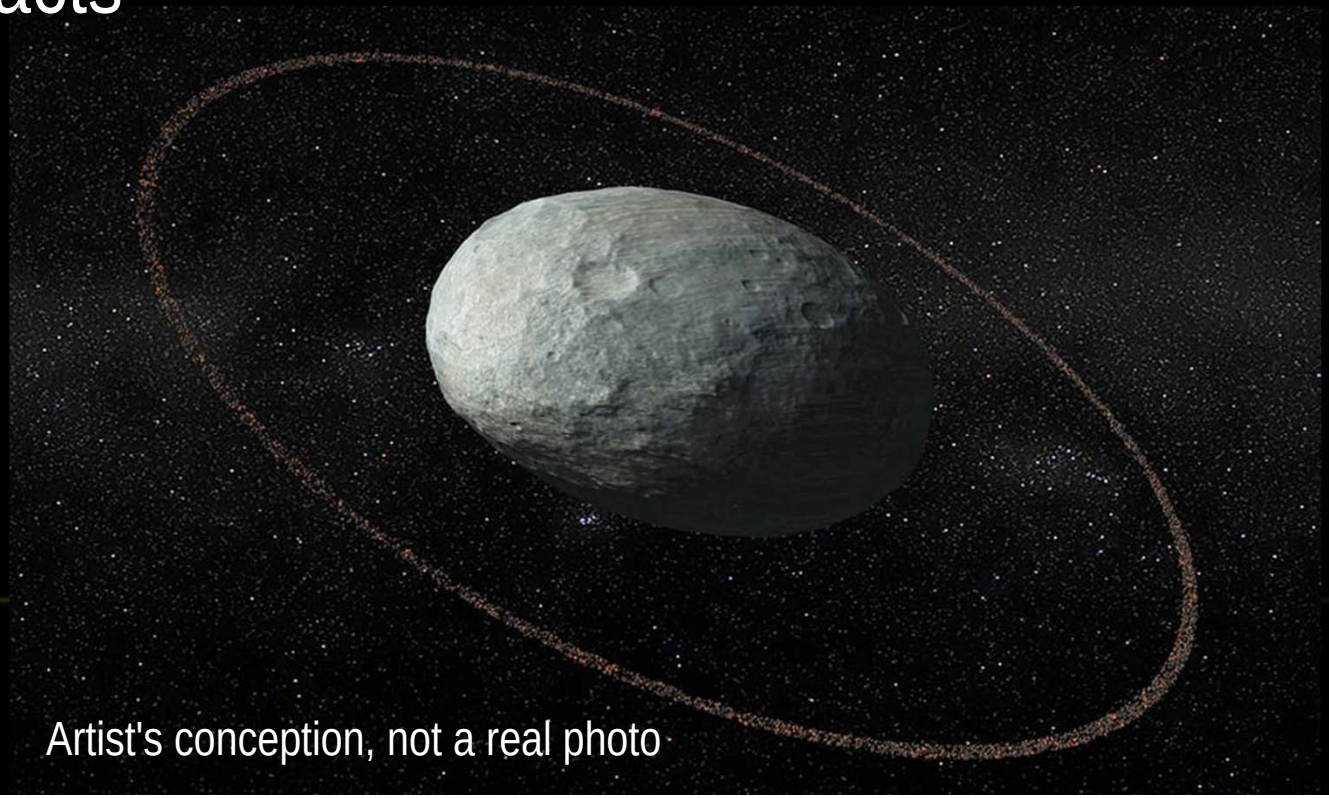
RING DISCOVERED AROUND DWARF PLANET

- Haumea, a dwarf planet in the Kuiper Belt was just found to have a ring. Why? Hint: what causes the Jovian planet rings?

Artist's conception, not a real photo

RING DISCOVERED AROUND DWARF PLANET

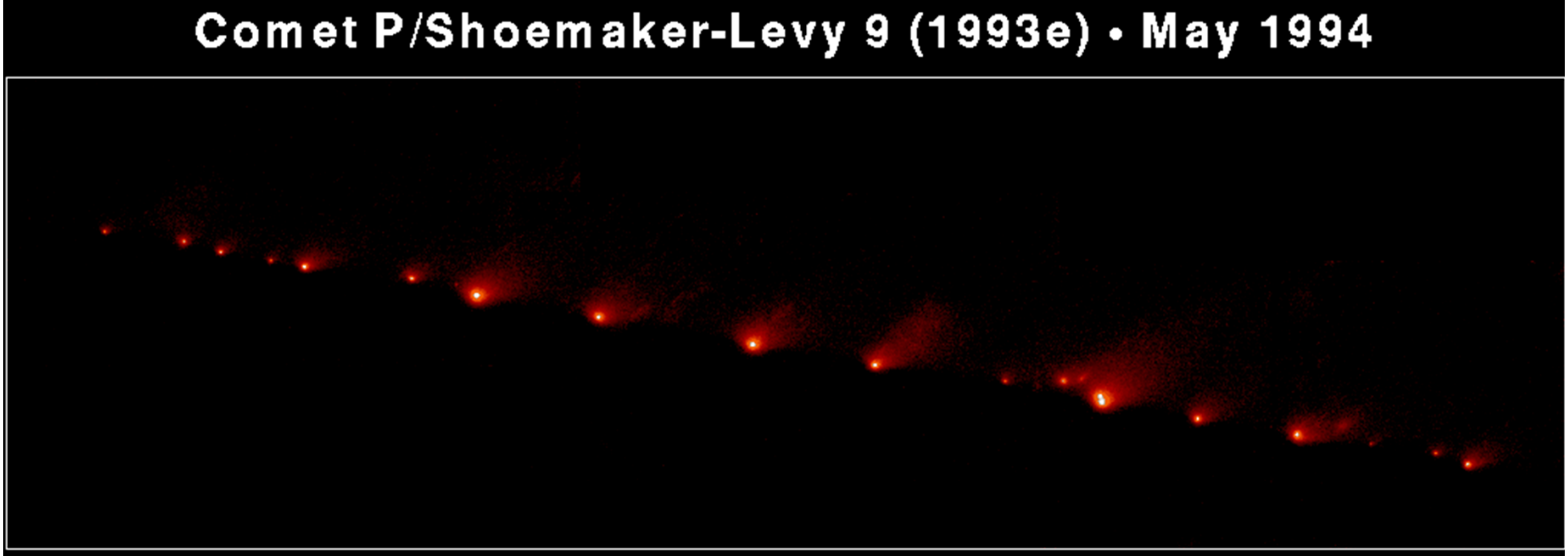
- Haumea has two moons, the larger of which is in the ring plane: probably moon dust from impacts



