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White dwarfs in Sirius-like binary systems

Ptolemy made a book called the Almagest which recorded the positions of all the fixed stars. The stars were considered to be embedded in a great crystal sphere and were unable to move, unlike the wandering planets.

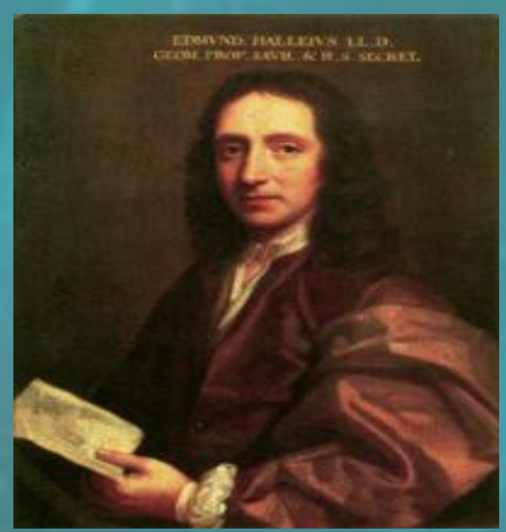
Edmund Halley was measuring the positions of the stars. He noticed that some of the stars were in different positions compared to the positions recorded in the Almagest, particularly Sirius and some other bright stars. He realised that the stars are not fixed. They move relative to each other, but the motion is so slow that it only becomes noticeable over a long period of time.

Friedrich Bessel was measuring the proper motion of stars. He found that Sirius and Procyon did not more in straight lines as expected. They wobble back and forth. He hypothesised that an unseen companion star could be causing this strange behaviour as the stars would orbit around each other.

Alvan Clark and his son Alvan Jr. were testing a new telescope they were building by looking at Sirius. They were the first people to see the faint companion star which is now known as Sirius B. It is the closest white dwarf to Earth.

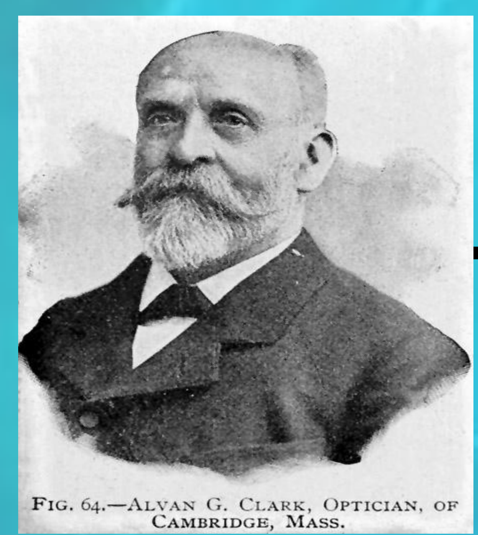
Professor Martin Barstow and collaborators used the Hubble Space Telescope to observe the spectrum of Sirius B. Using this data, they were able to measure the gravitational red-shift and use this to calculate the mass of Sirius B.

