Topics: angular measure, determining the size of the Sun and scale of the Sun-Earth system, begin gravity and orbits and the inverse square law of light (continued in Thursday’s class)

Summary of reading:

- Two short, approximate proofs of the expression for centripetal acceleration.
- Short video demonstrating the relationship among angular size, linear size, and distance.

These readings are available on the class website. And in the last section of this document are some hints and tips and advice about what to focus on in these readings.

Summary of work to submit:

- Nothing to hand in at class on Tuesday (though some days there will be). But be ready to discuss any/everything in this document and potentially in the outside reading. You may want to bring some notes to class (especially on the topics listed in the four bullet points on p. 2). And you should be ready to solve problems and make measurements in class.

Here are the things you should be thinking about:

This first class we’re going to focus on the Sun. The Sun is the dominant source of energy here on the Earth and the driver for life. Stars like the Sun are responsible for producing most of the optical light in the universe and for synthesizing most of the heavy elements in the universe.

*Overall themes:* (1) The Sun is a star; all stars are more or less like the Sun, but very far away. (2) Almost everything we know about what’s beyond the Earth comes from observing light (photons). Techniques we use for inferring properties of the Sun from measuring the light we receive from it here on Earth will be applied in many different contexts to stars, the interstellar medium, and galaxies (and in other classes, to planets and moons, comets, asteroids,...too).

We’ll start the semester by seeing what we can figure out about the Sun from simple observations.

*First some facts* (we’ll see later this semester how we know these facts):

Stars (including the Sun) are spheres of hot gas (ionized plasma, really) held together by self-gravity. What keeps them from collapsing to arbitrarily small size and large density? ...Pressure related to energy generation deep in their interiors.

By measuring properties of the (observable surface of the Sun and global properties like radius and mass) we might be able to infer its interior properties. By doing this for many different stars, we can see how surface properties of stars vary and test our theories of stellar structure (interior temperature, density, pressure...) and evolution (how stars changes as they age).

In the bigger picture – since stars don’t live forever, they must be born, age, and die – with both the birth and death phases involving exchange of material between a star and its surroundings. (In fact, stars steadily eject material into the local interstellar medium via stellar winds during all phases of their lives.)

Stars and the interstellar medium as well as dark matter and black holes – including a massive black hole at the Milky Way’s center) make up galaxies, which are the self-gravitating (gravitationally bound) units
that often (as in the case of the Milky Way) form flattened, spiral-shaped structures. The light we see from
galaxies is mostly produced by individual stars in those galaxies (though note that every star we can see as
an individual star with our naked eyes is in the Milky Way, and in fact, in the relatively nearby parts of the
Milky Way).

All this is the scope of Astro 16.

Back to this first class...

What properties of the Sun can we measure?

- **Size**: amount of space occupied; diameter or radius. We can observe the angular size of the Sun and
  compute its diameter or radius if we know the distance between us and the Sun. Thinking about
  angular size and how it relates to both the actual size of an object and that object’s distance from you
  will be useful here. The short video posted on the website will help you think about tradeoffs between
  distance and size.

- **Mass**: the amount of stuff in the Sun. We can measure this by measuring the strength of the Sun’s
  gravity on an object at a known distance. Like the Earth. The Earth’s orbital properties (its speed
  and distance from the Sun) can be used to do this. The readings about Newton’s laws of motion and
  gravity and uniform circular motion and the derivations of centripetal acceleration will be useful for
  understanding how we measure the Sun’s mass.

- **Brightness or more specifically, luminosity** – its total power output (energy emitted per unit time).
  We can compute this by measuring the observed brightness (energy received per unit time per unit
  area – area of the detector, you can think of that as) if we know the distance to the Sun. We will
  review/derive the inverse square law of light in class and read a bit about it prior to Thursday’s class
  – but if you’re enterprising, you can find something about it in Ch. 13 of the textbook, in case you
  want to review before Tuesday’s class.

- **Surface temperature.** We can infer this from the distribution of photon energies emitted by the Sun (its
  spectrum). Does it make sense that hotter means more energetic means the light emitted by the hotter
  object has photons that are, at least on average, higher energy? ...in the visible part of the spectrum,
  what colors correspond to higher energies (and shorter wavelengths)? We’ll do a little reading and
  further discussing of these concepts next week.

Eventually we’ll learn how we can measure properties like the chemical composition, rotation speed and
period, age, energy source(s), and internal structure of the Sun and other stars. We can even learn about
the roster of planets orbiting stars (planets which are a direct result of the star formation process itself) and
the evolutionary fates of stars, including the Sun.

Commentary on the reading:

The material on Newton’s laws (motion and gravity) should be review to you – please let me know if this
material seems unfamiliar. If you push two different objects of different masses with the same force, which
one will move faster, the low-mass one or the high-mass one? What about if you push them with different
forces such that the two forces are proportional to their masses? How will their respective motions compare?
Are you okay with the definitions of and relations among position, velocity, and acceleration? If you know
the acceleration on an object, how do you calculate its velocity?

What does it mean that the Moon and an apple fall under the same force of gravity? Does that mean that
their accelerations are the same? What does it even mean that the Moon is *falling*? Are you okay with
circular motion as being a combination of linear motion (inertia) and a “correction,” or acceleration, toward the center? If the Earth were to suddenly disappear, the Moon wouldn’t stop moving; it would keep moving but in a straight line. The Earth’s gravity makes the Moon’s motion circular, rather than straight.

Are you comfortable with the idea that a spherical object acts as if its mass were concentrated as its center (from the point of view of its gravitational force on an external observer)? This is encapsulated in the rule on p. 98 of Bennet that the distance you plug into the gravitational force equation is the distance between the centers of the two objects.

The concept of uniform circular motion is one you are likely somewhat familiar with – please let me know if this is not the case. We’ll be using the expression for centripetal acceleration: \( a_{\text{cent}} = \frac{v^2}{r} \) to help us understand orbits. Make sure you’re comfortable with this expression (check that its units are acceleration) and the way that the acceleration vector points toward the center of the circle. I provided the derivations above (second bullet point) just to help make you comfortable with the expression. You are not responsible for reproducing them. And note that neither is rigorous, though the second one can be made rigorous by changing the Deltas into differentials.