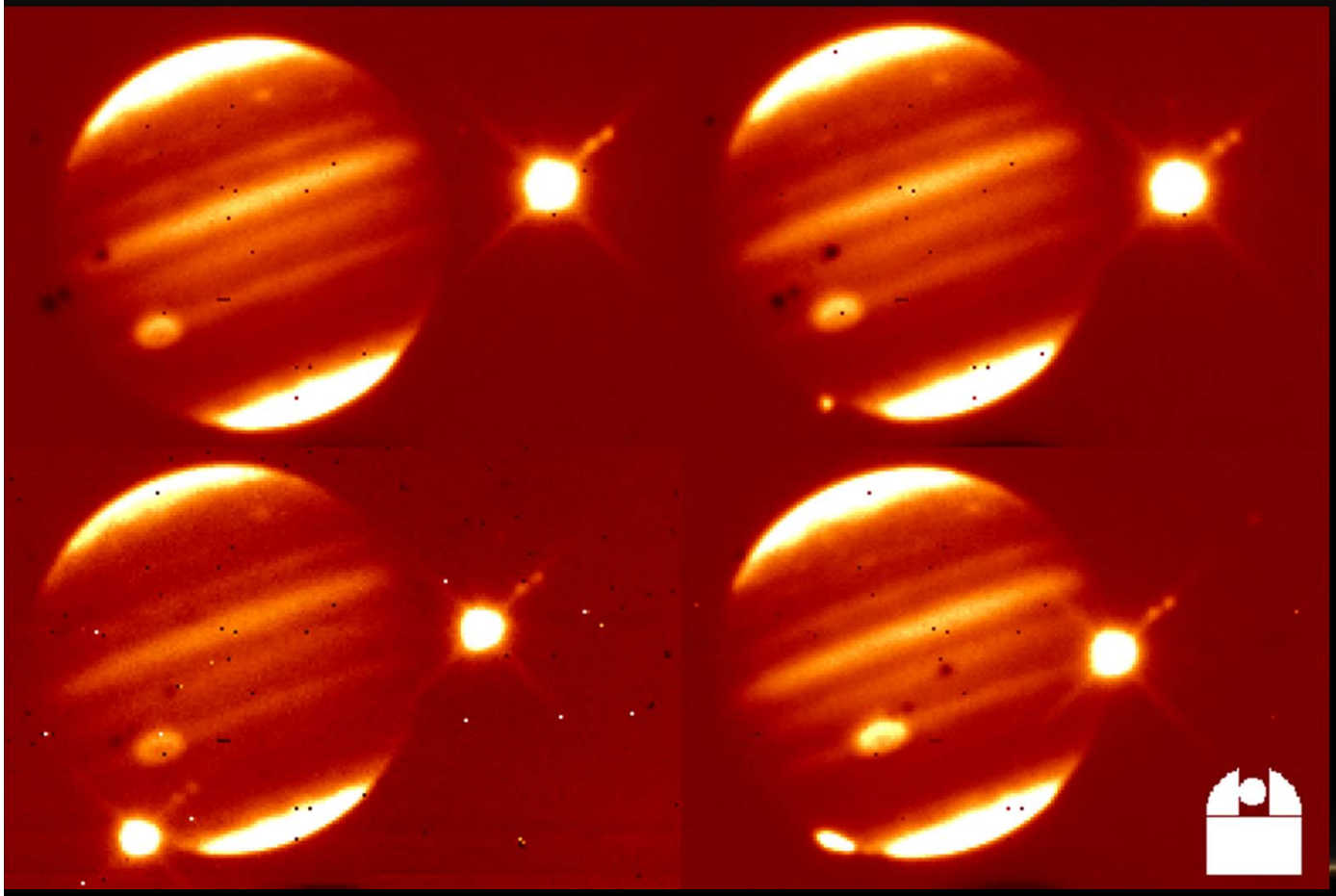
Artist's conception, not a real photo

COMET SHREDDED

- A comet got too close to Jupiter, broke up due to tides



COMET IMPACT



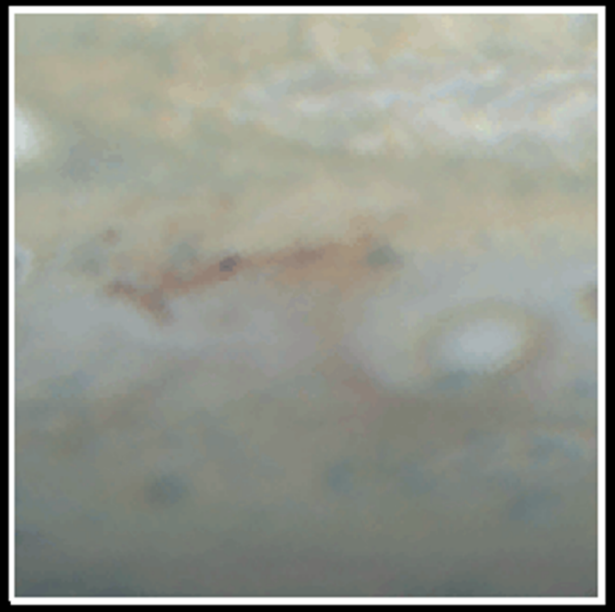
- Infrared sequence showing first chunk hitting Jupiter
  - Lower left
  - Moon Io is bright thing in upper right
- Spectra of fireball gives composition of comet

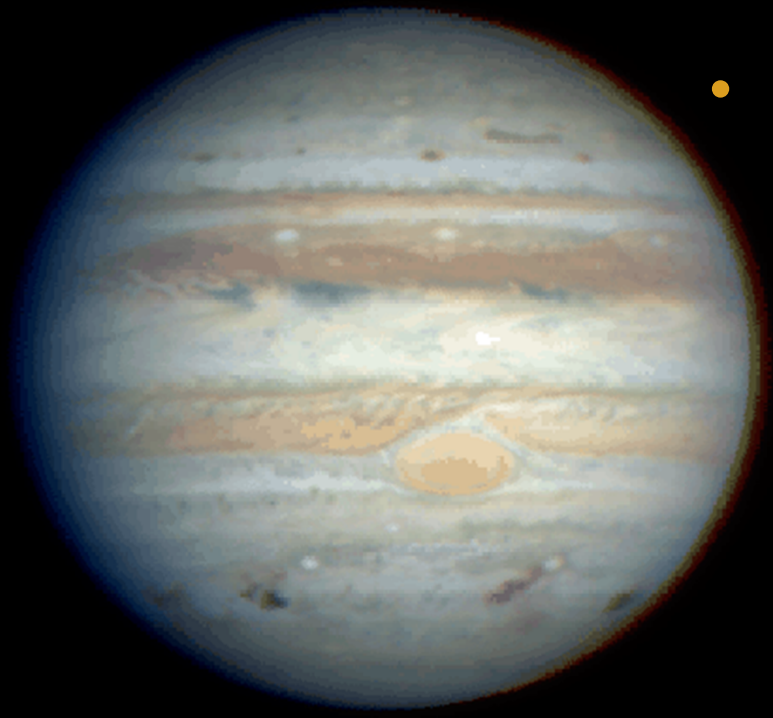
Calar Alto IR Observatory photos, courtesy
Max Planck Inst. fuer Astronomie, Heidelberg.

Jupiter 22 July 1994

ATMOSPHERE STIRRED UP

"A" impact site
after 5.5 days

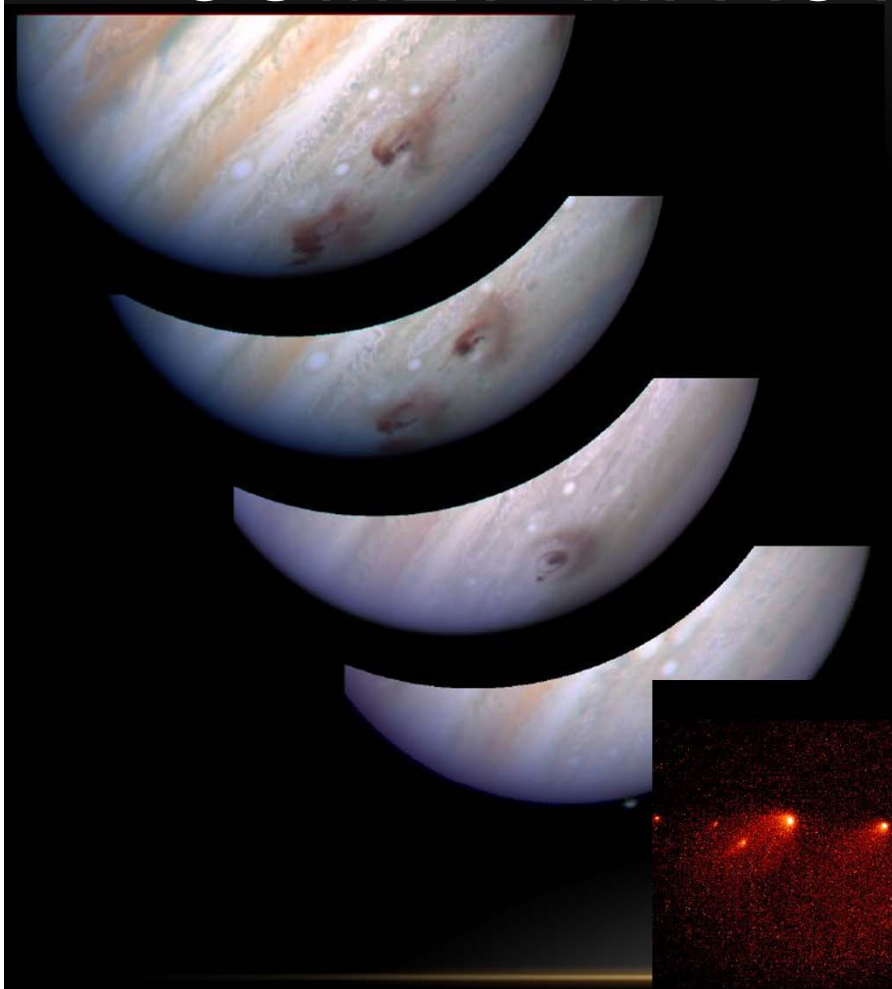




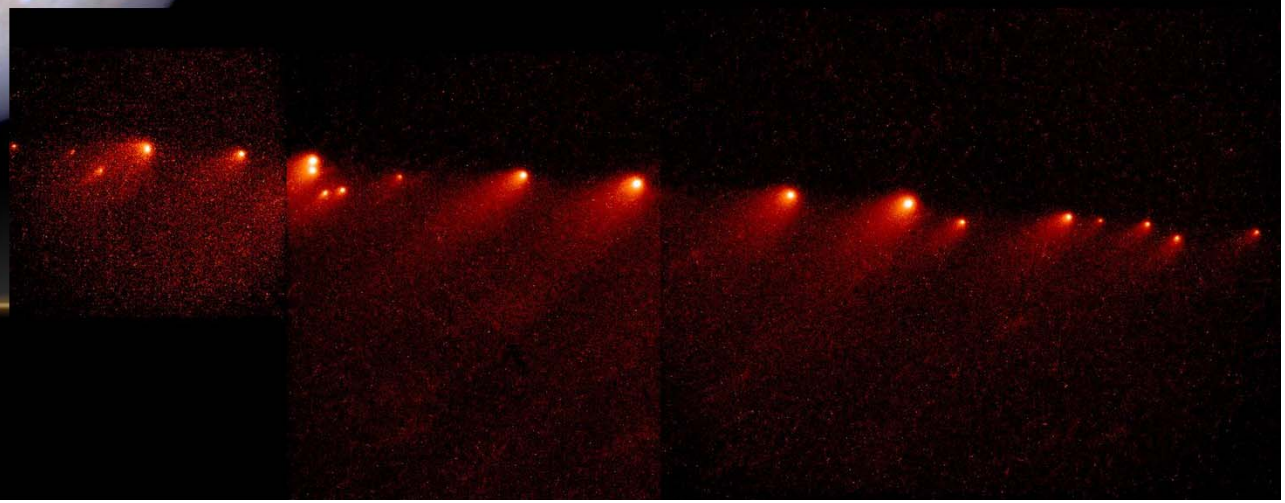
- Study of impact sites helps us understand Jupiter's atmosphere

