragm

Please use the brightest or most open diaphragm to be sure that the opening is always the same, since each time the diaphragm ring is touched the opening might.

Changing the diaphragm spoils the calibration and degrades the quality of the photometry. (e.g. f/4 for a f/4 lens)

Note that experts recommend not leaving the lens completely open as the image is less corrected for aberrations but in our case, these aberrations are not important.

Sensitivity

ISO 400 can be a reference. For dark skies in rural locations ISO 800 or higher can be used. In urban contaminated areas ISO 200 may be enough, but it is better to use ISO 400 and shorter exposure times.

Exposition

Exposure times in dark locations can be of the order of 1 minute. For urban areas you have to decrease this time to values that do not saturate the image. 5s can be used to start testing. Exposure time should not be less than 1s.

Focus

The focus should be set up to the infinite, as if we were going to take an astronomical photo or a landscape. We don't need a perfect focus as it is not a critical parameter.

During the analysis the signal of a small area will be added so it does not matter if the stars are out of focus looking a little blurred.

2.3 Monitoring station

The camera should be installed in a place that allows to take interesting pictures scientifically speaking.

The equipment should be working the same configuration and conditions trough time. This means that the camera should be installed in a weather proof station.

Location and targeting

The ideal situation for our station is a roof terrace that allows to see our zenith (the highest point of the celestial vault).

For collaborators living in the interior of cities or towns, the brightness and color of the sky at the zenith is preferred to be measured.

In the case of stations in locations outside large urban centers but with a direct view of their light haloes, the camera should aim to that glow.

The field of vision should cover the horizon and the height of the frame will depend on the objective (typically 30-45 degrees).

There are other situations that are especially interesting to monitor such as villages, roads, etc.

In any case, if you do not have access to a terrace with a zenith vision, a good option is to place the camera on a balcony or terrace.

This will make easier to access and protect the photographic equipment.

“To protect our camera from the weather we will need to use whatever we happen to have at home”

Camera protection

We should not leave a camera in the outside as it will suffer from bad weather.

To take images only on clear nights we could make a mount where to place the camera during those nights and remove it at dawn but for the purpose of this study we would like to get data in any situation so the manufacture of a protective casing will be necessary in most cases.

You can see the solutions that collaborators have developed on the website:

https://guaix.ucm.es/azoteaproject

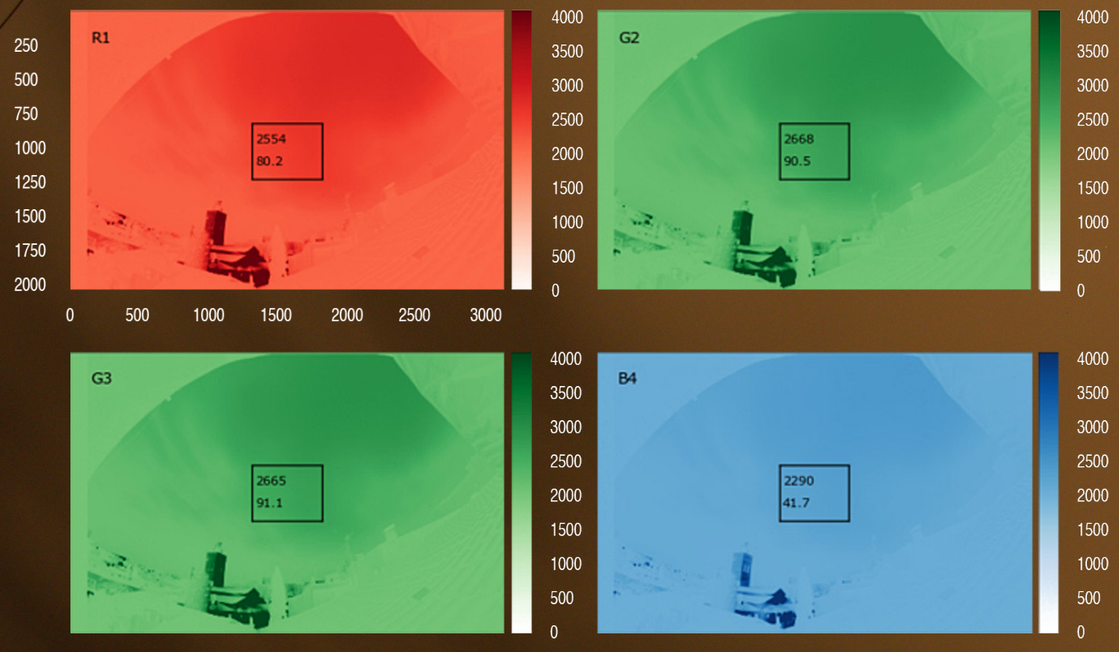
An easy way of making one is using PVC material like the one that is used for plumbing.

