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Pushing the Limits using Commercial Spectrographs

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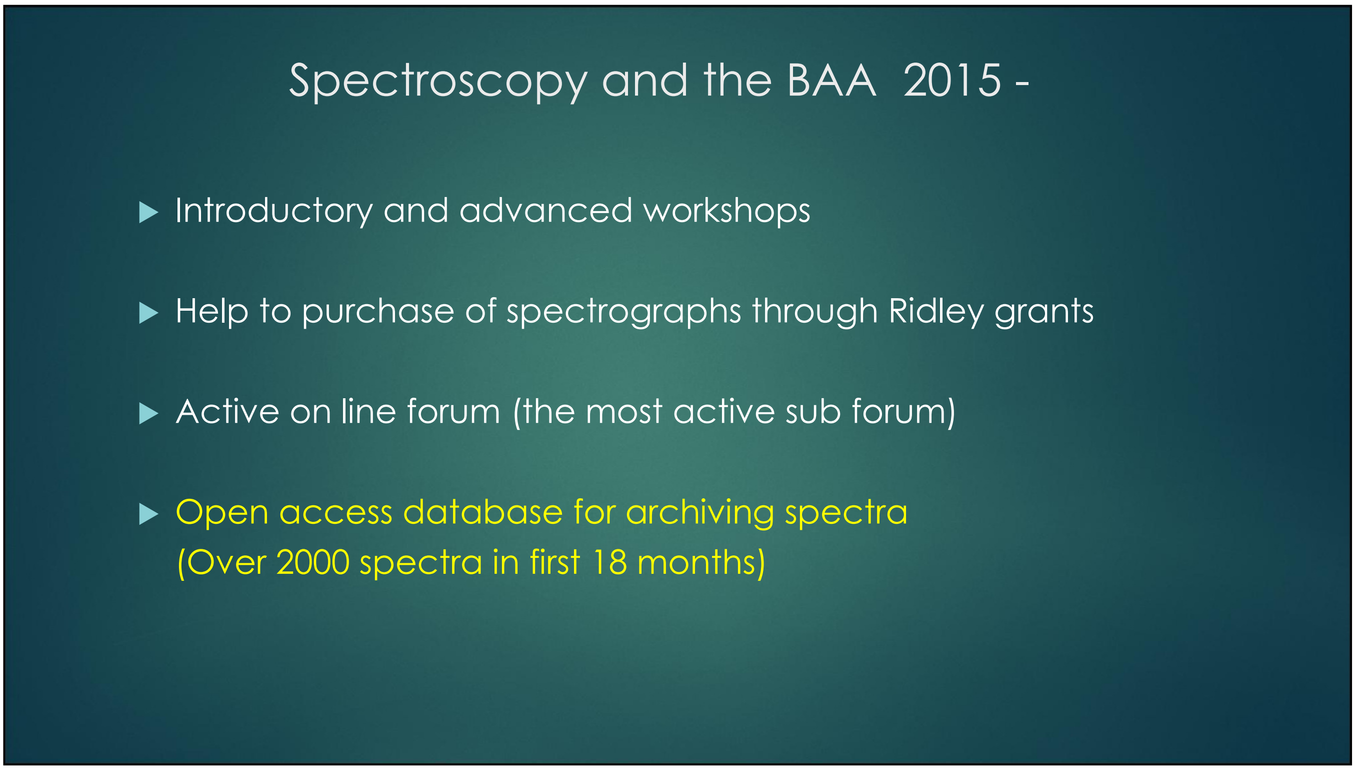
Good morning everyone, 10 years ago when I talked about what was happening in amateur spectroscopy in Europe I think it is fair to say that amateurs doing variable star spectroscopy were seen as something of a curiosity by both organisations.

BAA/AAVSO Meeting Cambridge 2008

The Spectroscopist at the
AAVSO/BAAVSS meeting
(With apologies to H M Bateman)

Nowadays though it is not unusual to find amateur spectra cited in Atels CBETS and peer reviewed papers



And in the past couple of years the BAA has been providing support for members wanting to get into this area.

Of particular interest to the wider community has been the building of a database giving long term security to the observations, which already contains over 2500 spectra

Observations which stretch the capabilities of three commercial spectrographs

- High Cadence Spectrophotometry Using a Star Analyser Grating
- Confirming Supernovae using a modified ALPY Spectrograph
- High Precision RV measurements using a LHIRES III Spectrograph

Today I thought I would describe briefly some observations made over intervening years which stretched the capabilities of my three commercial spectrographs,

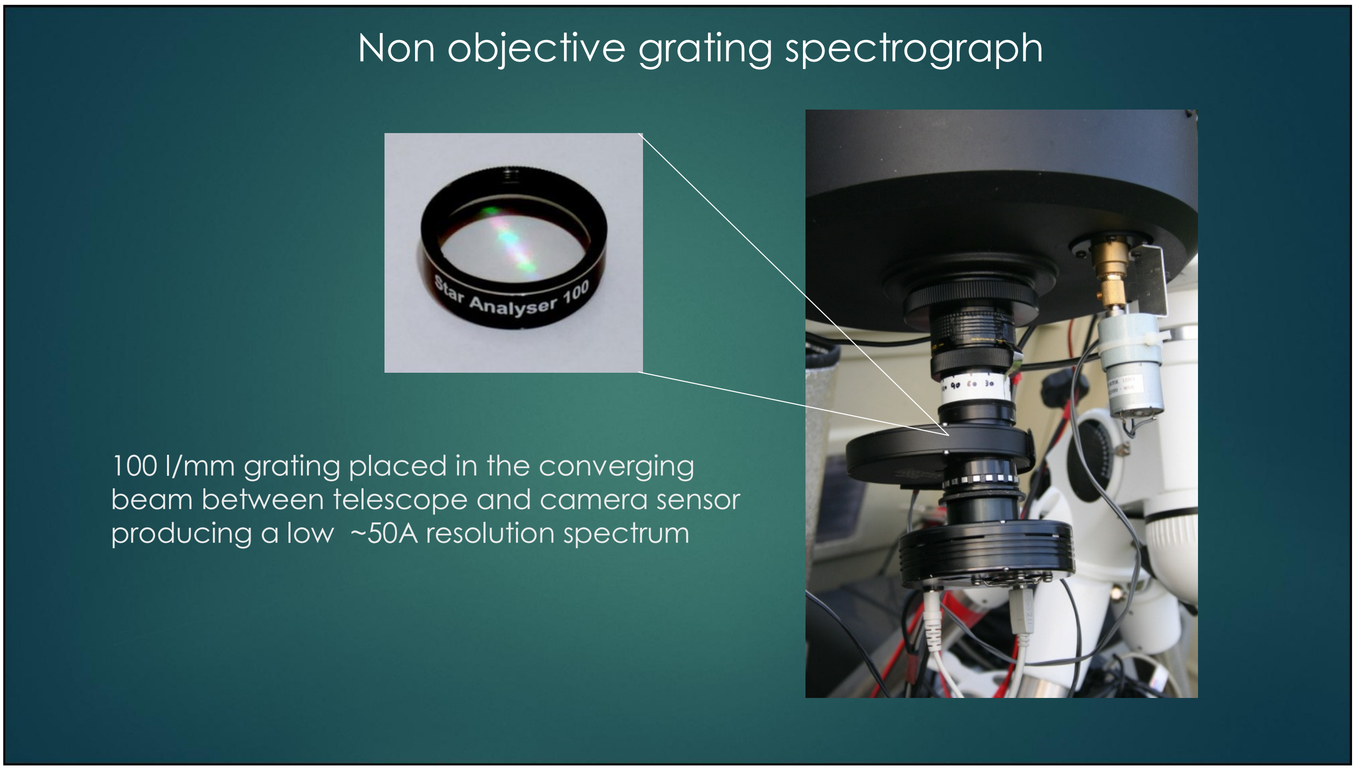
The Star Analyser grating which I developed back in 2005 as a simple low cost way to try spectroscopy but which is also capable of producing some interesting science

