SN-IIP PHOTOMETRIC TYPING

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Introduction: Plateau Supernovae

* Most common core collapse supernovae $(8\text{-}10M_{sun} < M < M_{upp})$

* Hydrogen absorption in spectra

* Characteristic plateau in light curve

* independent distance indicators … but few at $z > 0.1$

Introduction: Plateau Supernovae

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✳ Hydrogen absorption in spectra

✳ Characteristic plateau in light curve

✳ independent distance indicators ... but few at z>0.1

   ⬛ independent rate evolution & SFH ⇨ mass range estimate!

Past and current SN-IIP surveys

Spectroscopically confirmed

∗ Locally (z<0.05) : 37 SNe IIP

∗ SDSS (0.015<z<0.16): 34 SNe IIP

∗ SNLS (0.1<z<0.35): 12 SNe IIP

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➡ hundreds of unclassified SNe

Future SN surveys

* DES: ~3000 SNe, ~100 CC-SNe (to z~0.6) (Bernstein et al. 2009)

* PTF: ~1000 transients per year, ~200 CC-SNe (to z~0.4) (Rau et al. 2009)

* Pan-STARRS: ~20 000 CC-SNe per year (to z~0.6)

* LSST: ~160 000 CC-SNe per year (to z~0.9) (Ivezic et al. 2008)

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➡ expensive spectra!

➡ photometric typing!

SN IIP typing: goals

- easy and automated SN IIP typing method

- with/without prior redshift knowledge

- few contamination and good efficiency

- rate purposes (SNLS for example)

Typing techniques

Examples:

✳ Light curve fits

✳ color-magnitude and color-color plots

Typing techniques

Examples:

✽ Light curve fits

✽ color-magnitude and color-color plots

L

plateau (<1mag)

t
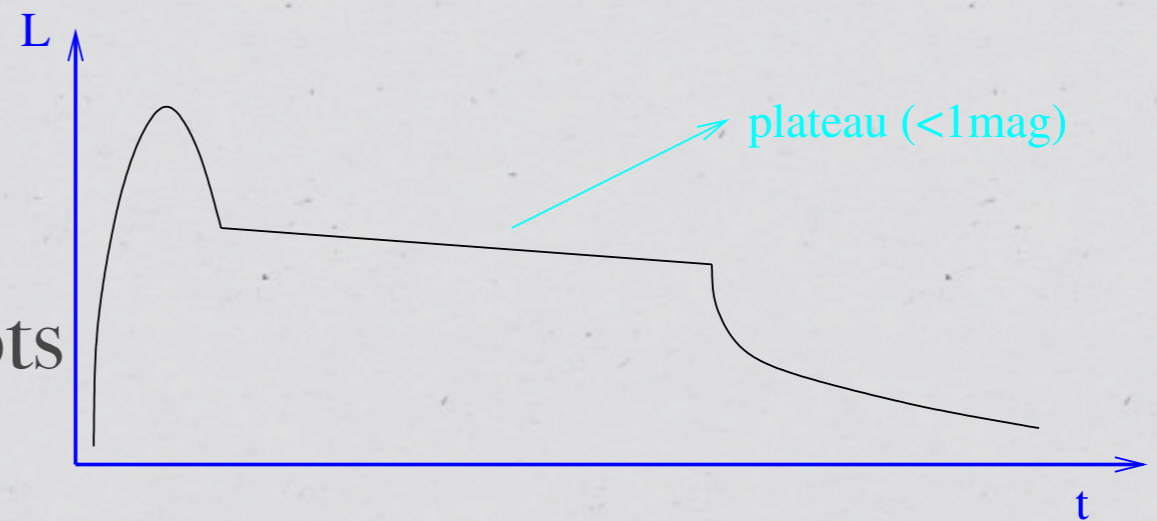
Typing techniques

Examples:

✽ Light curve fits

✽ color-magnitude and color-color plots
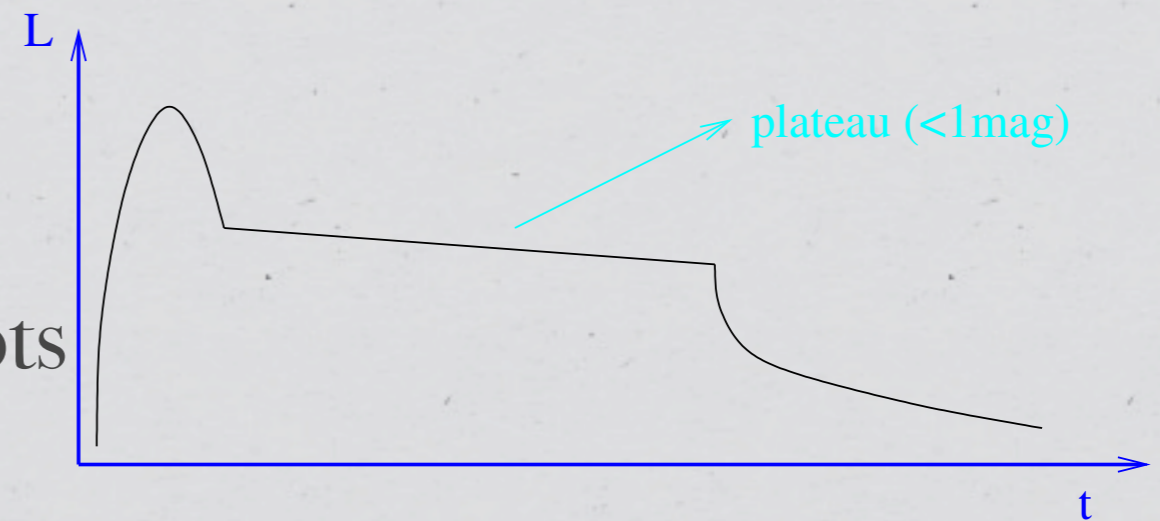
SN-IIP: use of characteristic plateau:

✽ post-maximum linear (in mag) fit and constraints on slopes

Post-max linear fit typing

1. Find the time of maximum t_{max}: get maximum of all filters and take the earliest (as long as S/N>5)

2. Fit data between t_{max} and t_{fin} to a line in magnitudes: m= αt (or fluxes, f=$10^{\alpha t}$) in each filter

3. Explore slope-slope space and slope-flux at t_{fin} for different filter combinations

WORK IN PROGRESS

Training sets: local

SNe IIP (z<0.05)

| Name	Redshift	Source
SN1968l	0.0017	Wood & Andrews (1974)
SN1970g	0.0008	Winzer (1974); Barbon et al. (1973)
SN1973r	0.0024	Ciatti & Rosino (1977)
SN1986i	0.0080	Pennypacker et al. (1989); Tsvetkov (1988)
SN1988a	0.0051	Benetti et al. (1991); Turatto et al. (1993)
SN1990e	0.0041	Schmidt et al. (1993); Benetti et al. (1994)
SN1991al	0.0153	Hamuy (2003)
SN1991g	0.0025	Blanton et al. (1995)
SN1992af	0.0187	Hamuy (2003)
SN1992am	0.0477	Hamuy (2003); Schmidt et al. (1994)
SN1992ba	0.0040	Hamuy (2003); Pastorello (2003)
SN1993a	0.0293	Hamuy (2003)
SN1993s	0.0330	Hamuy (2003)
SN1995ad	0.0061	Pastorello (2003)
SN1996an	0.0047	Pastorello (2003)
SN1996w	0.0056	Pastorello (2003)
SN1998a	0.0070	Pastorello et al. (2005)
SN1999br	0.0032	Hamuy (2003); Pastorello et al. (2004)
SN1999ca	0.0093	Hamuy (2003)
SN1999cr	0.0202	Hamuy (2003)
SN1999eg	0.0224	Hamuy (2003)
SN1999em	0.0024	Hamuy et al. (2001); Leonard et al. (2002b); Elmhamdi et al. (2003)
SN1999gi	0.0020	Leonard et al. (2002a)
SN2000cb	0.0064	Hamuy (2003)
SN2001dc	0.0072	Pastorello et al. (2004)
SN2001x	0.0049	Tsvetkov (2006)
SN2002hh	0.0002	Pozzo et al. (2006); Tsvetkov et al. (2007)
SN2002gd	0.0089	Pastorello (2003)
SN2003gd	0.0022	Hendry et al. (2005)
SN2003hn	0.0039	Krisciunas et al. (2009)
SN2003z	0.0043	Pastorello (2003)
SN2004a	0.0028	Tsvetkov (2008); Hendry et al. (2006)
SN2004dj	0.0004	Chugai et al. (2005); Vinkó et al. (2006); Zhang et al. (2006); Tsvetkov et al. (2008)
SN2004ek	0.0173	Tsvetkov (2008)
SN2004et	0.0002	Misra et al. (2007); Sahu et al. (2006)
SN2005ay	0.0027	Tsvetkov et al. (2006)
SN2005cs	0.0015	Tsvetkov et al. (2006); Brown et al. (2007); Dessart et al. (2008); Pastorello et al. (2009
SN2006bp	0.0035	Dessart et al. (2008)

Training sets: local

SNe non-IIP (z<0.1)

Name	Type	Redshift	Source
SN1990s	SNIIn	0.0252	Hamuy et al. (1993)
SN1994y	SNIIn	0.0085	Ho et al. (2001)
SN1997bs	SNIIn-impostor	0.0025	Van Dyk et al. (2000)
SN1998bw	SNIc	0.0087	McKenzie & Schaefer (1999); Sollerman et al. (2000); Patat et al. (200
SN1998s	SNIIL	0.0030	Liu et al. (2000)
SN1999el	SNIIn	0.0048	Di Carlo et al. (2002)
SN1999ga	SNIIL	0.0049	Pastorello et al. (2009a)
SN2001b	SNIb	0.0052	Tsvetkov (2006)
SN2002ao	SNIbn	0.0051	Pastorello et al. (2008b)
SN2002ap	SNIc	0.0022	Gal-Yam et al. (2002); Yoshii et al. (1988); Foley et al. (2003)
SN2003bg	SNIIb	0.0046	Hamuy et al. (2009)
SN2003jd	SNIc	0.0189	Valenti et al. (2008)
SN2003lw	SNIc	0.1055	Malesani et al. (2004)
SN2004aw	SNIc	0.0159	Taubenberger et al. (2006)
SN2004ao	SNIb	0.0056	Elmhamdi et al. (2010)
SN2004gk	SNIc	0.0007	Elmhamdi et al. (2010)
SN2005bf	SNIb	0.0189	Folatelli et al. (2006)
SN2005la	SNIb/IIb	0.0019	Pastorello et al. (2008a)
SN2006aj	SNIc	0.0331	Sollerman et al. (2006); Pian et al. (2006)
SN2006gi	SNIb	0.0094	Elmhamdi et al. (2010)
SN2006gy	SNIIn	0.0192	Agnoletto et al. (2009)
SN2006jc	SNIbn	0.0056	Pastorello et al. (2007, 2008b); Anupama et al. (2009)
SN2007bg	SNIc	0.0346	Young et al. (2010)
SN2007bi	SNIc-Pl?	0.127	Young et al. (2010); Gal-Yam et al. (2009)
SN2007gr	SNIc	0.0017	Hunter et al. (2009)
SN2007rt	SNIIn	0.0224	Trundle et al. (2009)
SN2008es	SNIIL	0.213	Miller et al. (2009)
SN2008ax	SNIIb	0.0019	Pastorello et al. (2008c); Roming et al. (2009); Tsvetkov et al. (2009
SN2008d	SNIb	0.0065	Modjaz et al. (2009)
SN2008s	SNIIn-impostor	0.0002	Smith et al. (2009)
SN2008iy	SNIIn	0.0411	Miller et al. (2010)
+ 212	SNe Ia	z<0.1	Union Set

