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Circulation of Jupiter's Great Red Spot measured from amateur and Hubble images

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1. Introduction

The GRS has been shrinking ever since the early 20th century [1,2]. The shrinkage was particularly rapid in 2012-2014, so in 2014 the GRS had the smallest size ever recorded [4]. At the same time, the GRS became darker and redder, and its drift rate decelerated, which usually occurs only during SEB Fades. Changes in the internal circulation of the GRS can also be studied from amateur images, which are now good enough to record small streaks circulating within the GRS, as measured in 2006 and 2012 [2,3]. We have now measured amateur images in 2014-15, and on HST images for comparison, characterising the acceleration and shrinkage of the flow field within the GRS.

2. Shrinkage of the GRS

Methods: The length of the GRS was taken from the general JUPOS database [http://jupos.org]. The latitude was measured specially using WinJUPOS on selected images where the limb was clearly defined.

Results: The longitudinal shrinkage of the GRS since 2003 has been similar to the long-term trend overall, but it was static for several years, then shrank very rapidly from 2012-2014. In 2013-14, the GRS was smaller than ever before: 13.5º (±0.2º) long [4,5] – recovering slightly to 14.2º (±0.4º) in 2014 Oct-Nov.

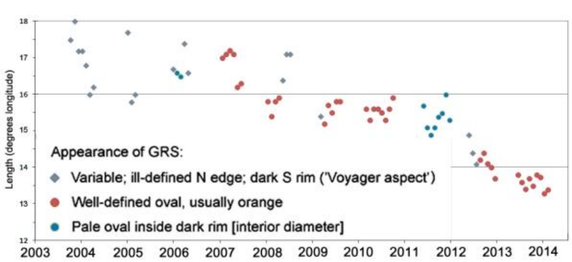

Figure 1. Chart showing length of the GRS, 2003-2014: monthly means (updated from [3]) .

The GRS has shrunk in latitude as well as longitude: in 2013/14, when the width in latitude was only 9.4º, compared with 10.2º from 2008-2012, and 11.9º historical average (1952-1990 [1]). The width has changed less than the length, so the ellipticity has continued to decrease.

3. Circulation period measured from amateur images

Methods: Amateur image quality increased greatly in the early 2000s, due to the use of webcams for taking short sequences of hundreds of images, coupled with programs such as Registax for selecting and stacking the sharpest images. In the last two years, further improvement has resulted from a new function in WinJUPOS for 'derotating' images, which extends the useful timespan for integration from ~3 min to ~20 min. These imaging techniques have allowed many amateur images to detect features within the GRS, e.g. dark streaks near the outer edge, which persist for days or weeks and allow its circulation to be measured. As we can obtain higher precision for changes in position angle (PA) than absolute displacements in these images, we make the simplifying assumption that the GRS circulation is an elliptical projection of circular motion [2]. In some sequences we use images on which the GRS is near the central meridian or is placed on it by digital rotation. In others, we project the images into cylindrical projection maps. The image is then stretched in the north-south direction until the GRS appears circular. The position angle of the streak is then measured, and plotted against time. Despite the approximations in the assumptions and projections, we generally find an excellent linear fit giving a precise rotation period over 1-4 rotations.

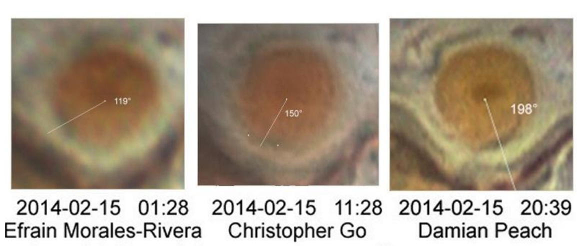

Figure 2. Circulation of the GRS, 2014 Feb. Excerpt from a set of reprojected images with PA measurements.

Results: We first measured the rotation period for 2006, finding a period of 4.5 (±0.1) days [2]. We have now measured images for 2005 May, finding 4.7 (±0.1) days. In 2012, the period was 4.0 days [3]. Each value was determined over ~3 rotation periods. From 2014 Jan. to 2015 March, the best images (e.g. Fig.2) often detected small grey streaks within the GRS and have allowed nine separate determinations (Fig.3). (All were from measurements of a single spot or streak around 1-4 rotation periods, except the last, which is an average of 6 separate measures over ~10 hours each on 6 different dates.) The observed period has been 3.6 to 3.8 days throughout.

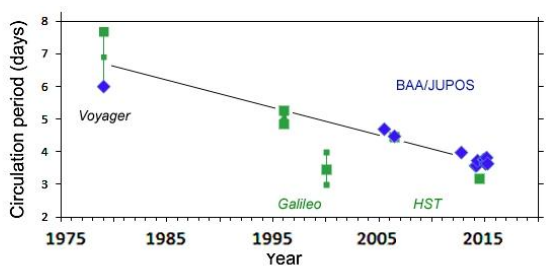

Figure 3. Rotation period of the GRS: Chart from [2] plus data from [5,6] & this paper. Dark blue, rotation periods measured directly; green, calculated from hi-res wind field.

In 2014-15, improved images sometimes resolve multiple features within the GRS, revealing its rotation over ~1 hour as it crosses the jovian disk, although the interval is too short for measurement.

4. Circulation rate measured from HST images

Method: We use the same technique as for ground-based images, but measure the angular velocity over ~10 hours between images, and express this as an implied rotation period. Errors due to the approx-imate assumptions and projections are likely to be no greater than the uncertainties due to the extended size of the features, and are minimised by sampling features all around the GRS.

Results: We made preliminary measurements of the rotation rate within the GRS from HST image pairs on 2009 Sep.22, 2012 Sep.20, and 2014 April 21, as compared with the published wind field from 2006 April [6]. The HST and ground-based measurements agreed on the periods for large streaks: 4.5 days in 2006, 4.0 days in 2012, 3.8 days in 2014. This confirms that amateur images can track the circulating features accurately. However, they do not always capture the fastest wind speeds. Most features in the HST images in 2009-2014 had faster rotation rates, which were consistent within the high-speed collar from r~6000 km to r~7000-8000 km **(Fig.3)**. The rotation period decreased from 3.8 d (2009 Sep.) to 3.5 d (2012 Sep.) to 3.2 d (2014 April; agreeing with professional analysis [5]), entirely due to the physical shrinkage of the GRS. The peak wind speeds in these years were always in the range 147-152 m/s, higher than in 2006 but not accelerating further.

5. Discussion

The GRS appears to be evolving towards the state of Cassini's spot of 1665-1713 [ref.1, pp.262-3]. At the recent rate of shrinkage, it could even become circular by ~2030. If the smaller GRS is interacting less with the SEBs jet [5], this could explain its increased redness and slower drift rate, resembling the situation during a SEB Fade.

