Lab #3: Computer imaging — Astronomy 184L — Life in the Universe

Due by 2 October 2009

The goals of this lab are for you to get some experience looking closely at space imaging and to make some measurements of astrobiologically interesting features on other bodies in our Solar System. These techniques are fundamental to the modern study of astrobiology.

The assignment is described below. **This assignment is due by 3 pm on 2 Oct 2009.** Only hardcopies – no electronic versions – are accepted. Please work with a partner you have not worked with yet. The goal of working with a partner is to make less work for you and for you to have someone to talk over your procedure and results with. Both group members will receive the same grade for this lab. You should turn in one (1) final lab per group. You should have plenty of time to do a good job on this lab if you do not procrastinate working on it.

1 The assignment

Look on the course web page for this lab (lab #3). There are four sets of images, one each for Mars, Europa, Enceladus, and Titan, which are at present the four most astrobiologically interesting bodies (besides Earth) in the Solar System. *Your assignment is to answer any two (you choose) of the four following questions.*

(1) Mars. These images were taken by the Mars Reconnaissance Orbiter.

These three images of Mars show gullies in various crater/cliff walls. Estimate the total width of *all* the gullies in each image, combined. What percentage of each cliff wall is gullies?

In images 2 and 3, it looks like the gullies start not at the surface (top of the cliff), but about a third of the way down or so. What depth below the surface does this correspond to? You can assume that the cliff walls have a slope of 30 degrees (the angle of repose). What are the temperatures and pressures at this depth below the surface? You can assume that Mars' surface temperature is 220 K and that the subsurface temperature on Mars increases by 15 K for every 1 km you down. You can also assume that the pressure at depth h is approximately $\rho g h$, where ρ is the density of rock and g is the acceleration due to gravity at the surface of Mars. (Be careful with your units here.) Given the pressure and temperature that you calculate, is it surprising that liquid water could have originated at those depths? If you're not sure, you can check the phase diagram of water[1].

(2) Europa. These images were taken by the Galileo spacecraft.

Image #1 shows a part of the Conamara Chaos region on Europa. The most accepted explanation for this unusual topography is that part of a thin ice shell broke into icebergs and drifted apart on the surface. What percentage of this image is the "old" material (with the grooves on it), and what percentage is "new" matrix material (in between the icebergs)?

There is a block toward the center top of this image that has a strong shadow to its left. This block is particularly interesting in the iceberg model. Imagine that this iceberg is a titled block (plate) of ice, with the lower right side submerged. This block cannot be very thick, or else the shadow on the upper left would fall on the block, and not onto the surface of Europa. We might imagine that this plate's thickness represents the local thickness of the Europan ice layer (over the global ocean).

What is the thickness of this plate of ice, and therefore the thickness of Europa's ice sheet locally? You can assume that the Sun is 30 degrees above the horizon to the right, and that the block is tilted 60 degrees down from upper left to lower right. I'm sure it will help if you draw a picture of what's going on here.

[1] For instance, at `http://www.physics.nau.edu/~trilling/teaching/fall2008/lecture/lectures/lecture20/s60.3.html`

Image #2 shows a large fault (dark stripe horizontally across the image). The insets for this image show the vertical profiles of one of the cracks running through this image. The height of these ridges is around 300 meters, and the ridges are separated by around 1.5 km. What is the displacement across the fault (dark horizontal stripe)? That is, how much has Europa's surface spread in this region (in the vertical direction)? How does this compare to the displacement on a big terrestrial fault like the San Andreas fault?

What is the approximate volume of the ridges shown in the right side insets? If the ridges took 1000 years (no one knows, really) to form, and formed from material that was ejected from a liquid water ocean beneath the ice, what was the rate of water ejection here?

(3) Enceladus. Enceladus is a moon of Saturn. These images were taken by the Cassini spacecraft.

There are three different pictures of the Enceladus plume on the web page. Measure the height and width of the plume as seen in each of the three pictures. Estimate the volume of water in the plume, assuming that it is a cone ($V = \frac{1}{3}\pi r^2 h$) and that the space density is 1% (that is, that only 1% of that plume volume is actually water, and the rest is just the vacuum of space; the actual space density is probably a lot less than this). Are your answers the same in all three cases? Why or why not?

One theory for how the plume arises is that there is a subsurface reservoir of water that is under pressure and jets out its water periodically — just like the geysers at Yellowstone. If the plume sprays for, say, a week at a time before emptying the reservoir, what is the volume of this underground reservoir? How does this water ejection rate compare to the one you derived for Europa in problem 2?

An equation that describes this relationship between geyser spray velocity and subsurface overburden (from Bernoulli's equation):

$$\frac{1}{2}v^2 = gh$$

where v is the velocity of the plume material, which Porco et al. estimated to be around 60 m/s; g is the acceleration due to gravity at Enceladus' surface; and h is the subsurface distance. (Note: You'll probably need to use the Universal Law of Gravitation here, which says that $g = GM/r^2$.) Using this equation, how deep under the surface must the liquid water reservoir be?

(4) Titan. The Titan images were taken by the Huygens lander probe (image #1) and the Cassini spacecraft (image #2).

In image #1, what fraction of Titan's surface is covered with pebbles? Discuss briefly how this differs from the lunar landscape, and why.

Image #2 is of a different region on Titan. This is a radar "image," which means that the dark areas are smooth (no radar reflection), and the bright areas are rough. This is typically interpreted as showing liquid (dark) and land (bright) – that is, an ocean and a shoreline. Discuss briefly how the part of Titan shown in image #2 compares with the terrestrial image (of where?) given, and what implications there may be for Titan's geological history.

Also: Check out the series of circles that can faintly be seen in the center to left of the terrestrial image. What might those be?

2 What do we turn in?

You should turn in one assignment per group. Your entire lab might be just a few pages. You do not need to turn in any hardcopies of these images, but of course you'll need to show all the work that you do.