Examples
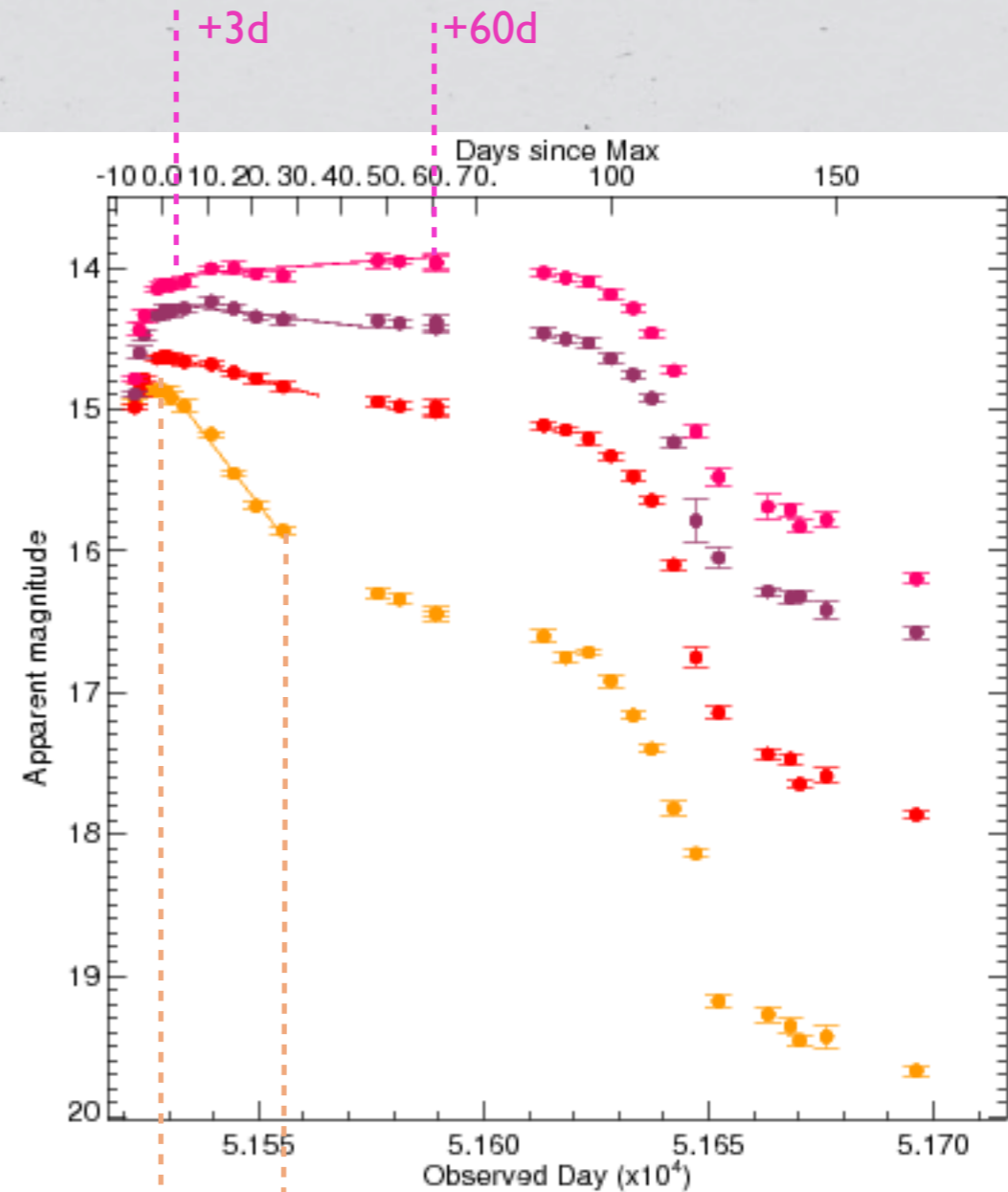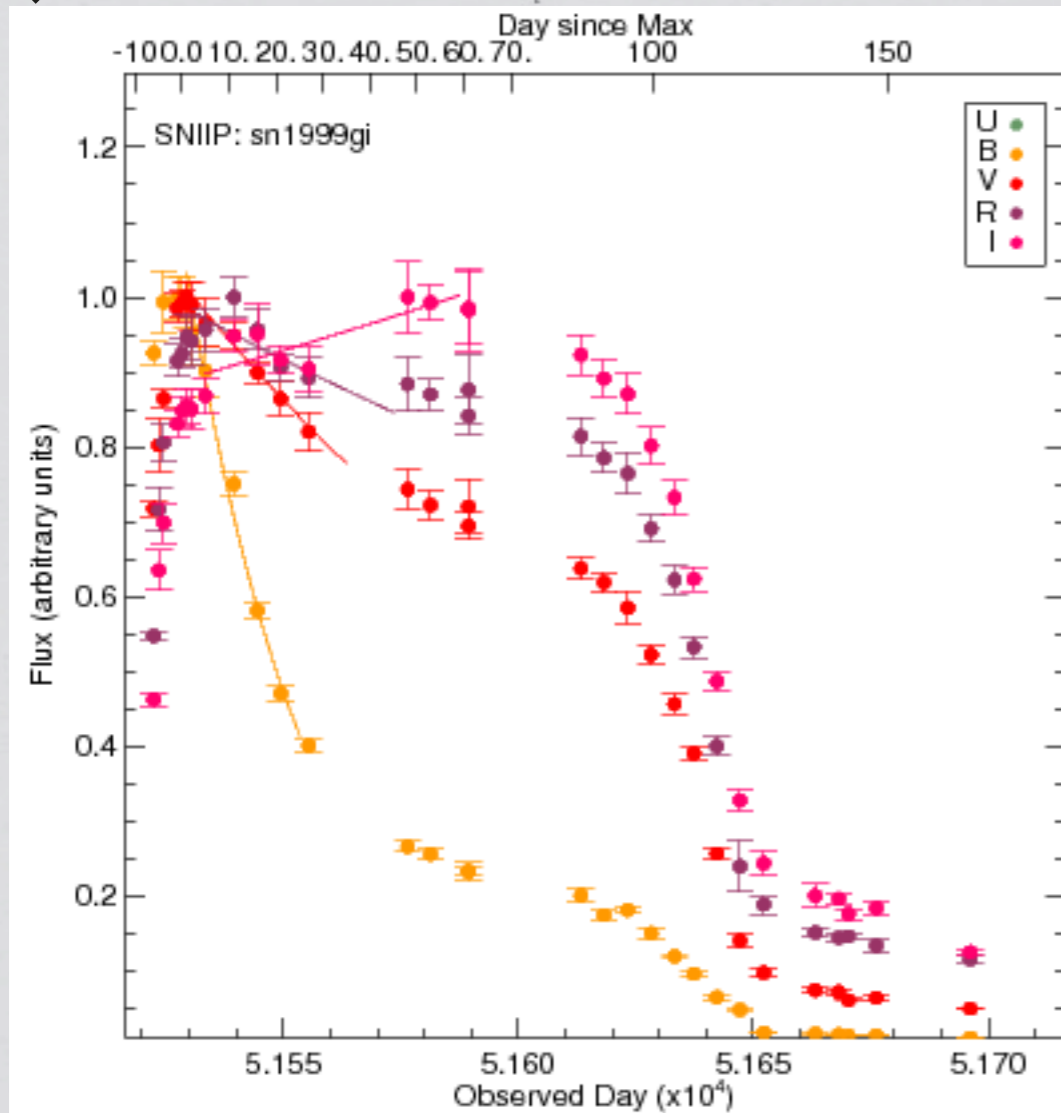
Filter: U B V R I
Initial Day: 0 0 1 2 3
Final Day: 20 25 35 45 60

Always require at least 3 points per filter in the desired region!

Examples

SNe IIP have less steep slopes!
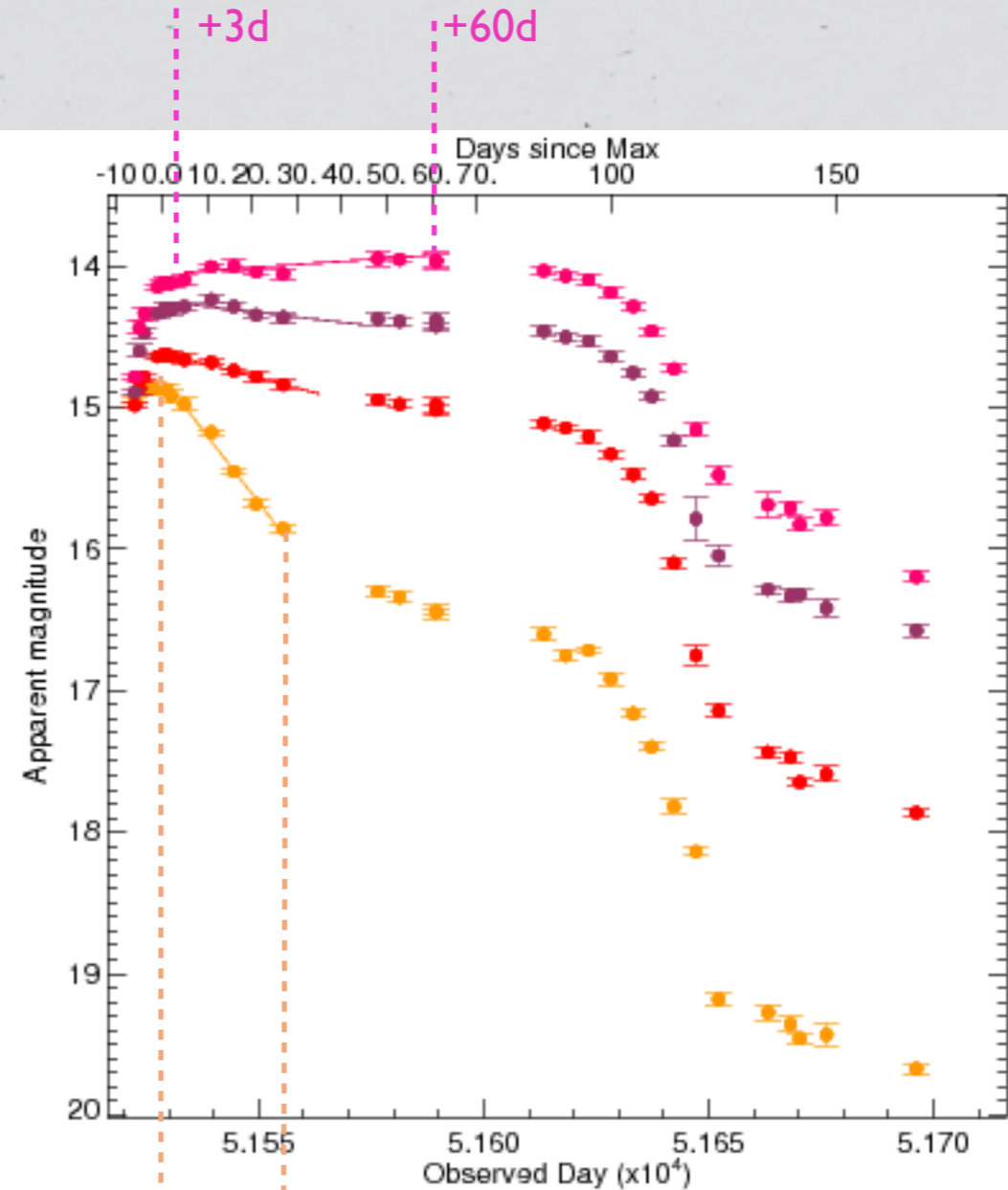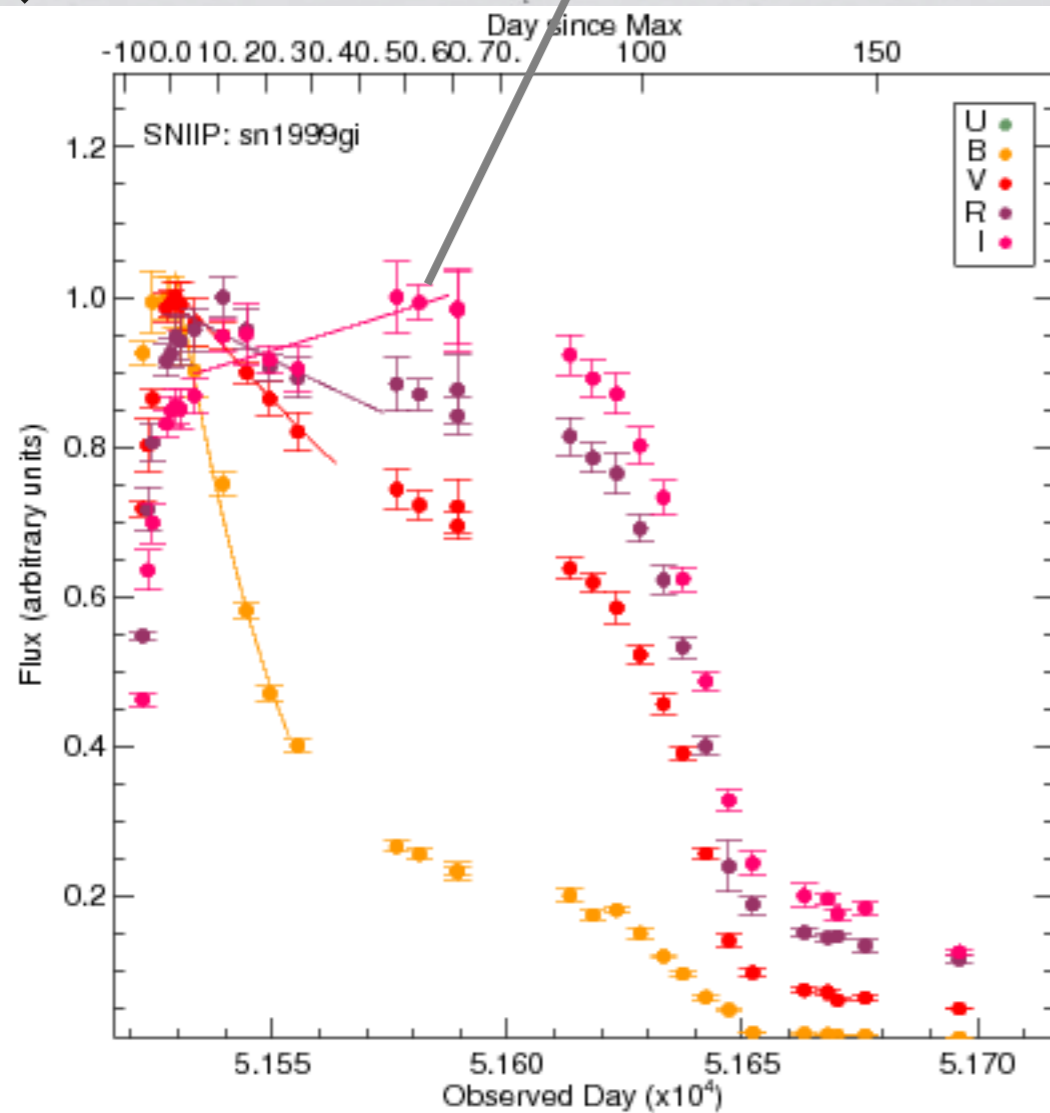
SNIIP: sn1999gi

Filter:	U	B	V	R	I
Initial Day:	0	0	1	2	3
Final Day:	20	25	35	45	60

Always require at least 3 points per filter in the desired region!