Hubble Space Telescope
Wide Field Planetary Camera 2

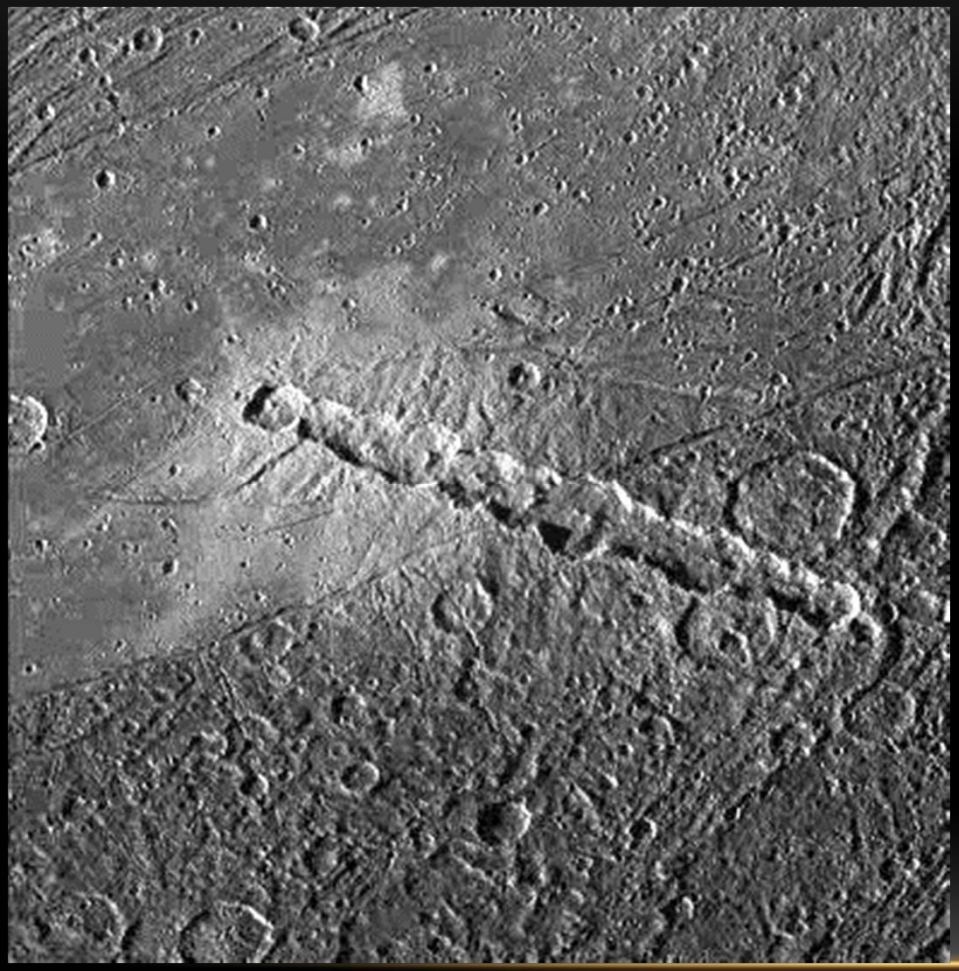
COMET IMPACT



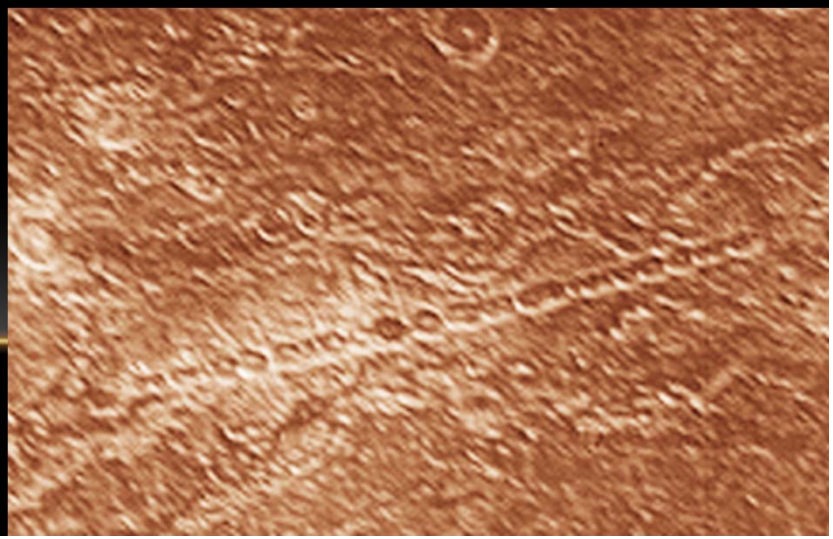
- In July 1994, comet Shoemaker-Levy 9 hits Jupiter's night side
- Previously broken up by Jupiter's tidal action during a close pass



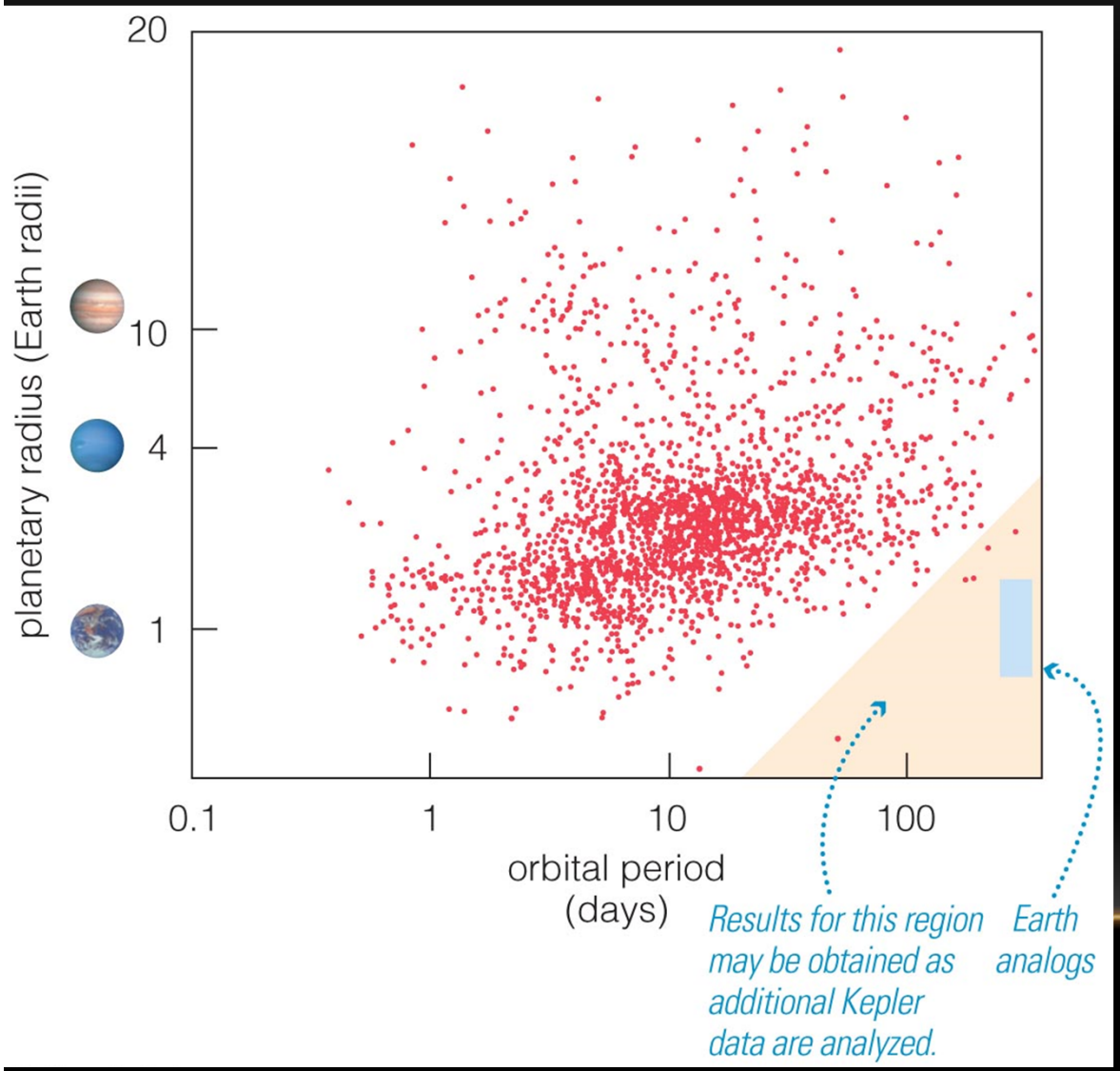
NOT SO UNUSUAL



- A Galileo photo of Ganymede reveals
  - A 120-mile long crater chain
- A 620 km chain on Callisto is below



