Some Examples of Internet Planetology

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Abstract

When thinking about planetology, one usually invokes robotic or human space missions and other forms of state of the art technology. This line of reasoning may lead to the conclusion that planetology is a "reserved domain" for a restricted number of scientists. The aim of this lecture is to show on several realistic examples what can be done in planetology using the Internet, publicly available data banks and shareware software packages.

Introduction

Planetology is usually defined as a branch of astrophysics dealing with the study of bodies in the planetary system excluding the Sun. Problems related with the motion of these bodies are considered to belong to the "zone of interest" of astrometrists. In this lecture we shall demonstrate on various examples that research work in planetology can be performed by using just a computer with Internet access, publicly available data banks and software packages. The examples which we shall discuss pertain to various bodies in the solar system, and they are classified according to their distance from the Earth.

1 The Earth

All our practical life and scientific work takes place, or at least starts, at the surface of our home planet. The Earth and its neighbourhood are the objects of many kinds of studies by space probes, and it would be completely out of place attempting to review all of them here.

Broadly speaking, they can be grouped into two great categories:

- applicative studies and

- fundamental investigations.

The first group encompasses space missions like various communication satellites, the GOES satellites or the TOPEX/POSEIDON mission. Examples belonging to the second group are the POLAR satellite (devoted to the study of the aurora) and the CLUSTER mission aiming at the study of the magnetosphere. As this lecture contains the word Internet in its title, here is a useful url on which you can find a review of some aspects of Earth studies and observation: http://www.cnes.fr/WEB_UK/activities /programmes/sommaire.html. A wealth of photographs of various parts of the Earth's surface can be found at the address http://visibleearth.nasa.gov/. Entering the site http://www.esa int/ and searching for the key words "earth observation" gives access to 719 documents. The photographs on the first server already give the possibility to perform some planetological work. It is possible, for example, to follow the temporal changes of the surface of fertile land resulting from flooding and draughts, or to study the spread of smokes which are the consequences of forest fires and/or urban pollution ccorrelating data concerning the Earth's atmosphere and solar activity offers a much wider possibility for research work. Concern has risen in the past 20-30 years about the depletition of ozone in the upper layers of the atmosphere. To render things personal, I remember that in the early seventies, when I was in secondary school, sporadic "news notes" started appearing in "Sky&Telescope", in which first satellite observations of the depletition were reported. At the time,"ozone holes" have been detected only above the South Pole; unfortunately, they are now more extended. A lot of work has been done on the problems of the depletition of zone and the increase of the surface of the ozone holes. A specialized satellite, called TOMS (Total Ozone Mapping Spectrometer) is collecting data on the concentration of ozone in the upper atmosphere and its optical characteristics. This mission begun in 1991, and it will last at least until 2001. Its home page is at the address http://jwocky.gsfc.nasa.gov/TOMSmain.html. Apart from measuring on a daily basis the concentration of ozone, TOMS measures the quantity of solar energy which reaches the Earth's surface in the wavelength interval $290 \leq \lambda\,(nm) \leq 320$. The point is that radiation with wavelength in this interval is extremely harmful and can cause skin tumors and even cancer. Medical details about this problem are available at the addresses http://www.safesun.com/scientific.html and http://www.map2.ethz.ch/ lapeth/doc/www_uv.html

Data collected by TOMS open up a "window" into research work in planetology, but also plasma physics.By general physical arguments, one could expect that the depletition of ozone and the incoming solar UV flux at the surface of the Earth are correlated. Starting from such reasoning, I began following TOMS data for the Balkans, an in particular Yugoslavia, on a daily basis. It turned out that my basic idea was wrong - on multiple occasions the Balkans were in the zone with nearly the maximal possible incoming solar UV flux, while the concentration of ozone remained "moderate". What can be the explanation? It seems to me that there exist two possible outcomes: either there is a hidden "bug" in the data collected by TOMS, or, preferably, there exists an interesting open problem in the physics of the atmosphere. In view of its applicative consequences, this problem certainly merits detailed consideration, and someone from this audience could perhaps contribute to its clarification. It would also be useful trying to correlate data furnished by TOMS with those provided by the SOHO mission. SOHO is the acronym for "Solar and Orbiting Heliospheric

Observatory". Details about this mission, as well as the latest data on solar activity can be found at the address http://sohowww.estec.esa.nl/.

