ASTR 1120 Section 1 (3 credit hours): Spring 2006

SUMMARY OF KEY CONCEPTS: WEEK #5

Lecture #9 – textbook Chapter S2 `Space and Time'

We began discussing the Theory of Relativity, which was developed in two parts. The *Special Theory of Relativity* describes how space and time, which we normally perceive to be completely different concepts, are actually closely linked. The Special theory does not include gravity. The *General Theory of Relativity* goes much further, and explains how mass curves spacetime.

Special relativity is based on two concepts:

1) The laws of physics are the same in all inertial frames (an inertial frame is one in which the experimenter is not subject to any external forces, such as gravity). In particular, this means that there is no preferred frame as far as velocity is concerned – observers moving at different velocities relative to each other are in equally valid positions.

2) The **speed of light is the same constant** when measured in any inertial frame, regardless of how that frame is moving relative to the source of the light. This is very weird, but it's an experimental fact!

We showed that these concepts imply some strange behavior – moving clocks appear to run slow (we actually derived this one) and moving objects appear to be length contracted. The effects are only significant once we are moving close to the speed of light, hence we don't notice them in everyday life.

We outlined the *twin paradox* – suppose one twin flies in a super-advanced spaceship to a distant star at close to the speed of light and then returns to Earth. Because of time dilation, the twin on the spaceship can reach the distant star even if it's (say) 100 light years away (since the clock on the spaceship runs `slow', a journey that takes at least 100 years as seen from Earth requires less time as seen by the astronaut). But, when the twin returns to Earth, there's a big mismatch in the amount of time that has elapsed on Earth as compared to on the spaceship, and the twin on Earth is probably long dead.

Lecture #10 – textbook Chapter S3 `Spacetime and Gravity'

The central physical idea (there's also a *lot* of mathematics) behind the General Theory of Relativity is the *equivalence principle* – **the effects of gravity and acceleration are exactly equivalent (indistinguishable) locally** (locally here means that we restrict ourselves to experiments that could be done in a small box – on much larger scales we can measure effects such as tides which are characteristic of gravity not acceleration).

The equivalence principle is in some ways obvious (in an elevator accelerating upward you certainly feel heavier, just as if gravity had become stronger), but it's also profound since gravity and acceleration appear to be completely different concepts! One of the most immediate consequences is that gravity deflects light, by an amount that turns out to be exactly twice what Newtonian theory predicts.

This light bending was detected shortly after the publication of the General Theory of Relativity, and has subsequently been measured very accurately. It agrees with the prediction very well. More recently, examples of *gravitational lensing* have been observed, which are another manifestation of the same effect.