The ALPY low resolution slit spectrograph

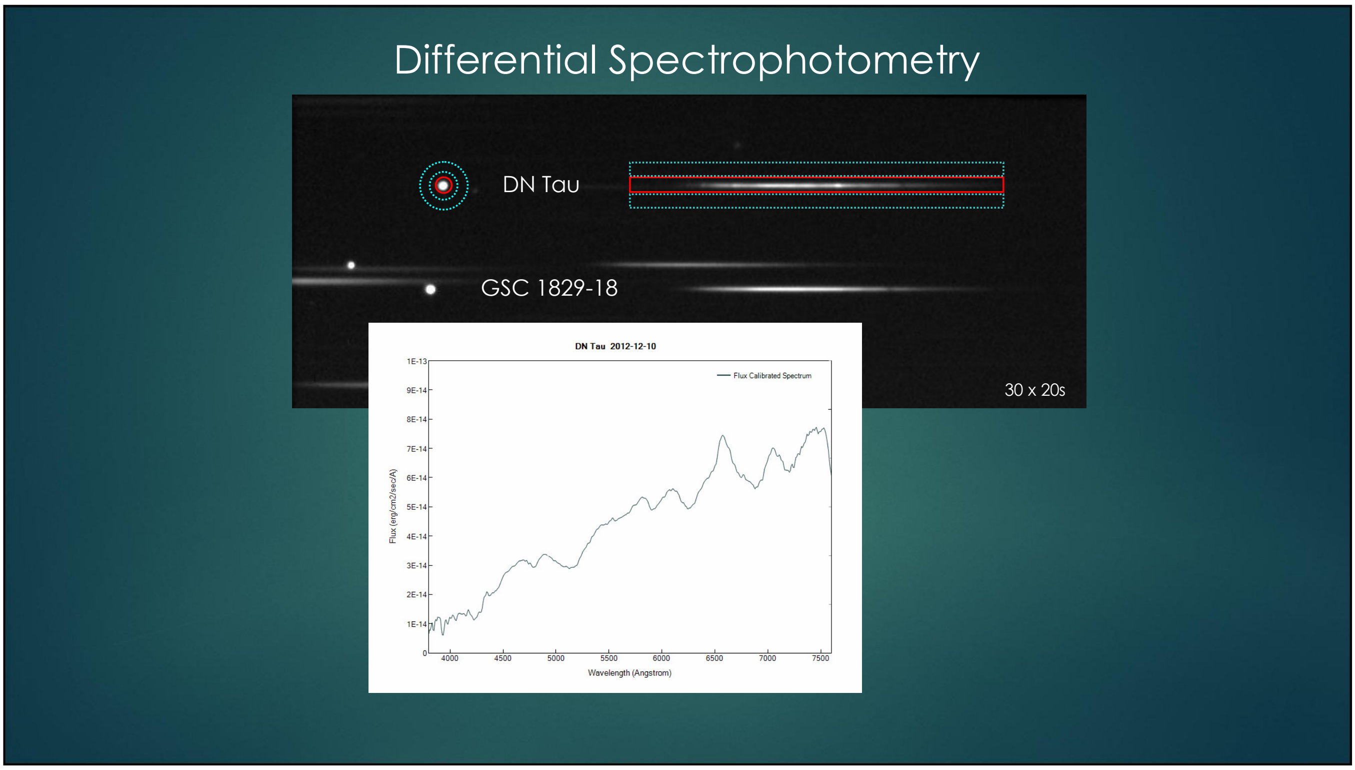
And the LHIRES III spectrograph which produces the highest resolution available to the amateur commercially

High Cadence Spectrophotometry Using a Star Analyser Grating

So firstly – doing photometry with a Star Analyser



This is the setup with the grating mounted in a filter wheel between my 11 inch Celestron SCT and the camera, producing a very low ~50A resolution spectrum of any star in the field



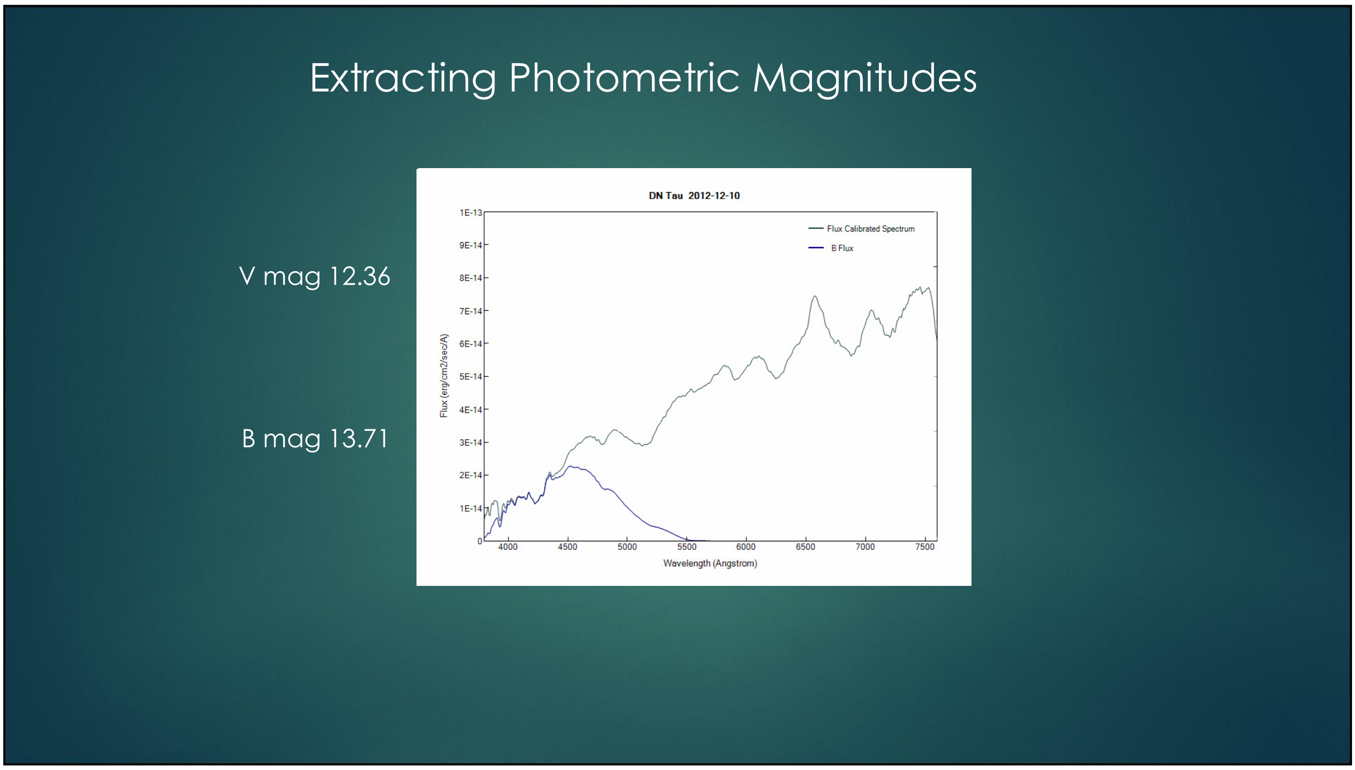
And here is the sort of image you get. For each star some light goes straight through the grating to form an image of the star while the rest is diffracted into a spectrum, blue on the left red on the right.

Here at the top we see the T Tauri star DN Tauri (note the bright spot in the spectrum from H alpha emission from the accreting material) and below it another star of similar brightness which we will use as a reference.

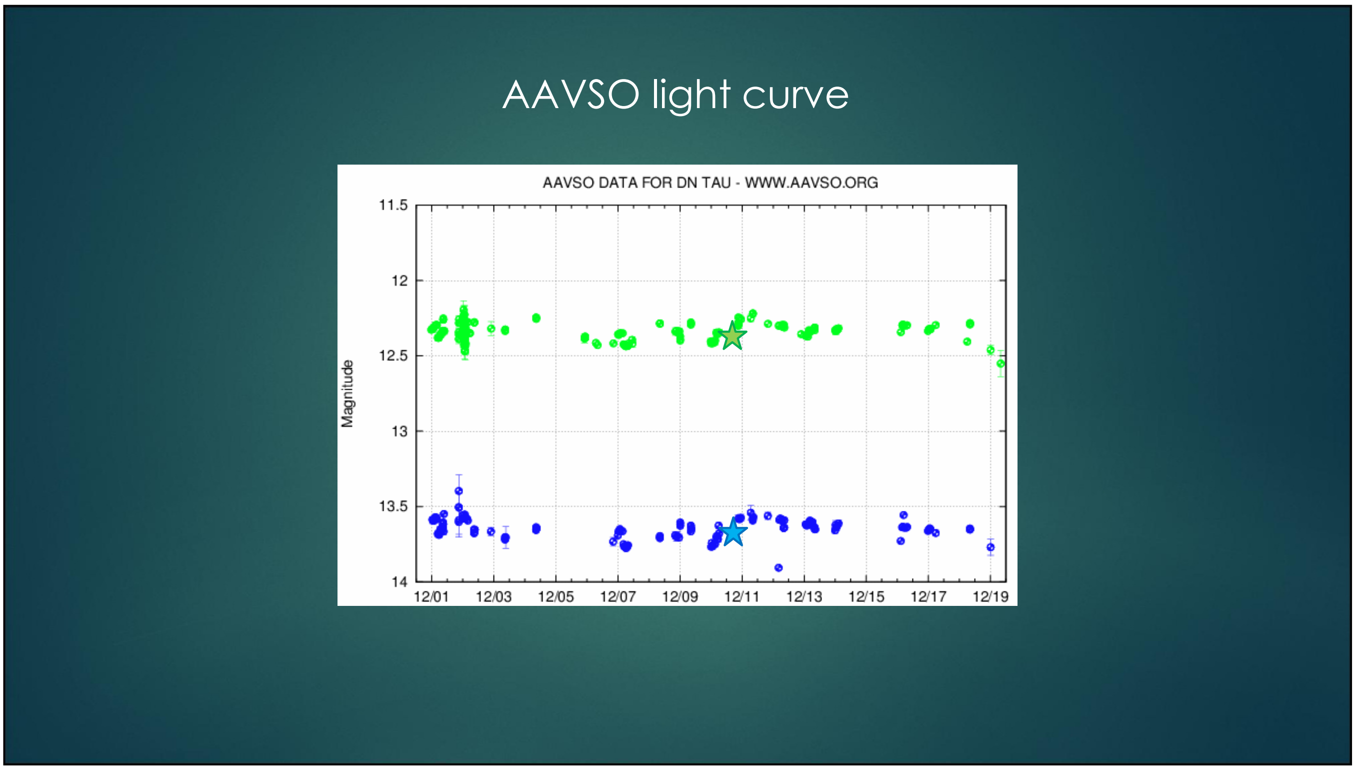
In conventional aperture photometry we would put an aperture over the star to measure the flux, and an annulus round it to measure the sky background, do the same for comparison star of known brightness (from APASS for example) and calculate the magnitude eg in BVRI depending on the filter being used.

