july 24th, 2025

plots of similar solar systems to our own

stuff i worked on

- working on new graphs of **systems similar to our solar system**
- identifying certain systems with interesting properties (*ex.* hot jupiters)

dataset

- NASA Exoplanet Archive

```
# Exoplanet data from NASA Exoplanet Archive - Planetary Systems Composite Data on September 15th, 2024:
# https://exoplanetarchive.ipac.caltech.edu/cgi-bin/TblView/nph-tblView?app=ExoTbls&config=PSCompPars
```

basic data cleanup

- casting features to proper corresponding data types
- getting rid of flagged controversial exoplanets

```
[ ] nasa_exoplanets_data['pl_controv_flag'].value_counts()
```

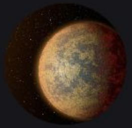
pl_controv_flag	count
0	5803
1	31

dtype: int64

types of exoplanets

- based off of the basic classification provided by NASA at [Exoplanet Catalog - NASA Science]

KEY TO EXOPLANET TYPES



Terrestrial

A type of exoplanet made of rock or metal, smaller than Earth, possibly with oceans or atmospheres (artist's concept).

Super Earth

Super-Earth exoplanets are also rocky, but between Earth and Neptune in size (artist's concept).

Neptune-like

This variety of exoplanet is similar in size to Uranus and Neptune, with an atmosphere of mostly hydrogen or helium (artist's concept).

Gas Giant

Gas Giant exoplanets are as massive as Saturn or Jupiter, or larger; this category also includes "hot Jupiters," which orbit close to their stars (artist's concept).

```
[ ] nasa_exoplanets_data.loc[(nasa_exoplanets_data['pl_rade'] <= 1), 'pl_type'] = 'Terrestrial'
    nasa_exoplanets_data.loc[((nasa_exoplanets_data['pl_rade'] > 1) & (nasa_exoplanets_data['pl_rade'] <= 2.1)), 'pl_type'] = 'Super-Earth'
    nasa_exoplanets_data.loc[((nasa_exoplanets_data['pl_rade'] > 2.1) & (nasa_exoplanets_data['pl_rade'] <= 7)), 'pl_type'] = 'Neptune-Like'
    nasa_exoplanets_data.loc[(nasa_exoplanets_data['pl_rade'] > 7), 'pl_type'] = 'Gas-Giant'
    nasa_exoplanets_data['pl_type'].value_counts()
```

types of exoplanets

- based off of the basic classification provided by NASA at Exoplanet Catalog - NASA Science

	count
pl_type	
Neptune-Like	2117
Gas-Giant	1818
Super-Earth	1628
Terrestrial	224

limit to G star systems (since Sun is G-type)

- also limit to single host star systems

st_spectype	count
G	539
K	468
M	375
F	181
A	13
B	4

```python
# Select Sun-like G star for analysis. Selection criteria: 0.8 solar_mass <= st_mass <= 1.2 solar mass
st_mass_vs_pl_orbit_plot_data_sun_like_g_stars = st_mass_vs_pl_orbit_plot_data_g_stars.loc[
    (st_mass_vs_pl_orbit_plot_data_g_stars['st_mass'] >= 0.65) & (st_mass_vs_pl_orbit_plot_data_g_stars['st_mass'] <= 2.53)]
hz_zone_plot_data_sun_like_g_stars = hz_zone_plot_data_g_stars.loc[
    (hz_zone_plot_data_g_stars['st_mass'] >= 0.65) & (hz_zone_plot_data_g_stars['st_mass'] <= 2.53)]
st_mass_vs_pl_orbit_plot_data_sun_like_g_stars['pl_type'].value_counts()
```

pl_type	count
Gas-Giant	372
Neptune-Like	126
Super-Earth	40
Terrestrial	1

limit to G star systems (since Sun is G-type)

- also limit to single host star systems

```
[ ] # Select Sun-like G star for analysis. Selection criteria: 0.8 solar_mass <= st_mass <= 1.2 solar mass
    st_mass_vs_pl_orbit_plot_data_sun_like_g_stars = st_mass_vs_pl_orbit_plot_data_g_stars.loc[
        (st_mass_vs_pl_orbit_plot_data_g_stars['st_mass'] >= 0.65) & (st_mass_vs_pl_orbit_plot_data_g_stars['st_mass'] <= 2.53)]
    hz_zone_plot_data_sun_like_g_stars = hz_zone_plot_data_g_stars.loc[
        (hz_zone_plot_data_g_stars['st_mass'] >= 0.65) & (hz_zone_plot_data_g_stars['st_mass'] <= 2.53)]
    st_mass_vs_pl_orbit_plot_data_sun_like_g_stars['pl_type'].value_counts()
```

pl_type	count
Gas-Giant	372
Neptune-Like	126
Super-Earth	40
Terrestrial	1

habitable zone range calculations

- used the formula from: Analysis of Habitability and Stellar Habitable Zones from Observed Exoplanets