A piece of pipe or a big enough connecting sleeve with a perforated cover and a methacrylate window attached would do the trick.

As we are experiencing a lockdown, we will need to use anything available, that could be a waterproof suitcase, a plastic container box or any other household item.

A wooden box with a glass on top secured with silicone could work as well.

“During the processing of the images, the information will be broken down into channels R, G and B”



3- SCIENTIFIC ANALYSIS

3.1 PROCESSING OF IMAGES

An automatic execution of instructions (‘pipeline processing’) is being developed so it will automatically:

- Read the image files.
- Get the EXIF data from the metadata header
- Decompose the images on its channels R, G and B.
- Measure the flow (counts/s) of the central area of the R,G and B images.
- Measure the BIAS value (counts/s) from the DARK images.
- Convert this value into instrumental quantities of sky brightness (mag/arcsec^2).
- Write the resulting files.

“we will measure the flow of the central area and we will represent the evolution of the sky brightness and its color”

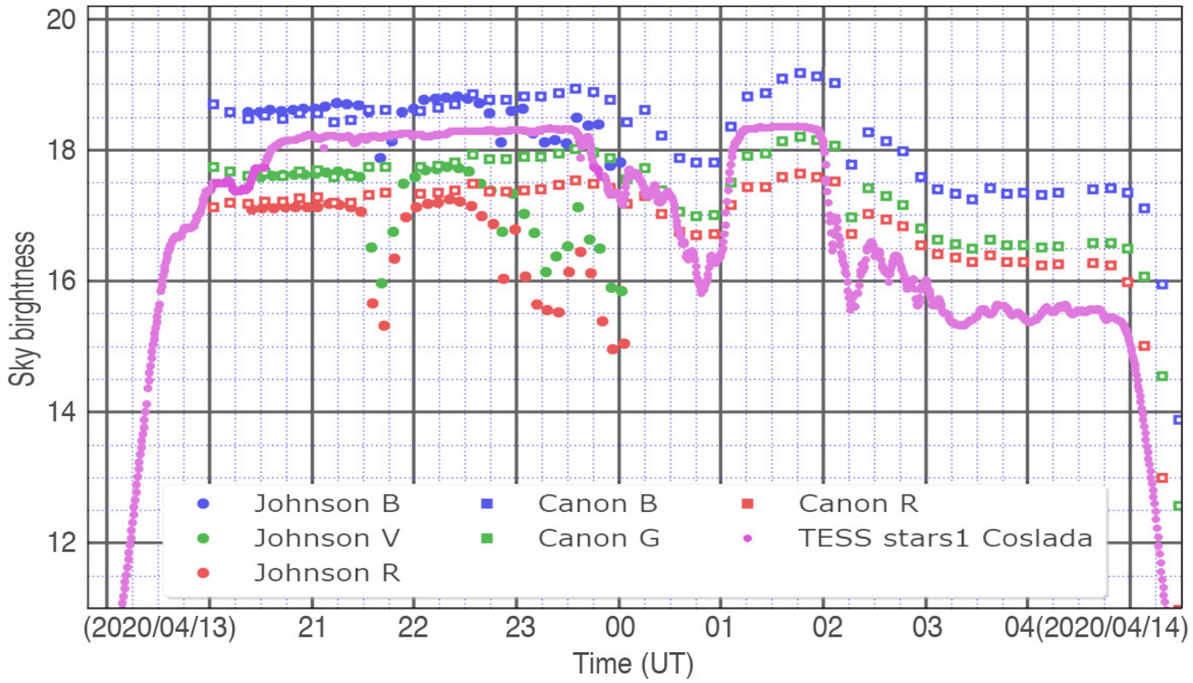
3.2 GRAPHIC REPRESENTATIONS

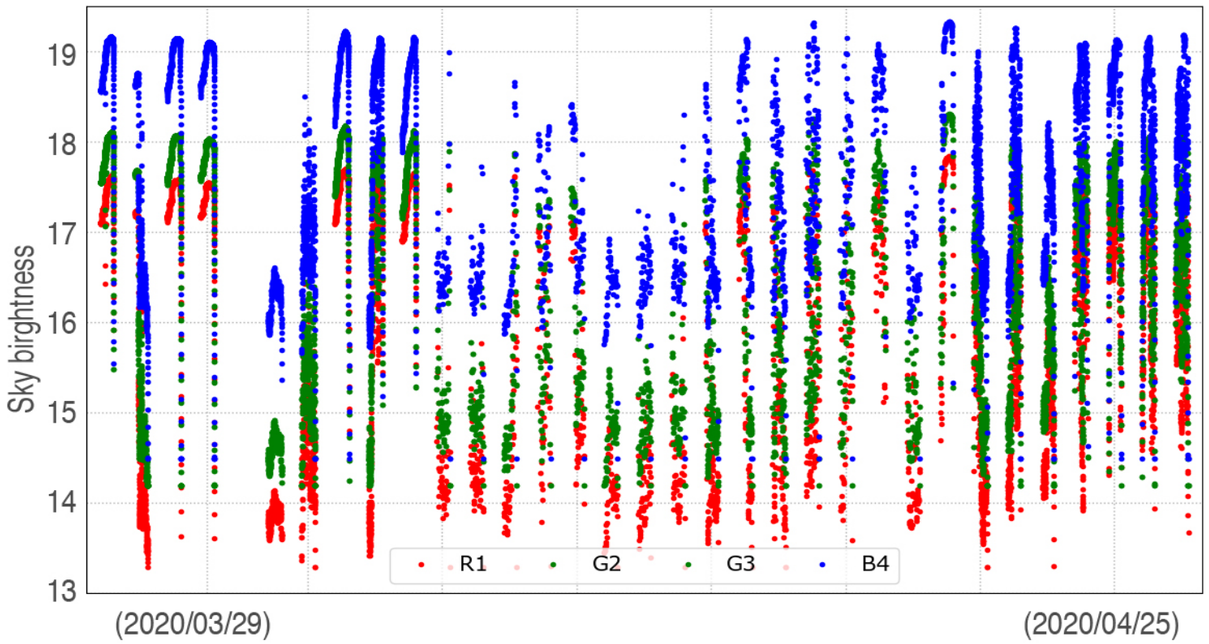
Sky brightness measurements of this project can be compared with those of professional instruments for the same night. This graph shows RGB measurements taken by Jaime Izquierdo with a SLR camera at Madrid city, measurements of the Johnson B, V, R photometric bands obtained by the AstMON-UCM instrument installed on the roof of the Facultad de Físicas UCM and measurements taken with TESS-W stars1 photometer from the city of Coslada.

The data from the RGB channels of the camera adjust well to the astronomical photometry measurements (once scaled). This indicates that when we calibrate the cameras we will be able to use them to measure the evolution of the brightness and color of the night sky. The stars1 photometer data shows slightly different values as it is not located at the same place.

3.3 STATISTICAL ANALYSIS