2 The Moon

Our satellite is so "faithfully" present in the sky spoiling deep-sky observation, it has been visited and observed by the missions of the "Apollo" program and many other probes, that the first idea may be that it is deprived of any scientific interest.T his is certainly not true, as we all have learnt from the Lunar Prospector mission. It has been launched in January 1998, and the mission ended in July 1999, with a directed crash in the lunar surface. The hope was that a cloud of water vapour would be detected. No such cloud was seen, although during the mission various on-board instruments indicated that it exists under the surface, and even its quantity was estimated. Information about the Lunar Prospector mission is available at the address http://lunar.arc.nasa.gov/ while details about the spacecraft itself can be found at the url http://nssdc.gsfc.nasa.gov/planetary/lunarprosp.html.

The lunar surface has been mapped ever since the invention of the telescope. Making a lunar atlas now would be deprived of interest, except, perhaps being a useful practice in astrophotography. However, using existing atlases, even those made a few decades ago, one can perform useful work.

An example of a lunar atlas has been compiled in the sixties, from photographs taken by the Lunar Orbiter spacecraft. It is accessible at http://www.lpi.usra.edu/research/lunar_orbiter. It exists also in "standard" form, as a NASA special publication [1] . Use of this atlas enables one to perform at least two kinds of studies of the lunar surface:

- the determination of heights and depths of surface details, and

- reflection spectrometry of the surface.

The necessary requirement for performing such studies is the ability of measurement of the relative brightness and coordinates of surface details. Standard software packages, such as Adobe Photoshop, do not give this possibility. It became common practice in astrophysics to convert all photographs which are to be used in research work into the so called FITS (Flexible Immage Transportation System) format.

The main motive for the introduction of the FITS format into research practice was to enable scientists to interchange data taken at different research institutions. Full details about FITS are available in the literature [2].

Practically speaking, an astronomical observation recorded in one of the usual formats (GIF,TIFF,JPEG,..) has to be converted into FITS, and then viewed and analyzed in a special software package. The first step can be performed in "Graphic Workshop", a software package for Windows 95/98 produced by Alchemy Mindworks Inc.,available at http://www. shareware. com/.

The choice of a FITS viewer is correlated with the characteristics of your computer. Of course, the best possible choice would be the FITS Data Analysis Software Package developed by NASA and available in the form of a CD [3]. However, do not envisage the use of this package if your computer does not have at least 64 MBytes of RAM. The computer used in the preparation of this lecture has only 32 MByte of RAM, a simpler package had to be found. The choice was the Avis FITS viewer, developed in Italy by Martino Nicolini and Fabio Carvicchio, downloadable freely from the Internet address http://www.sira.it/msb/avis.htm.

The determination of heights and depths of details on the lunar surface is based on a simple calculation. Denote the angular height of the Sun by α,the length of the shadow by s,and the height to be determined by H.

Using simple trigonometry, it can be shown that

$$H = stg\alpha$$

In this formula H and s can be expressed in pixels, and only later converted into "normal" units such as kilometers or miles, if the scale of the photograph is known. In the Lunar Orbiter atlas, the scale is not given directly, in the form of a number of kilometers per unit length. Instead,it is given indirectly, in the form of a diameters of certain craters (in kilometers) whose diameters in pixels are measurable on the photographs. The problem with crater diameters is that all of them do not have thin walls, which obviously enlarges the measurement errors of the diameters.

Physically, the determination of heights and depths in any specified region of a lunar surface is motivated by two scientific reasons:

- getting detailed information about a crater, cliff, ridge,..and deriving conclusions about their formation and selenological history;

- the other reason is comparative: studying, for example, similarities and differences between the surfaces of the Moon and Mercury.

As a practical example, we have determined the profile of a cross section of the crater Linne, famous from the epoch of the first landing on the Moon. This crater is suitable, because it has thin walls.

It is visible on photo 4-98H1.jpg of the Lunar Orbiter atlas. According to the procedure described earlier, this photo was at first converted into FITS, and then the relative brightness was measured in the vicinity of the crater. The result is shown in the figure 1.

The zero point of the coordinate system on Fig. 1 is placed at an arbitrary point near the crater, which means that only relative distances on the Fig. 1 have physical significance. It is stated in the atlas that the diameter of Linne is 2km, and the figure shows that it is equal to 8 pixels. This defines the scale of figure 1, and the whole photograph as 1 pixel = 250 meters. It can be estimated that the relative error of the diameter, and accordingly of the scale determined from it is $\leq \pm 10\%$.Using this value of the scale, simple inspection of the figure shows that the diameter of the small crater is around 750 m. The interest of this result is not so much the numerical value of the diameter, but much more the fact that the small crater is not visible directly on the photograph.

