So $N_{star} \cdot \Gamma_v \cdot Q_v = N_{det}$.

3. 17/04/01

$Q_v = Q_{completeness} \; Q_{geom} \; Q_{win}$

?? ?? ??,

0.5 — 0.25

(0.3–0.8) 0.05 ?

N planets/star $\int$ in $(R_p, P)_{vol}$

$\Gamma_v \overset{?}{\approx} 0.01 \overset{?}{-} 0.1$ ⟸ actual thing we trying to measure

$N_{star} \approx 1500$.

($Q_{coplanar} = 1$)

if $N_{det} = 1$, $Q_{geom} = 0.05$, $Q_{complete} = 0.5$

$\Gamma_v = \dfrac{N_{det,pl}^{\text{search in vol}}}{N_{star} \cdot Q_v}$ would have $\Gamma_v > 0.027$.

What if $N_{det} = 0$?

You say with some confidence level that $\Gamma_v \lesssim \underset{\smile}{0.027}$

(really, a higher number, if you want to be more certain that you'd have seen something)

What is Γ_v from e.g. Armstrong's work?

they found:

$R_p = 6 - 10 R_\oplus$, orbiting $P_{BP} \approx 10 - 300d$,

rate is $10^{+18}_{-6.5}$ % (higher but consistent w/ single ★ rates).

could calculate our corresponding rate density.

Roughly $N_{det,pl} \approx 10$, $N_{star} = 1500$, $Q_v \overset{?}{\approx} \underbrace{0.3}_{Q_{complete}} \times \underbrace{0.1}_{Q_{geom}}$?

Gives $\Gamma_v \approx 0.2$ ②

(over Armstrong's range)

Point would be: The result of ~~the suggestion of~~ ~~In agreement w/~~ At 2014 ~~[illegible]~~ can be shown to empirically hold for contact binaries as well; we find $\Gamma_v^{P<5d\ EBs} < \Gamma_v^{P>5d\ EBs}$. ~~[illegible]~~ (This result should not surprise anyone following the literature; it is "scientifically usual"

Turn DFM Eq (14) around.

Ask: to detect N CBPs in our volume, what occurrence rate density is required?

say $4 R_\oplus < R_p < 12 R_\oplus$

$1\,\text{day} < P_{CBP} < 100\,\text{days}$

$$N = \iint d^2N = \iint \Gamma_V \, d\ln P_{CBP} \, d\ln R_p$$

$$N \approx \frac{C}{Z} \underbrace{\iint d\ln P_{CBP} \, d\ln R_p}_{= V}$$

N: # planets per ★ in sample, in volume V

C: # detections in vol V

Z: prob of detecting a planet orbiting ★ in vol

$$\underbrace{Z}_{\text{detection prob, (× \# of stars)}} \underbrace{\frac{N}{V}}_{\text{\# planets per ★ in sample, per } (R_p, P) \text{ volume}} = C$$

C: # detections

Stupid OOM:

$$\#\,\text{stars} \times \frac{\#\,\text{planets in } (R_p,P)\text{ vol}}{1\,\text{star}} \times \underbrace{\text{prob of detection per planet in } (R_p, P)\text{ vol}}_{Q_V} = \#\,\text{planet detections} = N_{det}$$

say $N_{stars} = 1500$

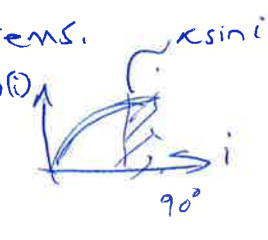
$$Q_V = Q_{completeness} \underbrace{Q_{geom}}_{= Q_{\text{inclination coplanar CBP}}\ (??)\ Q_{\text{transit prob}}(i)} Q_{win}$$

$$N_{star} \times \Gamma_V \times Q_V = N_{det}$$

well, if randomly drawn ★s, $Q_{geom} < 0.1\%$, if we assume $Q^{CBP}_{coplanar} = 1$, and IGNORE that we selected transiting (overcontact) systems.

But we did. So maybe 10% – 25% transit b/c p(i)

we might still have many too-inclined sys ms).



DFM occurrence Calcn

1. 17/04/01

$Q_{det,k}(\vec{w})$: prob of detecting transit w/ given params, conditioned on an exoplanet transiting ~~a~~ star during Kepler observations.

