October 2015

Before we begin, a couple of cautions. A couple warnings, some few note bene.

The Writer's Warning: Before you go down this particular rabbit wormhole, please outline your work first, or at least have some idea of the path your story will take and the scope of the story you want to tell. Particularly because this is a field which has seen a lot of new and exciting research and discoveries and development lately, it is very possible to get lost in *ooh new and shiny* and end up not writing whatever it is you sat down to write when you started this worksheet. Before you start creating your own solar system, please make sure it is necessary. At certain points, I will also provide shortcuts to give you an idea of how to describe things if the bulk of your story takes place in limited scope, and you only want to imply a larger stage beyond what you're writing. That may be easier for you, less time consuming, and less distracting than filling out the full worksheet.

The Science Warning: Look, when I was a kid, Pluto was a planet. (Yes, I went there.) Mars was dead, Star Trek was not the done thing (this actually changed while I was in school, I'm happy to say), and we had no idea how many stars had their own planetary systems. Today we've given Pluto its own seat at the kiddie table, Mars quite probably has flowing water and *possibly* the beginnings or ends of some form of life, and we've mapped many, many new planetary systems. Incompletely, and we still have no idea how many, but they're there. Science marches on. This worksheet may be obsolete in ten years, it might be obsoleted next year. At which point I'll update it, but be aware. Pay attention. Keep informed. Hey, the trinary system in Pitch Black was a fiction until recently. You never know what you can come up with that might really be out there.

All right, enough with the caution, you're here for some fantastic astronomy.

Sol-1: The Center Point

For simplicity's sake we're going to say your solar system consists of planets orbiting a single star, because while we do know that multiple star systems exist, I at least am not educated enough to say how they operate. I'm not sure our leading scientists know enough to say. They might! That might be a thing we have enough information on to create theoretical models of. But we're simplifying things for the sake of putting a grounding of science under our fiction that we can understand well enough to write about. Describing the science in your science fiction without getting overly technical or kicking the relevant scientists (or science hobbyists) out of the story by too much generalizing is a tightrope. One best walked with the proper tools and understanding. If you're stuck as to how well you understand it, try and explain to a friend (who is not an astronomer or space scientist of any kind.) If they understand what you're saying, congratulations! You are ready to describe it in science fiction.

How old is your star?

So, we all know the rough life cycle of a star, right? It begins out of what is I believe technically known as Stuff (okay, it begins out of hydrogen and helium, and if you're going to rewrite the periodic table of elements for your science fiction that's a whole other worksheet I am not equipped to give you) that has fused together enough to convert the first into the second, creating a fusion reaction, creating a protostar, then a star, then at the end of its life cycle any of a handful of things. We'll get to those. Basically what I want you to do for now is determine whether this is a young star that still has quite a bit of debris in orbit, whether it has a fully formed system of planets and planetoids, or whether it's a dying planet which might affect your civilization's ability to survive and thus your story.

How many planets do you have?
This is pretty self evident, but I'm also going to go over the rules for what a planet is, since there are now formal rules as to what can and can't be called a planet. (Again, this could be different for your civilization, but for the sake of simplicity and saving everyone from having to make up a new science system from scratch, we're going to go with the rules adopted by the International Astronomical Union.) A planet must be:

1. In orbit around the sun/a star
2. Have sufficient mass to assume a round shape
3. Have cleared its orbit of all other bodies

That third one is where Pluto fell down, it's also why there are gaps between the rings of the further planets, because there are satellites of those further planets that have cleared their orbits of natural space debris. Pluto however has a number of other objects of similar or slightly greater size in orbit at its same rough distance. This means that its path is not clear and therefore it is not a planet. No matter how much we of a certain generation may pout and sulk. (I was one of those.) Clearing the neighborhood means that the planet has become so large everything in the vicinity has either been ground to space dust, drawn into its orbit to become another satellite, or possibly repelled. SO! With all that said, give yourself a number of planets. We only have our solar system to go on for sure, but you can also look at the discovered stars and solar systems to see what a good average might be.

How big is your star system?
We measure our system in Astronomical Units, which is the average distance between the Earth and the Sun. We're very terracentric that way.

What are your units of measurement?
(And this, by the way, is a good worldbuilding note: if you're not setting your work in a Earth-based world but in some galaxy far far away, they'll use a different measurement system. Underneath that it would probably be easiest to put AUs and measure it in a similar way, between the central planet of your civilization and its sun, but they might *call* it something else like, oh, Coruscant Units. Or something.)

(By the way, we also tend to describe things in terms of Earth masses. Jupiter is about 318 Earths, for example. The Sun is over 332,000 Earths, or for the sake of non-scientific scale many many lots. Mars is about .1 Earths. And again, you can use this if you have a civilization that originates on Earth-That-Was, or Terra, or you can pick a different basal reference such as, oh, Arrakis. Giedi Prime is X Arrakis Masses, and so forth.)