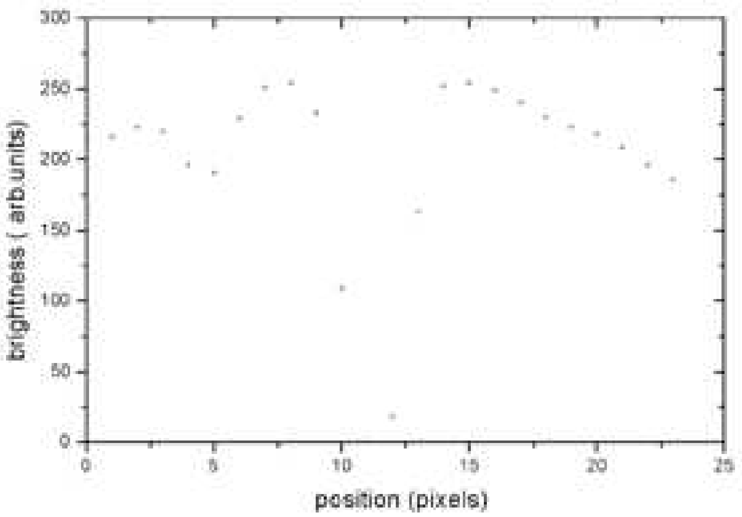

Figure 1: The relative brightness of the crater Linne

A minor clarification is in place at this point. We have repeatedly used the term "brightness" for the quantity measured on the photographs. Actually, it is the reflected part of the flux of solar radiation incident on the lunar surface. It could have been expected that the data would be normalized by dividing the measured values with the smallest of them. We have deliberately not done it, because the smallest measured value is in fact zero. In cases when the smallest measured value is not zero, it is of course necessary to normalize the results.

The determination of the brightness profile of Linne is just an example of the procedure which has to be used in such work. Using this method on a larger crater, or region, one could easily determine height profiles for more complex regions, such as some of the complex craters on the southern hemisphere of the Moon.

Reflection spectrometry of the lunar surface can be performed along the same principles, measuring the "brightness" as a function of position on photographs in FITS format. However, the big practical problem is that in order to get the spectra, you must have as much photographs as you can taken in different wavelengths.J udging from experience, these are difficult to find. However, a more interesting form of spectrometry of the lunar surface can be performed by using data from the Lunar Prospector. Those interested are advised to take a look at the web site of this mission.

3 The asteroids and Mars

Asteroids were discovered on the first night of the XIX century. Since then, until relatively recently, it was nearly impossible to envisage direct imaging of their surfaces. They were mostly visible as point sources of light, but, in spite

of that tremendous knowledge has been gained about them. A breakthrough in asteroid observation occurred with the launching of the Hubble Space Telescope (HST).Although Hubble's primary task is not to observe Solar System objects, it does so a certain fraction of its observing time. The HST has, for example, made the famous time series of photographs of 4 Vesta, which testifies about its rotation and inhomogenities on its surface. It is accessible at http://www/stsci.edu/.
The real "jewel" of space studies of asteroids is NEAR-Shoemaker, which is currently (in autumn of 2000) in orbit around 433 Eros. Details about this mission are available on the address http://near.jhuapl.edu/. What research work on asteroids can be performed using the Internet? Possibilities are numerous.

Earth, as well as space observations give apparent magnitudes of asteroids as a function of time. After appropriate reduction, analysis of these data gives the possibility of determining asteroid rotation periods and the orientation of their axes of rotation. The knowledge of these characteristics is important in planetology for constraining models of the origin of the asteroids and the whole planetary system. Several examples of asteroid rotation curves, with full details on the observing procedure are available at http://inferno.physics.uiowa.edu/RESEARCH_Proj/research_proj.shtml
. Asteroid. As an example of results obtained by observation of asteroids from space, the following figure represents the reflection spectrum of 433 Eros obtained from NEAR.