Examples

SN Ia

SN Ibc
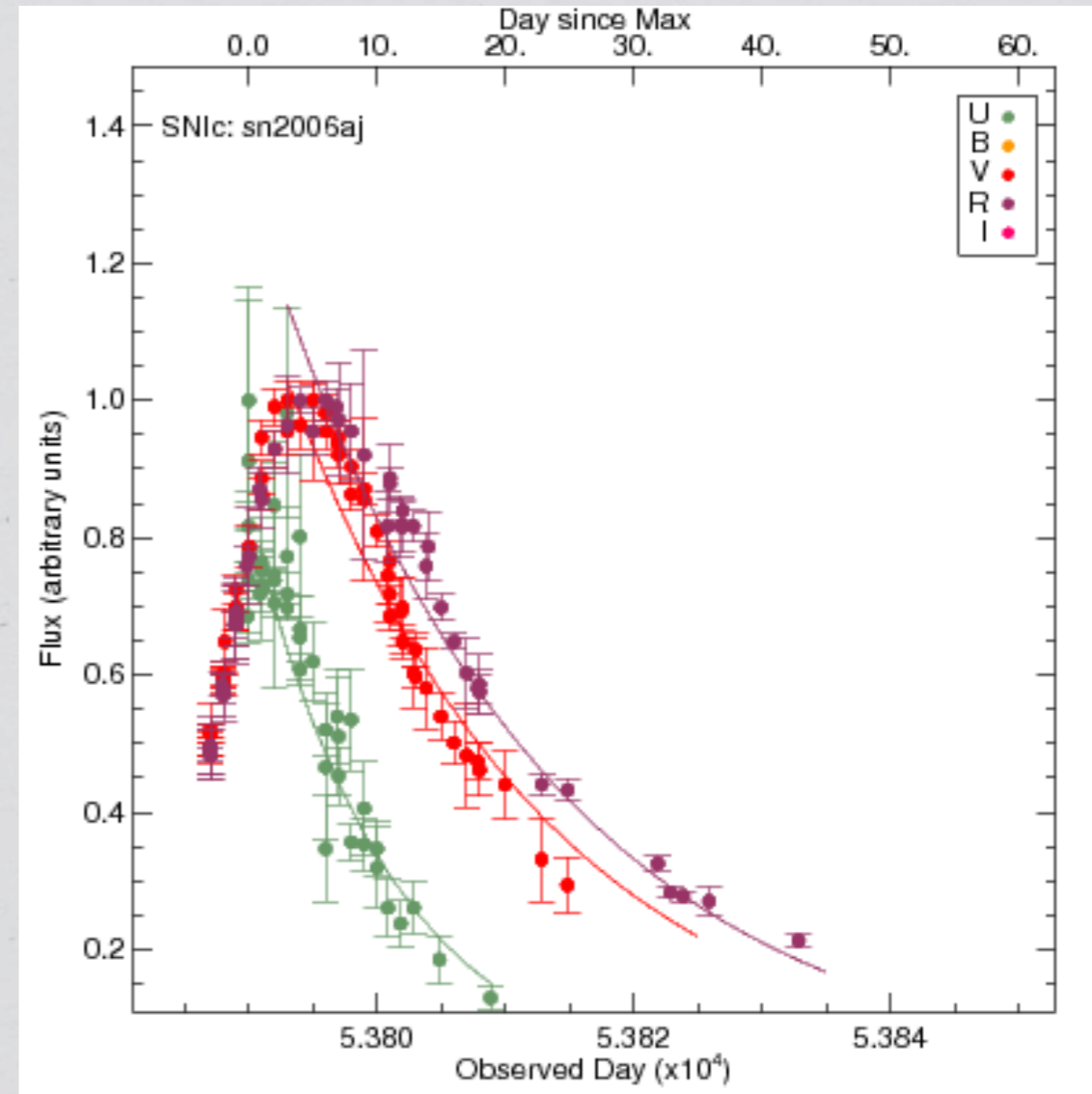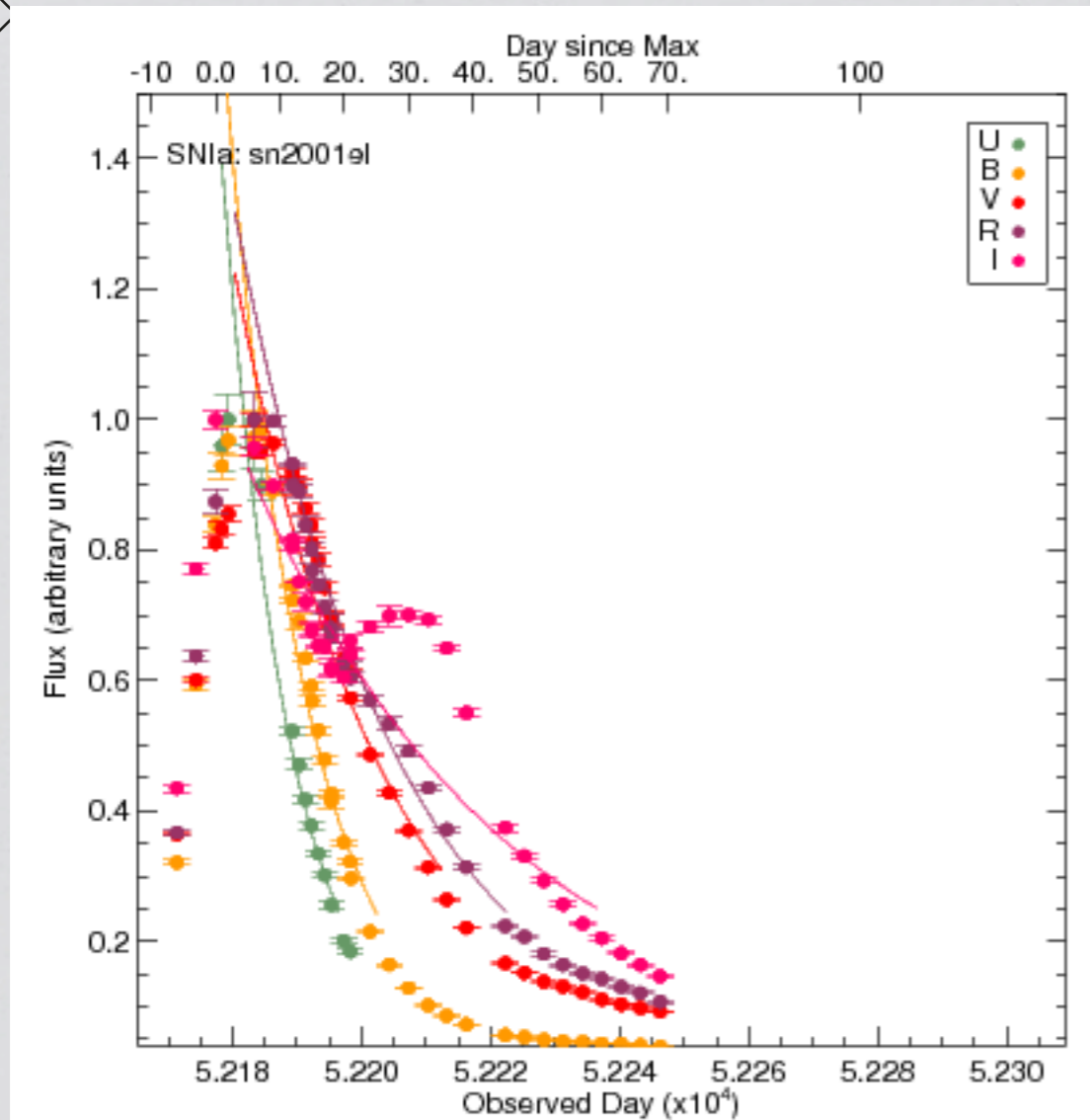
Filter:	U	B	V	R	I
Initial Day:	0	0	1	2	3
Final Day:	20	25	35	45	60

Examples

SN Ia

SN Ibc

steeper slopes

Filter:	U	B	V	R	I
Initial Day:	0	0	1	2	3
Final Day:	20	25	35	45	60

Training sets: SDSS

* 33 SNe IIP (D'Andrea et al. 2010), z<0.16
* 99 SNe Ia (Holtzman et al. 2008), z<0.35
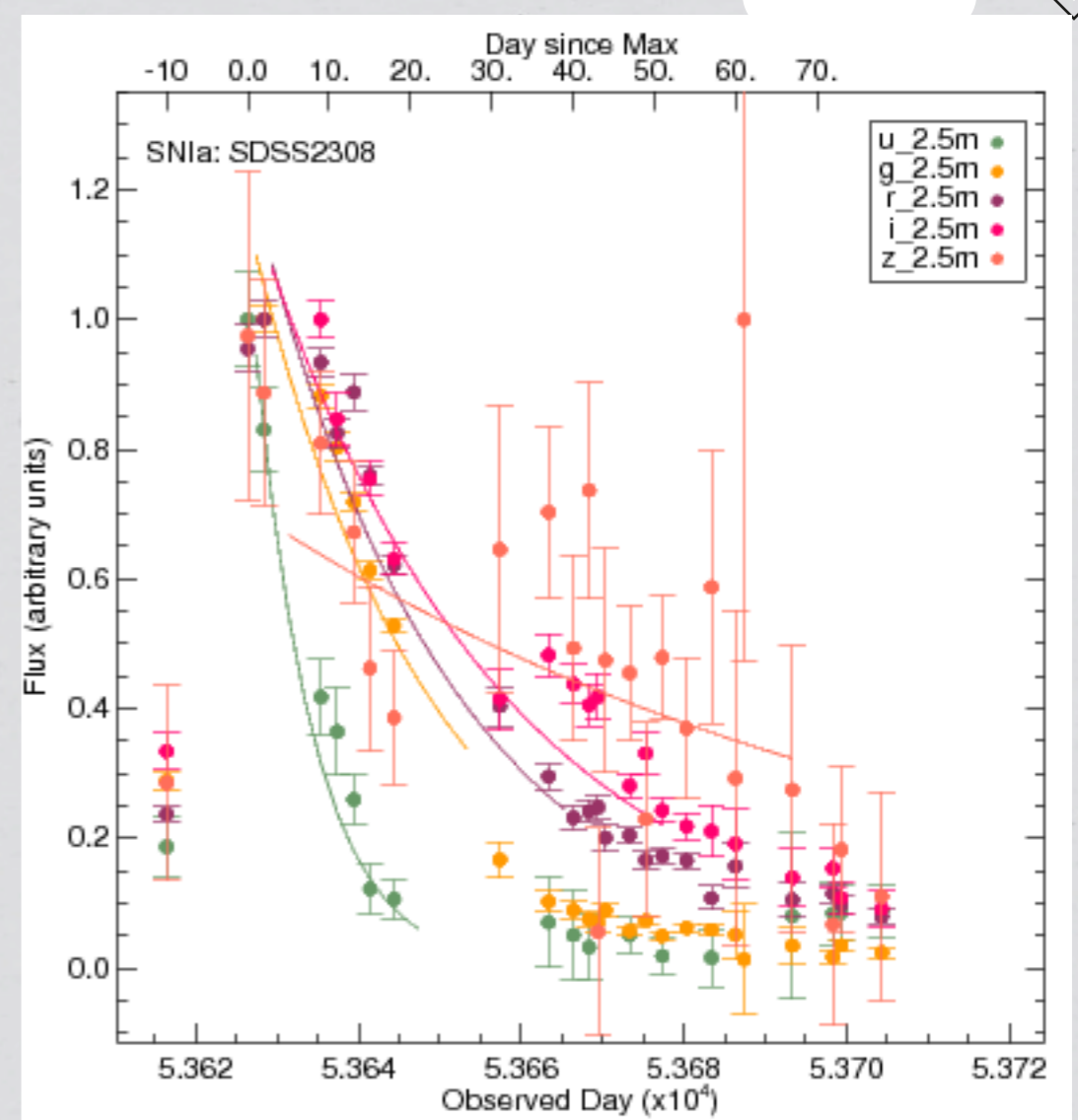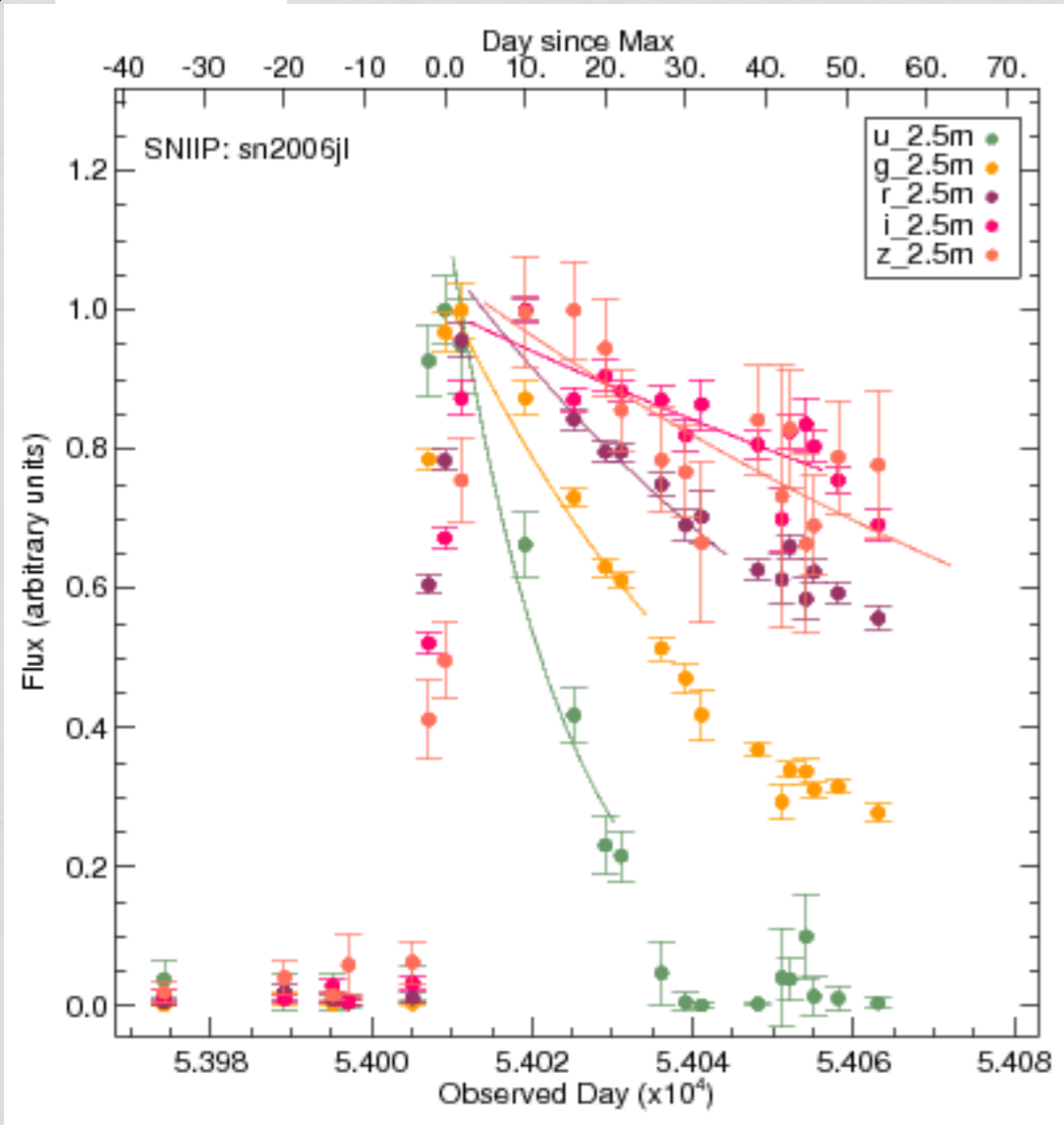
SN IIP

