Stars Temperature (Wien's Law)
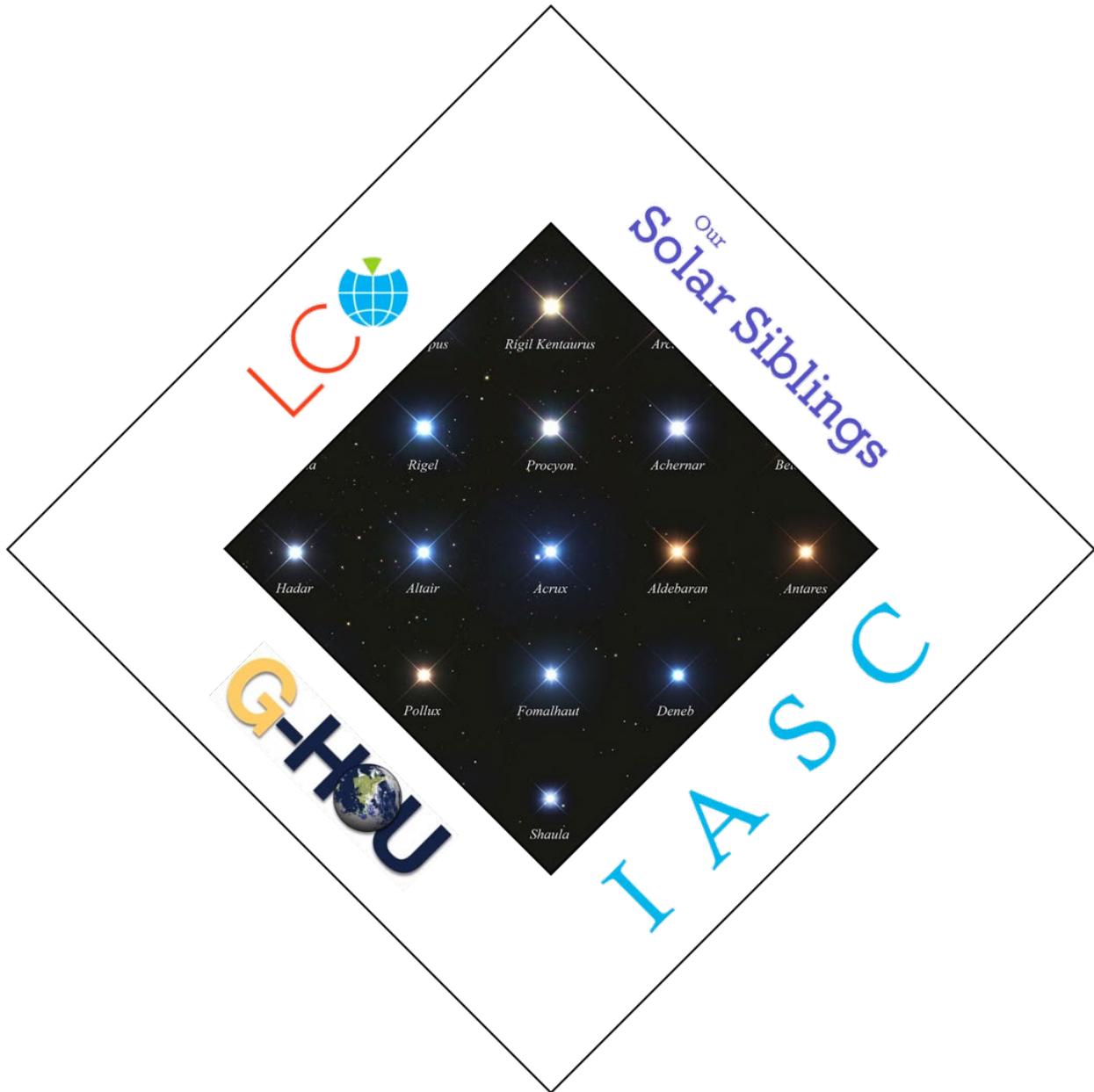
Wilhelm Carl Werner Otto Fritz Franz Wien was a German physicist who used theories about heat and electromagnetism to calculate the emission of a blackbody at any temperature from the emission at any one reference temperature known as Wien's law.

Wien's law states that the temperature of an object is inversely proportional to its wavelength. In other words, as the temperature increases, the wavelength decreases. The formulas to calculate the temperature or the wavelength are:

$$\lambda_{Max} = \frac{2.898 \times 10^7}{T} \qquad\qquad T = \frac{2.898 \times 10^7}{\lambda_{Max}}$$

where T is the absolute temperature in kelvins and λ_{Max} is the wavelength in Angstroms (Å).

