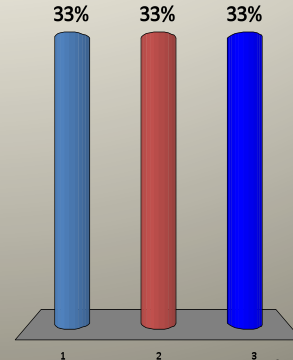
Which of today's learning objectives seem most difficult?

1. 3 Key req. for life found on Europa's & why we don't expect abundant life.
2. Explain Habitable Zones, planet type & conditions.
3. Exoplanets found: effect on planet formation theory & how we plan to I.D. life.



Remember to set your channel to 80!

2

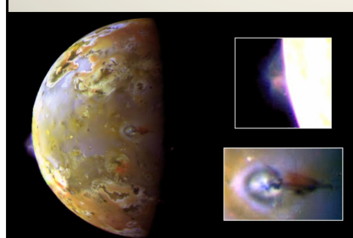
Which is NOT a way for a planet or moon to retain geological activity?

1. Fusion reactions at its center
2. Fission reactions at its center
3. Latent (left over) heat from formation
4. Tidal heating

Remember to set your channel to 80!

3

Small moons can be Geologically Active!



Consider: Jupiter's moon <u>Io</u>

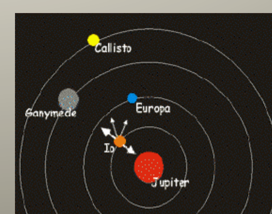
Not a single crater here. The entire surface is smooth and multicolored from various sulfur compounds.

Those are active volcanoes! <u>Io</u> is THE MOST GEOLOGICALLY ACTIVE BODY in the solar system! Yet its even *smaller* than Mars (<u>Io</u> and Europa are the size of Earth's Moon).

How does this happen?

Tidal heating from Jupiter and the outer three massive moons. <u>Io</u> is being pulled in all directions, and is worked like 'taffy', kneading the moon to remain hot at its center.

But <u>Io</u> is so hot, all of its water has boiled off long ago. In our search for life, we will move one moon further from Jupiter.. To Europa. The `goldilocks' moon



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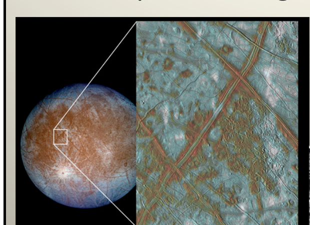
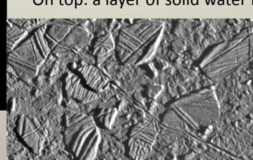
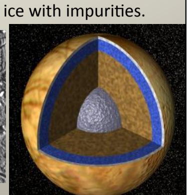
Europa: The largest ocean in the solar system



Its surface is void of craters. Instead, it shows many cracks and iceberg-looking features.

Deep beneath: a solid metal core and rocky mantle. But above that: ice, slush or possibly liquid water. On top: a layer of solid water ice with impurities.





<u>Evidence for liquid ocean</u>

1. Lack of impact craters: requires a resurfacing liquid.
2. Chaotic terrain: iceberg-like blocks appear to have been moved.
3. A MAGNETIC FIELD. This requires a conducting fluid: salty ocean.
4. Calculations indicate tidal heating is sufficient to keep this much water liquid.

Where there is liquid water, there is the possibility for life

http://www.youtube.com/watch?v=7vAUMS6VtXo

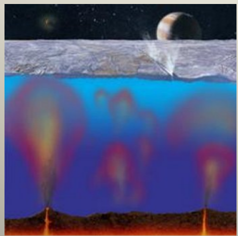
5

Which below is not one of the THREE REQUIREMENTS for life?

1. A Liquid (probably Water)
2. Protection
3. Source of Energy
4. Elements (raw materials) for life

6

There is liquid water, but where would Europan life get the needed elements and energy?



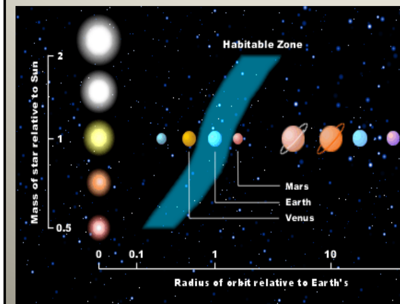
The ocean is heated by a warm, possibly volcanic upper mantle which *may provide* an exhaust of chemicals and elements needed by life.