SN Ia

Filter:	u	g	r	i	z
Initial Day:	0	0	1	2	3
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Training sets: SDSS

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SN IIP

SN Ia

Filter:	u	g	r	i	z
Initial Day:	0	0	1	2	3
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Can also use flux at t_{fin} as an extra tool to classify them

Training sets: SNLS

* 12 SNe IIP (0.1<z<0.35)

* 381 SNe Ia (z<1.0), 17 SNe Ibc (z<0.6), 1 SN IIn (z=0.19)
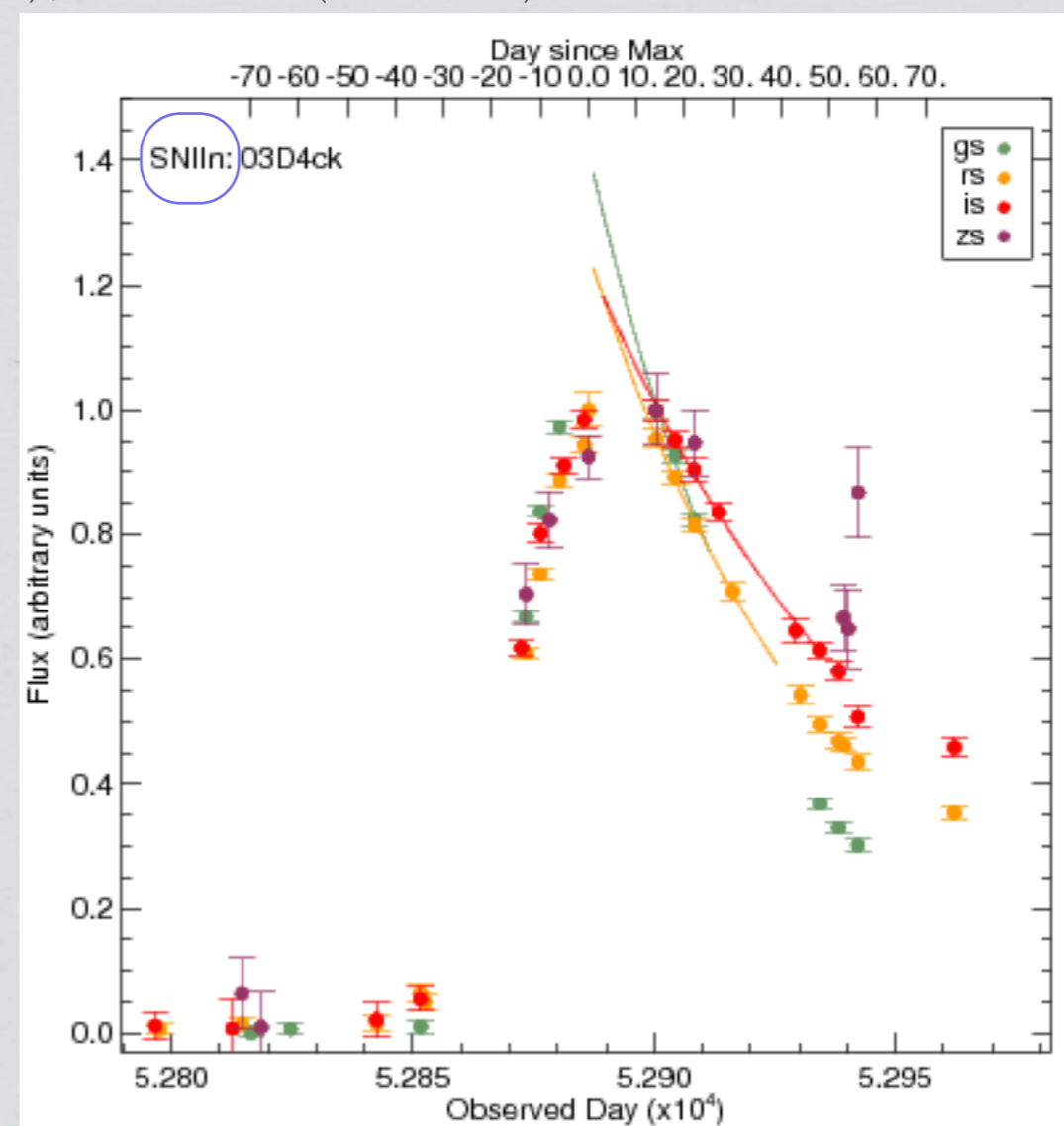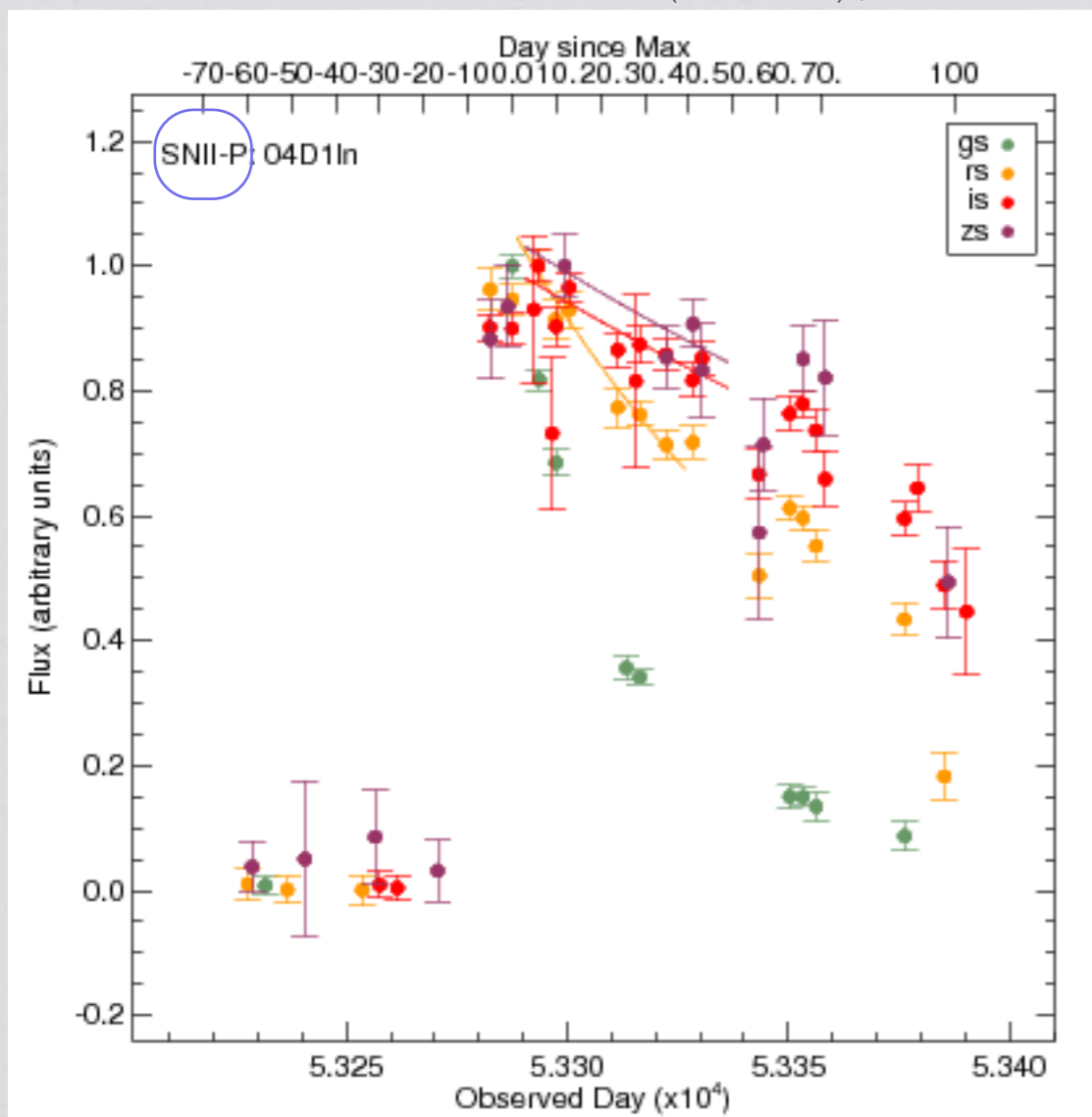
Add interpolated fluxes at t_{fin}

Filter:	g	r	i	z
Initial Day:	0	1	2	3
Final Day:	25	40	50	50

Training sets: DES

SN typing challenge (Kessler et al. 2010)

SUPERNOVA PHOTOMETRIC CLASSIFICATION CHALLENGE

RICHARD KESSLER,[1,2] ALEX CONLEY,[3] SAURABH JHA,[4] STEPHEN KUHLMANN[5]

Challenge Released on Jan 29, 2010. Last update: March 16, 2010

* ~19000 SNANA simulated BLIND SN sample (5352Ia, 2185 Ibc, 8637 IIP, 1884 IIn, 289 IIL)