Angstroms (Å) is a unit of measurement named after 19th Century Swedish physicist Anders Jonas Ångström. An Angstrom is equivalent to one ten billionth of a meter (10^{-10}m), or 0.1 nanometer. One of its uses is to measure wavelengths of visible light. The visible light spectrum ranges between 3800Å to 7800Å. Directly above 7000 Å is Infrared, and directly below 3000 Å is Ultraviolet. Below is a picture showing how small the visible light spectrum is compared to everything else the human eye cannot see.
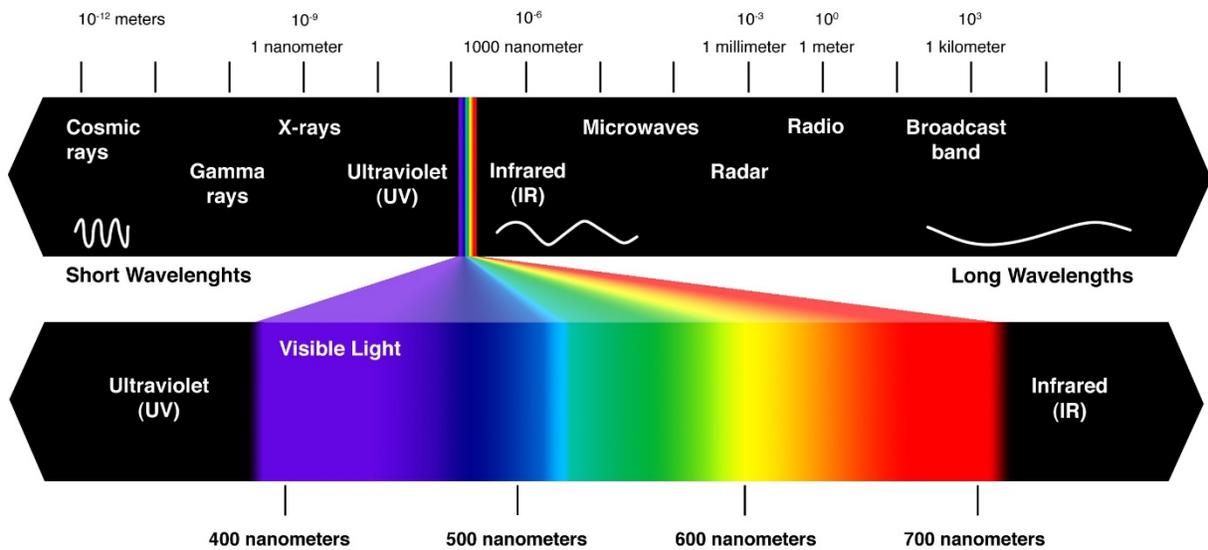
Exercises:

1   Arcturus (α Boo) is a red giant star belonging to the constellation Boötes (The Herdsman). It is the 4th brightest star in the night sky overall and located approximately 37 light years away from Earth.

      Arcturus' temperature is ≈ 4130K. What is Arcturus' max wavelength?

2   Capella (α Aur) is a giant star belonging to the constellation Auriga (The Charioteer). It is the 6th brightest star in the night sky overall and located approximately 42 light years away from Earth.

      Capella's temperature is ≈ 5400K. What is Capella's max wavelength?

3   Procyon (α CMi) is a main sequence star belonging to the constellation Canis Minor (The Little Dog). It is the 8th brightest star in the night sky overall and located approximately 11 light years away from Earth.

      Procyon's temperature is ≈ 6851K. What is Procyon's max wavelength?

4   Altair (α Aql) is a white main sequence dwarf star belonging to the constellation Aquila (The Eagle). It is the 12th brightest star in the night sky overall and located approximately 16.73 light years away from Earth.

      Altair's wavelength is ≈ 3803Å. What is Altair's temperature?

5.   Aldebaran (α Tau) is a red giant star belonging to the constellation Taurus (The Bull). It is the 15th brightest star in the night sky overall and located approximately 65 light years away from Earth.

      Aldebaran's wavelength is ≈ 7431Å. What is Aldebaran's temperature?

6   Pollux (β Gem) is a giant star belonging to the constellation Gemini (The Twins). It is the 17th brightest star in the night sky overall and located approximately 34 light years away from Earth.

      Pollux's wavelength is 6078Å. What is Pollux's temperature?

Bonus Question:

Main sequence stars, as seen in the Hertzsprung–Russell (HR) diagram, include stars that are in their Hydrogen-Burning phase, like our Sun. We can calculate the luminosity, mass, radius and average density of these stars. In addition, we can also calculate how long Hydrogen-Burning stars will take to exhaust their hydrogen fuel before going into their next phase of life (Helium-Burning).