WHY DO WE FIND FEW GAS GIANTS?



- Even though bigger planets are easier to see when they transit…
- We need to watch longer to see longer orbits!

Fig.10.11

BUT WHAT ABOUT THE GAS GIANTS WE DO FIND?

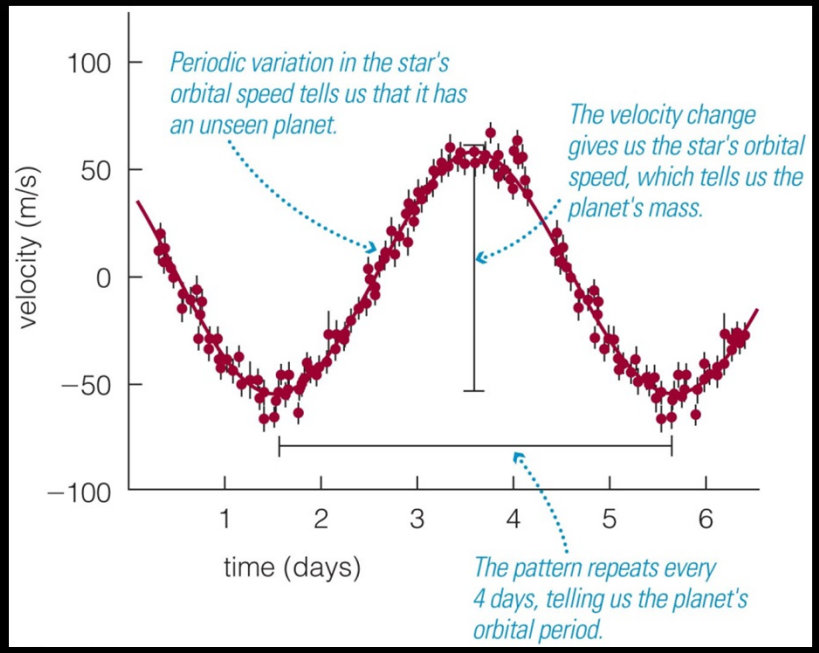


Fig.10.4, 51 Pegasi

- They're in close. Fast. Pulling strongly on the star.
- Is it easier to see big or little planets via the Doppler effect?

BUT WHAT ABOUT THE GAS GIANTS WE DO FIND?

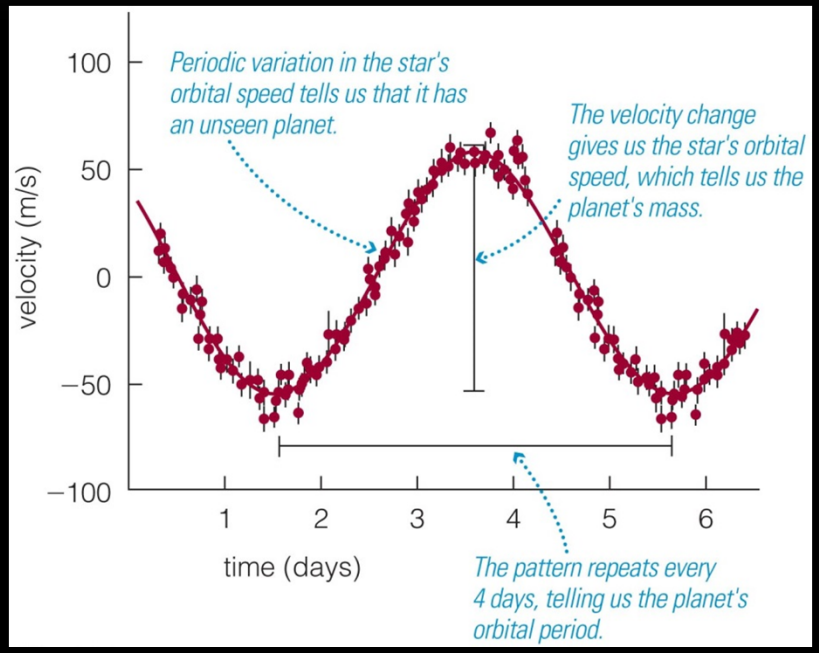


Fig.10.4, 51 Pegasi

- Big planets make the star wobble more strongly, making it easier to see big planets rather than little ones via the Doppler effect method
- So, many of the big planets that have been found were discovered via the Doppler method
  - Although the Kepler satellite's transit method has cranked out many more exoplanets than any other method overall

MASS VS RADIUS

- There's a larger diversity of things out there than in our solar system
  - As you might expect, when looking at more things

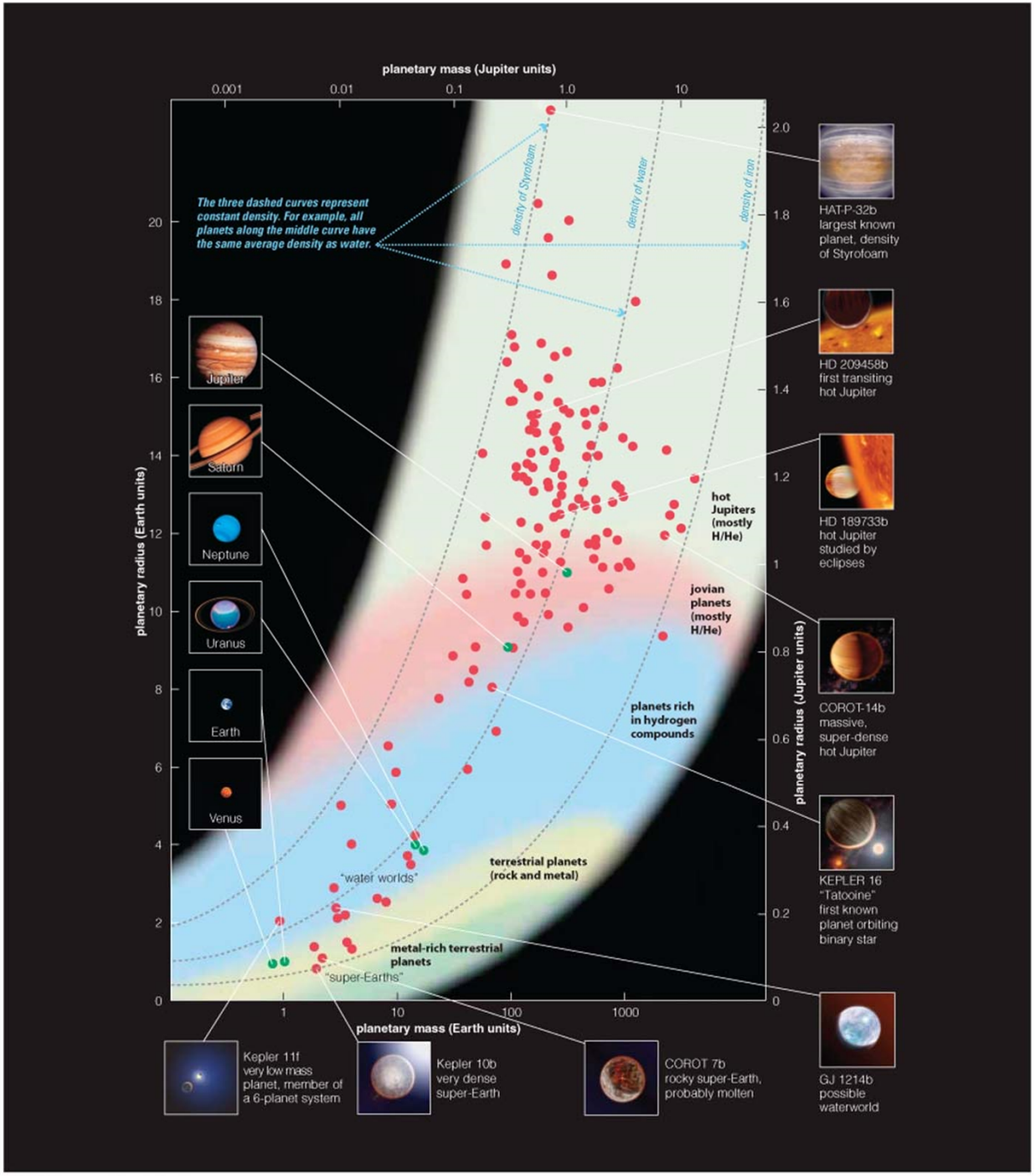


Fig.10.12

SUPER-EARTHS?