This evolution of the GRS size and the circulation appears to be intrinsic to the GRS itself. It does not appear to be a response to any major external factors which occurred during these years, such as SEB Fades and Revivals, or STBn jet spot outbreaks, apart from transient lengthenings in 2007 and 2008 possibly due to interactions with other spots. Most notable is the high wind speed in 2009, when a prolonged SEB Fade began, cutting off the supply of mid-scale vortices to the GRS from the SEBs jet. This contradicts the prevailing view that influx of these vortices sustains the circulation of the GRS.

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The results of the 2015 campaign of observation of mutual events of the Jovian satellites

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Abstract

From September 2014 to June 2015 mutual events of the Galilean satellites occurred around the Jovian equinox occurring on February 6, 2015. The observations of these events provide very accurate information on the relative astrometry of the satellites. Previous campaign of observations have shown the high interest of such observations now performed mainly by amateur astronomers: the Galilean satellites are bright and the magnitude drop during these events is easily observable. The 2014-2015 campaign is especially favorable because of the maximum of events which will occur during the opposition between the Sun and Jupiter. More, eclipses of Thebe and Amalthea by the Galileans have been observed. Note that the positive declination of Jupiter made the observations easier inthe Northern hemisphere where, unfortunately, the meteorological conditions were bad.

1. The mutual events

The mutual occultations and eclipses of the Galilean satellites of Jupiter are now observed since 1973.It has been demonstrated that the astrometric accuracy of the deduced relative positions of the satellites is good enough to refine the dynamical models of these objects. These observations usefully complete the astrometric positions derived from imaging the Jovian system. Note that the bright magnitude of the satellites prevents from easy imaging of the system. Sophisticated filters are needed, making the observations not enough numerous.

2. The Phemu campaign

In order to be able to observe as many events as possible, we need a network of observers worldwide that allows us to catch most of the events as we did previously (Arlot et al. 2014). At the date of the writing of this abstract (April 2015) we received about 300 observations under the form of light curves. Some examples are shown in the figures herewith. A website has been especially set up in order to help the observers (see www.imcce.fr/phemu). A page for uploading the data is also available.

3. The observations

Below, you will find an example of an included figure. You should use the "Figure_caption" auto-formatting style for the caption.

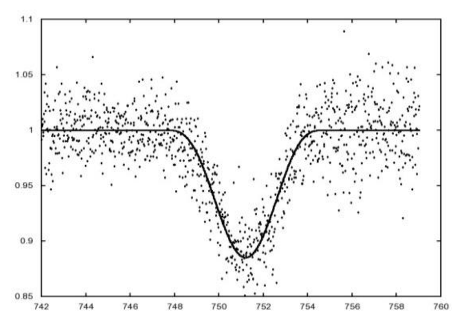

Figure 1: 3E1 on January 19, 2015 (SCO)

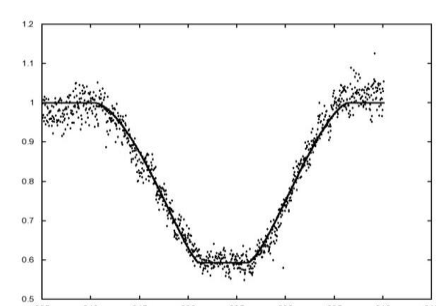

Figure 2: 3O1 on December 28, 2014 (KUR)

4. Observing Amalthea and Thebe

Among the mutual events, some are very specific: there are the occultations and eclipses of Amalthea and Thebe by the Galilean satellites. Only the eclipse are easily observable because of the large magnitude drop, the satellite disappearing completely. Note that the difference of magnitude between the Galileans and the small inners is about 10 magnitudes making the observation of both at the same time impossible. We succeeded to observe a few events as Christou made it during the former campaign in 2009 (Christou et al. 2010). Light-curves obtained are shown below.

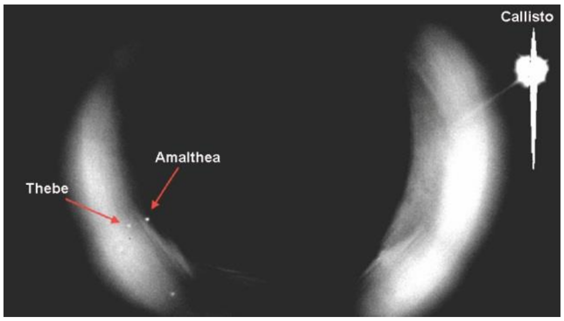

Figure 3: Amalthea and Thebe as seen on the 1m-telescope at Pic du Midi Observatory

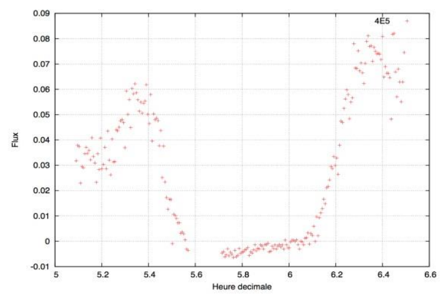

Figure 4: Eclipse of Amalthea by Callisto

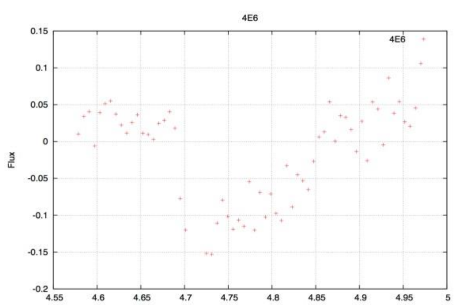

Figure 5: Eclipse of Thebe by Callisto

5. Summary and Conclusions

As we did during the previous campaigns, we obtained useful observations for studying the dynamics of the Galileans. More, we succeeded to observe the inner Amalthea and Thebe. We now look forward planning observations during the next years when no mutual events occur. After the arrival of the Gaia astrometric reference catalogue, new types of observations should be started on ground based observatories (Arlot et al. 2012).

Acknowledgements

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Virtual Observatory tools and Amateur Radio Observations Supporting Scientific Analysis of Jupiter Radio Emissions

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Abstract

In the frame of the preparation of the NASA/JUNO and ESA/JUICE (Jupiter Icy Moon Explorer) missions, and the development of a planetary sciences virtual observatory (VO), we are proposing a new set of tools directed to data providers as well as users, in order to ease data sharing and discovery. We will focus on ground based planetary radio observations (thus mainly Jupiter radio emissions), trying for instance to enhance the temporal coverage of jovian decametric emission. The data service we will be using is EPN-TAP, a planetary science data access protocol developed by Europlanet-VESPA (Virtual European Solar and Planetary Access). This protocol is derived from IVOA (International Virtual Observatory Alliance) standards. The Jupiter Routine Observations from the Nancay Decameter Array are already shared on the planetary science VO using this protocol. Amateur radio data from the RadioJOVE project is also available. We will first introduce the VO tools and concepts of interest for the planetary radioastronomy community. We will then present the various data formats now used for such data services, as well as their associated metadata. We will finally show various prototypical tools that make use of this shared datasets. A preliminary study based on January-February 2014 data will also be presented.