We can do something analogous using the spectrum except that the aperture becomes rectangular and we add up the flux in columns to give a measure at each wavelength. Similarly we measure the sky background in areas above and below the spectrum and subtract this. This is also done for the comparison star which either already has a published spectrum (unlikely as there is no spectroscopic APASS equivalent) or which we have already measured relative to a spectroscopic standard star (The spectroscopic equivalent of all sky photometry)

Armed with this information we can produce the spectrum. Note that we are measuring absolute flux from the star here, in physical units, something you cannot do directly with a narrow slit spectrograph as you don't know what fraction of the light passes through the slit.



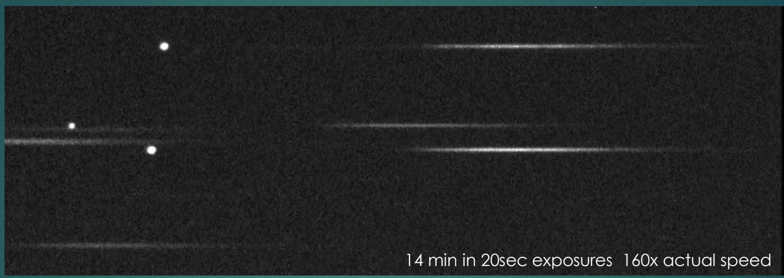
We can now take this spectrum and extract the photometric magnitudes by applying the photometric filter passband, measuring the flux in that passband and transforming it to the particular magnitude scheme. Here Johnson/Bessel V and similarly B



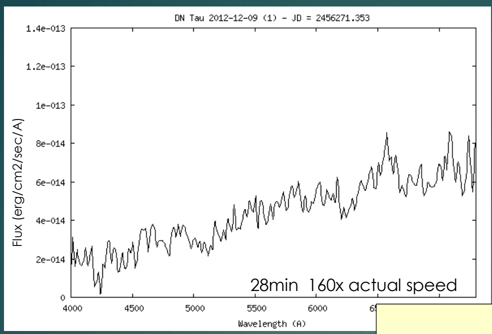
As a sanity check we can compare our results to those in the AAVSO database (where there is a lot of data as there was a campaign running on the star) Our results fit nicely within the conventional measurements.

Now this is all very interesting but to be honest it would probably have been much simpler to just measure the brightnesses conventionally.

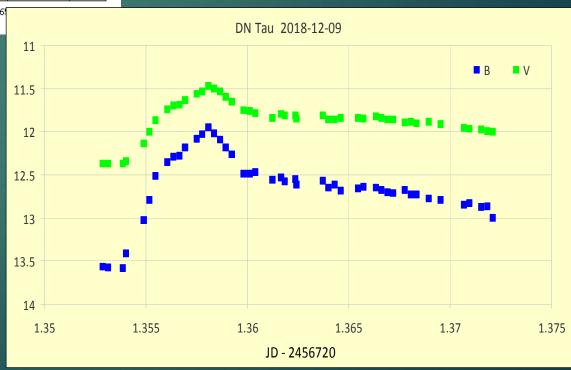
2012-12-09 A Fast Transient



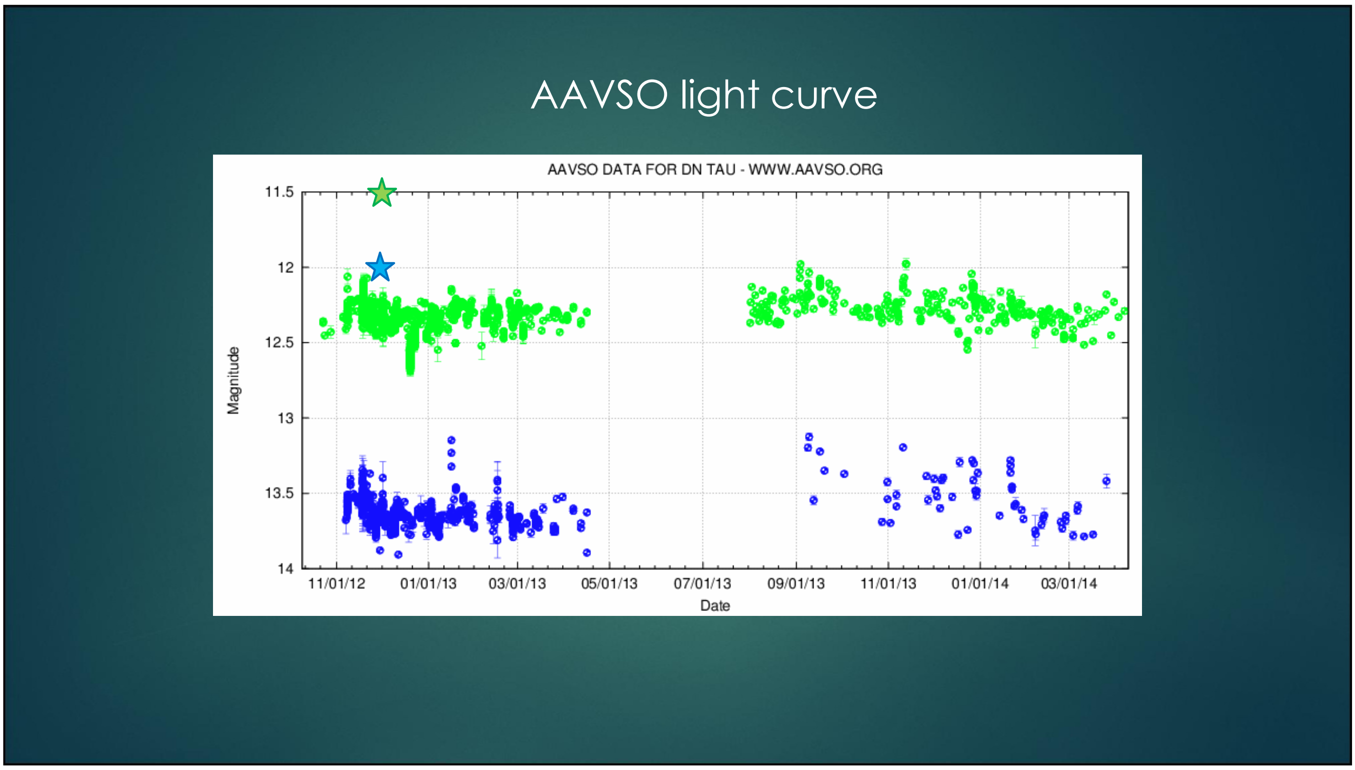
If however we look at what was happening to this star the previous night we find something rather interesting. (This animation shows a series of individual 20 second sub exposures over a 14 minute period) DN Tauri clearly brightened dramatically before fading. If we had been monitoring with a slit spectrograph, though would probably have been put down to the star wandering off the slit or intermittent cloud. We can clearly see however from the fact that other stars In the field remained unchanged that this is a real event



