

Evolution of Night Sky Brightness and Color in Madrid

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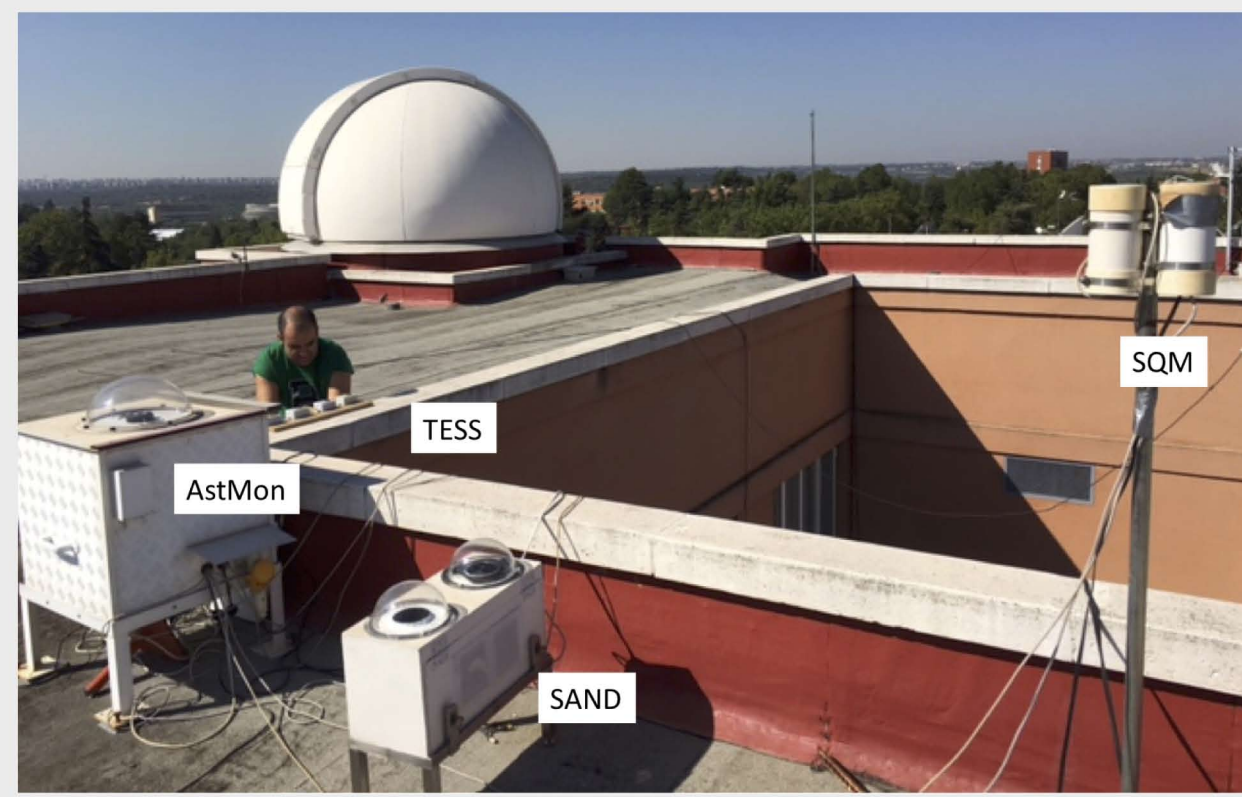


Introduction

The street lighting of Madrid and the surrounding urban areas has been changing in recent years from mainly High-Pressure Sodium lamps (HPS) to Light-Emitting Diode (LED) technology.

We are assessing the impact of this upgrade on light pollution by measuring the sky brightness using several instruments located in the astronomical observatory of the Universidad Complutense de Madrid, located in Ciudad Universitaria which is within the metropolitan area of Madrid.

Instrumentation



Instrumentation at the UCM observatory on top of the Physics building.

Data available

- SQM-LE and SQM-LU (since 2011).
- STARS4ALL TESS-W (since 2016).
- ASTMON All-Sky Camera for Johnson's B, V, and R astronomical bands (since 2010)
- SAND spectrometer (since 2013).

General objective

- To statistically study the brightness and long-term color evolution of the night-sky in Madrid.