What are your distances?
So, to give you some perspective, the Sun to the Earth is 1 AU. The Sun to Mars is 1.5 AU. Out to Jupiter is about 20 AU, and out to Neptune is about 30 AU. Keeping in mind here that these are *averages* not concrete, unchanging values. The more elliptical an orbit is as opposed to circular, the more range you have in distance from the sun. So give your planets an order, some rough sense of distance, and we'll work on orbits and proximity and what this all means in short order.

Describe your orbits:
Most of our planets have the same orbit direction, the same rotation direction which is itself the same as the orbit direction (they spin and go around the sun in the same direction), the same rough plane (if you stick a sheet of something through a model of the system bisecting the center star it will also hit most of the planets), and a similar tilt of about 23-25 degrees from "vertical" which we'll consider as This Side North Pole Up. Again, we don't have a big enough data sample to know yet whether or not this is typical or whether we're the odd ones out, but we'll work with what we have.

There are sound physical theories behind this, conservation of angular momentum, the way one feels the pressure on a spinning merry-go-round, spinning everything out into about the same direction and plane and so on. There are formulae and measurements that one can take, but since we're working with descriptions and fiction and not math we won't focus on them. I will introduce you to some terms:

eccentricity - the deviation of an orbit from the circle/circularity
perihelion, aphelion - perihelion is the point in a planet's orbit when it is closest to the central body/the sun, aphelion is when it is furthest.
orbital resonance - when two bodies orbit around the same parent body, with body A being an integer multiple of the orbit period of body B. (This Will Be Important Later)

Orrery
An orrery is a moving model of the (or a) solar system. If you're feeling *very* ambitious, have time and resources and space to spare, you might build one to better be able to chart the movements of your planet. If you are ever able to find or code a virtual one, please share with the rest of us.

Frostline
The Frostline marks the point at which distance from the sun leads to a change in temperature such that different types of planets form out of different compounds. Scientifically this is known as Terrestrial and Jovian, from Earth and Jupiter respectively. Again being simplistic, the Terrestrial planets tend to have a molten iron core, and the Jovian planets tend to have a gas center and be made of hydrogen and hydrogen compounds. What this effectively means is that your closer in planets are more likely to support humanoid life, while your more outer planets are more likely to have humanoid life on their moons or, depending on the technological level of your civilization, be strip-mined for their useful gases. Terrestrial, closer in planets tend to be smaller, Jovian planets tend to be larger, along the scale of 1-3 hundred times bigger.

As far as other systems are concerned that we can detect, there are a number of Jovian sized planets located close enough to their suns that they in theory should be within the frostlines, unless, again, our system is the anomaly and things work differently from the model we've based on our own solar system. That said, our system is the one we have data on, so for a more science grounded brand of fiction, it might be best to base it on the area of most data collected.

Many Colored Dots

What are the basic structures of your terrestrial and jovian planets?

We all remember from middle school geology that the earth has a crust (lithosphere, including part of the...) mantle, and a core, yes? Mercury, Venus, and Mars have them too! Some simple facts when you're building your planets:

Size: The larger a terrestrial planet is, the longer it's likely to remain hot in the center. Heat in the core leads to flowing molten iron, which leads to a magnetic field, which leads to a lot of other things I'll get to in a second. Size also means a bigger center of gravity, meaning the ability to sweep things out of a somewhat bigger orbit. See also: Jupiter is a giant dickplanet and disrupts everything in its vicinity and even some things not in its vicinity.

Fields: There are a lot of ways to lose a magnetic field. Rotating too slowly. Being too small so your core cools off quickly and therefore you lose your magnetic field. A magnetic field is good and necessary, though, it helps us keep our atmosphere. And atmosphere is necessary because it helps us keep a regulated temperature, gives us semi-predicatble (okay, who am I kidding) weather, keeps all those important gases on the inside instead of the outside. Provides a greenhouse effect so the planet doesn't entirely cool or bake, either. (Venus, we're all looking at you.) Basically, the atmosphere keeps an even average as opposed to letting your planet become Crematoria, on fire on one side and frozen on the other.

Distance: Specifically, distance from the sun. This one should be reasonably self-evident, i.e. if you're too close to the sun it's going to be too hot for life, geological events, etc, and if you're too far away it's going to be too cold. If you're far enough away you're outside the frostline, you end up with a gas planet of hydrogen and hydrogen compounds, and you've got resource mines again.

What is the weather like on your planet? What are the seasons like?

