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# Science from PVOL2 (The Planetary Virtual Observatory and Laboratory): A database of amateur observations of Solar system planets integrated in VESPA

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## Abstract

The Planetary Virtual Observatory and Laboratory (PVOL2) stores and serves publicly through its web site a large database of amateur observations of solar system planets [1, 2]. The PVOL service started in 2003 and was completely rebuilt in 2016 into a new service PVOL2 in the framework of the Virtual European Solar and Planetary Access (VESPA) services developed through the Europlanet 2020 Research Infrastructure. After 15 years of use of the PVOL service we review its use in professional studies of solar system [3], we strengthen the new capabilities in the modern PVOL2 service, and we show current research projects based on the analysis of the amateur data. PVOL2 contains amateur observations from Mercury to Neptune including the Moon and the Galilean satellites and is integrated in the VESPA portal (Virtual European Space and Planetary Access) as one general service in VESPA. PVOL2 can be consulted in http://pvol2.ehu.eus or through the VESPA portal in: http://vespa.obspm.fr/

## 1. Introduction

The original PVOL website and the current PVOL2 are a database of amateur images of Solar System planets contributed by hundredths of observers. The PVOL2 website offers different searching tools that allow retrieving observations from specific objects, a particular range of dates, a given observer, particular locations in a planet, movies, map projections and many others searching options. Data can be uploaded by amateur astronomers with a personal username and password or can be submitted by e-mail to pvol@ehu.eus. Most users of PVOL2 are amateur astronomers and the webpage includes relevant news and alerts, short reports and even links to other major image sources such as ALPO-Japan or the Junocam images of Jupiter. For professional astronomers PVOL2 can be also consulted using other platforms like TOPCAT. The main important characteristic of PVOL2 is that it is now fully integrated in the VESPA query portal which offers different services to the professional community. VESPA is building a Virtual Observatory for Planetary Science, connecting all sorts of data and providing modern query and inter-comparison tools. For instance, queries on VESPA of spectra of a particular planet in a given time range would also show images of that planet in PVOL2 obtained in the time range of the spectra.

## 2. Updated data in PVOL2

PVOL2 contains amateur observations of Jupiter since the year 2000 and has been expanding ever since then. It now contains more than 35,000 image registries contributed by about 400 observers. Most of the images are Jupiter observations (71%) followed by Saturn observations (23%) with an increasing number of Mars and Venus images since 2016. Uranus and Neptune observations (about 450 images for each planet) are also present in PVOL and, although they constitute a minor volume of the data, they are considered of high value for scientific research of these planets [4]. Observations of Mercury, the Galilean satellites and the Moon are also available on the site and can be used for teaching projects. Images uploaded since 2017 can be “tagged” so that it becomes easy to find images containing a particular detail like a particular crater on the Moon. Images acquired by amateur astronomers sometimes operating telescopes of the 1-m class are also available in PVOL2.

## 3. Science

Planetary observations currently obtained by an increasing number of amateur astronomers reach a spatial resolution that is rarely obtained from professional telescopes. The combination of observations from many different observers allows time-resolved studies of the atmosphere dynamics of different planets that can be compared with snapshots at high-resolution obtained by large telescopes with Adaptive Optics, HST observations of the Giant planets, or spacecraft observations of Mars dust storms and cloud systems. While historically most research works using PVOL data have concentrated in the study of Jupiter atmosphere dynamics, the increased quality of the observations improves research opportunities in Saturn [5], Uranus [6] and Neptune [4], Venus [7] and Mars [8] science. The outcome of professional and amateur collaborations is very large and the PVOL website lists about 30 scientific publications with amateur data available in PVOL2 including publications in major scientific journals (Nature or Science). We aim for a wider use of the data by the professional community. PVOL2 also hosts an specific page about impacts in Jupiter and their detection with software tools like DeTeCt3.1 [9-10] where an active collaboration with many amateurs is essential.

Current "hot topics" followed by amateur astronomers contributing relevant data in PVOL are the wide range of atmospheric activity in Jupiter in comparison with data from the Juno mission, the bright polar and equatorial features in Saturn [5], and the follow-up of atmospheric activity in Neptune. At the time of this writing amateur astronomers are also making a survey of Martian clouds and small dust storms with the expectancy based on Martian seasonal phenomena to observe a Large Dust Storm at high-resolution.

The current version of PVOL is indented to boost new professional and amateur collaborations in these and other related fields.

## Acknowledgements

We are very grateful to the ensemble of amateur astronomers that kindly provide their data to databases like PVOL and ALPO-Japan. This work has been developed in the framework of the Europlanet 2020 RI. Europlanet 2020 RI has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654208. This work has also been supported by the Spanish MINECO project AYA2015-65041-P (MINECO/FEDER, UE) and Grupos Gobierno Vasco IT-765-13.

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# Use of CMOS cameras in exoplanet transit photometry

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## Abstract

For a few years modern CMOS cameras revolutionized amateur astrophotography. Their use can be seen also in some scientific aspects, parallel with widely used CCD cameras. I present my photometric results of 21 detected exoplanet transits obtained so far from SOTES observatory, using cooled camera with 1/1.8" IMX178 sensor developed by ZWO[1]. Attempts on targets with different magnitudes, depths and durations allowed to determine limits for low budget photometric setup, that can be also accessed for astronomy amateurs. CMOS efficiency allows a short exposure recording, which is necessary in high cadence photometry.

## 1. Introduction

Observatories around the world (also the amateurs) are mostly equipped with CCD cameras. Recently, CMOS sensors began to play important role especially in planetary imaging. Low noise sensors with high quantum efficiency work great deep sky astrophotography, especially after adding of cooling and reducing the ampglow.

Photometric accuracy with a specified telescope is mostly determined by scintillation and noise level. By observing known targets with different magnitudes, we can predict if an exoplanet transit in front of star with similar brightness could be detected. Other aspects, such as background light level (light pollution, Moon), elevation or duration must be also taken into account.

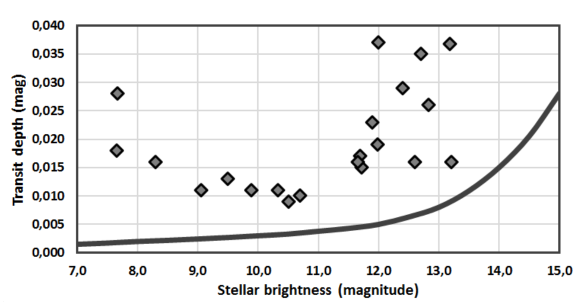
All tests were performed for a preparation of TESS ground-based follow-up observations, to show amateur role in detection of exoplanet candidates. The start of the program is planned for the beginning of 2020, after first expected release of possible targets in northern hemisphere.

Frames were acquired using *SharpCap v3.0* software[2]. To perform photometry, *C-Munipack*[3] and *AstroImageJ v3.2.0*[4] were used. For lucky imaging analysis, *MS Excel* spreadsheet program is necessary.

## 2. Results

IMX178 is a small 1/1.8" sensor and was chosen due to its 14-bit output, low ampglow and small pixel size giving a large 3096x2080 resolution. Other sensors in ZWO's offer (IMX290 and IMX174) were not chosen mostly due to higher ampglow, which has a large impact in photometry, where milimagnitude accuracy is needed. Also, little pixel size (2.4μm) with Canon FD 300mm f/2.8 L lens (aperture 107mm) give a scale of 1.65"/px. It is good enough to resolve blended eclipsing binaries primarily found as possible exoplanet candidates by observatories such as KELT[5], which I also collaborate with, Kepler or upcoming TESS.

The determinant if a specified dip can be seen, is the photometric accuracy. Based on 3-minute (time precision) and additional 15-minute bins (depth check) of the star's brightness flux, we can measure how small decrease of brightness could be detected. Mostly, results are consistent from observations made in the previous nights.



Ground-based photometry observations by amateurs are less accurate than the space-based TESS ones. However, amateurs can still play an important role on detecting false positives, where a fainter nearby star (unresolved by TESS) show eclipsing binary behavior (NEB), or redefine the ephemeris[6]. The main task is to find the variability source. If it's the brightest star, it could be tested later with radial velocity observations or high resolution imaging. To make it possible, a decrease of brightness in a predicted moment must be observed, also proving that other blended (on TESS frames) stars are stable. This is a very important test for CMOS sensors, if it's performance allow to rule out targets as NEBs.

If true variable companion is far enough, the drop would be easier to detect than from the main star itself. Sessions of targets having expected depth below the limit are also useful, as no detection of neighbour stars variability is an indication that the brightest object contains a small transiting object. If the predicted depth is large enough, a photometric filter can be applied. This is also preferable in observing TOI (TESS Objects of Interest) candidates. A difference of depth in other bands may suggest that the target is an eclipsing binary. The highest S/N was seen in R band, followed by V filter, afterwards.

All observations resulted in discovery of more than new 50 variable stars (mostly eclipsing binaries), which have been submitted to Variable Star Index (VSX) database[7]. Moreover, results of K2-232 b candidate detection in September 2017 were also presented in discovery paper by Yu et al. 2018[8].

## 3. Use of short exposure frames

The CMOS sensors tend to have low noise levels, but atmosphere has larger impact on photometric accuracy. Thanks to the fast download time, frames can be acquired up to few per second. If a target is bright enough and is located close enough to a proper reference star, one can crop the image for even higher FPS rate. This is opposite to CCD, where we need to wait a few seconds to get an image. This advantage can be used in high cadence photometry.

## 4. Summary and Conclusions

CMOS sensors, as well as CCDs, can be also used in photometry. Thanks to their price, amateurs can now explore exoplanet transits at lower cost. The precision is also comparable on both type of sensors, so low budget cameras can be used too. The next goal is to upgrade SOTES observatory with three small-sized Newtonian telescopes (0.20m f/4.0) and cameras based on CMOS IMX178 sensor. Each one would allow to observe 3 different targets at the same time (for better accuracy), or a single star with multiple photometric filters, which give many possibilities around KELT and TESS candidates.

## 5. Acknowledgements

I would like to thank Tomasz Ściężor for making comments.