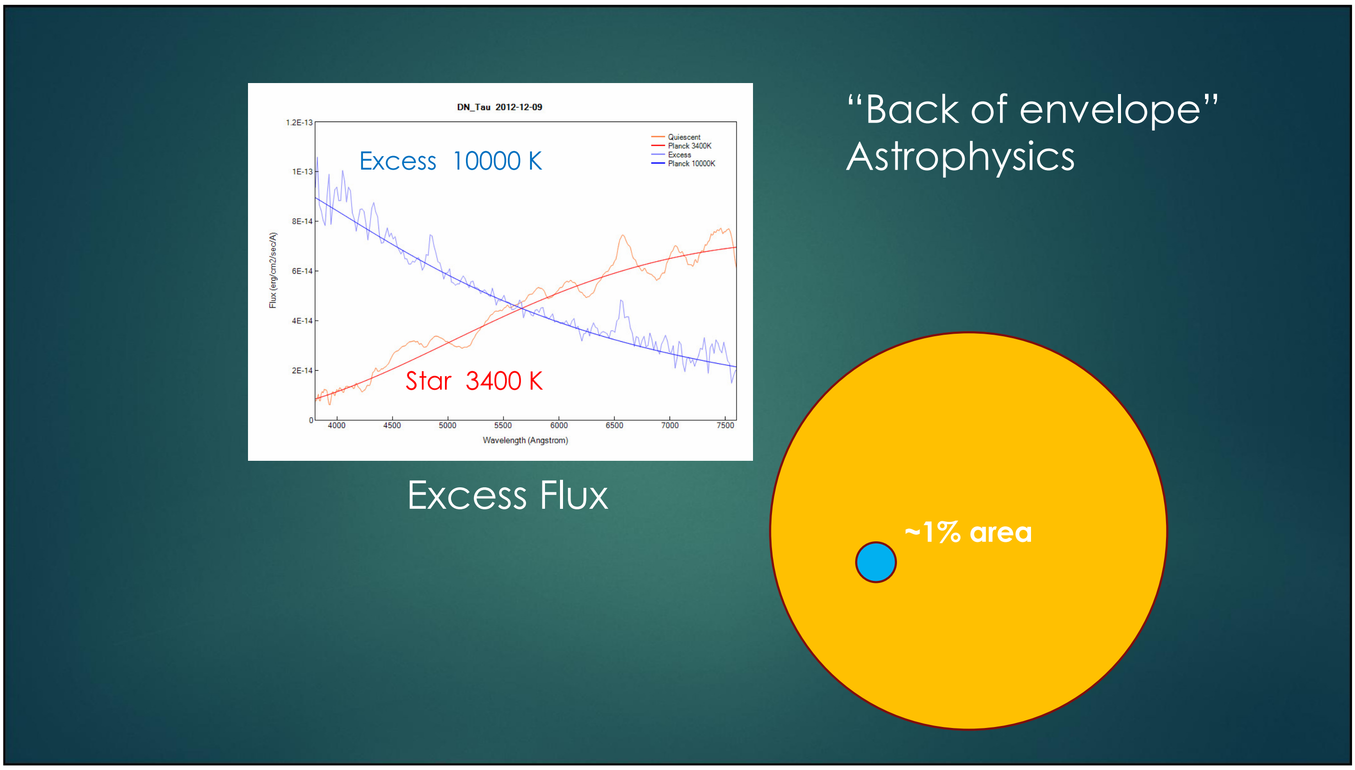
B mag
13.6 – 11.9 in 6 minutes



We can produce spectra from each 20 sec exposure and although they are rather noisy we can clearly see the nature of the brightening, predominantly to the blue end of the spectrum. We can also extract the B and V magnitudes as plot the light curve where we see that the star brightened by 1.7 magnitudes in B in just 6 minutes.

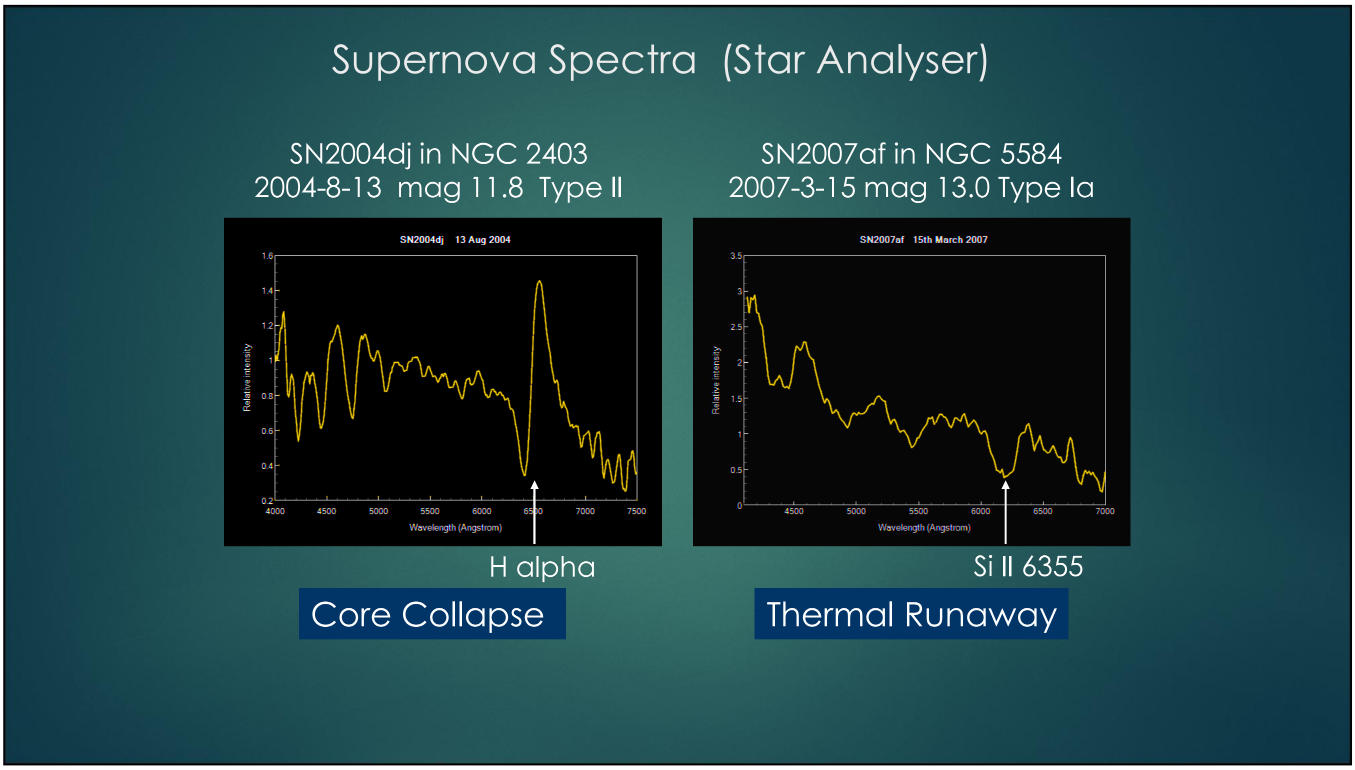


If we take the peak values and superimpose them on the AAVSO data covering the 18 month period of the campaign we can see how the event stands out dramatically, nothing like this being detected in the conventional data.

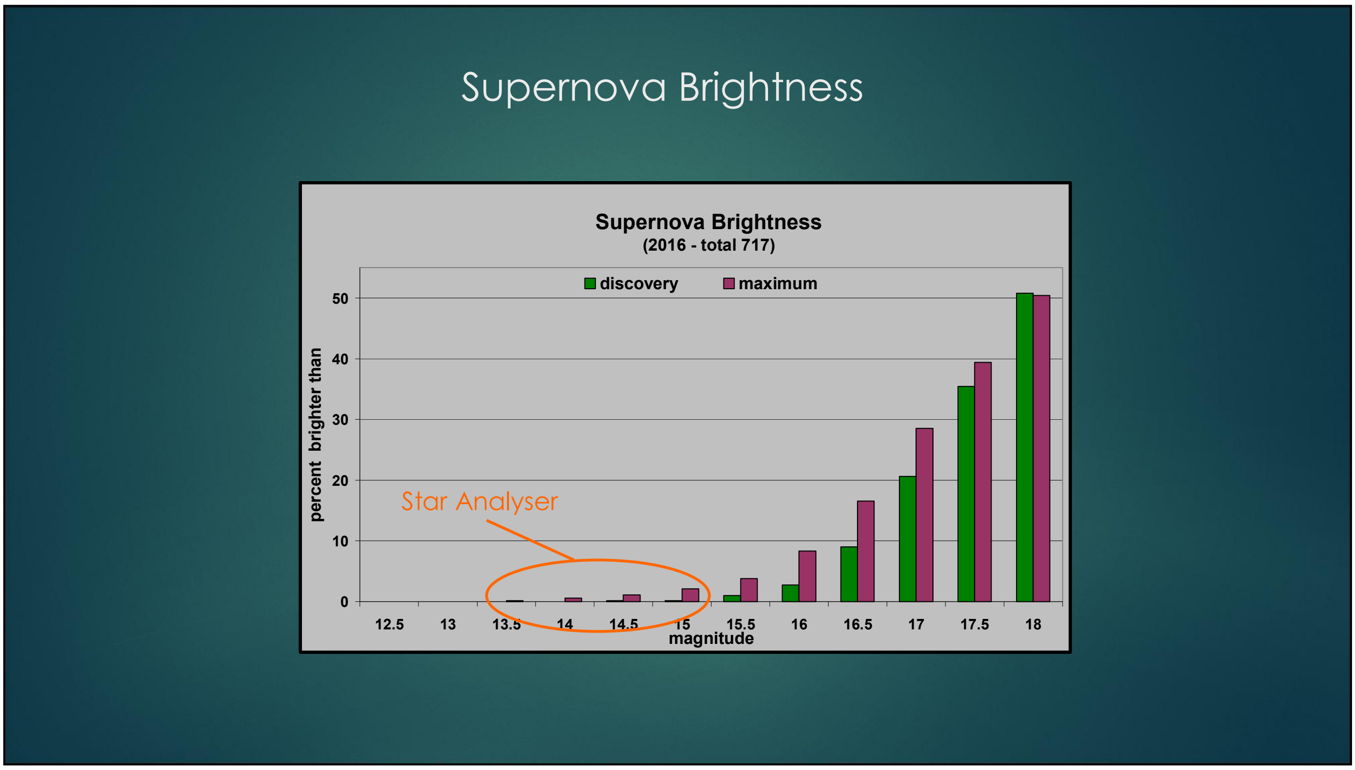


Since we have the complete spectra we can also do some fun back of envelope astrophysics. For example we can extract the spectrum of the excess flux, grab the spectrum at maximum and fit a black body curve to it to estimate the temperature which comes out at ~10000K. Similarly the star in quiescence is a cool M type star with a temperature of ~3400K with this information and the fluxes we can estimate the area of the source of the excess which turns out to be ~1% of the stellar disc.