Ptolemy
A.D. 168



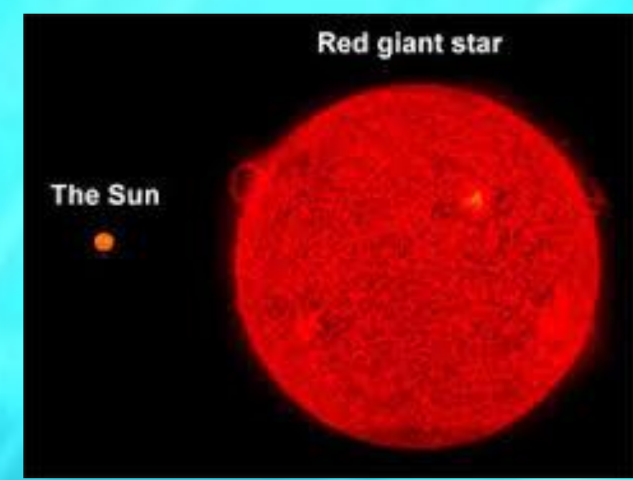
Edmund Halley
A.D. 1718

Friedrich Bessel
A.D. 1844



Alvan Clark
A.D. 1862

Martin Barstow
A.D. 2005

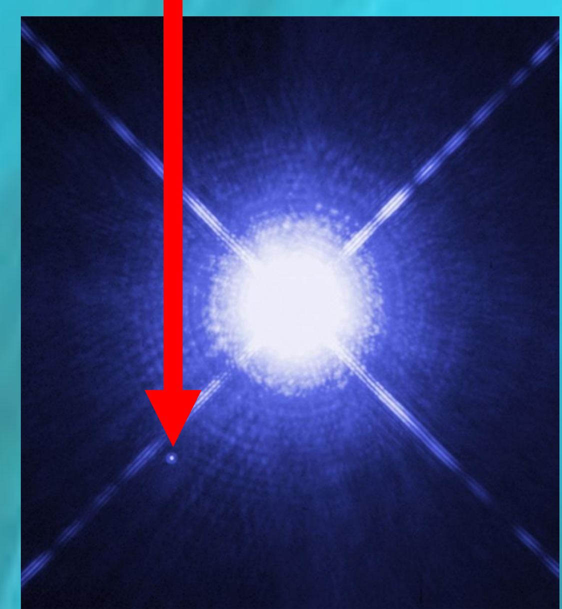


The Sun becomes a red giant
A.D. 5,000,000,000

The Sun becomes a white dwarf, approximately the size as Earth.
A.D. 7,000,000,000

The gravitational pull of the white dwarf is so strong that any light escaping from it is stretched to longer wavelengths. We can measure how much the light has been stretched by observing absorption lines in the spectrum. These provide a kind of marker and are expected to be seen at particular wavelengths. If we compare the wavelength where the line occurs to the wavelength we would expect it to be, based on lab experiments, we can get an idea of how much the light has been stretched by the gravity of the white dwarf. This gives us a way to measure the white dwarfs mass.

Unfortunately, the strong gravity of the white dwarf is not the only thing that can cause this wavelength shift. It can also be caused by the movement of the star towards or away from us, the motion of the Hubble space telescope and the motion of the Earth around the Sun. It is like listening to someone playing a trumpet as they drive past you in a car. Its difficult distinguish how much the change in pitch was due to the motion of the car and how much it was due to the trumpet player playing a bad note.



Even with the Hubble Space Telescope, Sirius B appears as a tiny dot compared to the bright star Sirius A.