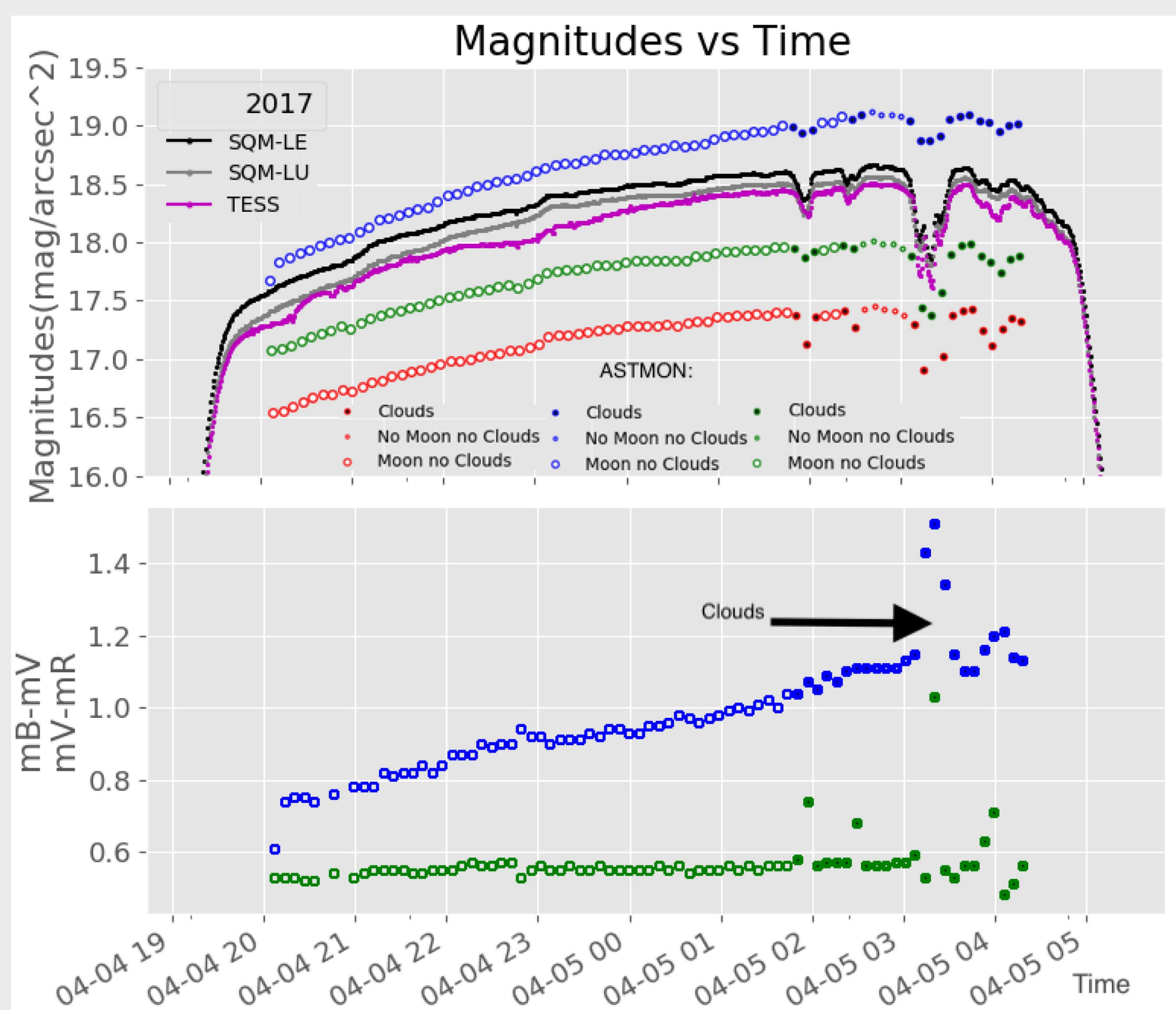
Specific objectives

- To verify changes in the night sky brightness in B, V, and R Johnson photometric bands.
- To develop a methodology for quantifying changes in the night sky brightness of Madrid.