- Dense planets like Earth (so probably rocky), but several times as massive
- How do they accrete enough stuff to get so big, when there's not much rock and metal to work with?
  - Maybe things were hot enough at the start where they were forming to only let metal condense, which is heavier, so they "snowball" faster?

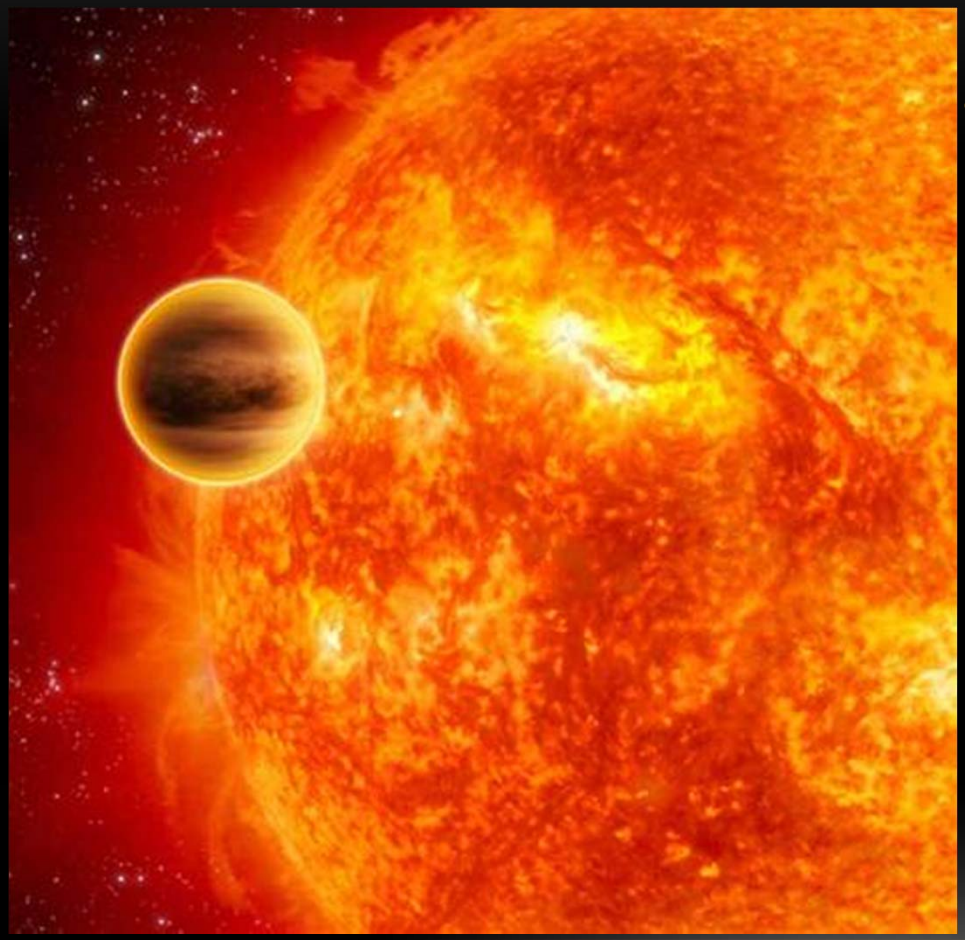
WATER WORLDS?

- Denser than Uranus and Neptune, perhaps more liquid and solid hydrogen compounds rather than our planets' gassy state
  - Jupiter is more dense than Saturn because it's bigger and has more gravity to squish stuff
  - But how do you get a smaller gas giant denser?
  - Maybe a stronger or earlier stellar wind clears out the nebula before a lot of the gasses can stick to the planets

HOT JUPITERS?

- These were the most surprising: planets as big as Jupiter
  - closer to their stars than Mercury is to ours
  - twice the radius of Jupiter (so with an average density of 0.14 g/cm^3, comparable to styrofoam!)
- We see a lot of them, because they're big enough to make a large Doppler wobble, and go around fast enough we can see the wobble in days (like the 51 Pegasi plot)

HOT JUPITERS?

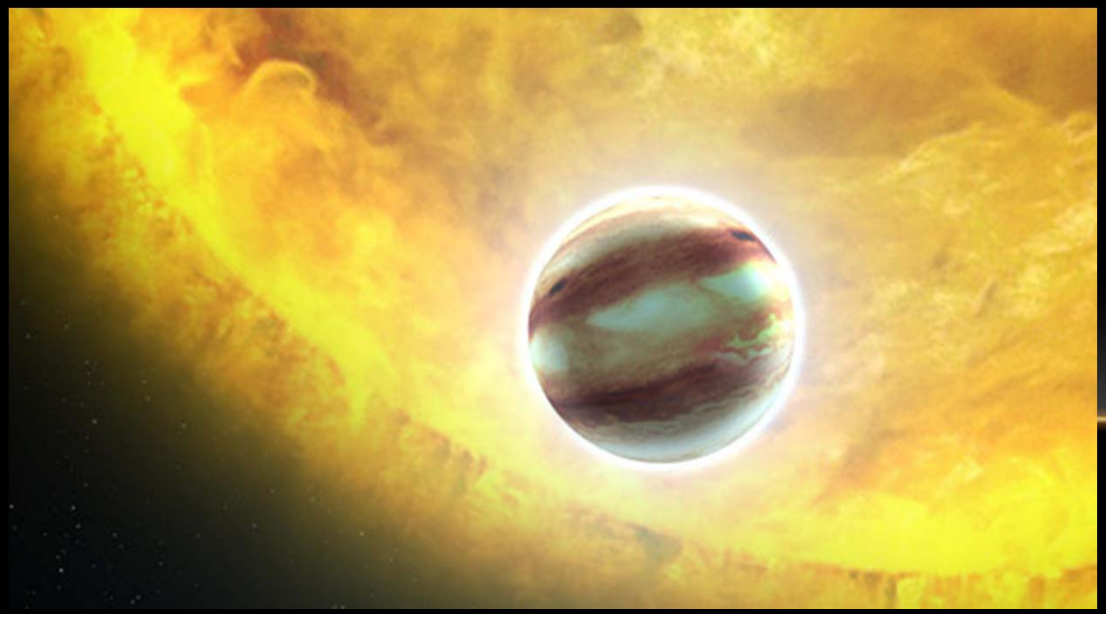


Artist's conception, not a real photo

- This is very counter to the “frost line” arguments we’ve used to explain the differences between terrestrial and jovian planets in our solar system

DENSITY AND COMPOSITION MAKE SENSE

- Hot things expand, so low density seems right
- HST followups on eight of them get spectra, see steam, measure pressures (and thus indirectly the winds)



Artist's conception, not a real photo

BUT WHY DO THEY EVEN EXIST?