($\vec{w}$ = set of all params affecting detectability; k index runs over all target ~~*s~~).

$Q_{geom,k}(\vec{w})$: geometric transit probability. For star k, (Winn 2010)

$$Q_{geom,k}(\vec{w}) = \frac{R_{*,k} + R_p}{a_k} \frac{1 + e\sin\omega}{1 - e^2}$$

$$= \left(\frac{4\pi^2}{GM_{*,k}}\right)^{1/3} \frac{1 + e\sin\omega}{1 - e^2} (R_{*,k} + R_p)\, P^{-2/3}$$

* need to account for the inclination here too?

$Q_{win,k}(\vec{w})$: observational window funcn (approximate) (Burke & McCullough, 2014)

$$Q_{win,k}(\vec{w}) = \begin{cases} 1 - (1 - f_{duty,k})^{T_k/P} & \text{if } P < T_k \\ T_k f_{duty,k} / P & \text{otherwise.} \end{cases}$$

Total detection efficiency is then given by

$$Q_k(\vec{w}) = Q_{det,k}(\vec{w})\, Q_{geom,k}(\vec{w})\, Q_{win,k}(\vec{w})$$

$\vec{w}_k = \{P_k, R_{p,k}\}$

(n.b. DFM computes an analytic approxn to $Q_{det,k}(\vec{w})$)

Assuming Poisson likelihood, the occurrence rate density in a volume V i.e. in $P_{min} < P < P_{max}$ and $R_{min} < R_p < R_{max}$ is

$$\Gamma_V \equiv \frac{d^2 N}{d\ln P\, d\ln R} = \frac{C(P_{min}, P_{max}; R_{min}, R_{max})}{Z(P_{min}, P_{max}; R_{min}, R_{max})}, \quad (14)$$

for $C(\ldots)$ # of actual detected planets in the volume, &

"volume" $Z(\ldots) \approx \frac{KV}{J} \sum_{j=1}^{J} Q_{k_j}(w^{(j)})$, (sum is over all injections in volume V. K is # of inj/recov expts).

assuming uniform sampling in (log) period & radius.

for N the expected # of planets per star.

Rucinski (2006) LF & Absolute Magnitude Calibration for Contact Binaries

$$M_V = a_p \cdot \log P + a_{BV} (B-V)_0 + a_0$$

Claimed precision: $\sim 0.2-0.25$ mag.

Recall $m_x - m_{x,0} = -\frac{5}{2} \log_{10} \left(\frac{F_x}{F_{x,0}} \right)$ $\qquad L_x = 4\pi R_x^2 F_x$

$$\underbrace{m_x - m_{x_0}}_{\text{"}\Delta m} = -\frac{5}{2} \log_{10} \left(\left(\frac{R_x}{R_{x_0}}\right)^{-2} \frac{L_x}{L_{x_0}} \right)$$

For $\Delta m = 0.25$, $R_x = R_{x_0}$ means $\frac{L_x}{L_{x_0}} \approx 0.8$,

So the claim is that the calibration gets luminosities good to $\sim 20\%$.

Why should this scaling exist??

It means the lumonsity of the contact binary scales with its period...

Armstrong's short-EB period claim 1. 17/03/31

- Split debiased sample into $\lessgtr$ 10 days. (& 7 days, to see if fine-tuning matters)

"For coplanar CB planets w/ $P_{CBP} \lesssim 10.2\, P_{bin}$, the prob that the occ. rate is lower around short-period binaries is 96% (4–10$R_\oplus$), 98% (6–10$R_\oplus$), 96% (8–10$R_\oplus$)".
("& becomes more significant for more misaligned distrib^{n}s").

Cumulative distrib^n F has pdf f, s.t.

$$f_X(x) = \frac{dF_X(x)}{dx} \quad \text{for any random variable } X.$$

Then

$$P(X \text{ in } A) = \int_A f_X(x)\,dx$$

any set A

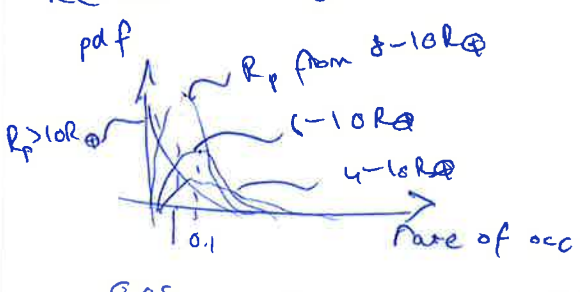
For differences btwn populations:

$$P(X = Y) = \int_{-\infty}^{\infty} f_X(x)\, f_Y(x)\, dx$$

and for 1 less than the other,

$$P(X < Y) = \int_{-\infty}^{\infty} \int_{-\infty}^{x} f_X(t)\, f_Y(x)\, dt\, dx.$$

Results then given as



Gaussian incl^n distrib^n, with $\sigma = 5°$,
for $P_{CBP} < 10.2\, P_{EB}$,
and $5 \lesssim \frac{P_{EB}}{\text{day}} < 60$.

17/03/31 0.

$L_1 = 4\pi R_1^2 \sigma T_{eff,1}^4$ $\quad L_2 = 4\pi R_2^2 \sigma T_{eff,2}^4$

combined:

$$L = L_1 + L_2$$
$$= 4\pi\sigma\left(R_1^2 T_{eff,1}^4 + R_2^2 T_{eff,2}^4\right)$$

Just 1 (1 is eclipsing 2):

$$L = 4\pi\sigma\left(R_1^2 T_{eff,1}^4\right) \qquad (1)$$

When 2 eclipses 1:

$$L = 4\pi\sigma\left(R_2^2 T_{eff2}^4 + (R_1^2 - R_2^2)\, T_{eff,1}^4\right) \qquad (2)$$

If MS stars, then $R_1 > R_2 \Rightarrow T_{eff,1} > T_{eff2}$ & $L_1 > L_2$.

Then "primary" eclipse is when 2 eclipses 1. (Eq (2)).

$$\frac{L_{sec}}{L_{pri}} = \left(R_1^2 T_{eff1}^4\right)\left(R_1^2 T_{eff1}^4 + R_2^2 (T_{eff2}^4 - T_{eff1}^4)\right)^{-1}$$

drop the "eff"

$$= \frac{R_1^2 T_1^4}{R_1^2 T_1^4 + R_2^2 (T_2^4 - T_1^4)}$$

$$= \frac{R_1^2 T_1^4}{(R_1^2 - R_2^2) T_1^4 + R_2^2 T_2^4}$$ (more obviously positive...)

under some limit... ??

$$\approx \left(\frac{T_2}{T_1}\right)^4$$

(is the armstrong thesis claim, sec 6.2.4)

17/03/29

Follow DFM's blog.

Given an incomplete catalog of planet parameters (smaller planets at longer periods are harder to find), what can we say about the underlying distrib^n of properties?

Use: Poisson process likelihood to compute prob of a set of measurements (e.g. P, R_p, ...) $w_k = (P_k, R_{pk})$, given a parametric model for the underlying "occurrence rate" $\Gamma_\theta(w)$:

$$p(\{w_k\} | \theta) = \exp\left(-\int Q(w)\,\Gamma_\theta(w)\,dw\right) \prod_{k=1}^{K} Q(w_k)\,\Gamma_\theta(w_k)$$

for $Q(w)$ the estimate of the mean detection efficiency (completeness) as a func^n of parameters w.

Following Burke + (2015), & DFM's blog, $\Gamma_\theta(w) = \Gamma_\theta(P)\,\Gamma_\theta(R_p)$.
(the occurrence rate is independently dep^t on P & R_p).

More mathematically: [(P, SNR, found/not), ...]

have tuple $(x, y, 0/1)$.

want (for each bin), the fraction of tuples in this bin with 1 (out of all, with 1 & 0).

- what do we know about the tertiary companions in contact EB systems?
  → direct imaging!
- How did Tokovinin+ (2008) find the tertiaries?
  ↳ Table 3 of this. Δm from 3-5 typically (so
- Talk with Ondrej ~~[illegible]~~ Pejcha about contact EB params
- KICs 6144827 → EB? like 1.94d, on top of 0.2346d contact.
  and 5302006 → likely δ Scuti