Calibrating the Flux-Weighted Gravity-Luminosity Relation in Blue Supergiant Stars

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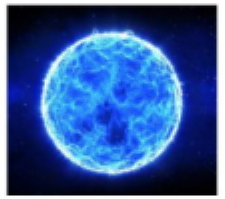
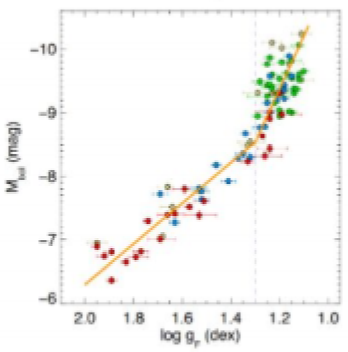
Background



Blue Supergiant Stars (BSG)
- Spectral Class: O, B, or A
- Luminosity Class I
- Surface Temperature: 10,000K-50,000K
- Top left of the H-R Diagram
- Often observed in spiral/irregular galaxies and open clusters

Piecewise linear regression scatter plot generated by Urbaneja et al. (2017).



Flux-Weighted Gravity-Luminosity Relation (FGLR)

$$M_{BOL} = a(\log g_F - 1.5) + b$$

- Relates the bolometric magnitude of a star with its flux-weighted gravity (log (g/T_eff^4))
- Allows BSGs to be used as standard candles
- Improves upon the method used for Cepheid Variables by accounting for interstellar reddening for individual stars

Methodology

1. Collect data from sources as described in Data Collection
2. Compute flux-weighted gravity using the equation:

$$log(g_F) = log(g/T_{eff}^4)$$

3. Compute Intrinsic Color Index using the formula:

$$T = 4600\,\mathrm{K}\left(\frac{1}{0.92(B-V)+1.7} + \frac{1}{0.92(B-V)+0.62}\right)$$

4. Compute Interstellar Extinction using the equation:

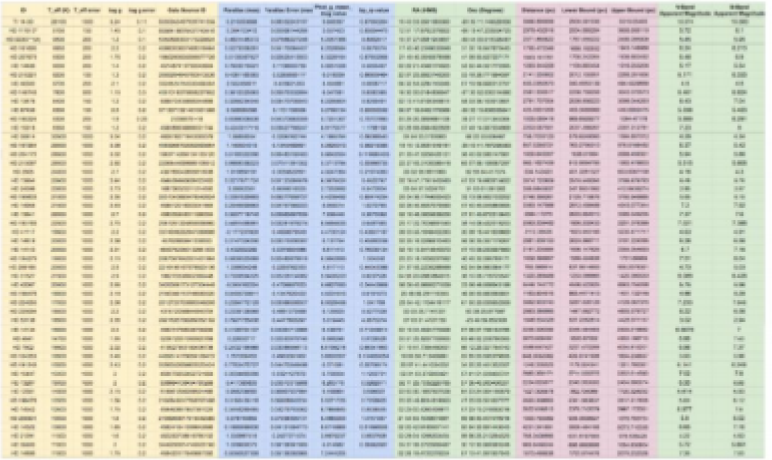
$$I.E. = 3.1((B-V)_{observed} - (B-V)_{intrinsic})$$

5. Derive Bolometric Corrections (B.C.) using interpolation on empirical values from Schmidt-Kaler (1982)
6. Compute bolometric magnitude using the formula:

$$M_{BOL} = m - 5 * log(d/10) - I.E. + B.C.$$

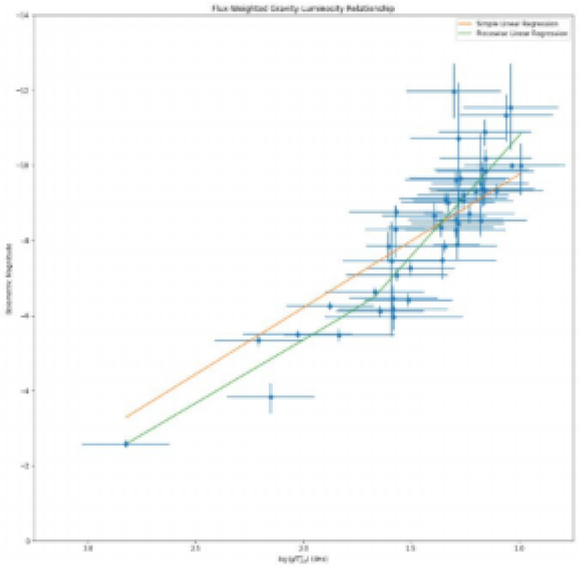
7. Run Monte Carlo, Piecewise Linear Regression on scatter plot of bolometric magnitude vs. flux-weighted gravity

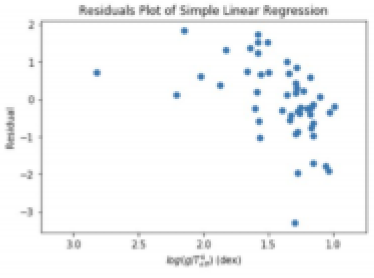
Data Collection

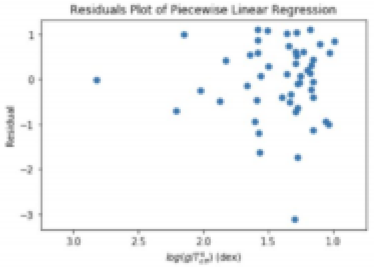


Individual Papers
Gaia
Simbad
Bailer-Jones and Vizier database

Results







After running a simple linear regression 100 times, we generated an average slope of **a = $3.55^{+0.35}_{-0.32}$** and an average y-intercept of **b = -7.98 ± 0.13** mag.

Analysis

The slope and intercept found in Urbaneja et al. (2017) below their breakpoint were a = 3.20 ± 0.08 and b = -7.90 ± 0.02 mag. In addition, the parameters found by Kudritzki et al. (2008) were a = 3.41 ± 0.16 and b = -8.02 ± 0.04 mag. Running discrepancy tests, we find that our values agree with both papers. We note that the slope of our simple linear regression is slightly greater than the values derived by both Kudritzki and Urbaneja. This is indicative of an increase in the slope above the potential breakpoint influencing the overall slope of the line.

While our project studied galactic blue supergiants, Urbaneja et al. investigated the LMC, and Kudritzki et al. extended the FGLR to galaxies outside the Local Group. This indicates that the FGLR is a promising distance indicator for both the galactic and extragalactic regimes.

Is There a Break?

While Urbaneja et al. (2017) predicts a change in the slope of the FGLR around 1.29 dex, we cannot accurately define a break in our data due to the scale of our errors in the logarithm of the flux-weighted gravity.

With this in mind, we ran a Monte-Carlo piecewise linear regression accounting for only the errors in bolometric magnitude. This led to a piecewise function with a breakpoint of 1.7 dex and parameters of a_low = 6.43 ± 0.70, a_high = 3.37 ± 0.20, and b = -7.03 ± 0.20. Compared to Urbaneja's values of a_low = 8.34 ± 0.25, a_high = 3.20 ± 0.08, and b = -7.90 ± 0.02, we see that values of a_low, a_high, and b are smaller, slightly greater, and smaller, respectively. Furthermore, we see that our breakpoint is 0.4 dex above the expected breakpoint.

The residual plot of the simple linear regression displays a moderate, negative correlation, while the the residual plot of the piecewise linear regression displays no pattern. This indicates that a piecewise linear regression is the more promising route for further study.

Conclusion and Future Work

Our project was successfully able to use Gaia parallax data to confirm the flux-weighted gravity-luminosity relationship for galactic blue supergiants. In addition, our derived slope and intercept closely matched prior calibrations of the FGLR.

On the other hand, the lack of spectroscopy data for our supergiants forced us to rely on surface gravity and effective temperature values provided in the literature. This increased the error in our calibration and made it difficult to identify a clear break in the slope, as recently discovered by Urbaneja et al. (2017). Furthermore, the lack of metallicity data for our BSGs made it impossible to analytically compute bolometric correction values, forcing us to rely on the empirical bolometric correction values compiled by Schmidt-Kaler (1982). Further improvements to our work should be based on precise stellar parameters from spectroscopic surveys targeted toward blue supergiants, which remain of great importance to extragalactic astronomy.

Acknowledgements

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