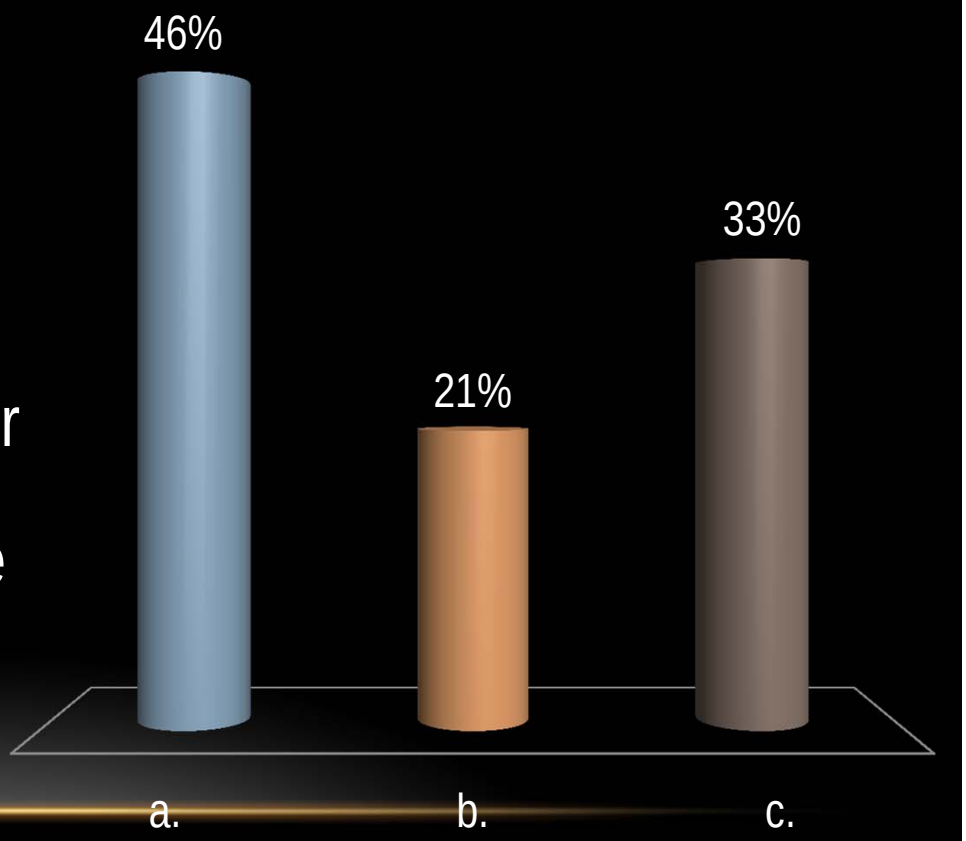
- That close and hot, how do they gather up the hydrogen compounds and gasses needed to make a gas giant?
- Need to modify our ideas about the nebular theory more than for the other new planet types: could something big have happened, and something that's not all that uncommon?

WHAT HAPPENS IN A GRAVITATIONAL ENCOUNTER THAT ALLOWS A PLANET'S ORBIT TO MOVE INWARD?

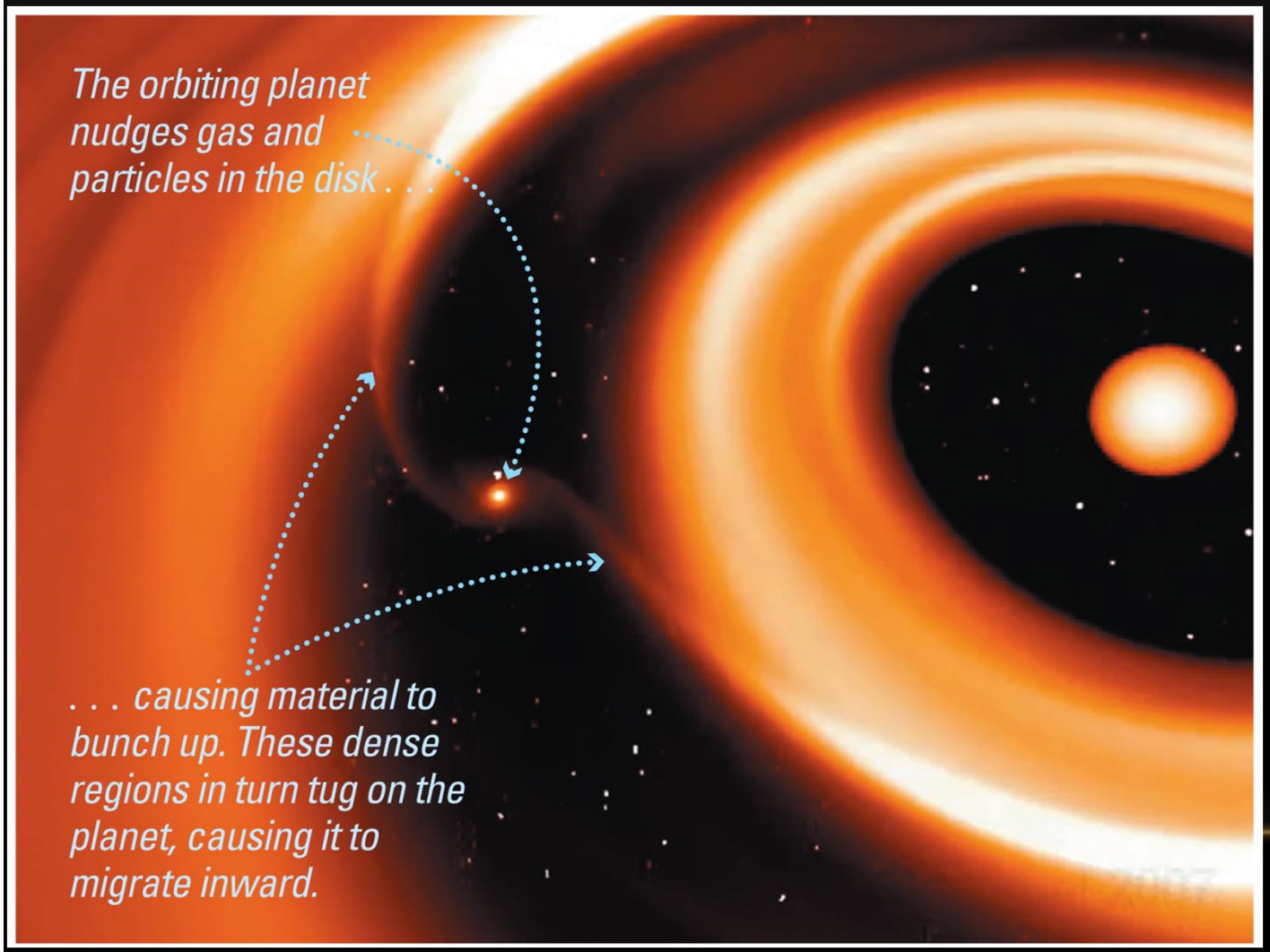
✓ a. It transfers energy and angular momentum to another object.

b. The gravity of the other object forces the planet to move inward.

c. It gains mass from the other object, causing its gravitational pull to become stronger.



MIGRATION

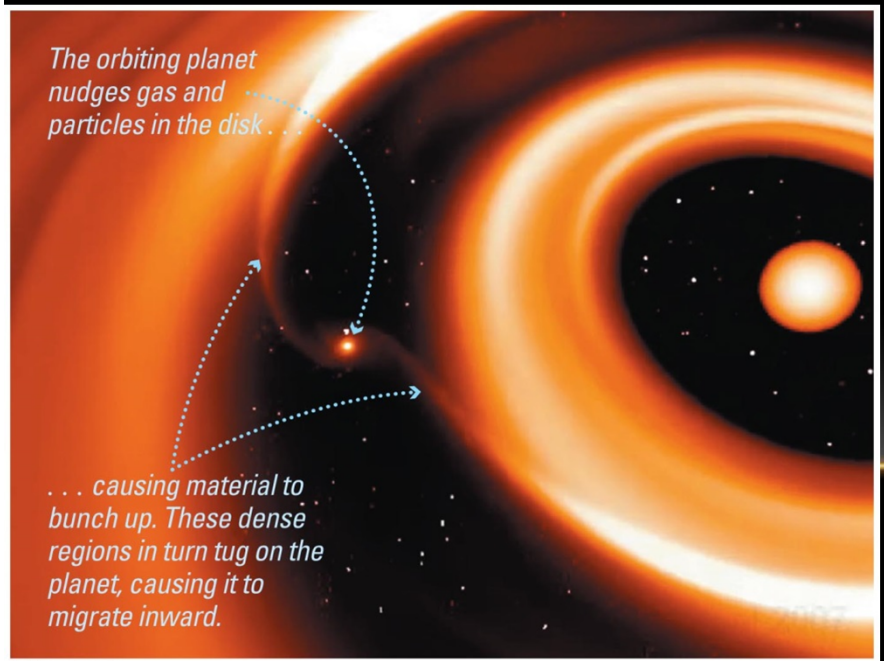


- How might you form a gas giant in the usual way, then move it inwards?

