NSSPlots
(Neutron Star Sequences Plots)

June 20, 2019

1 How it works

This plotting tool written in pyhton 2.7 computes different types of plots to analyze the different properties of a rotating neutron star, these are a series of constant rest mass tracks of neutron stars with changing spin frequency. It uses the output data from *NSSS*, which are the parameters seen in Table 1, that are worth noting that these are some of the parameters used in [1].

There are two codes, the main code, *Plots.py*, generates various plots combining the data obtained from the ten different equations of state (EOS), and the second one, *Plot-oneEOS.py*, which generates the same plots as the previous one, but using just one EOS, instead of the 10. To run either from the Terminal, the following command line is used

```
python Plots.py
```

and by typing a number from 1 to 28 and "enter" we get the chosen plot from a list shown in the terminal.

Table 1: Parameters obtained from the computation of a sequence of neutron stars

Parameter	Description
ε_c	Central energy density
M	Total mass (in $M_\odot$)
M_0	Baryonic mass, also know as rest mass (in $M_\odot$)
M_*	Mass when the neutron star is not rotating in a sequence (in $M_\odot$)
M_{max}	Maximum mass of a non-rotating NS for a given EOS (in $M_\odot$)
R	Radius of the NS (in km)
r_p/r_e	Ratio of the polar radius and the equatorial radius
R_*	Radius when the neutron star is not rotating in a sequence (in km)
ν	Rotational frequency (in Hz)
ν_K	Kepler limit for rotation (in Hz)
J	Angular momentum (in cm^{2}g/s)
T	Rotational kinetic energy (in g)
U	Gravitational binding energy (in g)
R_{max}	Maximum radius of a non-rotating neutron star for a given EOS (in km)
$M_{max/R_{max}}$	Quotient of the maximum mass and radius of the non-rotating NS for a given sequence

When plotting the different variables, the normalization shows the behaviour of the data can be seen better. The angular velocity can be normalized in the following manner

$$\Omega\left(\frac{R^3}{GM}\right)^{1/2},$$

where G is the gravitational constant. The compactness is given by

$$\zeta = \frac{GM}{Rc^2},$$

where c is the speed of light. A way to normalize this quantity is by dividing it by the maximum compactness, which instead of being the total mass, M, divided by the equatorial radius, R, it is M_{max}

divided by the corresponding radius, R_M,

$$\frac{\zeta}{\zeta_{max}} = \frac{M/R}{M_{max/R_M}}.$$

The Kerr spin parameter can be obtained as well,

$$a = \frac{cJ}{GM},$$

and the normalized version of this parameter is

$$\frac{a}{M} = \frac{cJ}{GM^2},$$

The fraction of mass that comes from relativistic sources compared with the baryonic mass is given by

$$\frac{M - M_0}{M_0},$$

and the comparison of the total mass of the neutron star with the mass of the non rotating star with the same properties is

$$\frac{M - M_*}{M_*},$$

and similarly to the last ratio, the comparison of the equatorial radius of the neutron with the radius of the non rotating star with the with the same properties is

$$\frac{R - R_*}{R_*},$$

2 Output

We can see in Figures 1, 2, and 3 some of the types of plots that can be obtained using this code using the normalized quatities previously mentioned. It can output 2D and 3D plots.