1. Introduction

Radio-JOVE is an educational and public outreach project developed in the USA that introduces low frequency radioastronomy concepts to students and teachers, but also the amateur radio community as well as the general public. The participants are building their own radio telescope, using a kit sold by the Radio JOVE team. This instrument can observe the sky at frequencies around 20 and 30 MHz. The users can share their observations on an archive web site, and on a mailing list.

Radio-JOVE web site:
http://radiojove.gsfc.nasa.gov

Radio-JOVE data Archive:
http://radiojove.org/cgi-bin/calendar/calendar.cgi

We are proposing to set up a prototype interoperable service dedicated to the distribution of Radio-JOVE data in the Virtual Observatory (VO). This service shall:

- store the data sent by the users in a standard format,
- allow a data selection by the science team before putting the data online,
- share the data using VO standards, specifically EPN-TAP, but also those linked to the SPASE (Space Physics standards), or the HELIO project, for solar radio observations.

During this project, we test how amateur data can be shared to the scientific community, using the VO. We also want to consolidate the use of the EPN-TAP protocol, testing it with a new type a dataset, and a new type of data provider (distributed amateur community).

2. Scientific interest

In the Radio-JOVE frequency band, there are 2 main radio sources, wich canbe observed: the Sun and Jupiter. Other radio sources also contribute: the Galactic Background radiation, the radio counterpart of terrestrial lightnings, and local radio interferences. There are 2 large instruments in the world that routinely observe Jupiter in this frequency range: the Nançay Decameter Array in France, and the Iitate radio observatory in Japan. Other instruments can also observe Jupiter during dedicated observation campaigns, such as the UTR2 array at Kharkov in Ukraine, the LOFAR telescope in Europe, or the new LWA telescope in New Mexico, USA. These instruments do not provide a full time survey of Jovian radio emissions. Extending the temporal coverage is scientifically interesting, in particular, for the upcoming space missions that are going to explore the Jovian system (JUNO and JUICE), in which the LESIA at Observatoire de Paris in involved.

The Jovian radio emissions are appearing as "arc-shaped" structures in the time-frequency plane. This shape indicates how the observer is "beamed" by the radio source, which has a very anisotropic beaming pattern and is rotating around Jupiter, following its off-axis magnetic field. The study of these radio arcs is a powerful tool that can remotely probe the plasma is the radio emission regions. Their observed temporal variability is correlated to their intrinsic temporal variability, and the spatial variability of the emission medium. The short term variability requires a series of a radio observatories spread other the Earth, with simultaneous observations. The Radio-JOVE observer's network is the perfect candidate for such studies. The same kind of study could be done with solar radio emissions.

3. RadioJOVE Data Distribution

The Radio-JOVE kit is sold with the "Radio Sky Pipe" software, which drives the Radio-JOVE instrument and proposes to: save data into files or stream data to connected users. A limited series of metadata is attached to each observer. The Radio-JOVE data are distributed both ways: either using emails on the RadioJOVE-data mailing list, or on the Radio-JOVE online archive. The data format is most usually a screenshot (PNG or GIF files), as well as WAV files. A few events are shared using the native Radio Sky Pipe format.

At the occasion of the annual meeting of SARA (Society of Amateur Radio Astronomer), on July 2014, in Green Bank, USA, we have contacted the Radio-JOVE team and the Radio Sky Pipe developer. It has been decided to study the possibility of using CDF (Common Data Format) files for data distribution. The choice of the CDF as an standard format is rather natural:

- It is developed and maintained by NASA for Space Physics dataset.
- It is used as an archive format for Space Physics data at NASA (including space borne radio observation).
- It is now accepted as an archive format by NASA for planetary data.
- It has a recommended configuration and metadata description (ISTP standard and PDS guidelines).
- It has been recently added as an input format in TOPCAT.

The Radio Sky Pipe will study how to implement CDF output in his software, using the software library distributed by NASA/GSFC. We have studied the CDF file formatting, for the various Radio-JOVE data products.

5. Conclusion

The CDF format as a data distribution format for Radio-JOVE data is well adapted, if we except the compression aspects. The foundation of the data and metadata structures has now been drafted. The next step is to implement the CDF generation support into the Radio Sky Pipe software. The server part of the study is not finished yet, and we will go on working on this direction to propose a prototype as soon as possible. The current plans for the longer term are to deliver the server to the Radio-JOVE team in the US, once it is working and they have found a sustainable hosting solution for the server. They are also looking for a data storage solution for the data files. With the NASA/PDS compliance, a possibility could be to submit the data files to that archive facility.

Finally, the collaboration with the Radio-JOVE team has been very fruitful, and we are very happy to continue this project that links a very involved amateur community with a scientific community. We hope that this collaboration will enable new studies on solar and planetary radio emissions.

Acknowledgements

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Online Resources

CDF at NASA/GSFC: http://cdf.gsfc.nasa.gov
CDF archiving for PDS:
http://ppi.pds.nasa.gov/doc/cdf/PDS4-Archiving-of-CDF-Files-v3.pdf
CDF ISTP guidelines:
http://spdf.gsfc.nasa.gov/istp_guide/istp_guide.html

Radio-JOVE web site: http://radiojove.gsfc.nasa.gov
Radio-JOVE Archive site: http://radiojove.org/archive.html
Radio Sky Pipe software:
http://www.radiosky.com/skypipeishere.html

VOParis Europlanet web resources:
http://voparis-europlanetobspm.fr
TOPCAT: http://www.star.bris.ac.uk/~mbt/topcat/
AutoPlot: http://autoplot.org
UCD standard:
http://www.ivoa.net/documents/latest/UCD.html

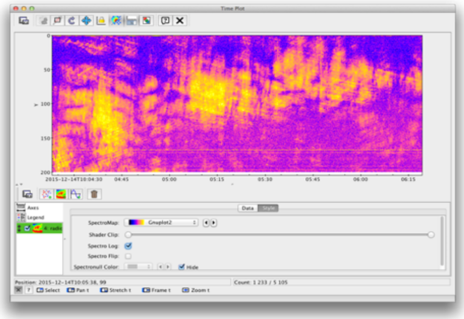

Figure 1: Radio-JOVE SP1 data from D. Typinski displayed in TOPCAT after conversion in CDF.

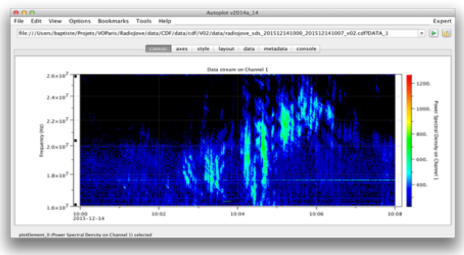

Figure 2: Radio-JOVE SP1 data from D. Typinski displayed in Autoplot after conversion in CDF.

