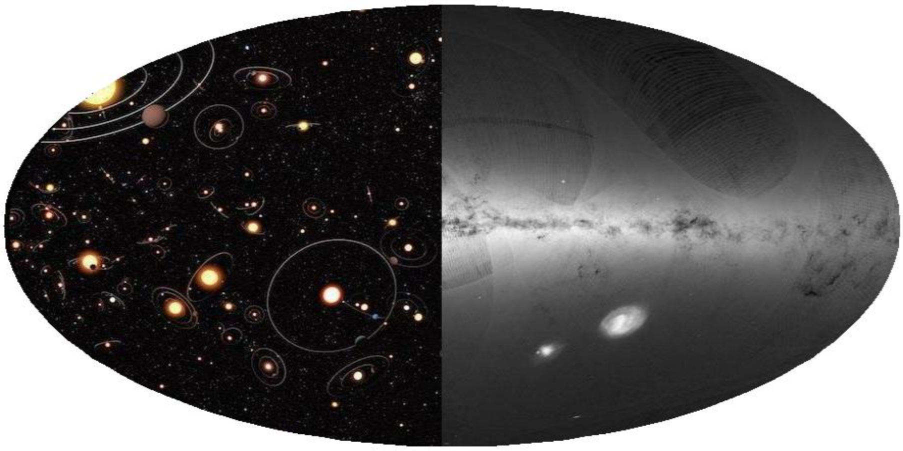
ON THE SEARCH FOR EXO-RINGS IN *GAIA* DATA



MAJOR RESEARCH PROJECT IN ASTRONOMY

Presented by:

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To obtain the MSc. Astronomy degree

Under the supervision of

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ABSTRACT

Nlah blah

Key words:*Submillimeter galaxies - (SMGs), ALESS-survey, CO line emission, Spectroscopic redshift, Molecular mass.*

Wat mij betreft weet ik niets zeker,
maar naar de sterren kijken zet me aan het dromen.

—Vincent Willem van Gogh
(1853 —1890) Dutch Post-Impressionist painter .

It is sometimes said that scientists are unromantic,
that their passion to figure out robs the world of beauty and mystery.
But is it not stirring to understand how the world actually works —that white light is made of colors, that color is the way we perceive the wavelengths of light,
that transparent air reflects light, that in so doing it discriminates among the waves,
and that the sky is blue for the same reason that the sunset is red?
It does no harm to the romance of the sunset to know a little bit about it.

—Carl Sagan, Pale Blue Dot: A Vision of the Human Future in Space
(1935 - 1996) American astronomer, cosmologist, astrophysicist, astrobiologist, author, science popularizer, and science communicator in astronomy and other natural sciences .

In third Dialogue there is first denied that base illusion of the shape of the heavens, of their spheres and diversity.
For the heaven is declared to be a single general space, embracing the infinity of worlds,
though we do not deny that there are other infinite 'heavens' using that word in another sense.
For just as this earth hath her own heaven (which is her own region), through which she moveth and hath her course,
so the same may be said of each of the innumerable other worlds..

—Giordano Bruno
(1548 —1600) Italian Dominican friar, philosopher, mathematician, poet, and cosmological theorist .

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Also, to Paula Andrea Ortíz Otálvaro who helped me to get rapidly involved in the Dutch lifestyle and feel Leiden as a second home since the first day. To my fellow master Colombian friends Juan Manuel Espejo Salcedo and Andrés Felipe Ramos Padilla for all those good times lived inside and outside the university. For all those enriching talks which shed light when problems seemed to have no solution. Someone, who motivated me to study and to look forward, Guadalupe Cañas Herrera, my little Spanish friend, thanks for all those good advises and funny times.

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Before coming to The Netherlands I was going through a bad time and now that I am here witnessing this dream coming true I really need to thank to my cousin Jaime Muñoz and his husband William Lundquist because they took care of me while in California during one of my darkest times, helping and cheering me up when needed. They always encouraged me to continue straight on the science path, being humble and never backing off.

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1.1 INTRODUCTION

During the last years, the exo-planetary astrophysics field has been getting stronger and stronger. Searching for new worlds revolving around other stars have imposed important challenges in current science such as planetary formation models, observational and instrumentation challenges, for example. With the arrival of new instruments, each time more powerful, Astronomers are able to study and characterize these distant worlds and lately compare them with our solar system. In despite of it, we still have a long way to go in studying and understanding these interesting objects.

This project is mainly focused on studying exo-planets with rings around young stars. At the moment, there is a lot of debate on whether or not, we have observed some features in light curves which could be explained by transiting exo-rings in front of a parent star. On top of that, it is well-known that rings are not an exception in our solar system, where we can observe majestic structures as Saturn's rings or modest ones as the other gaseous-planets. As there is no clear consensus at what time exactly during the stellar life and planetary formation this objects could be formed, we aimed to enhance our chance of detecting these structures while studying young stars. These particular stellar population is expected to be forming planets at early stages which makes them good candidates in our search. The targeted field is known as Sco-Cen, a really young OB stellar stellar association at a distance of 100 – 100pc from the sun. Sco-Cen is composed of (number of star, or any other information) and it is located between the constellations of Scorpius, Centaurus and Crux in the southern hemisphere.

In addition, all the characterization of astrophysical sources is mainly dependent on the relative distance to the observer. Therefore, aiming for excellent measurements of distance is essential to properly address our study. A few years ago in (year), the *Gaia* mission was launched to measure with high precision the parallax of stars using their proper motion. As *Gaia* samples the whole celestial sphere, and we need as much as possible accurate measurements for stars in Sco-Cen, we decided to use this mission.

In this chapter, a brief introduction to planet-formation and exo-rings is provided. Also, we describe the most relevant features of the *Gaia* mission, and a general description of the Sco-Cen OB association.