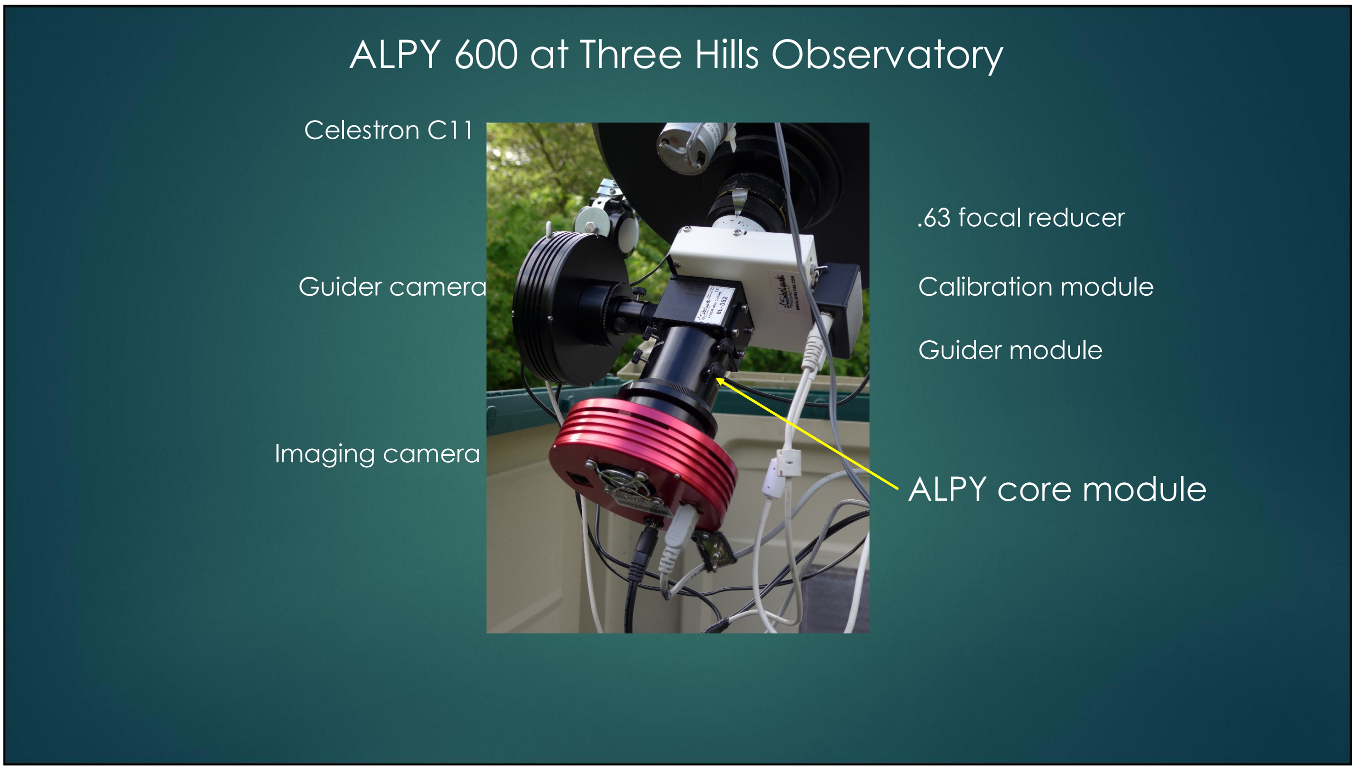
Confirming supernovae spectroscopically is an area that has traditionally been beyond the capability of amateurs



Although it is possible to classify supernovae even at the resolution of the Star Analyser as here, it is difficult to measure supernova candidates fainter than around mag 14-15 because of interference from the sky background.

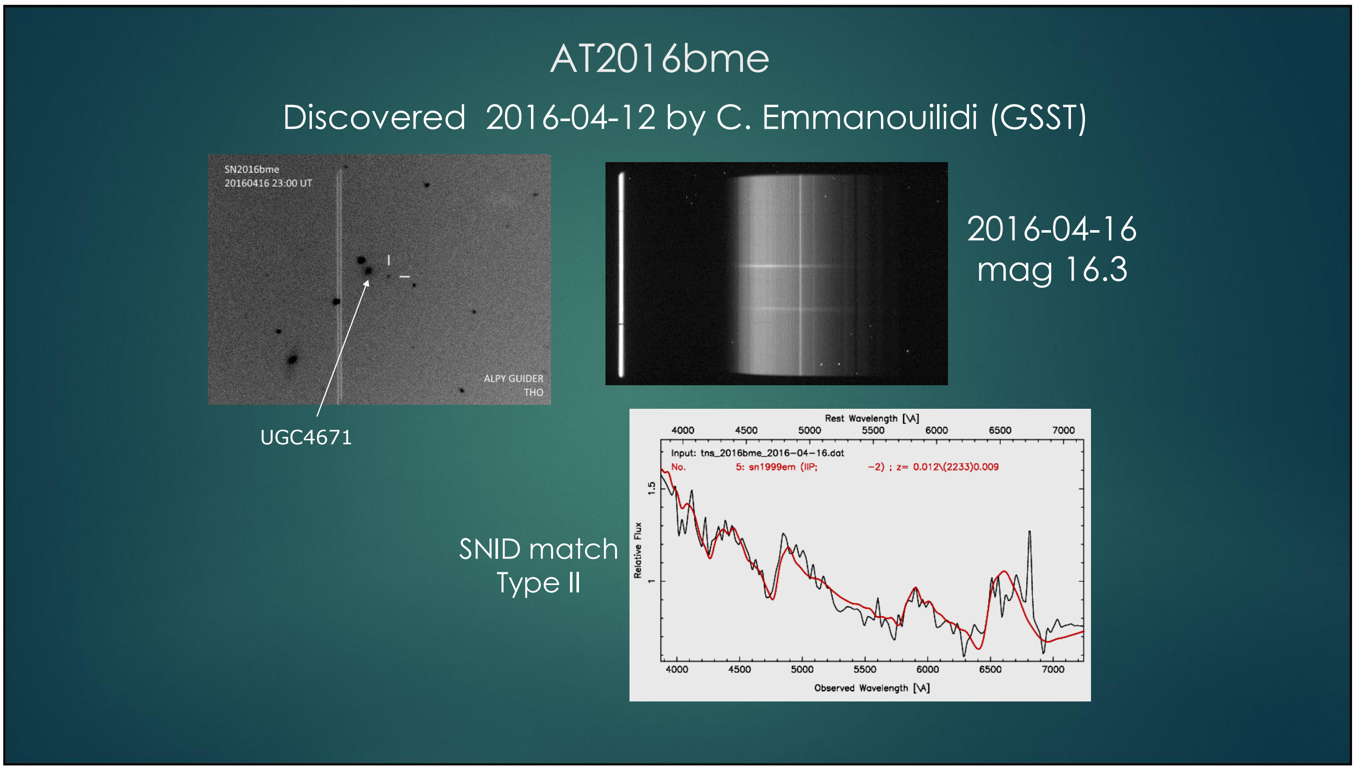


Unfortunately only a handful of supernvovae a year reach this level and most of these are discovered and confirmed when much fainter.