* Spectroscopically confirmed set of ~1200 SNe

* 0<z<1

* host photo-z information also available

* lots of light-curves not well sampled

Low-z slope-slope
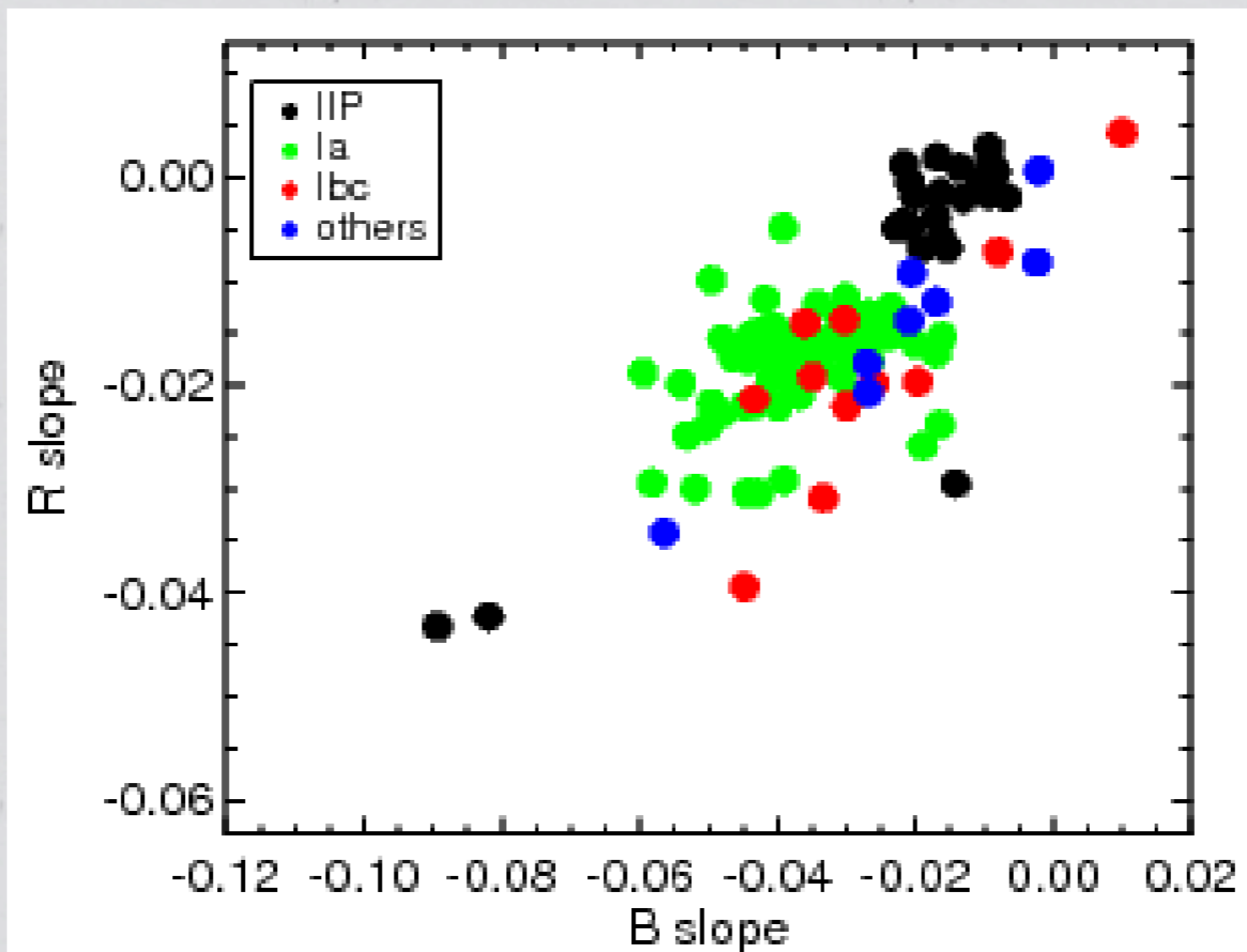
Low-z slope-slope
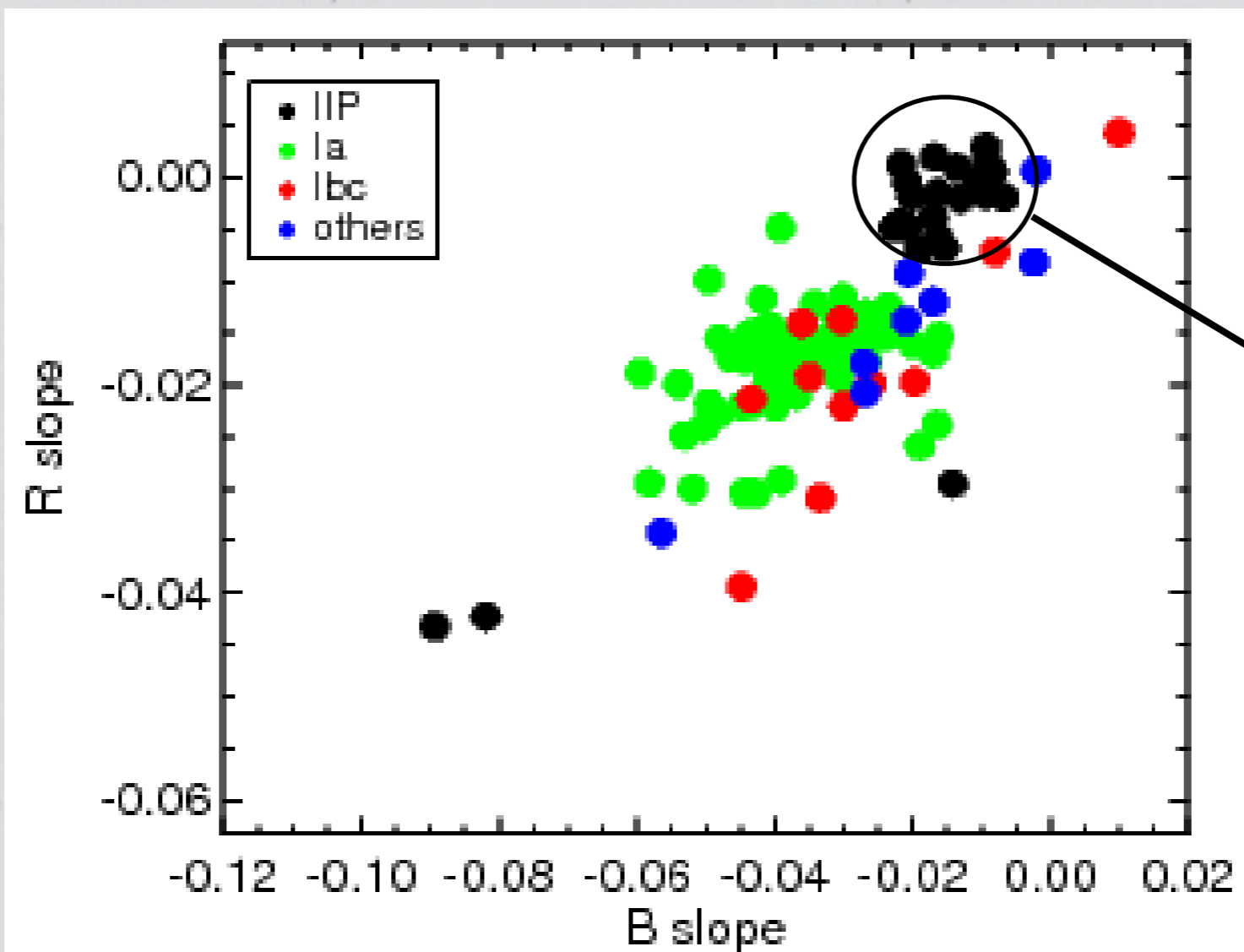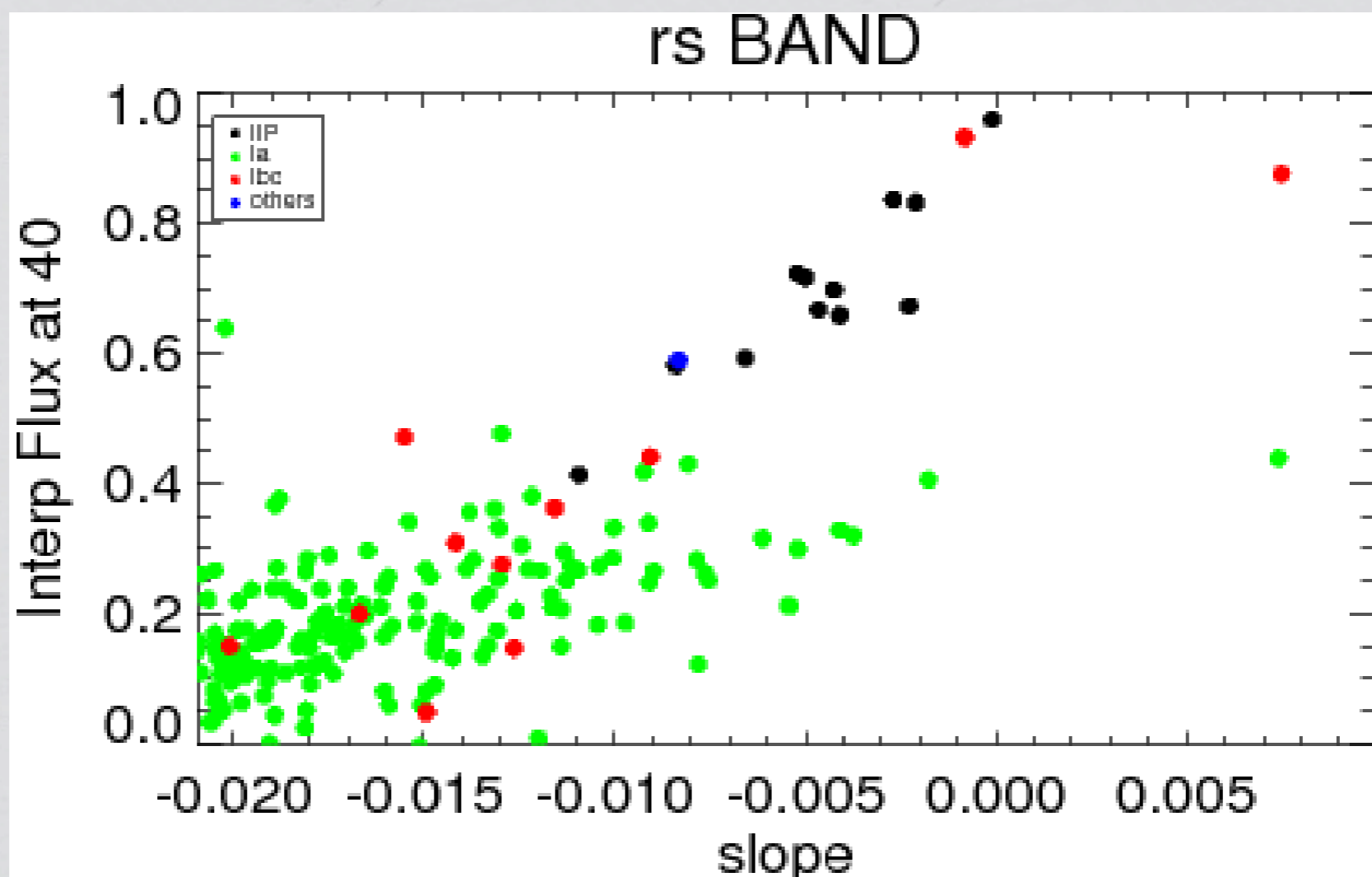
SNLS slope-flux

SNLS slope-flux
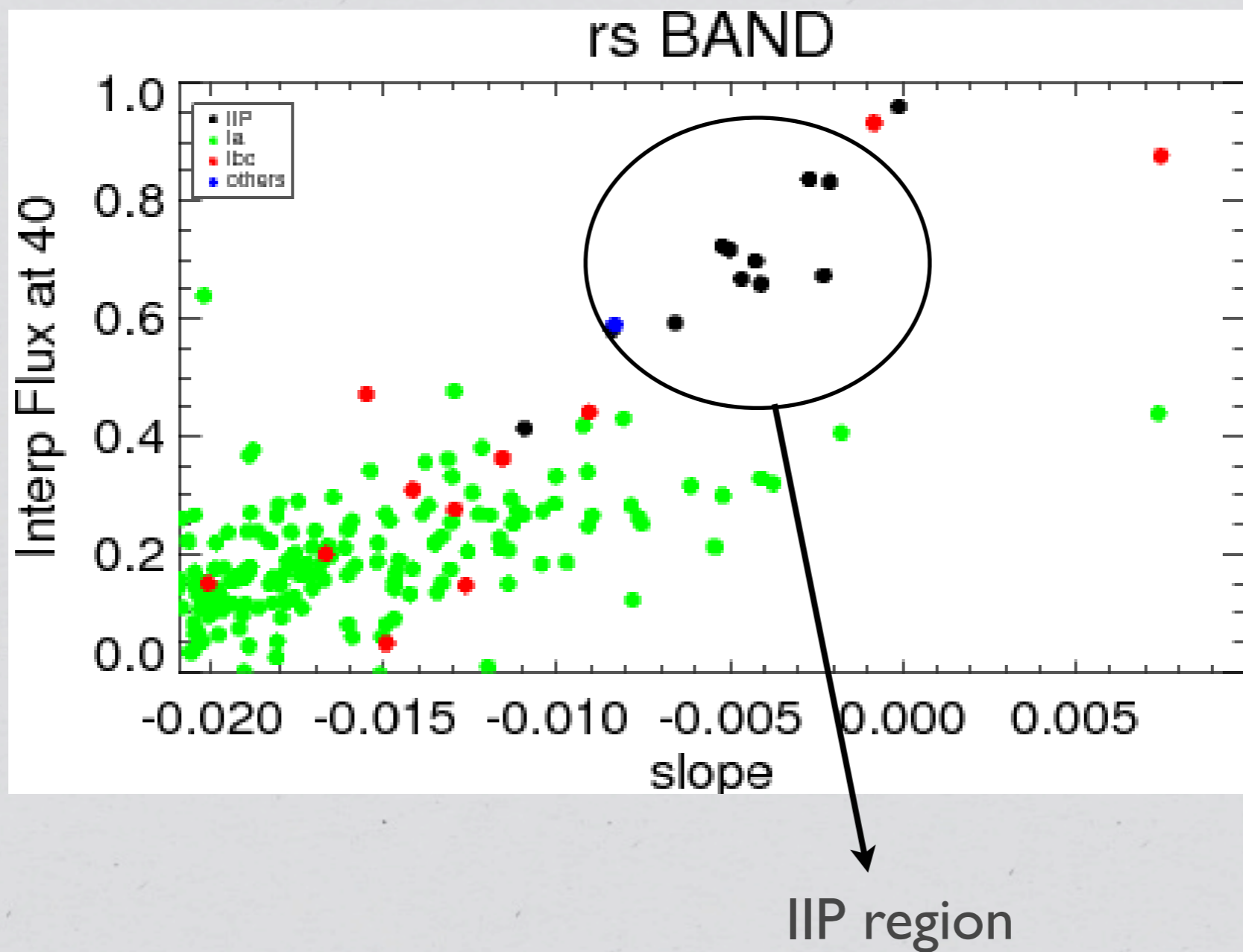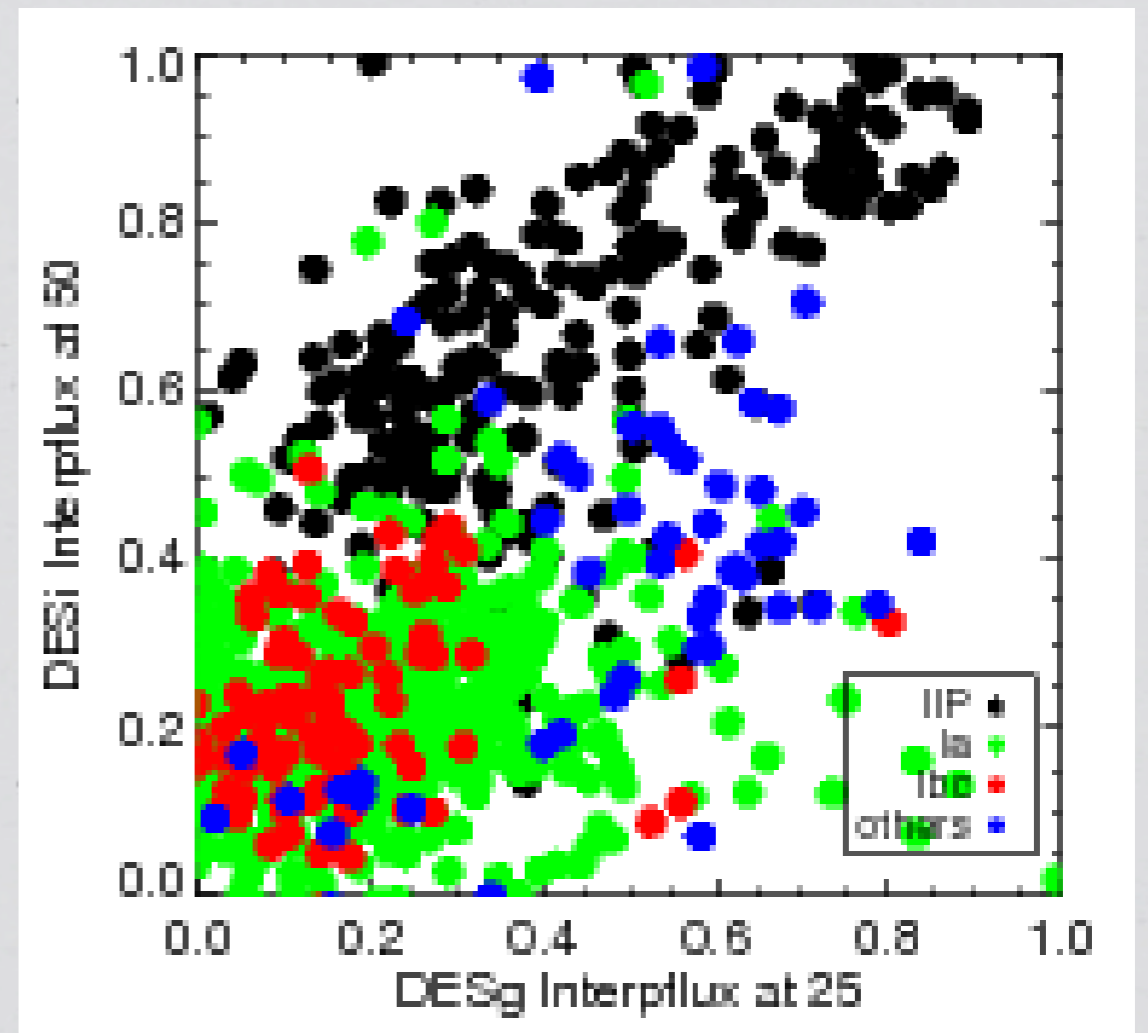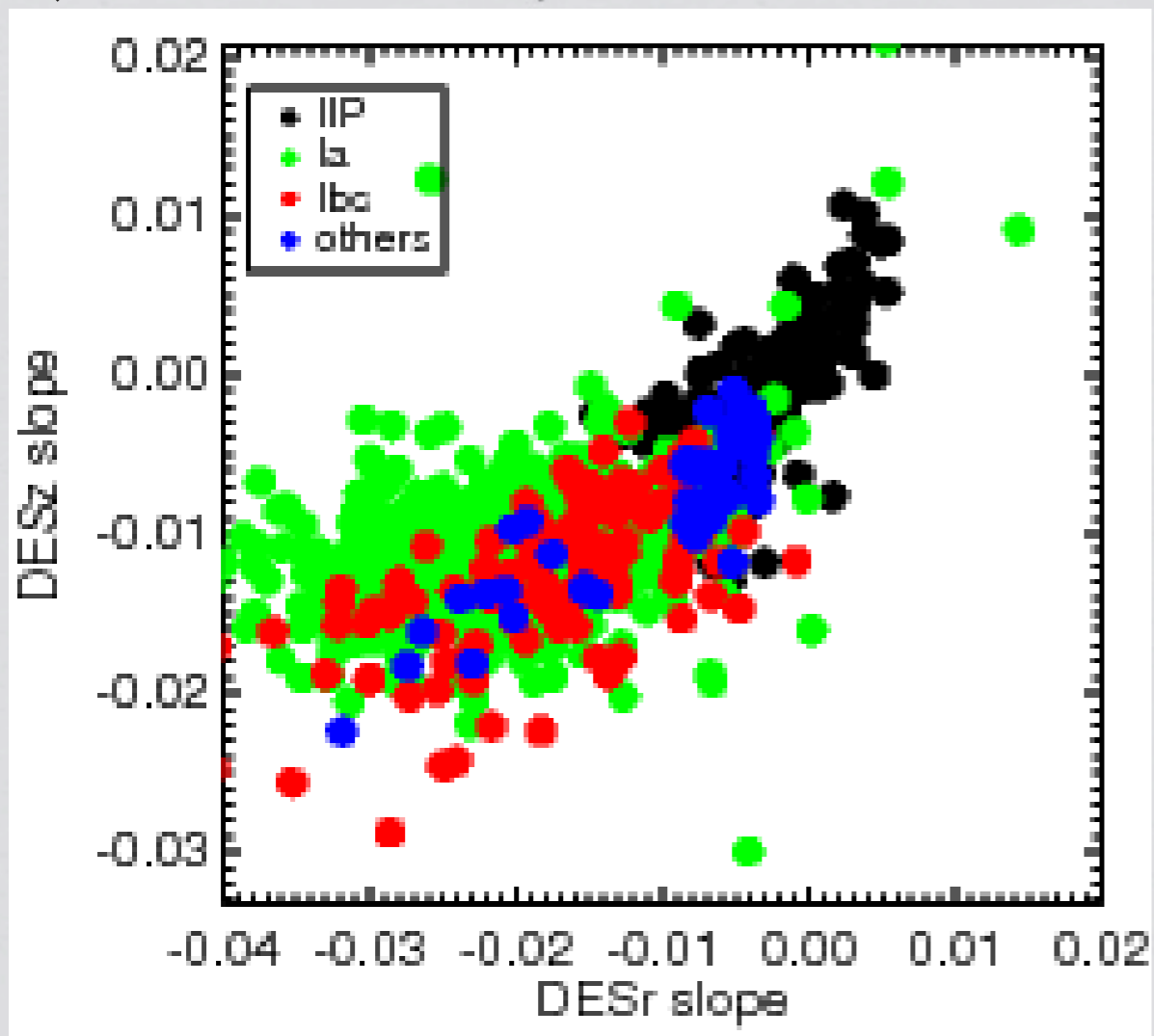
DES slope-slope, flux-flux

