

Tips for JUPOS Observers

(Miscellaneous thoughts by G. Adamoli – August 2011)

Introduction

The JUPOS project provides an up-to-date comprehensive database of positions of Jupiter features (longitude, latitude), by measuring images produced by amateurs worldwide who employ digital cameras (webcams, CCDs). We have already secured more than 600,000 positional records and numbers are growing at a fast pace.

Software developed by Grischa Hahn (WinJUPOS) can manage such a huge database through various functions, such as listing positions of specific features, averaging values, plotting and computing drifts in latitude or longitude, and so on. This program allows the compilation of whole-planet (or partial) maps from images, and provides comprehensive ephemerides both of the planet and its Galilean satellites (indeed, similar functions are at disposal for any other of the major bodies of the Solar System).

Our cooperation with amateurs as well as professionals all over the world is bringing increasingly successful results in the study of both short and long time scale phenomena of Jupiter. Every serious, scientifically-minded amateur, with even a modest backyard telescope, a webcam and inexpensive software to acquire and process images, can contribute to the scopes of our project.

Jupiter images shown here were taken by Antonio Coconcelli, Riccardo Cosenza, Sadegh Ghomizadeh, Riccardo Mancini, Damian Peach, Jean-Jacques Poupeau, Franco Rosi. South is always up.

The serious Jupiter observer

Amateurs belong to several categories. Some put a considerable amount of money on their hobby but hardly get results of any consistence, because they only sporadically try their instruments on Jupiter – or any other astronomical object. On the other side, many dedicate themselves to learn the subtlest of technicalities, spending wealth of time, to get amazing images to show friends and posters to embellish their observatories. These amateurs tend to be artists rather than scientists. There is no bad judgement about this choice, but their way diverts from ours.

And then, there are people who feel a desire to seriously contribute to our knowledge of the planets, as humbly as their instruments concede. Our project is made for them. Let's see a list of desirable mental habits that will improve their results:

- 1) Observations should be planned, taking account of the rotation period of Jupiter (about 10 hours), distributing efforts in order to maximize the span of observed longitudes and to keep the planet under control for prolonged periods.
- 2) One must be aware that continuity of surveillance is very important. Jupiter is not observable from Earth for some weeks around solar conjunction. For a couple of months before and after, it is a hard object, low in the evening or dawn sky. But one should try to get the best even from these unfavourable periods. Such results, poor as they may appear, are as important as those obtained when the planet is easy to follow around opposition, high in a dark sky.
- 3) One should consider to observe also at discomfoting hours, in the middle of the night or before dawn, if this would give a more complete surveillance.
- 4) It's useful to get a basic knowledge of Jupiter, by reading about it, in order to become acquainted of its phenomena, as studied in the past, and as they present themselves to us.
- 5) It's useful to compare one's results with others', through mail and magazines, in order to share knowledge and expertise.
- 6) Standards should be followed in reporting observations, in order that no ambiguity might arise when subsequent analysis is done. It's important to wholly document one's results, accompanying them with notes on date, time, site, seeing conditions, type of telescope and aperture, optical elements used (filters, Barlows...), camera employed, exposure time, name of author and all other information that is considered relevant.

Image orientation

Whatever the personal taste in reproducing own Jupiter images is, one should make an effort to assure easy interpretation by the analyser. A tradition followed by the amateur community through the decades (not by

today professionals, however), imposes to orient images in order that they have the South pole of the planet upward, and the direction toward which the planet moves in the sky on the left (that's also toward which features appear moving on the visible disk). In this manner, Jupiter appears as seen through an inverting telescope with an even number of reflections (e.g. a typical Newtonian), operated in the Northern hemisphere of the Earth.

