Physics of Planetary Systems — Exercises

Astrophysikalisches Institut und Universitätssternwarte Jena
Thüringer Landessternwarte Tautenburg

2009-07-09

Solutions to Set 10

Problem 10.1

The relative magnitude of a star is given by

$$m = M + 5\log_{10}\left(\frac{d_*}{10\ \text{pc}}\right),$$

where d_* is the distance to the star and M its absolute magnitude. Thus, the maximum distance for given M and maximum m is

$$d_* = 10\ \text{pc} \times 10^{(m-M)/5} = 10\ \text{pc} \times 2.5^{(m-M)/2} = 10\ \text{pc} \times 1.58^{(m-M)},$$

whichever version you like most. And so, using the Milky Way's radius $R_{\text{MW}} \approx 15$ kpc, we find

$$\begin{aligned}
&\text{(a)} \quad d_{\text{M0V}} = && 249\ \text{pc} && \approx 1.7\%\ R_{\text{MW}},\\
&\text{(b)} \quad d_{\text{G0V}} = && 2.06\ \text{kpc} && \approx 14\%\ R_{\text{MW}},\\
&\text{(c)} \quad d_{\text{A0V}} = && 11.3\ \text{kpc} && \approx 75\%\ R_{\text{MW}}.
\end{aligned}$$

Problem 10.2

One important point related to a highly eccentric orbit through the Galaxy is related to the following equation:

$$\langle v_{\text{rel}} \rangle \approx e v_{\text{K}},$$

where v_{K} is the Kepler velocity, e the eccentricity, and v_{rel} the resulting average relative velocity. Thus, a direct consequence is that the solar system would fly at a much a higher v_{rel} through its surrounding environment – instead of more or less floating with it. The shielding effect that the solar wind and radiation pressure have would be less efficient in preventing interstellar material (gas and dust) from entering the system. Especially at earlier evolutionary stages this can have drastic effects on the survival of the circumstellar gas and dust cloud.

Another important equation is the one that relates collisional rate R to relative velocity v_{rel} and system density n:

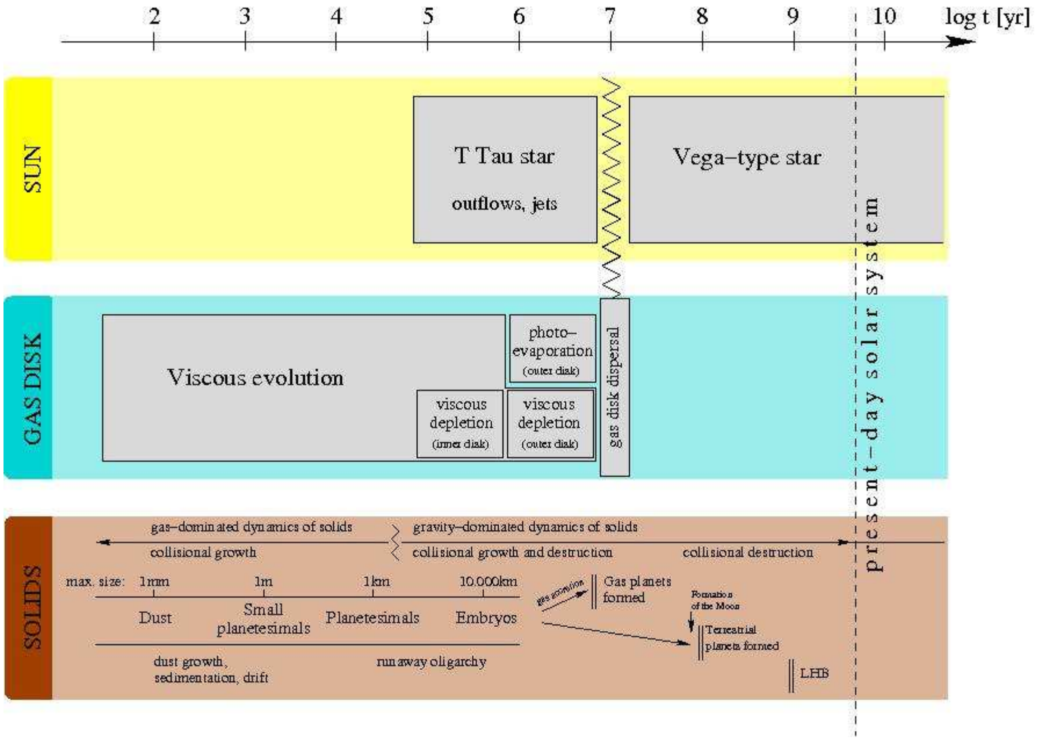
$$R = \sigma n v_{\text{rel}},$$

where σ is the cross section for interaction. One can see that a higher relative velocity directly leads to a higher rate, and thus to a higher chance for a potentially hazardous close encounter to another star. In particular, luminous OBA stars pose a threat to the development of life because of their strong radiation in the UV, and because of their short lifetime and violent death: supernova explosions.

In general the current residence of our solar system is one of the calmest in the Galaxy because we are surrounded by the so-called Local Bubble, a region almost void of interstellar matter, and thus, also void of new star forming regions. However, that will not always be the case, since the bubble will slowly fade away.

Problem 10.3

The following scheme falls into the category "correct and not too simple":



Problem 10.4

Here are some of the currently still open questions

1. Do planets form in a “standard” way or through gravitational instabilities?
2. What are typical masses of gaseous disks—about MMSN or much larger?
3. How large is Shakura-Sunyaev’s α in protoplanetary disks?
4. What is the role of dead zones, does episodic accretion occur?
5. What are the mechanisms of disk dispersal in $\sim 10^7$ yr?
6. Why do meter-sized planetesimals survive fast inward drift in a gas disk?
7. Does the massive midplane dust layer form?
8. How efficient is sticking at micrometer to millimeter sizes?
9. What causes planetesimals to grow from meter to kilometer sizes?
10. How long did gas accretion of Jupiter and Saturn take?
11. Do pulsational instabilities during gas envelope growth occur in reality?
12. Is it true that Uranus and Neptune formed in the Jupiter-Saturn region and then migrated?
13. Are masses and orbital spacing of terrestrial planets rather chance quantities?
14. What is the origin of water on Earth?
15. What allows sub-Earth mass embryos to survive fast type I migration?
16. What stops migration of “hot Jupiters” near the star?
17. Why didn’t Jupiter and Saturn in our Solar System migrate?
18. How to explain large orbital eccentricities of many extrasolar planets?

19. What mechanisms clean up planetesimal disks at later stages?
20. What caused the late heavy bombardment in the Solar System?

and so on...