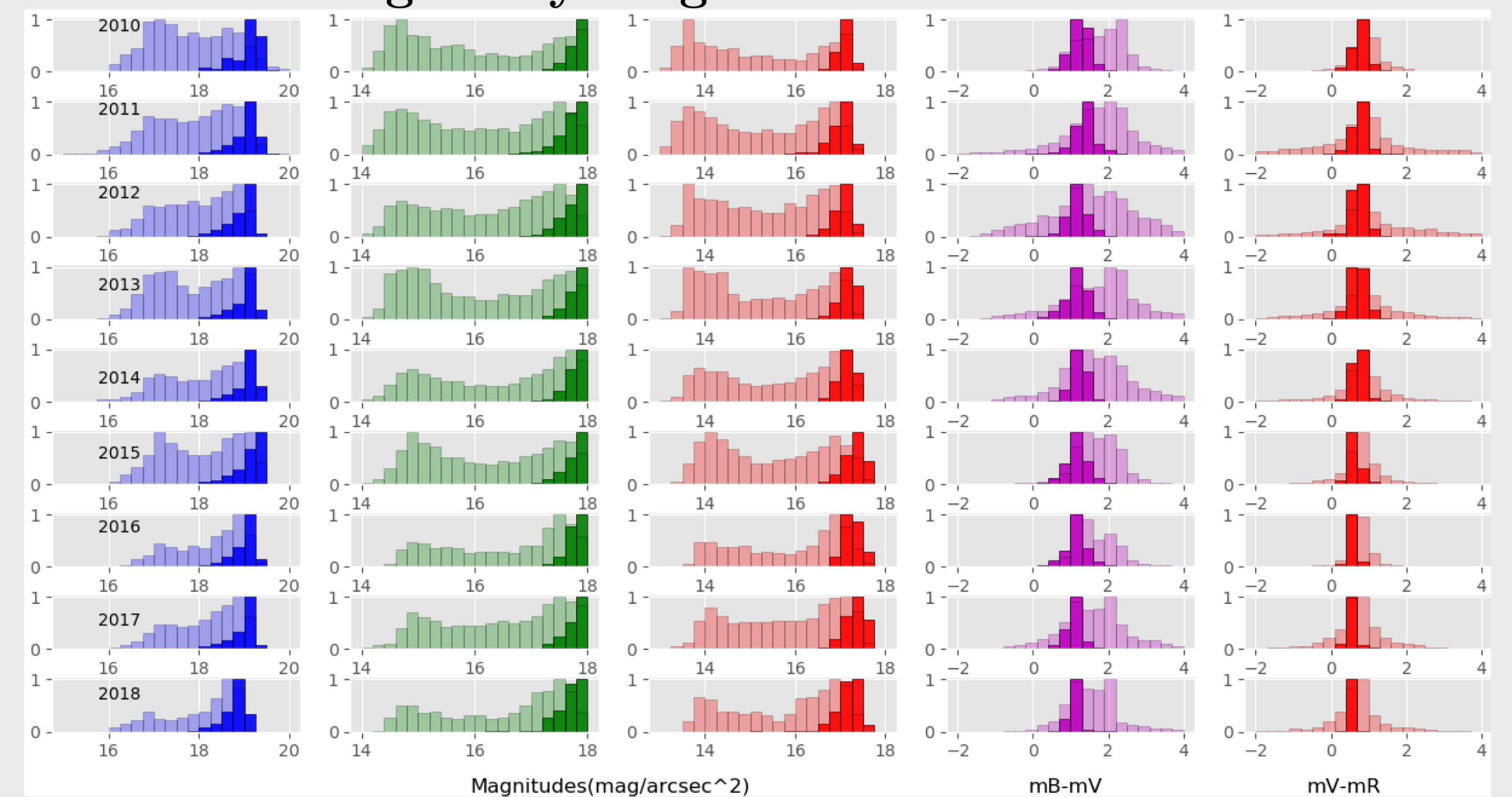
Filtering Process

A custom program was developed to classify the data:

- Detecting data with moon over the horizon automatically.
- Specifying events due to specific anthropogenic activities.
- Using photometers to verify local night sky brightness variability.
- Color indexes for detecting variability when photometers data were not available
- Manual expertise decision making process to identify NSB jagged values.