If one thinks it is odd to follow a rule that brings the planet upside-down, so to say, with respect to the "natural" North-South geographic orientation, there are two reasons that make this decision not as awkward as it sounds:

- 1) That is the way in which visual observers (in the Northern hemisphere, where most operate) see the planet, and it is thought useful to maintain the link with our direct experience and the way the planet has been represented in most of the scientific literature available through the centuries;
- 2) With this orientation, both longitude and time increase going from left to right, so permitting a natural integration between numbering systems, cylindrical maps and time/longitude graphs.

Take note that a diagonal, often employed visually to get a comfortable observing position with refractors, Casségrains and other types of instruments, delivers a mirror-inverted image, because of a further reflection in the optical path. That can be confusing. There is no need to use a diagonal when acquiring images (indeed, it should not be used in photography, in order to avoid light loss and not to introduce further optical aberrations).

If your telescope, for any other reason, delivers mirror images, you must invert them before sending to a JUPOS measurer. Even some camera acquisition software sometimes invert images, without clear specification from the manufacturer, so one should keep most attentive that no inversion be introduced in any step of the processing; otherwise a further mirror inversion of the final image is needed.

Timing of observation

Comprehensive instructions and recommendations about this topic is written in "Jupos – Tips for Measurers", available on the JUPOS site, so one is addressed to that paper.

It should be hardly underestimated the importance of correctly timing observations. The JUPOS project is a positional and cartographic one, and is based, among other things, on the accuracy of measures of longitude. Uncertainties come from a number of causes, going from little errors in placing the measuring masque by the analyzer, to indefiniteness of the measured features, but nothing can render images useless and, worse, deceptive, as bad timing by the observer.

The high resolution attainable with current digital cameras leads to measured positions routinely consistent to within 1° , for a single measure, and substantially better if an average is taken.

But the planet rotates rapidly: within 5 minutes, features move by 3° in longitude. So, it is absolutely required that observers time their images at least to the nearest minute (that is, ± 30 seconds, which translates to $\pm 0.3^\circ$ in longitude); if time is given to the nearest tenth of a minute, better still.

An image usually comes from elaboration of frames acquired in a film (more than one film when stacking results in different wavebands). The time to assign to the final image is the average between the instant of the beginning and that of the end of the making of the film. If an image comes from the stacking of frames from more than one film, one has to consider the average time between the beginning of the first and the end of the last film employed.

It's impressive to see how some imagers, even expert ones, tend to do mistakes, such as just taking the time automatically assigned to the film file by the software (this often being just the start, or the end of the acquisition), or taking for granted a PC clock not thoroughly checked at least at the beginning of each observing session. Not to mention the exchange of time labels between different films acquired at minutes' distance during the same observing session.

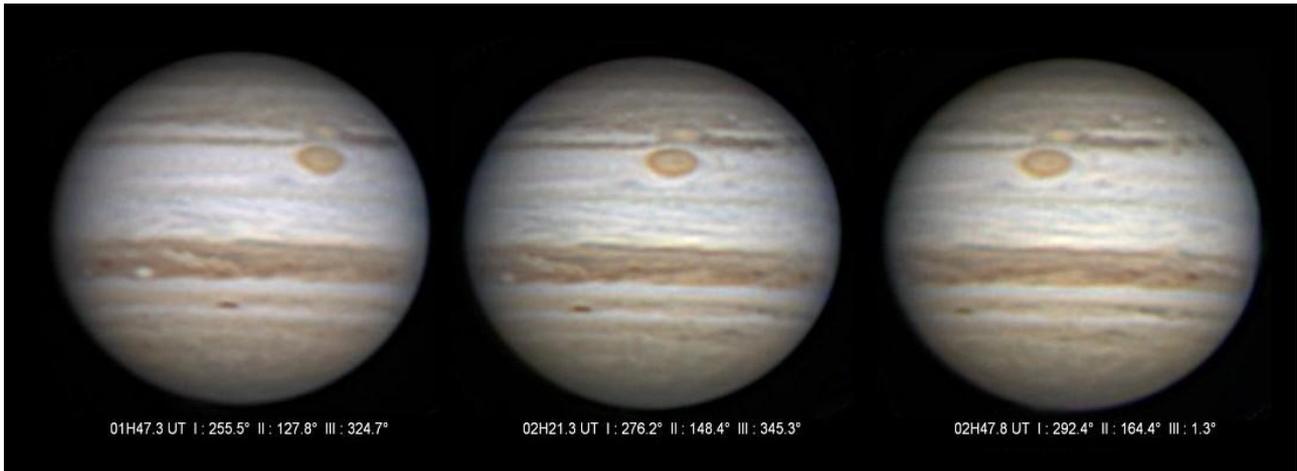
This list might continue: we see observers who give the wrong integer hour, because they fail to compute the correct difference between their time zone and UT, or forget to take account of the use of civil saving time employed in certain seasons in their countries. Observers sometime fail to record the change of date around 0 UT. Also to be considered that, for example, February 25th, 00:30 Central European Time, corresponds to

