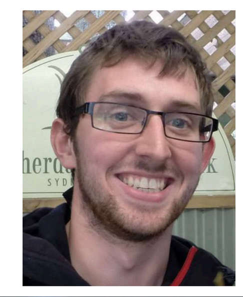
Type Ia Supernovae: Candles in the Dark

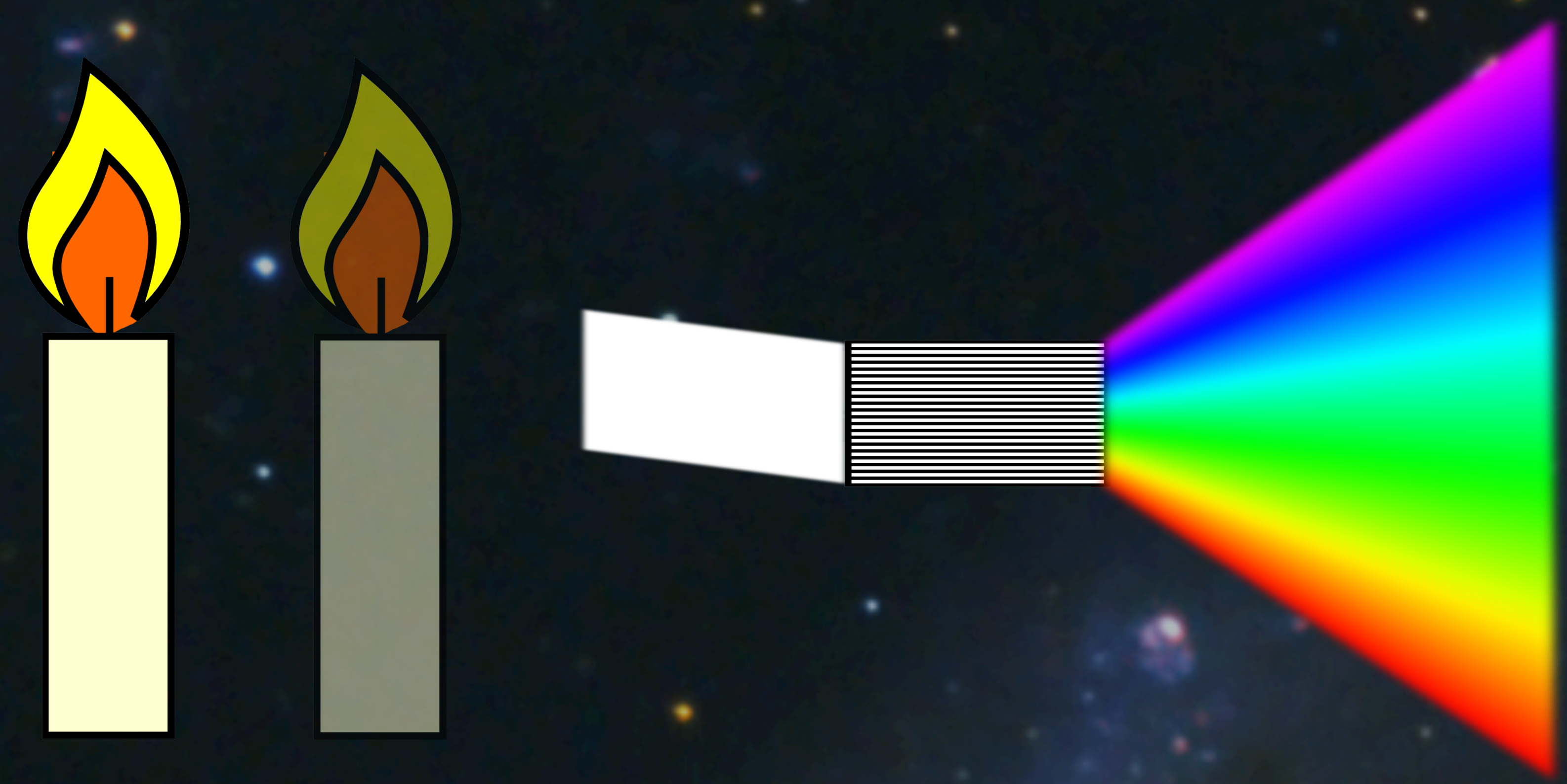
Robert Firth

UNIVERSITY OF Southampton

PALOMAR TRANSIENT FACTORY



Supernovae are explosions that mark the death of some types of stars. They are classified using the presence or absence of hydrogen and silicon in the spectrum of light that they emit. Supernovae Type Ia (SNe Ia) show no hydrogen and lots of silicon. For a few weeks they outshine the galaxies in which they explode, and we can use them to look deep into the universe and probe the nature of dark energy.



SNe Ia act as *standard candles*: they all have very similar brightnesses. We believe this is due to the uniformity of the stars that explode, called white dwarf stars. The white dwarf, an Earth-sized remnant of an earlier star, gains material from a neighbouring star until it can no longer support itself against gravity. A massive thermonuclear explosion results.
Once we classified a Supernova by splitting up the light that it emits into a spectrum, we can deduce its '*luminosity distance*' – since we know how bright they should be, and how bright they appear. A Supernova that is twice as distant will appear four times fainter.

We can also use another method to deduce the distance, *redshift*. A light emitting object travelling away from an observer will redden as the light is stretched out. It will also become bluer if it is viewed travelling toward the observer.
Distant galaxies are observed to be travelling away from us, meaning their light is *redshifted*. *Cosmological models*, mathematical descriptions of the Universe, make predictions about how redshift changes with distance, depending on what the Universe contains. This is how we can use SNe Ia distance measurements to inform us about what the universe is made of – *matter*, *dark matter* and *dark energy*. In 2011 work in this area was awarded the Nobel Prize in Physics.

