Digital daylight observations of the planets with small telescopes

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Abstract

Planetary atmospheres are extremely dynamic, showing a variety of phenomena at different spatial and temporal scales, therefore continuous monitoring is required. Amateur astronomers have provided the astronomical community with a great amount of observations, some of which are unique, made under difficult observational conditions. When the planets are close to the sun, observations can only be made either in twilight or in broad daylight. The use of digital technology in recent years has made feasible daytime planetary observing programs. In this work we present the methodology and some results of digital daylight observations (DDO) of planets obtained with a small telescope (11inches, 0.28 m). This work may motivate more observers to digitally observe the planets during the day especially when this can be important and unique.

1. Introduction

Amateur astronomers worldwide continuously are capturing many interesting hi-resolution images of the ever changing planetary atmospheres. There are no dedicated earth-based permanent professional programs on planet monitoring, so amateur contribution is considered important [1, 2]. Online databases of planetary images contributed mainly from amateurs are available to both professional and amateurs [3, 4]. Continuity of observations is interrupted when planets apparently approach the sun. Hence there is a need to continue observation during daylight, since planets are very bright and observable. In the past, visual daylight observation has led to useful scientific results like recording of markings in Mercury by E.Antoniadi [5]. Nowadays, digital planetary imaging performed in daylight conditions, is extremely challenging but possible. In what follows we will provide in brief the planetary imaging methodology with the sun above the horizon and some observational results.

2. Methodology

The basic steps of digital planetary observations are presented at [6]. Though, there are some special difficulties in DDO, which will be presented along with some solutions:

1. *Telescope base polar alignment*. Fixed go-to base setups are ready to be used. In case of portable setups, alignment should be made from the previous night and the mount should not be moved until the next day. Otherwise marks should be made on the ground (from a previous night session) to where the telescope base should be placed.

2. *Filters* Scattering of light in the earth's atmosphere is more effective at short wavelengths. Imaging at UV and Blue band filters is almost impossible in broad daylight. The amount of light scattering is about 9 times less in 700nm (IR) than in 400nm (blue) (from Rayleigh scattering formula) therefore, the use of IR filters is required. Red channel imaging is possible and green channel imaging is challenging. All these are strongly dependent on the position of the planet and the sun as it will be discussed in the following paragraph.

3. *Position of the planet and the sun in the sky*. DDO difficulty depends on the position of the planet and the sun in the

sky as well as the distance between them (Elongation). The ideal situation for the planet is to be high in the sky, far from the sun and the sun to be low in the horizon. The worst is exactly the opposite. In cases where the Sun is well above the horizon then we talk about broad daylight imaging which is considered very difficult. In cases where we can plan observations we select the optimum condition (i.e. image with the sun near the horizon as long as the planet is above 30-40 degrees above horizon, or best near meridian) (Fig.1).

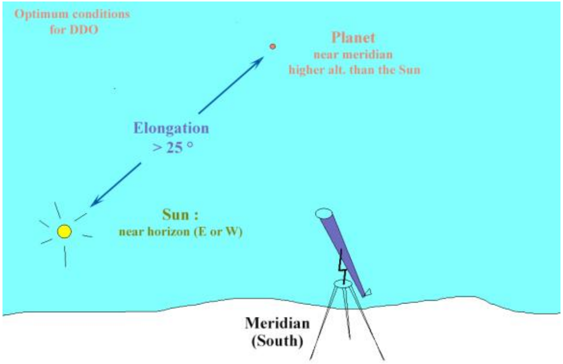

Figure 1. *Positions of planet and Sun for optimum daylight observation (good resolution images, mainly for Jupiter)*