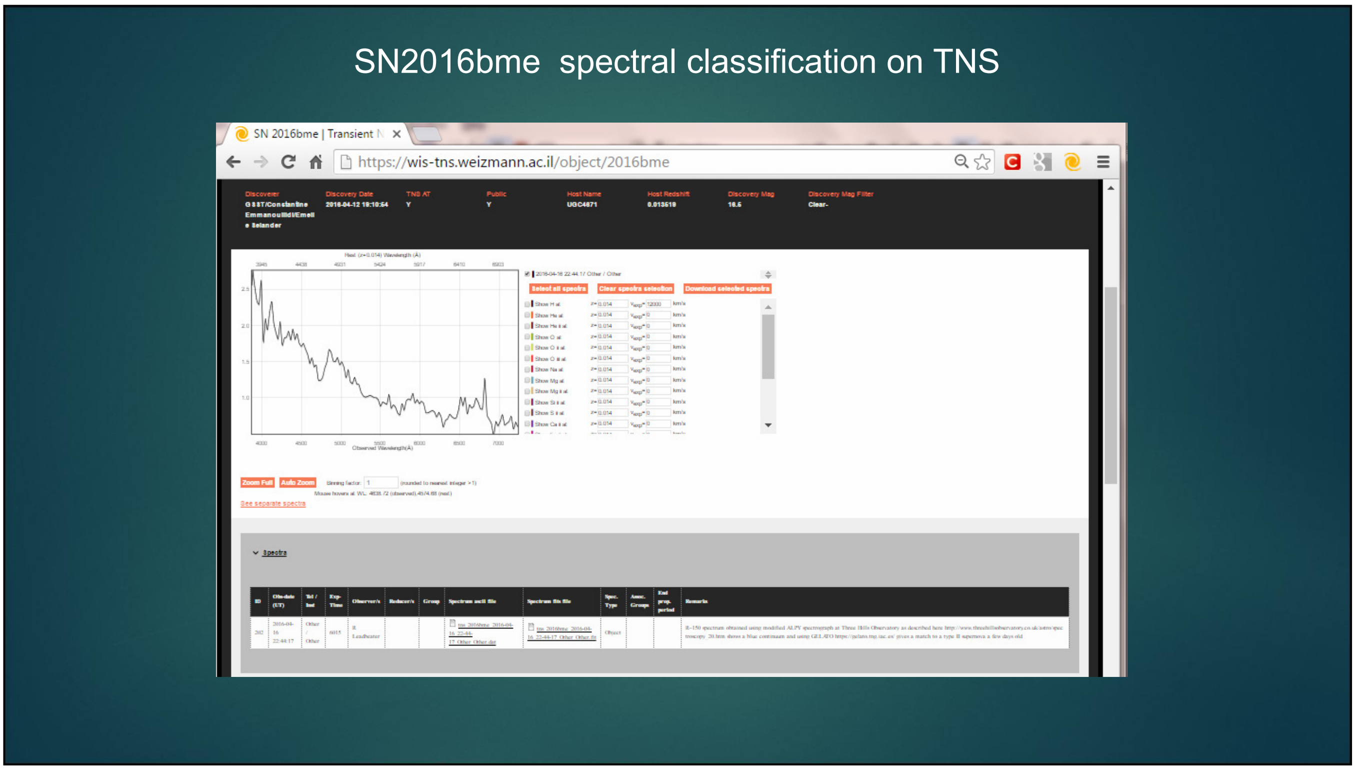


A low resolution slit spectrograph like the ALPY significantly reduces the sky background problem but in standard form disperses spectrum around 4x more than the Star Analyser to give a higher resolution and as a result is no more sensitive for this kind of work. What was needed was a slit spectrograph but with the low dispersion of the Star Analyer, so I decided to modify my ALPY

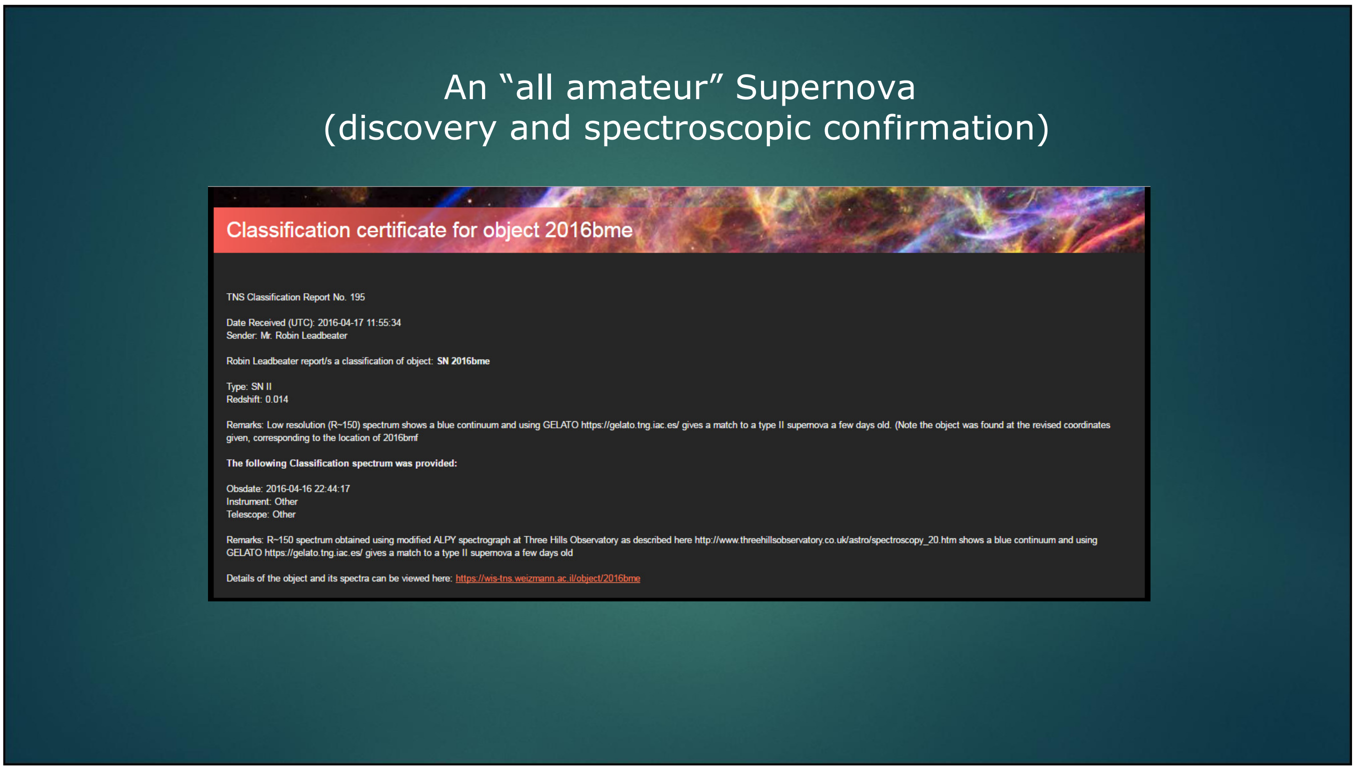
At the heart of the ALPY is a GRISM, a cylindrical wedge prism with a 600l/mm grating on one face. I changed this out for a 200l/mm version which resulted in an 8x brighter spectrum than the standard ALPY at resolution similar to the Star Analyser



This has proved very successful and is able to reach mag 16-17. I made my first confirmation and classification in April 2016 (sn2016bme at mag 16.3, also discovered by an amateur) which generated a classification certificate, as far as I know the first official confirmation of a supernova by an amateur and perhaps fitting that it was also an amateur discovery.