At least some of this has to do with your axial tilt, which is the reason for the seasons. If you have no tilt, your seasons pretty much stay static the whole year around, vis a vis the equatorial region and the polar regions which remain at roughly the same distance from the sun, etc. The troposphere, the lowest level of the atmosphere, is where the weather happens. Up into the stratosphere, there is no weather, which is why radar and probes and observational equipment and sometimes really sophisticated plane-shuttles tend to like it there. Down in the troposphere is where the greenhouse warming happens, shifts in temperatures, and thus weather. We also have weather, or at least this kind of variety of it, because of the Coriolis effect. This helps split the convection cells per hemisphere so that we have multiple cells, multiple wind currents, and multiple variables to give us the erratic weather we all know and love.

What about your continents? What about your planetary life?
I'm not going to go into too much detail about this, for one thing figuring out what types of life would appear on your planet, assuming non-human, requires far more biochemistry than I have right now. (*Yet.* Fear my avarice of knowledge.) Continents happen because of shifts in the earth's crust, plate tectonics, Pangaea split, you know the drill. If you don't, have some new search terms! This also results in new crust forming, usually through the ocean floor or at least so I presume because if it formed on land where there are people to see it we'd probably have a whole new set of creation myths. So, really, the create your own planet worksheet might be a sub-sheet for this project. Also the planetary life one. I'm not a geek I swear.

So, about those gas mines...
Jovians! Jovians are basically gas and rocks that accreted into giant bastards of planets. Their sizes and masses depend on how much crap they took from the solar nebula, yes I'm going to be making jokes like that all worksheet, but *size and mass are not directly correlated*. Saturn, for example, is less dense than water. If you could get a galactic space bathtub, you could float it like a pool toy. Jupiter, on the other hand, is only slightly larger but three times as massive. Usually, the further from the sun, the slower the planetesimals (baby planets) build. The core of jovian planets are rock and ice; there is no molten core, and if you dig deep enough you'll find an ice block you wouldn't want floating in your whiskey. Assuming you adulterate your whiskey. So, keep that in mind.

Jovian planets tend (at least in our observable records) to rotate rapidly. This leads to storms, it leads to a slight squashing effect, it leads to interesting weather patterns. The various hydrogen compounds combine at the troposphere, at different latitudes to create different colored bands along the surface, or a different colored surface. Neptune and Uranus are blue-colored because of the methane. The rapid rotation also leads to storm cells forming that can last, literally, for years, so if you're going to place a gas mining operation on here, something like Cloud City that operates up in the stratosphere somewhat out of the range of such things wouldn't be the worst idea ever.

Jovian moons are the likeliest to have life. In particular, there are two moons of Jupiter which are being looked at for signs of life now or in the future, due to something called tidal heating. Basically what this means is that they orbit in such an elliptical shape (keep that in mind when you're mapping your solar system) that the change in tidal forces cause a cycle of compression and release. Similar to how you can compress and release a stress ball rapidly, or a muscle, and feel it heat up; this causes tidal heating, which then causes a warmer moon/planetoid?/object upon which life can sit. Io is the most volcanically active object in our solar system because of tidal heating. So if you're going to put life out on the distant edges of the solar system, that's where you want it to go. Now consider the Kardashev rating of a civilization that has a whole damn gas giant to mine. Ooooh.

Asteroids, Comets, And Other Sealed Cans
Asteroids aren't just dinosaur killers, they're also the rocky leftovers of the solar nebula that formed our protostar, our star, our solar system. Comets are icy leftovers of the same! Think if you stuck something in the back of the freezer like, say, a lobster and left it for a *really really* long time, and then it mutated and sought life to feed off of and took over the second you opened that freezer door. And then you had to space the freezer out the airlock to the tune of the Nutcracker Suite.

Okay, that's a bit specific, but being as asteroids and comets are leftovers from the original material of the solar system, they have a lot to tell us about its beginnings. Which means they have a lot to tell your characters and your readers about the origin of your setting as well. If you're into space magic, there might be some sealed evil in there. If you're into space virii, there might be some sealed in the tail of a comet! And when you go drilling (which we did in real life! sort of. more like smashing.) well, then you have a whole other problem for your protagonists to deal with. A lot of potential here!

Remember when I said orbital resonences would come in handy later? Orbital resonance with Jupiter is why we have an asteroid belt instead of another planet. When the planetesimals, baby would-be planets attempted to form, they were caught in orbital resonance with Jupiter and weren't able to form their own mass sufficient to escape its gravity, and yet they weren't pulled into Jupiter's orbit either. So if you want to have your own asteroid belt somewhere in your system, a Jupiter-like planet might be a good thing to have, just outside the frostline and the asteroid belt.

So! To recap.
-- do you have the age of your sun?
-- do you have your planets and frost line?
-- do you have their masses and locations?
-- do you have their orbits? make sure they're clear!
-- do you have all the satellites for your planet?
-- have you accounted for the leftovers in your fridge?
You should be good to go!