Fig.10.13

MIGRATION

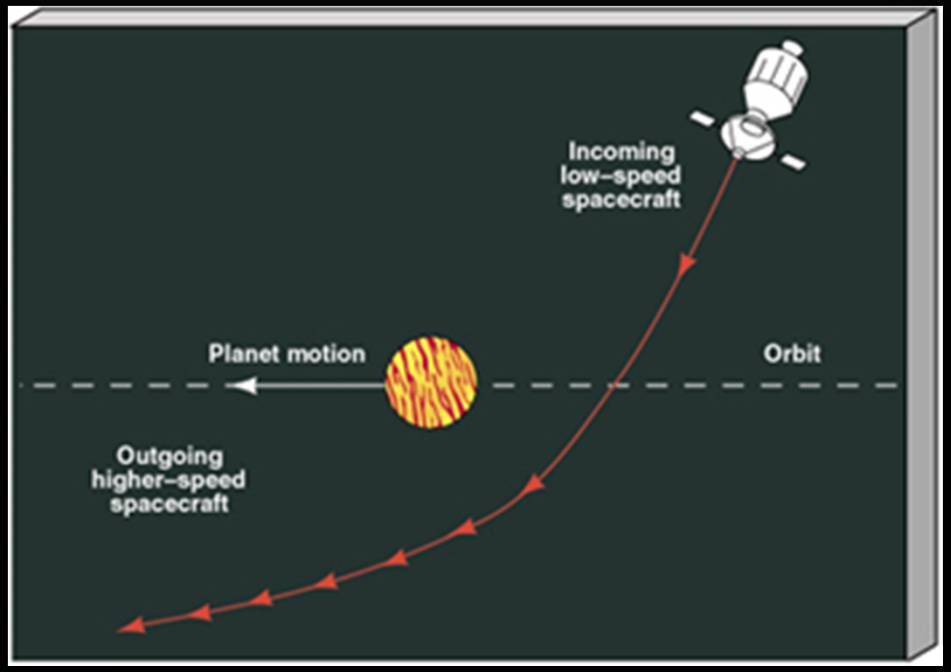
- If planets form earlier, or the gas in the nebula isn't cleared out till later, there's a lot available to slow planets down (and move them in)
  - Models show specific ways tidal forces can bunch stuff up



In fact, we see some planets with decaying orbits that are about to splat, and spectral signs in some stars that look like they've eaten up some planets

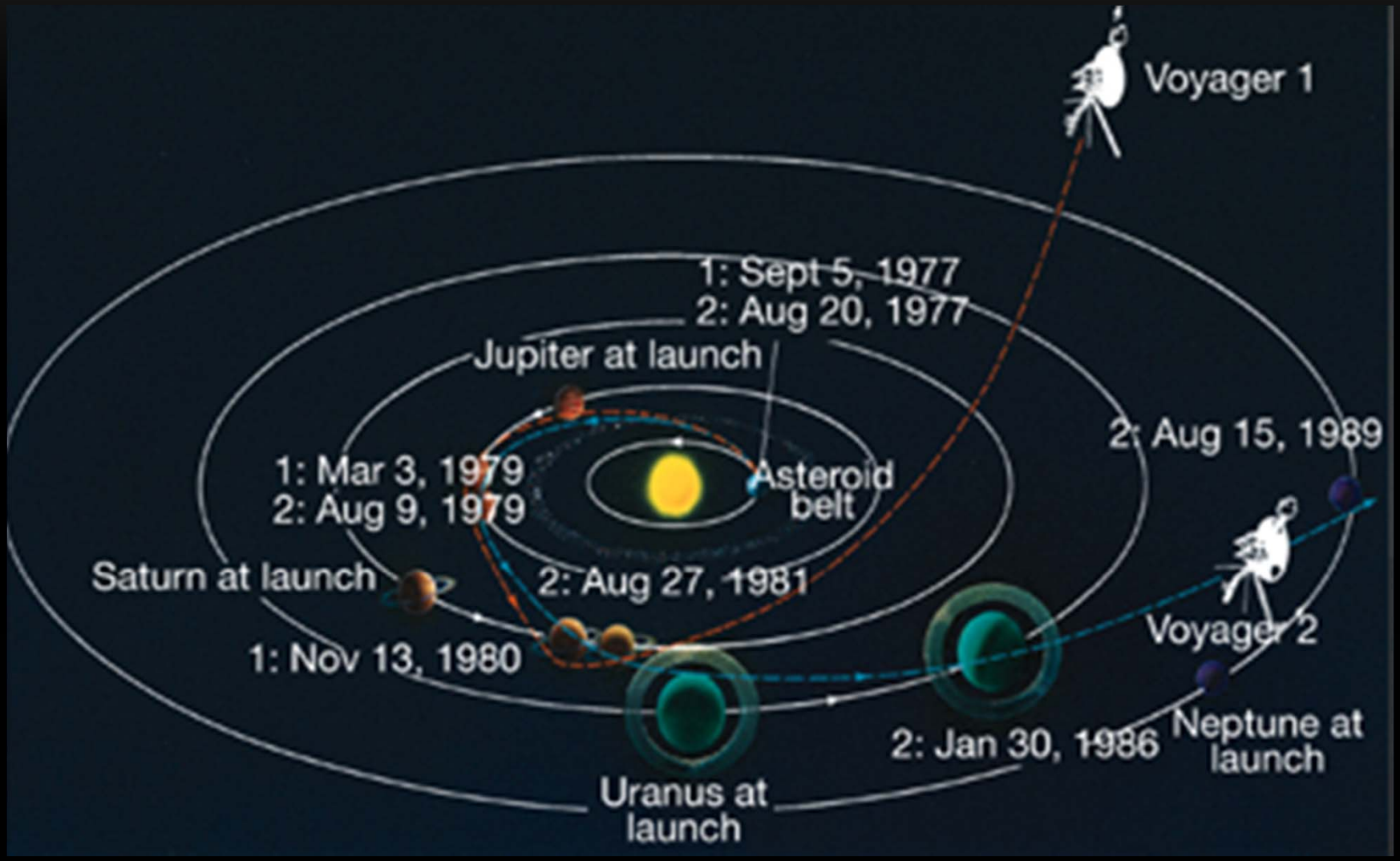
Fig.10.13

SLINGSHOT

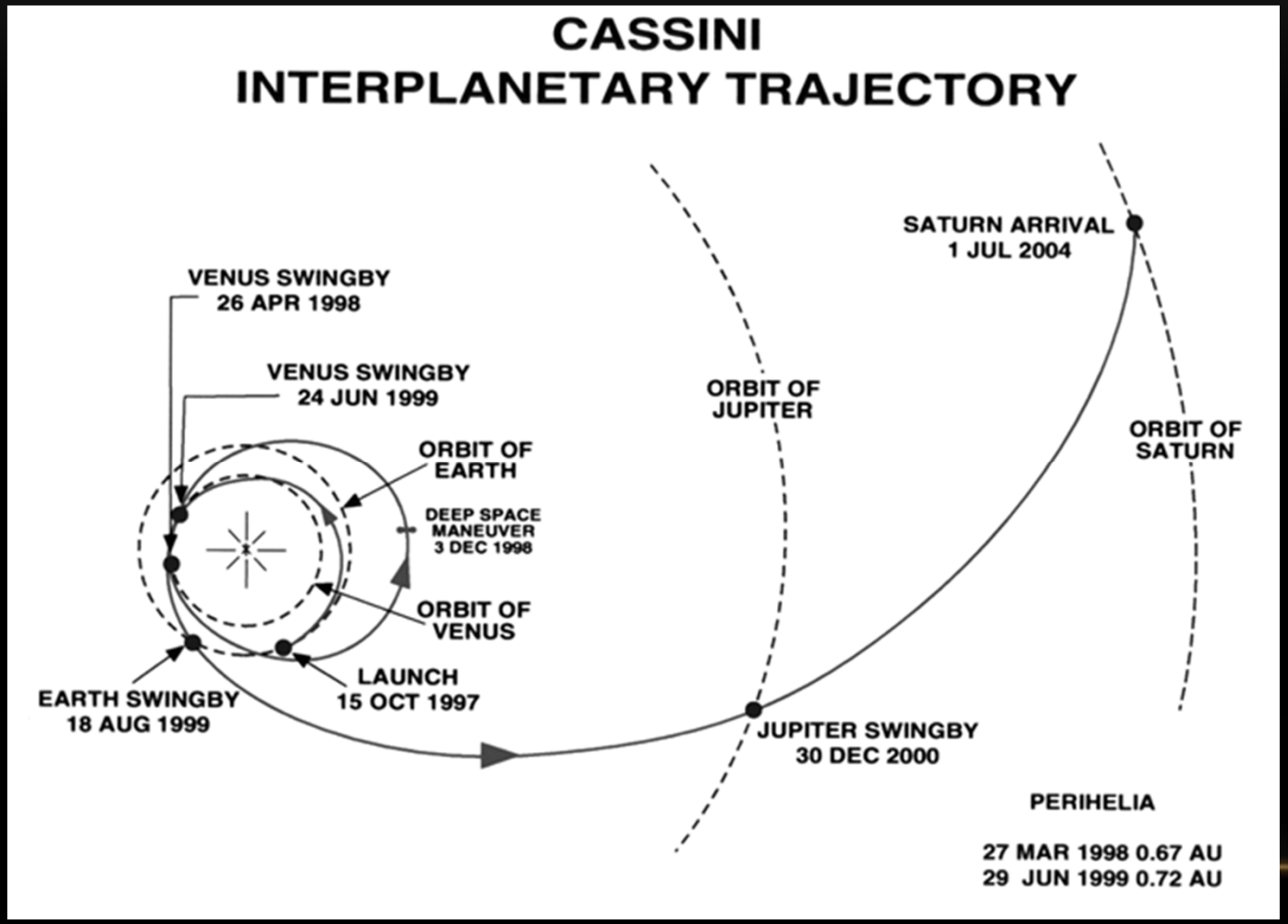


- Spacecraft pass by planets, use their gravity to speed up or slow down
- Approach from behind, speed up
- Approach from the front, slow down
- This is much more efficient than bringing along big rockets

VOYAGER SLINGSHOTS



TAKING THE LONG ROAD



- Two Venus slingshots
- One from Earth
- One from Jupiter

SCIENTIFIC PROGRESS

- As we learn more (*in this case, discover a lot more planets*) we see different things
  - *eg*, Super-Earths, Water Worlds, Hot Jupiters
- So, our explanations for what's going on have to account for the new things we see
  - without breaking the old explanations
- We're all playing by the same rules
  - but conditions are different in different places
  - and now we can see the effects of this
- So, back to the original question: is our style solar system common or unusual?

