Data Exercise Notes

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1 Photometry

1. **Do you understand what is changing?** – using *autocut, colour map, intensity map,* and *colour bar.*
2. **How can you determine which object is the nova?**

   Using multiple images. Nova are transients with their luminosities fading over time, typically few days/weeks. So, looking out for stars with luminosities fading over time would help us determine which object is a nova. $\alpha = 00:44:41.05, \delta = 40:08:36.00$
3. **Header contents, position and pixel information**

file	DATE-OBS	MJD	EXPTIME	AIRMASS	x-axis span
phot_00.fits	2016/07/16 01:54:04.626	57585.079220	120	1.7258910	1049–1061
phot_01.fits	2016/07/17 01:57:55.414	57586.081891	120	1.6665240	1049–1061
phot_02.fits	2016/07/18 01:43:20.318	57587.071763	120	1.7491860	1049–1061
phot_03.fits	2016/07/19 01:36:39.439	57588.067123	120	1.7721150	1050–1061
phot_04.fits	2016/07/22 02:34:57.627	57591.107611	120	1.3530670	1052–1058
phot_05.fits	2016/07/25 01:29:33.555	57594.062194	120	1.6443790	1053–1058
phot_06.fits	2016/07/27 01:35:03.477	57596.066012	120	1.5562500	1052–1058
phot_07.fits	2016/08/03 03:15:00.354	57603.135421	120	1.1115970	1053–1058
phot_08.fits	2016/08/09 01:19:45.090	57609.055383	120	1.3717510	1050–1060
phot_09.fits	2016/08/17 01:26:10.686	57617.059846	120	1.2355820	1053–1058
phot_10.fits	2016/08/19 02:09:48.268	57619.090142	120	1.1156090	1053–1058
phot_11.fits	2016/08/21 02:53:30.765	57621.120495	120	1.0482370	—
phot_12.fits	2016/08/27 01:30:12.240	57627.062642	120	1.1306350	1053–1057
phot_13.fits	2016/08/29 03:01:21.059	57629.125938	120	1.0244450	1054–1057
phot_14.fits	2016/09/06 02:28:01.479	57637.102795	120	1.0250930	1054–1057
phot_15.fits	2016/09/13 23:52:30.836	57644.994801	120	1.1904340	1054–1056
phot_16.fits	2016/09/24 02:27:20.058	57655.102315	300	1.0329910	1053–1056
phot_17.fits	2016/09/28 02:53:32.834	57659.120519	300	1.0706010	1054–1056

   GAIN = 1.62, Position = (1055,978) for all entries.

4. **Are the number of pixels containing light from the nova (i.e. the point spread function or PSF) the same in every image? What two effects could be changing this?**

   No. Change in auto-cut value and variations in brightness of background or nova can change the viewed psf.
5. **Why is it important to do this?** – enter *exposure time* and *gain* for each observation.

   Image of a faint object captured over long exposure time may be brighter than the image of a bright object captured over smaller exposure time. Similarly, high gain would require more photons per data unit. Therefore, for different values of gain too, our perception of bright and faint objects may vary from one image to another. Hence, it is important to account for exposure time and gain for each image.
6. **Why would it be undesirable to use an aperture that is either too small or too large?**

   A very small aperture would lead to loss of signal by disacrding useful signal. A large aperture would include a lot of noise. Hence in both cases, signal to noise ratio is decreased, although in different ways. An optimal aperture considers all the signal while discarding maximum possible noise. In aperture photometry, the outer annulus is used to account for calculate average noise value. This value is subtracted from the aperture signal to obtain true signal. If the aperture contains noise (very large aperture) or discards signal (very small aperture), the calculated value will account for smaller than true overall value of signal or signal to noise ratio.
7. **Signal to noise ratios for different apertures. How do you decide which aperture is optimal?**

radius	magnitude	mag error	signal	noise	SNR
6.0	-8.02378	0.00512	3656.2	1620.0	2.257
10.4	-8.13224	0.00738	3629.6	1790.2	2.0275
15.5	-8.15562	0.01047	3627.2	1829.1	1.983
26.5	-8.16615	0.01745	3626.2	1847.0	1.963

   Optimal is systematically decided using data count results instead of magnitude results. A rough estimate for better understanding can be performed using table above.