and submitted it to the IAU transient name server



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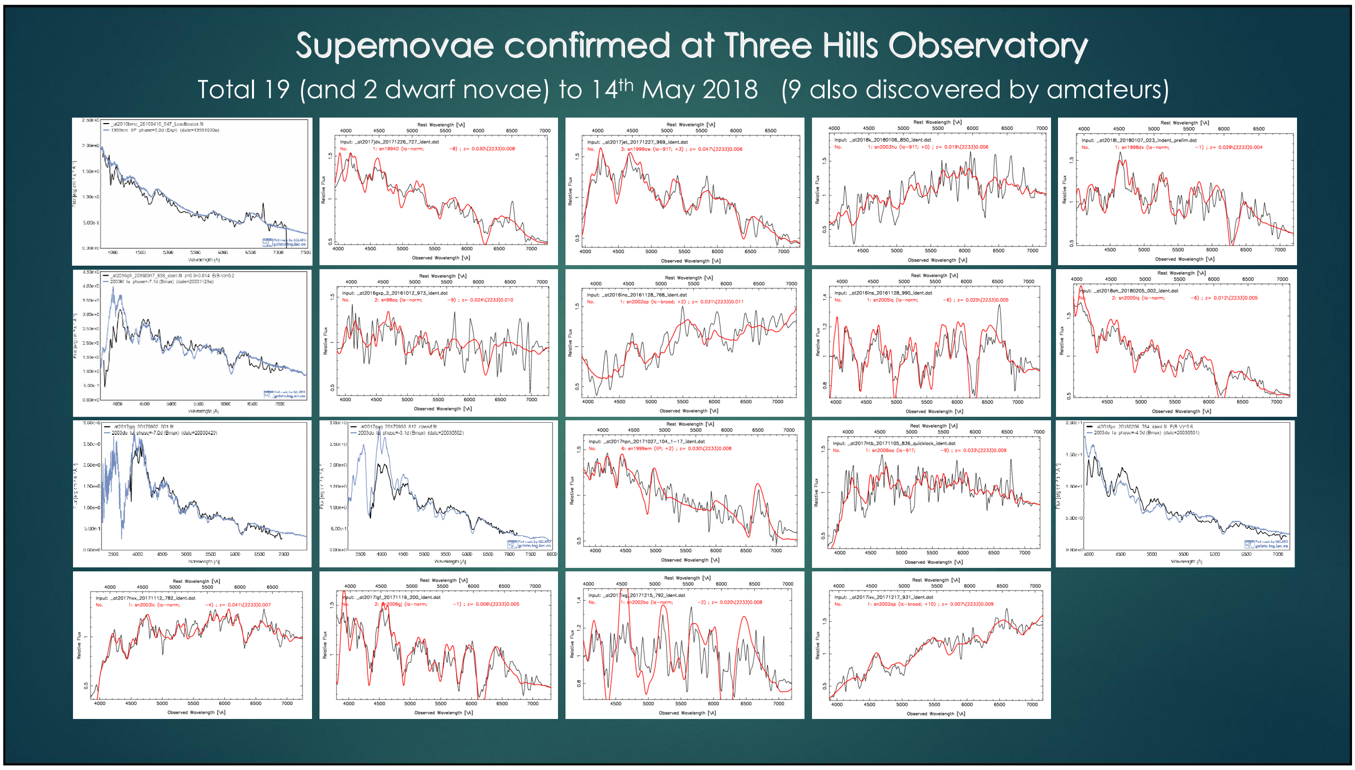
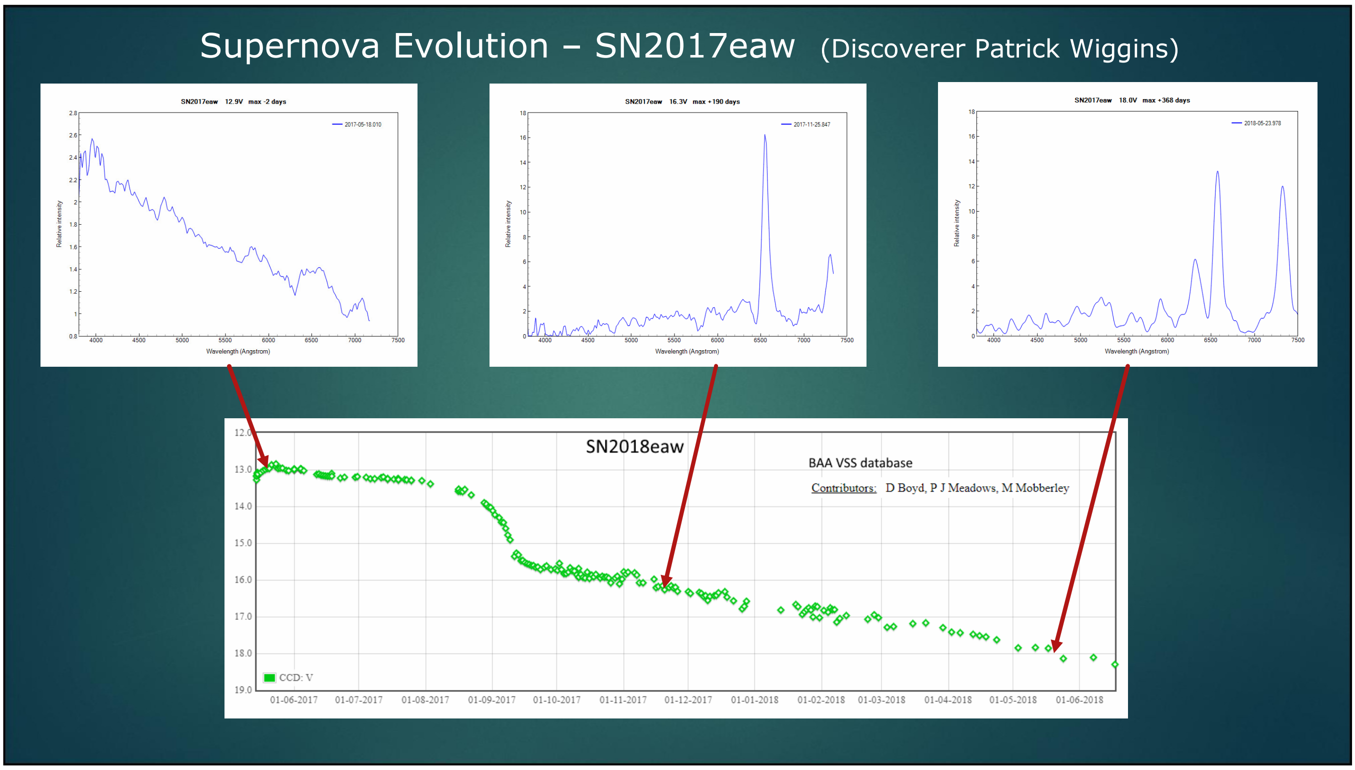


Since then I have run the setup on and off and to date the number of confirmed supernovae stands at 19 (plus 2 which turned out to be dwarf novae), 9 of which were also discovered by amateurs. The faintest being mag 18 which as far as I know is the faintest amateur spectrum to date



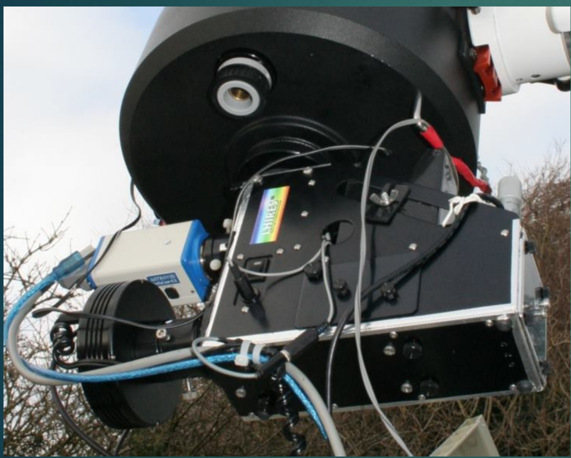
The ability to go significantly fainter also means that the evolution of bright supernovae can be followed further. Here for example are spectra of sn2017eaw (which was one of the brightest supernova of last year) near maximum at mag 12.8, at 6 months at 16.3 and at 1 year at mag 18.0

High Precision Radial Velocity measurements using a LHIRES III Spectrograph

And finally a quick tip for getting the highest wavelength precision out of the LHIRES III

Convento/BRITE campaign – Deneb

Link between mmag brightness, H alpha line and RV pulsations (~8km/s pp) ?



LHIRES III at Three Hills Observatory

Dispersion	~0.1A/pixel	(~5km/s/pixel)
Resolution	0.4A	(20km/s)
RV precision	0.1 pixel	(0.5km/s)

Flexure and thermal effects

Intrinsic stability	+-5km/s
With repeated calibration	+-2km/s

I wanted to use the LHIRES for a Pro-Am campaign on Deneb combining amateur spectroscopy with mmag brightness measurements from the BRITE satellites. The radial velocity measurement precision needed was of the order of 1km/s

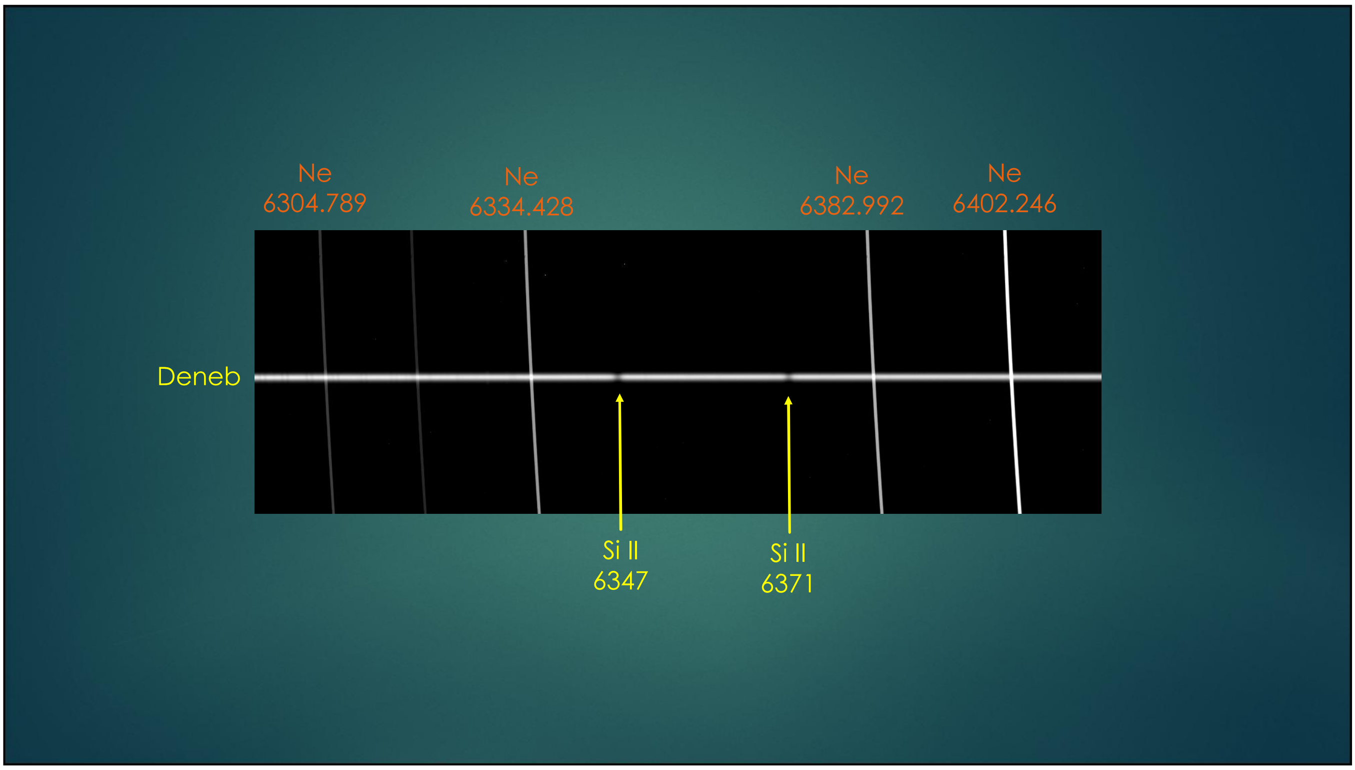
All telescope mounted spectographs are susceptible to thermal and flexural instability and my LHIRES III is particularly prone

Although in theory is should be capable of measuring to better than 1km/s, the intrinsic stability is only around 5km/s, which can be improved to around 2km/s with frequent calibration during a run.

