**Lecture 13: small bodies**

* 1. What is on the exam?
     1. Exam will be similar format to midterm
     2. Again, most focused on questions in the lecture questions
     3. Material will cover indoor labs in the lab book, up through PLANETS (not Milky Way or Exoplanets, since Weds didn't get to those)
     4. Cumulative, so definitely go back over the midterm
  2. Generalities
     1. Not only planets and moons: many smaller things
     2. **What other things are there?** asteroids, comets, dust
     3. not just incidentally important
     4. give important clues to origin of solar system and primordial state
     5. occasionally spectacular shows (comets)
     6. occasionally, run into planets, including us!
     7. e.g. shooting stars and meteors
  3. Spherical, non-spherical
     1. We have some excellent pictures of asteroids from solar system missions
     2. what is clear is that they are quite non spherical
     3. whereas most moons and all planets are basically spheres or close to
     4. this is an important watershed
     5. **Why are moons and planets spherical but asteroids are not?**
     6. some objects are big enough that their own gravity pulls them into a sphere
     7. essentially all asteroids and comets are not of this variety
     8. their self-gravity is just too weak to pull down the irregularities of the surface
  4. Asteroids, the rocky ones: origins and orbits
     1. asteroids extremely common in the solar system; down to smallest sizes probably 100 million; we know of ~ 1,000,000
     2. primarily in the asteroid belt but also spread through out it
     3. large range in sizes: m to km
     4. some sort of “failed planets” -- pulverized each other
     5. in early solar system these would have been spread throughout
     6. but all collided with big planets (source of ancient craters)
     7. asteroid belt is a stable place, so orbits there have persisted
     8. collisions and gravitational disturbances from outer planets occasionally drive them out
     9. also, other stable places (like Trojans and Greeks around Jupiter)
  5. Asteroids: what are they?
     1. **What are they made of?**
     2. they are basically made of rock
     3. but two different sorts: chondrites, which are primitive rocks
     4. and the others, which have been processed through “planetary evolution”
     5. and are more enriched or depleted in iron
     6. why: probably part of some larger objects which differentiated
     7. it turns out that these can be distinguished on the basis of their colors
     8. outer asteroids tend to be chondrites, inner ones more likely to be processed
     9. they exist in various “families” of orbits
     10. signs that they originated together, perhaps from the same objects destroyed
  6. How are they found?
     1. **How are they found?**
     2. are generally found in the sky by search for things moving quickly against the background
     3. e.g. this multiexposure image from an infrared satellite, WISE
     4. much is known about these, clearly we have tons of orbits
  7. Near-earth asteroids
     1. clearly there are asteroids in the inner solar system as well
     2. those crossing earth orbit are known as near earth asteroids
     3. here is an example of one which came pretty close about 10 years ago
     4. a bunch of images as it came by (see it spinning)
     5. rather alarming animation of asteroids around Earth
     6. some of these come remarkably close!
     7. current record holder is 99942 Apophis: will come very close in 2029
     8. will return in 2036, but much further (originally thought to have some chance of hitting that year).
     9. a tiny chance (1/200,000) of impact in 2068
     10. around 300m in diameter, which would be a big thing to hit the earth
     11. want to think of that as a few hundred megatons of energy
     12. fairly devastating
     13. but chances are very low
     14. interestingly, it will be a rather amazing sight as it goes by
     15. a magnitude 3 star moving about a degree per minute across the sky
     16. Minor Planet Center at Harvard keeps track of these things
     17. a bunch of amateurs and some professionals look for these objects
     18. several large surveys beginning or planned to better track them
  8. Craters and impacts
     1. though it is unlikely that Apophis or anything else will hit in our lifetimes
     2. it will definitely happen someday, because it has happened in the past
     3. things of Apophis's size hit about once every 100,000 years
     4. you’ve already learned some of the craters on the moon are young
     5. Tycho is only 100 Myrs old!
     6. Meteor Crater 50K (1.2 km wide)
     7. Manicouagan 210 Myrs, 70km
     8. center filled with lava, ring of water in valley formed from glacier-gouged sediment
     9. to reach Earth surface intact, need to be 100-200m across or so
     10. otherwise it will break up, perhaps a bunch of smaller craters
     11. famously Tunguska, a 50m object disrupted in mid-air
     12. as you probably have heard, impacts are implicated in mass-extinction events
     13. e.g. the Chicxulub crater; first evidence found in 1950s for this crater by Pemex
     14. didn't release information (searching for oil and gas)
     15. geology (which rocks are where) tells it happened right at end of Cretaceous
     16. killed the dinosaurs?
  9. Meteor showers
     1. but most asteroid strikes are less devastating
     2. you have all seen shooting stars at some point
     3. **How big do you think things that cause shooting stars are?**
     4. these are actually mostly little bits of dust or grains mm-sized or less
     5. really quite tiny, even the bright ones!
     6. many, particularly the “showers” that occur, are associated with particular objects
     7. most commonly comets
     8. e.g. the Eta Aquarids, which were active on Friday
     9. are associated with Comet Halley
     10. paired with Orionids in October from same source
     11. emanate from direction of orbit: thus the “radiant”
     12. there are a series of meteor showers during the year
     13. many are listed in the Peterson guide
     14. in dark sites can see, e.g. more than 1 a minute!
  10. Meteorites
      1. occasionally there are big “fireballs” which are bigger objects
      2. you have to be pretty big to reach the ground without being destroyed
      3. hitting atmosphere at 10s of km/s which is FAST: so easy to burn up
      4. if it is big enough, some part remains
      5. largest known is 34-ton Ahnighito found in Greenland (in AMNH)
      6. iron -enriched
      7. but many smaller ones known
      8. the chondrites (unprocessed stony ones) are rarer in collections even though they are more common ones to fall, because they look like rocks
      9. and weather easily
      10. iron meteorites are very heavy, so noticeably odd, and survive longer
      11. though chondrites fall more often, iron ones are more commonly found
      12. Antarctica is a bonanza for finding things
      13. lunar and mars meteorites
  11. Comets, the icy ones
      1. asteroids are just one type of body in the SS
      2. comets are another. In general they are found further out
      3. two types: short period (< 200 yr) and long period
      4. **What are comets made of?**
      5. dirty snowballs
      6. ice water and dust grains, maybe light crust
      7. **Why are they spectacular?**
      8. quite fragile
      9. when far from sun, quite quiescent
      10. when they interact with light and solar wind near the Sun, become active
      11. stuff pours off, gas and dust
      12. in general, forms two tails
      13. gas: H, CO, CN straight out, entrained in outgoing solar wind
      14. dust trail not as entrained, lags
      15. this jet activity is enough to actually perturb the orbits!
      16. they are extremely fragile
      17. Holmes brightened by huge amount Oct 23, 2007, essentially a big explosion
      18. not uncommon for them to break apart
      19. many that pass close to the Sun or Jupiter are torn apart by tides
      20. Holmes, Shoemaker-Levy
  12. Where do comets come from?
      1. short-period and long-period have different sources
      2. short period are in ecliptic, long period are not
      3. short period from Kuiper belt; hypothesized in 1950s to 1970s to exist and to be source of short period comets, which are in the ecliptic
      4. interactions out in Kuiper belt occasionally send one plunging in
      5. Oort cloud: long-period comets come from MUCH further out, and perhaps bumped inward by gravitational interaction with passing stars
  13. That's where I will have to stop! So much more to talk about! Each lecture this Spring could have been an entire course, some of them are entire careers of people's study. We know an amazing amount, but still less than what we don't know ...