IF these vents occur they would also provide chemical imbalances in the rock/water boundary, which chemo-autotrophic life might thrive around, just like it does at the base of Earth's oceans around black smokers.

NOTE: the abundant life seen at the base of Earth's oceans is greatly fortified by life above (organic debris falling to ocean floor). If black smokers are the ONLY source of energy/organics, life on Europa will be **very, very, very simple and small**. See Fig 9.17 in book!

Earth, the Goldilocks planet

Earth lives the perfect distance from our Sun for liquid surface water



If our Sun was BRIGHTER Mars may be in the habitable zone. If our Sun was DIMMER, Venus might be in the habitable zone

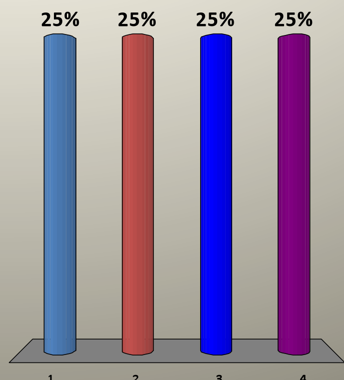
As a star ages, the habitable zone changes. Stars get brighter with time, then dim at `death'.

Can life exist outside of the habitable zone?

Yes! …At least we are hoping so: Consider Mars and Europa

Our moon exists in the Sun's habitable zone. Why is it not habitable?

1. It was a captured moon.
2. The zone definition only applies to Earth-like planets .
3. It has moved out of the habitable zone.
4. All of the above.

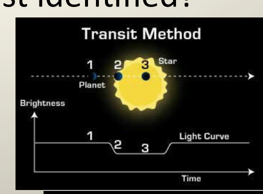


What is an exoplanet?

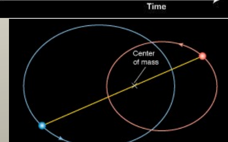
1. A demoted planet (like Pluto).
2. A planet in the outer Solar System.
3. A planet with an exotic atmosphere
4. A planet around another star.

How where exoplanets first identified?

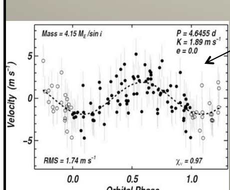
Exoplanets are too dim to see *directly*, but we can see changes in their host star. This is called, *indirect* detection.



Indirect methods recognize the influence a planet has on their host star.



There are three indirect techniques:
1) Astrometric: see the host star moving

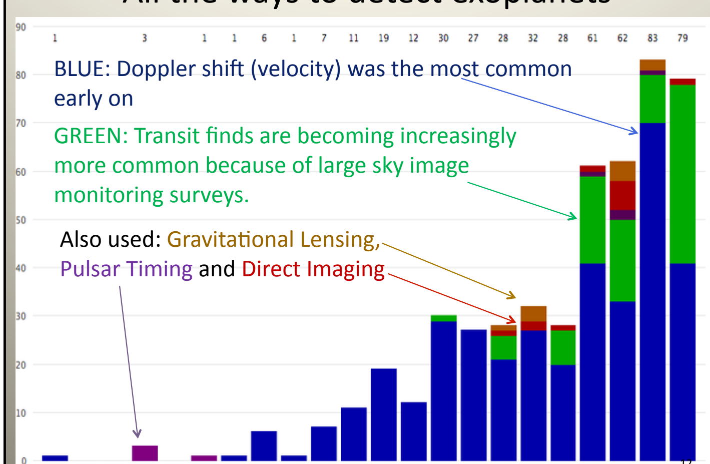


2) Doppler: velocity motions in the host star spectrum

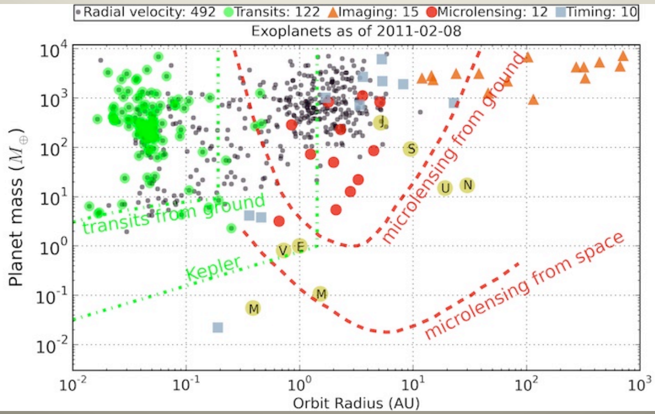
3) Transits: the light from the host star drops as the planet moves across the front.