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[7] AAVSO Variable Star Index database website, https://www.aavso.org/vsx/index.php

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# Changes on Mars 2003 - 2018

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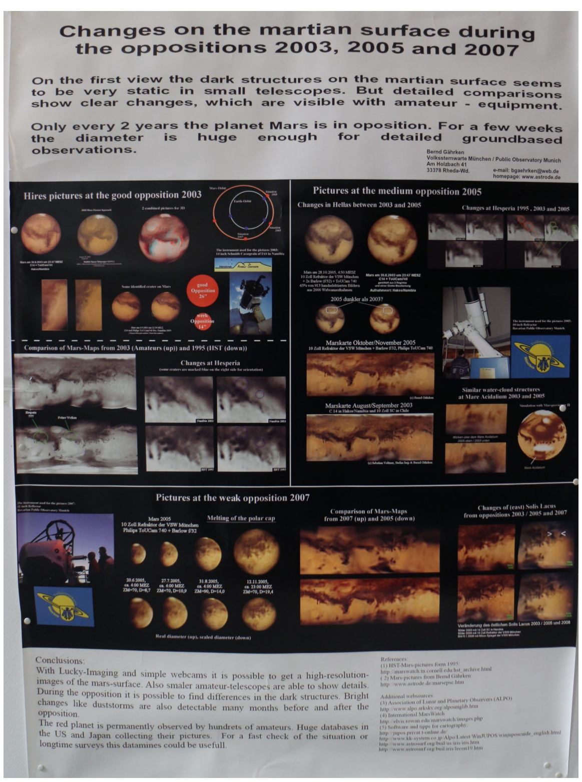
## Abstract

Changes on Mars are visible with amateur telescopes. The changes are reported several times during the last 200 years.

With modern Astro-Webcams it´s possible to generate detailed groundbased pictures. Detailed comparisons show clear changes.

Some images from 2003, 2005 and 2007 will be presented and compared with new pictures.

## 1. Poster




A new poster with pictures from 2018 is planned. Here is a poster from EPSC 2008:

## 2.

[1] Gährken, Bernd: Changes on the martian surface during the oppositions 2003, 2005 and 2007.

http://cdsads.u-strasbg.fr/abs/2008epsc.conf..940G

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# Exoplanet Observations in Taurus Hill Observatory - History and Current Activities

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## Abstract

Taurus Hill Observatory (THO) [1], observatory code A95, is an amateur observatory located in Varkaus, Finland. The observatory is maintained by the local astronomical association Warkauden Kassiopeia. THO research team has observed and measured various stellar objects and phenomena. Observatory has mainly focused on exoplanet light curve measurements, observing the gamma rays burst, supernova discoveries and monitoring [2]. We also do long term monitoring projects [3].

The results and publications that pro-am based observatories, like THO, have contributed, clearly demonstrates that pro-amateurs are a significant resource for the professional astronomers now and even more in the future.

## 1. High Quality Measurements

The quality of the telescopes and CCD-cameras has significantly developed in 20 years. Today it is possible for pro-am's to make high quality measurements with the precision that is scientifically valid. In THO we can measure exoplanet transits < 10 millimagnitude precision when the limiting magnitude of the observed object is 15 magnitudes. At very good conditions it is possible to detect as low as 1 to 2 millimagnitude variations in the light curve.

## 2. Exoplanet Transit Observations in THO

THO research team has made for some years transit and light curve measurements about the exoplanets. To this date the team has measured over 60 different exoplanet light curves, some of them several times. The first THO measurements were added to AXA-database that was maintained by Bruce L. Gary and now observatory is also using EDT (Exoplanet Transit Database) maintained by Variable Star and Exoplanet of Czech Astronomical Society.

In Figure 1 below is one recent example of THO exoplanet measurements. Exoplanet HAT-P-13b was observed in THO 31.3./1.4.2018 19:50 – 00:44 (UTC). Despite the already quite light Finnish sky, the team managed the measure about 4 millimagnitude drop in transit light curve. The transit last, according to THO measurement, 196 minutes. Used telescope setting was: 16 inch Meade ACF, SBIG STT-8300M CCD camera and colour G filter.

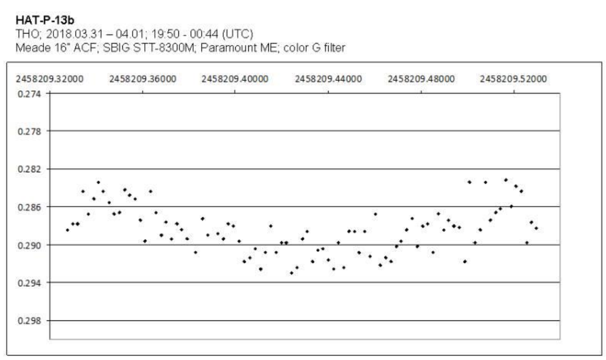


Figure 1: HAT-P-13b light curve 31.3./1.4.2018 19:50 – 00:44 (UTC).

THO site is optimal place in Finland to observe and measure transits and light curves during the winter due the lack of the light pollution (Figure 2). This gives the observatory possibility to have long measurement periods.

Figure 2: THO observatory site includes two (2) telescope buildings (two buildings on left) including overall 4 telescopes, control room (right) and large main building (not in this image).

## 3. Summary and Conclusions

Taurus Hill Observatory and other similar pro-amateur based observatories have a good record in field of astronomy and especially in the light curve measurements and photometric monitoring.

The research teams have the knowledge for making a good and high quality photometric light curve measurements. The publication records are one of the good examples from this knowledge. In the future the THO research team aims for more challenging astronomical research projects with professional astronomers and observatories.

As a conclusion it can be stated that it is possible to do high quality astronomical research with pro-amateur astronomy equipment if you just have the enthusiasm and knowledge to use your equipment in the right way.

## Acknowledgements

The Taurus Hill Observatory will acknowledge the cooperation partners, Pulkova Observatory, Finnish Meteorological Institute and all financial supporters of the observatory.

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# Characterization of Jupiter's Atmosphere by Juno and a Network of Earth-Based Observations

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## Abstract

A key part of the Juno mission from the very beginning has been the involvement and coordination of supporting Earth-based observations, both from the professional and amateur communities. These have supplemented Juno's science return and even guided spacecraft operations and planning. In parallel to these efforts, quasi-continuous observations of Jupiter by a network of amateur astronomers and their analysis of JunoCam observations in the sub-micron range have greatly aided their interpretation. An overview of these results will be presented.

## 1. Introduction

The Juno mission is coordinating an active program of Earth-based support from both professional and amateur observers and space scientists. The additional observations provided by Earth-based stations include Earth-proximal, Earth-orbiting platforms, as well as ground-based telescopes operated by professional astronomers and citizen scientists. The supporting observations (1) provide additional spatial context that expands the area covered by often narrow spatial coverage of Juno's instruments, (2) document the evolution of features that Juno only observes in a single "snapshot", and (3) cover spectral regions not in the range of Juno's set of instruments. Observations by amateur astronomers provide key contributions to the first two categories, expanding the spatial and temporal context of Juno's observations. Furthermore, work by citizen scientists has been a key to understanding details of Juno and supporting observations, particularly in the visible range.

## 2. Space-based and large ground-based observatory results

Observations of Jupiter in support of the Juno mission from the professional community cover the spectrum from the X-ray to the radio. Over sixty observing groups are involved in this observing campaign, with a coordination of the results between contributors made through emails and posting on an interactive web site that can be accessed by the investigators and is mirrored on a web site available to the public: https://www.missionjuno.swri.edu/planned-observations.

Among the earliest of these were observation of Jovian auroral phenomena at X-ray, ultraviolet and infrared wavelengths and measurements of Jovian synchrotron radiation from the Earth simultaneously with the measurement of properties of the upstream solar wind. Other observations of significance to the magnetosphere measured the mass loading from Io by tracking its observed volcanic activity and the opacity of its torus. Observations of Jupiter's neutral atmosphere included observations of reflected sunlight from the near-ultraviolet through the near-infrared and thermal emission from 5 microns through the radio region. The point of these latter measurements is to relate properties of the deep atmosphere that are the focus of Juno's mission to the state of the "weather layer" at much higher atmospheric levels. We will summarize the results of measurements during the approach phase, as well as observations made by Juno and the supporting campaign during Juno's perijoves 1 through 14.

## 3. Small ground-based observatory results

Besides a global network of professional astronomers, the Juno mission also benefits from the enlistment of a network of dedicated amateur astronomers, "citizen scientists" who provide a quasi-continuous picture of the evolution of features observed by Juno's instruments. This complements the broad spectral network provided by professional astronomers at a much lower observational cadence. The quasi-continuous observing record is extremely important to understand the time evolution of atmospheric features that Juno observes, as well as characterizing the spatial context of features observed that have not been covered by the professional community because of observing restrictions, such as solar-avoidance requirements.

## 4. Public involvement with Juno data.

These observations are reported on the Mission Juno web site as a part of an outreach program [1]. The original goals of the outreach program involved allowing the public: to choose where to point the JunoCam visible camera and to process the data we get. To achieve this, four steps were envisioned: planning, discussing, voting and processing. The planning step is the one that involves observing Jupiter to characterize the state of Jupiter's cloud structure and dynamics. The images uploaded are then subject to discussion - commenting on the background and merits of cloud features as objects to be imaged by JunoCam. Voting involves selection of features of highest priority to be observed. JunoCam images are made available on our web site within 2-3 days of their reception from the spacecraft. The public is then free to download the images, processing them in various ways, and uploading them. The processed images have ranged from fanciful to seriously quantitative. The results of all these steps are posted on the JunoCam sites that is linked from the general Mission Juno site, although voting is no longer a part of the process: https://www.missionjuno.swri.edu/junocam/. Because of the restricted geometry of the orbits of the mission through early 2021 – covering up to perijove 33 (Table 1), the selection of regions to observe is extremely limited. As a result, the voting process has been suspended. However, it has been replaced.

## 5. Analysis: the "Think Tank"

A new addition to the JunoCam page has been activated, which involves the quantitative analysis of JunoCam data, with the title "Think Tank". There, threads of very early to very mature areas of JunoCam results are shown, such as "Mesoscale Waves" and "Hazes", as well as the results of specific orbits. In this way, the way in which scientific research proceeds is made available to the public. Examples will be discussed.