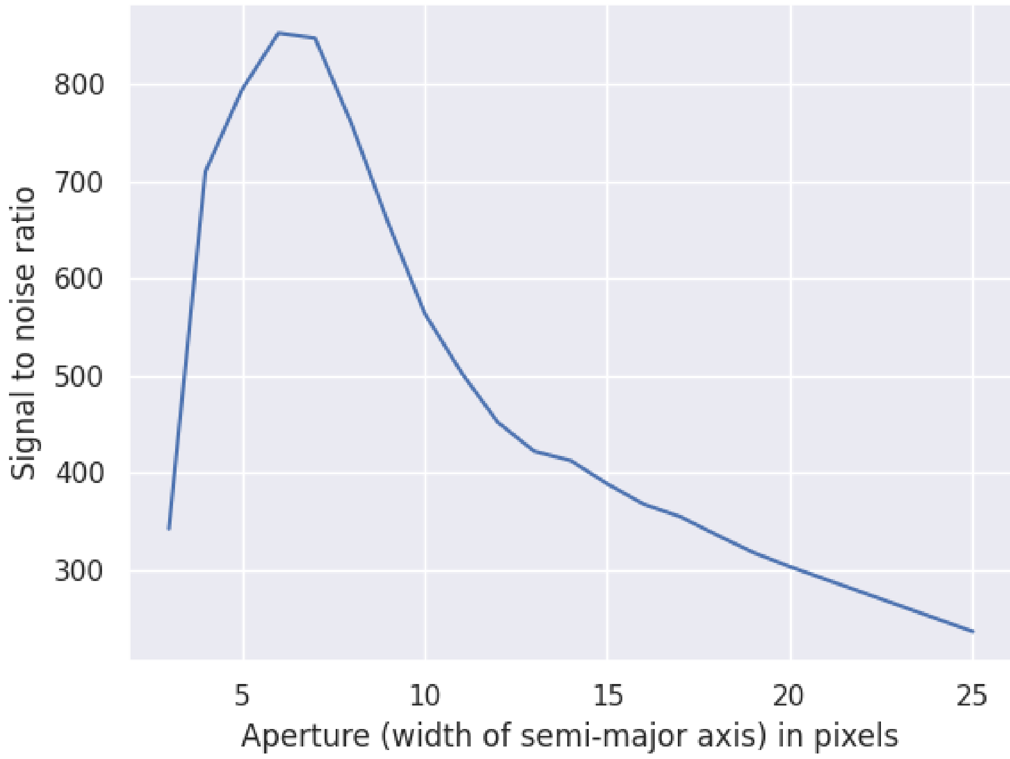
8. **Do the results you have obtained, by varying the aperture size, vary randomly as you might expect with measurement error?**

   No. Results vary in a well defined manner according to the reasons stated above. The errors are not random, and instead depend upon the radius of the aperture. Both small and large apertures are inefficient and an optimum aperture lies in between that range.

9. **determine the optimal aperture size.**

aperture (semi-major axis)	mean counts	error in counts	SNR
3.0	36.784	0.10739	342.527
4.0	26.835	0.037792	710.071
5.0	19.433	0.024469	794.189
6.0	14.398	0.016884	852.760
7.0	11.029	0.013013	847.537
8.0	8.6644	0.011412	759.236
9.0	6.9651	0.010593	657.519
10.0	5.7077	0.010112	564.448
11.0	4.7566	0.0094432	503.706
12.0	4.0395	0.0089313	452.286
13.0	3.4646	0.0082037	422.322
14.0	2.9852	0.0072329	412.725
15.0	2.6030	0.0066956	388.763
16.0	2.2916	0.0062298	367.845
17.0	2.0352	0.0057338	354.948
18.0	1.8190	0.0054112	336.155
19.0	1.6286	0.0051199	318.092
20.0	1.4728	0.0048525	303.514
25.0	0.94289	0.0039804	236.883

$r_a = 1.5$ and $r_b = 2.0$. SNR = [342.527,710.071,794.189,852.760,847.537,759.236, 657.519, 564.448, 503.706, 452.286, 422.322, 412.725, 388.763, 367.845, 354.948, 336.155, 318.092, 303.514]



10. **What would be the effect of changing the aperture size between measurements within the same image?**

    Would give inconsistent values of magnitudes for different objects, given that same ratio of magnitudes would not be considered for all cases.

11. **Optimal apertures for all images.** Given in table.

12. **Does the optimal aperture size vary between the images? If so, what causes this?**

    Optimal aperture size varies for different images depending upon atmospheric seeing (or the background noise), exposure time, object brightness, etc.

13. **Why does this approach work? What problems might be associated with this method?** – using secondary stars for photometry.

file	aperture
00	7.0
01	6.5
02	5.5
03	5.4
04	4.9
05	4.9
06	8.0
07	4.4
08	7.5
09	4.6
10	3.1
11	4.4
12	3.6
13	2.5
14	2.3
15	4.2
16	3.3
17	2.9

We need to consider only the stars which have been observed to remain static (i.e. not a variable star) over extremely long periods, so that its low photometric uncertainty can be considered reliable for calibration. If such a non-variable star lies in our field of view while observing the science object, the photometry of that object can be calibrated using the nearby secondary standard. Even if the atmospheric conditions are not very favourable, photometry can still be performed if we can safely assume that the extent of unfavourability of conditions is similar for both the objects, which is a reasonable assumption for nearby secondary standards. Secondly, widely separated secondary stars in the field of view can be used to estimate variability in atmospheric extinction across field of view. For faint events, exposure times are long and many of the primary standards appear saturated. Dimmer secondary stars therefore are more helpful in these cases.

