A ‘Verse that Holds Up to Logic

 Since I found the Serenity movie and later the show that brought it about, I was wondering what kind of system could have all these suns and planets. I had imagined all kinds of different possibilities with different arrangements of star systems and habitable zones. All of those were based on the laws of orbital dynamics I learned by being interested in the solar system when I was young.

 You can imagine my disappointment when the *Official Map of the ‘Verse* was released. While it’s an extremely beautiful poster, the lack of attention given to the laws of physics was heartbreaking. Could I forgive that the Red Sun would have to be older than the entire life span of the White Sun and probably order than the current age of the universe? I guess. Could I forgive that the Blue Sun would have had to have lost its outer layers to be that size and color, and would be brighter and more massive than the White Sun that it orbits? Maybe. Could I forgive that the stars were in planetary spaced orbits around another star without even an additional order of magnitude of mass? Probably not. But when I found out someone took the time to learn about Lagrangian points and not only applied them to co-orbital bodies that were way too massive, but actually placed the Red Sun in the L3 point that’s clearly known to be unstable, I was completely unable to suspend disbelief.

 This left me thinking about what could be done to make the ‘Verse possible in the real world without deviation from what we’ve seen onscreen, so I started doing research. The Red Sun would need to be a star in the last stages of life to be both a major star in the system and be red, or in other words, a red giant. At first, the Blue Sun seemed totally impossible because blue stars don’t live long enough for rocky planets to solidify, but then I found that when stars die, newly formed white dwarfs are actually very blue and very bright. The White Sun could never be massive enough to hold all these stars in close orbit especially for it to have planets of its own, but after being stumped for a while, I considered a system where the White Sun was in close orbit around a black hole. The black hole would be the true center of the system, but it wouldn’t be visible, so the White Sun would appear to be the center of the system.

 I’m not sure when I came across the oh-so-fun PC program *Universe Sandbox.* It’s a simulator that allows all kinds of experiments with existing systems and custom systems. It’s an incredible learning tool and they’re moving along in development of *Universe Sandbox²* which is available in alpha release. The desire to simulate the ‘Verse and see all the worlds turning was only obvious.

 At some point, I had also come across *The Verse in Numbers* written by Andy Gore. This is a wonderful attempt to put all canon together and fill in the gaps. It adds in a bunch of what I assume is fan fiction, and makes a nice well rounded ‘Verse. Its goal was dissimilar to mine in that it was trying to compile all the information about the ‘Verse system and not to try to reshape it into a system that can work in a simulator. It also had some minor physics errors like brown dwarfs that were more massive than real world stars. Overall, it’s a great document that I used heavily for my work.

 *The Verse in Numbers* talked about “heiloforming” to turn brown dwarfs into usable suns. The brown dwarfs masses were already off so I started looking into what masses they should be, and how much they would have to be heiloformed. I was surprised to find that brown dwarfs are warm enough due to the heat of their formation to have habitable zones even billions of years after their creation. I knew, to have a white sun, the system would have to be quite young, so I decided to throw heiloforming into the same not-believable-bucket as a stable L3 Lagrangian point.

 I was now firmly entrenched in the part of the project where I decide what masses to use for all these suns, planets, and moons along with a newly added black hole. I knew the White Sun needed to be more massive than our Sun to be white, so I started with 1.5 solar-masses. Bigger stars live shorter lives, so the Red Sun and Blue Sun would have to start well above the White Sun, to be at the end of their lives while the White Sun is still in the middle of its life. I started with 2.5 solar-masses for them, with the Blue Sun being just a couple percent more, since it’s just after fusion ended, and the Red Sun is just before fusion ends. The black hole would be like the sun is in the solar system, and the White, Red, and Blue Suns, would be like the planets, so the mass ratio of the most massive star to the black hole should be around the mass ratio of Jupiter to the Sun, since Jupiter was already big enough to keep a planet from forming in the asteroid belt. That’s a little over 1000 to one, so the black hole should be around a 2500 solar-mass monstrosity. After I came to this conclusion, I’m proud to say that I didn’t just give up.

 I know it wouldn’t work out, but I started putting the system together to see what I had to work with. A red giant’s habitable zone, is very large, so for the Red Sun’s hill sphere (the area under its gravitational control) to be large enough while orbiting a 2500 solar-mass black hole for planets to be livable, its orbit would need to be more than a light year from the black hole. The ‘Verse doesn’t have faster than light travel, and trips are supposed to take weeks, not years, so that wouldn’t do. The White Sun would need to be much further from the black hole than I have originally hoped to keep it from being torn apart by tidal forces. This would leave the White Sun swinging back and forth across the sky, and the tidal forces on the planets would make them about the least hospitable planets in the ‘Verse instead of the core of civilization. On the bright side, there was plenty of room between the White and Red Suns for the Blue Sun and all the other star systems.

 I didn’t have any better ideas at the time, so I went ahead and started populating the rest of the ‘Verse. The mass distribution of the bodies defined in *The Verse in Numbers* was clumpy and didn’t feel right to me, so I did more research. I found the masses in a system tended to loosely follow a pattern. The 50th most massive body in a system tended to be around as many times more massive than the 100th most massive body as the 100th most massive body is more massive than the 200th most massive. It makes a nice line in Excel when both axes are set to logarithmic. I picked a slope and starting point I liked, but I didn’t want to match the line perfectly, because that’s not realistic either. I added a random component to the values, and learned just how much randomness can make it all feel more real. I heavily utilized random number generators throughout the rest of the project.