1.2 EXO-RINGS

1.3 GAIA MISSION

1.4 SCO-CEN

2

MODEL AND SAMPLES

2.1 INTRODUCTION

2.2 POWER LAW DISTRIBUTIONS

It is well-known that the stellar mass, and planetary mass and period can be described by power laws. As those parameters are essential in our formulation for the probability of exo-rings transits, and the subsequent analysis, we must pay attention to how model samples which can reproduce faithfully the observation.

A power law distribution can be defined as the relative change of two quantities, which are related through a common exponent. In other words, we can predict the change in one of the variables once the exponent and an initial set of values for the second variable are known. Mathematically speaking, we define a power law distribution as Equation 2.1, where N and X are the variables, and α is the exponent relating the relative change between them and it is assumed $\alpha \neq 1$. Generally, the variable N refers to the number of objects one would expect to find in a given interval $x_1 \leq X \leq x_2$, where the variable X in our particular case may refer to the planetary period, planetary mass, stellar mass or any other parameter which we want to study.

$$\frac{\mathrm{dN}}{\mathrm{dX}} \propto \mathrm{X}^{-\alpha} \tag{2.1}$$

Power-laws can consist of a single or multiple exponents relating two or more variables. The easiest case is the single power law which has the mathematical form shown in Equation 2.1. However, the equation lacks of a proportionality constant or normalization constant which must be found with boundary conditions. Therefore, Equation 2.1 can be rewritten in a more general fashion as Equation 2.2, where A corresponds to the normalization constant and can be found using Equation 2.3 with $\gamma = 1 - \alpha$.

$$\frac{\mathrm{dN}}{\mathrm{dX}} = \mathrm{A\,X}^{\alpha} \quad ; \quad x_1 \leq \mathrm{X} \leq \mathrm{x}_2 \tag{2.2}$$

$$A = \int_{x_1}^{x_2} X^{-\alpha} dX = \frac{x_2^{1-\alpha} - x_1^{1-\alpha}}{1-\alpha} = \frac{x_2^{\gamma} - x_1^{\gamma}}{\gamma} \tag{2.3}$$

Furthermore, we can define the cumulative distribution function (CDF) $F(X)$, which will give us all the accumulated probability less than or equal to X. It is widely used to determine the probability of an observation being greater than a certain value, or between two values. The CDF will be of great importance in Section 2.5 where the randomly distributed variable is obtained making use of it to generate the real variable. The mathematical form of the CDF is given in Equation 2.4 where the upper limit in the integral x here refers to a value between the upper limit (x_1) and lower limit (x_2) over which one wants to generate the distribution.

$$F(x) = A^{-1} \int_{x_1}^{x} t^{-\alpha} dt = \frac{x^{\gamma} - x_1^{\gamma}}{x_2^{\gamma} - x_1^{\gamma}} \tag{2.4}$$

Subsequently, if the random variable is distributed uniformly between 0 and 1, one can generate the real variable by inverting the CDF shown in Equation 2.4 which leads to Equation 2.5. As expected, if one evaluates the last equation in $y = 0$ and $y = 1$ which are the extreme values of the random variable, the result is $x = x_1$ and $x = x_2$ respectively in the real variable.

$$\begin{aligned} y &= F(x) = \frac{x^{\gamma} - x_1^{\gamma}}{x_2^{\gamma} - x_1^{\gamma}} \\ x &= (y\,(x_2^{\gamma} - x_1^{\gamma}) + x_1^{\gamma})^{1/\gamma} \end{aligned} \tag{2.5}$$

The planetary mass-period distribution, and the stellar mass distribution will be generated following the simple power law explained above with a Monte-Carlo process in Section 2.5. Although a different method was also explored for the planetary mass-period distribution due to a possible weakly dependence in both parameters (Jiang et al.,2007, Zucker and Mazeh,2002), we decided to kept the power law method to model them as it is also widely used and studied in literature (Nielsen et al.,2010, Cumming et al.,2008, Butler et al.,2006).

2.3 EXOPLANETS: PERIOD-MASS DISTRIBUTIONS

In order to draw a reliable distribution sample of period and mass for exoplanets, we used two different approaches. The first approach uses the β-distribution because there exits a weakly correlation between the period and mass of an exoplanet as shown by Zucker and Mazeh,2002 which makes the distribution analysis not suitable to be addressed by two independent power laws that describe the joint period-mass distribution. Alternatively, one can assume that as the correlation is weak, then each variable can be treated as independent and the distributions may be generated using single power laws as it is also widely explored by other authors (Nielsen et al.,2010). Therefore, as there exists two different forms to address the generation of these distributions, both ways were explored and implemented in this work.

In Section 2.3.1 and Section 2.3.2, the method is widely explained taking into account the different observations and arguments of the former authors.

2.3.1 *β-istribution*

Using a data set of 66 exoplanets Zucker and Mazeh,2002 suggested a possible correlation between the mass and period. Subsequently Jiang et al.,2007 using a data set of 233 exoplanets supported this idea measuring a positive correlation coefficient of 0.1762. As a result of the positive correlation, describing the distribution as two independent power laws it is not correct, and a new coupled positively correlated function is needed to describe the problem. However, generating this type of distributions needs β-distributed random variables which was not provided until Magnussen,2004 work.