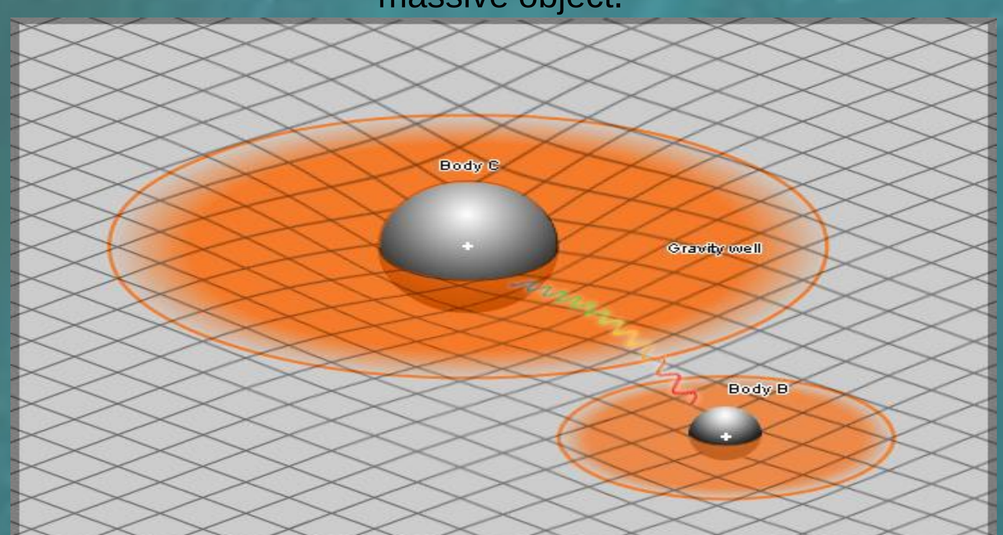
The Sirius challenge

We have found that the 3 methods of measuring the mass of Sirius B give us 3 slightly different answers. Understanding the cause of this discrepancy will lead us to a greater understanding of the physics involved and also the systematic effects inherent in each of the methods.

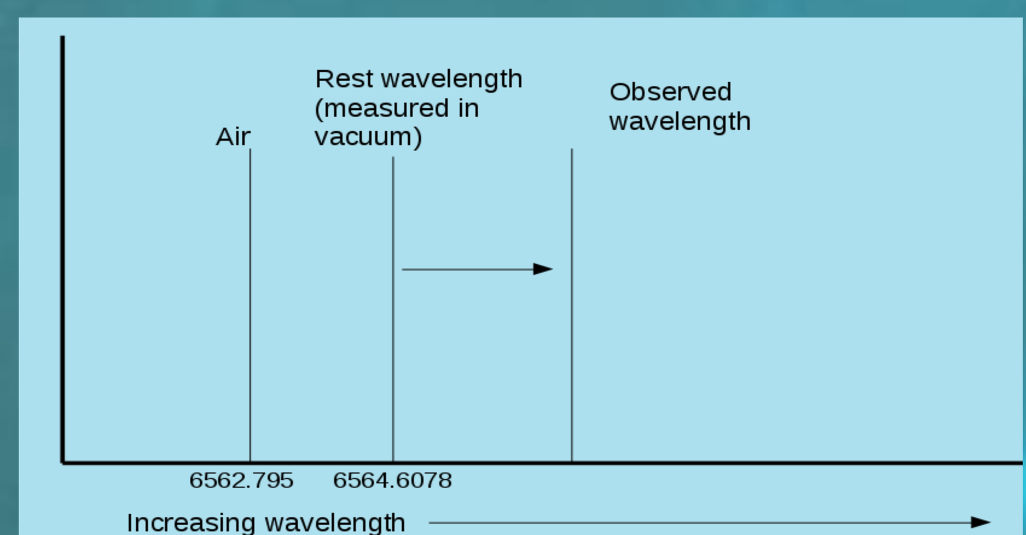
This could have wide reaching consequences as observations become ever more ambitious and are therefore more sensitive to these small systematic effects.
Also, history has shown us that whenever a small mystery remains unsolved, the answer has led to a whole new understanding of Sirius and a deeper understanding of the way the universe works .

3 ways to weigh a star

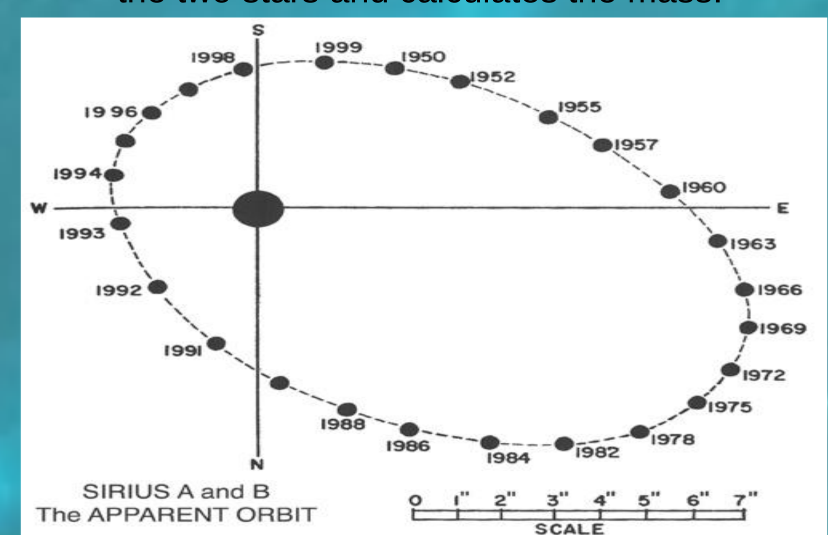
Einstein's theory of General Relativity predicts that light will be stretched to longer wavelengths by the gravity of a massive object.