Madrid Night Sky Brightness and Color Evolution

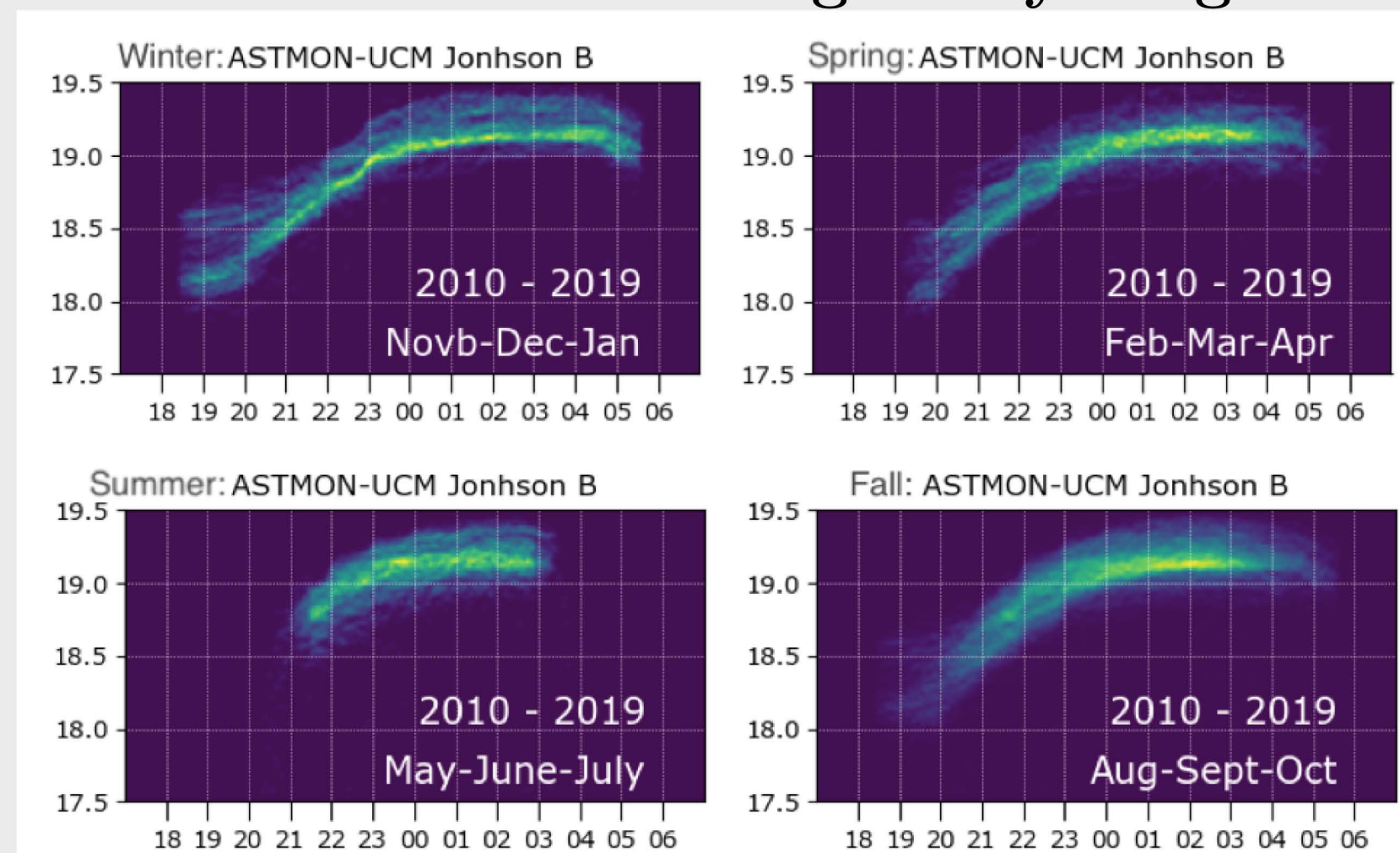


Night Sky Brightness and Color Statistics from 2010 to 2018. From left to right of B, V, R, B-V, and V - R respectively. We present the histograms with darker bars for filtered data (no clouds and no moon over the horizon), and lighter bars for unfiltered data (with moon and clouds).