14. **How can we determine which of the PS1 stars might be suitable to use?**

    Vicinity to the nova and comparable brightness. Vicinity would lead to correlating atmospheric extinction values, which would be roughly similar for all, and therefore, easily accounted for. Similar brightness or *spread* of stars would aid the use of same aperture for all standard stars and nova in the image. Also, every secondary star selected should be properly resolved in the image.

15. **Secondary stars**

    ID = [11,2,6,30,10]

16. **Photometry of nova and stars**

image	nova	star 1 (1079,741)	star 2 (985,665)	star 3 (740,1205)	star 4 (392,1111)	star 5 (1275,1305)
00	-8.06917,0.00554	-8.79153,0.00311	-8.19322,0.00501	-8.43167,0.00413	-6.81993,0.01639	-9.23457,0.00222
01	-8.11788,0.00477	-9.08614,0.00228	-8.49188,0.00355	-8.72659,0.00296	-7.11721,0.01104	-9.52156,0.00168
02	-7.78778,0.00655	-8.94943,0.00261	-8.34755,0.00414	-8.58463,0.00344	-6.95411,0.01345	-9.37925,0.00192
03	-7.7492,0.00711	-9.06624,0.00248	-8.47205,0.00392	-8.70987,0.00324	-7.09267,0.1257	-9.50961,0.0018
04	-7.01378,0.01582	-8.67234,0.00379	-8.0789,0.00621	-8.32961,0.00501	-6.72892,0.02037	-9.10936,0.00268
05	-6.7958,0.01559	-8.76096,0.00302	-8.16958,0.00477	-8.41133,0.00394	-6.80057,0.01552	-9.20142,0.00218
06	-6.22505,0.02621	-8.4437,0.0039	-7.86253,0.00628	-8.09466,0.00516	-6.45922,0.02131	-8.86995,0.00281
07	-6.00348,0.00998	-8.78424,0.00191	-8.19902,0.00259	-8.44785,0.00226	-6.83937,0.00566	-9.23819,0.00152
08	-5.19026,0.03097	-8.44701,0.00266	-7.86816,0.00381	-8.10531,0.00328	-6.48753,0.01046	-8.89045,0.00205
09	-5.31643,0.04588	-9.07027,0.0021	-8.47533,0.00321	-8.72066,0.00267	-7.124,0.00931	-9.51246,0.00158
10	-4.58417,0.07163	-8.58765,0.00271	-8.00687,0.00403	-8.26852,0.00333	-6.63258,0.01166	-9.03455,0.00204
11	0.351068,0.28434	-7.62915,0.00734	-7.06545,0.01171	-7.29312,0.00969	-5.63848,0.04075	-8.08902,0.00511
12	-4.08713,0.03827	-8.71743,0.00193	-8.13829,0.00256	-8.38544,0.00226	-6.7756,0.00543	-9.16339,0.00156
13	-3.75681,0.03747	-8.40337,0.00228	-7.81135,0.00305	-8.07205,0.00267	-6.45187,0.00618	-8.85114,0.00185
14	-3.27988,0.05617	-8.46164,0.00225	-7.89683,0.00291	-8.15279,0.00256	-6.5255,0.00592	-8.93343,0.00178
15	-3.37124,0.19267	-8.81852,0.00219	-8.2141,0.00324	-8.4636,0.00275	-6.86197,0.00885	-9.25069,0.00169
16	-2.69049,0.10301	-8.5127,0.00143	-7.91725,0.00196	-8.17252,0.0017	-6.53396,0.00448	-8.95882,0.00114
17	-1.99732,0.1288	-8.08944,0.0018	-7.49395,0.00242	-7.76262,0.00208	-6.09845,0.00533	-8.51768,0.00149

17. **Catalog entries SDSS conversions.**

ID	r	r error	g	g error	r'
2 (1079,741)	16.1868	0.0044	16.8984	0.0052	16.194
6 (985,665)	16.7696	0.0065	17.5087	0.0059	16.777
10 (740,1205)	16.5210	0.0066	16.9415	0.0034	16.525
30 (392,1111)	18.1143	0.0062	18.5278	0.0049	18.118
11 (1275,1305)	15.7283	0.0020	16.0337	0.0042	15.731