The scientific results of the project will be obtained after studying the results of the statistical analysis of the data.





4 - TO DO LIST

- Launch of the project.
- Volunteers recruitment.
- Creation of a WEB page.
- (guaix.ucm.es/azoteaproject)
- Translation of the webpage into English.
- Preparation of the software.
- Image storage platform.
- Layout of the manual.

5 - FREQUENTLY ASKED QUESTIONS

Can I use my color CCD or CMOS camera that also has the Bayer matrix instead of a camera?

Of course.

Do I need a tripod?

Yes, to participate in this project you will need a tripod or a system or mount that guarantees the camera aim and frame. In an ideal situation the camera should be fixed the whole project duration.

How precise should the be the frame? Could I set the camera every night?

If you do it carefully, it can work as super precise aim is not crucial, (although it is recommended).

I have no power supply to the camera, only its battery. Can I participate?

Yes, you can although your battery will eventually run out throughout the night. If this is your case we recommend to reduce the photo frequency to one every 10-12. It is better to start at the sunset even if only the first part of the night is recorded since at that moment ornamental lighting is still on and there is more human activity.

If I cover the camera with a glass or set it behind the window, is the photometry not spoiled?

Photometric calibration will be different for each camera and we will use the stars that appear in the photos to make it. A glass reduces the amount of light that reaches the camera but calibration uses images behind that very same glass. In the case of windows, a lighting shield might be so the camera does not receive reflections of light from the interior of the house.

IMAGES CREDITS

Cover: Fancycrave1 (Pixabay)
Pg. 4: Jose Ignacio Pompe (Unsplash)
Pg. 5: Eric Ward (Unsplash)
Pg. 6: Josh Hild (Unsplash)
Pg. 9: Alexander London (Unsplash)
Pg. 10/11: Jaime Izquierdo (UCM)
Pg. 12: Antonio García (Astroguada)
Pg. 12: Jaime Zamorano (UCM)

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