> 500 exoplanets have now been discovered.

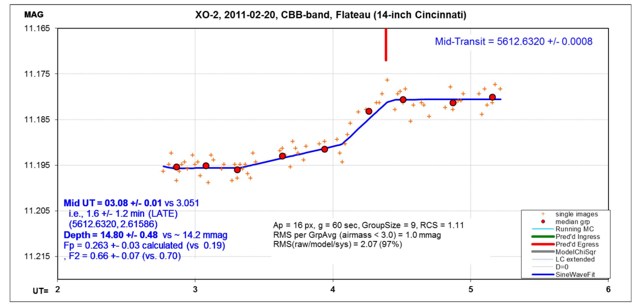
All the ways to detect exoplanets



The cover of Nature, 3 February 2011



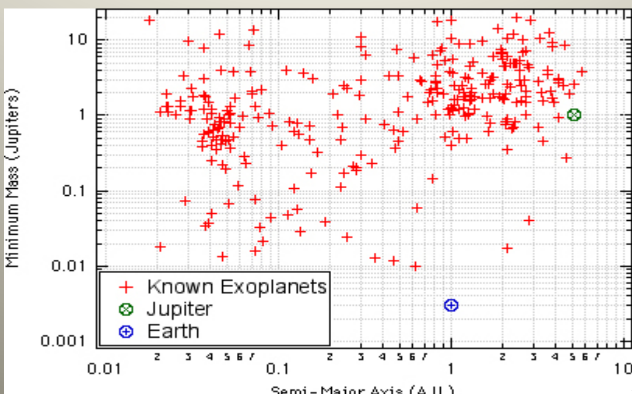
Exoplanet transits detected at UC's Braunstein Hall Telescope!



As part of their senior Capstone, several astrophysics majors have detected the transit of an exoplanet with UC's 14" telescope on the top of Braunstein Hall.

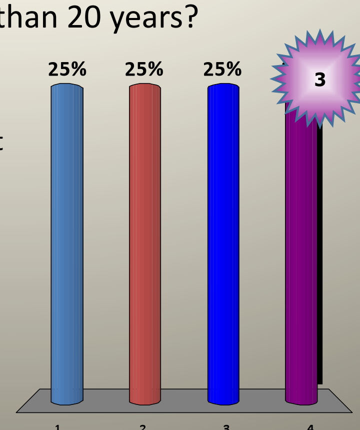
What do these exoplanets look like?

High Mass (all more massive than Earth) and near their host star.



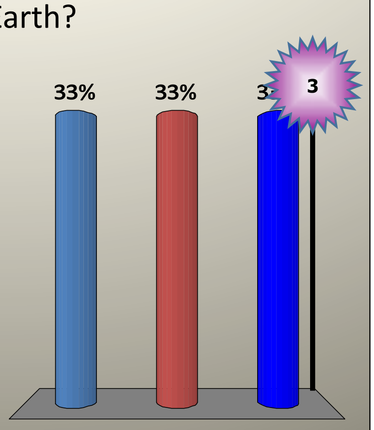
Why have we not found exoplanets with orbital periods greater than 20 years?

1. None exist.
2. Our measurements don't go back far enough.
3. These planets are too small to detect.
4. We have found exoplanets with 20 year orbital periods.