18. **Airmass and Z values for each star.**

airmass	star 1	star 2	star 3	star 4	star 5
1.7258910	24.98553,0.00711	24.97022,0.00901	24.95667,0.00813	24.93793,0.02039	15.99236, 0.02636
1.6665240	25.28014,0.00628	25.26888,0.00755	25.25159,0.00696	25.23521,0.01504	15.98576, 0.02342
1.7491860	25.14343,0.00661	25.12455,0.00814	25.10963,0.00744	25.07211,0.01745	16.25722, 0.02611
1.7721150	25.26024,0.00648	25.24905,0.00792	25.23487,0.00724	25.21067,0.12970	16.27953, 0.06946
1.3530670	24.86634,0.00779	24.85590,0.01021	24.85461,0.00901	24.84692,0.02437	17.31224, 0.03807
1.6443790	24.95496,0.00702	24.94658,0.00877	24.93633,0.00794	24.91857,0.01952	17.32355, 0.03586
1.5562500	24.63770,0.00790	24.63953,0.01028	24.61966,0.00916	24.57722,0.02531	17.95682, 0.04862
1.1115970	24.97824,0.00591	24.97602,0.00659	24.97285,0.00626	24.95737,0.00966	18.49384, 0.02681
1.3717510	24.64101,0.00666	24.64516,0.00781	24.63031,0.00728	24.60553,0.01446	19.12250, 0.04948
1.2355820	25.26427,0.00610	25.25233,0.00721	25.24566,0.00667	25.24200,0.01331	19.09294, 0.06365
1.1156090	24.78165,0.00671	24.78387,0.00803	24.79352,0.00733	24.75058,0.01566	19.91031, 0.09037
1.0482370	23.82315,0.01134	23.84245,0.01571	23.81812,0.01369	23.75648,0.04475	24.89334, 0.31344
1.1306350	24.91143,0.00593	24.91529,0.00656	24.91044,0.00626	24.89360,0.00943	20.39669, 0.05496
1.0244450	24.59737,0.00628	24.58835,0.00705	24.59705,0.00667	24.56987,0.01018	20.80234, 0.05463
1.0250930	24.65564,0.00625	24.67383,0.00691	24.67779,0.00656	24.64350,0.00992	21.27881, 0.07318
1.1904340	25.01252,0.00619	24.99110,0.00724	24.98860,0.00675	24.97997,0.01285	21.07015, 0.21031
1.0329910	24.70670,0.00543	24.69425,0.00596	24.69752,0.00570	24.65196,0.00848	21.86260, 0.11905
1.0706010	24.28344,0.00580	24.27095,0.00642	24.28762,0.00608	24.21645,0.00933	22.52909, 0.14532

19. **Z at airmass 1 for secndary stars.**

star	Z at airmass 1	slope
1	24.58518	0.72978
2	24.58542	0.71267
3	24.58767	0.68760
4	24.55271	0.70689
5	24.57150	0.71021