 To get the number of worlds I needed, the slope of the line needed to be much shallower than the slope made by our own solar system. Because of this, every random result always ended up with a second most massive object that was much larger than 2.5 solar-masses. It was also very rare for the 2nd and 3rd largest masses to be only 2% apart. I came to the conclusion that another much larger star was once in this system, but long since died and collapsed into another black hole. I simply placed it in a super close orbit around the big black hole (that I had started referring to as Titan), where it wouldn’t have any effect on the system.

 It still took a lot of adjustment and attempts to end up with 3rd and 4th masses around 2.5 solar-masses around 1/20 of a solar-mass apart, the 5th mass around 1.5 solar-masses, and about 12 bodies with the right amount of mass to work as suns. At the end, I settled for 14 suns, and upgraded Elphame and Daedalus from gas giants to brown dwarfs, and Titan ended up quite a bit more massive than I had originally planned to allow the stars to be closer to one another in their orbits.

 I knew I needed to make the system smaller, so I decided to skip having planets around the Red Sun at all and have the White Sun as simply the innermost star with planets orbiting it normally. This got the size of the system down to less than 13000 AU, which is still months at light speed and 30 times larger than canon. Went through some random orders of the other stars until I found an order that worked. I didn’t feel the need to strictly adhere to the random result, because bodies naturally find stable orbits in time, and since I didn’t have the time, I had to do it myself.

 Before I had completed this 1st system, I had noticed that the habitable zone of the Red Sun was larger than some of the orbits around Titan. I had contemplated putting the Red Sun in tight orbit around Titan to utilize its habitable zone, but red giants can’t handle any tidal forces. Then I realized the Red Sun could be in normal orbit around Titan and planets could be in the tight orbit since Titan would always be in the habitable zone. This also had the advantage of trojan planets sharing the Red Sun’s orbit in the stable L4 and L5 Lagrangian points would also be the habitable zone. The only problem was, the White Sun had to be the core.

 Then I started thinking, what does “core” mean. We know from the show that the Core Worlds are the center of civilization. They’re also the center of technology, history, culture, population, and government, among other things. Did it mean it had to be the gravitational center as well? People often get to using a particular term for unusual and sometimes outdated reasons. The floppy disk save symbol at the top of this word editor is evidence to that fact. The core needs to feel like the center of the system, but that leaves some room for thinking outside the box.

 If you take look at the ‘Verse as described by the *Official Map of the ‘Verse* when the Blue Sun, Kalidasa, and Georgia are in the same part of their orbits, on the left side of the White Sun, the major suns line up like so: Blue Sun, Kalidasa, Georgia, White Sun, and the Red Sun. Take this list and add Titan to the end of it and you have a system where the White Sun is not the gravitational center, but in the middle from between being very far away from everything and from being very deep in the gravity well of an immense black hole. Sounds like a fine place to call the core.

 How compact the system could be, was severely limited by the White Sun’s hill sphere. It didn’t take me long to revisit the idea of tight orbit around a black hole. A moderate sized black hole would have a much larger hill sphere. The secondary black hole (which I’ve named Esther), would’ve started out as a 200 solar-mass star, which I figured could result in around a 30 solar-mass black hole. We’re actually a little hazy on how massive black holes are after a massive star’s core collapse as current theory doesn’t align well with the new gravity wave observations. The hill sphere of Esther is large enough to even have Qin Shi Huang in orbit without a particularly large system.

 I added in orbits for the smaller suns in-between the 5 main ones and ended up with a ‘Verse that was only 2430 AU across worse case, which is 6 times larger than canon, but that was with the Blue Sun and Kalidasa on the far opposite sides of Titan. Most of the system is within the orbit of Georgia any way which was only 420 AU from Titan. This would be crossable in only 2 weeks at light speed, or a couple months in a typical ship, if we’re to avoid time dilation in the fastest ships.

 Some of the space taken up by the system was from the smaller stars that in the *Official Map of the ‘Verse* were in orbits around other stars. Being in planetary style orbits is a challenge because the masses are just too similar. I barely managed to do it with Qin Shi Huang around Esther so the other ones couldn’t orbit the larger stars. I had already been placing the smaller stars in binary style orbits because their habitable zones are so small there’s room to orbit each other. The Red Sun already had trojan planets, but that got me to thinking, were trojan stars possible? After doing the math, only Esther had enough mass to support stable trojan stars. The Blue and Red Suns could’ve when they were younger, but with the Red Sun, it was a moot point. The Blue Sun however could’ve had one until recently. I decided to put Burnham in an orbit that conflicts with the Blue sun, because there just hasn’t been enough time for their 200+ year orbits to conflict enough to kick Burnham out. I put Lux in one of Esther’s Lagrangian points and the triple dwarf star system containing Murphy, Elphame, and Daedalus in the other. The White Sun being half way in between these two systems further emphasizes that it’s the center of the ‘Verse.

 This final change led to a ‘Verse that could stay less than 1200 AU across for decades at a time. That could be crossed in 3 weeks at a third the speed of light. It’s a system that even has a reasonable origination story (see *The Worlds of the ‘Verse*). I further described how the system would work with the pulse drive seen in the show in another document titled *Fusion Powered Transport*

 For a long time now, I’ve been placing the worlds in stable orbits with randomly generated attributes. As I’ve mentioned, *Universe Sandbox²* is in alpha release, and while it’s a beautiful piece of software, it’s slightly incomplete when dealing with orbits around binaries, and very large systems. The order of the planets’ masses is as random as possible, and I’ve tried to assign names to make it as close to canon as possible. I still have some testing to do to verify the stability of the orbits, though anything stable for a thousand years makes for a valid terraforming project.