2.2. Habitability Zone Determination

The habitable zone of a given exoplanet was determined based on its calculated average surface temperature, denoted as $T_{surf,\,ave}$, a critical indicator of potential liquid water presence. We categorized exoplanets as "Too Hot" ($T_{surf,\,ave} > 100$ °C), "Too Cold" ($T_{surf,ave} < 0$ °C) or within the habitable zone ("In HZ") for $T_{surf,\,ave}$ between the benchmark temperature range of 0 and 100 °C. This classification was vital to identifying exoplanets that could potentially support life under the assumed necessary precursor of surface-accessible liquid phase H_2O.

Utilizing the basic Radiative Equilibrium equation as derived from first principles of radiative heat transfer, the exoplanet average surface temperature calculation considered several characterizing factors. These include the observed exoplanet's distance from its host star (d), the host's effective surface temperature (T) and radius (R), along with an assumed exoplanet albedo (A) and additional scaler to account for bulk atmospheric greenhouse gas effect (k):

$$T_{surf,ave} = kT(1-A)^{0.25}(R/(2d))^{0.5} \quad (1)$$

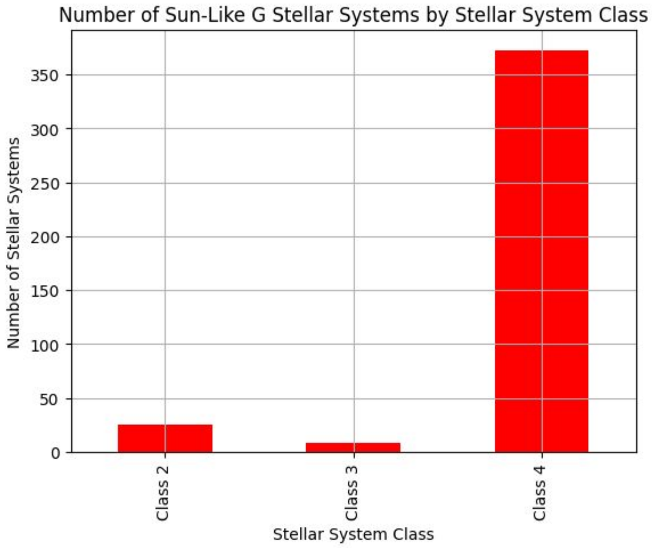
final dataset to graph

- 406 systems that meet our requirements
- **we will split these systems into basic classifications**