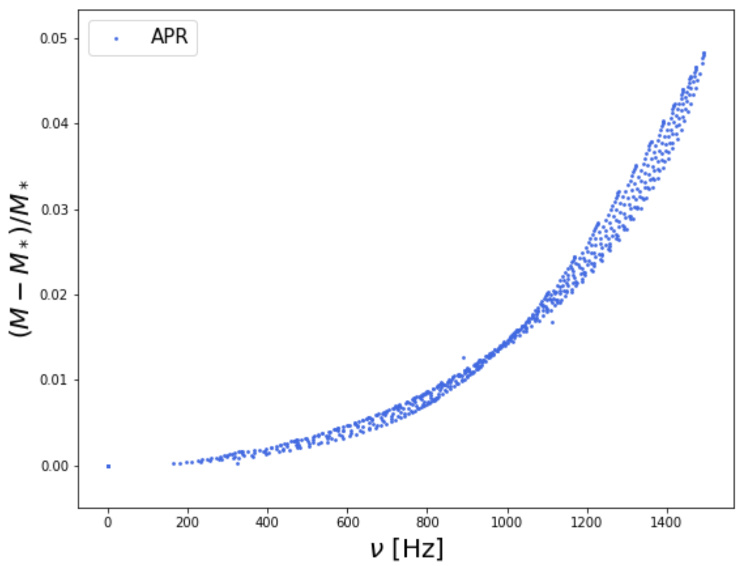

Figure 1: Fraction of mass gain of neutron stars with constant value of M_0 for one EOS, as a function of the normalized frequency

References

[1] Cook, G. B., Shapiro, S. L., & Teukolsky, S. A. 1994, ApJ, 424, 823

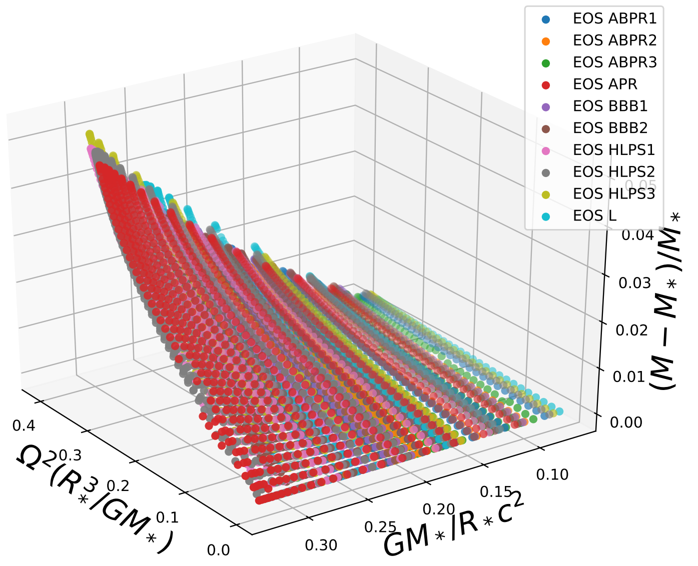

Figure 2: Fraction of total mass gain of neutron stars with constant value of M_0 for ten EOS, as a function of the normalized squared value of angular velocity and the compactness.

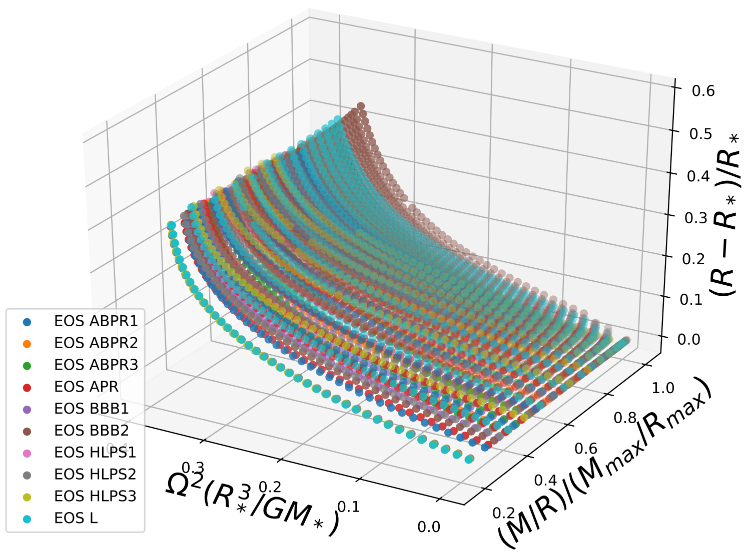

Figure 3: Fraction of total radius gain of neutron stars with constant value of M_0 for ten EOS, as a function of the normalized squared value of angular velocity and the maximum normalized value of M/R