4. *Finding the planet.* This can be the most challenging point. Planets are bright, and in practice, they can be found if there is knowledge of the exact positions in the sky. Planetary coordinates are available on all planetarium software. The only problem remaining is the exact alignment of the base. Accurate fixed robotic go-to bases are ready to be used. Non-permanent equipment needs to be accurately adjusted. This can be done by aligning the telescope on the moon, if visible or more easily on the sun with a solar filter. This requires extensive care because a mistake may result in permanent damage to the eyes or the equipment. After entering all the data (date, time, time zone e.t.c.) in a go-to mount the telescope should be pointed roughly at Polaris. Then we add the solar filter and order the scope to go at the coordinates of the sun. We center the sun manually. Now the scope is aligned. We are now ready to order the base to "go to" the required planet. The use of Barlow lenses optimizes resolution and eliminates sun-light interference effect but is much more difficult to find and focus the planet. A flip-mirror with an eyepiece can be useful in exactly centering the planet (Fig.2).

Figure 2. *The flip-mirror helps centering the Sun (during alignment) and the planet with the eyepiece and then the observer let the light pass to the filter wheel and the camera.*

5. *Planetary viewing on the pc screen / Focusing*

A classic problem in DDO is the ability to look at the PC screen in broad daylight. This can be done simply by putting a blanket over observer's head and PC. A better idea is a permanent construction that will reduce the light around the PC, the observer will be comfortably seated and simultaneously he/she will be protected from direct sunlight and heat (Fig.3).

While centered on the alignment target (Sun) we may set the camera in order to view part of the sun on the screen. The settings can be easily found by adjusting exposure, gain and gamma buttons to see the "surface" of the Sun. You then try to focus as best as possible.

All the settings of the camera depend on the camera, the telescope, the focal length, the conditions, height of the planet and sun, distance between planet and the sun e.t.c. like in normal night imaging.

Figure 3. *A draft construction for DDO to permit viewing the pc screen, protect the observer from direct sun and allow him to work comfortably.*

6. Camera settings

It’s time to order the telescope to go to the desired planet. When that is done you remove the solar filter and center the planet with the flip mirror/eyepiece. Turn the flip mirror and let the light to your camera. The settings of exposure, gain and gamma must be changed again now. The speed must be at least 60 fps. Since you will just see a white screen and nothing else, you firstly reduce gamma to a value of about 10-30% of the value you use for the night mode (For DMK cam. the night value is 100 and the day 10-30). You then reduce the gain value near minimum. Finally you start to reduce exposure time till you see a gray screen and the planet pops-up on the screen. In order to find the optimum values, use the histogram. In the histogram all vertical lines should start near the left edge and finish smoothly on the right edge. Some settings and the histogram during capturing Jupiter, at different focal lengths, are presented at Fig. 4&5.

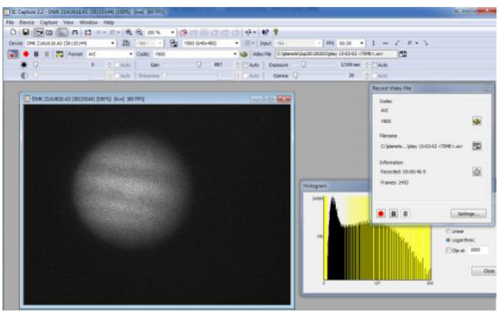

Figure 4. *A snapshot of the PC screen during DDO of Jupiter on 2nd,Feb.2013 captured with a 0,28m/f10 telescope and a 3x Barlow.*

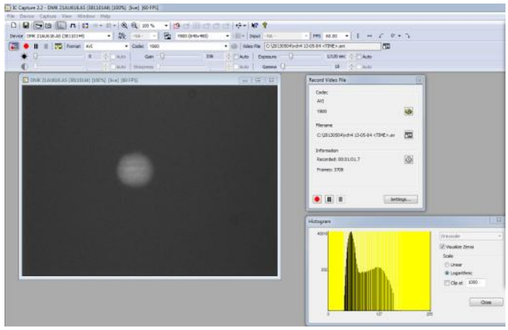

Figure 5. *A snapshot of the PC screen during DDO of Jupiter on 4th, May2013 captured with a 0,28m/f10 telescope at prime focus.*