Table 1. Properties of Juno mission perijoves through perijove 33 (PJ33) of the continuation mission.

| PJ | Date | Solar Elong. | | PJ | Date | Solar Elong. |
|---|---|---|---|---|---|---|
| 1 | 2016/8/27 | 23ºE | | 18 | 2019/2/12 | 63ºW |
| 2 | 2016/10/19 | 17ºW | | 19 | 2019/4/6 | 112ºW |
| 3 | 2016/12/11 | 61ºW | | 20 | 2019/5/29 | 166ºW |
| 4 | 2017/2/2 | 110ºW | | 21 | 2019/7/21 | 137ºE |
| 5 | 2017/3/27 | 167ºW | | 22 | 2019/9/12 | 88ºE |
| 6 | 2017/5/19 | 136ºE | | 23 | 2019/11/3 | 43ºE |
| 7 | 2017/7/11 | 86ºE | | 24 | 2019/12/26 | 1ºW |
| 8 | 2017/9/1 | 43ºE | | 25 | 2020/2/17 | 41ºW |
| 9 | 2017/10/24 | 2ºE | | 26 | 2020/4/10 | 85ºW |
| 10 | 2017/12/16 | 40ºW | | 27 | 2020/6/2 | 135ºW |
| 11 | 2018/2/7 | 86ºW | | 28 | 2020/7/26 | 159ºW |
| 12 | 2018/4/1 | 139ºW | | 29 | 2020/9/16 | 113ºE |
| 13 | 2018/5/24 | 164ºE | | 30 | 2020/11/8 | 66ºE |
| 14 | 2018/7/16 | 139ºE | | 31 | 2020/12/30 | 25ºE |
| 15 | 2018/9/7 | 64ºE | | 32 | 2021/2/21 | 18ºW |
| 16 | 2018/10/29 | 22ºE | | 33 | 2021/4/15 | 105ºW |
| 17 | 2018/12/21 | 20ºW | | | | |


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# First light of the affordable adaptive optic system “CIAO” at Pic du Midi Observatory

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## Abstract

The Pic du Midi observatory in the French Pyrénées mountains is known for the quality of its planetary observations[4]. The results obtained have a renowned scientific value[1][3]. Imaging techniques are constantly evolving and teams at Pic du Midi are always looking for new technologies. The most recent step is the development of an adaptive optics system named CIAO. It is a compact and affordable system of adaptive optics developed in a very fruitful collaboration between Imagine Optic, Paris Observatory, and S2P (the planetary team at Pic du Midi Observatory). The device could interest many observatories equipped with telescopes between 0.5 and 2m in diameter. Introduced for the first time at EPSC 2017[2], CIAO has been tested on the sky since then, and we present the results.

## 1. Introduction

The CIAO system for "Compact Innovative.Adaptive Optics" is an adaptive optics system incorporating standard components available on the market. It incorporates a deformable mirror, and a wavefront sensor based on a microlenses array (a Shack-Hartmann). It can be put up directly on a standard telescope eyepiece holder. A control software uses the images of the wavefront sensor to control the deformable mirror. The static aberrations of the telescope can then be removed, but also the aberrations caused by the atmospheric disturbances above the telescope. The imaging camera is in a secondary imaging plane and benefits of the corrections made by the deformable mirror. The quality of acquired images therefore increases considerably.

## 2. CIAO tested on the sky

At the end of October 2017, we made our first measurement campaign at the Pic du Midi on the 1m diameter telescope open at f / 17.
The first targets observed were stars. The system was in a very classical configuration of adaptive optics because the source is punctual. Very good results were obtained among others on the star Fomalhaut (magnitude 1.17), when it was at 17 ° of elevation (see figure 1). The diffraction limit of the telescope was obtained under seeing conditions of the order of 0.7 arcsec. The loop was then working at around 400Hz. A narrow filter centred at 890nm made it possible to get rid of atmospheric refraction.
Under equivalent conditions of seeing, the Mars planet was targeted (see figure 2). The planet was only 4 arcseconds in diameter at this date. One series was acquired in a closed-loop configuration and another in open-loop configuration with the deformable mirror set to plane. Traditional and identical processing of sorts, registrations, enhancement of contrasts were applied on each of the two sets of images to compare them. The improvement of the image quality is remarkable, even better than expected. We were pretty confident in the ability of the device to compensate the optical defaults of the telescope itself, but it’s also very efficient to compensate the blurring effect due to air turbulence.

## 3. Figures

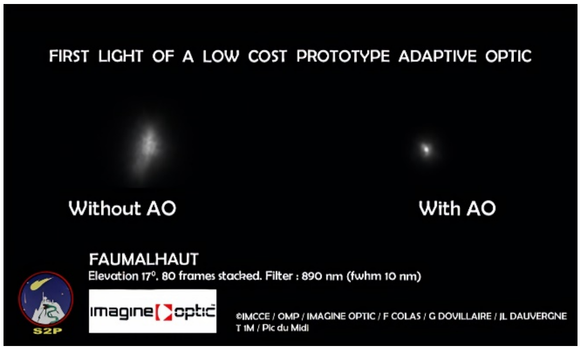


Figure 1: CIAO results on Faumalhaut observation

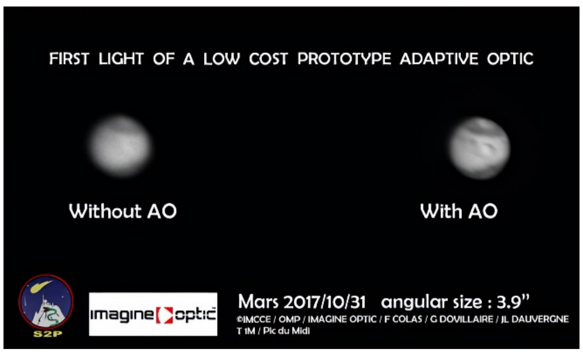


Figure 2: CIAO results on Mars observation

## 4. Summary and Conclusions

We have shown that an approach based on the use of shelf components can build a high performance adaptive optics system. The images obtained from the planet Mars show a notable gain and allow to consider a second very promising measurement campaign when the planet will be in a more favorable position.

The CIAO prototype continues to be modified and improved to ensure its smooth operation in all sky conditions, regardless of the object observed provided it is sufficiently bright, and on most telescopes. It is in planetary imaging that we expect the most spectacular results.

## Acknowledgements

We thank the National Program of Planetology, the Scientific Council of the Observatory of Paris and the Institute of Celestial Mechanics and Calculation of Ephemeris for their financial support.

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# Jupiter's banded pattern changes in the 0.89μm band

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## Abstract

Jupiter’s atmosphere is generally organized in dark belts and bright zones the presence and intensities of which are changeable. Long-term variations in this banded pattern are not systematically measured especially in the 0.89 μm methane absorption band.

In this work we present a method of measurements from a single average image, made from the best observations (0.89μm band) in the days around every recent opposition. The latitude and longitude measures of the edges of belts & zones made from these images of Jupiter’s will be displayed. A comparison of annual images of the latest apparitions will reveal changes in the banded pattern during JUNO and prior to JUNO years.

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# Follow-up observations of transiting exoplanets: data collection and analysis

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## Abstract

The presented work is a long-term project to monitor transiting exoplanets with small and medium scale telescopes, with the aim of improving their ephemerides and help their characterization. In the case of a project on characterising exoplanets, long-term continuous monitoring of targets is necessary.
This is a process that amateur astronomers can work together with professionals and contribute by obtaining or analysing data from small ground-based telescopes. In this context, our team consists of both amateur and professional astronomers and together we have conducted a number of observations using the equipment at two observatories in Greece: the Holomon Astronomical Station and Nunki Observatory.
For data analysis and lightcurve extraction, our team has developed The Holomon Photometric Software (HOPS). We designed the software in a user friendly way to facilitate participants' use, and in parallel, to ensure high data quality and reliability in the scientific results. We will present the methodology, the tools and the first scientific results that have been produced out of this collaboration. We are open for contributions in our project either on the observation part or the data analysis. Our ultimate goal is to create a collective list of observations from transiting exoplanets to better identify their ephemerides and characteristics. At the same time, such an effort would contribute to future space missions dedicated to exoplanet research.

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# Photometric observations of asteroids – in support of the Gaia Mission

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## Abstract

Photometric observations of four asteroids are presented. They were performed simultaneously with the Gaia spacecraft, within the Gaia-GOSA programme.

## 1. Introduction

Asteroid photometry gives clues about asteroid surface physical properties and compositions since more than 100 years. The most significant progress in the last decade was driven by spacecraft observations [1]. Huge contribution is delivered by Gaia mission due to its accurate photometry, astrometry and low-resolution spectra [2]. It opens new perspectives for improvement of ground-based observations: first, observers got much more dense set of calibration stars with precision of few millimag [3], second – ground based observations can be calibrated by Gaia observations executed at the same time.

In my amateur work I focus on asteroid astrometry and photometry contributing to the Gaia-GOSA (Gaia-Groundbased Observational Service for Asteroids) programme. According to authors of the tool, "the data collected by the GOSA community will be exploited to enhance the reliability of the Gaia's Solar system science" [4].

## 2. Telescopes

### 2.1 Nerpio (Spain)

In Nerpio a remote Corrected Dall-Kirkham (PlanWave) 12.5" (f/8) telescope with Finger Lakes Instrumentation ProLine 16803 cooled camera (front-iluminated KAF-16803, diam. 52.1 mm, 9.0 µm pixel) and Astrodon L, Ha, SLOAN i', r', g' filters is used.

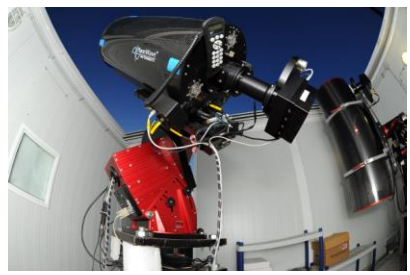

Figure 1: The Nerpio telescope.

### 2.2 Lusowko (Poland)

In Lusowko a Celestron Rowe-Ackermann-Schmidt Astrograph 11" (f/2.2) with high sensitive ZWO ASI290MM (2.9 µm pixel) and ZWO ASI1600MM (3.8 µm pixel) cooled CMOS mono cameras with the 12bit A/D converter are used. This system takes advantage of speed, sensitivity and low read-noise of the CMOS cameras to collect high frequency frames for better astrometry and photometry reduction. The site is registered in IAU as K80 "Lusowko Platanus Observatory".

## 3. Observations

In 2017 the following observations were submitted to Gaia-GOSA:

Table 1: Asteroids observed in 2017

| Object | Date | Vmag |
|---|---|---|
| 774 Armor | 22/23.05.2017 | 13.90 |
| 409 Aspasia | 23/24.05.2017 | 11.64 |
| 409 Aspasia | 24/25.05.2017 | 11.66 |
| 387 Aquitania | 05/06.06.2017 | 11.78 |
| 387 Aquitania | 06/07.06.2017 | 11.79 |
| 387 Aquitania | 07/08.06.2017 | 11.80 |
| 704 Interamnia | 23/24.07.2017 | 10.99 |

## 4. Reduction

All observations have been performed in the observatory in Nerpio. All frames have been calibrated with the bias, dark and flat field frames. In Gaia-GOSA programme full photometry reduction is performed by professional astronomers and final result comes from observations received from many observers around the world. This cooperative work produces quality lightcurve of an asteroid and hence its period.

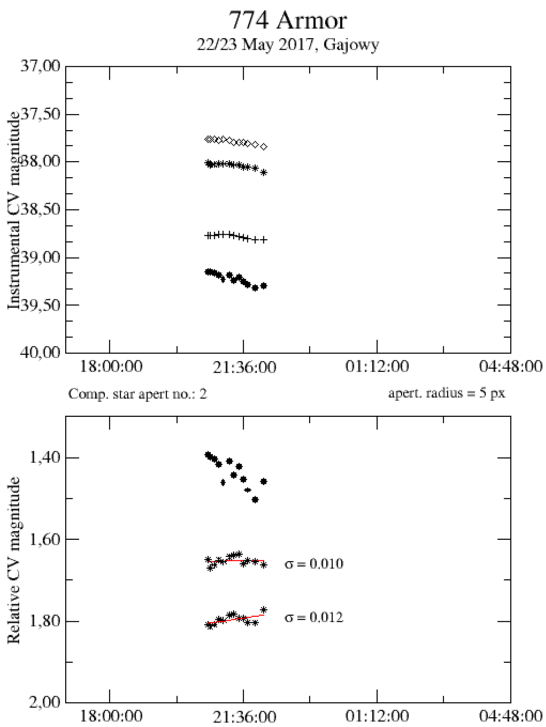


Figure 2: Lightcurve of 774 Armor observed at Nerpio and reduced by the Gaia-GOSA operators. The observations were done through the Astrodon Cousins-V filter. The upper plot shows the instrumental magnitudes which are used to trace weather conditions. The lower plot presents differential magnitudes of the asteroid and comparison stars. It is assumed that the latter should be constant so the scatter of their magnitudes is a measure of the photometric accuracy.

## 5. Summary and Conclusions

Cooperation between amateur astronomers and professionals in Gaia-GOSA program brings added values for both: professional astronomers got much more quality observations done and amateurs can improve observation skills and have significant input in science. Technological progress increases availability of quality equipment for amateurs and opens areas reserved for professionals so far. It can be assumed that cooperation between both groups will intensify in coming years with benefit to science.

## 6. Future work

The involvement in Gaia-GOSA is not my only activity in asteroids. In May 2018 I observed 1627 Ivar from Lusowko Platanus Observatory. The goal was to check if CMOS cameras are suitable to obtain a quality lightcurve and if frequent sampling would improve the quality. Approximately 28k frames have been taken on 3 successive nights covering 3 full periods. The reduction is ongoing and results will be presented during the Congress.

Additionally, in the future work I will check how short-exposure photometry can be used for fast-movers (NEOs) and fast rotators.

## Acknowledgements


I thank Dr. Tomasz Kwiatkowski for the idea of the work, advices, patience, support and motivation.

I am also grateful to Dr. Dagmara Oszkiewicz for encouraging me to publish some results of my observations.


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# Recent high-cadence photometry and outburst characteristics of Comet 29P/Schwassmann-Wachmann 1

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## Abstract

Results of high-cadence observations of Comet 29P during 2014–2018 are presented and the types of outburst characterised. Between 2014 March 03 and 2018 April 24, a total of 59 outbursts were detected and quantified in terms of outburst date and amplitude. The observed frequency corresponds to an average of >12 outbursts p.a. which is much higher than seen in previous years because of the fact that some 46% of the observed events were of less than 1.0 mag amplitude (i.e. mini-outbursts) and so would have essentially been missed by previous observers. Owing to the very high cadence, outburst timing accuracy was extremely good at 0.05d (mode), 0.27d (mean), and 0.34d (st.dev.). The brightest outburst attained $\boldsymbol{r} = 12.1$ and the greatest observed amplitude was 5.1 mag. For the first time, 29P was imaged whilst outbursting (on 2017 July 02) and the derived photometry showed the rise from quiescence to half maximum light occurred within only 0.018d. Coma morphologies indicate prograde nuclear rotation.

## 1. Introduction

29P is arguably the most enigmatic and little understood comet known, especially given the fact that it has exhibited several outbursts each and every year since its discovery in 1927, and despite it occupying a relatively distant near-circular orbit about 6 au from the Sun, where incident solar radiation is weak and somewhat uniform over time. Two papers based on observations of 29P made between 2002–2014 resulted in a more detailed understanding of the comet showing that the spin period of the nucleus is extremely long, exhibiting a Mean Solar Day of 57.7d [1, 2]. In 2014, as a follow-up to this previous work, intensive photometry of Comet 29P was begun, initially by the first two named authors but later supported by many other amateur astronomers, more especially those named here. This paper describes the results of these latest observations.

## 2. Observational Coverage

Each apparition of 29P lasts about 13 months, of which 2-3 months are out of view from Earth, being close to solar conjunction. The breakdown of the 59 outbursts detected since 2014 is as follows: 11(6) in 2014; 10(9) in 2015; 17(6) in 2016; and 20(8) in 2017. The number of outbursts of >1.0 magnitude amplitude are given in brackets, from which it can be seen that proportionately more mini-outbursts were detected in 2016 and 2017.

The chronology of outbursts has been evaluated by plotting the outburst times folded on a periodicity of 57.71d as illustrated in Figure 1. The seasonal distribution is very clearly non-random. Furthermore, 77% of **all** outbursts fall into two very distinct categories: either they are separated in time by almost exactly a **single** revolution of the nucleus (shown in green), or they occurred less than 0.2 of a revolution after a previous outburst (shown in red). These follow-up studies confirm earlier findings that several discrete cryovolcanoes are active and that one eruption can trigger one or more further events from nearby locations on the nucleus. Recent data show seasonal effects to be more pronounced than before.

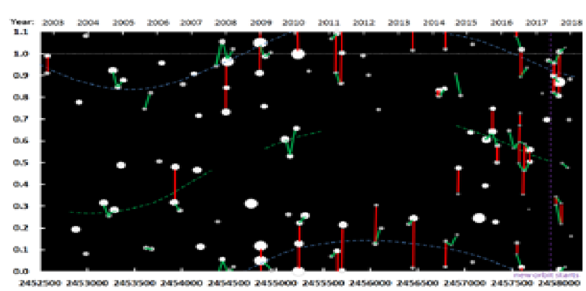


Figure 1: Seasonal plot of times of 120 outbursts (2002-2018) folded on a period of 57.71days.

## 3. Outburst: Rise to Maximum

Prior to 2017, no observer had ever measured the rising light-curve of any outburst of 29P. Miles et al. previously inferred from outburst statistics that the mean rise-time was about 1.7h [2]. Astonishingly, **two** European observers took a time-series of observations on 2017 July 02.05-02.11 that by chance happened to coincide with an outburst some 2.0 mag in amplitude. Figure 2 illustrates the first 75% of the observed rise to maximum, which was completed in about 0.05d or 1.2h confirming the earlier work. Half-light (50% maximum amplitude in magnitude terms) was reached after just 0.018d indicative of the explosive nature of these events at the nucleus. Expansion of the dust and debris cloud appears to go through two regimes: a fast early stage when gas pressure accelerates material, followed by steady-state expansion during which time the debris cloud turns optically thin and some further disintegration of material may also occur.

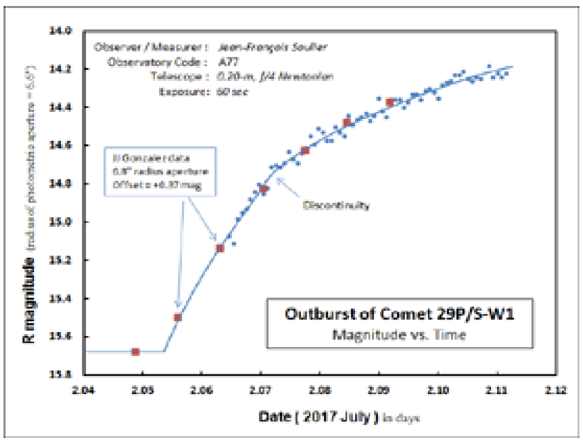


Figure 2: Plotted data from J.-F. Soulier (blue circles) and J.J. Gonzalez (red squares) of outburst light-curve of 2017 July 02.

## 4. Coma Morphology

Much more work will be needed to link the changes in the coma in the days following an outburst with active sites on the nucleus. Imaging of 29P using 1.0-m and 2.0-m telescopes has been crucial for studying the nature of the coma within about 2 days of an outburst. Given that cryo-eruptions are triggered by solar heating during local afternoon at the location of any eruption, preliminary findings indicate that rotation of the nucleus is in the prograde direction.

## 5. Conclusions

Much progress has been made in characterising the behaviour of 29P and this intensive monitoring by amateurs will continue, given that coverage of a 2nd orbital year of data began in 2017. As well as confirming seasonal dependence of outburst activity, it is hoped that new findings will support the proposed underlying mechanism in which hypervolatile CO (and potentially $N_2$), on dissolving in a hydrocarbon phase, liberates heat of solution thereby facilitating radial heat transfer in a very slowly rotating nucleus [3]. Waxy hydrocarbons would also facilitate the formation of an extensive crust able to withstand a significant internal pressure, but which could be easily weakened by long-lasting insolation. This work has yielded further evidence that repeat eruptions can arise from the same cryovolcano, the signature of which is evident from the resultant coma morphology, and which vent must therefore be easily plugged following each eruption.

## Acknowledgements

The main author wishes to thank Paul Roche of the *Faulkes Telescope Project*, and the *Las Cumbres Observatory* for scheduled access to their global network of 0.4-m, 1.0-m and 2.0-m telescopes [4]. Without their contributions it would not have been possible to attain such high outburst timing accuracy or to study the coma expansion characteristics at such high resolution.

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# The new South Tropical Disturbance and its interaction with the Great Red Spot

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## Introduction

A South Tropical Disturbance (STropD) is one of the most distinctive phenomena of Jupiter's atmosphere. It is a large dark structure spanning the South Tropical Zone (STropZ), produced by recirculation between the jets at 20ºS (retrograding, SEBs) and 26ºN (prograding, STBn). It was first defined by the great example that appeared in 1901, which first demonstrated visible recirculation between the jets in 1920, and persisted until 1939 [1]. Since then, at least 7 shorter-lived examples have been observed. The best-studied was in 1979, during the Voyager 2 flyby [2]. Since then, STropDs have arisen in 1993 and 2007; these arose when the SEB was fading, and were then destroyed by the turbulence of the subsequent SEB Revivals. A new one appeared in 2017. It must have arisen in a different manner from the 1979 example*, and is the first well-observed one since the 1920s to be passing the Great Red Spot (GRS). We therefore have a unique opportunity to study its dynamics and its interaction with the GRS, from hi-res amateur ground-based images and from JunoCam images.

*The creation of a new STropD was observed by Voyager 2, but it occurred in a different way from the present one, by interactions of large anticyclonic vortices retrograding on the SEBs jet [2]. There are no such vortices at present.

## Observations

The new STropD was discovered by JunoCam, at Juno's perijove 9 (PJ9) on 2017 Oct. 24 during geocentric solar conjunction. Juno's outbound images, projected and merged to make a cylindrical map, revealed the unmistakeable form of a STropD. Measurements of ground-based images in preceding months by the JUPOS team, show its probable origin. It was initiated in early August when dark streaks, modestly retrograding in the northern STropZ, merged and recirculated into the mid-STropZ alongside the east end of a cyclonic circulation known as the STB Spectre. It is likely that one or more further mergers with similar dark streaks during solar conjunction led to the complete recirculation that characterises a STropD, with a typical eastward drift rate of 6.5º/30d relative to the GRS. By 2018 Jan. it had distinct ends, 20º apart in longitude. The preceding (east) end (p-STropD) was most conspicuous and was approaching the GRS .

Hi-resolution images revealed unexpectedly intricate turbulence throughout the STropD. This was evident within the SEB, where convective rifts revived alongside and west of the STropD; and within the dark p-STropD itself; and on the stream of material flowing from it past the GRS. As the p-STropD accelerated towards the GRS, the STropD grew longer, reaching 33º in length in early Feb.

On about 2018 Feb.4, the p-STropD arrived at the bright collar of the GRS (Red Spot Hollow, RSH) and halted there. Much dark material from it then started flowing around the S side of the GRS. During Feb. and March, turbulent dark material accumulated in the S. Tropical Band and S. Temperate domain east of the GRS [3].

At PJ12 (2018 April 1), Juno fortuitously flew just 10º east of the east end of the GRS, directly over the large expanse of turbulence that had emanated from the STropD. JunoCam took a series of images of this region over 19 minutes. The images show a chaotic scene, in which the STBn jet cannot be discerned, but many eddies are apparent on different scales. Most of them look cyclonic, but there is a large anticyclonic eddy in contact with the east end of the GRS, dark grey but evidently pulling orange streamers from the GRS around it. There are strong streamlines in this region, including elevated ridges of white cloud, and streaks of different colours crossing each other.

Ground-based images show anticyclonic circulation not only at the ends of the STropD but also within it; on the other hand, both ground-based and JunoCam images suggest that much of the turbulence that has passed the GRS consists of cyclonic eddies. An animation of ground-based images around April 1 shows that the SEBs and STBn jets are still present within the STropD and east of the GRS, despite the apparent chaos. The dynamics east of the GRS will be investigated by animation of the JunoCam images.

## Discussion

We are now watching a STropD interacting with the SEB and the GRS in a way that has never before been observed at such high resolution. The encounter with the GRS was keenly awaited because of the remarkable behaviour of the great STropD over a century ago. Whenever it caught up with the GRS, the p-STropD was reported to stream rapidly round the S side of the GRS and to re-form east of the GRS within days or weeks. However, the original BAA publications actually record that in most such encounters, the p-STropD was not observed for some weeks after it arrived at the RSH, and did not re-form in its classic curved dark form for some months. The rapid passage was only inferred by extrapolating its subsequent motion back to the RSH.

Given the observations in 2018, we propose that the re-formation of the p-STropD in these historic observations was actually a stochastic process that was mediated by eddies in the STropZ which, sooner or later, trapped the SEBs jet into the expected recirculation pattern.

As of 2018 April 1 (PJ12), the turbulence east of the GRS had not (yet) crossed the northern STropZ nor perturbed the SEBs jet. In ground-based images, this was still the case up to early May. So, apart from the fact that this disturbance is not obviously dark, it is not inconsistent with what used to happen a century ago. Alternatively, it is possible that the STropD will not re-form east of the GRS, but will dissipate in the STB latitudes instead.

## Acknowledgements

Some of this research was funded by NASA through the Juno project. A portion of this was distributed to the Jet Propulsion Laboratory, California Institute of Technology.

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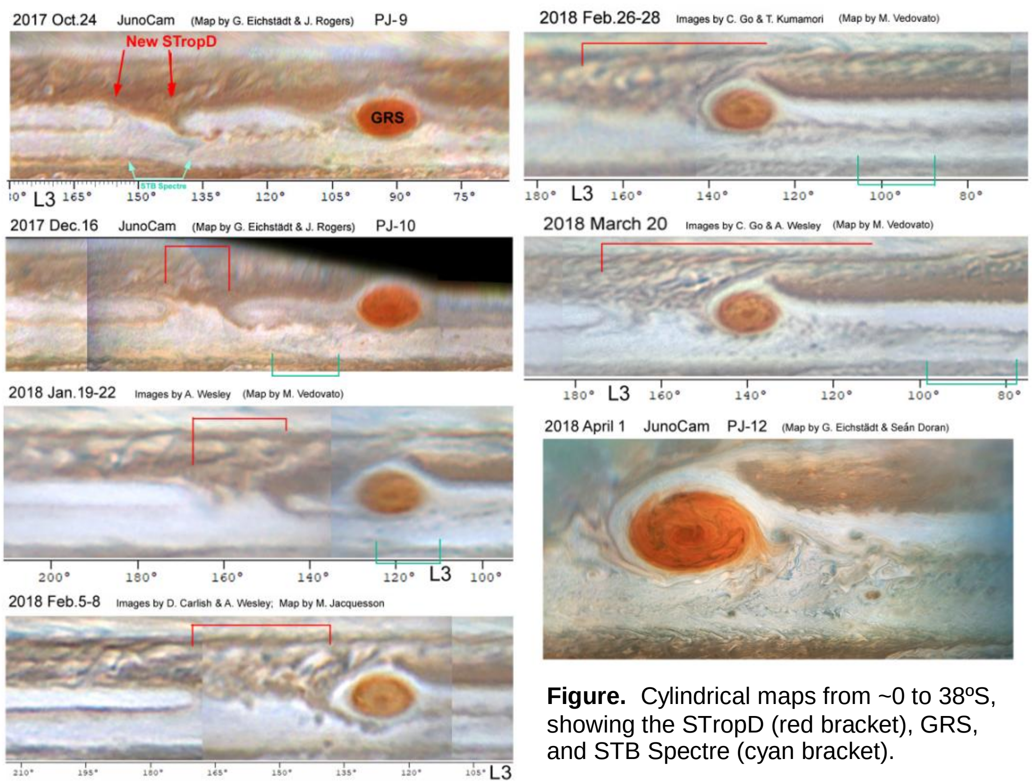


**Figure.** Cylindrical maps from ~0 to 38ºS, showing the STropD (red bracket), GRS, and STB Spectre (cyan bracket).

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# On the Value of JunoCam's Marble Movie Images

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## Abstract

JunoCam took thousands of "Marble Movie" images of Jupiter. Those can be evaluated for accurate in-flight camera calibration, as well as for map renditions based on this calibration. Accurate camera calibration increases the science return of wind field analysis from close-up stereo pairs, since global displacements can be interpreted as target data rather than as calibration inaccuracies. Alternative lense distortion models, other than the straightforward Brown-Conrady approach, are considered and investigated.

## 1. Introduction

NASA's Juno spacecraft has successfully completed several perijove passes. JunoCam [2] is Juno's visible light and infrared camera. It was added to the instrument complement to investigate Jupiter's polar regions, and for education and public outreach purposes.

JunoCam has taken several thousand images of Jupiter from a distance. In most of these images, Jupiter has an apparent size of less the 100 raw pixels. These images are informally called "Marble Movie" images. About half of the images are in RGB. Their renditions can be tested for their centroid alignment of the three color channels of a Jupiter image, and for Jupiter's position and shape relative to its expected position and shape derived from SPICE kernel data. Defining a formal distance between actual rendition and anticipated rendition is the key to minimization methods applied to a family of camera models. This is an approach for in-flight JunoCam calibration.

An accurately calibrated camera model can then be used to create maps from marble movie images. It is also useful to infer cloud dynamics from pairs or n-tuples of close-up Jupiter images. Resolving inaccurate camera calibration by band pass filtering the cloud displacement field would remove low-frequency properties of the cloud feature velocity field. With an accurate geometrical camera model, the radius of the the low frequency boundary of the band pass filter can be enlarged, or even completely removed.

## 2. JunoCam Marble Movie Images

Especially during Juno's Jupiter approach phase, and between the first few orbits, JunoCam took a large number of images of Jupiter from a distance. Those images are informally called "Marble Movie" images, since Jupiter looks like a small marble in those images with a horizontal field of view of about 58 degrees.

Figure 1 shows an image of the Perijove-12 approach phase. In that image, Jupiter appears a little larger than in typical marble movie images. But it's well-suited to show the effect of varying camera parameters. For calibration purposes, the respective centroid positions of the red, green, and blue channel of the rendered Jupiter image can be compared. The centroid position of each color is described by its x and y pixel position. The deltas of the red and the blue centroid position with respect to the green centroid position form a 4-tuple of real numbers. In general, this allows pinning down four geometrical camera parameters, provided all other parameters are known.

If at most three image-specific unknowns are to be determined, with a larger number of marble movie images, additional stable camera parameters can be approximated.

## 3. Alternative Geometrical Lense Distortion Models

The widely applied Brownian lense distortion model [1] can get unstable for wide-angle cameras, since it's essentially a class of Taylor polynomials. Those polynomials tend to oscillate for higher degree approximations presumably needed for accurate JunoCam calibration, and they diverge rapidly to infinity beyond some radius like shown in Figure 1 for some hypothetical radial lense distortion.

Therefore, alternative classes of distortion models will be defined and investigated. One straightforward example is using cosine series. The cosine function is smooth without diverging to infinity for increasing arguments, and it encodes an infinite set of Brownian distortion coefficients.

Figure 1: PJ12 approach image `JNCE_2018090_12C00001_V01` with the raw in the left column, and two renditions in the right column, the upper rendition with well-chosen camera paramaters, the lower one with a less appropriate Brownian K1 parameter.

Within the family of radial distortion functions described by

$$R(r) = r \cdot \sum_{j=0}^{n} a_j \cos(n \cdot b \cdot r), \tag{1}$$

the hypothetical lense distortion presumed in Figure 2 could be described accurately by two coefficients, the wavelength and the amplitude of the oscillation. All $a_j$ except $a_1 := 1$ would be zero, and $b$ would be set to $b := 1$.

# 4. Applications

Accurate camera calibration improves the accuracy of maps or reprojections derived from JunoCam images. Maps of Jupiter close-ups can be used to infer cloud velocity fields. An example is shown in Figure 3. With accurate maps, velocities can be determined in a more global fashion, than just relative to a regional mean velocity.

# 5. Summary and Conclusions

Marble movie images help calibrating camera models. Models other than the immediate Brownian lense distortion model appear appropriate for JunoCam. Good geometric calibration improves the quality of derived products, including maps and velocity fields.

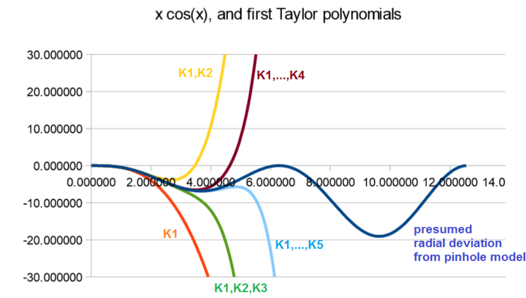


Figure 2: Approximation of a hypothetical radial lense distortion with increasing order of polynomial.

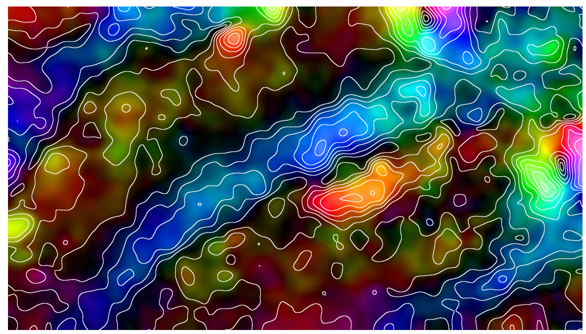

Figure 3: Approximate isotachs derived from a pair of Perijove-12 JunoCam images.

# Acknowledgements

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# Amateur studies of Venus in the near IR and UV

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## Abstract

Cameras and filters now available to amateurs allow them to usefully study Venus with telescopes in the range 0.2m-0.5m in the near-UV and near-IR. At low phase angles, studies in UV between 300 and 400nm allow the rotation of the upper atmosphere to be measured, from measurement of the permanent dark cloud markings, and allow other changes to be monitored, for example the changing brightness of the polar hoods. At high phase angles, imaging in the IR at around 1000nm allows the thermal emission from the surface and lower clouds of the night side of the planet to be recorded. New results obtained by Wesley and Miles are tentatively reported, which appear to show an unexplained hot-spot in the thermal emission in a lowland area of *Eistla Regio* in 2017 April-May.

## 1.Introduction

Venus is a problematic planet to study from the Earth primarily because its general proximity to the Sun in the sky means it must be studied either in full daylight, or when it is quite low, both conditions leading to typically turbulent seeing and poor resolution. In addition, as the angular diameter grows, the phase shrinks, mitigating against detailed global coverage of the cloud patterns.

However, recently, the increased sensitivity in the ultraviolet and infrared bands of fast frame rate CCD and CMOS cameras inexpensively available to amateurs has made practical shorter exposures, and improved the quality of images in these non-visible bands obtained using standard lucky imaging techniques of quality selection from large image statistics, stacking and sharpening.

## 2.The cloud-tops in UV

In the visible and UV the cloud tops of Venus are seen, but the contrast is highest in the UV. Successively longer wavelengths probe lower levels of the cloud-deck. Most of the best amateur images of the cloud patterns are taken using filters with peak transmission at 300-400nm, such as the Astrodon UVenus filter. Care is needed to use a filter, or combination of filters, that completely blocks the IR signal, or this easily overwhelms the UV.

The planet-scale albedo features observed in UV are of the nature of permanent waves, and often called the Y-horizontal, C-reversed, and ψ-horizontal features [1]. Under particularly good conditions, finer transient features comprising banding and mottling can be observed. There are also bright polar caps of variable size or intensity seen in UV.

Images of the clouds can be combined into cylindrical projection maps, though it is typically difficult to assemble enough of these covering the whole planet in a short enough period to be valuable. A rotation period known as System 2 has been defined for the cloud tops of one revolution in 4.2 days. This 4.2 day period is built in to the *WinJUPOS* software commonly used by amateurs to reduce planetary observations. However, recent work by McKim [2] has shown this is not appropriate, and that the average rotation period of the cloud-tops, as measured from the main violet-UV albedo features over an 8-year period, is actually 4.0 days.

## 3.The atmosphere in IR

Features may also be imaged in the IR between 725 and 950nm, but these are finer and lower in contrast than he UV features, hence more rarely imaged by amateurs. They correspond to the cloud morphology at the base of the upper cloud, altitude 60km [1].

## 4.The night-time surface in IR

There are three fairly transparent windows in the atmosphere between 1000 and 1020nm, and amateur imagers (as well as the Venus Monitoring Camera of *Venus Express*) have been able to use this band to record thermal emission from the night side, though amateurs' detectors are typically only about 10% efficient in this band. The images can only be obtained when Venus presents a narrow illuminated crescent, otherwise leakage from the sunlit side dominates the signal. The signal normally correlates with the *Magellan* radar altimetry, higher areas of the surface cooling faster at night and so appearing darker in the IR images, though it can also be modulated by low-level clouds [3]. Amateurs have normally used a filter that transmits all radiation beyond 1000nm.

In 2017 April-May Anthony Wesley and Phil Miles made a series of observations with a 508mm Newtonian using a new method, utilising the 1000nm+ filter in combination with one covering 850-1020nm, to isolate the 1000-1020nm band and reduce scatter from the bright crescent. As well as the normal topographic features, a distinct bright spot was observed in a lowland area south of *Eistla Regio*. This spot was observed on 4 successive days, and was seen to rotate with the topographic features. While it is speculative to apply any particular interpretation to this spot, it appears real but temporary, and it has not been seen in previous comparable amateur images. Possibilities are that it is a cloud thinning, a hot spot on the surface caused by ongoing vulcanism, or a volcanic plume.

## 5.Conclusions

1) Mapping of the upper clouds of Venus in UV light needs to take into account the new measurement of the cloud-top rotation rate of 4.0 days.

2) Further monitoring of the planet at crescent phase beyond 1000nm is needed to determine if temporary hot spots occur that might be related to vulcanism.

## Acknowledgements

I am grateful to all contributing observers to the British Astronomical Association's Mercury and Venus Section, and to its Director Richard McKim for his analyses. Particular thanks are due to Anthony Wesley and Richard Miles, for permission to reproduce their results.

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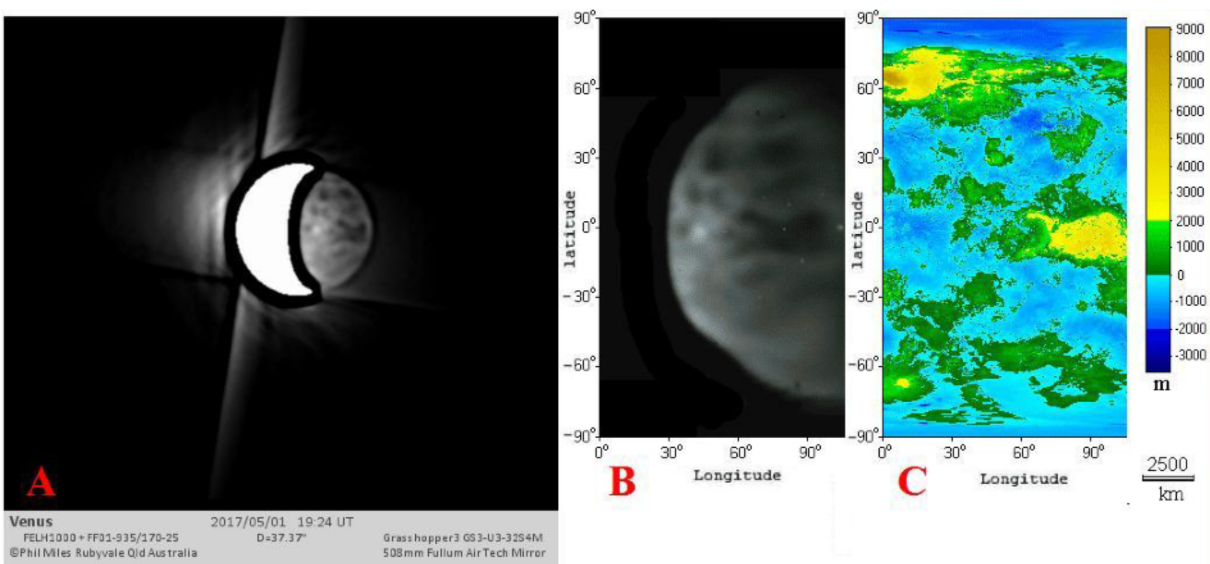
Figure 1 (below): A comparison of the bright feature imaged by Wesley & Miles on 2017 May 1 with *Magellan* altimetry



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# The COBS comet database: Structure and content

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## Abstract

The Comet Observation Database (COBS) [1, 2] is a unique web service that enables comet observers to submit, display and analyse comet data in a single location. The service is currently representing one of the largest databases of comet observations available (containing more than 230.000 observations) and is available to comet observers worldwide.

## Introduction

The goal of every serious comet observer should be to publish the observations, so that they become available for scientific research.

COBS has been very successful in its task and has been widely accepted by the comet observing community. It offers a unique and simple way to store the comet observations in ICQ format [3] by using simple web forms to guide the observer in the input of the comet observation.

## Website platform and development

The COBS website was introduced to the public in May 2010 at the Meeting on Asteroids and Comets in Europe (MACE) held in Višnjan (Croatia). It is maintained by the Črni Vrh Observatory [4] team.

The foundation of the website is a PostgreSQL database, which holds all the information about the observers and their observations. The front-end of the webpage was written in the Python programming language. It uses the Apache mod-python library to communicate with the Apache http server which is running on a Linux server to generate the dynamic page content.

The current website enables the user to choose between dark or light colour themes. The website layout is presented on Figure 1.

COBS has taken on the task of providing new ICQ-style observer codes and abbreviation keys, as the ICQ has not operated for a number of years. New observers will be assigned a unique observer code when creating an account. The observer code is required for observation submission.