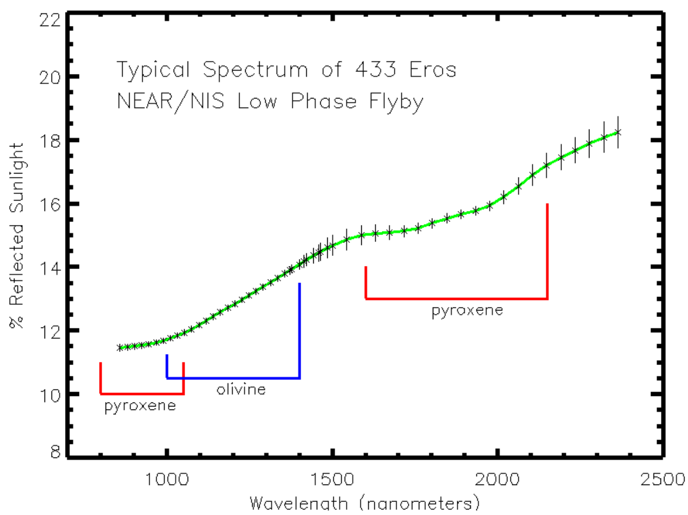

Figure 2: The reflection spectrum of Eros

The scientific interest of data like those in Fig. 2 stems from the fact that the reflection spectrum is a direct consequence of its chemical composition, implying that reflection spectrometry is one of the methods which can be used in determining the composition of the asteroids. Other examples of results from

NEAR can be found at the address http:// nssdc.gsfc.nasa.gov/ planetary/mission/near/near_science.html.

Space probes offer another possibility of research on asteroids, namely the analysis of their surfaces from photographs. The procedure used in such studies is similar to what we have described in the case of the Moon. As an example, take the image of Eros number 132151598, taken by NEAR on April 26,2000, from a distance of only 50 kilometers.

Scientifically, this photo is interesting because it shows nearly square shaped craters on the surface of Eros! Such a shape is highly unusual for craters,and it is interpreted by the mission control team as a consequence of the fact that Eros had cracks before impacts which formed the craters. Detailed interpretation certainly involves complex solid state physics,and demands the knowledge of the size of the craters. This can be determined, as the scale of the photograph is known. The result is that the biggest crater visible on the image is a square with the sides of nearly 900 meters.

Apart from the Earth, Mars is the only planet whose surface can be observed from the Earth an spacecraft. Existing atlases of Mars give the possibility of analyzing formations on its surface-determining the lengths and heights of mountains,ridges, cliffs,craters.A "library" of online atlases and maps of Mars is accessible at http://cmex.arc.nasa.gov/ MarsTools/ MarsAtlas Maps/MarsAtlasMaps.html. Due to the fact that space probes have landed on Mars, meteorological data are also available for this planet.

A typical plot of meteorological data collected by Mars Pathfinder can be accessed at http://mars.jpl.nasa.gov/MPF/ science/atmospheric.html. Data presented on this and similar figures give the possibility of following and modeling the diurnal changes of the temperature, as well as following the evolution of the dust storms on Mars.

4 Jupiter

Jupiter is the biggest and most interesting planet in the Solar System. It is being observed by all kinds of telescopes ever since the first evening on which Galileo pointed his first telescope towards it. Certainly, the most interesting object in its atmosphere is the Red Spot, a huge hurricane observable by amateur and professional telescopes and space probes. Since 1995, Jupiter is continuously being observed by the space probe GALILEO, in orbit around the planet. GALILEO has returned a wealth of results, many of which are available through the JPL at http://www.jpl.nasa.gov/.

As an example, we have in the following analyzed in some detail the image PIA 00720-14549.jpg, taken by Galileo on June 26, 1996. The image was taken at the wavelength on 757 nm, and the scale is 1pixel = 30 km. The original image was converted into FITS, and then the relative brightness was measured along the long axis of the Red Spot. The brightness was normalized, by dividing the measured values with the smallest one, and the length was expressed in a relative scale, by dividing the measured distances by the length of the Red Spot.T he result is shown in the following figure.