7. *Reflections & Thermal heating* observing in broad daylight hours causes additional problems since solar heating produces turbulent air in the surrounding environment and in the telescope which results in poor seeing. During the morning times it is usually better, since the ground hasn't yet been warmed up by solar heat. Electronic equipment is also biased by heating that produces more noise. Therefore, it would be a good solution to have equipment to be shadowed with a special construction or placed in a sun-shielded place. If the telescope is in a dome-observatory, then the dome may protect the equipment from the direct sunrays. Solar observers coat equipment with reflecting aluminum foil. This is a good solution also. Furthermore, direct sunlight may produce unwanted reflections entering the planet-observing light path. This is prominent especially when planets are getting closer to the sun. Barlow lenses with coatings produce even more reflections, thus should be avoided.

Figure 6. *Protecting equipment from Sun with aluminum foil (credit Philippe Tosi, CN)*

3. Observations & Results

All DDO's were obtained with a small 0.28m telescope and a DMK21AS618 camera during 2010-2013. Experiments were made in the following wavelength bands: the near infrared band ~700-900nm (Baader IR685, Asronomik IR742 and Hutech CH4 892 bandpass filters) the visual Red, Green, Blue bands (RGB Astronomik filters) and UV band (UV Venus Astrodon filter). IR filters provide better resolution (suffers less from earth's atmospheric disturbance) but most important are less influenced by broad daylight radiation. In contrast, imaging at Blue and UV bands is challenging and in many cases impossible. Imaging with the sun at low altitude, near the horizon and the planet far from it, is very similar with the night time imaging and almost all filters can be used.

3.1 Terrestrial planets

The vicinity of Mercury with the sun, makes observations through the day inevitable. Greek astronomer E.M. Antoniadi in 1924-29 used the 83cm- telescope of Meudon Observatory and tried to create the first map of Mercury [5]. He followed the planet to within 4 degrees of the sun's limb proving that visual daylight observations are possible and useful. The hi-res mapping of the planet by the Messenger spacecraft and the absence of atmosphere make Mercury's observations from Earth almost useless. Nevertheless, the planet can be a nice target for experiments, since it's never too far from the Sun. DDO revealed some details. As we can see in Fig.7&8 patches of dark and bright albedo features, characterizing surface features, can be captured.

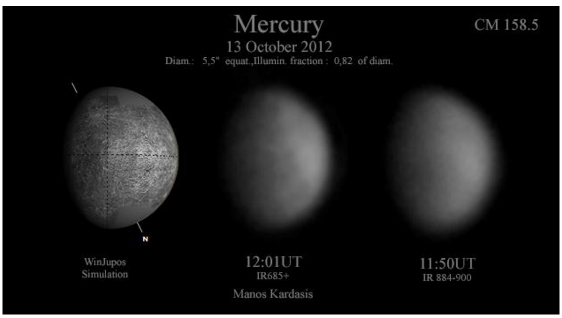

Figure 7. *Digital daylight observation (DDO) of planet Mercury (LT +3 hours from UT, Planet alt.:33.5º, Sun alt.: 37.2 º, Elongation: 21º E)*

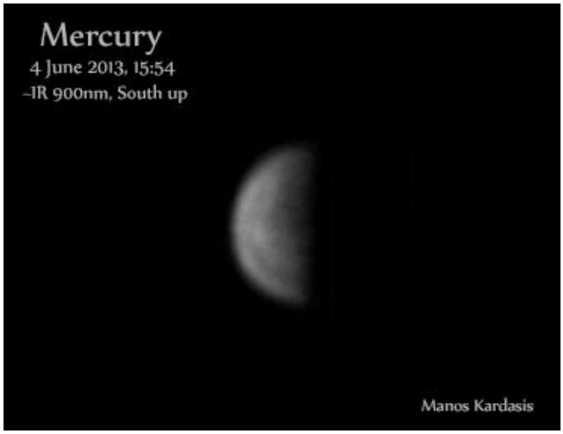

Figure 8. *Digital daylight observation (DDO) of planet Mercury (LT +3 hours from UT, Planet alt.:40º, Sun altitude: 19º, Elongation: 22.5 ºW)*

On the other hand, the dynamic atmosphere of Venus and the apparent vicinity (in many cases) with the sun require DDO which can be particularly useful [7]. Some DDO's showing different aspects of Venus are shown at Fig. 9,10,11,12.