My work focuses on the observational signatures of the power source of SNe Ia using data from the Palomar Transient Factory (PTF). The dominant energy source is radioactive decay; heavy, unstable elements such as Nickel (^{56}Ni) and Cobalt (^{56}Co) break apart, releasing high energy *gamma-rays*. These gamma rays are absorbed by the expanding debris, known as ejecta, heating it up. It is the radiation from this heated ejecta that we observe with optical telescopes.

The distribution of the ^{56}Ni can have a large effect on the shape of the light curve – brightness plotted against time (see figure below), particularly in the first week after explosion. By measuring the shape and of the light curves very shortly after explosion and applying theoretical models, I constrain the distribution of ^{56}Ni and look for evidence of other power sources, such as the ejecta colliding with material around the dying star.

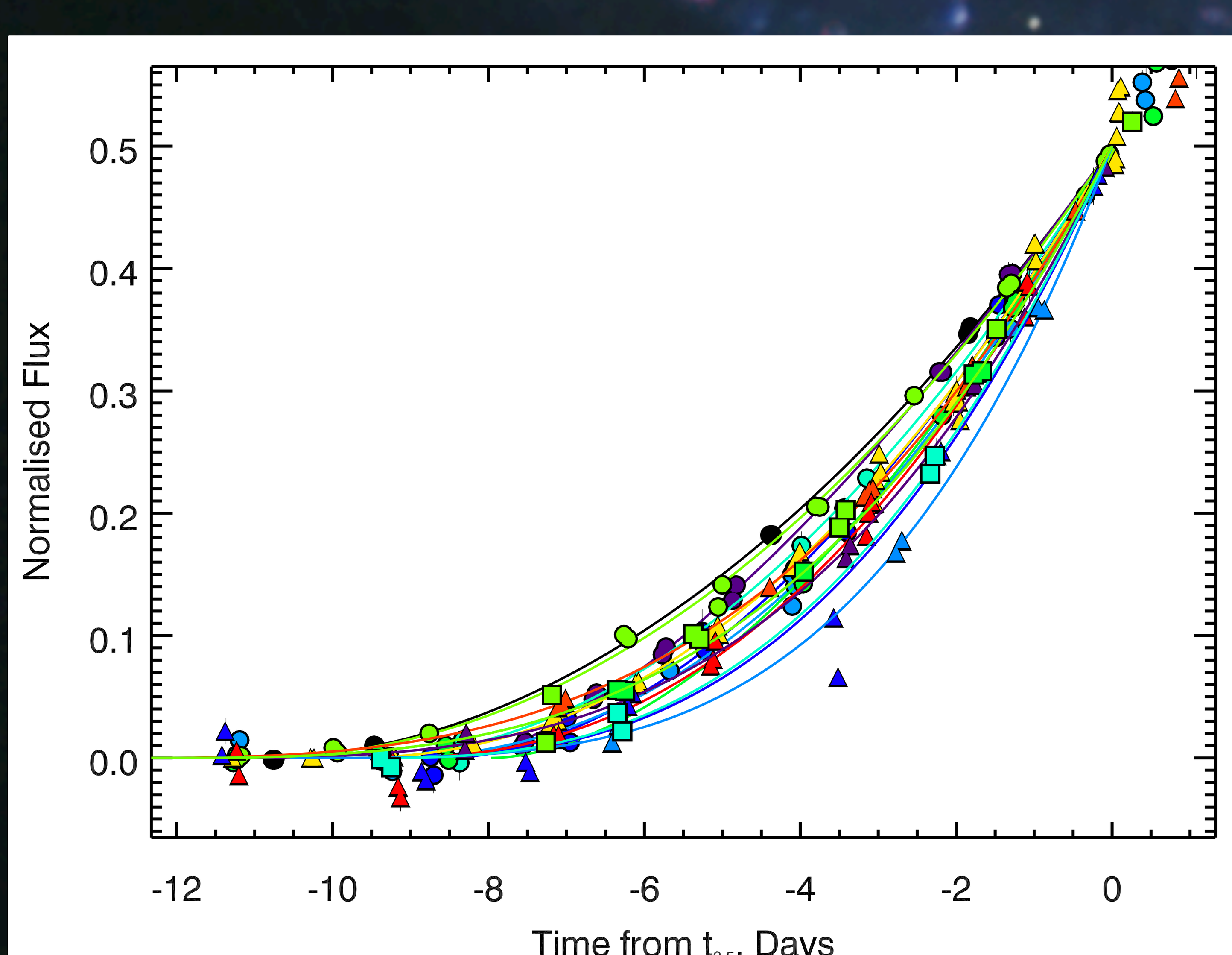


Figure: The 18 SNe Ia used in my analysis, from the Palomar Transient Factory. $t_{0.5}$ is the point at which the SN Ia is at half of its maximum brightness

My work shows that even after the calibrations made to standardise, there is significant variation in the early light emmitted (see figure) and therefore the ^{56}Ni distribution. I have found that it is not necessary to have large amounts of radioactive elements like ^{56}Ni in the upper layers of the ejecta- a hallmark of violent mergers between two white dwarfs, to explain this data. This focuses our knowledge of the progenitor, and will increase the accuracy of our SNe Ia as standard candles, allowing better measurement of the contents of the Universe.

Background Image Credit: BJ Fulton, LCOGT

Website: goo.gl/9qik4x

@berto54