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Amateur – professional collaborations in Giant Planets Atmospheres Research through the Planetary Virtual Observatory of the International Outer Planets Watch (PVOL - IOPW)

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Abstract

The atmospheres node of the International Outer Planets Watch (IOPW) maintains a large database of observations of the Giant Planets called Planetary Virtual Observatory Laboratory (PVOL) [1]. This image repository is contributed by amateur astronomers worldwide and its images keep a record of atmospheric activity on Jupiter, Saturn and Uranus over the years. PVOL was created as an unfunded project that has been online since 2004. Its data content has been growing ever since then, now containing about 25,000 image files that cover the period 2000-2015. The main characteristic of PVOL, when compared with other amateur images repositories, is that it is built as a database with different searching tools. This characteristic has made PVOL an important research tool over the years for various scientific teams. Here we update the description of the data in PVOL and we discuss new development plans in the context of the Virtual European Solar and Planetary Access (VESPA) collaboration which will bring life to a Virtual Observatory for Planetary Sciences. The database is available in the following address:

http://www.pvol.ehu.es

1. Introduction

The Giant Planets Jupiter and Saturn have dynamic atmospheres with complex weather patterns that vary in time in a largely unpredictable way. Continuous monitoring of both planets is not possible by professional astronomers but amateur astronomers worldwide observe them during most of the year. The increasing quality of these observations has been essential in discovering unexpected events such as impacts [2-4], the development of large-scale storms [5, 6] or the study of changes in the coloration or dynamics of Jupiter clouds [7]. The combined analysis of images acquired by hundredths of amateurs can be also used to characterize zonal winds in Jupiter [8] or study particularly interesting atmospheric features.

2. Driving themes for improving databases of amateur images

1. Excellent observations. Observers use a variant of the "lucky imaging" technique that in many cases achieve spatial resolutions that match the diffraction limit of the telescope. The relevance of these observations has been acknowledged by professionals many times in the last few years and excellent collaborations are under way [9]. We plan to incorporate tools in PVOL to measure and quantify the quality of observations so that observations matching a certain quality criteria can be found in the historical database.

2. Juno collaboration The Juno spacecraft on route to Jupiter (arrival in July 2016) will require a broad collaboration from amateurs to observe the atmospheric dynamics at cloud level while Juno peers into the planet interior with its dedicated instrumentation. We plan to network with the Juno team and amateurs to contribute to the atmospheric characterization of Jupiter at the time of the Juno mission.

3. Saturn atmosphere. Cassini extended mission (2004-2017) is well complemented by ground based observations of the planet. While Cassini keeps on its polar orbits around the planet ground-based observers can obtain valuable data concerning the

low and mid-latitudes as well as the north polar hexagon [10].

4. Uranus and Neptune. While intrinsically difficult, Uranus and Neptune have been the subject of recent collaborations between amateurs and professionals with bright features detected repeatedly by amateurs [11].

5. Objects. Amateurs have started to achieve images with enough spatial resolution to observe surface features on Io and Ganymede. Amateur images of Mars and Venus have shown the capability to produce novel scientific results that go from Venus cloud top tracking to studies of Mars high cloud features not generally observable from spacecrafts [12].

3. A Planetary Virtual Observatory

The Europlanets Research infrastructure plans to develop a virtual observatory for Solar System Sciences. VESPA (Virtual European Solar and Planetary Access) works towards that aim. VESPA will provide common data mining capacities, advanced visualization, cross-comparison potential, and data analysis functions to all connected data services. We will network with VESPA to largely improve the contents, search capabilities and visualization tools available at present in PVOL.

Acknowledgements

The PVOL database is hosted at the Universidad del País Vasco UPV/EHU. This work was supported by the Spanish project AYA2012-36666 with FEDER support, Grupos Gobierno Vasco IT765-13 and UPV/EHU UFI11/55.

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2014 Uranus storm activity observations by amateur astronomers

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Abstract

In 2014, for the first time several amateur astronomers have been able to follow a very bright storm on Uranus, bringing useful information for the professional community.

1. Introduction

In 2011 a bright spot on Uranus was observed from Pic du Midi one meter professional telescope (T1M) by an amateur (see [1], [2]). On Aug. 5th, 2014, seven years after equinox, major storm activity was discovered with a Keck telescope, followed by amateur observations of one specific spot, re-observed later by many professional telescopes.

2. Amateur data

Amateurs use mostly reflectors with an aperture from 28 to 40 cm. Their observations are in 4 months around Uranus's opposition but this planet is not often observed, as it was not considered that details could be imaged with amateurs' small apertures telescopes. The data comes from different sources (French Astronomical Society, forums, social networks, mailing lists…). Observations by a few amateurs from France, Australia and USA from August to November 2014 have been studied, included some from the T1M at Pic du Midi, yielding 63 individual measurements of suspected white spots, in near infrared long-pass filters. This allowed to track one particular spot in the northern hemisphere. WinJUPOS software, used by amateur astronomer associations on Jupiter and Saturn, was used to measure the position of features, and follow the drift rate in longitude of this spot from amateur measures.

Measuring Uranus amateur images is a challenge, for different reasons:
- the size of the planet on the amateur images is very small (usually around 50 pixels), and the images noisy as the planet is not bright.
- the orientation of the planet: on the contrary of Jupiter with its details or Saturn with its ring, the planet itself do not show how it is tilted on the image. The only solutions are that the author of the image would leave satellites in the image (best solution, as with WinJUPOS it is possible then to both tilt and size the contour correctly in such a case), or show the orientation (for example by letting the mount drift on AD on one image).

3. Results

3.1 Non confirmed spot observations

In Aug. 2014, a Russian amateur, Alexander Obukhov, made 3 images on Aug. 10th, 16th and 19th 2014 which showed possible spots along with some banding (see figure 1). Unfortunately the spots could not be confirmed between the observations and with other observations, still given the quality of the images and the correct position of the bands (around +3°N and +50°N planetographic), these seem possible. One of them, located at +21°N (planetographic), +265° Syst.I could match a spot observed with the Keck on Aug. 5th/6th, 2014.

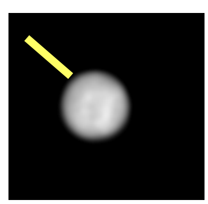

Figure 1: red/infrared (>610nm) Uranus on 2014.08.10 23h43UT (28cm telescope). Suspect spots and banding are visible. North pole lower right corner.
Alexander Obukhov

Measuring this image was made possible because the author included a virtual globe showing the orientation.

3.2 Long lived spot observation

After the Keck observations, professionals (Larry Sromovsky) issued an alert to the amateur community (through the author), suspecting that one specific bright spot (K0) could be observed. That was not confirmed, despite an ephemeris calculated by the author (except maybe on figure 1).