February 24th, 23:30 UT. There are so many pitfalls in timing, that a special attention should always be dedicated to it.

It's worth to explicitly declare that the time frame used by the JUPOS project is UT (Universal Time). Please don't use other references, such as Ephemeris Time, Terrestrial Dynamic Time, and so on.

Duration of exposure

Because of the rapid rotation of Jupiter, testified by the sequence of images below, even a few minutes' exposure shows evident signs of smearing of the features in longitude, altering their shape and losing definition.



This poses strict limits to the total duration of an exposure, that must be kept in mind also when a stack is made of images taken through different filters. Given the $\sim 1^\circ$ shift allowance matching the typical resolving power of an amateur image, a total exposure longer than about 1 or 2 minutes inevitably alters features, tending to elongate them and leading to loss of definition.

The exposure time should be a balanced compromise between avoiding rotational shift, and getting a sufficient number of frames to stack. For low-resolution images, in poor seeing or through very small telescopes, the total exposure may probably be increased up to ~ 3 minutes. On the other hand, to fully exploit the power of big telescopes under good seeing, even 1 minute may be rather long. Everyone just has to experiment with his or her instrumentation and sky conditions.

Spectral range

As explained in "Tips for Measurers", the JUPOS project uses images taken in the visual waveband or broadband infrared. You should focus on visual colour, monochrome red, broadband infrared, and green, here sorted by descending priority. Digital sensors have a substantially different sensitivity window with respect to the human eye. They capture visual light as well as near infrared, with decreasing sensitivity to about $1 \mu\text{m}$ wavelength (the eye catches signals to $0.7 \mu\text{m}$ at most).

In order to produce images easy to interpret, one should not mix visual and infrared. This is avoided by using proper "infrared-blocking" filters, to acquire the visual waveband, or "infrared-pass" filters, in order to block the visual.

Some imagers have developed techniques to get sharp planetary details through infrared images, used as "luminance", while contemporarily preserving colours by stacking together R, G and B channels. Even if such images are aesthetically pleasing, they don't yield more information than ordinary separate infrared or RGB images; rather, they deliver ambiguous results, and tend to require long total exposure times, because of the many distinct films to get. For these reasons, the use of such a technique is strongly discouraged in the JUPOS project.

Image acquisition

Hardware and software developments have been so rapid in these years, and promise to march as rapidly in the foreseeable future, that it's hard to fix even the rough outlines of a guide to imaging. Today's "digital"