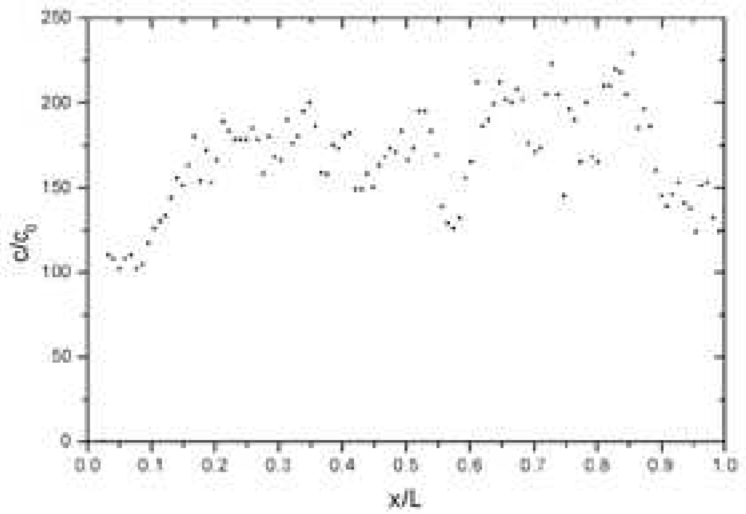

Figure 3: The brightness profile of the Red Spot

Obviously, this figure shows that the Red Spot is of highly non-uniform brightness. Physically, this can be interpreted as a consequence of the fact that the Red Spot is not one "storm" in the Jovian atmosphere, but actually a combination of several of them. The usual practice in situations like this is to decompose the profile obtained in experiment into a combination of simpler profiles. This task can now performed by using a software package called Origin, produced by Origin Lab (www. originlab.com). Decomposing the profile presented in Fig.3, into five Lorentzian profiles, one gets the following Fig. 4.

This number of Lorentizans was determined by picking the peaks of given height and width in the composite profile. The parameters of the Lorentzians thus obtained are given in the following table:

Peak	Area	Center	Width	Height
1	68.071	0.27169	0.41630	104.10
2	9.7933	0.15830	0.15865	39.297
3	5.8014	0.65291	0.069821	52.896
4	63.834	0.48748	0.53119	76.503
5	89.272	0.83597	0.36898	154.03

This analysis of the brightness of the Red Spot is just one example of work which can be performed by using publicly available data banks and shareware software packages. Our conclusion, namely that the Red Spot consists of several "small" storms is in line with results obtained by different techniques, such as the temperature measurements.

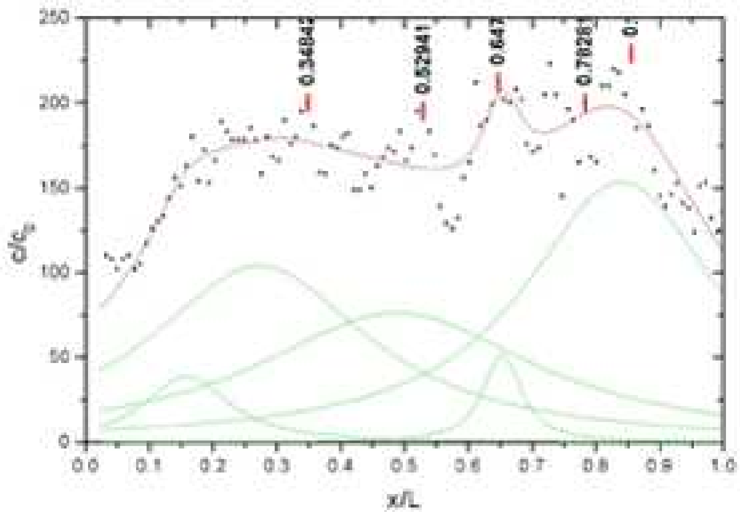

Figure 4: Figure 3 decomposed in 5 Lorentizans

5 Without space probes

In all the examples discussed so far, we have used data obtained by space probes. The obvious question concerns the possibility of work in planetology with earth based telescopes. Even for those in astronomy departments and institutes without telescopes, a real possibility exists to observe planetary system objects. The solution is of course based on the use of the Internet. Practically speaking, enter any of the search machines and as key words put "automated+telescopes". You will obtain a list of remotely controlled telescopes, connected to the Internet, on which you can request observing time. The waiting time is different, and depends on the location of the telescope, demand and meteorological conditions. Personal experience shows that the waiting time for telescopes in California can be just a couple of weeks.

In attempting any kind of observation,one has to have good ephemeris. For Solar System objects, a useful source of ephemeris is http://ssd.jpl.nasa.gov/. If you are into asteroid observation, a good source of ephemeris is http: //asteroid.lowell.edu/. Short range weather forecasts are available at http://weather.yahoo.com/ .

At the end, where can you find a top-level compilation of planetological data, such as the masses, radii moments of inertia,..which are needed for theoretical work in dense matter physics applied to planetology? The best address is http:// nssdc.gsfc.nasa.gov/planetary/

Conclusion

In this lecture you have not heard new and exciting results in astrophysics. Its aim was methodological, to provide you with practical advice on how you can start research work in planetology, which is rapidly developing and applicable field of astrophysics. The methods described can be applied in any branch of astrophysics, and even pure physics.

References

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