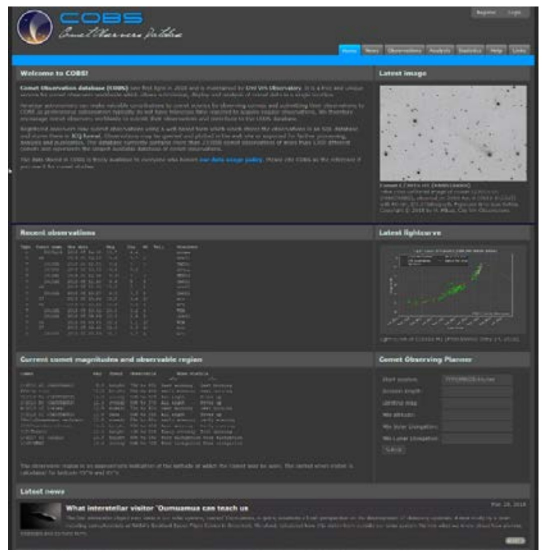

Figure 1: The COBS website layout.

Observers may also request new ICQ abbreviation keys for sensors, cameras, filters passbands, photometric catalogues etc. if they are not present in the available lists.

The website uses simple web forms to guide the observer to input all necessary information about the comet observation. A validation script processes all submitted observations and verifies the adequacy of entries according to the ICQ formatting rules.

## Import of archive observations

Many major associations of comet observers have imported their observation archive to the COBS database. The complete archive of SMPH (Czech Republic) was imported in 2011 followed by the import of VdS (Germany), DCV/NKV (Netherlands), SAAF (Sweden), REA (Brazil), BAA (United Kingdom) and ALPO (USA) archives in 2015.

In January 2016, an import of the available ICQ archive was completed. This archive contained the data submitted to ICQ headquarters up to the year 2009 and contained over 160.000 observations, dating back to 1930. The cumulative number of observations stored in the database through the years, with major imports marked, is presented on Figure 2.

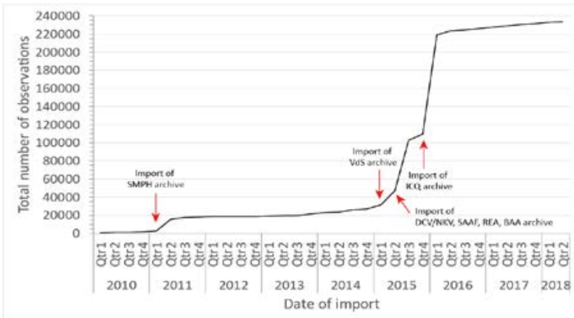


Figure 2: Cumulative number of observations in the COBS database through the years. Major association archive imports are marked.

## Database statistics

Currently there are more than 2.500 registered observers in the database, representing 68 different countries all over the world. Almost 90% of these observers have contributed observations to COBS.

The database stores more than 233.000 visual and photometric (mainly CCD) observations (dating back to 1884) of 1.201 different comets. More than 85% of the submitted observations are visual. On average, more than 400 new observations are currently submitted to the database each month.

Table 1: Number of observations for different comet types.

| **Observed comets: (1201)** | **Total** | **Visual** | **CCD** |
|---|---|---|---|
| Short-period comets: (319) | 81 303 | 68 416 | 12 887 |
| One-apparition Short-period comets: (148) | 2 065 | 1 180 | 885 |
| Long-period comets: (733) | 149 763 | 133 052 | 16 711 |

The best observed comet in the database is C/1995 O1 (Hale-Bopp), with over 15.600 observations. Observations of many short-period comets cover more than just one perihelion passage. Among them 29P/Schwassmann-Wachmann and 1P/Halley have the most observations available in the database.

The number of observations for different comet types is presented in Table 1. The majority of all observations are of long-period comets, followed by short-period comets.

## Data usage policy

The COBS Comet Observation Database is the product of the ongoing efforts and expertise of the volunteer observers who contribute the data and the COBS technical staff who prepare and maintain the database.

Data stored in the database are freely available to the community and can be processed with online analysis tools or exported as a CSV file and imported into any other analysis software.

In the publication of results obtained by using COBS, we appeal that users adhere to our data usage policy that can be access on the help tab. Doing so indicates that you support the purpose of COBS and respect the worldwide community of observers who provided the data.

## Summary and Conclusions

The Comet Observation Database (COBS) is currently one of the largest databases of comet observations and is open to comet observers worldwide. The service has been widely accepted and is used by major associations of comet observers, as well as individual observers.


## Acknowledgements

The authors are grateful for the assistance given by Jakub Černý, for his engagement and suggestions for new features that helped evolve COBS during the past years.


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# The COBS comet database: Observer tools and case study

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## Abstract

This paper introduces the main functionality of the COBS database [1, 2] that are of interest to a comet observer, with application to C/2004 R2 (Machholz).

## Introduction

COBS is one of the most complete databases of comet observations available, containing over 230.000 observations from 1884 onwards. Among its capabilities are data filtering, display and analysis, including user specific functions.

## Submission and editing observations

The Observation page provides three web form options for observation submission. Individual visual and CCD observations may be submitted via individual fields while preformatted ICQ observation strings [3] may be submitted individually or as a list.

The My Obs page (accessible after login) provides access to observations made by the logged in observer. Observations may be edited and downloaded in ICQ format, irrespective of how they were originally entered.

## Observation display and analysis

The database may be queried freely. On the Analysis tab the following parameters are selectable:

- Comet
- Time period
- Type of data: visual, CCD
- Plot parameters: magnitude, coma diameter, tail length, tail pa, degree of condensation
- Source: observer, association, country
- Data display: Tabulated data only, plot of selected data, plot with data comparison (source identified)
- Analysis type: best-fit light-cruve parameters $H_0$ and $n$, perihelion date

The number of observations retrieved are presented together with the number of observations made by the source, if one is selected. Negative or uncertain data may be excluded from the plot.

The result table may be downloaded in CSV format, the plot may be saved to an SVG file and the result page can be accessed directly and shared by a specific URL.

## Recent comet magnitudes

This module is accessible on the main page and lists the most recent observations in chronological order. It is linked to a page with more details on the observations.

## Current comet magnitudes and observable regions

This module lists the present comets brighter than visual or V-band magnitude 14. For each comet, the magnitude trend, latitude range where it is observable, and the optimum observing time for latitudes 45 N and 45 S are given.

Magnitudes and trends are based on observations in the COBS database. Magnitudes based on MPC light curve parameters are given if the comet has not been observed during the last 30 days.

## Comet Observing Planner

With this tool the user can generate a detailed list of observable comets for a given observing session. Input is an observation interval, comet magnitude and altitude limits, and minimum distances to the Sun and the Moon.

On the result page, observable comets are listed in order of optimum observing time. For each comet, the magnitude and trend based on COBS data, coordinates, apparent motion and more are shown. If the user is logged in, rise, transit and set times and transit altitude are calculated for the observing location set in the user profile, otherwise the times are calculated for Crni Vrh Observatory.

The MPC 1-line orbital elements [4] of the observable comets can downloaded as a text file. The list can be used in telescope control programs to setup automated patrol scripts.

## Observation statistics

The Statistics tab provides a number of tables detailing the present content of the database. The most frequently observed comets are tabulated in order of total number of observations, followed by the most active observers, associations and countries.

The database is also broken down into individual years, with the total number of observations, visual and photometric observations for each year. Links on the statistics pages provides access to the observations made in a specific year, for a specific comet, or by a specific observer, association or country.

## Case study

Three plots of C/2004 R2 (Machholz) are shown below to illustrate the display capability of COBS (Fig. 1, 2 and 3).

This comet has 4 702 observations (all visual) between 2004 December 10 and 2005 May 12. The plots show the presence of the full Moon as gaps in the temporal coverage. The 55 observations contributed by the Swedish Amateur Astronomical Society are highlighted. In addition to these plot types, also tail length and degree of condensation may be plotted.

## References


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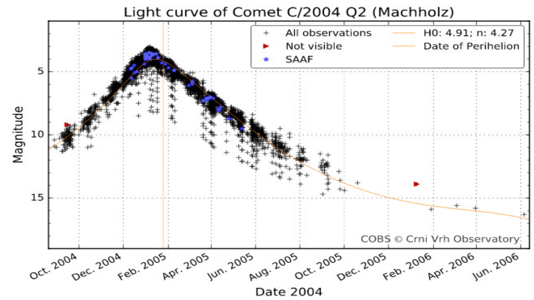


Figure 1: Magnitude of C/2004 R2 with best fit light curve and date of perihelion overplotted. SAAF observations are shown as blue stars, negative observations as red triangles.

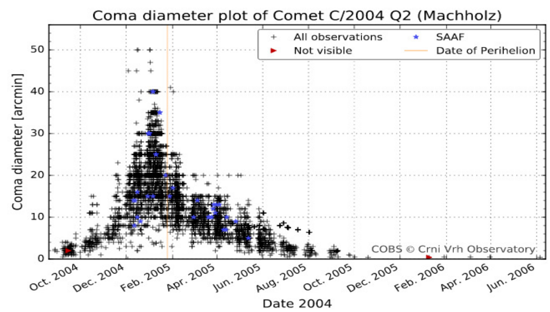


Figure 2: Coma diameter of C/2004 R2. The maximum diameter was over 40 arc minutes.

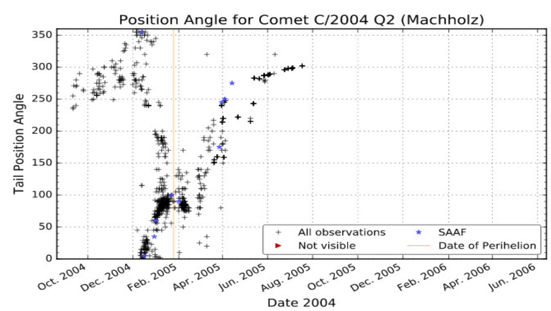


Figure 3: Tail position angle of C/2004 R2. The tail revolved a full 360 degrees throughout the appariton. The maximum tail length (not shown) was 7 degrees.

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# Repeat Illumination Observations of the Moon

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## Abstract

A world wide network of amateur astronomers is attempting to solve some historical observational puzzles known as Transient Lunar Phenomena (TLP), by re-observing specific features on the Moon under very similar illumination conditions to those of the original observations. We now have several examples where we can explain past TLP events as observers being deceived by the natural appearance of the lunar surface.

