Supplementary Information for "SNLS-03D3bb — a super-Chandrasekhar mass Type Ia supernova"

SN Location SNLS-03D3bb is located at RA: 14:16:18.920 Dec: +52:14:53.66 (J2000) in the D3 (extended Groth Strip) field of the Supernova Legacy Survey (SNLS), located in a satellite galaxy to a larger tidally distorted spiral (Supplementary Figure 1). The SN is $0.18''$W and $0.03''$S from the centre of its host and $4.04''$E and $2.53''$S from the centre of the larger galaxy.

Spectroscopy Spectroscopic observations were obtained on 2003 May 6.3 at Keck I using the Low Resolution Imaging Spectrograph (LRIS) in with a $1''$ slit, placed at a $261°$ position angle to get the redshift of the faint host and the large nearby galaxy. From the two dimensional spectrum it is apparent that both galaxies are at the same redshift. Two 1000 second observations were taken, dithering between observations. The 560 dichroic was used to split the observations between the grism on the blue side (600 lines at 400 nm) and the grating on the red side (400 lines grating blazed at 850 nm with central wavelength 725 nm).

Follow-up photometric observations were obtained during the "presurvey" commissioning phase of the SNLS. Basic photometric reductions were done using the Elixir pipeline, and deep reference images containing no supernova light were subtracted from each image to remove galaxy contamination. PSF-photometry was done on the difference image.

At day 20 after maximum brightness, where the colors are well measured, SNLS-03D3bb has $B - V = 0.74$, and $V - R = 0.16$, within the distribution of local SNe Ia. There is no evidence that the SN Ia is significantly reddened from dust, but we do not know the instrinsic color of such an odd SN Ia. Any extinction correction would make the SN Ia intrinsically more luminous, and thus require a higher white dwarf mass.

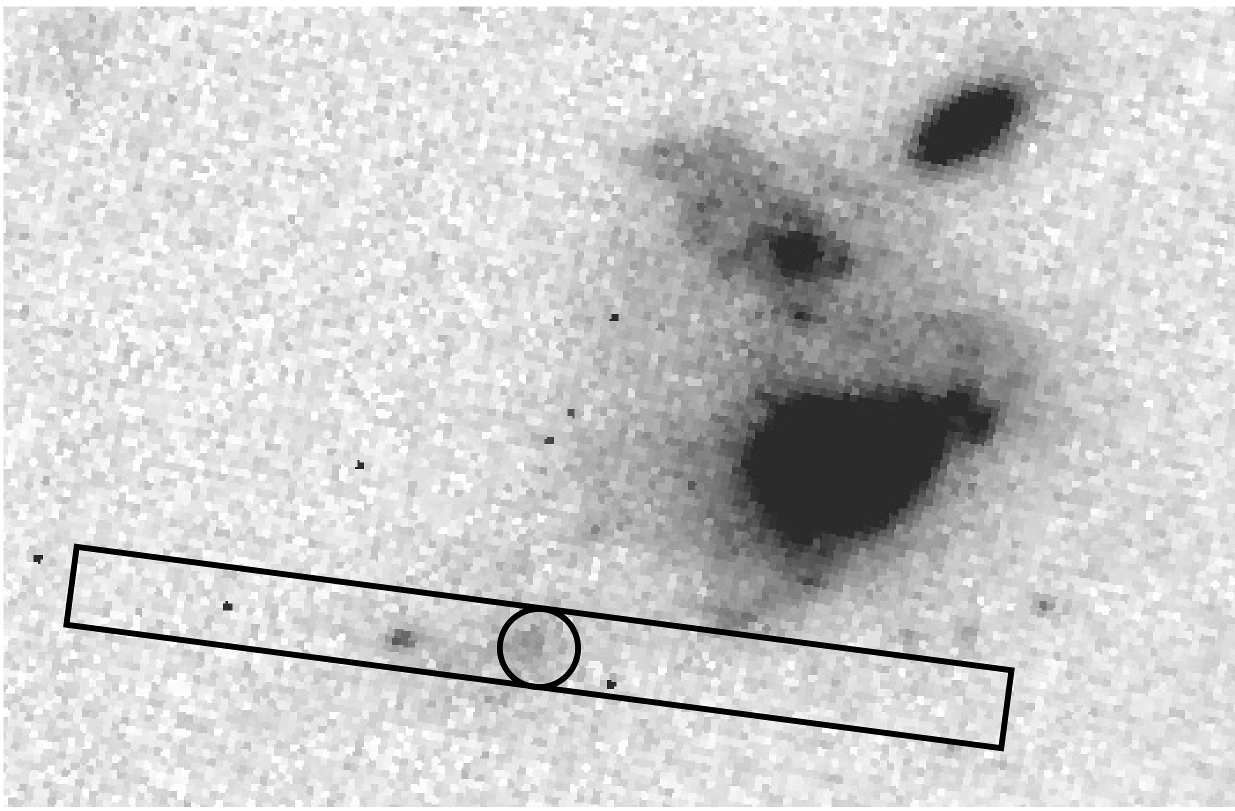

Fig. 1.— A Hubble Space Telescope ACS image of the host galaxy of SNLS-03D3bb taken through the F814W filter. Though the supernova is not present in this image, the circle marks its position. The spectroscopic slit was placed at 261° to get the redshifts of both the small host and the larger neighboring galaxy. Both are at $z = 0.2440$.