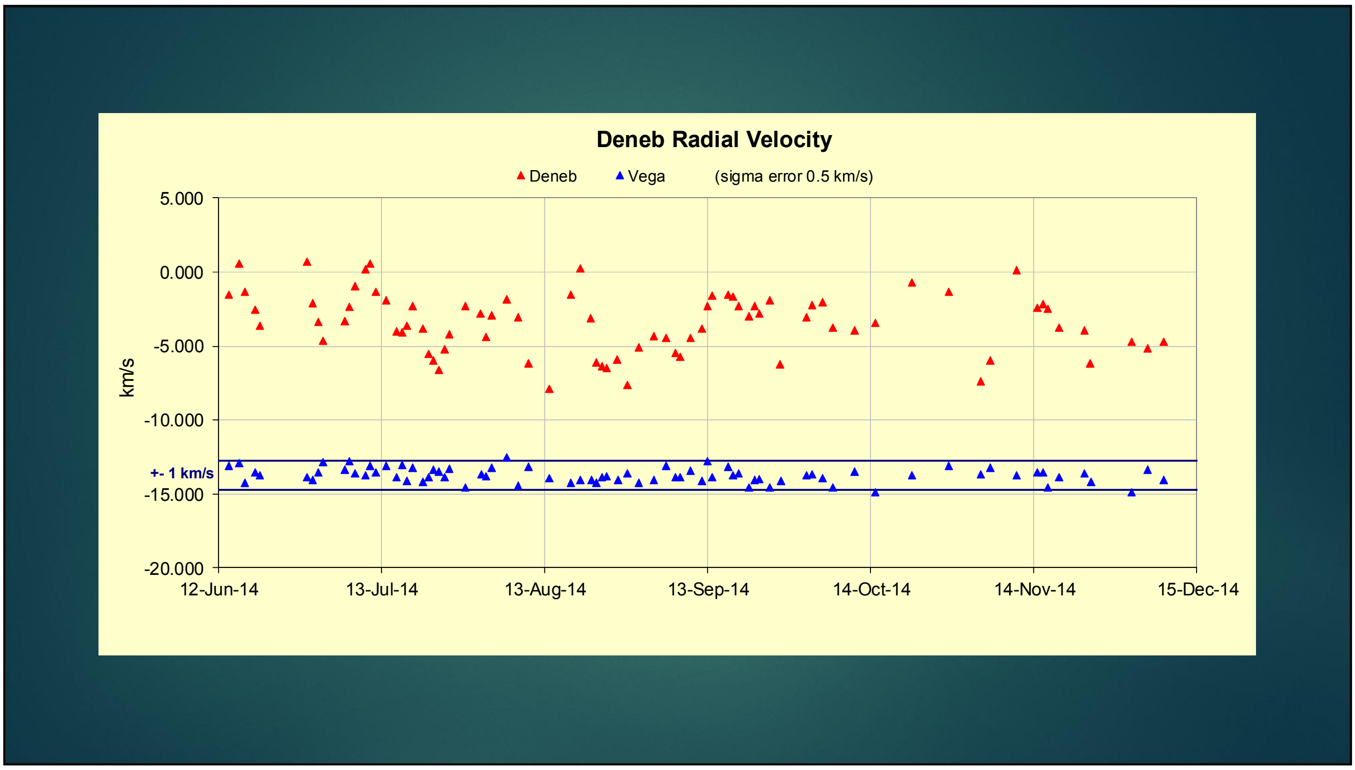
To try and improve on this I decided to try superimposing calibration lines directly on the star spectrum

“Filly Dot” decorative gas discharge lamp (Ne,Ar,Xe,Kr)

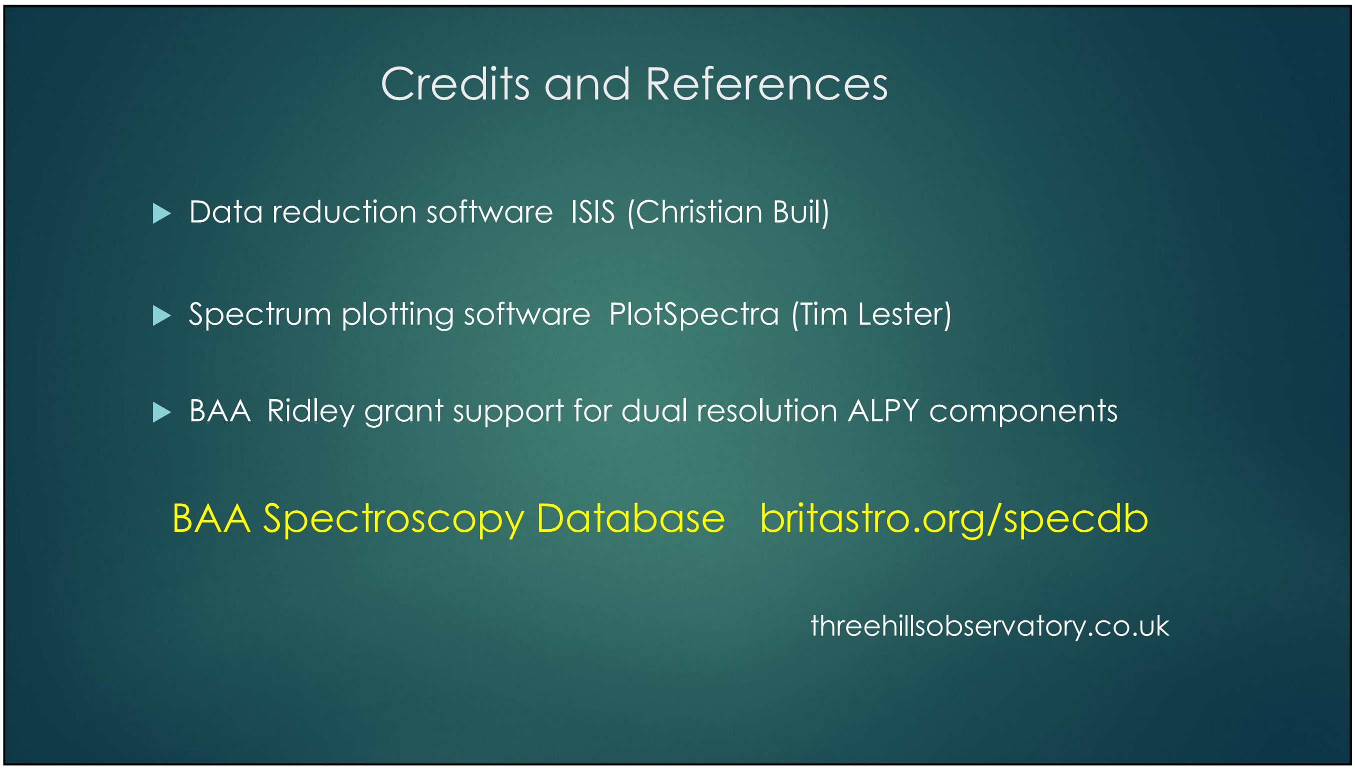
I used a decorative gas discharge lamp mounted in front of the telescope aperture. (This lamp is a bit of a legend in amateur spectroscopy circles. Found by Christian Buil in a home furnishing store its spectrum was found to contain dozens of lines across the entire visible spectrum from several noble gasses making it an ideal calibration source.)



This spectrum shows the Deneb spectrum with two Silicon lines I used for the RV measurements with the calibration lamp lines superimposed



Using this arrangement I was able to measure the RV to 0.5 km/s one sigma precision over a 6 month period as seen in the Vega reference measurements. Good enough to track the complex pattern of pulsations in Deneb.



Well I hope you have found these observations interesting and don't forget if you are taking spectra, to add them to the BAA database for long term security, even if you are also submitting them to ARAS for example.