J/MNRAS/448/1206 Superluminous supernovae in faint galaxies (McCrum+, 2015)

Selecting superluminous supernovae in faint galaxies from the first year of the Pan-STARRS1 Medium Deep Survey.

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Abstract:

The Pan-STARRS1 (PS1) survey has obtained imaging in five bands (griz y_{P1}) over 10 Medium Deep Survey (MDS) fields covering a total of 70 square degrees. This paper describes the search for apparently hostless supernovae (SNe) within the first year of PS1 MDS data with an aim of discovering superluminous supernovae (SLSNe). A total of 249 hostless transients were discovered down to a limiting magnitude of M_{AB}~23.5, of which 76 were classified as Type Ia supernovae (SNe Ia). There were 57 SNe with complete light curves that are likely core-collapse SNe (CCSNe) or type Ic SLSNe and 12 of these have had spectra taken. Of these 12 hostless, non-Type Ia SNe, 7 were SLSNe of type Ic at redshifts between 0.5 and 1.4. This illustrates that the discovery rate of type Ic SLSNe can be maximized by concentrating on hostless transients and removing normal SNe Ia. We present data for two possible SLSNe; PS1-10pm (z=1.206) and PS1-10ahf (z=1.1), and estimate the rate of type Ic SLSNe to be between 3^{+3}_{-2}x10^{-5} and 8^{+2}_{-1}x10^{-5} that of the CCSN rate within $0.3 \leq z \leq 1.4$ by applying a Monte Carlo technique. The rate of slowly evolving, type Ic SLSNe (such as SN2007bi) is estimated as a factor of 10 lower than this range.

Description:

From the period starting February 25th 2010 and ending July 9th 2011, 249 hostless transients or "orphans" were discovered in the PS1 Medium Deep fields. AN orphan is defined as an object that is >3.4" away from the centre of a catalogued galaxy or point source brighter than approximately 23.5m (in any of the g_{P1} r_{P1} i_{P1} filters that the transient was detected in).

The PS1 observations are obtained through a set of five broadband filters, which we have designated as g_{P1}, r_{P1}, i_{P1}, z_{P1}, and y_{P1}. Although the filter system for PS1 has much in common with that used in previous surveys, such as SDSS (Abazajian et al., 2009ApJS..182..543A), there are important differences. The gP1 filter extends 20nm redward of g_{SDSS}, paying the price of 5577Å emission for greater sensitivity and lower systematics for photometric redshifts, and the zP1 filter is cut off at 930nm, giving it a different response than the detector response which defined z_{SDSS}. SDSS has no corresponding y_{P1} filter. Further information on the passband shapes is described in Stubbs et al. (2010ApJS..191..376S). The PS1 photometric system and its response is covered in detailed in Tonry et al. (2012ApJ...750...99T, Cat. J/ApJ/750/99). Photometry is in the "natural" PS1 system, m=-2.5log(flux)+m', with a single zeropoint adjustment m' made in each band to conform to the AB magnitude scale.

File Summary:

FileName	Lrecl	Records	Explanations
ReadMe	80	.	This file
table3.dat	112	28	The 28 spectroscopically confirmed PS1 SN Ia
table4.dat	71	48	The 48 plausible PS1 SN Ia, classified using the soft and psnid photometric classification codes
table5.dat	109	12	*The 12 confirmed PS1 CCSNe
table6.dat	63	17	*The 17 plausible PS1 CCSNe
table7.dat	136	75	Observed photometry for PS1-10pm
table10.dat	105	64	Observed photometry for PS1-10ahf
tablea2.dat	67	28	The 28 SN-like orphans
tablea3.dat	53	116	The 116 unknown orphans

Note on table5.dat: Of note is the high percentage of SLSNe Ic confirmed.

Note on table6.dat: The values in the soft and psnid columns represent the probability that the object is classified as the type II subclass listed.

See also:
J/ApJ/750/99 : The Pan-STARRS1 photometric system (Tonry+, 2012)

Byte-by-byte Description of file: table3.dat

Bytes	Format	Units	Label	Explanations
1- 4	A4	---	Field	Field
6- 16	A11	---	Name	Supernova PS1 designation (PS1-NNAAA or PS1-NNNNNNN)
17	A1	---	n_Name	[*] Note on Name (1)
19- 26	F8.4	deg	RAdeg	Right ascension (J2000)
28- 34	F7.4	deg	DEdeg	Declination (J2000)
36- 40	F5.3	---	zsp	Spectroscopic redshift
42- 47	F6.3	mag	rP1mag	Peak rP1 magnitude
49- 53	F5.3	mag	e_rP1mag	rms uncertainty on peak rP1 magnitude
55- 62	A8	---	Tel	Telescope
64- 73	A10	"date"	Date	Observation date
75	A1	---	Note	[*] Note for spectral classification (2)
77-112	A36	---	Ref	References

Note (1): The MD06 object PS1-11acn is designated as PTF11dws in the cited source of classification.
Note (2): * = spectral classifications for these objects as SNe Ia can be found in Rest et al. (2014ApJ...795...44R)

Byte-by-byte Description of file: table4.dat

Bytes	Format	Units	Label	Explanations
1- 4	A4	---	Field	Field
6- 16	A11	---	Name	Supernova PS1 designation (PS1-NNAAA)
18- 25	F8.4	deg	RAdeg	Right ascension (J2000)
27- 34	F8.4	deg	DEdeg	Declination (J2000)
36- 40	F5.3	---	soft	?=- Probability that the object is classified as an SN Ia with soft photometric classification code (G1)
42- 46	F5.3	---	psnid	?=- Probability that the object is classified as an SN Ia with psnid photometric classification code (G1)
48- 52	F5.3	---	zph	?=- Photometric redshift
54- 58	F5.3	---	e_zph	?=- rms uncertainty on zph
60- 65	F6.3	mag	rP1mag	?=- Peak rP1 magnitude
67- 71	F5.3	mag	e_rP1mag	? rms uncertainty on peak rP1 magnitude

Byte-by-byte Description of file: table5.dat

Bytes	Format	Units	Label	Explanations
1- 4	A4	---	Field	Field
6- 16	A11	---	Name	Supernova PS1 designation (PS1-NNAAA)
17	A1	---	n_Name	[a*] Note on Name (1)
19- 26	F8.4	deg	RAdeg	Right ascension (J2000)
28- 35	F8.4	deg	DEdeg	Declination (J2000)
37- 48	A12	---	Type	Type
50- 54	F5.3	---	zsp	Spectroscopic redshift
57- 61	F5.3	---	soft	?=- Probability that the object is classified as the SNe type given in Typesoft column (soft photometric classification code) (G1)
63- 65	A3	---	Typesoft	Type from soft
67- 71	F5.3	---	psnid	?=- Probability that the object is classified as the SNe type given in Typepsnid column (psnid photometric classification code) (G1)
73- 75	A3	---	Typepsnid	Type from psnid
77- 82	F6.3	mag	rP1mag	?=- Peak rP1 magnitude
84- 88	F5.3	mag	e_rP1mag	? rms uncertainty on peak rP1 magnitude
90- 92	A3	---	Inst	Instrument
94-103	A10	"date"	Date	Observation date
105-109	A5	---	Ref	Reference(s) (2)

Note (1): Notes as follows:
* = the two objects are explored further in this paper.
a = PS1-10afx has been shown to be a lensed SN Ia, and is included here for completeness of objects, although we do not use it in any of our rate estimates
Note (2): References as follows:
1 = McCrum et al. (2014MNRAS.437..656M)

2 = this paper
3 = Lunnan et al. (2014ApJ...787..138L)
4 = Chomiuk et al. (2011ApJ...743..114C)
5 = Chornock et al. (2013ApJ...767..162C)
6 = Quimby et al. (2013MNRAS.431..912Q, 2013ApJ...768L..20Q)
7 = Quimby et al. (2014Sci...344..396Q)

Byte-by-byte Description of file: table6.dat

Bytes	Format	Units	Label	Explanations
1- 4	A4	---	Field	Field
6- 16	A11	---	Name	Supernova PS1 designation (PS1-NNAAA)
18- 25	F8.4	deg	RAdeg	Right ascension (J2000)
27- 34	F8.4	deg	DEdeg	Declination (J2000)
36- 38	A3	---	Type	Type
40- 44	F5.3	---	soft	?=- Probability that the object is classified as the type II subclass listed with soft photometric classification code (G1)
46- 50	F5.3	---	psnid	?=- Probability that the object is classified as the type II subclass listed with psnid photometric classification code (G1)
52- 57	F6.3	mag	rP1mag	?=- Peak rP1 magnitude
59- 63	F5.3	mag	e_rP1mag	? rms uncertainty on peak rP1 magnitude

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Byte-by-byte Description of file: table7.dat

Bytes	Format	Units	Label	Explanations
1- 10	A10	"date"	Date	Observation date
12- 19	F8.2	d	MJD	Modified Julian date
21- 27	F7.2	d	Phase	Phase, in observer frame, not rest frame
29	A1	---	l_gP1mag	Limit flag on gP1mag
30- 34	F5.2	mag	gP1mag	?=- gP1 (481nm) magnitude (1)
36- 39	F4.2	mag	e_gP1mag	? rms uncertainty on gP1mag
42	A1	---	l_rP1mag	Limit flag on rP1mag
43- 47	F5.2	mag	rP1mag	?=- rP1 (617nm) magnitude (1)
49- 52	F4.2	mag	e_rP1mag	? rms uncertainty on rP1mag
55	A1	---	l_iP1mag	Limit flag on iP1mag
56- 60	F5.2	mag	iP1mag	?=- iP1 (752nm) magnitude (1)
62- 65	F4.2	mag	e_iP1mag	? rms uncertainty on iP1mag
68	A1	---	l_zP1mag	Limit flag on zP1mag
69- 73	F5.2	mag	zP1mag	?=- zP1 (866nm) magnitude (1)
75- 78	F4.2	mag	e_zP1mag	? rms uncertainty on zP1mag
82- 86	F5.2	mag	gmag	?=- g magnitude (1)
88- 91	F4.2	mag	e_gmag	? rms uncertainty on gmag
95- 99	F5.2	mag	rmag	?=- r magnitude (1)
101-104	F4.2	mag	e_rmag	? rms uncertainty on rmag
108-112	F5.2	mag	imag	?=- i magnitude (1)
114-117	F4.2	mag	e_imag	? rms uncertainty on imag
121-125	F5.2	mag	zmag	?=- z magnitude (1)
127-130	F4.2	mag	e_zmag	? rms uncertainty on zmag
134-136	A3	---	Tel	Telescope