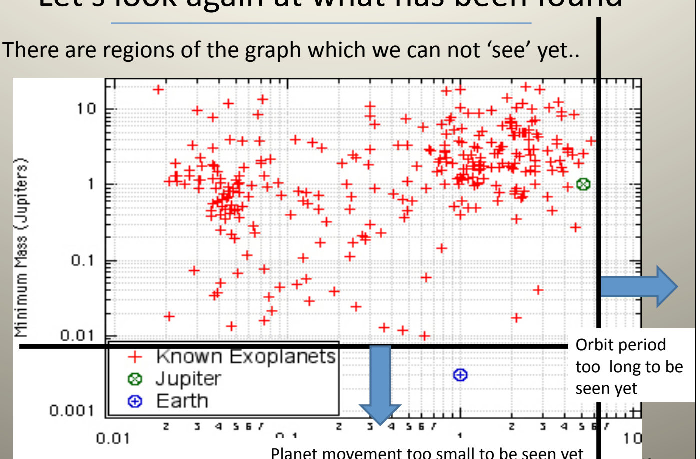
Why have we not found exoplanets with masses as small as the Earth?

1. None exist.
2. Our measurements are not sensitive enough.
3. We have found exoplanets with masses as small as Earth.



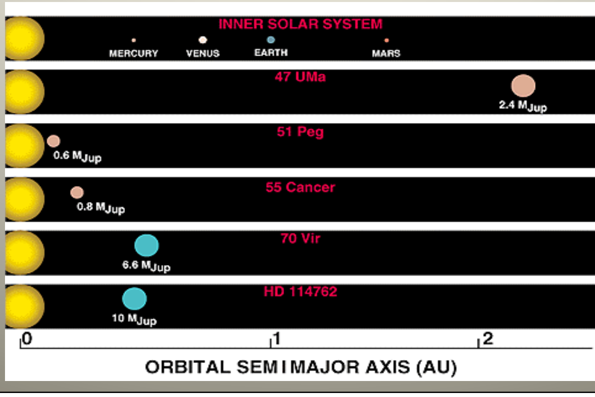
Let's look again at what has been found

There are regions of the graph which we can not 'see' yet..

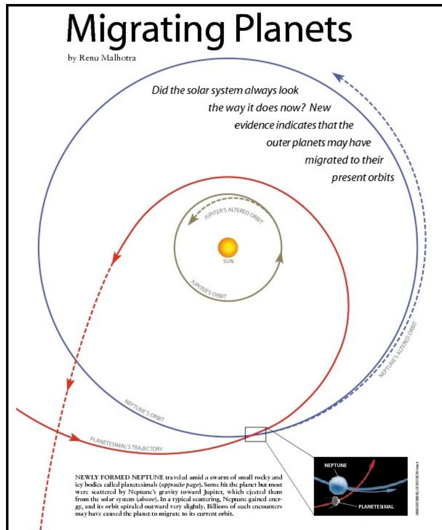


What do these solar systems look like?

There is something very wrong with these solar systems!
Why would 'Gas/Ice Giants' form where Terrestrial Planets form?



19



Evidence of migration in our own solar system!

What have we learned from exo-solar systems?

Collisions, leading to migration, can move planets from their original formation zones.

This is how Gas Giants exist at 'Terrestrial' locations. They migrate to the inner solar system *after* formation.

20

Where are these exoplanets?

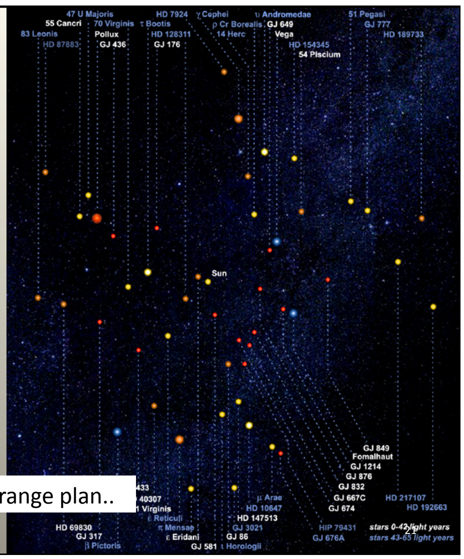
Most are within 100 light years of us.

Most probably have terrestrial planets that have not been detected yet. (But they will!!)

Researchers have concentrated search efforts on Sun-like stars. Why??

Might there be life on planets in any of these solar systems?

