Week 4 Notes
Astro 2 (Discussion Section 101)

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Updated April 18, 2011

Administrative Tasks

Survey(s) I went over the survey results as well as last quarter's written comments. It seems people are happy with the idea of focusing primarily on examples coupled with review of relevant equations. There was a significant pull for conceptual review as well, so I'll try and include a bit more of that, especially since concepts play a larger role in this course than in its predecessor. Group work was phenomenally unpopular, though in my course evaluations, students requested more classroom engagement. I'll try to find more ways to get you involved in the discussion.

In-Class Notes Now available online: my in-class notes! On my section's website, you'll find a link to a pdf of my in-class notes. You might find them helpful in reviewing and filling in holes in your own notes. They follow the lectures mostly, so they will go nicely with the presentations.

Midterm 1 Your first exam is a week from Thursday. I'll plan on just doing review next week in section. I'll go over relevant equations and a few important concepts, but it's up to you to ask specific questions. Consider asking questions about concepts that you don't understand, since those will also be on your exam.

Review

Sample Test Question

A type Ia supernova explodes in a spiral galaxy. The peak magnitude is observed to be $m = 23.5$, and the spectrum of the supernova is redshifted with $z = 5$. Knowing that the absolute magnitude of a type Ia supernova at peak is $M = -19.5$, measure the Hubble constant.

Solution We know that the Hubble constant is the ratio of a galaxy's receding velocity and its distance away from us: $H_0 = v/d$. We are given the redshift, so we can determine the velocity. Also, the distance can be determined from the distance modulus, $m - M$.

Since $z > .1$, we must use the relativistic formula to determine the velocity:

$$v = \frac{(5+1)^2 - 1}{(5+1)^2 + 1}c = \frac{35}{37}c \approx 285,000\,\mathrm{km/s}$$

So this velocity will be what we use to calculate H_0.

The distance can be obtained from the distance modulus. Recall

$$m - M = 5\log\left(\frac{d}{\mathrm{pc}}\right) - 5$$

Rearranging, we have

$$
\begin{aligned}
m - M + 5 &= 5\log\left(\frac{d}{\text{pc}}\right) \\
\frac{m-M}{5} + 1 &= \log\left(\frac{d}{\text{pc}}\right) \\
10^{\frac{m-M}{5}+1} &= \frac{d}{\text{pc}} \\
d &= 10^{\frac{m-M}{5}+1}\,\text{pc}
\end{aligned}
$$

(This formula is also in your book.) Plugging our values for m and M, we get

$$d = 10^{\frac{23.5+19.5}{5}+1}\,\text{pc} = 10^{9.6} = 3.98 \times 10^{9}\,\text{pc} = 3980\,\text{Mpc}$$

Then we can get a value for Hubble's constant:

$$H_0 = \frac{285,000\,\text{km/s}}{3980\,\text{Mpc}} = 71.6\,\text{km/s/Mpc}$$

Blast from the Past: Schwarzchild Radius

Recall that the Schwarzchild Radius, or event horizon (the two are interchangeable), is the effective "size" of a black hole. Anything (including light) that passes within the Schwarzchild radius cannot escape the gravitational pull of the black hole, and it will be gobbled up by the singularity. Mathematically, it is given by

$$R_{\text{Sch}} = \frac{2GM}{c^2}$$

Obviously SI units must be used there, even though masses are typically given in solar masses at this level of complexity. Interestingly, *only* the mass of the black hole is relevant in calculating its Schwarzchild radius. In fact, you can completely describe any black hole with three quantities: its mass (makes sense), its spin (a little weird, since it doesn't have any actual width), and its charge (really weird that it would have any charge at all).

Video on Gamma Ray Bursts

See it in terrible quality at

`http://www.youtube.com/watch?v=0YQof5_E7sk&feature=related`

Varying Redshifts Discussion

Universe 24.40 Some quasars show several sets of absorption lines whose redshifts are less than the redshifts of their emission lines. For example, the quasar PKS 0237-23 has five sets of absorption lines with redshifts in the range from 1.364 to 2.202, whereas the quasar's emission lines have a redshift of 2.223. Propose an explanation for these sets of absorption lines.

One Possible Explanation Different clouds of dust and gas are in the way along the path of the light on its way to us. At those clouds, the light will appear to be at a different redshift. It will absorb the light at the redshifted wavelength that it perceives. As the remaining parts of the spectrum continue their journey towards us, they become further redshifted due to universal expansion, so the absorption lines also become redshifted!

Brief Discussion of Black Hole Jets

One topic brushed over in lecture was that of the nature of jets from black holes. I spent a summer studying these, so I will give a brief, qualitative discussion of the topic for your own enrichment.

In an accretion disk near a supermassive black hole, the accreting material becomes extremely hot and dense. Under these conditions, it becomes s fully ionized **plasma**. That is, all electrons are shed from their nuclei and are free to move about the plasma due to their extreme kinetic energies. One property of fully ionized plasmas is that of **flux freezing**, which ensures that any magnetic field lines present in the plasma will remain anchored in the positions they are already in.

Let's adopt a simple model where the magnetic field line is anchored in the plasma at some distance R from the singularity. We can calculate the speed at which it is orbiting. Charged particles can get a thermal kick onto the magnetic field lines, which they will follow in a helical fashion. They would then follow the magnetic field line to wherever it led them. If the field line is anchored in the accretion disk, the rest of it would be drug around the orbit with the anchor point at a speed of ωr, where ω is the angular speed of particles at the anchor point and r is the distance from the singularity. If the field lines travel along uniformly with this rotation, there is a problem: sufficiently far away ($r = c/\omega$), the field lines travel faster than the speed of light!

Part of the problem is that disturbances in an electromagnetic field only propagate at the speed of light anyway, but that's still not enough to overcome this ridiculous speed problem. Thus, the magnetic field lines *must* bend, and inevitably they will start piling up near each other. This causes a **magnetic pressure** gradient, which causes them to move outwards, like a spring, propelling particles up in a helical fashion.

Quite often this topic is taught with an analogy: the bead on a wire. A wire is tilted some angle away from the z-axis. This wire represents the magnetic field. The wire now rotates about the z-axis. Now a bead (representing a bit of plasma) is placed on the wire with some initial velocity outwards. Centrifugal forces cause the bead to move outwards and gravitational forces bring it back to the center. Depending on how fast the wire is rotating and how much it is tilted, the bead may or may not eventually be flung outwards or return back to the base.

There's a similar problem here, too. Eventually the wire is traveling faster than the speed of light. Typically this problem is ignored, but I spent a summer trying to make this more precise by adding in the bending of the wire to the problem (as well as other things). Ultimately a complete model wasn't finished, but I had some nice videos simulating the motion of the bead.

Related Question: Can you explain why any matter from accretion disks ever make it to the singularity itself?

Answer: Particles in close orbits interact via friction to transfer energy, allowing particles to move inwards towards the black hole and also generating heat. Angular momentum is further shed through the formation of relativistic jets.

Other Questions