## 1. Introduction

Transient Lunar Phenomena (TLP) are reported changes apparently seen against the lunar surface and can take the form of glows, changes in brightness, colours, flashes, and greyness in shadows. Catalogs of such events have been produced [1,2] by NASA, and a modern day analysis[3] has suggested that some craters are more prone to TLP than others, however we now know that the Moon is a pretty inactive place, so many of the effects reported are difficult to explain. At Aberystwyth University, we hold the World's most up-to-date catalog of 2789 TLP reports, and for comparison a database of 23,308 routine observations that we can call upon to calibrate out the effects of observational bias. Each TLP in the database has an associated weight ranging from 1 (least reliable) to 5 (most reliable). We are conducting an analysis, using this data in order to see which of the many TLP theories[3] proposed can be supported, or rejected, according to the statistics.

In order to see if the original observer(s) were mistaken in what they visually described as anomalous, we encourage amateur astronomers to attempt to re-observe under very similar illumination, to within ±0.5˚ in terms of selenographic colongitude and sub-solar latitude. On rare occasions it is even possible to re-observe both under similar illumination and topocentric viewing angles to a tolerance of ±1.0˚, or finer.

The predictions on when to observe are generated each month for different geographic localities around theon: http://users.aber.ac.uk/atc/lunar_schedule.htm . Observations can be submitted through an Amateur Astronomy Outreach web portal: http://support.imaps.aber.ac.uk/aao/login.php, which requires a user login and password, available from the author.

The repeat illumination observing programme has been running since 2003, and monthly reports are published in the Lunar section newsletters of the British Astronomical Association (BAA) and Association of Lunar and Planetary Observers (ALPO). Observers can contribute observations from simple text-based descriptions of what they see, to visual sketches, and monochrome/colour images. Even if the images are at higher resolution than was available to the original TLP observers, we can simulate the effects of the atmosphere/optics on degrading the images captured, by Gaussian blurring, or by offsetting the red and blue colour channels to emulate atmospheric spectral dispersion or chromatic aberration. Three examples of repeat illumination of past TLPs are given in this abstract.

## 2. The Pictisus Three Spot Effect

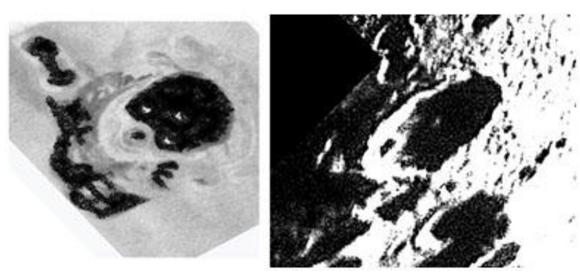

***Figure 1*** *Pictisus crater orientated with north towards the top.* ***(Left)*** *A sketch made by* Daniel del *Valle Hernandes, (ALPO) from: 2001 Jul 26 UT 00:17-00:45.* ***(Right)*** *A heavily contrast stretched version of an image supplied by Rik Hill (ALPO/BAA) from 2017 Feb 02 UT 01:49.*

Daniel del Valle Hernandes, witnessed three small patches of light on the shadowed floor of Pitiscus crater. Although rated as a low weight 1 TLP, this appearance nevertheless remained unresolved until ALPO astronomer Rik Hill re-imaged the region under similar lighting conditions (Fig 1). Thus proving convincingly that this effect is normal to see.

## 3. Daniell

On 1979 May 06 UT 20:30-20:46 Marcus Price reported that he had seen an obscuration inside Daniell crater. Whilst the NW interior was normal, the SE was somewhat fainter and less distinct. A repeat illumination image by Derrick Ward (BAA) confirms this appearance as normal (Fig 2). You can quite clearly see why the original observer unknowingly suspected a lack of detail was unusual.

***Figure 2:*** *Daniell crater near the top of this image as imaged by Derrick Ward (BAA) on 2016 May 16 UT 20:34 showing a normal fuzzy appearance of the SE rim and interior of the crater.*

## 4. Aristarchus

In 1963 Oct 30 Greenacre and Barr, using the 24" Clark refractor, at Lowell Observatory, Flagstaff, witnessed three red coloured spots in the Aristarchus area, that changed in strength and appearance over time. A campaign[4] to re-image under similar illumination, produced images (Fig 3) showed that no natural lunar surface colour could explain the 1963 report. Furthermore, attempts to simulate atmospheric spectral dispersion, or chromatic aberration, also failed to replicate the effects.

## 5. Discussion

Although it is possible to simulate the appearance of the lunar surface, with software such as LTVT, this cannot replicate colours or ray features well. Because of the nearly three thousand TLP reports, it is not practical to investigate all these in one concentrated effort. Instead analysis occurs of repeat illumination observations, submitted each month in a newsletter, which form part of the ALPO and BAA Lunar Section monthly circulars. After analysis, TLP reports discussed here can either be eliminated from the database or have their weights adjusted accordingly. In view of the fact, that some of the historic TLP reports maybe impact related[5], the TLP database could be of great benefit in future lunar impact related studies.

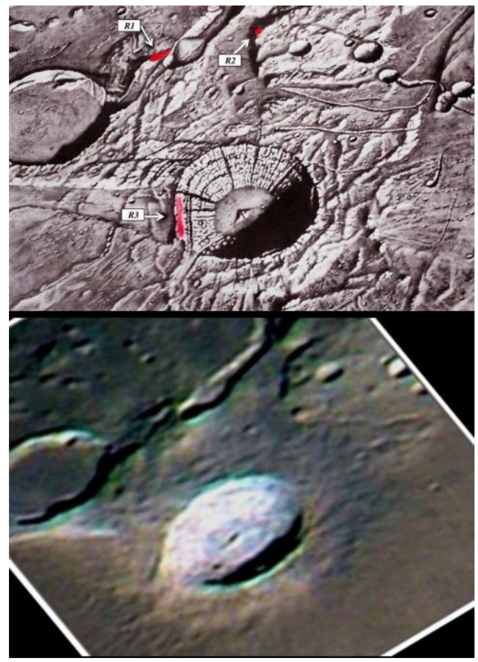


***Figure 3:*** *Aristarchus crater* ***(Top)*** *As sketched by James Greenacre and Edward Barr, in 1963 Oct 30.* ***(Bottom)*** *as imaged by Bev-Ewen Smith on 2011 Apr 15.*

## Acknowledgement

To: AEA, ALPO, BAA, GLR, LIADA, RASNZ, UAI observers, and other astronomical observing organisations

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# Amateurs' contributions to Saturn study during and after the Cassini era

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## Abstract

During the Cassini mission around Saturn, amateurs' observations were useful to follow the evolution of the features observed by Cassini with the Imaging Science Subsystem cameras. It also proved particularly useful for identifying and following the source of Saturn Electrostatic Discharges (SEDs) observed by the Radio and Plasma Wave Science (RPWS) instrument, as shown by a recent study on 2008 data.

With the mission's end, amateur observations prove even more important to measure the wind profile on the planet and to be able to issue alerts for ground instruments in radio wavelengths to attempt observing SEDs from Earth in order to continue the study of Saturn's storm, as shown by the example of a bright polar spot observed by amateurs in 2018.

## 1. Introduction

Since 2004, multiple works demonstrated the importance of amateurs' observations which provide very good time coverage of Saturn's features, even if the resolution is inferior to the one of the professional instruments whether ground based or embarked in Cassini (see references [1]-[19]).

## 2. Atmospheric features' studies

The tracking of features in the atmosphere is possible thanks to amateurs' good coverage of the planet during the apparition. The evolution of the 2010/2011 Great White Spot (GWS) was an excellent example (see [10]-[18]). More generally, it allows retrieving wind profile information through calculating drift rates of the same features on several different observations.

As an example, in 2018 a bright polar spot was first identified by Maciel Bassani Sparrenberger from Brazil with a 320 mm Newton telescope. With the next observations, an ephemeris for the transit of this bright spot at Saturn's central meridian was issued and maintained to help observers plan their observations. This spot proved to be complex, with brightness variations and secondary spots being faintly visible on a few occasions.

From the good quantity (more than 35) of observations, its drift rate could be calculated as -11.7°/jd (at +66°.6 planetographic latitude), which is about +61.6 m/s (see Figure 1).

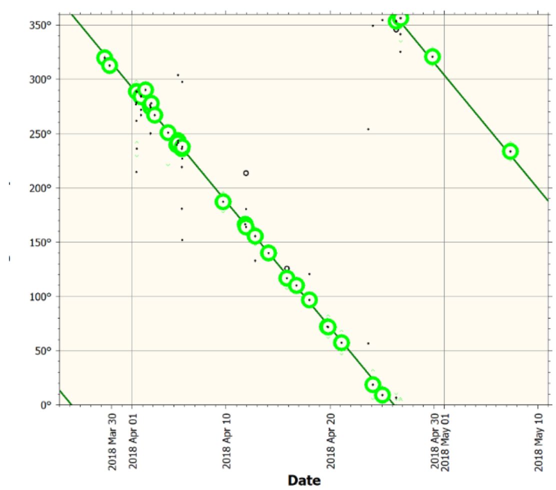


Figure 1: Longitude (system 3) of 2018 polar spot (green circles) over time, following a -11.7°/jd drift rate (blue line)

This spot is located at the latitude of a known jet, but the spot has a wind speed slower than the one derived from Cassini measurements (+95.6 m/s).

## 3. Storm studies

During the Cassini era, the RPWS instrument detected SEDs on many occasions. The instrument operating in radio wavelengths could not locate the exact longitude of the source of these. Here the amateurs' observations proved quite useful, identifying bright spots when SEDs were detected.

As an example, a complex two-cell lightning storm was observed between November 2007 and July 2008, at 35°S planetocentric latitude (area known as storm alley). It started as a single convective cell, with a second bright one appearing ~25° latitude east of it in March 2008. With many amateur observations (see [8]), we could observe that the separation between the two cells stayed steady, and that both were drifting at ~0.34°/jd. It could be used as the context for interpreting all the complex SEDs observations. This was the first time that Saturn lightning from different cells was observed in parallel.

## 4. Future works and conclusion

After the Cassini end of mission in 2017 (which orbited half a Saturnian year around the planet), amateurs' observations can play an even more crucial role in the planet study, in the following area:

- tracking evolution of atmospheric features to help cloud and atmosphere modelling

- retrieving wind profile to detect possible changes

- detecting new events, possibly related to seasons:

    - As a 1994 huge equatorial activity appeared 4 years after 1990's GWS, a similar activity could appear about one Saturnian year after (which would be now)

    - Occurrence of storms in a possible northern storm alley (first one observed in the southern storm alley by Cassini was in 2004, so northern activity could be observed half a Saturnian year later, around 2019)

- detecting bright spots of storms, issuing observational ephemeris for ground-based radio instruments to attempt detecting SEDs activity

- observe equinox related events (satellites mutual phenomena, spokes – see [19])

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