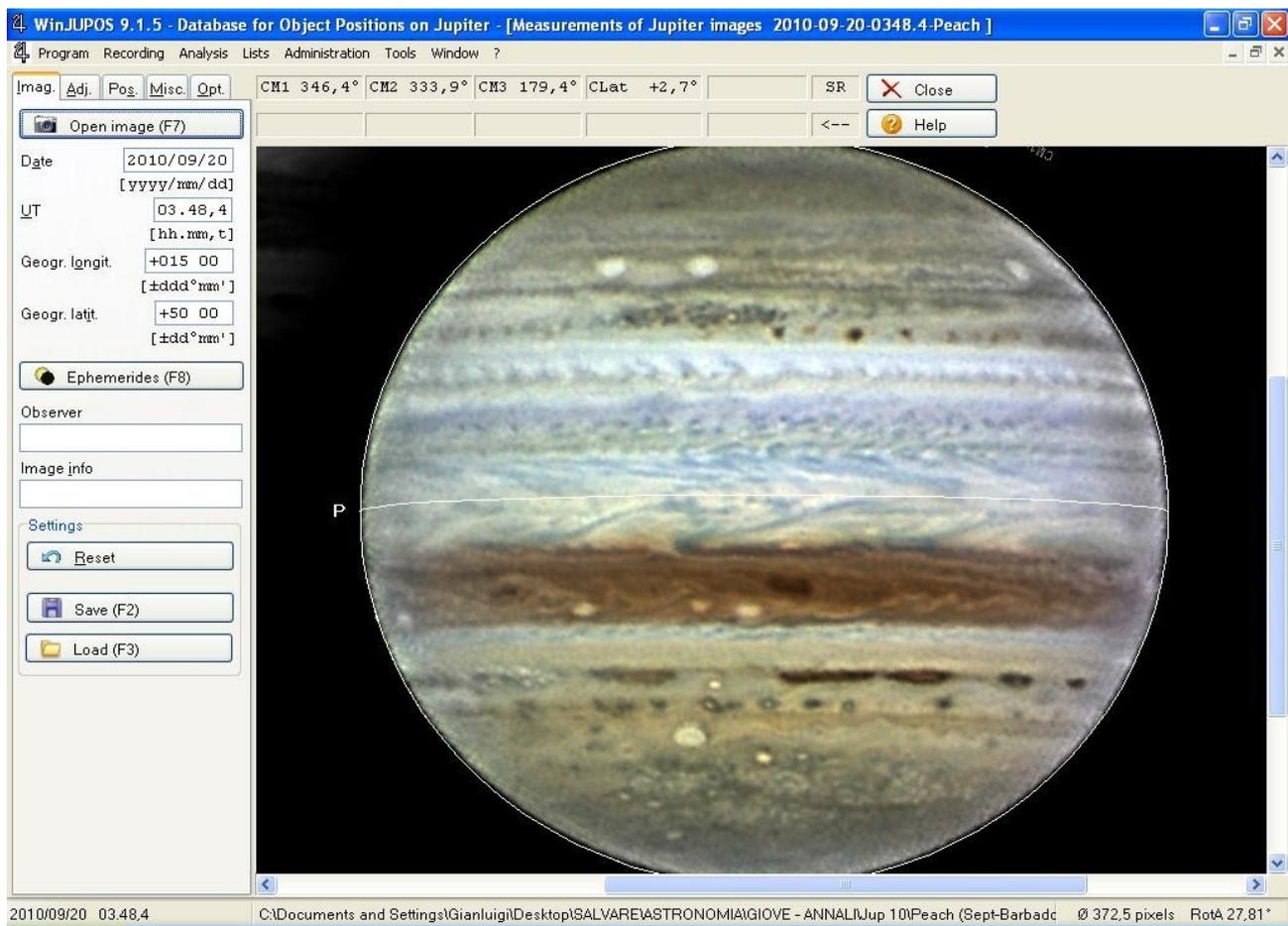
amateur tends to be self-taught, learning and trying new cameras and processing software as soon as new releases appear in the market.

On the other hand, one who dedicates himself or herself to image measurement and analysis tends to lose contact with such updates, so is not usually able to give but a few general recommendations to field observers.

One thing that an analyzer feels to recommend to newcomers, is to make experience of visual observing, to get acquainted with features that appear on Jupiter and will show on photographs.