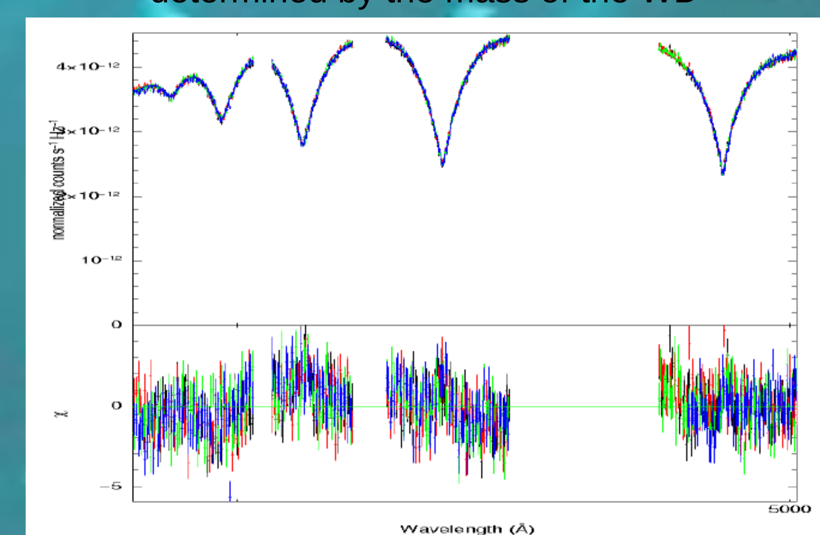
The mass of the white dwarf determines how much the absorption lines are shifted to longer wavelengths.



The astrometric method measures the orbit of the two stars and calculates the mass.



The shape of the Balmer lines is partly determined by the mass of the WD



The mass-radius relationship

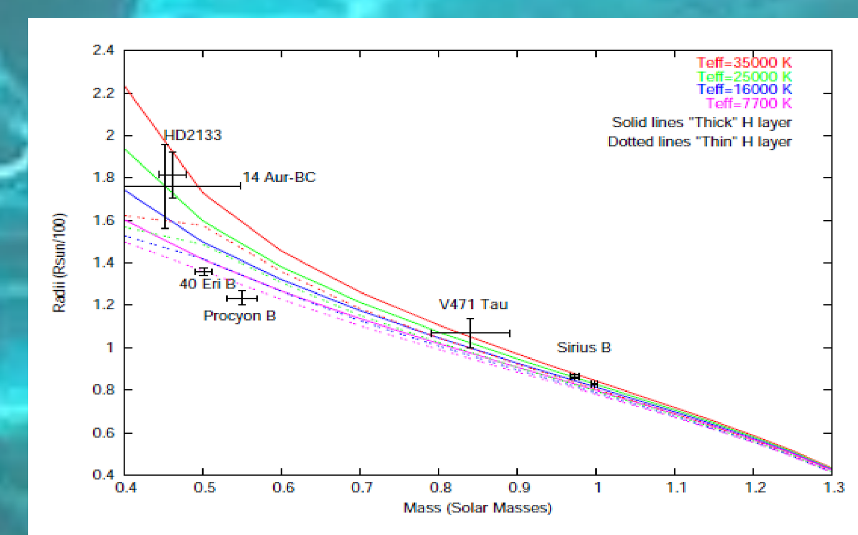


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Fig from Barstow et al 2015, ASP Conference series, Vol 493