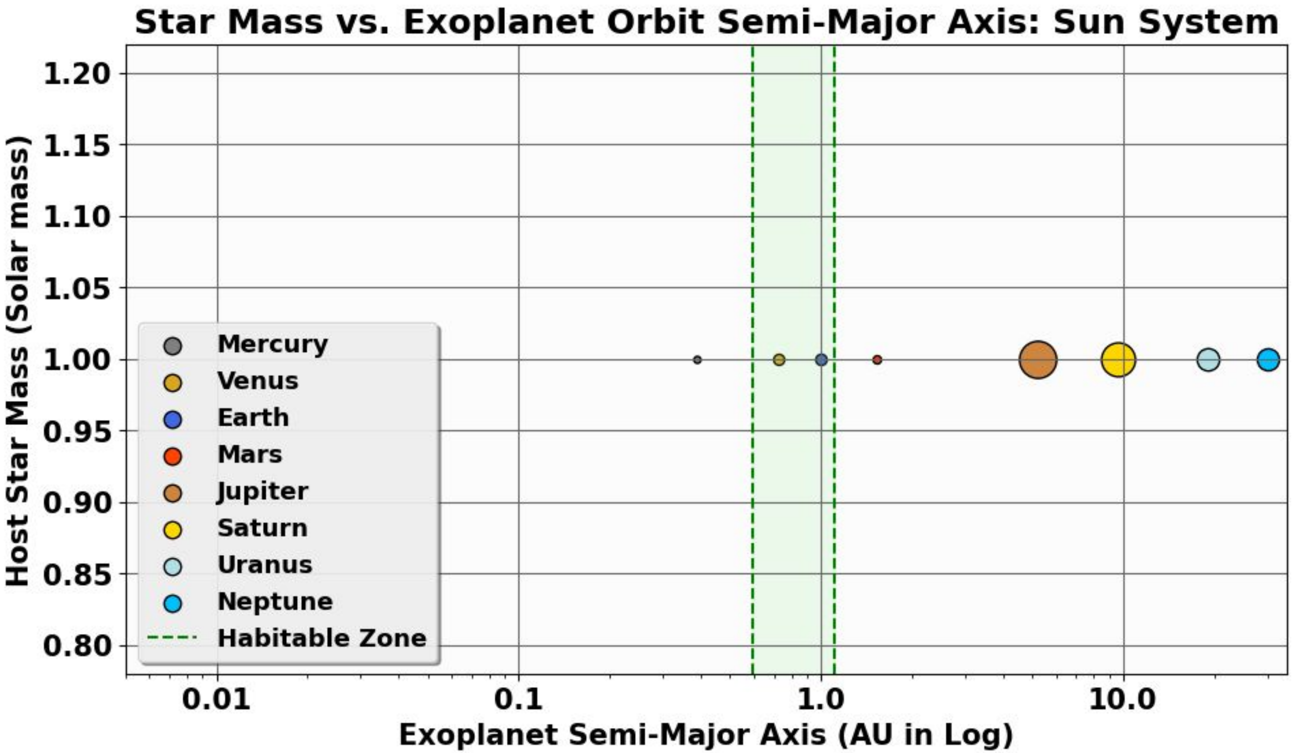
stellar system classification

- create simple stellar system classes based on **member planet types:**
  - **class 1:** at least one Terrestrial + at least one Neptune-Like or Gas-Giant
  - **class 2:** at least one Super-Earth + at least one Neptune-Like or Gas-Giant
  - **class 3:** only Terrestrials or Super-Earths
  - **class 4:** only Neptune-Likes or Gas-Giants

st_system_class	count
Class 2	25
Class 3	9
Class 4	372



star mass v. exopl. semi-major axis: our solar system

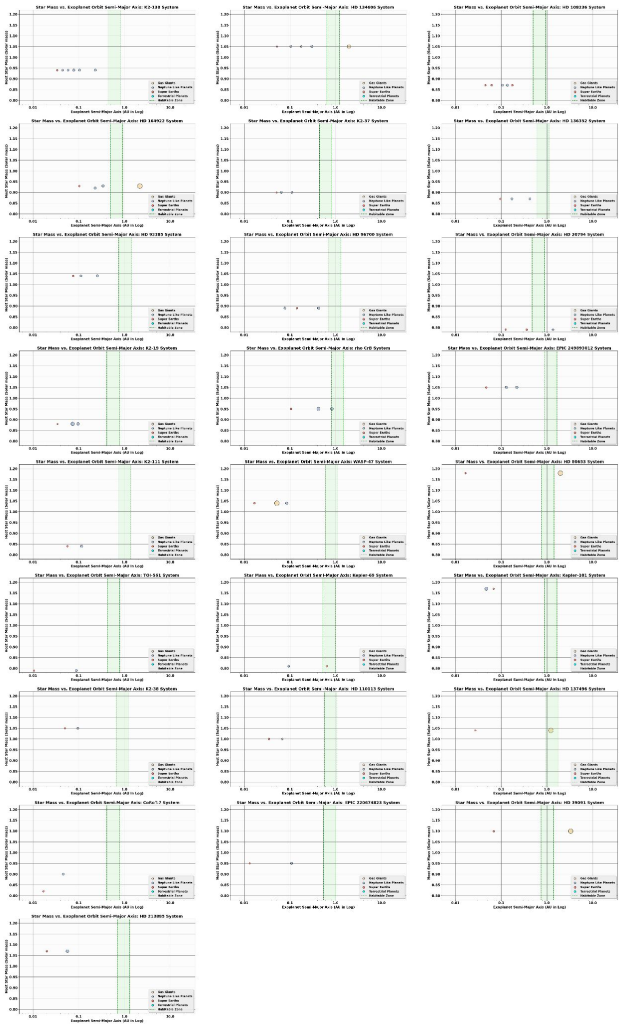


25 class 2 systems

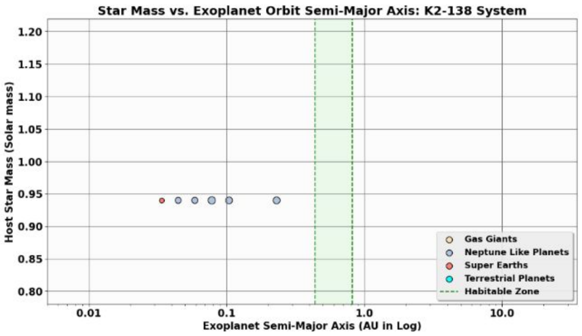
≥1 one Super-Earth + ≥1 Neptune-Like or Gas-Giant