About the acquisition process, it's advisable to have the light signal properly stretched over the sensitivity curve of the sensor, in order to use most of its "dynamics". On the other hand, saturation is to be accurately avoided over any part of the image, since it otherwise would produce loss of detail over the saturated area.

The image noise increases considerably when setting the gain of your camera to high values. But don't think to minimize noise by setting the gain too low. Jupiter has a natural limb darkening that may be not so apparent visually, but can lead to possible loss of signal, to nearly zero, in a narrow region along the limb. In this way, the subsequent sharpening process may further obliterate parts of the limb. Since the precision in the measuring process undertaken in the JUPOS project relies on the availability of the true limb, such an effect is potentially disastrous. See for example the following image, with the measuring masque superposed to show where the true limb is, taking account of the known latitude of some of the visible features. Even in this properly processed, high resolution image, you can see a slight but sensible effect of limb deletion. As written in "Tips for measurers", a smaller image than expected is frequently encountered, and imagers should be aware they must do all possible efforts to avoid or at least minimize such an effect.

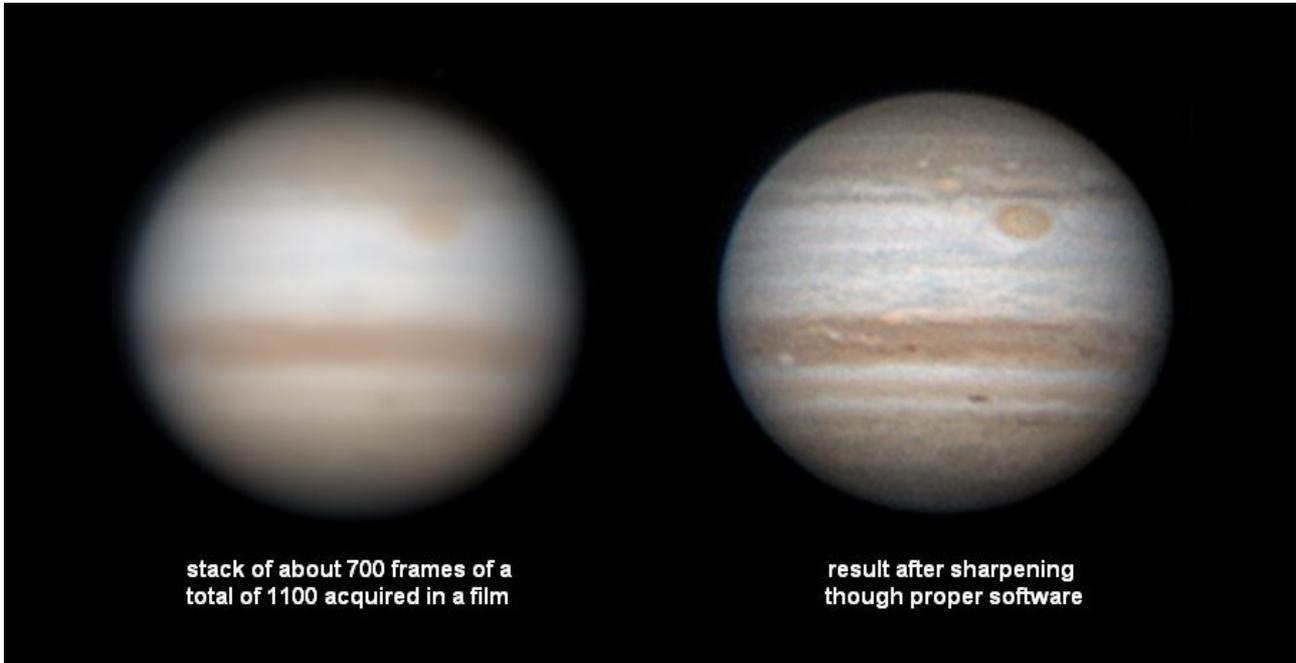


About the exposure time of the individual frames of a film, practical constraints lead imagers to choose a proper compromise. Shorter exposures can substantially "freeze" the atmospheric seeing, during fleeting moments when the telescopic image is temporarily more stable, often present even in less than ideal seeing conditions. Shorter exposures also permit higher acquisition frequency, which increases the number of good frames to stack, so smoothing noise. On the other hand, too short exposures lead to low light levels

available, making it worse if sky transparency is not so good or if we deal with a planet of low surface brightness (as well known, Jupiter is better in this respect than Saturn, but worse than Mars).