The probability distribution function (pdf) on a finite interval (c,d), $-\infty < c < d < \infty$, indexed by two positive parameters α and β is given by Equation 2.6, where $B(\alpha,\beta)$ denotes the beta function and can be computed using Equation 2.7.

$$f_\beta(x|\alpha,\beta) = \frac{1}{B(\alpha,\beta)} \frac{(x-c)^{\alpha-1}(d-x)^{\beta-1}}{(d-c)^{\alpha+\beta-1}} \quad ; \quad c \leq x \leq d, \quad \alpha > 0, \quad \beta > 0 \tag{2.6}$$

$$B(\alpha,\beta) = \int_0^1 t^{\alpha-1}(1-t)^{\beta-1}dt = \frac{\Gamma(\alpha)\Gamma(\beta)}{\Gamma(\alpha+\beta)} \tag{2.7}$$

Using the correct transformation, the pdf can be written in terms of a normal distributed variable to obtain the standard β-distribution as shown in Equation 2.8 which is a useful form to implement the algorithm provided in Magnussen,2004.

$$f(y \mid \alpha,\beta) = \frac{1}{B(\alpha,\beta)} y^{\alpha-1}(1-y)^{\beta-1} \quad ; \quad 0 \leq y \leq 1, \tag{2.8}$$

The final distribution for mass and period can be obtained through Equation 2.9, where $(\hat{\alpha}_m, \hat{\beta}_m) = (0.6524, 5.9070)$ and $(\hat{\alpha}_p, \hat{\beta}_p) = (0.3697, 3.8445)$ as a result of applying a Maximum-Likelihood Method to their observational data. The normalization constants in both cases are given by $A_1 = 115.5$ and $A_2 = 11650$, corresponding to the area below the observed histogram distribution for each one of the parameters.

$$
\begin{aligned}
\mathrm{f}_{\beta}^{\mathrm{M}} &= \mathrm{A}_1 \mathrm{f}_{\beta}(\mathrm{m}|\hat{\alpha}_m, \hat{\beta}_m) \\
\mathrm{f}_{\beta}^{\mathrm{P}} &= \mathrm{A}_2 \mathrm{f}_{\beta}(\mathrm{p}|\hat{\alpha}_p, \hat{\beta}_p)
\end{aligned}
\tag{2.9}
$$

In short, the mass and period distributions can be then generated using Equation 2.8 and Equation 2.9 through a Monte-Carlo process. These equations can be read as the probability of a planet to be in a mass range $[M, M + dM]$ and a period range $[P, P + dP]$. The actual upper and lower limits in mass, and period are given by the data set used to derive the normalization constant and the index of the β-distribution. Thus, we can generate samples in mass-period ranges of $0.008 < M(M_j) < 26.7$ and $0.8079 < P(days) < 6776.1$. The application of this model to our current problem is shown and discussed in Section 2.5.

2.3.2 *Single Power-Law*

As discussed in Section 2.2 and Section 2.3.1, the planetary mass and period are weakly correlated, so one can ignore that and addressed the problem as independent single power laws. In the past, this has been studied by (Cumming et al.,2008, Butler et al.,2006) considering the distributions of semimajor axis and planet mass of known radial velocity planets. However, in recent studies, Nielsen et al.,2010 noted that due to a decrease in sensitivity of the radial velocity method with orbital distance the exponent of the distribution must be modified. The single power law distributions in mass, semimajor axis and period are shown in Equation 2.10.

$$
\begin{aligned}
\frac{\mathrm{dN}}{\mathrm{dm}} &\propto \mathrm{m}^{-1.16} \\
\frac{\mathrm{dN}}{\mathrm{da}} &\propto \mathrm{a}^{-0.61} \\
\frac{\mathrm{dN}}{\mathrm{dP}} &\propto \mathrm{P}^{-0.74}
\end{aligned}
\tag{2.10}
$$

In the same way as stated before, we can interpret the former equation as the number of planets expected to be contained in a mass range $m_1 < m < m_2$, a semimajor axis range $a_1 < a < a_2$, and orbital period $p_1 < p < p_2$. Whereas in the case of β-distributions, the mass and period cover a wide range, here the mass is reduced to a range of $0.5 < M(M_j) < 13$ and an upper cut-off at $75 AU$ which leads to an upper limit of ~ 650yr in period allowing to study wider planetary orbits.

2.4 STELLAR MASS DISTRIBUTION

Apart from modeling the planetary mass and period, we aimed to obtain in the same fashion the stellar mass distribution. This is known as the initial mass function (IMF) and it is still a wide open question in current Astrophysics. There exists different power laws which try to describe the number of stars expected to lie in a given mass range. In this work, we decided to test two different forms of the IMF namely the Salpeter power law proposed by Edwin Salpeter in 1955 (Salpeter,1955) and the Kroupa power law proposed by Pavel Kroupa in 2001 (Kroupa,2001). The main difference between these two formulations resides on the value that each exponent can take according to each mass range in which one could be interested in. The main goal in using these power laws is to faithfully reproduce the actual observed IMF distribution of stars in a given mass range using the Monte-Carlo process technique. In Section 2.4.1 and Section 2.4.2 a brief introduction of the main features for both power laws is given.

2.4.1 *Salpeter Power-Law*

In 1955, Edwin Salpeter used the observed luminosity function for main-sequence stars in the solar neighborhood assuming that stars off the main-sequence have already burnt up 10% of their hydrogen mass, and also that stars in the solar neighborhood have been created at a uniform rate for the last five billion years to compute the rate of star creation as a function of stellar mass, and the number of stars in each mass range Salpeter,1955. Having said that, he found the power law describing the IMF to follow Equation 2.11, in which ξ_0 is a constant related to the local stellar density and $\alpha = 2.35$. The former equation gives us the number of stars expected to be in a mass range $[M, M + dM]$.

$$\xi(\mathrm{m})\Delta\mathrm{m} = \xi_0 \left(\frac{\mathrm{m}}{\mathrm{M}_\odot}\right)^{-2.35} \left(\frac{\Delta\mathrm{m}}{\mathrm{M}_\odot}\right) \tag{2.11}$$

As we are interested in using our own mass range, and just make use of the exponent to draw a mass distribution we can rewrite Equation 2.11 into Equation 2.12, and later apply all the steps listed in Section 2.2 to later make use of the Monte-Carlo process and obtain our sample of modeled stars. The proportionality constant can be found once the total number of stars in a mass range $m_1 < m < m_2$ is known, through Equation 2.3.

$$\frac{\mathrm{dN}}{\mathrm{dm}} \propto m^{-2.35} \tag{2.12}$$

2.4.2 *Kroupa Power-Law*

On the other hand, in 2001, a different formulation was proposed by Pavel Kroupa in which the main feature is a change in the slope (power-law index) near to $0.08M_\odot$ and $0.5M_\odot$ Kroupa,2001.