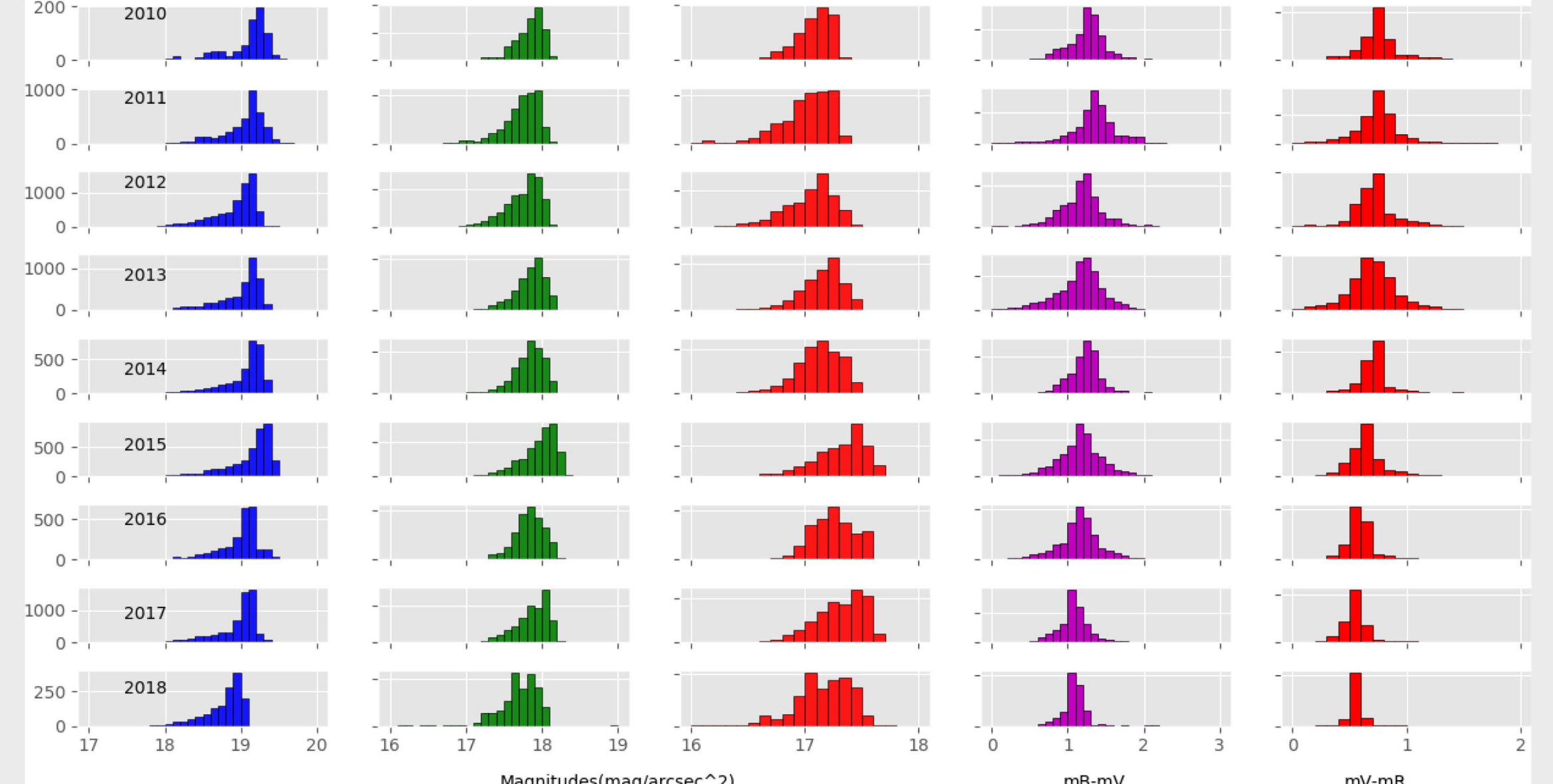
Kernel Density Estimation (KDE) with the y-axis in $\text{mag}/\text{arcsec}^2$ and the x-axis representing the time in UTC. This analysis evidence two aspect to consider:

- The night sky brightness characterization by seasons of the year.
- A comprehensive time series is mandatory to understand the NSB fully.