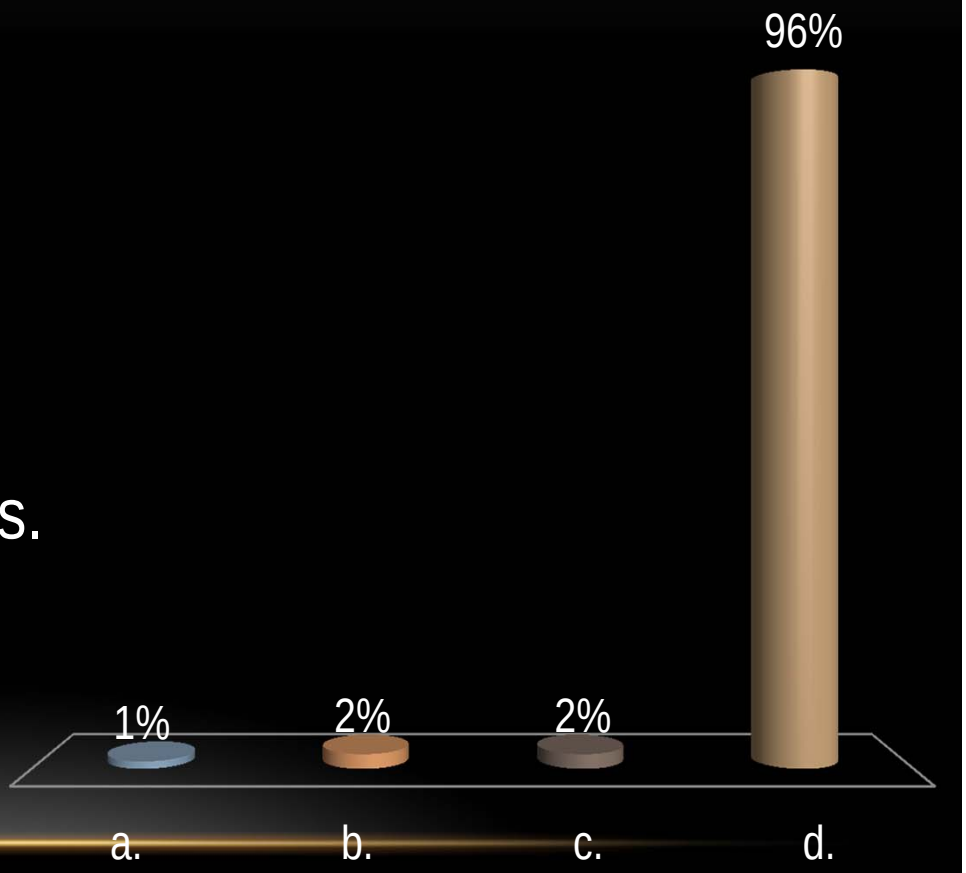
SPACE MISSIONS ARE CURRENTLY UNDERWAY TO:

a. search for Earth-sized planets transiting stars.

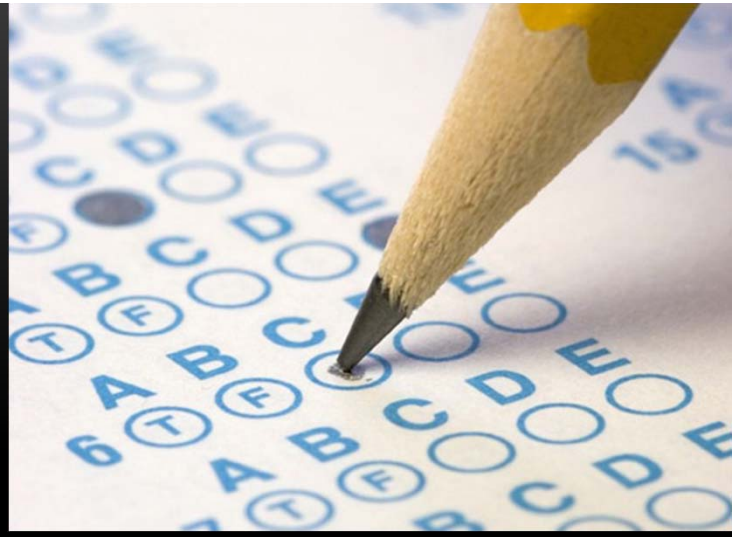
b. search for wobbles in stars caused by planets much less massive than Jupiter.

c. attempt to take more direct images of extrasolar planets.

✓ d. all of the above

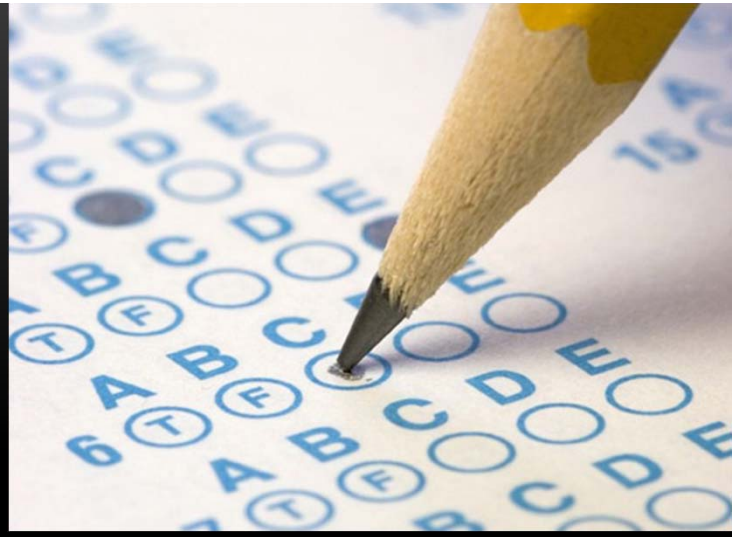


TEST MONDAY



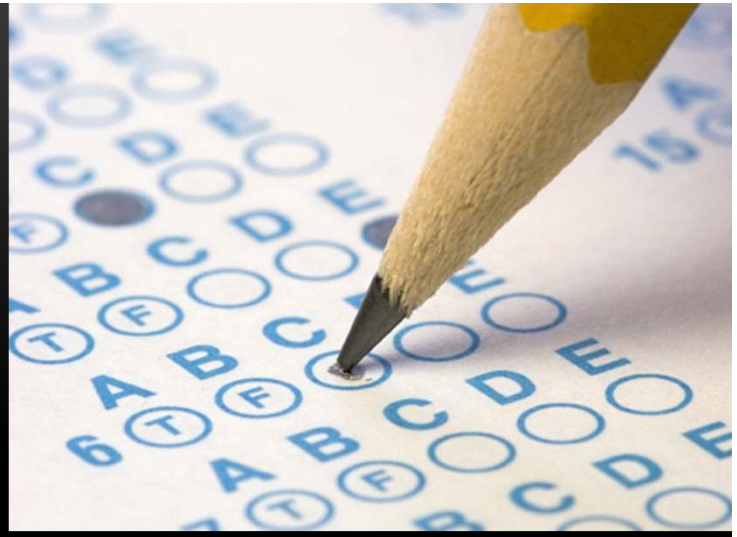
- Chapters 6-10
- Same format as the first test
  - Bring pencils, eraser, your student ID#
  - No need for calculator or phone
- Example test posted on the homework page again
  - So you can practice, and get a feel for what sort of questions get asked
  - “can you figure out what’s going on” style questions, not so much “memorize this factoid or number”

TEST MONDAY



- Look at the “summary of key concepts” page at the end of each chapter
- Review your Mastering HW. Take the practice quizzes there: which are asking about those key concepts
  - Can you get the right answers without re-googling everything?

TEST MONDAY



- A common mistake people make:
  - Doing the homework, practice test, online practice quiz, studying, whatever…
  - …while answering all the questions by just looking them up.
- You don’t get to google stuff on the test:
  - So “practice the way you play”: see how well you do without that “look stuff up” crutch.