In other words, the number of stars expected in a given mass range has different values for the power-law exponent in contrast to Salpeter's law which has only one index. The general form is given by Equation 2.13. One interesting feature of this power law is that 50% of the data generated falls into the mass range $0.01 \leq \frac{m}{M_\odot} \leq 1.0$, and 50% falls into $1.0 \leq \frac{m}{M_\odot} \leq 50.0$.

$$\xi(\mathrm{m}) \propto m^{-\alpha_0} = \begin{cases} \alpha_0 = +0.3 \pm 0.7, & \text{if } 0.01 \leq \frac{m}{M_\odot} \leq 0.08 \\ \alpha_0 = +1.3 \pm 0.5, & \text{if } 0.08 \leq \frac{m}{M_\odot} \leq 0.50 \\ \alpha_0 = +2.3 \pm 0.3, & \text{if } 0.50 \leq \frac{m}{M_\odot} \leq 1.00 \\ \alpha_0 = +3.3 \pm 0.7, & \text{if } 1.00 \leq \frac{m}{M_\odot} \end{cases} \tag{2.13}$$

The IMF generation will be addressed in the same fashion as explained above for the Salpeter's power law, where a Monte-Carlo process will be used and the normalization constant will be set to the total number of stars in a mass range $m_1 < m < m_2$.

2.5 MONTE-CARLO SIMULATIONS

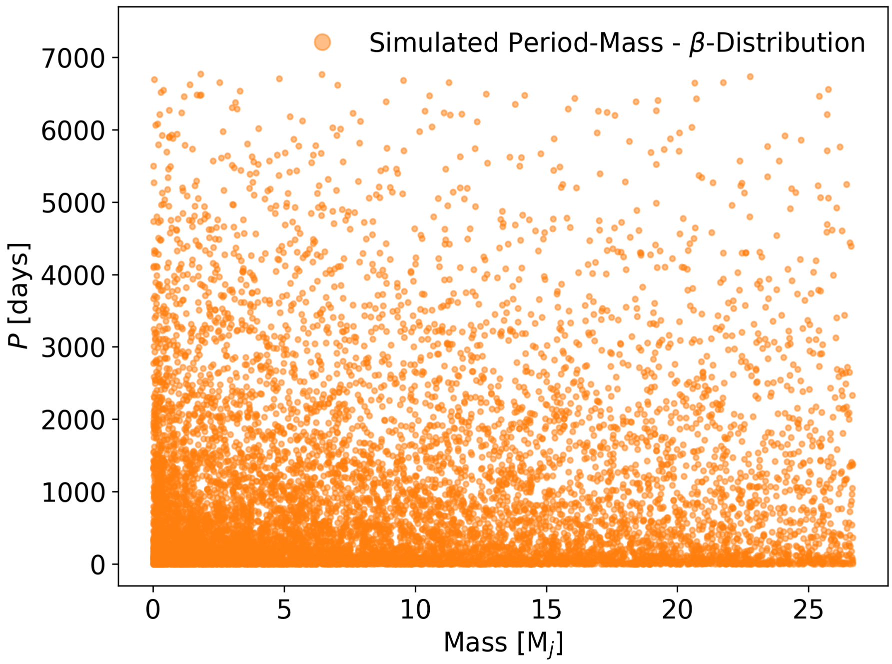

Figure 1: Something!

2.6 PROBABILITY OF TRANSIT DETECTION

One of the main goals in this work is to constrain the probability of detecting an exo-ring transit around young stars using *Gaia* observations. We should start thinking about the possible factors

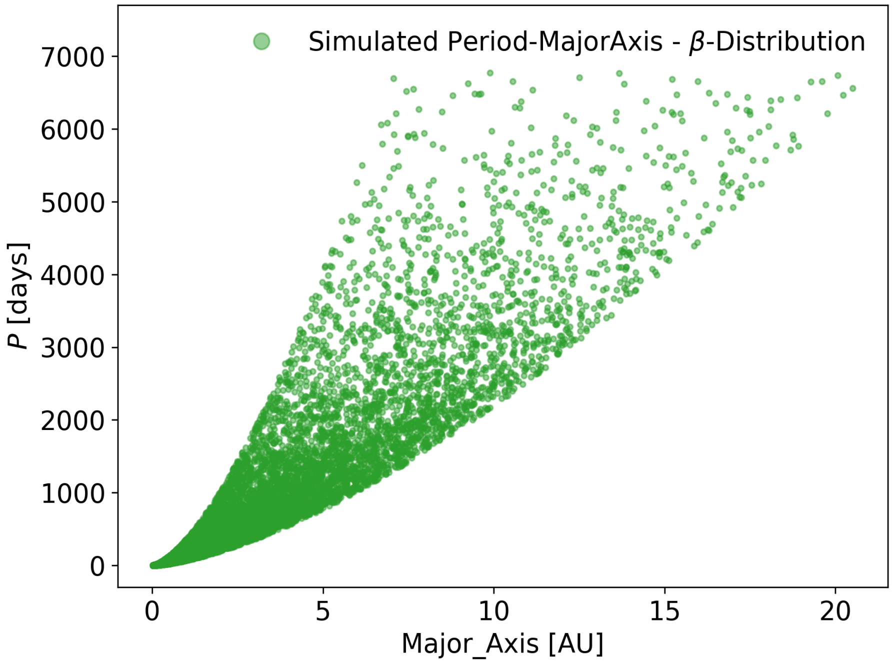

Figure 2: Something!