Image processing

The process of translation of a film into a still image has basically two steps: 1) aligning and stacking the best frames into a single “raw image”, so that averaging leads to minimum noise and enhanced signal; 2) sharpening through mathematical algorithms such as unsharp masking, wavelets and similar methods. You can see below typical results at the end of each of these two steps.



As a final retouch, one usually balances colours and contrast; many commonly use sophisticated software to further remove grain and render the final result aesthetically pleasing.

Even novice imagers have to follow the “learning curve” by themselves, given the many different programs available on the market. Many pitfalls, however, pave the way toward getting scientifically useful images, and at least some caveats must be underlined, though not exhausting this quite complicated topic.

It cannot be stressed too often that any sharpening process tends to delete a more or less wide portion of the limb. As said before, all precautions must be taken to limit such an effect.

Hard elaboration also tends to produce unnatural shapes of existing features, and to create artefacts, that are features often appearing deceptively similar to real ones, but simply non-existent, just the product of the mathematical algorithms employed. Try for yourself the difference between soft and hard elaboration; an example is reproduced below.



Imagers sometime tend to compensate for poor seeing with a harder elaboration: this temptation must be avoided. Any improvement that appears to be gained in features visibility is often simply artefact, or at least an unrealistic rendering of the planet. For the same reason, any further photographic retouch to the final image, even though rendering it more pleasing to the eye (for example reducing grain), almost invariably doesn't lead to more accurate results; instead, it tends to give ambiguous, if not strongly biased ones.

Some other pitfalls

If a composition is produced of images of different spectral range, such as red, green and blue to give a colour rendition, it is important to carefully check that their alignment be mutually congruent, i.e. they should not show any significant spatial offset. This can be easily done, for example, by switching between colour channels while examining the image under WinJUPOS (just repeatedly click the F9 key on tab Adjust. or Pos. of the measurement screen).

In the following example, the blue image was positioned substantially higher than the red and green ones, and that is betrayed by the blue line bordering some of the zones of the planet, and by the bluish hue over the whole of the Southern part of the disk..

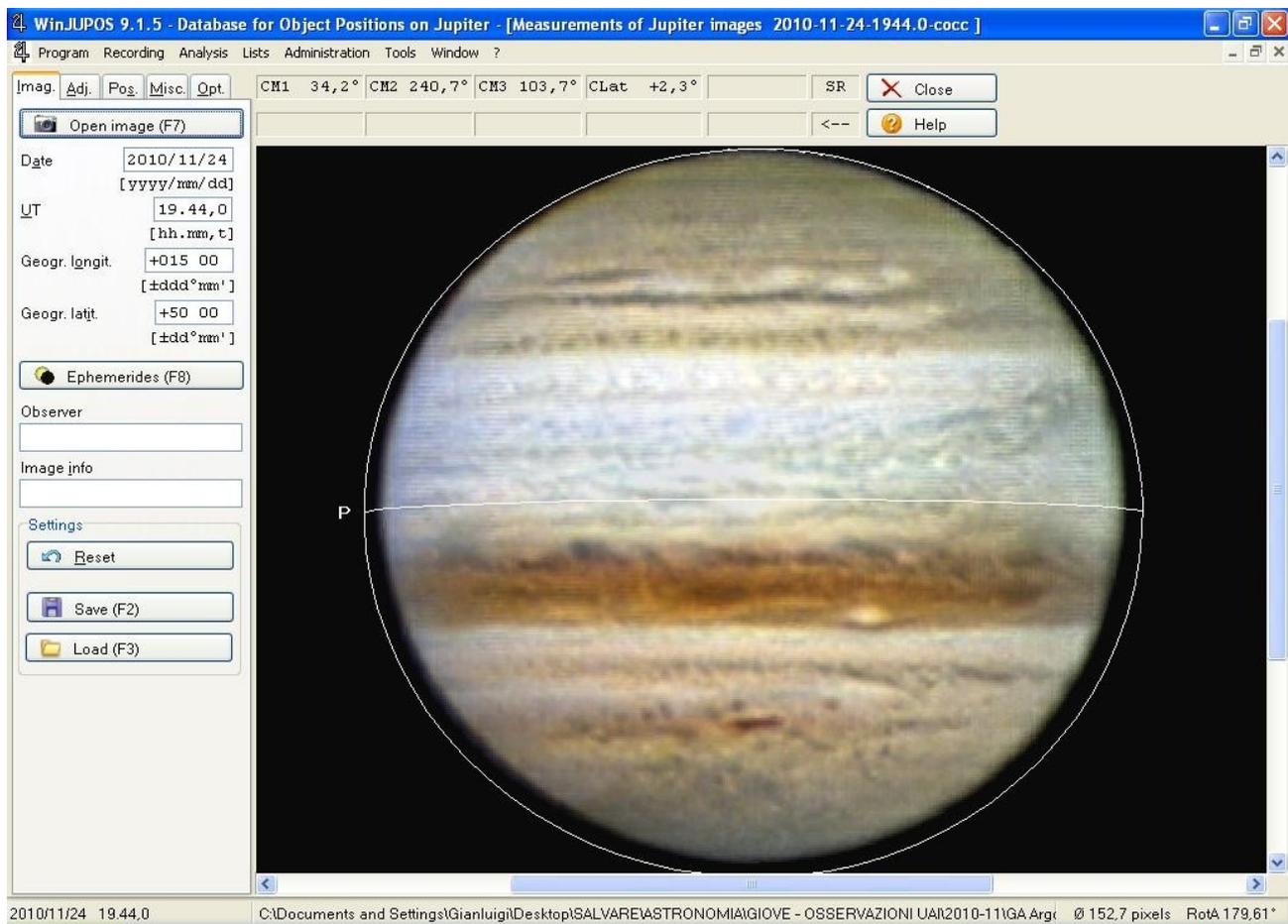


When the planet is low in the sky, an image acquired with a colour camera may show the effect of atmospheric dispersion, where the colours are shifted by nature itself relative to each other, with blue above, green centred and red below; his-res images can show a sensible shift even when Jupiter is relatively high. Check for this effect that can be compensated by elaboration programs through counter-shifting the frames by a few pixels.

We have stressed that elaboration tends to shrink the size of the planet. Rarely, an opposite effect is seen, with the apparent size larger than the actual one, usually by dispersion of light under poor seeing conditions.

Very rarely, North-South asymmetries are found, such that the Northern or the Southern limb of the planet appear darkened. It is quite impossible that the reason resides in the planet itself; sometime a shading effect in the optical path has been suspected. But we have ascertained at least one case in which improper use of the elaboration software was the cause.

In the following image, the WinJUPOS measuring masque has been placed over an apparently good image, in order that plausible latitudes are assigned to features of known position both in the Northern and Southern hemisphere. Besides revealing a general deletion of the limb all around, you can see that the Northern part of the disk appears selectively erased.



This defect arose by improper choice of the reference points on the disk that guided the alignment of the film frames: they were all picked up in the Southern hemisphere. This rendered the opposite limb more blurred in the “raw image” (the stack of the frames), and the subsequent sharpening led to a more pronounced deletion of it. Obviously, such outcomes can be very dangerous, since highly deceptive for the analyzer, especially if the asymmetry is subtler and not immediately evident as in the shown example.