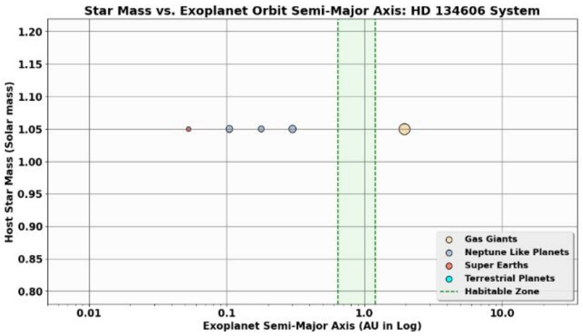
some cool ones i noticed:

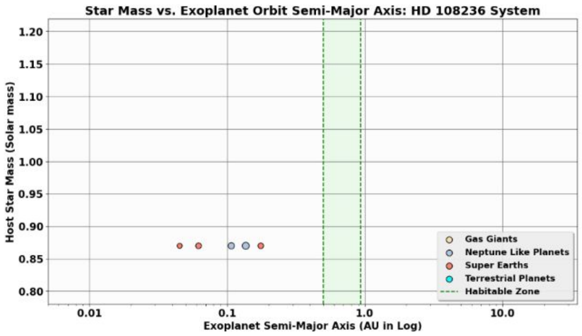
- HD134606
- HD164922
- WASP-47 (hot Jupiter at 0.1)

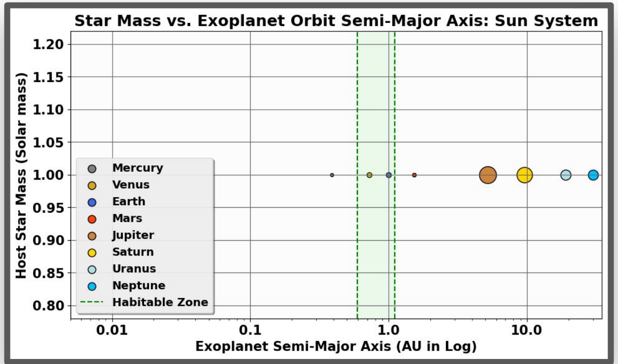


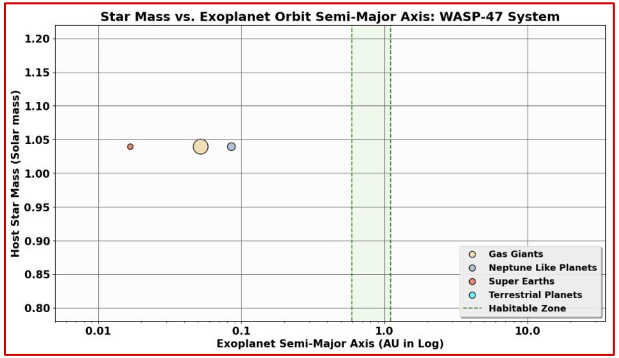
star mass v. exopl. semi-major axis: class 2 systems

