IoA Internship Summary

Local measurements of the Hubble constant: Type 1a supernova systematics

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I start by importing the raw supernova .txt and .dat files into SnooPy. This is the python package created by the Carnegie Supernova Project (CSP) to fit model light curves to Type 1a supernova (SN) and analyse them. In this case I analyse data from CSP data release 3 (DR3), containing 134 SN, as well as the RATIR sample which includes 44 SN. I wrote code which automatically iterates through the samples and fits each SN. When the fitting fails for a particular SN this is recorded and that SN is fitted manually which allows for further customisation of the fitting. I fit each SN with two different models in SnooPy: EBV-model2, which uses a colour-stretch parameter, sBV, (first used in Burns et al 2014) as a fitting template. As well as the MAX-model which assumes relationships exist between the different filters, in order to deduce the maximum magnitude of any fitted filter. The maximum J-band magnitude, m_J, is the main desired result from fitting both models. To fit in the J-band, the SN is initially fitted in the B-band in order to obtain a reliable value for the time of maximum brightness, T_{max}, from visual observations. In the few cases where the fitting fails the V or r bands are used, since they generally had good coverage. Each SN is then refitted in the J-band with a T_{max} value constrained to that obtained from the B-band fitting. I obtain two .snpy files for each SN (one for each model) which contain the fitted light curve data.

The m_J values (and their errors) are extracted and corrected for the SN restframe and milky way extinction. These are then plotted against the redshift, as seen in figure 1. Several cuts are made to the SN to get rid of questionable fits or unwanted SN. These include the following cuts: All SN with less than 6 J-band observations. This is because SnooPy struggles to accurately fit SN with only a few observations. All SN identified as having poor fits. These are SN that SnooPy clearly fitted incorrectly, e.g. the model light curve missed multiple data points. Most of which had not enough J-band data so were already removed. SN with $sBV < 0.5$ or $EBV > 0.5$ are removed as they are considered peculiar. For CSP SN, these values are taken from Burns et al 2018. Whereas for RATIR SN we used the sBV values from the EBV-model2 fittings and obtain EBV values by separately conducting a EBV-model2 fitting in all available filters. All SN with $z < 0.01$ are also removed, due to the fact that the peculiar velocity uncertainties aren't trusted at very low redshifts.

The SN identifications are matched to a file containing host galaxy masses (M_0) for SN from many data sets, this means that M_0 is available for most of the fitted SN. For the remaining sample, the peculiar velocity and redshift uncertainties are propagated into the errors on m_J, in addition to an intrinsic scatter parameter σ_{int}.

A separate batch of 15 'calibrator' SN are fitted in SnooPy with the same method as detailed above. These SN have absolute magnitude (M_J) values derived from Cepheid variable observations in their host galaxies.

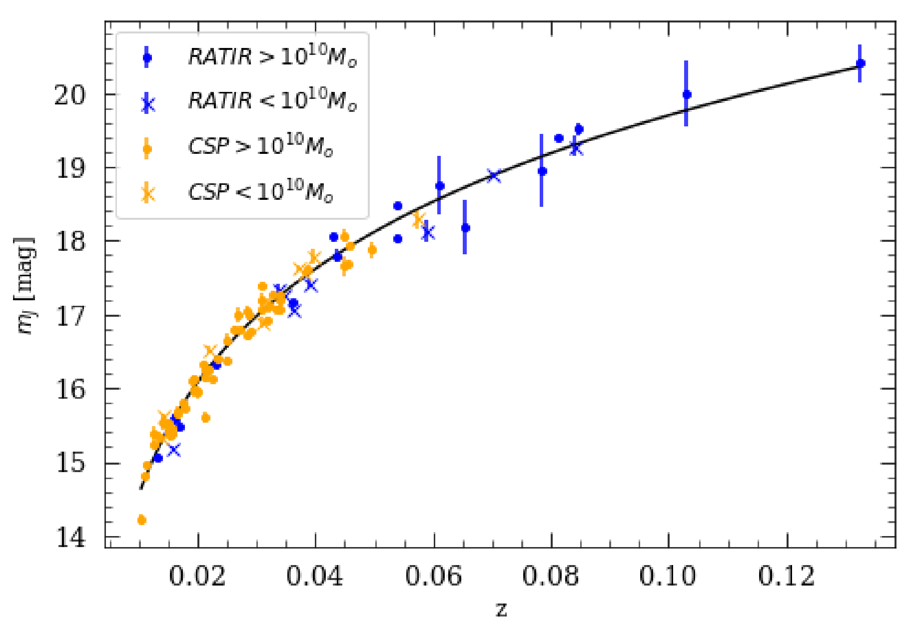

Figure 1: Hubble diagram for supernova in RATIR and CSP after several cuts, plotted with a host galaxy mass step of $10^{10}M_o$. A best fitting line from MCMC analysis of the plotted sample is included.

Table 1: MCMC fitting values of 5aj from RATIR and CSP SN with a $10^{10} M_0$ mass step.