DES slope-slope, flux-flux

IIP regions

DES slope-slope, flux-flux

IIP regions
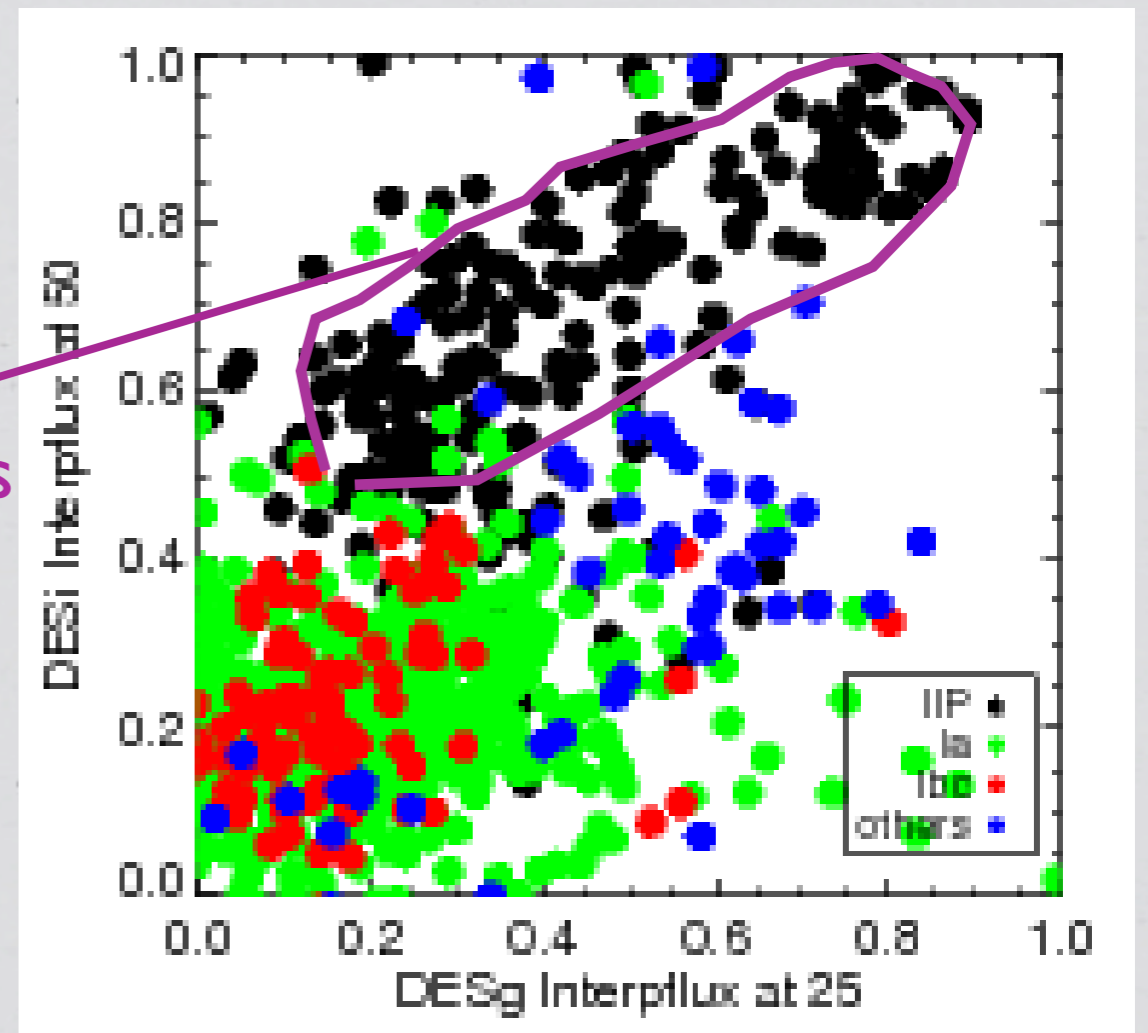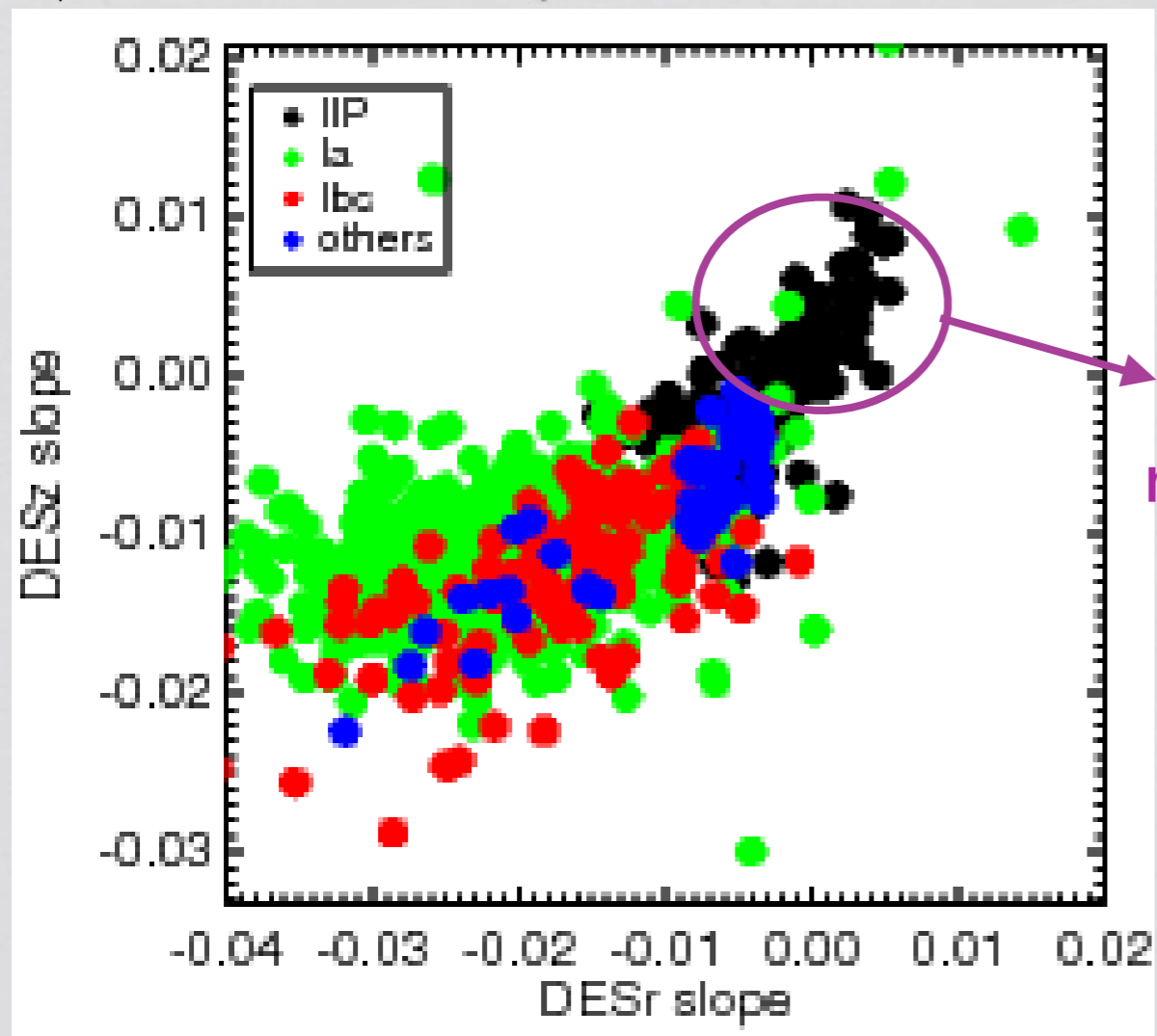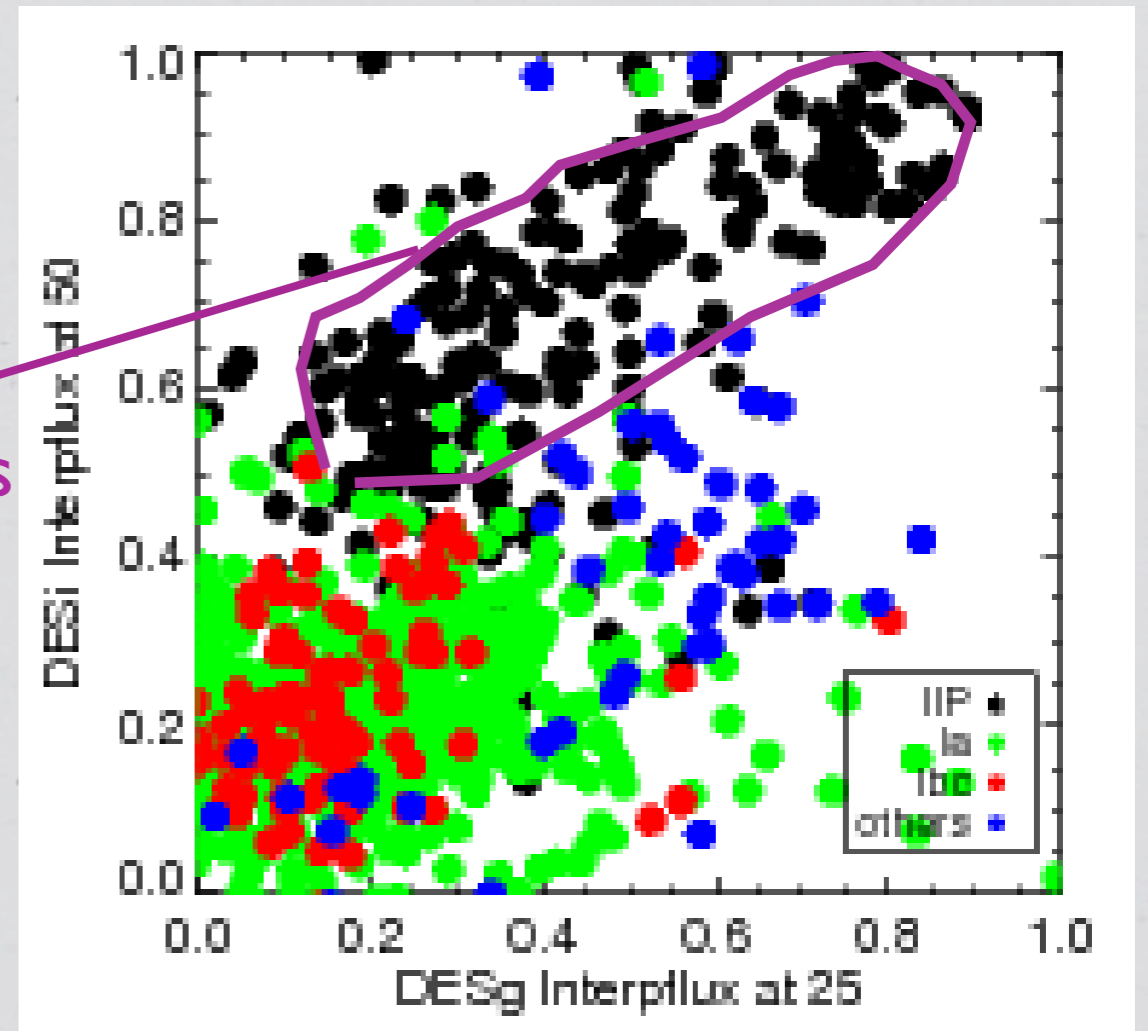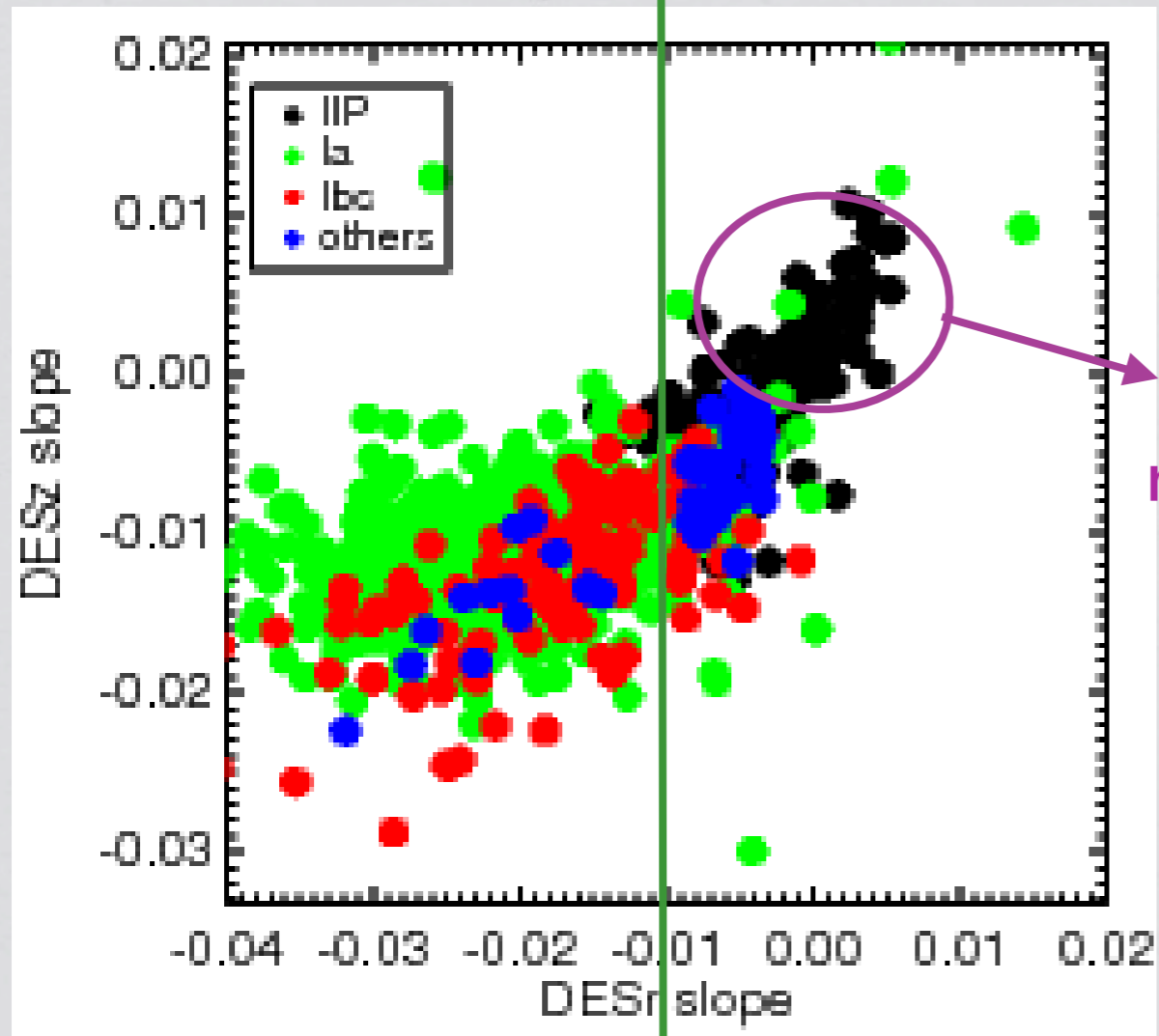
Ia, Ibc, IIL easy to separate