20. **Photometric measurements of nova using different standard stars.**

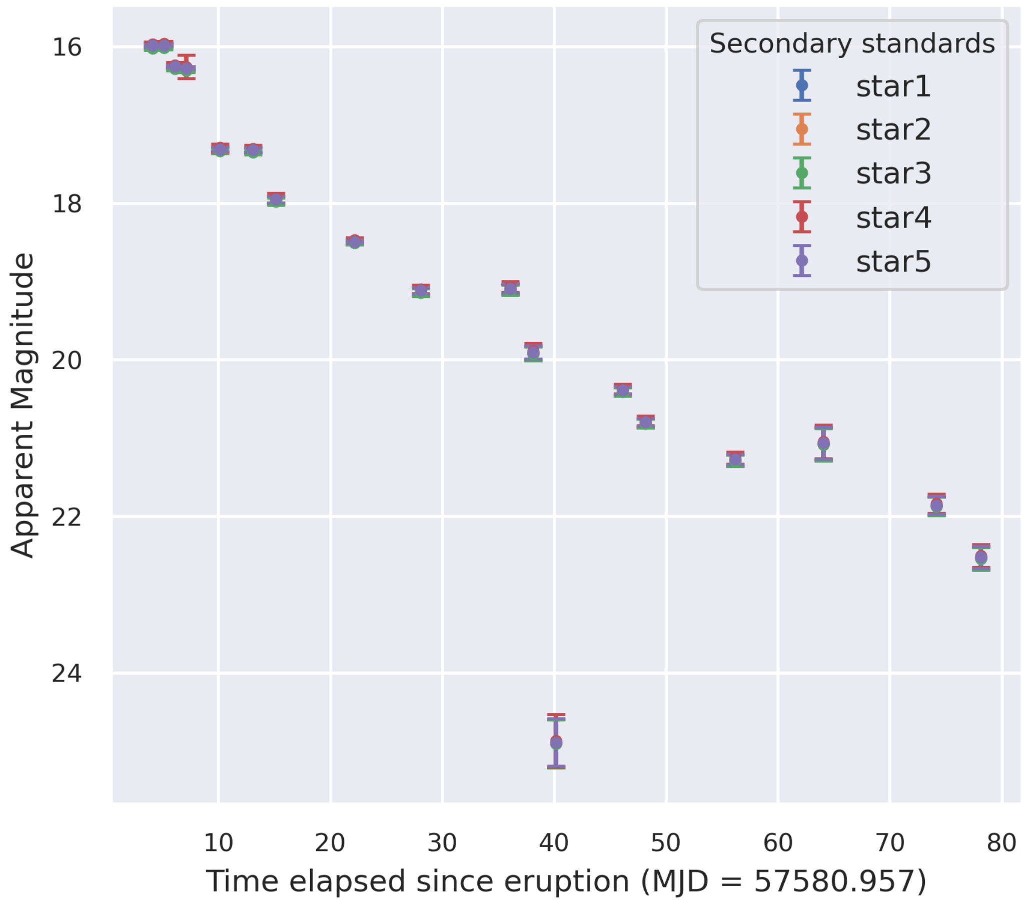
image	star 1	star 2	star 3	star 4	star 5	mean
00	15.98627, 0.02225	15.99893, 0.02695	16.01938, 0.02367	15.97041, 0.03703	15.98679, 0.01796	15.99236, 0.12786
01	15.98088, 0.02065	15.99253, 0.02472	16.01149, 0.02173	15.96367, 0.03091	15.98025, 0.01665	15.98576, 0.11466
02	16.25066, 0.02276	16.26372, 0.02709	16.28475, 0.02399	16.23534, 0.03510	16.25164, 0.01867	16.25722, 0.12761
03	16.27250, 0.02319	16.28596, 0.02743	16.30756, 0.02435	16.25771, 0.14791	16.27393, 0.01911	16.27953, 0.24199
04	17.31374, 0.03321	17.32002, 0.03843	17.33112, 0.03483	17.28935, 0.05129	17.30697, 0.02870	17.31224, 0.18646
05	17.31912, 0.03221	17.33039, 0.03676	17.34879, 0.03353	17.30140, 0.04621	17.31805, 0.02797	17.32355, 0.17668
06	17.95419, 0.04371	17.96394, 0.04889	17.98014, 0.04537	17.93445, 0.06262	17.95139, 0.03922	17.95682, 0.23981
07	18.50026, 0.02549	18.50240, 0.02897	18.50745, 0.02624	18.47034, 0.03074	18.48876, 0.02170	18.49384, 0.13314
08	19.12362, 0.04723	19.13022, 0.05118	19.14179, 0.04825	19.09966, 0.05653	19.11722, 0.04322	19.12250, 0.24641
09	19.09683, 0.06158	19.10109, 0.06549	19.10925, 0.06255	19.06975, 0.07029	19.08776, 0.05766	19.09294, 0.31757
10	19.91664, 0.08794	19.91885, 0.09206	19.92400, 0.08896	19.88682, 0.09839	19.90522, 0.08387	19.91031, 0.45122
11	24.90104, 0.30528	24.90211, 0.31245	24.90557, 0.30803	24.86968, 0.34019	24.88831, 0.29965	24.89334, 1.56560
12	20.40271, 0.05380	20.40519, 0.05723	20.41071, 0.05453	20.37323, 0.05880	20.39159, 0.05003	20.39669, 0.27439
13	20.81053, 0.05335	20.81118, 0.05692	20.81405, 0.05414	20.77862, 0.05875	20.79733, 0.04952	20.80234, 0.27268
14	21.28699, 0.07202	21.28765, 0.07548	21.29053, 0.07273	21.25509, 0.07719	21.27380, 0.06815	21.27881, 0.36557
15	21.07496, 0.20846	21.07846, 0.21231	21.08549, 0.20942	21.04685, 0.21662	21.06501, 0.20456	21.07015, 1.05137
16	21.87061, 0.11804	21.87141, 0.12137	21.87449, 0.11871	21.83890, 0.12259	21.85758, 0.11435	21.86260, 0.59506
17	22.53634, 0.14420	22.53778, 0.14762	22.54180, 0.14488	22.50548, 0.14923	22.52404, 0.14049	22.52909, 0.72642

21. **How do we calculate the apparent magnitudes using secondary standards and a calibrated catalogue?**

22. **How can we test whether our choice of secondary standard stars were indeed suitable?**

23. **Using the exact time of each observation and the apparent magnitude measurements of the nova, plot a light-curve the nova.**

24. **By reference to Strope, Schaefer and Henden (2010) attempt to classify the morphological type of the light curve, giving clear reasons for your classification.**
The shape appears to be that of a smooth light curve with no oscillations, flat top, cusp or any signs of dust dip within the ~ 80 days period of observation. Light curve can be represented by a power-law. The extreme variation in photometry around day 11 is probably due to poor photometric conditions and should not be confused for a dust dip because of 2 reasons



- the variation in magnitude is small as compared to textbook examples of dust-dip light curves and such a dip is not retained on further observations and cannot be such short lived.

25. **Utilising material in the course notes or otherwise, determine the following m_0 (maximum apparent magnitude), t_0 (maximum light), t_2, t_3, and m_{15} (the apparent magnitude 15 days post-maximum).**
Assuming that the peak occurred on approximately the same time as our first observation (which is roughly the brightest observation), we get the following approximate values. $m_0 \approx 16$ at $t_0 \approx 4.122$ days post-eruption. Therefore, $t_2 = 10.986$ days $t_3 = 34.30$ days and $m_{15} = 18.25$.

