ENG 101 English Composition I Essay 3: Science Paper on Planet Formation

The third essay will be in the style of a scientific research paper. The topic in question is the formation of planets.

Background

The Solar System consists of the Sun and the planets both large and small which orbit it. The Sun contains almost all of the *mass* in the solar system - its mass is about 1000 times that of the most massive planet, Jupiter (mass is the amount of material in a body or object). The planets orbit the Sun is almost-circular orbits, all revolving in the same direction and almost in the same plane. These facts give us important information about how the Sun and the planets formed: the best current picture is that the Sun formed by the collapse of a cloud of gas and the planets formed from the leftover gas, which formed a disk around the Sun from which the planets formed. The gas clouds in space, from which new stars form, consist of hydrogen and helium mixed with small solid particles (dust) made up of the elements heavier than hydrogen and helium. A strong prediction of this theoretical picture is that planets are more likely to form in clouds with more dust because the cores of planets are formed from the coagulation of the dust particles. However, until about 20 years ago the Sun was the only star with known planets. This all changed with technological developments which allowed us to find planets around other stars and by now many thousands of stars are known to have planetary systems. The amount of information which has been gathered in the past few years is now sufficient to support investigations into how planets form. There's a more detailed discussion of planet formation at the end of this writeup.

The Paper

The attached figure is from a beautiful paper by Debra Fischer and Jeff Valenti published in 2005 entitled: "The Planet-Metallicity Correlation". Here, the word "metallicity" means the abundance of elements heavier than hydrogen and helium, which can be measured for stars and represents the heavy elements in the material from which the star, and any planets, formed. Fischer and Valenti measured two things for about 1000 nearby stars: whether or not there are planets orbiting each star; and its metallicity. They then made the attached plot, which shows the fraction of the stars whch have planets versus metallicity (the logarithmic ratio of iron to hydrogen). This plot clearly shows that the higher the metallicity of a star, the more likely it is to have a planet or planets orbiting it.

Your assignment is to write a five-paragraph scientific paper describing this result and its implications. The paper will consist of:

Title

Short abstract describing the paper's contents (write this last)

1. Introduction:

lots of planets around other stars discovered recently (see review by Marcy and Butler 2000).

Marcy, G.W., and Butler, R.P. 2000, PASP, 112, 137

Planets are expected to form in the disks around stars and form more easily when there are heavy elements: cite the following references

Lissauer, J.J. 1993, ARAA, 31, 129

Goldreich, P.G., Lithwick, Y. and Sari, R. 2004, ARAA, 42, 549

Now that we can measure which stars have planets and can also make accurate measurements of heavy elements in the stars themselves, this hypothesis can be tested. The next 3 sections—

2. Counting planets

selected a sample of about 1000 stars which had been searched for planets at several observatories. Selected from the total list of about 5000 observed stars to be (a) stars with planets and (b) stars with observations at the same level, i.e. would have detected planets if the stars had them.

Butler, R.P., Marcy, G.W., Williams, E., McCarthy, C., Dosanjh, P., and Vogt, S.S. 1996, PASP, 108, 500

3. Measuring metallicity

Used computer models of the radiation from stars to analyze the radiation from each star to find its temperature and metallicity. Accurate to about 10%

Kurucz, R 1993, ATLAS 9 Stellar Atmosphere Programs and 2 km/s Grid (Cambridge SAO)

Gonzalez, G., Laws, C., Tyagi, S., and Reddy, B.E. 2001, AJ, 121, 432

4. Analysis

Grouped stars by metallicity

in each group measure what fraction have planets

plotted in Figure 1

5. Discussion and Conclusions

Followed by references and attach the figure at the end.

A random paper from the literature is attached to show the format. Note many things, in particular the switching between active and passive voice.

Planet Formation
(from The Hubble Space Telescope Web Site)

For centuries, astronomers and philosophers wondered how our solar system and its planets came to be. As telescopes advanced and space probes were sent out to explore, we learned more and more about our solar system, which gave us clues to how it might have taken shape.

But were our ideas right?

We could only see the end result of planet formation, not the process itself. And we had no other examples to study. Even with the knowledge gained about our solar system, we were left to wonder, are there other planetary systems out there, and did they form like ours? Discoveries made by the Hubble Space Telescope are helping us fill in key pieces to the puzzle of how planets form.

Current Understanding

A cloud collapses to form a star and disk. Planets form from this disk.

According to our current understanding, a star and its planets form out of a collapsing cloud of dust and gas within a larger cloud called a nebula. As gravity pulls material in the collapsing cloud closer together, the center of the cloud gets more and more compressed and, in turn, gets hotter. This dense, hot core becomes the kernel of a new star.

Meanwhile, inherent motions within the collapsing cloud cause it to churn. As the cloud gets exceedingly compressed, much of the cloud begins rotating in the same direction. The rotating cloud eventually flattens into a disk that gets thinner as it spins, kind of like a spinning clump of dough flattening into the shape of a pizza. These "circumstellar" or "protoplanetary" disks, as astronomers call them, are the birthplaces of planets.

Particles Merging

Small clumps of material within a disk stick together to form larger clumps. Eventually these clumps grow to become planets.

As a disk spins, the material within it travels around the star in the same direction. Eventually, the material in the disk will begin to stick together, somewhat like household dust sticking together to form dust bunnies. As these small clumps orbit within the disk, they sweep up surrounding material, growing bigger and bigger. The modest gravity of boulder-sized and larger chunks starts to pull in dust and other clumps. The bigger these conglomerates become, the more material they attract, and the bigger they get. Soon, the beginnings of planets – "planetesimals," as they are called –are taking shape.

Why do the planets in our solar system circle the Sun?

In the inner part of the disk, most of the material at this point is rocky, as much of the original gas has likely been gobbled up and cleared out by the developing star. This leads to the formation of smaller, rocky planetesimals close to the star. In the outer part of the disk, though, more gas remains, as well as ices that haven't yet been vaporized by the growing star. This additional material allows planetesimals farther from the star to gather more material and evolve into giants of ice and gas.

As each planetesimal grows bigger, it starts clearing out the material in its path, snatching up nearby, slow-moving rubble and gas while gravitationally tossing other material out of its way. Eventually, the debris in its path thins out and the planetesimal has a relatively clear lane of traffic around its star.

Protoplanetary Origins

Hundreds of these planetesimals are forming at the same time, and inevitably they meet up. If their paths cross at just the right time and they're moving fast enough relative to each other, SMASH! – they collide, sending debris everywhere. But if they slowly meander toward one other, gravity can gently draw them together. They form a union, merging into a larger object. If the participants are farther apart, they might not physically interact but their gravitational encounter can pull each body off course. These wayward objects start to cross other lanes of traffic, setting the stage for additional collisions and other meetings of the rocky kind.

After millions of years, countless encounters between these planetesimals have cleared out much of the disk's debris and have built up much larger – and many fewer – objects that now dominate their regions. A planetary system is reaching maturity.

How do we know all this? In part, because Hubble's exceptional vision has uncovered evidence in the disks around stars. This evidence helps to piece together the story of how planets form.