Note (1): No K-corrections have been applied.
Note that the PS1 observations have had any flux from a previous reference image removed through image subtraction (although note that no host object can be seen at the location of PS1-10pm) whereas the late time WHT and GN observations have not.

Byte-by-byte Description of file: table10.dat

Bytes	Format	Units	Label	Explanations
1- 10	A10	"date"	Date	Observation date
12- 19	F8.2	d	MJD	Modified Julian date
21- 27	F7.2	d	Phase	Phase, in observer frame, not rest frame, as more than one possible redshift value is presented in the text
29	A1	---	l_rP1mag	Limit flag on rP1mag
30- 34	F5.2	mag	rP1mag	?=- rP1 (617nm) magnitude (1)
36- 39	F4.2	mag	e_rP1mag	? rms uncertainty on rP1mag
41	A1	---	l_iP1mag	Limit flag on iP1mag
42- 46	F5.2	mag	iP1mag	?=- iP1 (752nm) magnitude (1)
48- 51	F4.2	mag	e_iP1mag	? rms uncertainty on iP1mag
53	A1	---	l_zP1mag	Limit flag on zP1mag
54- 58	F5.2	mag	zP1mag	?=- zP1 (866nm) magnitude (1)
60- 63	F4.2	mag	e_zP1mag	? rms uncertainty on zP1mag
66- 70	F5.2	mag	rmag	?=- r magnitude (1)
72- 75	F4.2	mag	e_rmag	? rms uncertainty on rmag

78- 82	F5.2	mag	imag	?=- i magnitude (1)
84- 87	F4.2	mag	e_imag	? rms uncertainty on imag
91- 95	F5.2	mag	zmag	? z magnitude (1)
97-100	F4.2	mag	e_zmag	? rms uncertainty on zmag
103-105	A3	---	Tel	Telescope

Note (1): No K-corrections have been applied.
Note that the PS1 observations have had any flux from previous reference image removed through image subtraction (although note that no host object can be seen at the location of PS1-10ahf) whereas the late time WHT and GS observations have not.

Byte-by-byte Description of file: tablea2.dat

Bytes	Format	Units	Label	Explanations
1- 4	A4	---	Field	Field
6- 16	A11	---	Name	Supernova PS1 designation (PS1-NNAAA)
18- 25	F8.4	deg	RAdeg	Right ascension (J2000)
27- 34	F8.4	deg	DEdeg	Declination (J2000)
36- 40	F5.3	---	soft	?=- Probability that the object is classified as the SNe type given in Typesoft column (soft photometric classification code) (G1)
42- 44	A3	---	Typesoft	Type from soft (2)
46- 50	F5.3	---	psnid	?=- Probability that the object is classified as the SNe type given in Typepsnid column (psnid photometric classification code) (G1)
52- 54	A3	---	Typepsnid	Type from psnid (2)
56- 61	F6.3	mag	rP1mag	?=- Peak rP1 magnitude
63- 67	F5.3	mag	e_rP1mag	? rms uncertainty on peak rP1 magnitude

Note (2): none of these objects met with the confidence restrictions placed upon the photometric classifiers for identifying SNe (see Tables 4 and 6 for objects that do), it can be seen here that a large number of these objects were given some sort of tentative, photometric SNe classification.

Byte-by-byte Description of file: tablea3.dat

Bytes	Format	Units	Label	Explanations
1- 4	A4	---	Field	Field
6- 16	A11	---	Name	Supernova PS1 designation (PS1-NNAAA)
18- 25	F8.4	deg	RAdeg	Right ascension (J2000)
27- 34	F8.4	deg	DEdeg	Declination (J2000)
36- 41	F6.3	mag	rP1mag	?=- Peak rP1 magnitude
43- 47	F5.3	mag	e_rP1mag	? rms uncertainty on peak rP1 magnitude
49- 53	A5	---	LC	LC Status (1)

Note (1): LC Status as follows:
INC = objects have incomplete light curves
VAR = objects have variable light curves with no obvious trend
FAINT = objects fall out of the magnitude range for spectroscopic or reliable photometric classification
RED = no detections in the g_{P1}- or r_{P1}-band filters but showed a faint peak in the i_{P1}- and z_{P1}-band filters, possibly as a result of a single, energetic outburst such as an SN at high redshift

Global notes:

Note (G1): soft and psnid photometric classification codes
(Sako et al., 2008AJ....135..348S, Cat. J/AJ/135/348, 2011ApJ...738..162S, Cat. J/ApJ/738/162; Rodney & Tonry 2009ApJ...707.1064R).

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