The formulas are:

$$L \cong T^{6.72} \qquad M \cong T^{1.92} \qquad R \cong T^{1.36}$$

$$\rho \cong \frac{1}{T^{2.16}} \qquad \tau \cong \frac{1}{T^{4.80}}$$

where *L* is the *Luminosity*, *M* is the *Mass*, *R* is the *Radius*, ρ is the *Average Density* and *τ* is the *H-Burning Age in years*.

7   Rigil Kentaurus (α Cen) is a main sequence star belonging to the constellation Centaurus (The Centaur). It is the 3rd brightest star in the night sky overall and located approximately 4.2 light years away from Earth.

Rigil Kentaurus' wavelength is ≈ 5039Å. What is Rigil Kentaurus' luminosity, mass, radius and average density? How long will it take Rigil Kentaurus to burn through its hydrogen fuel?

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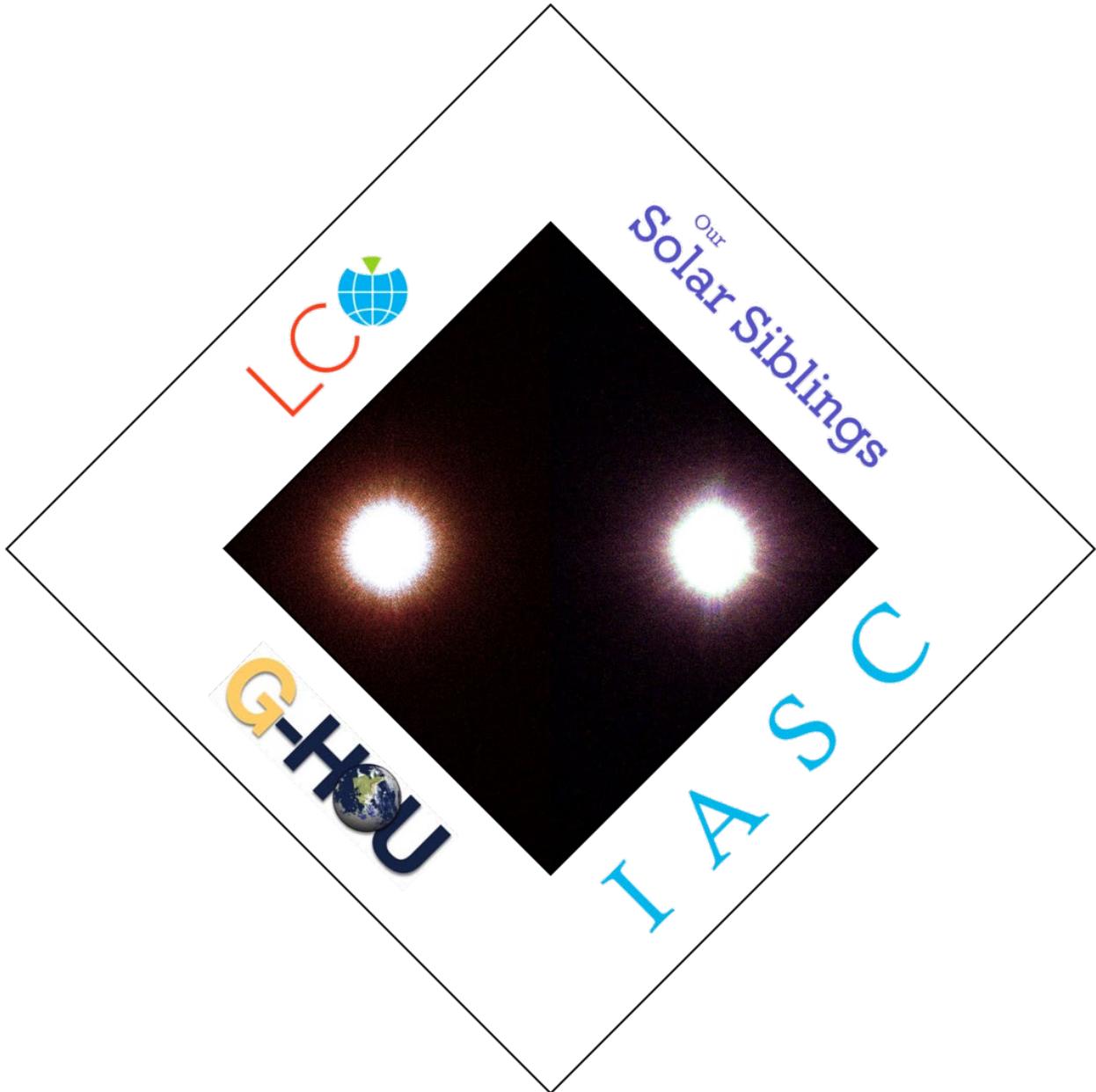
Arcturus (Left), Rigil Kentaurus (Right)
Taken by LCO and colorized using GIMP