SN sample	model	masses	num of SN	5aj [mag]	std dev	mod(H0 diff)
RATIR+CSP	MAX	all	87	2.845(+21/-20)		
RATIR+CSP	EBV	all	86	2.842(22)		
RATIR+CSP	MAX	high	69	2.849(22)	+0.18	0.21(+2.72/-2.62)
RATIR+CSP	EBV	high	69	2.838(24)	-0.17	
RATIR+CSP	MAX	low	17	2.856(+52/-51)	+0.22	0.43(+3.37/-3.18)
RATIR+CSP	EBV	low	16	2.857(60)	+0.25	
CSP	MAX	all	61	2.836(+22/-23)		0.75(+2.80/-2.66)
CSP	EBV	all	60	2.826(25)		
CSP	MAX	high	53	2.850(+25/-24)	+0.58	0.037(+2.70/-2.63)
CSP	EBV	high	53	2.842(27)	+0.59	
CSP	MAX	low	8	2.747(+73/-75)	-1.22	3.34(+3.65/-3.51)
CSP	EBV	low	7	2.701(+82/-83)	-1.52	
RATIR	MAX	all	26	2.870(+46/-45)		1.98(+3.32/-3.22)
RATIR	EBV	all	26	2.887(+50/-49)		
RATIR	MAX	high	16	2.851(+58/-60)	-0.33	0.75(+3.53/-3.36)
RATIR	EBV	high	16	2.825(+63/-64)	-0.98	
RATIR	MAX	low	9	2.952(+72/-70)	+1.17	4.06(+3.86/-3.71)
RATIR	EBV	low	9	2.992(+80/-79)	+1.33	

The python module emcee is used to conduct MCMC analysis and fit M_J, H_0 and σ_{int} with;

$$log(H_0) = \frac{M_J + 5aj + 25}{5} \tag{1}$$

Where aj arises from equation 2 for the data in the Hubble plot with cut SN removed. The optimal parameter values are then plugged into equation 1 to obtain a value for 5aj.

$$aj = log(cz) + log(1 + \frac{(1-q_0)z}{2} - \frac{(1-q_0-3q_o^2+j_0)z}{6}) - 0.2m_J \tag{2}$$

This process is undertaken, and parameter values are obtained for further cuts such as where SN from RATIR and CSP are separated as well as a $10^{10} M_0$ mass step cut. The value of H_0 is kept blind so we tabulate the value of 5aj in table 1 instead. All σ_{int} values are 0.16-0.21 [mag] and generally increase as the sample size decreases. Whereas optimal values of M_J tend to be around -18.48 [mag] with no clear trend between cuts. The standard deviation values in table 1 represent the discrepancy of the mass step 5aj values against the respective value using SN of all masses, as a fraction of their error. The modulus of the difference between the H_0 values from each cut and that of all SN from both samples is also included for the MAX-model, and is used to probe the optimal H_0 values obtained without directly observing them.

The variation of 5aj is depicted more clearly in figure 2. When CSP and RATIR are combined the mass step values agree with each other and with all SN. But when the samples are separated this is not the case. For CSP the 'higher' host-mass galaxies yield a larger value for 5aj (which is what is expected) whereas the opposite its true for RATIR. However the error bars are large enough for the shifts not to be statistically significant. It should be noted that a very similar conclusion is found from the EBV-model2 fits.

I am currently scrutinising the fits in more detail. My supervisor (Suhail Dhawan) and I are in the process of deciding the exact cuts to make, before repeating the MCMC analysis with more data.

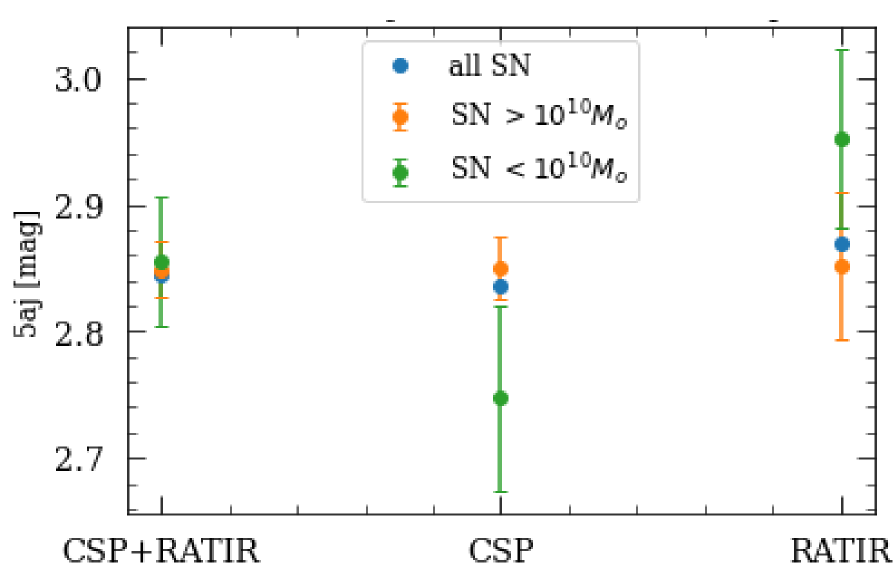

Figure 2: Values of 5aj for host-mass step cuts of RATIR and CSP SN samples using the MAX-model. The error in 5aj is not included to allow the other error bars to be seen more clearly.