# Impact Exchange Between Planets of Gliese 581


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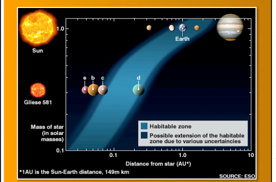
## INTRODUCTION

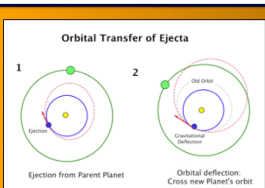
The discovery of meteorites from Mars and the Moon indicates that in our solar system large impacts can transfer rocky material from one planet to another. It has been suggested that living microbes can be exchanged among the planets by this mechanism [1]. An obvious extension is to ask whether this process could also operate in other solar systems.


The Gliese 581 system contains at least one planet located in the "habitable zone" where liquid water is possible (see figure). All four planets in the system lie in close proximity to the star and range from 0.03 to 0.22 AU, putting each planet inside the orbit of Mercury. Planets e and c are speculated to be rocky in composition due to their range of acceptable masses. Planet d is too massive to be considered only rocky and is thought to be composed of liquid water or ice. Planet b, however, is the most massive in the system and is comparable to Neptune.




Location of planets of Gliese 581 compared to our solar system From BBC News: http://news.bbc.co.uk/2/hi/8008683.stm)

## METHODS



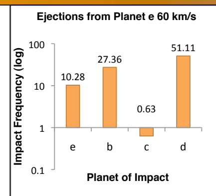

Ejecta has an initial Keplerian orbit with an a, e, and i similar to that of the planet it leaves (figure 1). As the orbit evolves, perturbations from another planet could alter the initial orbit (figure 2) causing it to impact a planet, the parent star, or eject it into interstellar space.

We used the Öpik-Arnold method to calculate the fate of 10,000 particles initially ejected from planets e-d. The initial velocity ranges (high, medium, low) were scaled from each planet's orbital velocities, which are rather high by solar system standards due to the extremely close proximity of these planets to their central star (see table below).

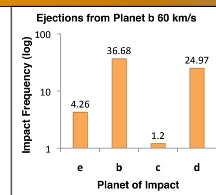
The actual mass of each planet is uncertain, and the literature cites only a range of acceptable values [2]. We chose the average values listed in the table for our work. We estimated the density by comparing our planet to another planet with a known value. This allowed us to calculate the radius of each planet.

| Planet | Distance (AU) | Average Mass | Similar Mass | Density Estimate (g/cc) | Orbital Velocity (km/s) |
|---|---|---|---|---|---|
| e | 0.03 | 2.52$M_{\oplus}$ | Kepler 11 f | 6 | 96 |
| b | 0.04 | 23.03$M_{\oplus}$ | Neptune | 1.5 | 83 |
| c | 0.07 | 7.88$M_{\oplus}$ | Kepler 11 e | 6 | 63 |
| d | 0.22 | 10.45$M_{\oplus}$ | Kepler 11 c | 2 | 35 |

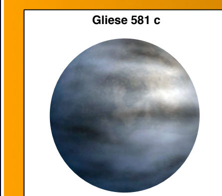
## RESULTS

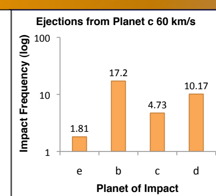




| Planet of Impact | 20 km/s | 100 km/s |
|---|---|---|
| Planet e | 17.73 | 8.28 |
| Planet b | 29.38 | 13.51 |
| Planet c | 0.80 | 0.17 |
| Planet d | 49.99 | 42.09 |

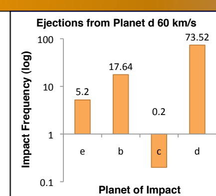




| Planet of Impact | 20 km/s | 100 km/s |
|---|---|---|
| Planet e | 4.85 | 3.42 |
| Planet b | 67.88 | 20.15 |
| Planet c | 2.54 | 0.45 |
| Planet d | 18.02 | 20.77 |




| Planet of Impact | 20 km/s | 100 km/s |
|---|---|---|
| Planet e | 17.7 | 0.06 |
| Planet b | 35.73 | 8.77 |
| Planet c | 17.54 | 4.47 |
| Planet d | 6.83 | 5.03 |

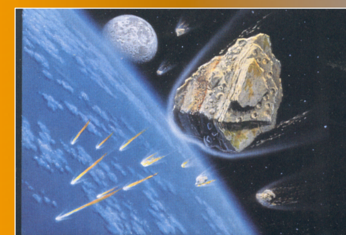




| Planet of Impact | 20 km/s | 100 km/s |
|---|---|---|
| Planet e | 5.55 | 3.80 |
| Planet b | 4.00 | 9.97 |
| Planet c | 0.04 | 0.17 |
| Planet d | 89.90 | 59.23 |

The transfer of particles within the Gliese 581 system depends strongly on the initial ejection velocity. Several numerical simulations were analyzed in the case of high (100 km/s), medium (60 km/s), and low (20 km/s). Our standard 10,000 particles were ejected at these various velocities from each planet e, b, c, and their fates tabulated. Ejections from planet e were most likely to impact planet d regardless of initial velocity. Ejections from planet b were most likely to impact planet b and d. Ejections from planet c have a high percentage of impacts on b, however, an increase in initial velocity resulted in a decrease of impacts on b. Ejections from planet d have a low probability of impact on any other planet than itself with most ejected particles entering an initial hyperbolic orbit and being ejected from the planetary system.

## CONCLUSION

Impact ejecta exchange in the Gliese 581 system is very different from our solar system due to the close proximity of the planets to their central star and the resulting large orbital velocities. Because of this, rather large initial velocities (20-100 km/s) are required for orbital perturbations to allow interplanetary exchanges. Planet d, which is speculated to harbor life or liquid water [6], would have a very small chance of transferring material to the other planets in the Gliese system and thus far more isolated, biologically, than the inner planets of our own solar system.



Artwork by: Don Davis

Abstract

Contact

## REFERENCES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