This is only one month later, on Sept. 11th 2014, that Regis De Benedictis (France) could observe another convincing spot (see figure 2), confirmed on Sept. 27th 2014 by Yann Le Gall (France) and Pascal Bayle (France), at a position matching the drift of a spot (K1) identified on the Keck images.

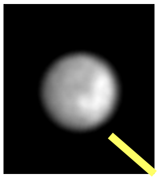

Figure 2: infrared (>685nm) Uranus on 2014.09.11 02h53UT (36cm telescope), showing spot K1. North pole lower right corner. *Régis De-Benedictis, processed by M. Delcroix*

Thanks to an ephemeris for K1 calculated from Sept. 11th image, HST usage was requested for targeting Uranus (on Oct. 14th). It was observed 19 times by 10 amateurs (see table 1) incl. on Oct. 4th by Marc Delcroix at Pic du Midi's one meter professional reflector (see figure 3), and by other professional facilities (VLT, GTC, WHT, Palomar…).

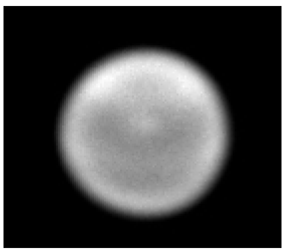

Figure 3: IR (>685nm) Uranus on 2014.10.04 00h52.7UT (106cm Pic dud Midi telescope), showing K1at CM. North up. *S2P/ IMCCE/ OMP/ M. Delcroix/F. Colas*

Date (2014)	Observer	Tele-scope	Filter	Lat. (pg)
Sep.11	R.De-Benedictis (FR)	36cm	IR>685nm	+35.1°
Sep.27	Y.Le-Gall (FR)	36cm	IR>685nm	+33.3°
Oct.01	Y.Le-Gall (FR)	36cm	IR>685nm	+33.3°
Oct.02	A.Wesley (Aus)	41cm	IR>650nm	+32.3°
Oct.04	M.Delcroix (FR)	106cm	IR>685nm	+34.6°
Oct.09	D.Milika (Aus)	36cm	RIR>610nm	+38.5°
Oct.18	A.Wesley (Aus)	41cm	IR>650nm	+34.0°
Nov.11	P.Gorczynski (USA)	36cm	IR>685nm	+34.6°

Table 1: best K1 observations (per rotation) from amateurs

The first 7 observations of table 1 are well aligned (see figure 4) on a drift rate line of -18,1°/JD (Julian day) (+/- 0,2°/JD), at a 34,4° planetographic latitude (+/- 0,8°), also in accordance with the Keck observation. The last one on Nov.11 is not on the same line, but coherent with professional observations. K1 drift might have changed, maybe due to a small change in latitude.

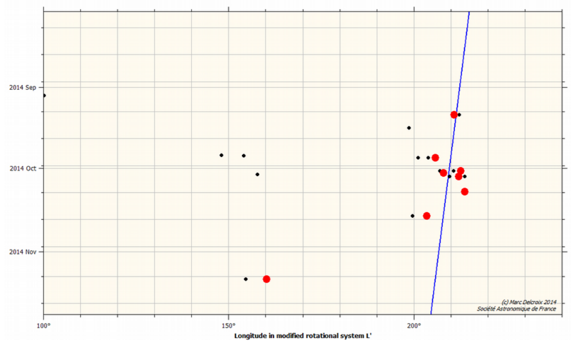

Figure 1: White spots in the [25°,45°] latitude range. Larger red dots are measures from table 1, following a constant drift rate line (except for the last one).

4. Summary and Conclusions

In 2014, amateurs proved successfully their ability of observing a very bright spot at ~34°N latitude on Uranus in infrared wavelength for two months, despite the small apparent diameter of the planet and its' faint luminosity. Their observations allowed to estimate the spot's drift rate of -18,1°/JD, coherent with the known wind profile and an initial observation with Keck, and helping professionals to use other telescopes to target it. This proves the interest of having this difficult planet as a target for regular amateur observations, if they use methods for identifying proper orientation on their images.

Such regular observations would be useful for targeting professional studies as these planets are not observed very often with professional telescopes.

Acknowledgments

To all other dedicated amateurs who provided their images, especially Régis De-Bénedictis (France) and Yann Le-Gall (France).

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The Campaign for the Occultation of UCAC4-347-165728 (R=12m2) by Pluto on June 29th, 2015

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Abstract

The occultation of UCAC4-347-165728 (R=12m2) on the 29th of June 2015 by Pluto is the last important occultation by Pluto before the New Horizons flyby 15 days later. Therefore it is a great opportunity to measure details of Pluto's atmosphere from Earth at the same time as the “on-site” determination. Observations from mobile stations and from certain fixed site observatories are planned in an international campaign in Australia and New Zealand. The telescopes will be equipped with EMCCD or CCD cameras to record a frame sequence linked to the exact timing by GPS. With high resolution astrometry in the months and weeks before the event, we intend to define the central line of the occultation so accurate that a positioning of instruments in close proximity of the central line is possible. - First results of the campaign will be presented in this report.

1. Introduction

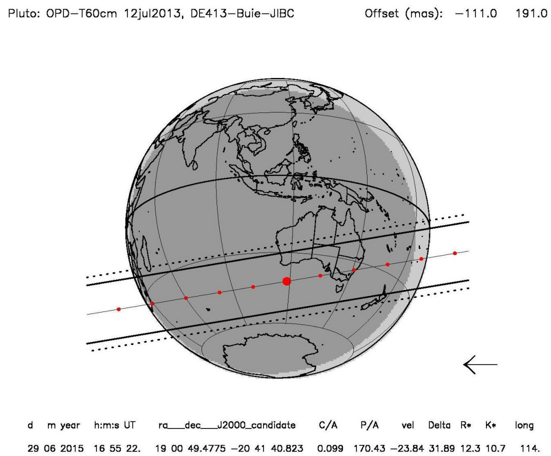
Occultation observations are one of the main techniques, to determine conditions of Pluto's atmosphere from earth. The New Horizons encounter will take place only 15 days after the occultation. It is a very unique opportunity to compare and link ground based and space based observations of Pluto and its atmosphere. In the past, Pluto's atmosphere has been detected and continuously monitored over the last 30 years by occultation astronomy. Important highlights were the discovery of the atmosphere in 1985 (Brosh [1] and 1988 (Hubbard [2]) and the determination of its expansion in 2001 [3], [4]. The brightness of the star (R=12m2, K=10m5) allows us to achieve a very good signal to noise ratio for this occultation. Frame rates and therefore spatial resolution can be high as compared to other past events. High precision astrometry in the months and weeks before the event is needed to be able to position mobile stations precise enough for recording the central flash of the occultation. Such observations allow the measurement of a possible oblateness of the atmosphere and absorption by aerosols. The main landfall of the occultation track is in Australia and New Zealand.

Cooperations between professional and amateur astronomers (PRO-AM) are essential for a good coverage of the occultation track as has been proved in the past [5], [3]. Space probes such as New Horizons can give precise data only for one time point. But a continuous monitoring of the variations of Pluto's atmosphere over years can only be achieved by occultation work. In case of Pluto with its highly eccentric orbit, its distance from the sun is increasing for the next 100 years and therefore the solar energy flux is decreasing strongly. This is a big meteorological experiment running already and should deliver insights in many processes of an atmosphere not only valid for Pluto. Using occultations over the next decades, we hope to monitor a possible “freezing out” of Pluto's atmosphere.

2. The Observations

2.1 The prediction and updates

The first prediction of this occultation has been published by M. Assafin et.al. in 2010 [6]. The central line crosses areas well populated with smaller and larger fixed site or mobile telescopes in southern Australia. The full shadow of Pluto moves across large parts of Australia and New Zealand. The graphics below results from an improvement in the star position and a new drift determination of Pluto's ephemeris as calculated based on Benedetti-Rossi et.al. [7].



Occultation track for Pluto occultation of UCAC4-347-165728 (29th of June, 2015, ~16h 55min UTC. Best prediction up to the time of 29th Apr 2015

This is the best occultation track available for the moment (29th of April, 2015). Further updates by astrometry to improve the prediction will be posted at http://devel2.linea.gov.br/~braga.ribas/campaigns/

Besides other information tools, the deployment of observers is shown in "OccultWatcher", a communication software written by Pavlov, H. (http://www.occultwatcher.net).

2.2 Observation technology

Because of the brightness of the star, instruments starting with about 8 inch diameter can be used for the observation campaign. The cameras in use are either EMCCD or CCD cameras either digital or video ones with inserted timing from GPS receivers. Determining the precise time for each frame is extremely important for data analysis afterward. The timing gives a fixed frame work which fits the different stations together.

Frame rates will range from 3 frames per second (fps) to 20 fps depending on instrument size. This gives a resolution of 8 km to 1.2 km based on the relative speed of Pluto's shadow of 24 km/sec. Stations will be distributed or fixed site observatories will be prepared at different distances from the central flash and also father away to capture the full body of Pluto.

Many observers use the Tangra software (Pavlov, H.,http://www.hristopavlov.net/Tangra/Tangra.html) for data analysis, specially suitable for video recording analysis.

2.3 The international campaign

For occultation work, international campaigns are essential as well as the cooperation of professional and amateur astronomers. A good overview of organizing and running full observation campaigns is given by Mousis et. al. [5]. For this event European observers will join with Australian and New Zealand observers and observers from other nations.

3. Expected results

Because of the brightness of the star, we intend to derive temperature and pressure profiles of the atmosphere with high signal to noise ratios. Data from the stations distributed close to the central track may lead to a study of the oblateness of the atmosphere as well as possible absorptions (central flash observations). The comparison of almost simultaneous space data (New Horizons) and ground-based occultation data will allow to improve the results derived from the ongoing monitoring of Pluto's atmosphere. Besides pure scientific results, the campaign should present one more good example of cooperations between professional and amateur astronomers as well.

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Amateur Astronomy – An Alternate Way of Astronomy Education

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Abstract

Astronomy, the oldest science is being subject of attention to increase scientific temper, awareness of science from school level. In India, history of amateur astronomy is quite bright. People of different zones in India got themselves involved in different sky observation projects of their own, form astronomical institutions, wrote books on astronomy, organize telescope making workshops, recorded data of different astronomical observations and endeavored popularizing astronomy. In 1991, amateur astronomers meet created platform and inspired amateur astronomers to run their works.

1. Introduction

Astronomy education in school level is not significant in India though in geography and science curriculum astronomical knowledge is included in different names. A survey shows (Author conducts the survey in 22 schools) most of the students do not know anything about astronomy. So, they have to introduce this subject separately with small practical arrangements with low cost materials. Amateur astronomers are working in this fundamental level as their own. In 1991, in Pune the amateur astronomers meet opens a forum to discuss the problems faced by individuals. About 200 amateur astronomers of several parts of India took part in this meet. Prof. Jayanta Vishnu Narlikar, the great cosmologist and astronomer realized that a common organization is needed. Prof. Narayan Chandra Rana, the astro-physicist, was deputed to help in the formation of the amateur astronomers' federation.

The enriched history of astronomical knowledge of India inspires students' years after years and in this paper I noticed two names, one in 19th century and other of 20th century.

From amateur astronomers meet the resolution is taken as: the proposed activities are a) observation, b) instrumentation, c) popularization. Another point should be added that astronomy education.

1.1 History of Amateur Astronomy in India

In 576 CE, Aryabhat was born made a great contribution on mathematical and observational astronomy. Here I mention a name , Samanta Chanra Sekhar who was born in a Royal family in Khandapara in 1835. He started doing astronomy at the age of fifteen. The astronomical texts (Siddhantas) dealing with the instruments gave hardly a hint here and there, which were to be improvised all by himself. He started recording his observations and formulations in the form of a treatise at the age of 23.

Another Indian amateur astronomer of outstanding merit is Radha Govinda Chandra, who is credited to e the first person in India to have observed a nova in the constellation of Aquilla on June7, 1918. Chandra contributed 37000 variable stars to Amarical Association of Variable Star Observers (AAVSO).

2. Activities to enhance consciousness of astronomy

* Popular Lecture

* Publish Newsletter

* Observation and Recording

* Instrumentation

* Publishing

3. Summary and Conclusions

Amateur astronomy is an important part of education in India. Amateurs are devoted in this work passionately as their individual effort. Interested learners and common people get their astronomical knowledge by this effort.

Acknowledgements

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Jupiter's Galilean satellites mutual events as a teaching tool

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Abstract

We present a set of observations of the mutual phenomena (occultations and eclipses) between Jupiter's Galilean satellites in 2014 and 2015 obtained with a Celestron 11 telescope from the Aula EspaZio Gela at E.T.S.I. - UPV/EHU. These observations are used as a practical teaching tool for photometry and astrodynamics in different matters of the Master in Space Science and Technology UPV/EHU.

1. Galilean Satellites Mutual Events

On February 5, 2015 the Sun transited the equatorial plane of Jupiter (the equinox) and the Earth passed this plane on November 8, 2014 and April 10 and May 5, 2015, and therefore the orbital planes of Jupiter's main satellites [1]. As a consequence mutual occultations (O) and eclipses (E) occurred between the main satellites. Because the Galilean satellites are bright objects and have appreciable sizes around ~ 1 arcsec, these mutual events are observable with small-medium telescopes and their accurate photometry and timing have been used for precise astrometry of their orbits [2]. In this communication we use the observations of the mutual phenomena as a teaching practice to accurately study the satellites properties and orbits, complementing our previous work on the same subject [3]. The present observations are also useful for astrometric use.