26. **Using this information and the maximum magnitude–rate of decline relationship, determine an estimate of the distance to the system.**
Using t_2 :

$$M_r = -8.663 \pm 0.773$$

Using t_3 :

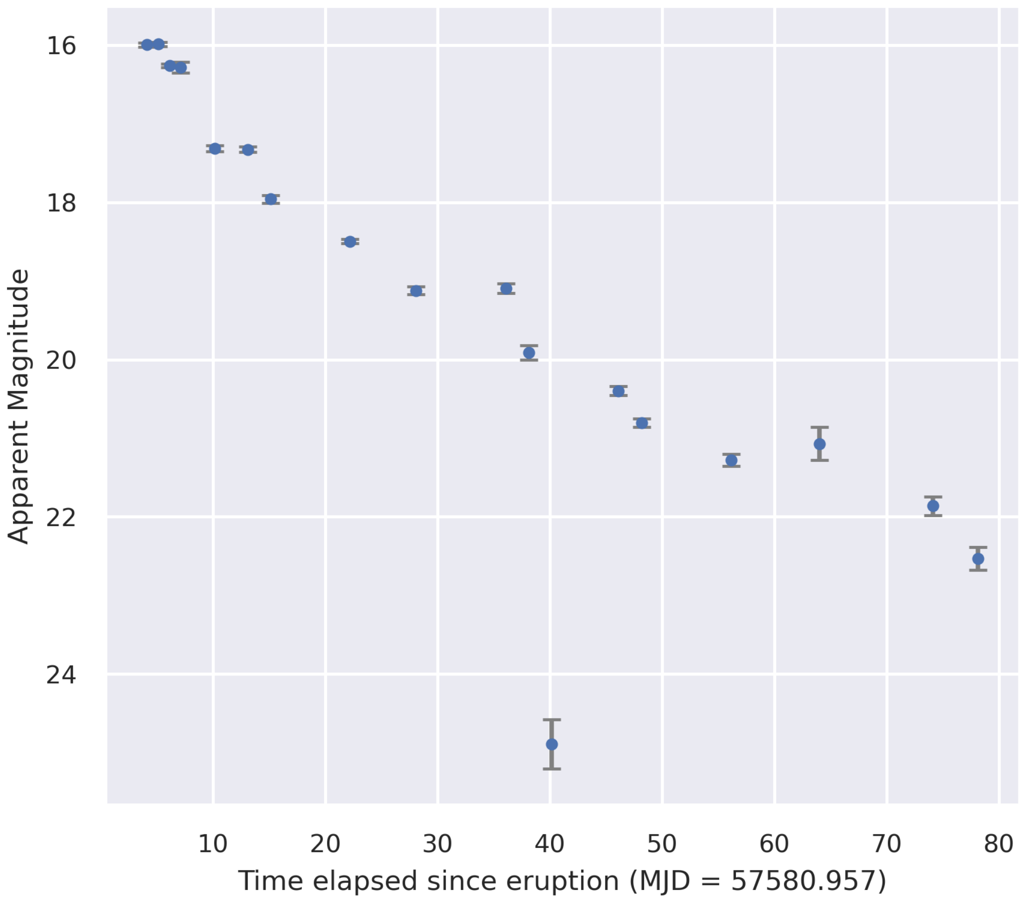
$$M_r = -8.090 \pm 1.098$$

From t_2 relation, $d = 857.43^{+366.62}_{-256.81}$ kpc
From t_3 relation, $d = 657.66^{+432.78}_{-260.83}$ kpc

27. **Estimate the distance using the t_{15} relation.**

$$M_{15,r} = -6.36 \pm 0.29$$

From t_{15} relation, $d = 835.60^{+119.39}_{-104.46}$ kpc


16
18
20
22
24
10
20
30
40
50
60
70
80
Apparent Magnitude
Time elapsed since eruption (MJD = 57580.957)

2 Spectroscopy

1. **Do you understand what these units (particularly those for the y-axis) are telling you?**
The spectrum obtained is a plot of power per unit area, per unit wavelength (flux density) as a function of wavelength, which essentially tells us the distribution of energy as a function of wavelength.

2. **Do you know what an 'erg' is?**
An *erg* is a unit of energy. Numerically, $1\text{erg} = 10^{-7}\text{Joules}$.

3. **Can you identify all five components?**
Yes. the continuum emission from the nova, emission lines formed within the nova ejecta, absorption lines from the interstellar medium, cosmic rays, and statistical noise.

4. **Do you understand how they each arise?**
Continuum emission from thermal radiations emitted over a large wavelength range by the inner dense material.
Emission lines from radiation emitted by surrounding ejecta which absorbs wavelengths from continuum and emits at specific wavelengths.
Absortion lines from radiation absorbed by the column of ISM in our line of sight of nova.
Cosmic rays of galactic, extra-galactic and solar origins.
Statistical noise inherent to measurements from instruments. Also called shot noise, it doesn't have any fixed pattern.

5. **The emission lines in these spectra are all 'recombination lines'. Do you know how such emission lines and the interstellar absorption lines form?**
Emission recombination lines form when an ion captures a free electron. The electron is captured at higher energy levels of the ion and then *cascades* down to lower energy levels, thereby emitting at multiple wavelengths.
ISM absorption lines are formed due to absorption of specific wavelength by cold gas of extremely low density. Dust containing metals also absorbs certain wavelengths depending upon the metals contained in the grains.