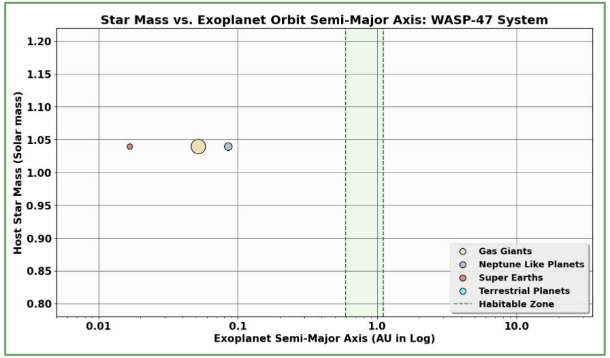










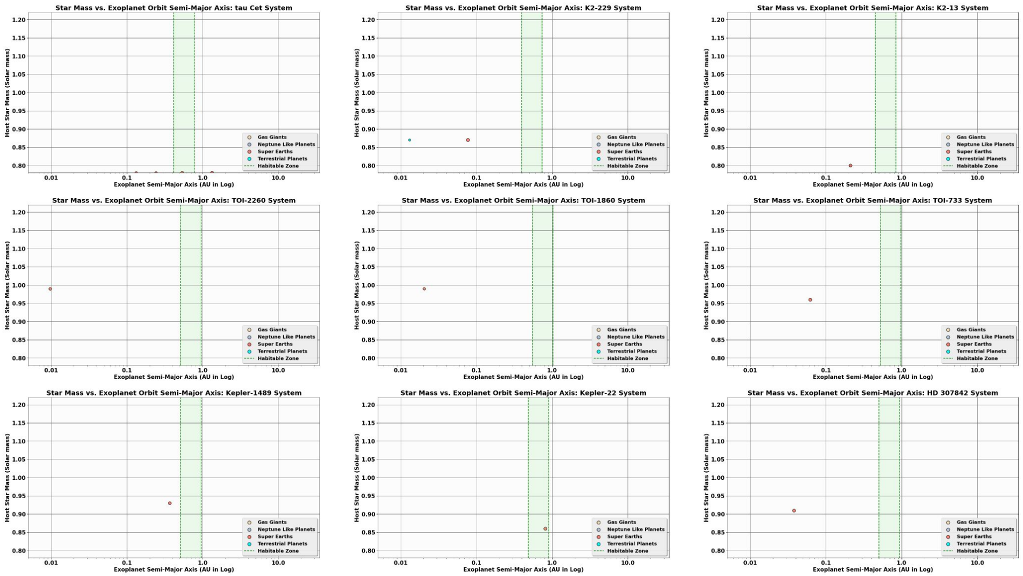


9 **class 3** systems

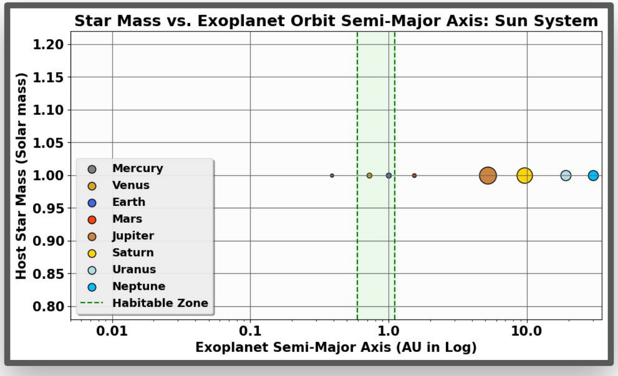
only Terrestrials or Super-Earths

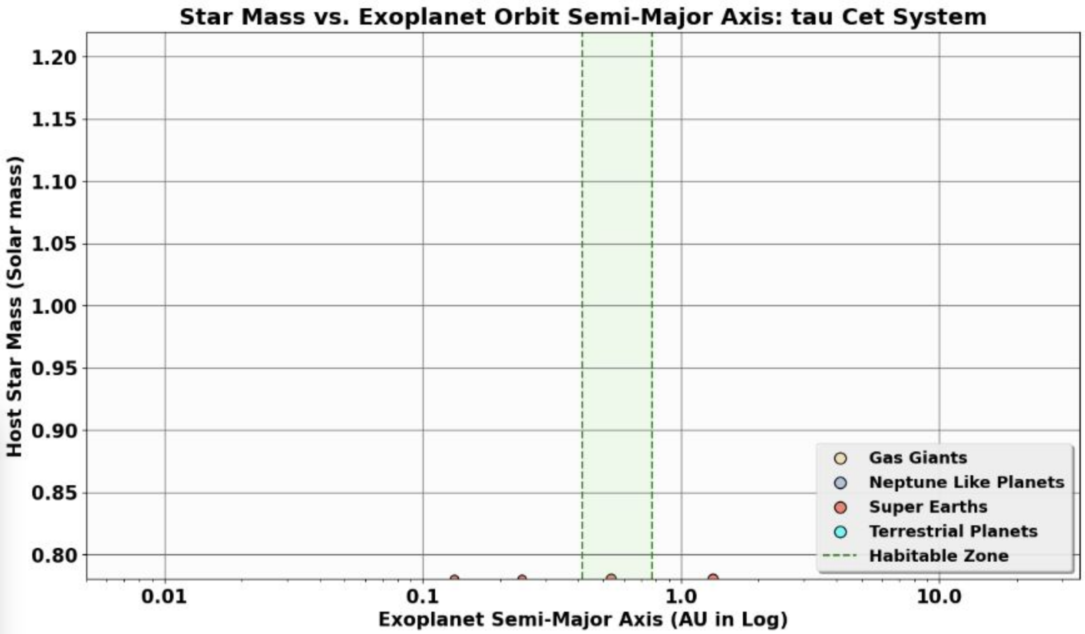
some cool ones i noticed:

- tau Cet



star mass v. exopl. semi-major axis: class 3 systems





372 **class 4** systems

only Neptune-Likes
or Gas-Giants

interesting system I
found here: