Likhith_Portfolio

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https://github.com/sherlock1108/pale-dot.git

Research Interests

Astrophysics, Cosmic Microwave Background & Early Universe, Dark Matter, Solar System evolution, Spectroscopy

My Projects (as yet)

Stellar Astrophysics

- **Analysis of SS Cygni**

Spectroscopy results: Deep absorption bands (*Titanium Oxide (TiO)*); ~3000 Kelvin & bright emission lines (*656.28 nm, H-alpha & ionized Helium*); at least 100,000 Kelvin

These are interesting results, two very different results from the same source. Part of why SS Cygni is so different from other stars (or star systems, since this one isn't a single star, as I shall infer). Clearly, there are very 2 different thermal signatures, and so it cannot be a single stellar object. This effectively confirms that it has to be a binary system.

The deep absorption bands imply a thick & cool atmosphere, while the emission lines are entirely a different case. Such high temperature and high ionization suggests the presence of an accretion disk.

Dynamics & classification, evolution:

Now it is certain there are two different compact sources. The two bodies likely orbit each other very closely. Given the huge temperature difference, it is highly probable one is a very luminous object while the other is a cooler star. From the HR diagram, it is a K/M-type Main Sequence dwarf star, specifically a dim red dwarf.

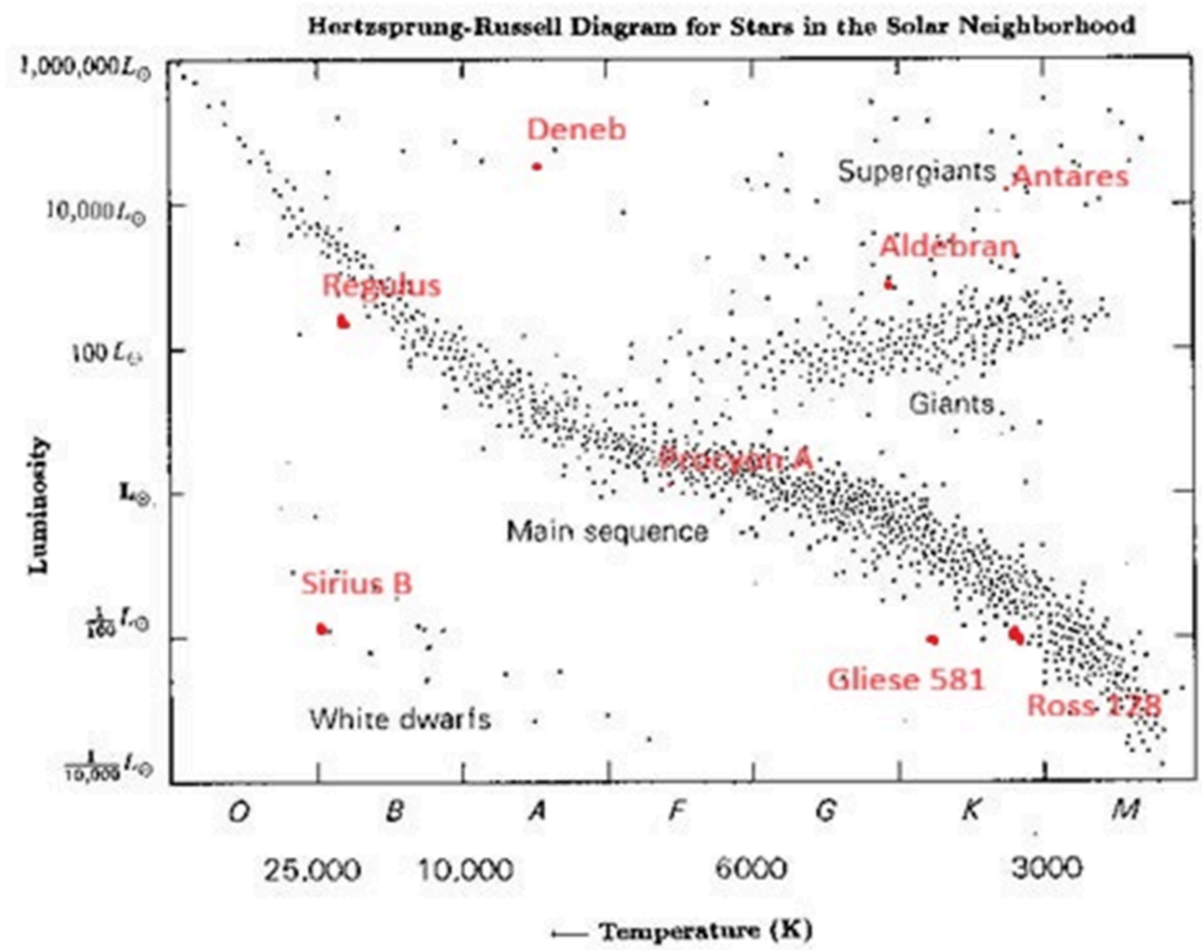
Given the high temperature of the other star, it could be a blue giant star. But the spectral evidence points to a white dwarf. Why? As mentioned the orbit is too close and fast. If it were a blue giant, it would show a brighter system of absolute magnitude greater than what was observed.

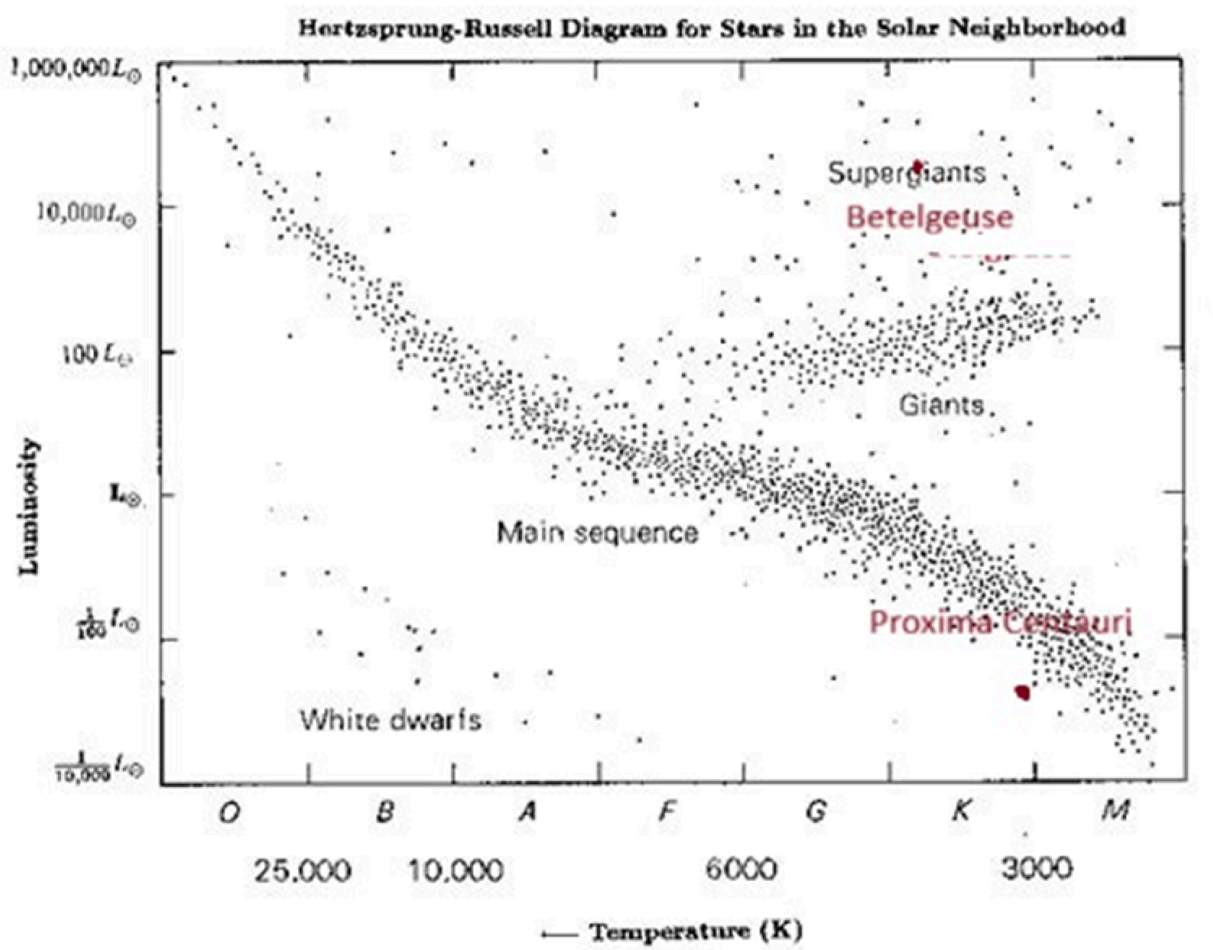
The variability in luminosity is due to friction and viscosity within the disk, in accordance with the most accepted models (disk instability).

As the white dwarf accretes material form its companion, if it crosses the Chandrashekar limit (~1.4 solar masses), it will eventually go out in a Type 1a supernova (subject to mass loss and accretion rate).

- **Fundamental Spectroscopic Classification**

Direct derivation from observational data to construct a HR diagram





<u>Objective:</u> To plot and compare the physical characteristics of the following stars in the HR-diagram

<u>Method:</u> Use the HR diagram and plot by luminosity & temperature, which is available from observation & spectroscopy. Then, located the approximate position in the diagram

<u>Learning:</u> Heavier stars are at the top, the giants & the supergiants. The dwarfs are below, and the cooler red dwarfs are almost out of the diagram, showing their low luminosities

<u>Observation & Conclusions:</u>

Star	**Luminosity**	**Temperature**	**Radius**	**Spectral Type**	**Evolutionary State**
Deneb	200,000	8,500 K	~203	A2 Ia Blue Supergiant	Fusing heavier elements; Supergiant trajectory

Regulus A	350	12,000 K	~3.9	B7 V Main-sequence	CNO Cycle, will end similar to the Sun
Sirius B	0.026	25,000 K	~0.008	DA2 White Dwarf	Degenerate Carbon-Oxygen core
Procyon A	7	6,500 K	~2	F5 IV-V Main-sequence end	Like the Sun but in advanced stage, similar future
Aldebaran	400	3,900 K	~44	K5 III Red Giant	Red Giant trajectory burning through Hydrogen, Helium core
Antares	75,000	3,500 K	~680	M1.5 Iab Red Supergiant	Near the end of Supergiant phase; Type II supernova likely
Gliese 581	0.013	3,200 K	~0.29	M3 V Red Dwarf	Convective red dwarf
Ross 248	0.0003	2,700 K	~0.19	M6 V Red Dwarf	Same as Gliese 581 but less luminous
Betelgeuse	120,000	3,500 K	~887	M1-M2 Ia Red Supergiant	Near the end of Supergiant phase, burning Helium to Carbon; Type II supernova likely
Proxima Centauri	0.0015	3,000 K	~0.15	M5.5 Ve Main-sequence dwarf	Nearest star to the Sun, ultra dim red dwarf

Luminosity & radius are relative to that of the Sun

Time to check whether luminosity & temperature hold up to the Stefan-Boltzmann law -

$$relative\ \ luminosity = (relative\ \ radius)^2\ X\ (relative\ \ temperature)^4$$

Assuming temperature of the surface of Sol to be $5772\ \ K$

Star	Observed* relative luminosity	Calculated relative luminosity	Ratio

Deneb	200,000	193803.88	1.03
Regulus A	350	284.15	1.23
Sirius B	0.026	0.022	1.18
Procyon A	7	6.43	1.08
Aldebaran	400	403.51	0.99
Antares	75,000	62515.06	1.19
Gliese 581	0.013	0.0079	1.64
Ross 248	0.0003	0.0017	0.17
Betelgeuse	120,000	106368.76	1.13
Proxima Centauri	0.0015	0.0016	0.93

***NOTE:** The observed values for the luminosities were taken from published stellar parameters and represent rounded estimates of the star's actual bolometric luminosities. Also the radii and temperature observations carry their own uncertainties. Therefore small offsets between the "observed" values and the calculated values is to be expected. In the end, my intention was to use the law as a sanity check.

