Give opening lecture on the geological activity of the moon. Does is posses volcanoes, earthquakes? No. Why? It is small enough to have cool of enough to no longer be geologically active. This will eventually happen to Earth. In this lab we will see if this is the case for all moons in our solar system.

Section I: Io

1. Figure 1 is an image of our own moon. What features do you notice? (Volcanoes, craters, lakes/oceans, etc.)

Figure 1: Our Moon

2. Does the moon appear to have an atmosphere?

3. Figure 2 shows many of the large moons in our Solar System to scale. What other moons are similar in size to our moon?

Figure 2: Large moons of our Solar System

4. Which moons look like our Moon? Which moons do not?

5. Figure 3 shows a detailed image of Io, the first Galilean moon of Jupiter. Describe it's surface (colors, features, etc).

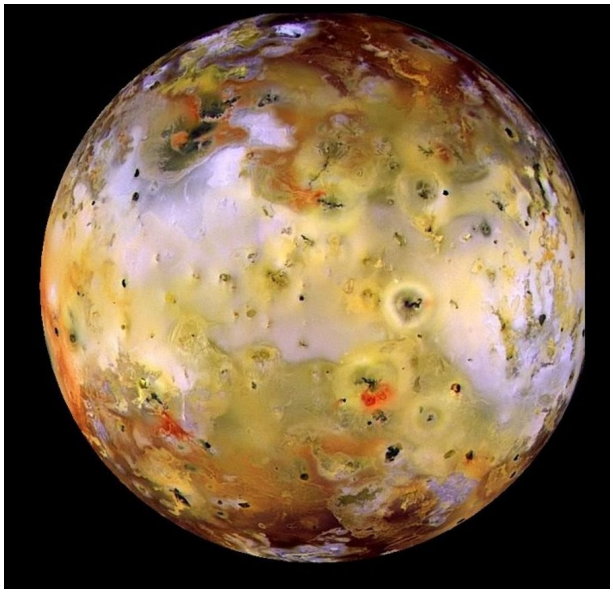


Figure 3: Io, the first Galilean moon of Jupiter.

6. Does Io appear to have craters?

7. Does it have more or less craters than our Moon?

8. Figure 4 is an image taken by the New Horizon's Spacecraft on February 28, 2007. How may active regions do you see on Io? Circle them on the picture.