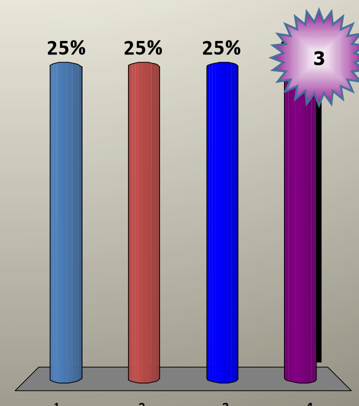
This is part of the long range plan..



21

How does NASA intends to detect life on a distant exoplanet?

1. Image the surface to look for life
2. Send an orbiter and lander to bring back samples.
3. Take spectra of its atmosphere
4. Look for water in an image of its surface.



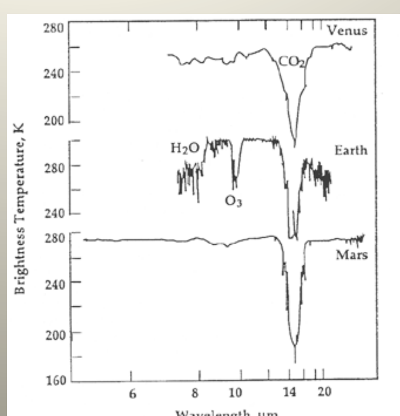
22

Water (H_2O) and Ozone (O_3)

NASA intends to put powerful telescopes in space which can obtain enough light from the planet (and not the star).

If we detect absorption of water and ozone in the planet atmosphere, we will know it has life.

If we don't detect it, there might still be life.

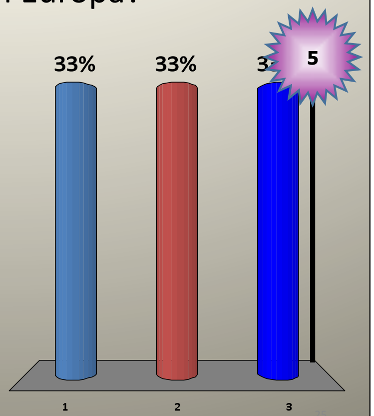


23

End of Class Quiz!

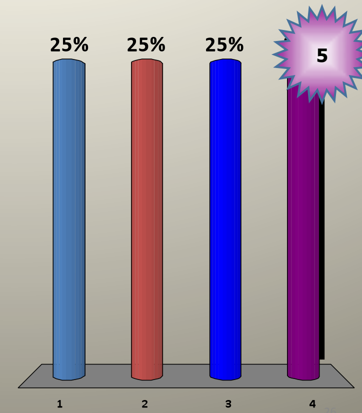
1. Which of the three requirements for life is only marginally met on Europa?

1. Liquid water
2. Source of Energy/ organics
3. Source of raw materials.



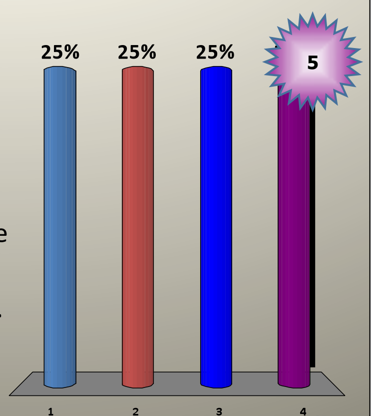
2. The definition of a star's habitable zone applies only to moons or planets that are ..

1. like Earth
2. not too close
3. not too far
4. All of the above.



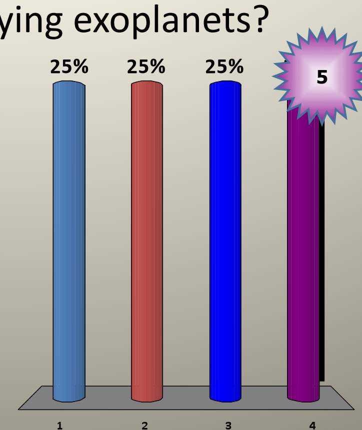
3. How might life exist outside a stars habitable zone?

1. It has significant liquid water
2. It has a source of elements
3. It has a significant source of energy
4. All of the above are met.



4. Which below is not an indirect method for identifying exoplanets?

1. Transits
2. Doppler technique
3. Astrometric technique
4. All are indirect methods



5. Most exoplanets found thus far are …

1. Short period, high mass
2. Short period, low mass
3. Long period, low mass
4. Long period, high mass