2. Observations

In Table 1 we list the captured mutual phenomena. The observations were performed with a Celestron 11 telescope (28 cm aperture, f/10) from the Aula EspaZio Gela of the UPV/EHU [4]. The telescope was placed in Getxo (Latitude 43° 21' 44.46" North and Longitude 3° 01' 06.65" West). We used a DMK21 AU618 camera with a Barlow X2 Celestron magnification lens in order to have enough spatial resolution to capture, under good seeing conditions, the disks of the satellites. For each event we took several image frame series with short exposures. The exposures ranged between 1/15 s and 1/100 s depending on the seeing quality. Photometry on the satellite target was performed by integrating the total number of counts in a disk aperture typically about three times the size of the satellite. A satellite not suffering the mutual phenomena is used as a photometric reference. When there is a mutual occultation, the summation of the integrated count numbers of both satellites is used to obtain the photometric curve.

Table 1: Observed Mutual Events

Date	Event type
28-Oct. 2014	2O3
22-Dec. 2014	4E1
24-Dec. 2014	2E3
05-Ener. 2015	3E1
07-Ener. 2015	4E3
09-Feb. 2015	3O1
09-Feb. 2015	3E1
09-Mar. 2015	3O2
11-Apr. 2015	1E3

Even type first number is the satellite producing the event and second number the satellite suffering the event: 1 (Io), 2 (Europa), 3 (Ganymede), 4 (Calisto). E = Eclipse, O = Occultation.

For generating imaging sequences of the mutual events, the 'lucky imaging' method has been used with the same tools described in previous works [3, 5]. This method provides high spatial resolution, once the frames are selected by their quality, then re-centered and co-added, allowing resolving the disks of the satellites. Figure 1 shows an example of a time occultation series.

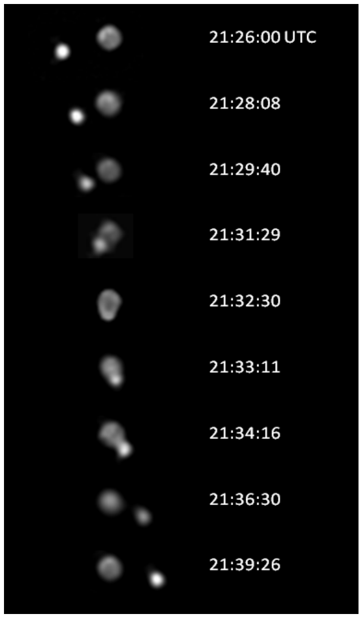

Figure 1: Mutual event of Ganymede occulting Europa on March 9, 2015.

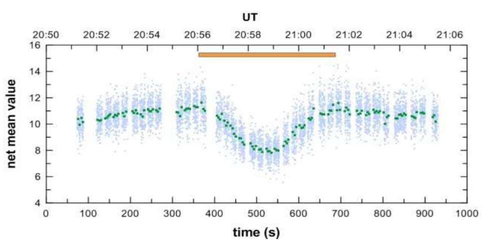

Figure 2: Photometric curve of the occultation of Io by Ganymede on February 9, 2015. The bar marks the event duration.

3. Results

The photometric curves (Figure 2) are fitted to a simple model for the satellites as disks of uniform surface brightness producing and suffering the occultations and eclipses [6]. The time lapse sequences allow the determination of the times of the start and end of the events and also de reduction in light received. From these data the basic orbital parameters and radii of the satellites can be measured and compared with a model prediction [7].

Acknowledgements

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How Amateur Astronomers Can Support the Juno Mission

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Abstract

The Juno spacecraft is on its way to orbit insertion at Jupiter in 2016. The Juno project is soliciting ground-based observations to provide contextual spatial information to supplement its narrow coverage of the planet in each orbit, as well as to track the evolution of the features that will be observed. We note their importance and how to upload images of Jupiter.

1. Introduction

Launched in 2011, the Juno spacecraft arrives at Jupiter in July of 2016 to begin the first of over thirty highly elliptical polar orbits whose periapsis distances are inside the radiation belts. The mission will determine the abundance and distribution of water in Jupiter's deep atmosphere, map the close-in gravity field of the planet, and map the electromagnetic environment of Jupiter over all longitudes. These investigations will relate features that are easily detectable in Jupiter's exterior to the state of the deep interior. Understanding these processes will provide clues to Jupiter's formation and evolution, providing insight into the formation of giant planets in general. The scientific instruments on board Juno consists of in-situ instruments that measure Jupiter's electromagnetic environment and remote-sensing instruments that cover a broad spectral range (Table 1).

The scientific phase of the mission is divided between gravity-mapping orbits, during which the high-gain antenna is pointed toward the earth, and "MWR" orbits, during which the MicroWave Radiometer and the other remote-sensing instruments can access nadir observations of the atmosphere. MWR orbits are placed early in the mission (Table 2) in order to avoid overexposure to Jupiter's harsh radiation environment. Remote-sensing observations will also take place during gravity-mapping orbits, as well. Table 2 updates information provided at the EPSC in 2014 (see [1]), with the biggest change adopting 14-day instead of 11-day orbits.

Instrument	Capability
MWR	Radiometry in channels centered at 1.3, 3.125, 6.25, 12.5, 25 and 50 cm wavelength
JIRAM	Broad-band imaging in filters centered at 3.4 and 5.0 µm; 9-nm resolution spectroscopy at 2.0-5.0 µm
JunoCam	Broad-band red, green, blue filters; medium-band filter centered on the 890-nm CH_4 absorption feature. Images for E/PO purposes only.
UVS	0.6-1.1 nm resolution spectroscopy at 70-205 nm

Table 1. Juno Remote-Sensing Instruments

2. Role of Amateur Observers

Amateur observations can provide continuous monitoring of the atmosphere, creating a fluid documentation of the evolution of atmospheric features. This is particularly important during the active-mission phase because Juno's remote-sensing observations will cover all latitudes from pole to pole, but they will be confined to strips of only 5 to 10° in longitude, except close to the poles themselves.

The Juno mission plans for the public to vote on which features appear to be the "most interesting" and decide where JunoCam should point during each perijove pass. This voting will take place in the context of discussion threads on the Mission Juno web site on features of interest that will begin around the time of this meeting, about a year before scientific measurements of Jupiter are to be made by Juno. These discussions will be enabled by the creation of composite cylindrical maps of Jupiter when possible on a weekly basis, as well as individual images uploaded by the amateur orbits.

3. Uploading Observations

Images will be accepted in any format that is convenient to the observer, e.g. standard GIF, TIF, JPEG, etc. In addition, a recent upgrade to the WinJupos package, not only provides the means to make cylindrical projections of images, but includes an option for compressing the data in a zip file for transmission to the Mission Juno web site (http://jupos.privat.t-online.de/index.htm). The most scientifically valuable images are not in a destructively compressed format (e.g. JPEG or GIF); if at all possible render them in a TIF or PNG (or FITS) format that preserves the linearity of the detector response.

Images can be uploaded using the Mission Juno web site (http://missionjuno.swri.edu/). Link on this site to "Participate in the Mission", which connects to a section devoted to the JunoCam instrument. Then link to "Planning: Upload your telescopic images of Jupiter to help the team plan the mission". That page ("Welcome to Planning") contains a detailed set of guidelines for submission in a PDF file. One final link to "+UPLOAD DATA" brings you to the upload site. You must upload a standard format (preferably PNG or TIFF, but JPG and GIF are accepted as well). Additionally you can also upload a zip file of FITS, IMS, measurement files, etc. that are derived from the WinJupos program. Although the WinJupos output is most convenient for the Juno science team, the Mission Juno web site currently has no means to parse the zip file and then transcode its contents into something standard for the display, so the Mission Juno web site needs the user to upload a standard browser-supported image file to be used for display. The uploaded information will also request information on where the data were taken, what date and time, and which filter was used (or whether a color camera was used). This process and the information to be provided will have been beta tested by the Mission Juno team with the cooperation of a small number of amateur astronomers who are experienced in observing Jupiter before being completely open. It is a Juno goal to display images well within a day of their submission to the Mission Juno web site.

An option is also to upload unsharpened images, as well standard sharpened versions that enhance the spatial resolution of planetary features. Because observers currently use a wide variety of approaches to image sharpening, Juno team will test using a single approach to image processing (accounting for differences in seeing between the images) that may result in more self-consistency in the weekly composite cylindrical maps that will form the center of discussion threads on the Mission Juno web site.

Orbit	Date	Key Event
0	2016 July 5	Jupiter orbit insertion
1	2016 Oct 19	Capture orbit
2	2016 Oct 30	Perijove reduction
3	2016 Nov 2	"Clean-up" orbit
4	2016 Nov 16	MWR orbit
5	2016 Nov 30	gravity-sensing orbit
6	2016 Dec 14	MWR orbit
7	2016 Dec 28	MWR orbit
8	2017 Jan 11	MWR orbit
9	2017 Jan 25	MWR orbit
10	2017 Feb 8	gravity-sensing orbit
11	2017 Feb 22	gravity-sensing orbit
12	2017 Mar 8	gravity-sensing orbit
13	2017 Mar 22	gravity-sensing orbit
14	2017 Apr 5	MWR orbit
15	2017 Apr 19	gravity-sensing orbit
16	2017 May 3	gravity-sensing orbit
17	2017 May 17	gravity-sensing orbit
18	2017 May 31	gravity-sensing orbit
19	2017 Jun 14	gravity-sensing orbit
20	2017 Jun 28	gravity-sensing orbit
21	2017 Jul 12	gravity-sensing orbit
22	2017 Jul 26	gravity-sensing orbit
23	2017 Aug 9	gravity-sensing orbit
24	2017 Aug 23	gravity-sensing orbit
25	2017 Sep 5	gravity-sensing orbit
26	2017 Sep 19	gravity-sensing orbit
27	2017 Oct 3	gravity-sensing orbit
28	2017 Oct 17	gravity-sensing orbit
29	2017 Oct 31	gravity-sensing orbit
30	2017 Nov 14	gravity-sensing orbit
31	2017 Nov 28	gravity-sensing orbit
32	2017 Dec 12	gravity-sensing orbit
33	2017 Dec 26	gravity-sensing orbit
34	2018 Jan 9	gravity-sensing orbit
35	2018 Jan 23	gravity-sensing orbit
36	2018 Feb 6	extra orbit
37	2018 Feb 20	deorbit

Table: 2 Juno perijove times (except for "Orbit 0")

Acknowledgements

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The "Station de Planétologie des Pyrénées" (S2P), a collaborative science program in the course of a long history at Pic du Midi observatory.

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Abstract

Founded in 1873 [4] (Davoust, 2014) by two amateurs (general Nansouty and engineer Vaussenat), the Pic du Midi observatory has been the result of collaboration between amateurs and professionals. The solar coronagraph works thanks to an association [9] (Vaissière, 2015) and private funds. We can also mention the fantastic history of the 60 cm telescope which has recently celebrated its 100th anniversary. This instrument, a gift of Marcel Gentili in 1945 is now fully managed by an association [3] (Castets, 2015). Due to recent budget cuts, the Bernard Lyot 2-m telescope involves several amateur observers [7] (Mathias, 2015). In the context of the 50th anniversary of the 1 m telescope, we will come back on the successful scientific colaborations of this operation and the future that opens with new information technology.

1. Planetology at Pic du Midi

1.1 The early times

Although meteorology was the main purpose of the early development of the observatory, astronomers quickly realized the stability of the atmosphere and the possibility of making good planetary works. It really began in 1860 with the expedition of the photographer and climber F. Maxwell-Lyte [8] (Sanchez 2014) during the solar eclipse of July 18th. These images noticed by the press helped to launch the foundation of the observatory in 1873. Pic du Midi history is marked by numerous private contributions like the continual supply of the Ramond Society [1] (Beigbeder, 2015), accompanying the Observatory since its foundation!

1.2 The modern times

It is difficult to summarize all the works carried out in planetary science at the Pic du Midi, but we must mention the tremendous work done by Bernard Lyot with the development of the solar coronagraph and outstanding planetary images which established the reputation of the Observatory. We can also highlight the cooperation between amateur and astronomer for the discovery and the confirmation of the super rotation of Venus's atmosphere [2] (Boyer, 1961). It also includes the discovery of Saturn satellite Helene [6] (Lecacheux, 1980) and the first ground-based observation of Venus surface [5] (Lecacheux, 1993).

2. Planetology Station (S2P)

2.1 One meter telescope

The telescope was built in the 60's in the wake of Apollo missions. Afterwards, it became almost exclusively devoted to planetary science mainly to study planetary surfaces. Now it continues to observe planets in parallel to space probes, but its main area of research has refocused on asteroids and comets. Its purpose is to carry on long-term studies of most families of small bodies.

2.2 Interplanetary dust

For fifteen years we have extended our research to the field of meteors and more generally of interplanetary matter. We installed at Pic du Midi CABERNET and FRIPON cameras for meteor observations and we regularly observed lunar impacts. Following the observations of the impact of comet SL9 on Jupiter, we are making a survey of asteroidal impacts on giant planets to constrain the density of interplanetary dust.

3. Conclusion

Since the beginning, the “S2P” asked and encouraged amateur astronomers to contribute to solar system research. As an example, the first permanent CCD detector used at 1-m telescope was developed by an amateur team from Toulouse. In the past, the price of sensors was the limiting factor. Now, it is the cost of manpower, therefore, we encourage amateur astronomers to contact the first author to participate to observations. The telescope is now equipped with high-level detectors (CCD for long exposures and CMOS for short exposures) We will soon install a low-resolution spectrometer for the characterization of the chemical composition of small bodies. The 1-m telescope has also completed a renovation, but it remains old and will never be completely automated, so we always need observers!

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