Seasonal Evolution of Night Sky Brightness



Madrid NSB and Color Evolution: No Moon No Clouds

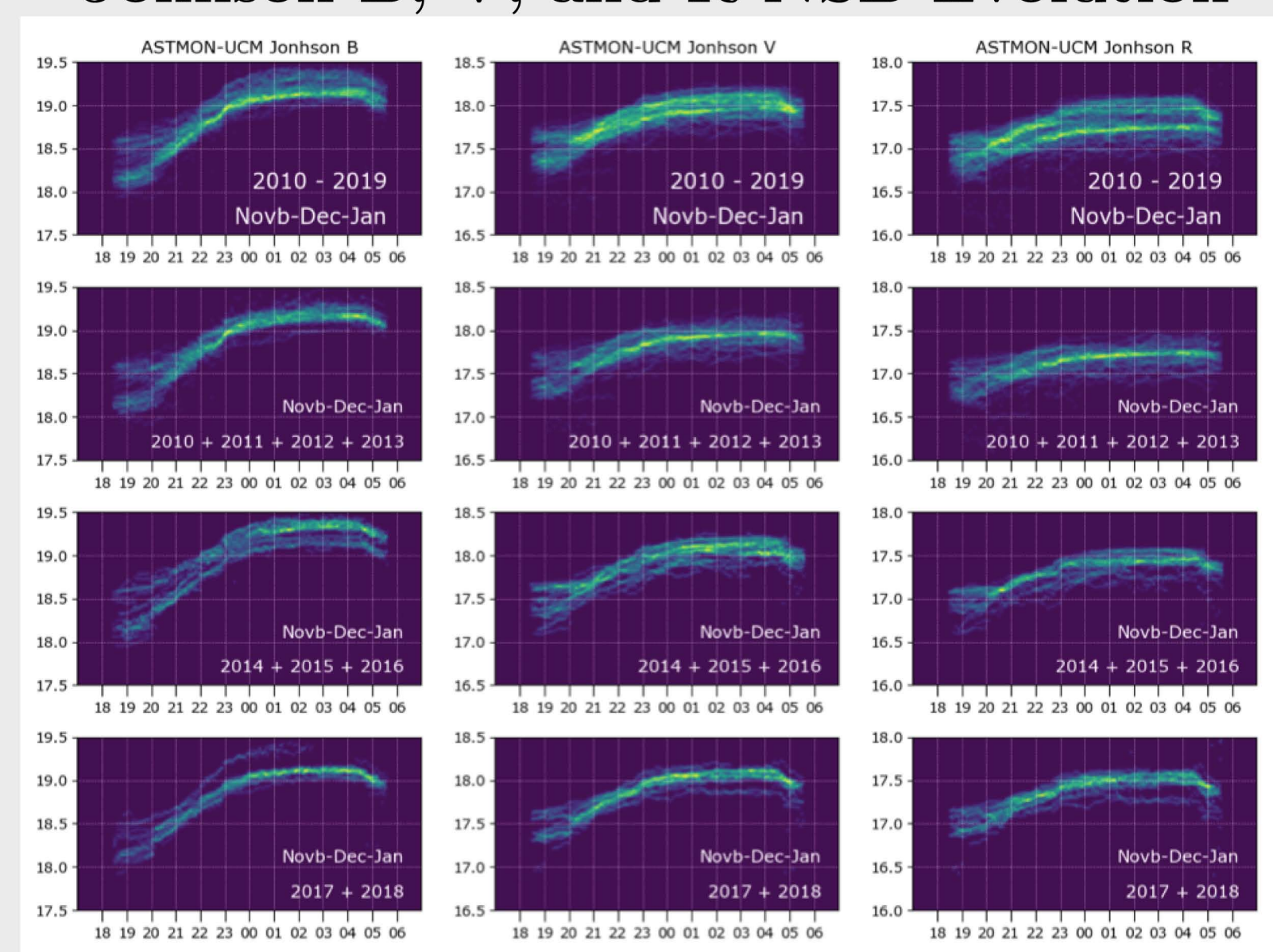


Night Sky Brightness and Color Statistics for Filtered Data. From left to right of B, V, R, B-V, and V - R respectively. Measurements in 2015 showed a particular shift associated with changes in street lighting. This demonstrates the capability of ASTMON to distinguish differences in night sky brightness and its associated colors.

A comprehensive time series allows us to:

- Detect changes from High-Pressure Sodium (HPS) to Light-emitting Diode(LED) street lighting.
- Distinguish changes to characterize night sky brightness according to the winter seasonal curve.
- Depict night sky brightness variability by seasons along with events before and after midnight.

