Introduction to Astronomy
Summary Questions Week 5

4 November 2019

1. Explain what the heliosphere and the heliopause are and how you detect the heliopause.

> **Solution:**
>
> The heliosphere is the region of space, *beyond the corona*, where the Solar wind and the Solar magnetic field have an impact. The heliopause is the *boundary of the heliosphere*.
>
> Three changes are expected across the heliopause, which can be used to identify it:
>
> - a *drop in temperature*
> - a change in *the direction of the magnetic field*
> - an increase in *the number of cosmic rays*.
>
> (Note: following the Voyager measurements, it turned out that the magnetic field direction did not change across the heliopause. Whether this is generally the case or merely a coincidence in the particular case of the Voyager probes, is not understood yet.)

2. Where does nuclear fusion happen inside our Sun?

> **Solution:**
>
> Nuclear fusion happens *mostly, but not exclusively, in the core* of the Sun. Specifically, the vast majority of nuclear fusion occurs in the range $R = 0 - 0.25\,\mathrm{R}_\odot$. Nevertheless, some level of nuclear fusion takes place *all the way out to* $R = 0.7\,R_\odot$.

3. What is the Solar wind and what powers it?

> **Solution:**
>
> The Solar wind is *a stream of charged particles* (mostly protons and electrons), coming from the Sun and streaming through the Solar System. *It has two components*: a fast and a slow wind. Its origin is unknown, but is probably connected to the *high temperatures in the corona* and to the *Solar magnetic field* – in particular to the winding of the field and the instabilities that this brings with it.

4. What do we know qualitatively about the Solar rotation; how does that affect the Solar magnetic field; and what does it have to do with Sunspots?

> **Solution:**
>
> The Solar rotation is *differential*: it rotates faster at the equator than at the poles. Because large parts of the Solar outer layers and the Solar atmosphere are ionised, this differential rotation causes the magnetic field to *wind up*, causing *instabilities, loops etc.* Such instabilities can cause magnetic field lines to locally protrude from the surface, causing areas of increased magnetic field strength, where convection gets constrained, resulting in a slightly cooler and therefore darker area known as a sunspot.

5. Aside from the core, there are two main parts to the Solar interior. Explain the difference between these zones in terms of how they transport energy.

Solution:

The two main zones in the Solar interior are the *Radiative* and the *Convective* zones. As their names indicaste, energy transport in the former happens through radiation, i.e. though continuous *absorption and subsequent re-emission of photons*. This works well at extremely high temperature and density, both of which are present in this inner region of the Sun. The latter zone achieves energy transport through convection, i.e. *through motion in convective cells*. This is more efficient at somewhat lower temperatures and densities, which are present in this outer region, which touches upon the Solar surface. (Note the Solar surface itself is called the photosphere, though, but this is only a very thin layer.)

6. In context of the Solar surface, what are granules and mention two observable facts that support this idea.

Solution:

Granules are *small, bright regions on the Solar surface, surrounded by a darker edge and a few thousand kilometres across*. They are the visual result of small-scale convection cells. One way to check this, is through *Doppler measurements* which should show that the bright centre of the cells is rising, while the plasma in the dark edges is sinking; a second observable that can support this notion is *spectroscopy*, as the brighter, rising regions can be found to be hotter than the darker, sinking regions, which have the blackbody spectrum of a cooler plasma.