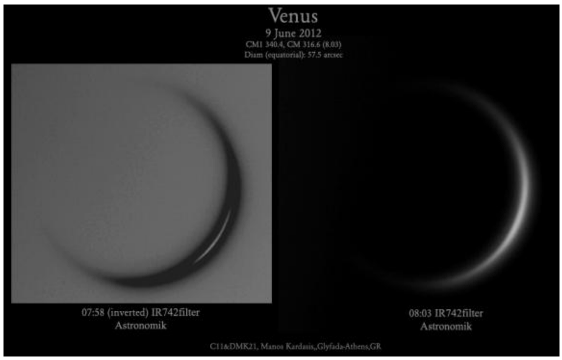

Figure 9. *DDO of planet Venus. It reveals scattering of Sunlight in Venus atmosphere. Illuminating fraction of the disc is only 0.004. (Planet alt.:59º, Sun alt.:55º, Elongation: 5ºW)*

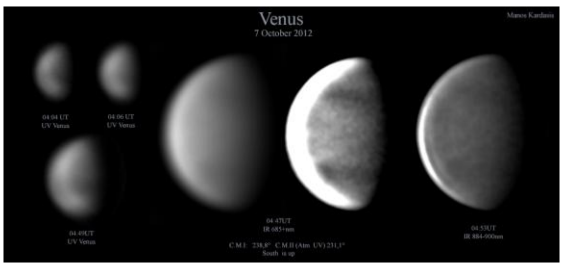

Figure 10. *A multispectral DDO set of Venus (times in UT, LT is +3hours from UT, Planet alt.:41º, Sun's alt.: 3.2º, Elongation 39.8º W)*

Colour observations are very challenging since the blue channel is very difficult to be used as it is biased by sunlight scattering at the Earth's atmosphere. However, it is possible when the sun is low in the horizon (Fig.11).

Figure 11. *A colour DDO of planet Venus (time in UT, LT +3hours from UT, Planet alt.:31°, Sun alt.:1.3°, Elong. : 40°)*

Figure 12. *A rare (almost full-disc) broad-DDO image of planet Venus (time in UT, LT +3hours from UT, Planet alt.:58º E, Sun's alt.: 70º, Elong.: 17.7 º E)*

Mars can also be captured in daylight mainly with IR and R filters. However, useful cloud-positions capturing with the use of Blue filter is extremely challenging (as mentioned above). Furthermore, when Mars is approaching conjunction the distance from earth is increasing, which yields a very small apparent diameter and very low resolution for amateur telescopes. However, some large area markings can be captured even in small apparent disk-size (Fig.13)

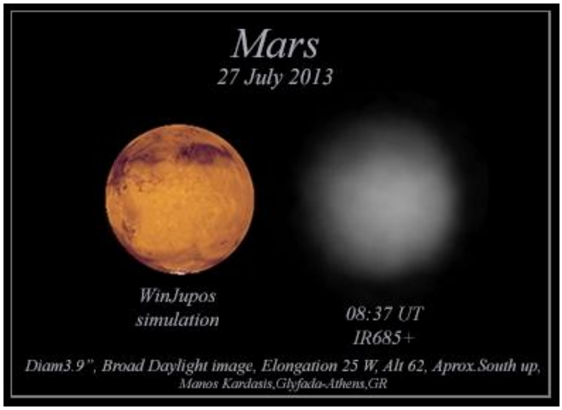

Figure 13. *A DDO image of planet Mars at 3.9 arcsec disk size. Amazonis-Tharsis look bright, the dark Mare Sirenum is visible on the top (time in UT, LT +3hours from UT, Planet alt.:75°, Sun alt. :59°, Elong.: 25° W)*

3.2 Gas giants

The Giant Planets Jupiter and Saturn have dynamic atmospheres with large time-variability. Continuous monitoring is achieved by worldwide observations. In many cases though, fast-evolving weather phenomena needs dense observations. The planet may be visible from the observing site when the Sun is still above the horizon or at twilight. A typical example of this occurred in 2010 on Jupiter's "SEB Revival" [8]. It is the most dramatic meteorological event on Jupiter's atmosphere and its evolution needed to be followed in every rotation of the Planet. The meridian of the "SEB Revival source area" was passing above local skies during daytime. In Fig.14 there is a colour DDO image made from R-G-B filter composition showing the evolution of the phenomenon 18 rotations of the planet after it started.

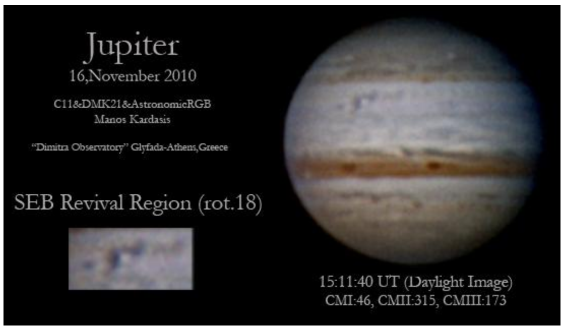

Figure 14. *A colour DDO revealing the Jupiter's 2010 SEB Revival source, (time in UT, LT +2hours from UT, Planet alt.:29°, near sunset, Elong.: 119° W)*

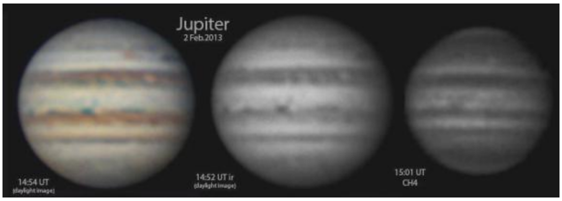

Figure 15. *A multispectral DDO, (Local time, +2hours from UT, Planet alt.:48°, Sun alt. 9°, Elongation. 112° E)*

Imaging with the sun in low altitude (<10º) and the planet high in the sky may produce excellent results with the use of RGB, IR and CH4 filters (Fig.15). Capturing is very similar to the night capturing methodology.

When Saturn or Jupiter are getting away from Earth, and as they approach conjunction the apparent disc diameter is getting smaller and they get very close to the sun. In these conditions observations can only be achieved with DDO's in broad daylight, and in some cases they can be very fruitful.

A typical example is the following. A few weeks before conjunction of Jupiter on May, 14th 2012, two important disturbances started in the North Equatorial Belt (NEB) and North Temperate Belt (NTB). Jupiter reappeared in early June 2012 but was very close to the sun for observations, even at twilight. DDO's of Fig.16 confirmed that both outbreaks had developed impressively leading to a North hemisphere upheaval [11].

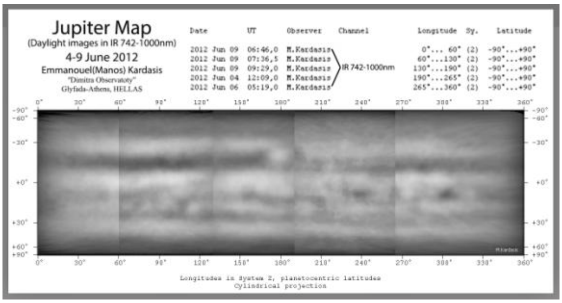

Figure 16. *The first Map of Jupiter of the obs.period 2012/13 [9].It is made with DDO's and the use of WinJupos software [10]. It confirmed the North hemisphere Upheaval [11]. (Local time, 3 hours from UT, Sun's altitude 41.2 °, 51.1 °, 70.5 °, 62.4 °, 24.2 °, Elongation 16-19 ° W)*

The first DDO's of 2012/13 apparition of Jupiter were made 22 days after 2012 conjunction (Fig.16) and the last DDO (Fig.17) was made 16 days before 2013 conjunction. It proves that low-res observations can be made on Jupiter even very close to the Sun. However, special care should be taken. The use of this observation methodology reduces dramatically the observation time-gap near conjunctions.

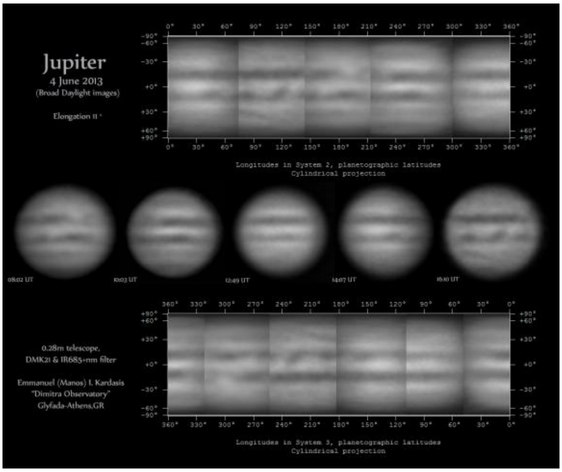

Figure 17. *The Last Map of Jupiter of the obs.period 2012/13 made with DDO's and the use of WinJupos software [10]. It was made when elongation of Jupiter from Sun was just 11 degrees, so all observations were made in broad daylight. The observing session started in the morning and ended in the evening completing one Jupiter day.*

Hi-res imaging can be achieved in broad daylight when position of objects is similar to those presented in Fig.1. Furthermore, even if the sun is too high in the sky, the planet is also high and the elongation between them is greater than 25º (Fig.18), hi-res imaging can be achieved with the use of IR filters (Fig.19).

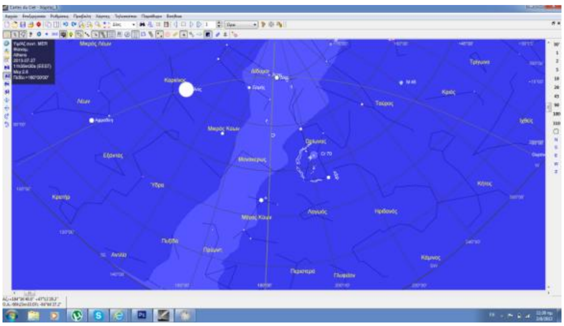

Figure 18. *Simulation of the daytime sky during observation of Fig.19 on 27th, July 2013 (Local time, 3 hours from UT, Planet alt.:74°, Sun alt. 60°, Elongation. 27.5° E.)*

Figure 19. *A hi-res image of Jupiter in broad daylight. It was made when elongation of Jupiter from Sun was 27.5° (Local time, +3 hours from UT, data position of objects are on the image)*

4. Summary and Conclusions

Modern capturing methodology and image processing techniques allow planetary observations almost all-year and all-day long. We presented the methodology and some preliminary results in some planets during daytime. When the sun is near horizon (alt. <10°) image capturing methodology is similar to the classic night-capturing methodology and excellent results can be achieved even with RGB filters. When the sun is high in the sky (broad daylight) imaging is also possible. Adaptations to the classic night-capturing methodology for digital daylight observations (DDO) were discussed. Experiments were performed on Mercury, Venus, and Mars and especially on Jupiter. This work may motivate DDO by amateurs to a large extent especially in cases where detected changes may be very useful.

Acknowledgements

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