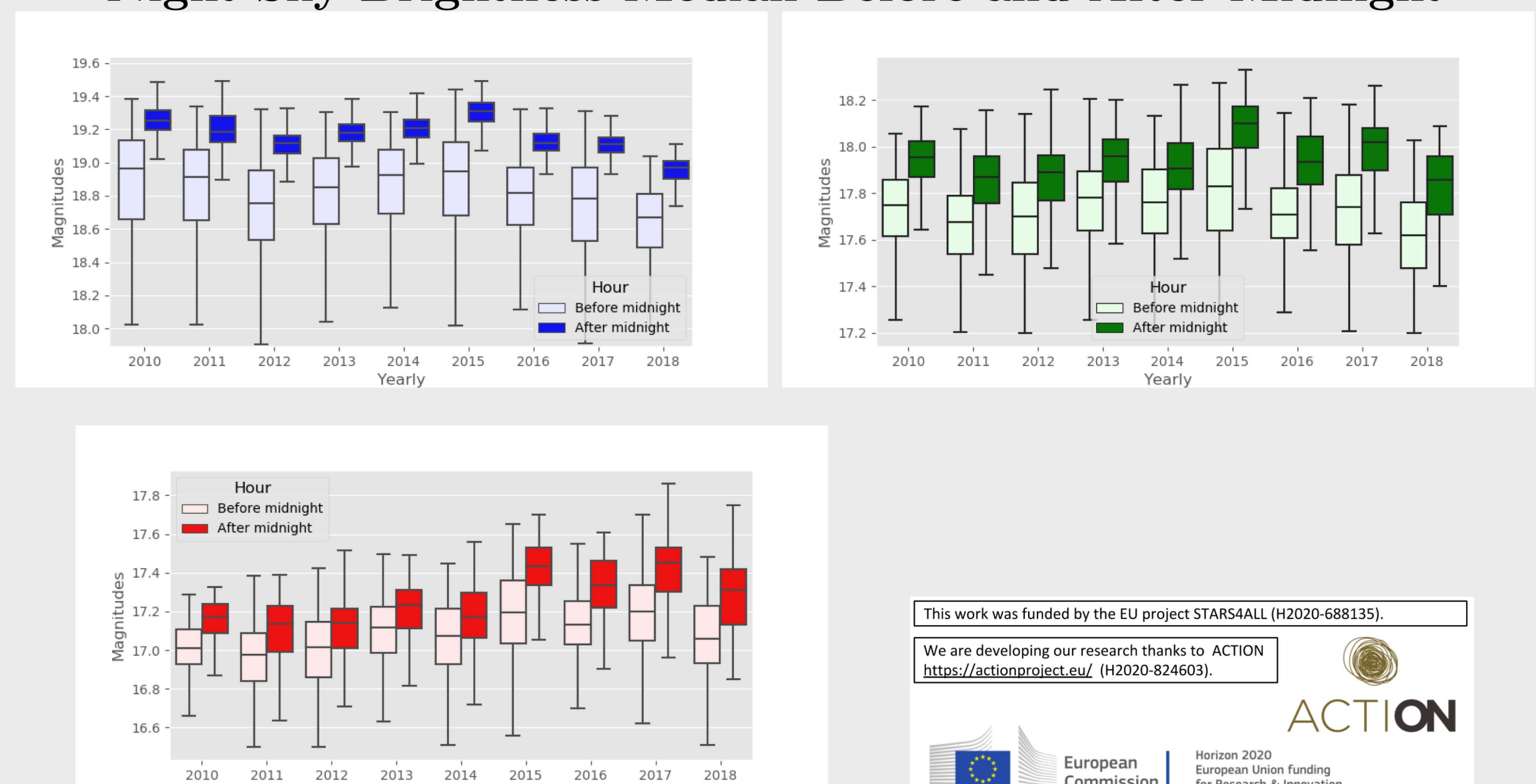
Johnson B, V, and R NSB Evolution



Summary

- We are detecting and measuring the retrofitting of the streetlight system in Madrid with the NSB and color indexes obtained by ASTMON (B, V, and R Johnson photometric bands).
- Night sky brightness filtered data (no moon, no clouds) shows a change from reddish to bluish with a distinctive transition in 2015.
- We are working to determine whether we arrive at the same results using filtered data and raw data in order to speed up similar studies in other locations.

Night Sky Brightness Median Before and After Midnight



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