SYNOW fit The best fit SYNOW parameters were a photospheric velocity of 8000 km s^{-1} with a maximum velocity of 12,500 km s^{-1} (except for Ca II at 10,000 km s^{-1}) and a underlying blackbody temperature of 9000 K (varried by ± 2500 K in the IR to account for uncertainties in the bolometric correction). The excitation temperature was 10,000 K for all ions except C II, which was placed at 35,000 K in order to get relative line strengths correct in the spectrum. This is similar to what was used in a preliminary fit to SN 2006D which showed 4 C II lines in the spectrum.

Alternative explanations It is possible to lower the implied Ni mass by decreasing t_R in Equation 2, i.e. by shortening the time from explosion to maximum light. However, to get 0.9 $M_\odot$ of ^{56}Ni would require $t_R = 14.6$ days, 66% of the rise time inferred from the post maximum decline. Such a fast rise and slow decline has never before been seen in a SN Ia, so we consider this possibility to be highly unlikely.

Another way to decrease the implied Ni mass for SNLS-03D3bb is asymmetry. Spectropolarimetric observations imply that some SNe Ia are aspherical[1 2 3 4], perhaps giving rise to a direction-dependent deviations in brightness. However, such brightness deviations amount to only a few tenths of a magnitude. No theoretical model predicts a factor of two increase in brightness due to viewing a SN Ia from a preferred geometry. The relative rarity of SNLS-03D3bb offers another constraint. The fact that this type of object has been seen only once out of hundreds of supernova observations implies that if such behaviour is common, the area of increased luminosity must have a small solid angle. This might be possible if we were looking down a jet, but SNLS-03D3bb has unusually low, not unusually high velocities.

Young population Super-Chandrasekhar white dwarfs should be more likely in a young stellar population[5 6]. The two white dwarfs in a double degenerate system must have a total mass above the Chandrasekhar limit if the secondary (by definition the lower mass star) is larger than 0.7 solar masses. Stars with an initial mass above 3 $M_\odot$ produce white dwarfs larger than 0.7 $M_\odot$[7]. Since it takes 900 million years for a 3 $M_\odot$ star to evolve off the main sequence[8], all white dwarf pairs created before 900 million years must have a combined mass above the Chandrasekhar mass. In the single degenerate scenario, the massive hydrogen envelopes of secondaries and higher starting primary white dwarf mass also make super-Chandrasekhar masses easier to achieve in a young population. Populations older than a few Gyr are a factor of 10–20 are less efficient than younger populations at creating even a Chandrasekhar mass white dwarf through the single degenerate path.[9] This inefficiency would increase if a super-Chandrasekhar white dwarf is required.

To estimate the age of the host galaxy of SNLS-03D3bb, we fit PEGASE.2 population synthesis models to the host galaxy $u^*g'r'i'z'$ photometry[1]0. We find log $M_{\rm gal} = 8.93^{+0.81}_{-0.50}$, where $M_{\rm gal}$ is the host galaxy stellar mass in $M_\odot$; the galaxy is less than a tenth the mass of the Milky Way. We find a star formation rate of $1.26^{+0.02}_{-1}$ $M_\odot$ yr^{-1}, averaged over 0.5 Gyr. This formally implies an age of $\sim$ 700 Myr, though the unknown star formation history of the galaxy makes a precise determination impossible. We treat this only as an indicator of a young stellar population, confirming that SNLS-03D3bb matches environmental expectations.

Table 1. Photometry of SNLS-03D3bb

MJD	Exptime	Flux	Flux Error	Mag	Filter
52721.62	720.6	1.302e-19	1.4e-19	24.88	g
52722.59	720.7	-3.566e-19	1.1e-19	25.16	g
52730.55	360.3	1.487e-19	1.4e-19	24.88	g
52785.43	900.9	7.926e-18	5.6e-20	22.03	g
52790.39	180.2	4.994e-18	1.5e-19	22.54	g
52791.44	360.4	4.434e-18	1.6e-19	22.66	g
52792.41	720.6	4.131e-18	9.7e-20	22.74	g
52813.34	720.7	2.131e-18	6.8e-20	23.46	g
52817.29	900.8	1.983e-18	5.3e-20	23.54	g
52721.57	1801.7	-2.021e-20	5.1e-20	25.21	r
52730.48	1080.7	-4.511e-20	5.0e-20	25.23	r
52755.46	2702.7	1.932e-17	4.6e-20	20.26	r
52759.46	720.8	2.072e-17	7.7e-20	20.19	r
52784.44	1800.9	1.176e-17	5.6e-20	20.80	r
52792.38	1801.0	7.486e-18	4.6e-20	21.29	r
52813.36	1440.7	3.814e-18	5.4e-20	22.03	r
52817.31	1173.3	3.583e-18	3.9e-20	22.09	r
52721.52	3603.6	-6.529e-20	2.8e-20	25.17	i
52723.57	2702.5	-7.554e-21	4.7e-20	24.61	i
52730.41	3781.7	-1.297e-19	3.7e-20	24.88	i
52753.52	3424.4	1.118e-17	6.9e-20	20.17	i

Table 1—Continued

MJD	Exptime	Flux	Flux Error	Mag	Filter
52758.43	1441.4	1.333e-17	6.0e-20	19.98	i
52783.45	3641.2	9.458e-18	6.5e-20	20.35	i
52787.46	3641.1	8.827e-18	6.9e-20	20.43	i
52792.32	3641.2	7.796e-18	4.4e-20	20.56	i
52796.43	3641.1	6.916e-18	4.0e-20	20.69	i
52812.39	1040.3	4.612e-18	2.2e-19	21.13	i
52816.33	3641.4	4.007e-18	6.7e-20	21.28	i
52820.28	3120.6	3.723e-18	3.3e-20	21.36	i
52824.28	3641.2	3.317e-18	3.6e-20	21.49	i

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