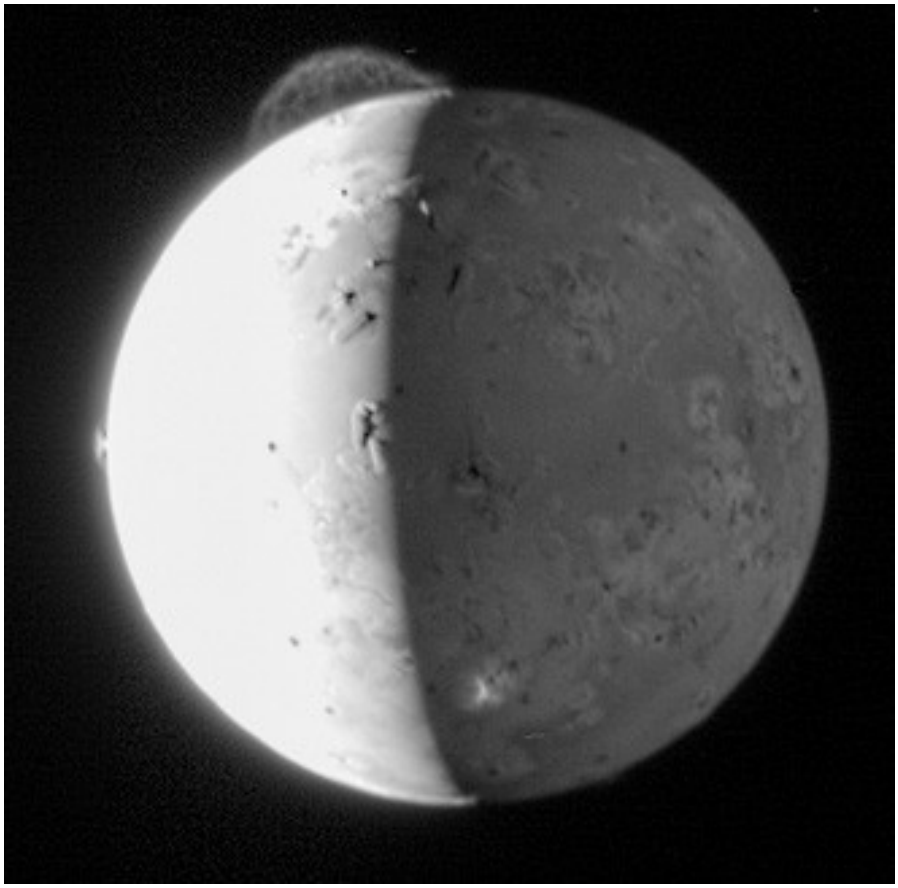


Figure 4: Io as viewed from the New Horizon's spacecraft

9. What do you think the plume could be? For example, gas, liquid, solid, ice particles, dust particles, lava, etc. There is no right or wrong answer, this is just a hypothesis.

10. Figure 5 is an optical image of Io while Figure 6 is an infrared image of Io, which displays temperature. Blue represents the coldest regions and white the hottest. What do you notice about the surface temperature of Io?

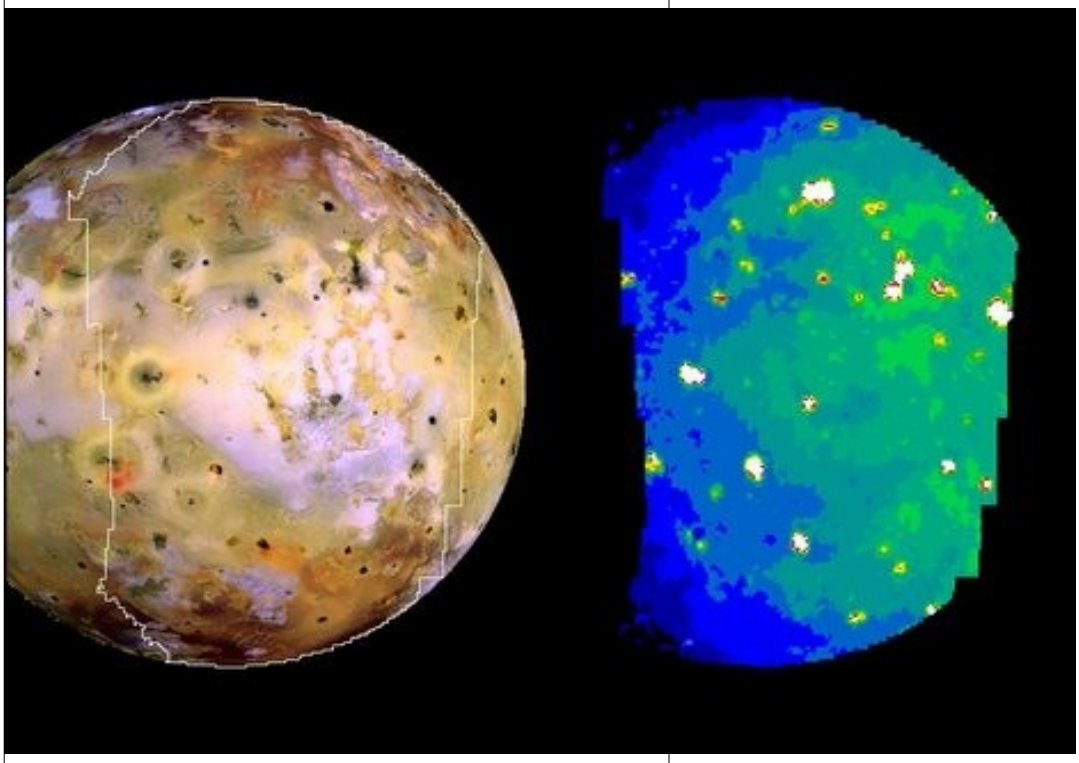


Figure 5: Optical image of Io.

Figure 6: Infrared image of Io

11. Using figures 5 and 6, what do you think the dark features in Figure 5 really are? Hint: they are not craters.

12. Io is the most geologically active body in the entire solar system. But earlier you were told that the Moon is not geologically active because it's too small. Given the size of the Moon and Io, should Io be geologically active?

13. Something is acting on Io to make it active. To help understand this, take the elastic band you were given and touch it on the area above your upper lip. What is the temperature (hot/cold)?

14. Now stretch the band quickly about 30 times (they should stretch about 5-6 inches) and note the temperature. Did it change?

The band is heated due to frictional forces caused when you stretch the band. (Frictional heating also occurs when you rub your hands together vigorously). The stretching of the band is a result of different forces being applied to either side of the band. This can be visualized if you think of your thumb holding one side of the rubber band fixed while you stretch it on the other side with your other hand.

Figure 7: Rubber band being stretched on the left and held fixed on the right.

The total stretching force being applied to the rubber band is equal to the strength (represented by size of the arrow) of the force being applied.

Now, instead of one side of the rubber band being held in place, we can apply more force on one side than another. But if the force is being applied in the *same direction,* then the rubber band is not stretched as much, as seen in Figure 8. Subtracting the two forces shows we have less total force being applied.

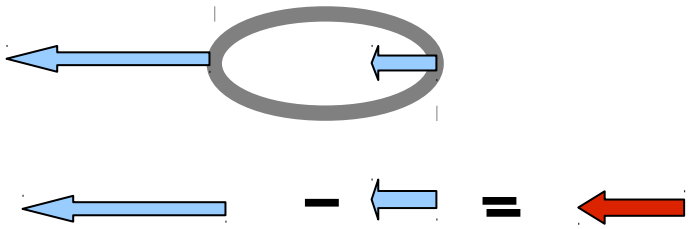


Figure 8. Different sized forces applied the same direction results in a less total stretching (red arrow) of the band.

Lastly, we can apply forces in *opposite* directions on either side of the band. This is result in *more* stretching, as see in Figure 9.

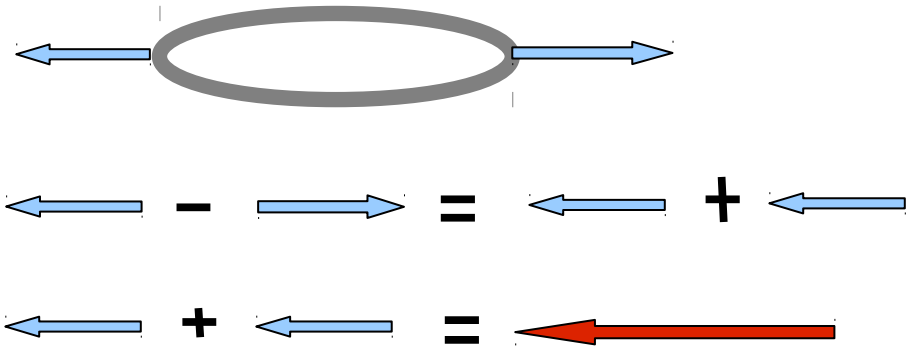


Figure 10. Equal forces applied in opposite directions increases the total stretching force (red arrow) on the band.

The force that causes this stretching in astronomical bodies is *gravity*. Gravitational force decreases as the distance between two bodies increases.

$F = G*M*m/d^2$
G = gravitational constant
M = mass of Jupiter
m = mass of Io
d = distance

In this case we consider Jupiter and Io. The side of Io facing Jupiter is closer than the side facing away from Jupiter, therefore, the closer side it will experience a larger gravitational force than the side facing away. Figure 11 shows Jupiter and Io (NOT TO SCALE!!!) with arrows representing the direction and amount of gravitational force being applied on Io.

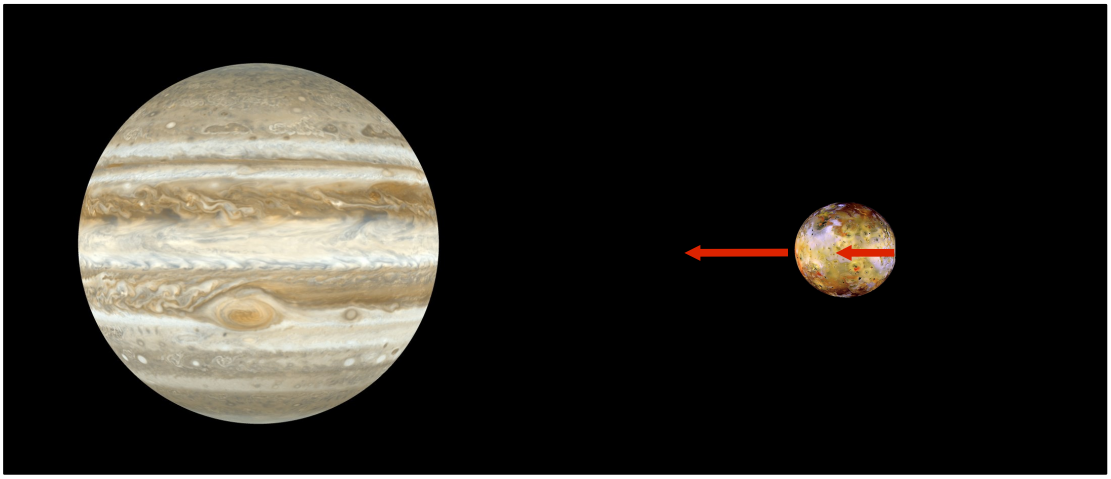
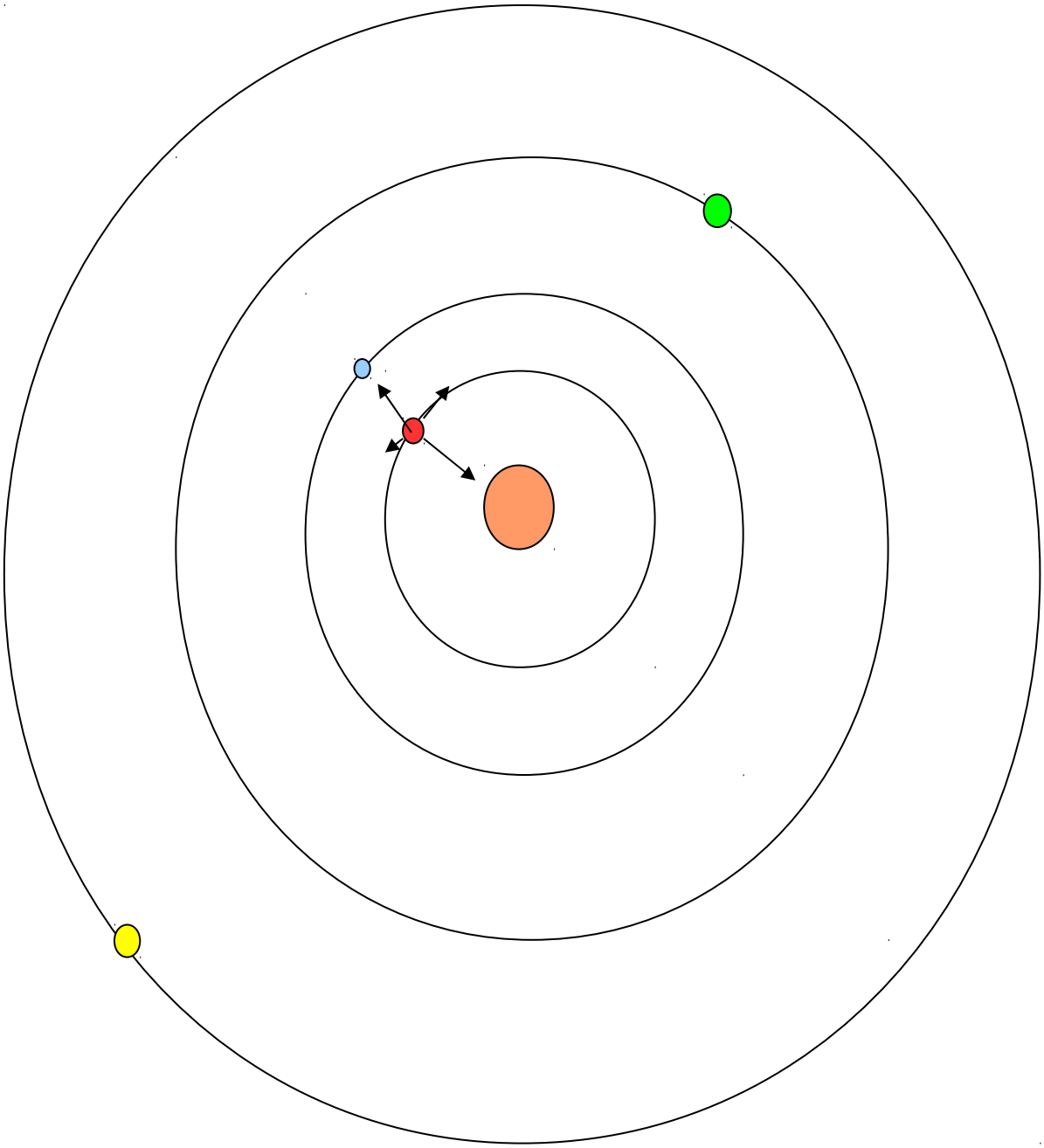
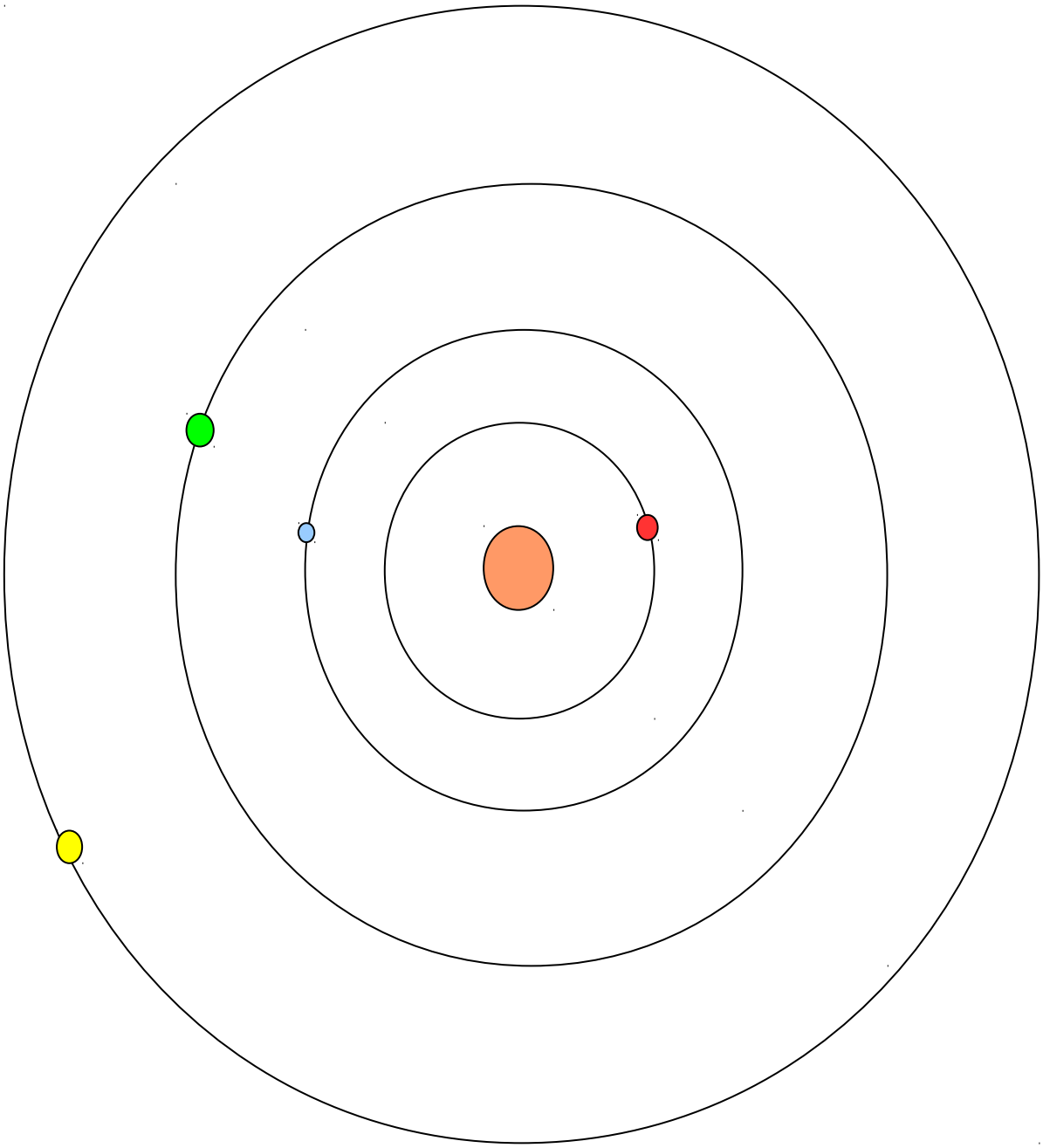


Figure 11. Gravitational force on near and far face of Io due to Jupiter.

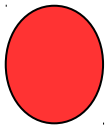
15. Redraw the arrows in Figure 11 below and draw the total stretching force being applied to Io (similar to the example show in diagrams 9). This total stretching force is known as a **TIDAL FORCE**.

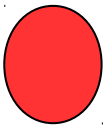
16. Below is a top down view of Jupiter (center) and the four Galilean moons Io (red), Europa (blue), Ganymede (green), and Callisto (yellow). The gravitational force from each body on Io is represented by arrows. Since Jupiter is so large and close, it has a large force arrow. Draw the force arrows due to Jupiter and each of the other Galilean moons on Figure 13. Draw long arrows for large amounts of gravitational force and short arrows for small amounts of force. Remember, force decreases and distance increases.





17. In order for Io to experience tidal heating (frictional heating like when you stretched your rubber band), it must experience *changing* tidal force (like when you repeatedly stretched and relaxed the band). Redraw the force lines you drew on Figures 12 and 13 to show that the force is different for the two scenarios.





Section II: Europa

18. The order of the Galilean moon is Io, Europa, Ganymede, and Callisto. Aside from Io, which other Galilean moon would you expect to experience tidal heating? Why?

19. Figure 13 shows Europa, the second Galilean moon of Jupiter. Does it look like our Moon? Does it have craters?

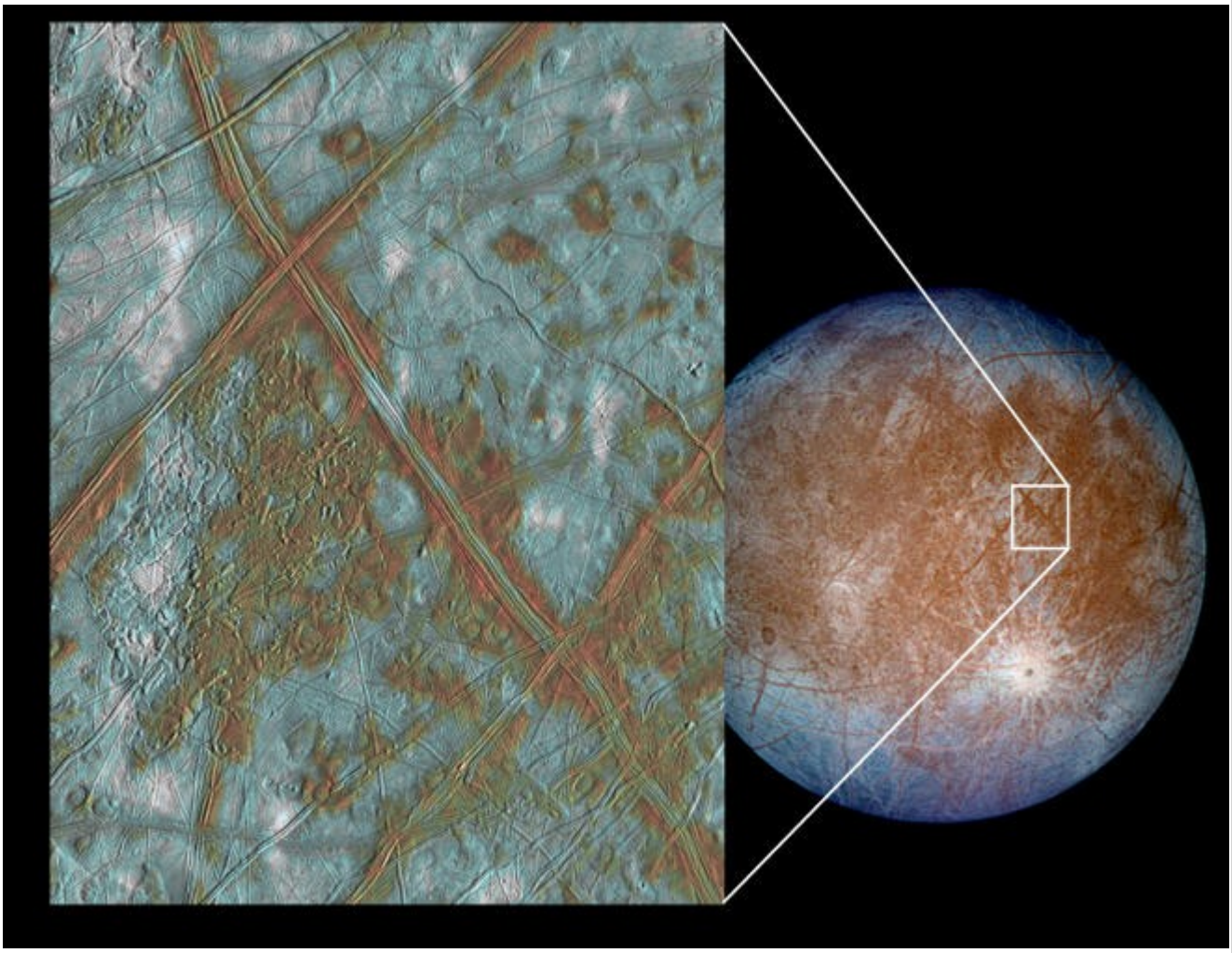


Figure 14: Images of Europa, the second Galilean moon of Jupiter

20. Figure 15 is a close up of the surface of Europa and Figure 16 is a picture of ice flows on Earth. Using this and the figures of Europa, what do you think is covering the surface of Europa?

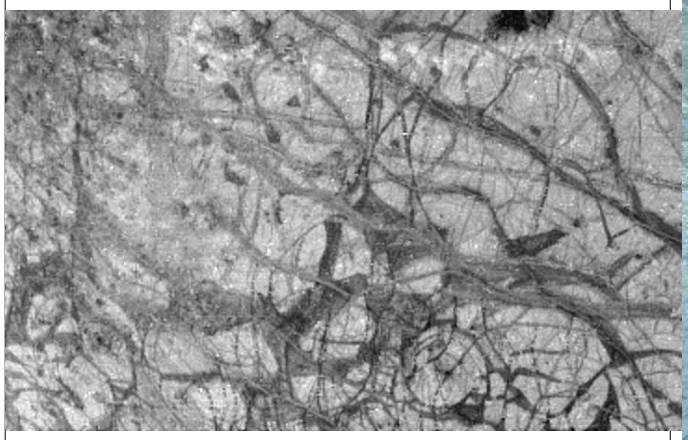


Figure 15. Surface of Europa

Figure 16: Ice flows on Earth

21. When considering the possibility of life outside of Earth, Europa is one of the most likely places to look. Why do you think that is?

Section III: Roche Limit

22. We now know that stretching an object repeatedly will cause it to heat up. Returning to your rubber band, what would happen if you stretched it *too* far?

23. What would the tidal force on Io change if Io were moved closer to Jupiter?

24. What do you think would happen to Io if its orbit were MUCH closer to Jupiter?

24. There is a limit past which no moon can survive the gravitational pull of its planet. This limit is called the Roche limit. The Roche limit of an astronomical body is located *roughly* 2.5x the radius of the body. Calculate the Roche limit of Jupiter and fill it in the table. Is Io close to Jupiter's Roche limit?

Table 1	
Object	**Distance**
Jupiter's radius	~71,000 km
Jupiter's Roche Limit	
Io	~ 420,000 km
Europa	~ 670,000 km
Ganymede	~ 1,10,000 km
Callisto	~ 1,90,000 km

26. Saturn has a radius of ~60,000 km, where (roughly) is it's Roche limit located?

27. Table 2 lists the location of the various rings of Saturn. Are they located inside or outside Saturn's Roche limit?

Table 2	
Ring	**Distance**
D	~ 70,000 km
C	~ 83,000 km
B	~ 105,000 km
A	~ 130,000 km
F	~ 140,000 km

28. Speculate how Saturn came to have rings.