6. **However, you should notice that the cosmic rays contained within each spectrum are in different places, do you understand why this is?**
Two components which are random for each exposure are the cosmic ray hits and statistical noises.

7. **Why might multiple exposures be advantageous over a single observation?**
This prevents saturation. Leads to fewer cosmic ray hits and noise due to transient moving objects in the sky (asteroids, satellites, etc.). Multiple exposures can be used to remove random defects.

8. **Are there any disadvantages associated with multiple exposures?**
Slight increase in readout noise.

9. **Do you understand how such an approach can lead to the removal of most (if not all) cosmic rays from a set of images/spectra?**
Median of (at least) three values would remove cosmic ray hits given that they are at different locations for each exposure. This is unlike statistical noise is present in each exposure at every wavelength.

10. **How do each the five components of the spectra (as determined in the previous section) change with time?**
Continuum emission - reduced in strength over time. More quickly in the earlier spectra.
Emission lines - reduced in strength over time. More quickly in the earlier spectra. Some weaker emissions fade completely over time.
ISM absorption is stronger when continuum emission is stronger. With passing time absorption fades.
Cosmic Rays - Remain constant, but their occurence has been removed from spectra upon taking median for each epoch.
Statistical noise increases very slightly as we go to later spectra. SNR value reduces with time.

11. **What effect has the stacking process had upon these spectra, has it been completely successful?**
Stacking removed cosmic ray hits almost entirely. Statistical noise, however, has not seen improvement. All other components have been preserved although extremely small signals may now seem lost in the statistical noise.

12. **Can the spectra be displayed in a more suitable fashion?**
Yes, once it's known that the strength of continuum reduced over time, it can be removed for comparing evolutions of line emissions.

13. **Using Table 3, identify each line and determine the spectroscopic class of this particular nova.** The lines observed are H I (H δ, H γ, H β, H α), Fe II (42,48,49), O I (1,21,55) and possibly Si II (4). The nova is of Fe II spectroscopic class.

14. **Can you devise a test, using the continuum fitting function, to ascertain whether you have successfully subtracted the continuum?**
Once the continuum has been fit, try fitting it once again. This time the new fitting curve should be a horizontal line corresponding to zero flux density. This would imply that the continuum has been fit.

15. **Continuum flux, line flux, equivalent width and E(B–V)**

central wavelength	continuum flux	line flux	EW	log[E(B–V)]	E(B–V)
5890.009 ± 0.061	$2.400 \times 10^{-16} \pm 1.5068 \times 10^{-17}$	$-1.345 \times 10^{-16} \pm 1.143 \times 10^{-16}$	0.560	-0.700 ± 0.15	0.199 ± 0.069
5895.935 ± 0.175	$2.402 \times 10^{-16} \pm 1.5068 \times 10^{-17}$	$-9.309 \times 10^{-17} \pm 1.263 \times 10^{-16}$	0.388	-0.802 ± 0.17	0.158 ± 0.062

Average value of E(B–V) $= 0.1785 \pm 0.093$.

16. **Do you understand the differences and rationale behind these three line models?** – Gaussian, Lorentzian, and Voight

17. **Measure the flux and FWHM of all the Balmer (H I) lines, plus at least one line from another species.**

Spectrum			**flux**		
	O I (1)	$H\alpha$	$H\beta$	$H\gamma$	$H\delta$
0	$1.968 \pm 0.019 \times 10^{-13}$	$4.959 \pm 0.026 \times 10^{-13}$	$7.585 \pm 0.074 \times 10^{-14}$	$3.180 \pm 0.043 \times 10^{-14}$	$2.087 \pm 0.032 \times 10^{-14}$
1	$2.985 \pm 0.030 \times 10^{-14}$	$2.755 \pm 0.013 \times 10^{-13}$	$4.081 \pm 0.060 \times 10^{-14}$	$1.889 \pm 0.045 \times 10^{-14}$	$1.501 \pm 0.045 \times 10^{-14}$
2	$1.558 \pm 0.019 \times 10^{-14}$	$1.704 \pm 0.009 \times 10^{-13}$	$2.492 \pm 0.043 \times 10^{-14}$	$1.090 \pm 0.024 \times 10^{-14}$	$8.932 \pm 0.290 \times 10^{-15}$
3	$1.126 \pm 0.016 \times 10^{-14}$	$1.271 \pm 0.007 \times 10^{-13}$	$1.855 \pm 0.037 \times 10^{-14}$	$8.255 \pm 0.203 \times 10^{-15}$	$6.127 \pm 0.205 \times 10^{-15}$
4	$7.303 \pm 0.351 \times 10^{-15}$	$8.415 \pm 0.066 \times 10^{-14}$	$1.195 \pm 0.031 \times 10^{-14}$	$5.503 \pm 0.388 \times 10^{-15}$	$2.740 \pm 0.407 \times 10^{-15}$
5	$6.702 \pm 0.411 \times 10^{-15}$	$7.874 \pm 0.057 \times 10^{-14}$	$1.082 \pm 0.029 \times 10^{-14}$	$5.517 \pm 0.427 \times 10^{-15}$	$2.394 \pm 0.817 \times 10^{-15}$
6	$5.837 \pm 0.534 \times 10^{-15}$	$7.238 \pm 0.054 \times 10^{-14}$	$1.002 \pm 0.027 \times 10^{-14}$	$3.805 \pm 0.464 \times 10^{-15}$	$2.256 \pm 4.815 \times 10^{-15}$
7	$5.881 \pm 1.159 \times 10^{-15}$	$7.259 \pm 0.061 \times 10^{-14}$	$1.012 \pm 0.032 \times 10^{-14}$	$4.478 \pm 0.297 \times 10^{-15}$	$5.712 \pm 6.099 \times 10^{-15}$
8	$6.599 \pm 1.156 \times 10^{-15}$	$7.073 \pm 0.061 \times 10^{-14}$	$9.503 \pm 0.313 \times 10^{-15}$	$5.096 \pm 0.630 \times 10^{-15}$	$2.575 \pm 1.085 \times 10^{-15}$
9	$5.217 \pm 1.526 \times 10^{-15}$	$6.777 \pm 0.061 \times 10^{-14}$	$9.140 \pm 0.270 \times 10^{-15}$	$4.743 \pm 0.382 \times 10^{-15}$	$4.123 \pm 69.090 \times 10^{-15}$

Spectrum			**FWHM**		
	O I (1)	$H\alpha$	$H\beta$	$H\gamma$	$H\delta$
0	78.714 ± 0.634	51.444 ± 0.219	47.185 ± 0.393	51.671 ± 0.620	51.791 ± 0.723
1	54.016 ± 0.461	34.377 ± 0.129	32.503 ± 0.395	40.518 ± 0.826	46.489 ± 1.218
2	40.734 ± 0.431	25.816 ± 0.107	24.359 ± 0.347	27.682 ± 0.525	33.247 ± 0.947
3	34.328 ± 0.425	21.706 ± 0.097	20.642 ± 0.335	24.232 ± 0.518	25.271 ± 0.750
4	27.558 ± 1.143	18.785 ± 0.120	17.328 ± 0.367	21.666 ± 1.342	12.441 ± 1.722
5	28.294 ± 1.528	18.681 ± 0.110	16.260 ± 0.368	22.766 ± 1.578	12.364 ± 4.088
6	27.210 ± 2.297	18.759 ± 0.114	16.619 ± 0.381	15.875 ± 1.816	12.843 ± 27.378
7	27.340 ± 5.240	18.760 ± 0.129	16.319 ± 0.445	19.282 ± 1.116	34.943 ± 37.214
8	33.103 ± 5.612	18.822 ± 0.133	16.453 ± 0.458	23.854 ± 2.776	15.605 ± 6.468
9	25.836 ± 7.491	18.884 ± 0.138	16.123 ± 0.404	23.214 ± 1.677	8.028 ± 33.176

18. **The widths of spectra lines are typically recorded as a velocity rather than as a change in wavelength, or frequency, (or energy,) why might we choose these units?**

19. **How do the line fluxes change with time?**

20. **How do the line (flux) ratios change with time?**

21. **How do the line widths (FWHM) change with time?**

22. **Can you determine simple relationships that describe the evolution of flux and FWHM?**

23. **Why might the FWHM of the spectral lines evolve the way it does?**
The trend indicates decrease in velocity of the ejecta.

24. **Think back to the original description of a nova eruption, what could be causing such a change in line widths?**
As time evolves, nova ejecta is slowed down eventually as it reaches and collides with the circum-stellar material ejected by the star while it was still evolving.

25. **Turning to the ten different continuum fits, can you comment about the evolution of the continuum, particularly with respect to the 'colour' of the system as the system evolves?**
As the system evolves the overall value of the continuum across all wavelengths decreases. Once the dereddening is performed, continuum contribution in the blue wavelengths begins to dominate than in redder wavelengths as time evolves, therefore, the colour of the nova tends towards blue as time evolves.

26. **Armed with an estimate of the extinction toward the system, update your distance estimates and comment on them.**

$$A_{r'} = 2.751 \times E(B--V) = 0.491 \pm 0.256$$

From t_2 relation: $683.282^{+413.701}_{-257.683}$ kpc

From t_3 relation: $524.807^{+453.780}_{-243.358}$ kpc

From t_{15} relation: $666.806^{+190.231}_{-148.006}$ kpc

27. **What is your estimate of the absolute magnitude of this nova, and how does it relate to a typical eruption?**
Absolute magnitude values are estimated using photometry in the previous section and is of the order of ~ -8 magnitudes. This is a fairly typical value for a classical nova.

28. **Based on your distance, where would you expect the nova to be located (i.e. what is its most likely host galaxy?)**
Most possibly in M31.