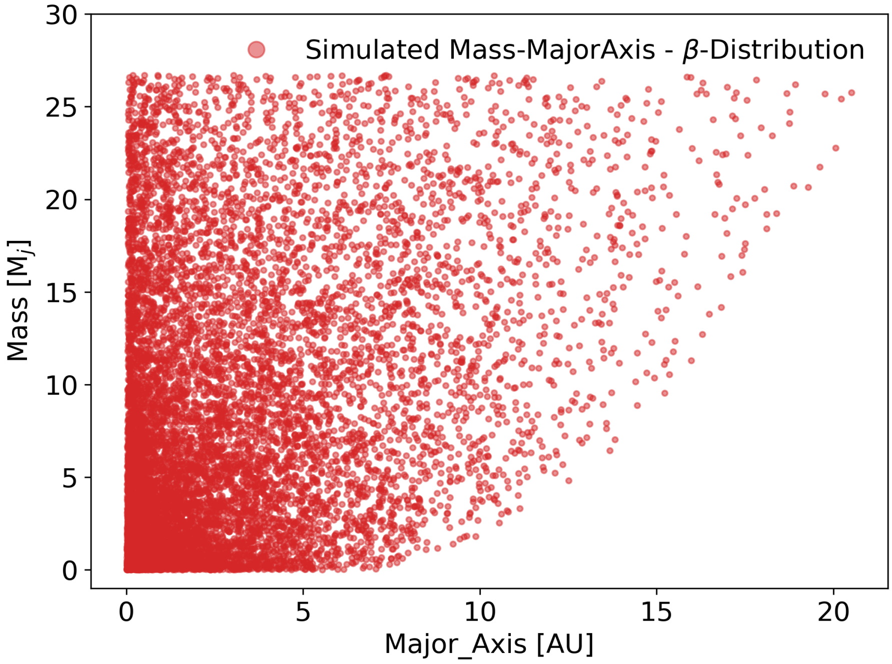

Figure 3: Something!

which could affect the most their detectability such as the geometry of the transit, the chance to observe a star with planets around it, the probability of detecting any feature with *Gaia*'s cadence, the time it takes to form a ring around a planet and how long it lasts, or the probability of a given planet to have its Hill sphere filled with some material which could possible form rings. A few of this probabilities are hard to compute, basically because the only knowledge we have is provided through observations of our own solar system as could be the rings lifetime. However, we can

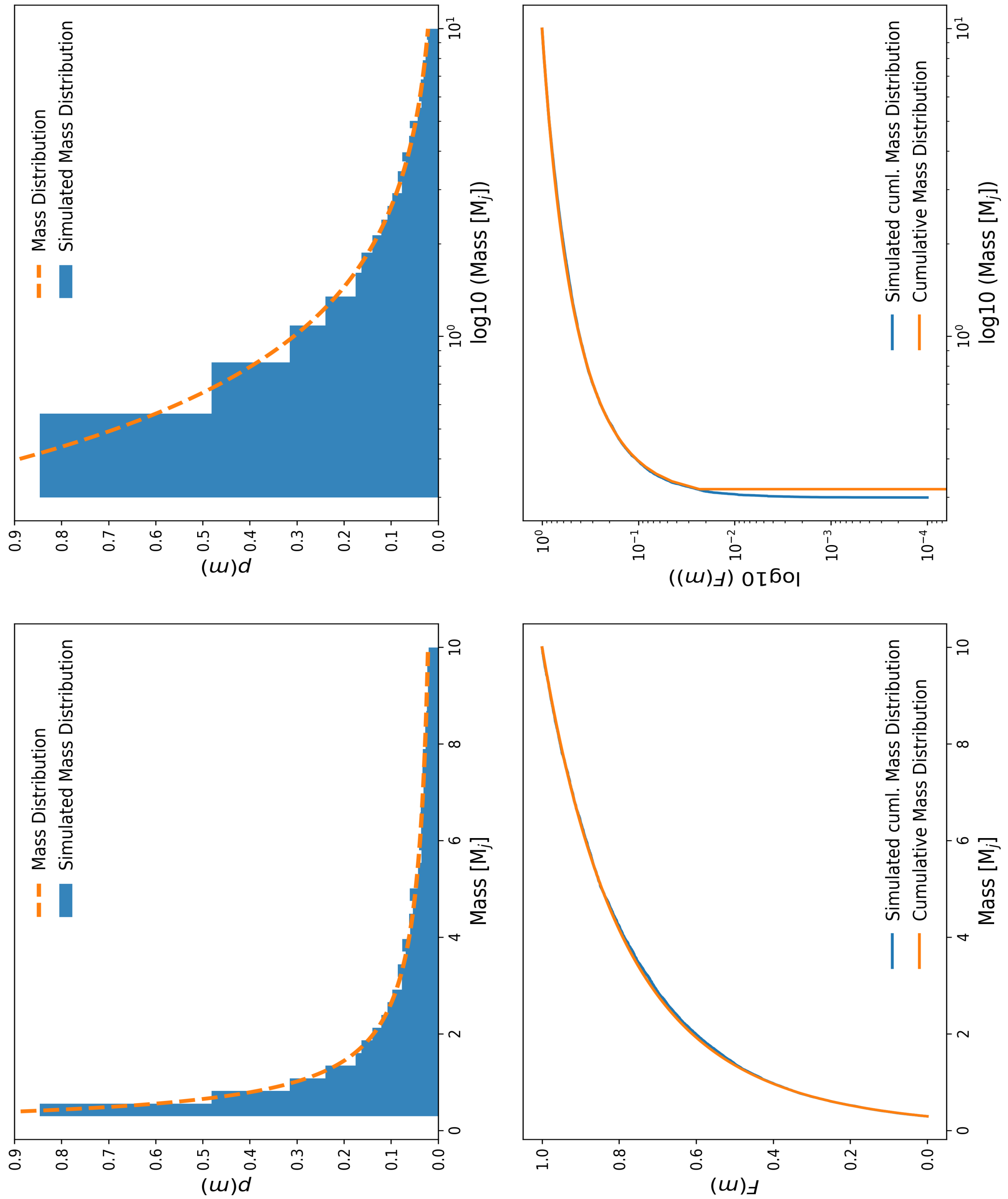

Figure 4: Something!

make our best guess and provide at least a lower boundary of the probability of transit detection, and lately obtain the number of planets one would expect to observe given some survey features.

First, we decided to constrain our detectability prediction as a product of five independent probabilities as shown in Equation 2.14, where P_1 corresponds to the probability of a given star to have a planet, P_2 gives the probability of a planet to have its Hill sphere filled with material that would coalesce and form rings, P_3 constrains the probability of observing exoplanetary rings

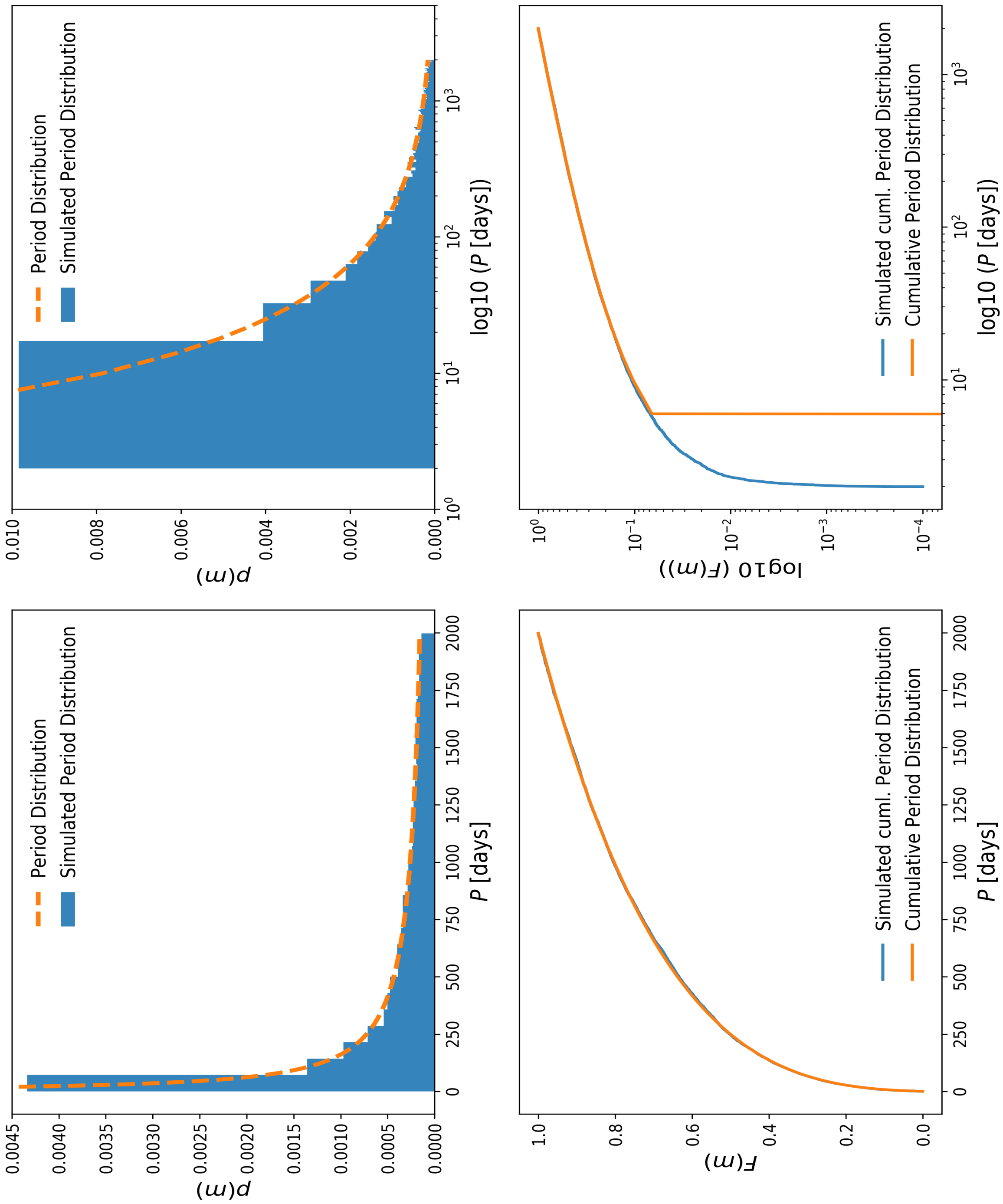

Figure 5: Something!

transiting in front of their parent star given an observer in the universe, and P_4 the probability of observing at least one transit with *Gaia* in all the mission lifetime. Apart from these four probabilities, we included another one to account for the rings lifetime but it was addressed

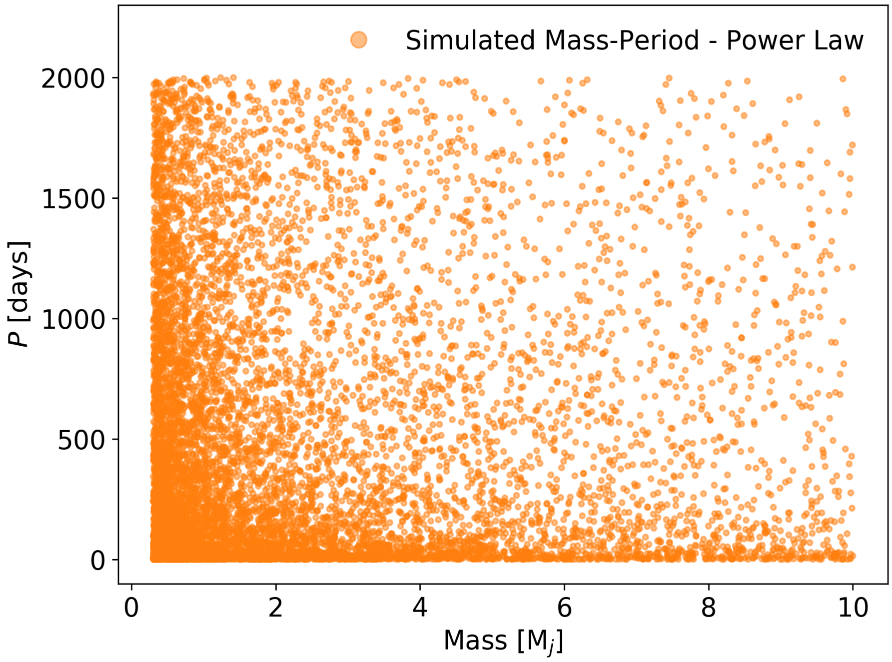

Figure 6: Something!

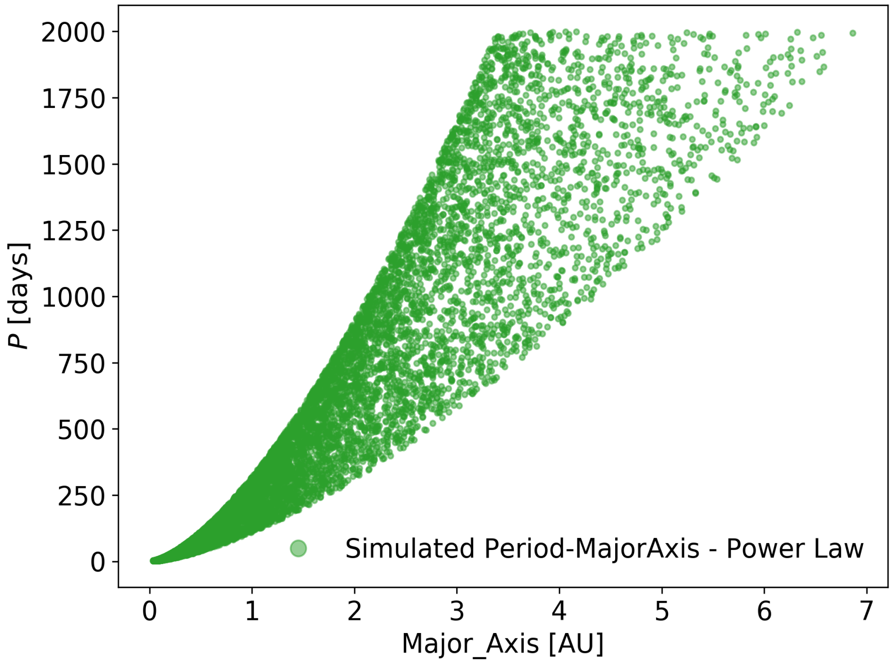

Figure 7: Something!

separately to study how this could affect the overall outcome and is explained in **??**.

$$P_{transit} = P_1 * P_2 * P_3 * P_4 \tag{2.14}$$

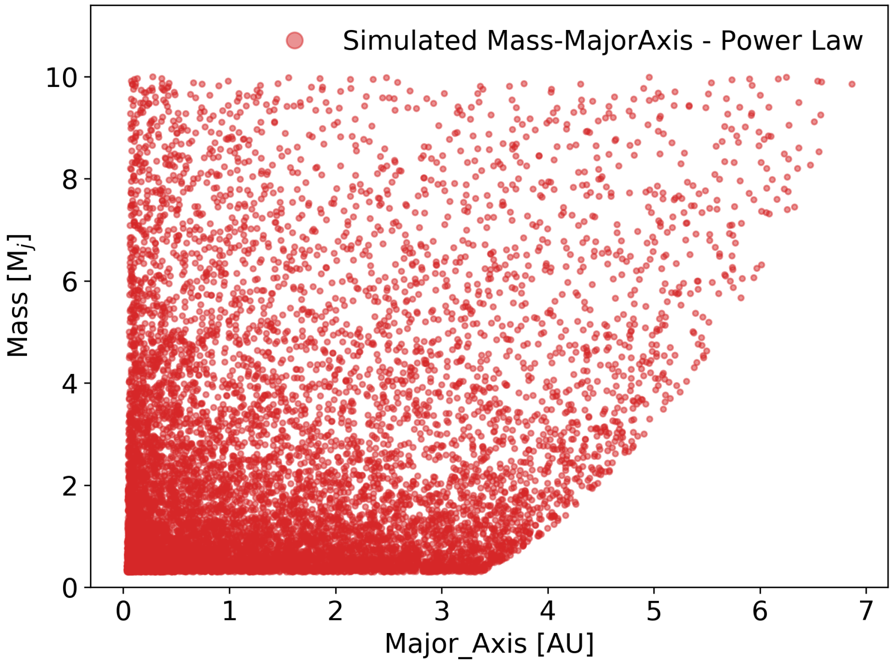

Figure 8: Something!

On top of that, we can start constructing each probability in terms of their main variables. Firstly, the probability of a star having a planet was set to a value of $P_1 = 0.17$ which means that a star has on average a 17% chance of hosting a planet. In Cassan et al.,2012,

2.6.1 *Geometry of the Transit*

2.6.2 *Hill Sphere*

2.6.3 *Rings Lifetime Constrain*

2.6.4 *Analytic Form*

3

3.1 INTRODUCTION

3.2 GAIA SAMPLES

3.3 STELLAR EVOLUTION MODELS

3.3.1 *Evolutionary Tracks*

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RESULTS AND DISCUSSION

4.1 INTRODUCTION

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SUMMARY

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6 APPENDIX

6.1 SQL-QUERIES

In this section, the queries performed in the *Gaia* database are shown for the three different fields of Sco-Cen OB Association namely Lower Centaurus Crux (LCC), Upper Centaurus Lupus (UCL), and Upper Scorpius (US).

Lower Centaurus Crux (LCC)

```
SELECT gaia.source_id,
gaia.ra, gaia.ra_error, gaia.dec, gaia.dec_error, gaia.parallax, gaia.parallax_error
    , gaia.l, gaia.b,
gaia.phot_g_mean_mag+5*log10(gaia.parallax)-10 AS g_mag_abs,
gaia.phot_g_mean_mag-tmass.ks_m AS g_min_ks,
78.7028422*POWER(10, (-0.4*(gaia.phot_g_mean_mag+5*log10(gaia.parallax)-10))) AS
    L_star
FROM gaiadr1.gaia_source AS gaia
INNER JOIN gaiadr1.tmass_best_neighbour AS xmatch
ON gaia.source_id = xmatch.source_id
INNER JOIN gaiadr1.tmass_original_valid AS tmass
ON tmass.tmass_oid = xmatch.tmass_oid
WHERE gaia.parallax >= 6 AND gaia.parallax <= 12 AND gaia.b >= -10 AND gaia.b <= 16
    AND gaia.l >= 285 AND gaia.l <= 313

SELECT gaia.source_id,
gaia.ra, gaia.ra_error, gaia.dec, gaia.dec_error, gaia.parallax, gaia.parallax_error
    , gaia.l, gaia.b,
gaia.phot_g_mean_mag+5*log10(gaia.parallax)-10 AS g_mag_abs,
tycho2.bt_mag-tycho2.vt_mag AS b_min_v
FROM gaiadr1.tgas_source AS gaia
INNER JOIN tycho2 as tycho2
ON gaia.tycho2_id = tycho2.id
WHERE gaia.parallax >= 6 AND gaia.parallax <= 12 AND gaia.b >= -10 AND gaia.b <= 16
    AND gaia.l >= 285 AND gaia.l <= 313
```

Upper Centaurus Lupus (UCL)

```
SELECT gaia.source_id,
gaia.ra, gaia.ra_error, gaia.dec, gaia.dec_error, gaia.parallax, gaia.parallax_error
    , gaia.l, gaia.b,
gaia.phot_g_mean_mag+5*log10(gaia.parallax)-10 AS g_mag_abs,
gaia.phot_g_mean_mag-tmass.ks_m AS g_min_ks,
78.7028422*POWER(10, (-0.4*(gaia.phot_g_mean_mag+5*log10(gaia.parallax)-10))) AS
    L_star
```

```
FROM gaiadr1.gaia_source AS gaia
INNER JOIN gaiadr1.tmass_best_neighbour AS xmatch
ON gaia.source_id = xmatch.source_id
INNER JOIN gaiadr1.tmass_original_valid AS tmass
ON tmass.tmass_oid = xmatch.tmass_oid
WHERE gaia.parallax >= 6.0 AND gaia.parallax <= 12 AND gaia.b >= 5 AND gaia.b <= 31
    AND gaia.l >= 313 AND gaia.l <= 337

SELECT gaia.source_id,
gaia.ra, gaia.ra_error, gaia.dec, gaia.dec_error, gaia.parallax, gaia.parallax_error
    , gaia.l, gaia.b,
gaia.phot_g_mean_mag+5*log10(gaia.parallax)-10 AS g_mag_abs,
tycho2.bt_mag-tycho2.vt_mag AS b_min_v
FROM gaiadr1.tgas_source AS gaia
INNER JOIN tycho2 as tycho2
ON gaia.tycho2_id = tycho2.id
WHERE gaia.parallax >= 6.0 AND gaia.parallax <= 12 AND gaia.b >= 5 AND gaia.b <= 31
    AND gaia.l >= 313 AND gaia.l <= 337
```

Upper Scorpius (US)

```
SELECT gaia.source_id,
gaia.ra, gaia.ra_error, gaia.dec, gaia.dec_error, gaia.parallax, gaia.parallax_error
    , gaia.l, gaia.b,
gaia.phot_g_mean_mag+5*log10(gaia.parallax)-10 AS g_mag_abs,
gaia.phot_g_mean_mag-tmass.ks_m AS g_min_ks,
78.7028422*POWER(10, (-0.4*(gaia.phot_g_mean_mag+5*log10(gaia.parallax)-10))) AS
    L_star
FROM gaiadr1.gaia_source AS gaia
INNER JOIN gaiadr1.tmass_best_neighbour AS xmatch
ON gaia.source_id = xmatch.source_id
INNER JOIN gaiadr1.tmass_original_valid AS tmass
ON tmass.tmass_oid = xmatch.tmass_oid
WHERE gaia.parallax >= 6.0 AND gaia.parallax <= 12 AND gaia.b >= 7 AND gaia.b <= 32
    AND gaia.l >= 337 AND gaia.l <= 360

SELECT gaia.source_id,
gaia.ra, gaia.ra_error, gaia.dec, gaia.dec_error, gaia.parallax, gaia.parallax_error
    , gaia.l, gaia.b,
gaia.phot_g_mean_mag+5*log10(gaia.parallax)-10 AS g_mag_abs,
tycho2.bt_mag-tycho2.vt_mag AS b_min_v
FROM gaiadr1.tgas_source AS gaia
INNER JOIN tycho2 as tycho2
ON gaia.tycho2_id = tycho2.id
WHERE gaia.parallax >= 6.0 AND gaia.parallax <= 12 AND gaia.b >= 7 AND gaia.b <= 32
    AND gaia.l >= 337 AND gaia.l <= 360
```