DES slope-slope, flux-flux

IIP regions
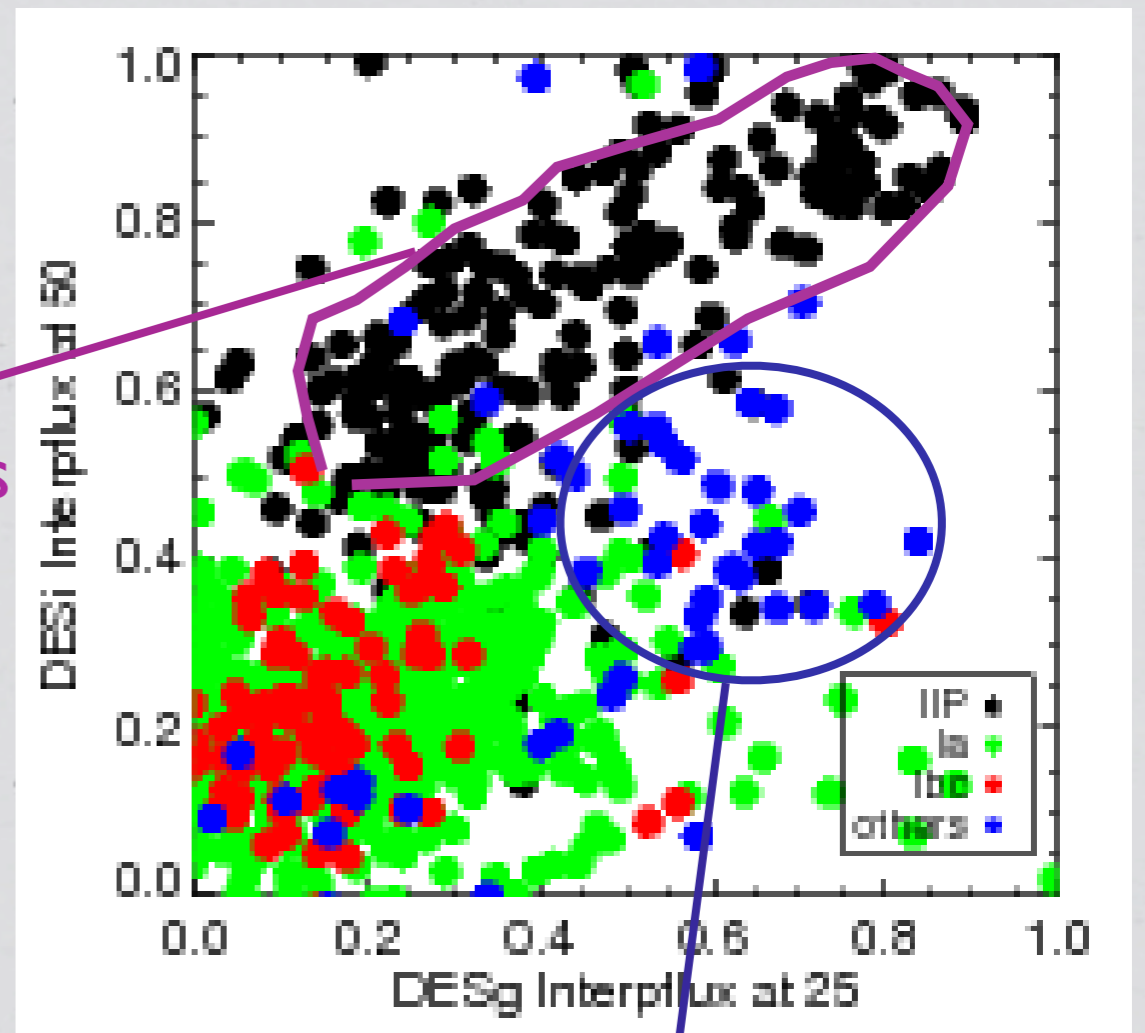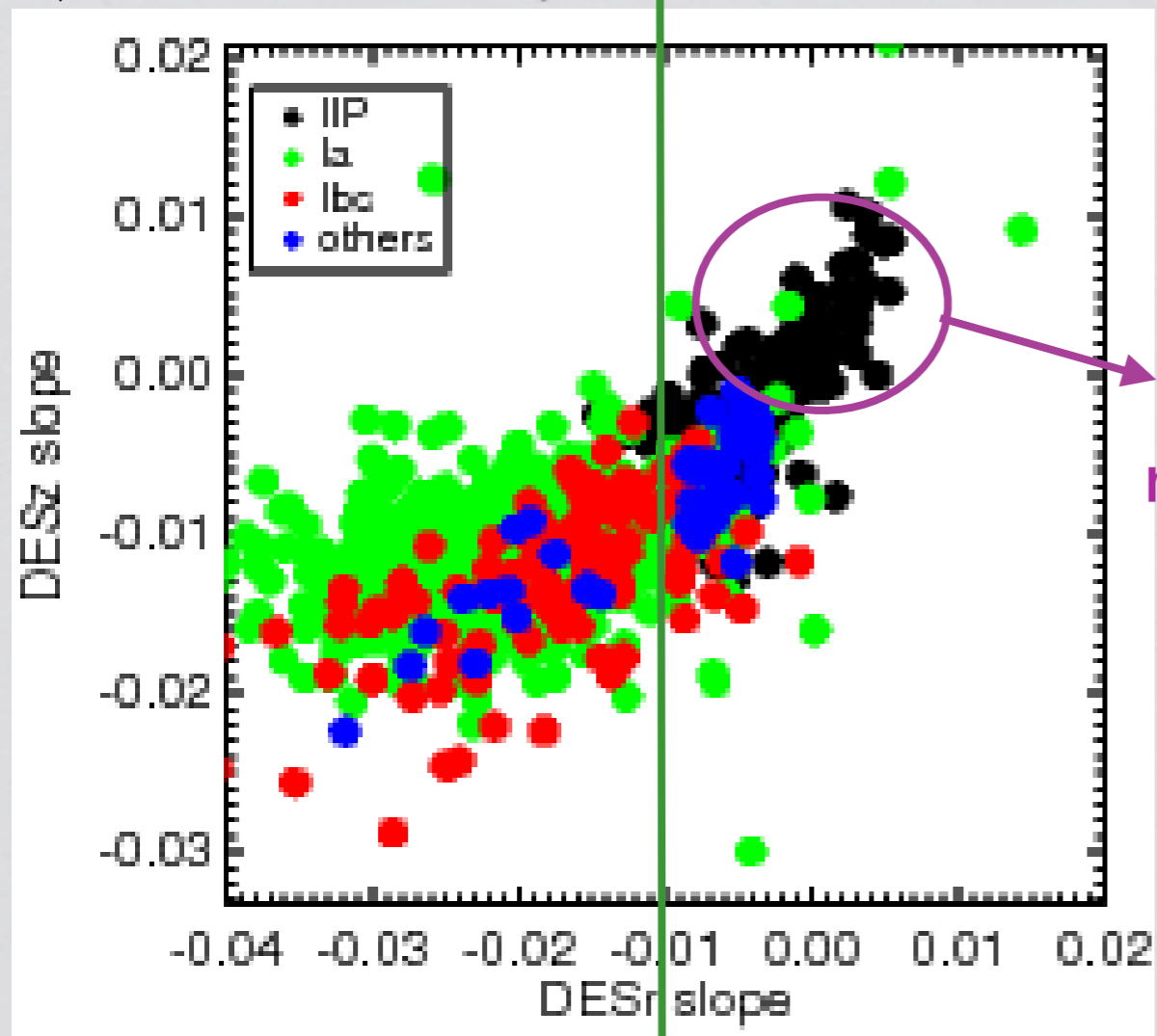
IIn regions

Ia, Ibc, IIL easy to separate

Continuous probabilities

* Based on slope-slope and flux-slope regions and 2D-histograms: 0-1 probabilities of being a IIP, Ia, Ibc and II are given to each object

