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PROFESSIONAL-AMATEUR COLLABORATIONS EXTENT IN PLANETARY SCIENCE

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Abstract. International planets' atmospheres studies have been using amateurs' images and analysis since years. Topics cover Venus' atmosphere rotation, high-altitude Martian clouds, Jovian features evolutions, Saturn's storms, clouds on Uranus and Neptune, Cassini and Juno probes ground based support, ... Other collaborations target specific studies like monitoring impacts on Jupiter, advanced techniques or professional observation facilities usage (1 meter telescope at Pic du Midi). We will present here some of the latest collaborations and potential future topics to improve pro-am collaborations in planetary science.

Keywords: planets, amateurs, professionals, collaborations, atmosphere

1 Introduction

Since early 2000's, the number of professional publications co-authored by amateurs has been fast increasing as shown in Mousis et al. (2014). The European Planetary Science annual congress (EPSC) offers sessions dedicated to professional-amateur cooperations since 2008, which are organized since 2011 by an amateur (the author), and presented by both amateurs and professionals (the number of submitted abstracts has been increasing over the years). The Europlanet consortium, responsible among others for EPSC, funds through its work-package "Innovation through Science Networking" (part of European 2020 program) projects and workshops between professional and amateurs, like planetary atmospheres monitoring with the 1 meter telescope at Pic du Midi or Juno ground-based support by amateurs.

This favourable environment enables amateurs to actively participate to planets' studies, giving them a strong motivation to do so. We will see why these cooperations are useful, the large scope of covered topics, collaboration being now even systematic or even mandatory for some of them.

2 Amateur data

2.1 Amateur observations

Amateur astronomers are nowadays capable of doing observations with their equipment covering very well planets and their phenomena of interest:

- the telescopes they use are more and more powerful (majority of them are in the 30-40 cm range), and their cameras regularly evolve, with better sensitivity in the 300-1000 nm range and faster acquisition speed (around 100 image per second nowadays). They use cutting-edge processing techniques: lucky imaging for selecting better images, multipoint alignment to select the best parts of images, derotation to compensate for planets' rotation in long sequences of acquisition, ... The best imagers can now produce regularly hi-resolution images of the planets showing many details.

- their geographical distribution (mostly in Europe, USA and Eastern Asia) makes them monitoring planets for several months around the opposition, almost continuously.

- their community is very active and connected through internet, enabling knowledge sharing and triggering observations as soon as an interesting phenomenon comes up.

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On the professional side, there are only a few planetary probes, which usually do not focus (only) on planets' atmospheres but on their magnetism, gravity, satellites, rings, ... Scarce observations are performed on the Hubble Space Telescope through the OPAL program or on the IRTF, Keck, Gemini, Lick, Pic du Midi, GTC observatories facilities; the large diameter ground-based professional telescopes are not often available for planets observations, and work generally in infrared wavelengths between 1 and 5μm longer than the ones accessible by amateurs.

This gives to the amateurs opportunities to provide useful time coverage, complementary observations, and discover dynamic events. Professionals associate systematically amateurs to their works, to justify and prepare their programmed observations with larger telescopes, provide a time and spatial context of the surrounding atmosphere's evolution and complement them in other wavelengths. The Planetary Visual Observatory and Laboratory (PVOL, `http://pvol.ehu.es`) professional database, connected to the Virtual European Solar and Planetary Access (VESPA, `http://europlanet-vespa.eu`) tools, collects thousands of planets' amateurs observations.

2.2 Amateur processing and analysis

Amateurs have developed their own tools for their processing and analysis needs, which are even sometimes used by professionals on their own data:

- **Autostakkert** (`http://autostakkert.com`) selects the best images in an acquisition film, aligns them decomposing the planet in small parts (multi-point alignment), and stacks the best parts in each image.

- **WinJupos** (`http://grischa-hahn.homepage.t-online.de`), multi-functional software, can not only compensate planets rotation in long films, but also measure the position and size of features, analyse their drifts over time, generate their ephemeris for planning observations, generate wind profiles as shown in figure 1, builds projected maps, etc.

- **DeTeCt** (`http://astrosurf.com/planetessaf/doc/project_detect.php`) analyses acquisitions looking for potential flashes resulting from impacts on gaseous planets

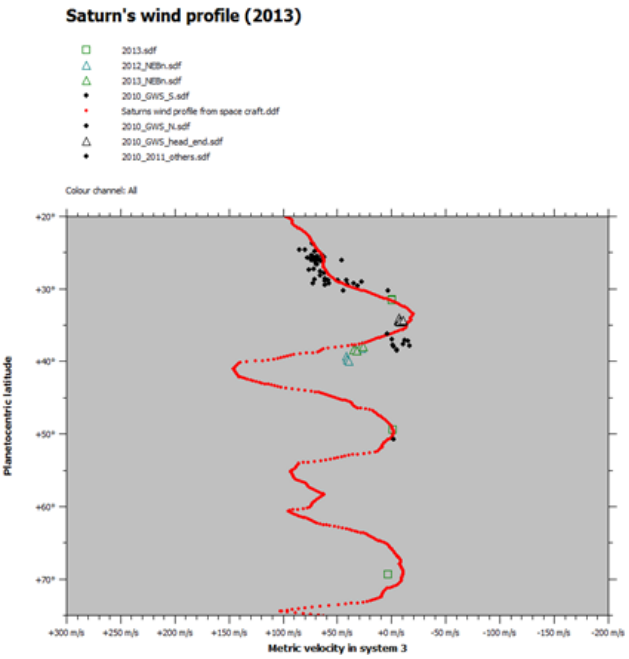

Fig. 1: Wind speed in Saturn's northern hemisphere. The red points is the known wind profile from spacecraft measurements. Each symbol is a wind speed calculated from tracking a feature on amateur observations over time (from a minimum of three to more than one hundred of observations). In black, wind speeds in 2010-2011 during the GWS (Great White Storm, see chapter 3.4); in green wind speeds in 2013. This work has been made by an amateur (the author) on amateurs' images using WinJupos, developed by an amateur, G. Hahn.

3 Current collaboration topics

Planets' atmosphere studies are nowadays almost systematically using with amateur data.

3.1 Venus

JAXA's Akatsuki probe is orbiting the planet since end of 2015, observing it with infrared and ultraviolet cameras. The infrared cameras operate at 1µm, 2µm and 10µm, at longer wavelengths than ground-based amateurs' observations who can hence complement the probe's coverage as requested in Peralta et al. (2017).

Some advanced amateurs also attempt to observe thermal emission of Venus' surface at 1µm with success, detecting colder and hotter zones in the unlit part of the planet.

3.2 Mars

Mars is being monitored by several probes in orbit, but those usually observe the planet around noon local time. As shown in Sánchez-Lavega et al. (2015), amateurs discovered in 2012 on the planet's morning terminator clouds higher as usual, which were the object of a scientific study which results were published in *Nature*.

They also routinely monitor the evolution of clouds and dust storms during the whole opposition.

3.3 Jupiter

Amateurs monitor on the giant planet many details and their evolution. Kardasis et al. (2015) describes changes in features they discovered, like Christopher Go did when oval BA turned to red (see de Pater et al. 2007), such as structures merging, disappearance or reappearance of bands, etc. These discoveries can trigger the use of professional observatories including space telescopes. Resolution reached in their images enables the amateur organization JUPOS to calculate precisely the wind of jovian winds at different latitudes, and track their evolutions.

Their observations proved to be very useful for giving a temporal and spatial context to the Junocam (visible camera of the Juno probe orbiting around Jupiter) fly-by images. Their images are required and collected in a dedicated mission database, used to select area of interest for the future fly-bys.

3.4 Saturn

Collaborations about this planet are similar to the one about Jupiter, despite details in the atmosphere being less visible by amateurs. This leads here to the study of seasonal effects on the atmosphere, much more important for Saturn given its inclination.

The rare (about once a Saturnian year) Great White Spot event which occured in 2010/2011 was studied through common professional-amateur works as demonstrated in Fischer et al. (2011) and Sánchez-Lavega et al. (2011). Furthermore the Cassini probe detected regularly Saturn Electrostatic Discharges (SEDs) with its Radio and Plasma Wave Science instrument(RPWS), sign of storm activity. Amateurs in this topic could detect in visible and infrared wavelengths the bright clouds source of these storms, leading to an accurate study of these phenomena.

3.5 Uranus and Neptune

Despite their small apparent diameter from the ground (around 4 and 2 arc seconds respectively), since a few years amateurs are able to detect activity in their atmospheres as shown in figure 2.

A major storm was observed by them on Uranus in 2014. Since 2013, bright zones on Neptune are imaged during each apparition, complementing perfectly the rare observations performed by the Keck, VLT and space telescopes (see Wong et al. 2018).

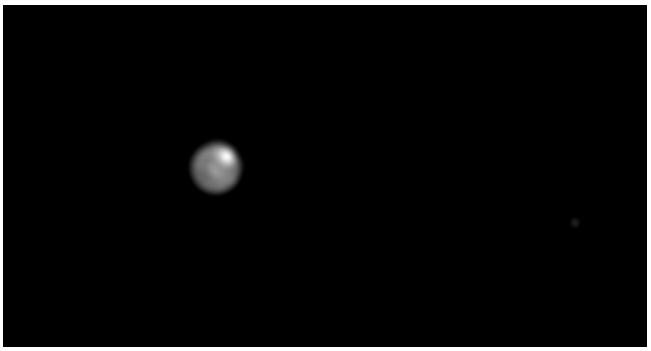

Fig. 2: Neptune's storm in infrared on 2018.10.10 with a 32cm telescope by Marc Delcroix, with Triton at right.

3.6 Impacts

After the predicted Shoemaker-levy 9 comet hit on Jupiter in 1994, amateurs discovered all other known impacts: the one which left a scar in the jovian atmosphere in 2009, then the flashes provoked by small bodies' entries in the atmosphere twice in 2010, in 2012, 2016 and 2017. Each flash was observed by at least two amateurs, and the discovery could be done with modest equipment (20cm telescopes) with standard planetary cameras, or even once visually at the eyepiece (see Hueso et al. 2018).

A dedicated project for amateurs, DeTeCt, aims at refining the impact frequency estimations on Jupiter and Saturn, using a specialized software (see chapter 2.2).

3.7 Mutual phenomena

Measuring time of mutual eclipses and occultations between planets' satellites is a way to achieve very accurate measure of these satellites positions, which is valuable data for modelling their orbits. These events are usually observable around the planets' equinoxes, hence frequent for Jupiter (every 5-6 years), less for Saturn and very rare for Uranus.

Dedicated campaigns targeted at amateurs by IMCCE (like the one described in Saquet et al. 2018) are organized (especially for Jupiter mutual phenomena). The number of participants has been increasing over the years.

3.8 Star occultations by atmospheres

Such events' light curves analysis is a way of probing remotely planetary atmospheres. Amateurs can observe them, as far as Pluto's star occultations? This proved quite important to study the atmosphere of the dwarf planet in a long term scale before the fly-by by New Horizons, to detect atmosphere depth variations.

3.9 Pic du Midi T1M observations

Since more than ten years, the one meter telescope at Pic du Midi has been used by advanced amateurs (J.-L. Dauvergne, M. Delcroix for planets) under the supervision of F. Colas, PI of the instrument. In 2017, a wider team called pic-net was created for broader usage and observational program.

Best planet images from the ground could be obtained thanks to this professional observatory and the amateurs experiences, with public and professional fallouts (Simon et al. 2018 describes a Jupiter mesoscale wave as an example).

4 Future collaborations topics

On top of continuing the topics described in section 3, amateurs could work on the following new topics:

- Mars auroras (see Lilensten et al. 2015)
- Saturn's spokes around equinoxes (Delcroix et al. 2011 describes 2009 detections by amateurs)
- Saturn's bright clouds to issue alerts for targeting storms from ground-based radio-telescopes observations
- Usage of other professional telescopes
- Performing polarimetry on planets
- Performing spectrometry on planets
- Improving collaborations on planetary atmospheres between French amateurs and professional astronomers

5 Conclusions

Professional astronomy associates systematically amateurs to the planetary science studies. The contribution of amateurs is of major importance, through their observations, analysis and discoveries, and this is for them a big motivation source to continue to observe with passion, interest and usefulness our solar system.

The author wants to thank all the many amateurs dedicating their time and energy to produce useful observations for the study of the planets.

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