That said, there are some stars here that show a slightly bigger offset. A range between 1.0-1.5 is perfectly reasonable given the aforementioned constraints and assumptions. The radius and temperature estimates for the giants are uncertain. In the case of the dwarfs, any small error margin gets blown up due to the exponents, producing a big change in L.

Because rounding to 1-2 significant figures can make the calculated value very different (than it really is) compared to the published figures.

Cosmology

- **Inquiry into the Hubble Tension**

3C 147 redshift **(z)** = 0.545
Velocity = 300000 x 0.545 = 163500 km/s
Distance with local value of the constant = 163500/73 = 2239.72 Mpc
Distance with CMB value of the constant= 163500/67.4 = 2425.81 Mpc

NGC 7619 redshift **(z)** = 0.01
Velocity = 300000 x 0.01= 3000 km/s
Distance with local value of the constant = 3000/73 = ~ 41 Mpc
Distance with CMB value of the constant = 3000/67.4 = ~ 44.5 Mpc

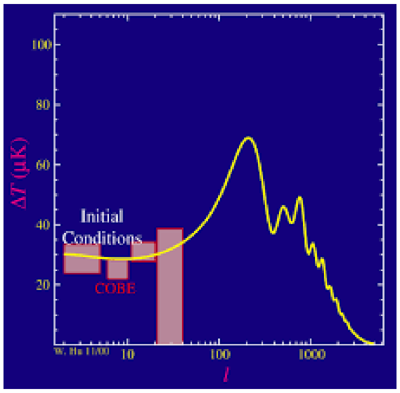
The Discrepancy

Clearly, there is a very noticeable difference when between the two measured Hubble constants. The CMB value was observed in the context of the early universe, and what the CMB map showed us. While the local value is from Cepheid variables & supernovae.

Both values are precise as long as they are within their own frameworks. So, either there is some missing physics that we haven't considered, or, the value of dark energy was different in the early universe. In fact, dark energy might be changing with time.

When I say dark energy, I mean the dark energy density factor or the cosmological constant. Assuming matter & energy densities have not changed value, the only other supposition is that dark energy density value changed with time. It had been observed that dark energy dominates at low redshifts, which implies, the relationship between velocity & distance is no longer linear, the further you go back in time (larger redshifts).

- **Acoustic peaks in the CMB**



https://background.uchicago.edu/~whu/intermediate/map5.html

In the power spectrum of the CMB, the first peak in the curve was predicted using models in plasma physics. The observed data from the WMAP & Planck experiments matched with what had been predicted.

In the CMB map, we have a visual representation of very minute differences in temperature fluctuations. Superimposed over the entire sky, there are warm and cold spots. The angular size of these spots – how much space they occupy in the sky – was predicted using models from theories in plasma physics.

The curve in the power spectrum shows the strength or power of the fluctuations, which directly translates to the angular size in the corresponding visual map. The standard ruler is the measured value of this angularity, so to speak.

Until around 370,000 years after the Big Bang, the Universe was very opaque. Photons could not escape until after. The CMB is the direct “photo” of these photons, which escaped first. But before that, the photons were trapped inside, and kept got scattered constantly by interacting with other particles, like electrons. These interactions became significant to the point that they started to counteract against the outward radiation that was trying to get out i.e. the photons themselves.

The aforementioned theories state that the predicted size of the standard ruler should not be more than 1 degree in the sky. The observed size was found to be not 0.5 or 2 degrees, but in fact very close to 1 degree, matching almost perfectly. Plasma physics models predict the parameters of the standard ruler inflation theory talks about the geometry of the Universe. It states that after a very short time immediately after the Big Bang, the Universe expanded by an incredible amount in an extremely short amount of time, which is the main reason why it has to be flat.

It expanded by a factor of 10^{26} *in a time interval of* 0.00000000000000000000000000000001 seconds!