* Highest summed probability of all contour regions determines the most probable type
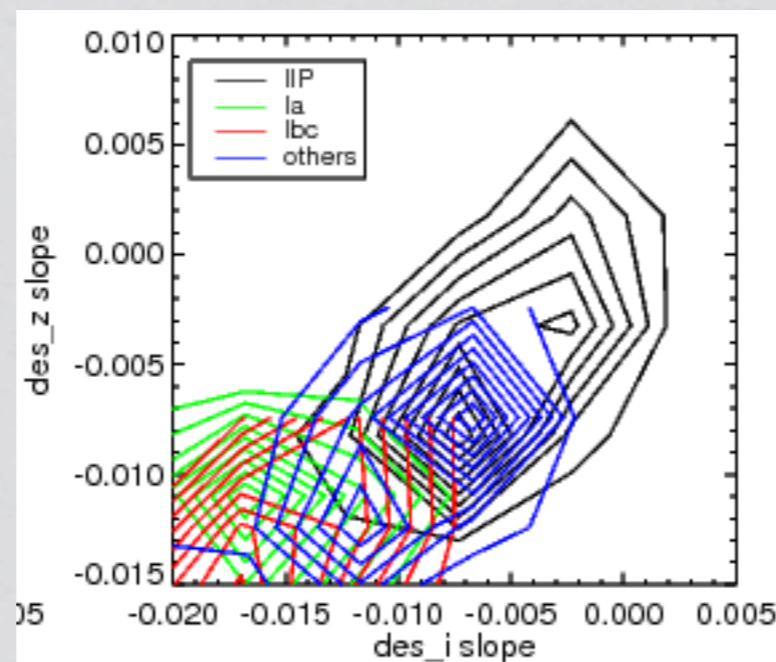
How good is it?
Efficiencies & Purities

$$\text{Efficiency} = \frac{N_{\text{IIP}}^{\text{tag}}}{N_{\text{IIP}}} \qquad\qquad \text{Purity} = \frac{N_{\text{IIP}}^{\text{true}}}{N_{\text{IIP}}^{\text{true}} + N_{\text{IIP}}^{\text{false}}}$$

SAMPLE	N_{IIP}	N_{cont}	Efficiency	Purity
Low-z	37	135	0.84	0.94
SDSS	33	99	0.97	1.00
SNLS	12	38	0.83	0.92
DES-challenge (spec-z)	8637(236)	9678(1043)	0.18(0.57)	0.88(0.94)
DES-challenge with host-z (spec-z)	8643(218)	9710(1038)	0.21(0.69)	0.90(0.92)
DES-post-mortem	8637	9678	0.71	0.78
DES-post-mortem with host-z	8643	9710	0.67	0.83

Purity can be made better at cost of efficiency
(IIn need to be further separated)

Post-mortem: after the SN challenge results

DES efficiencies/purities
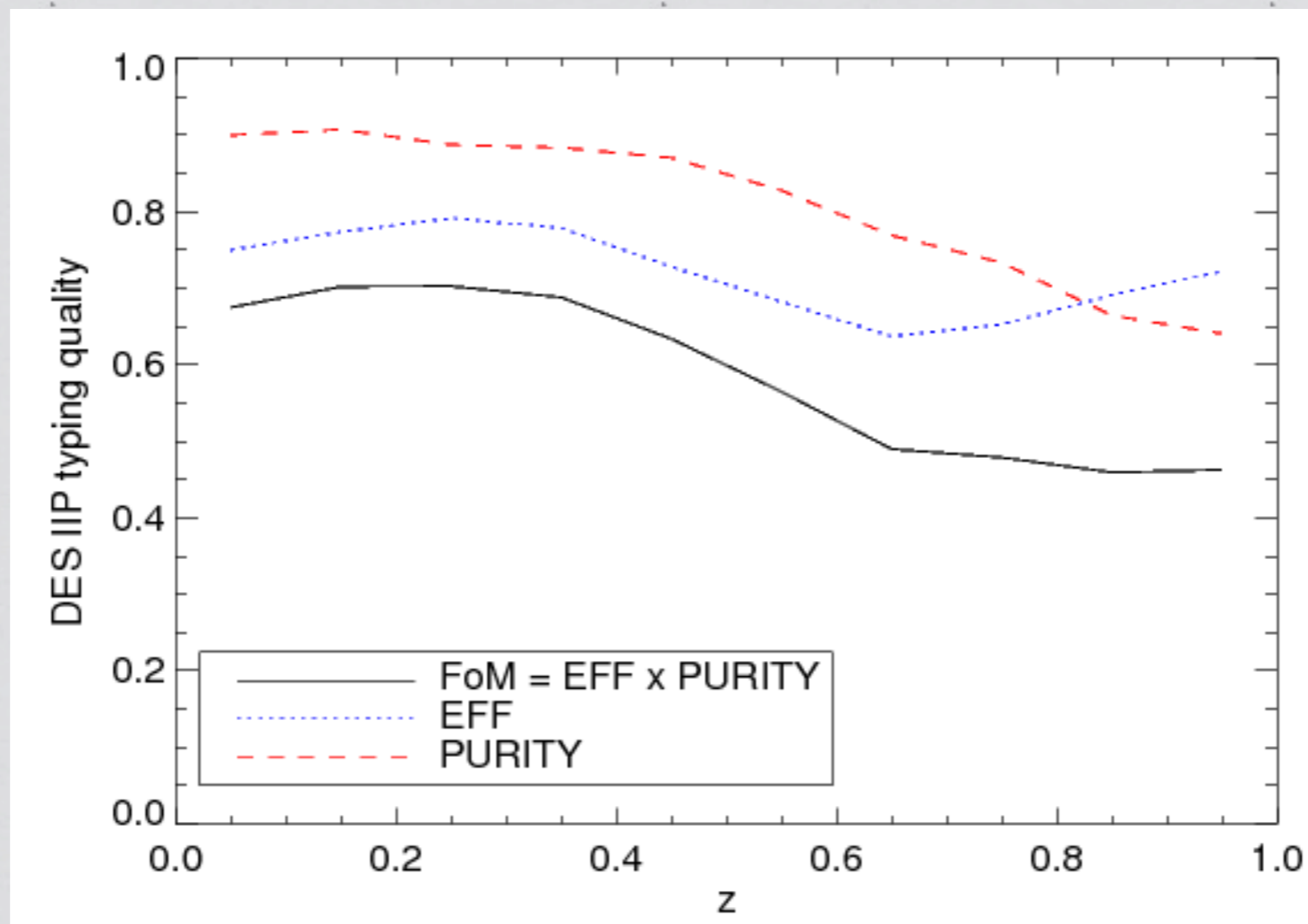
no host

post-mortem

Summary and future work

* Good IIP typing technique: purely photometric, fast, no need of templates

* Works for a variety of SN surveys and redshifts

* Works almost as good without redshift information

* IIn - IIP need to be further disentangle: use of only specific slope-slope regions

* Serves also to identify general II type

* Use to identify IIP in SNLS (rates)

Backup slides

DES efficiencies/purities
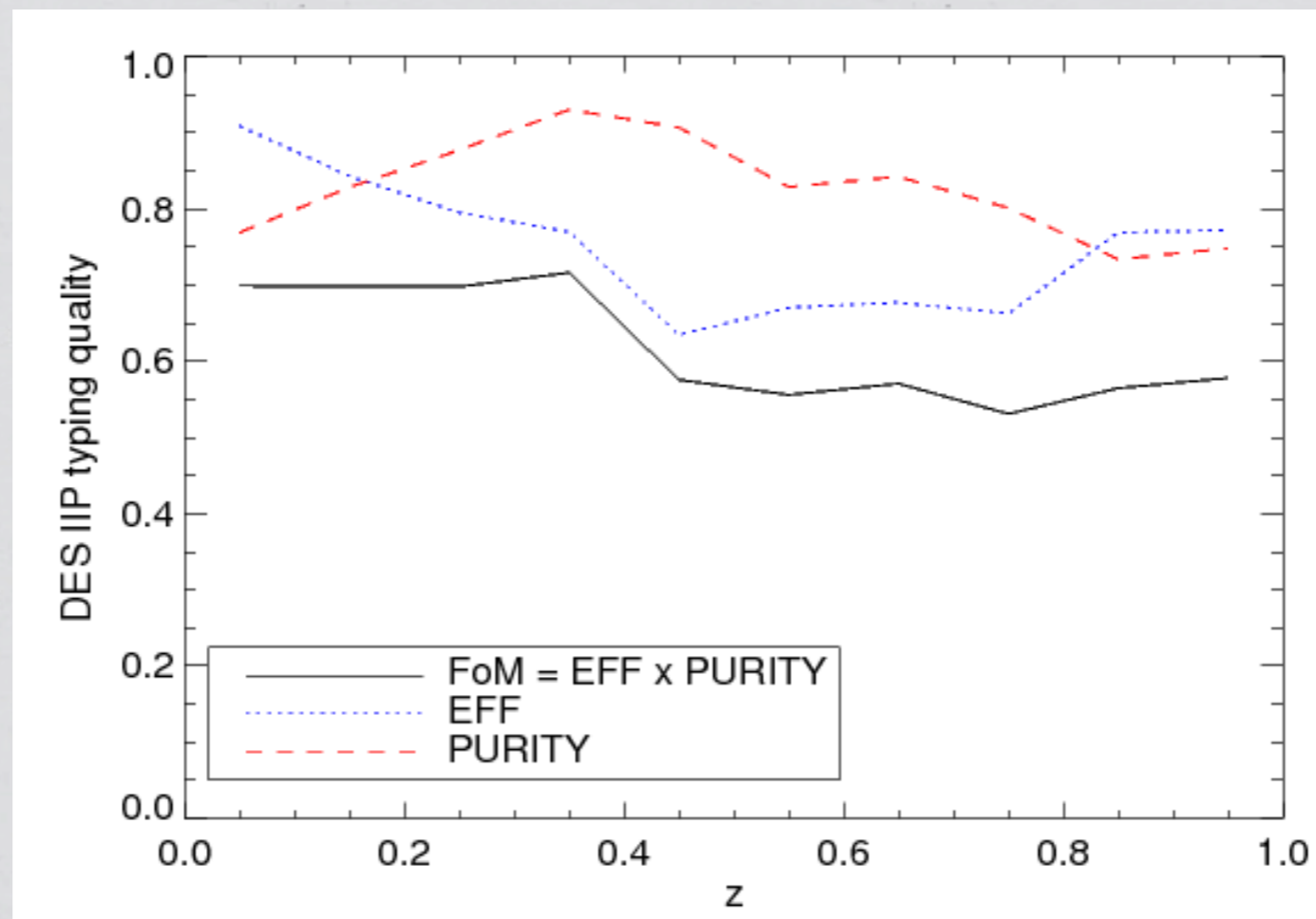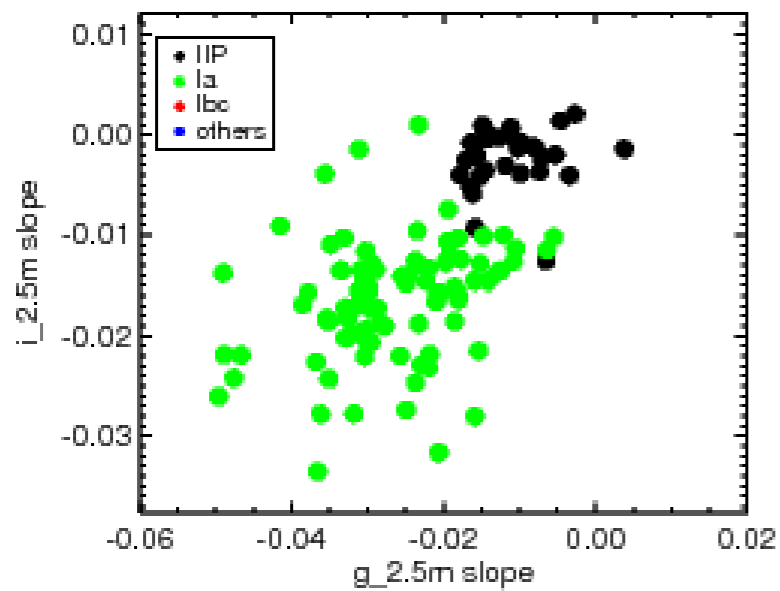

host: using (1+z)t

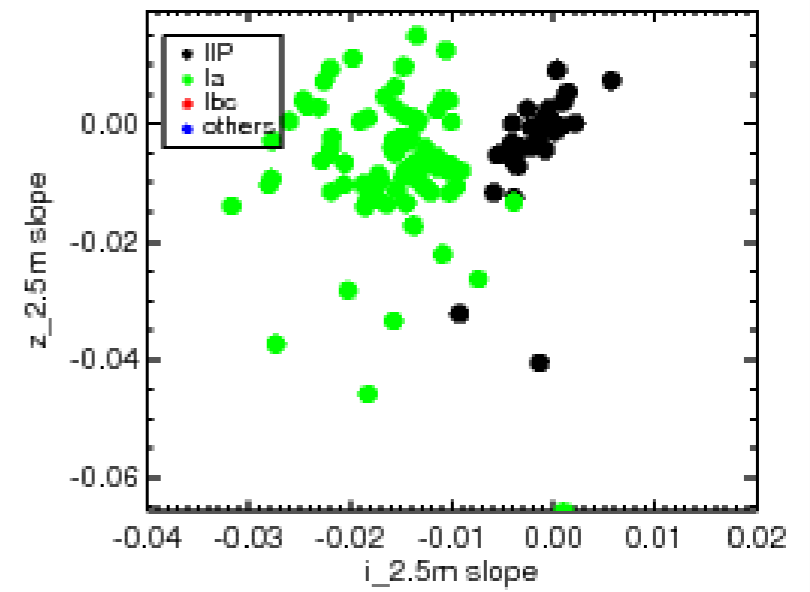*post-mortem*

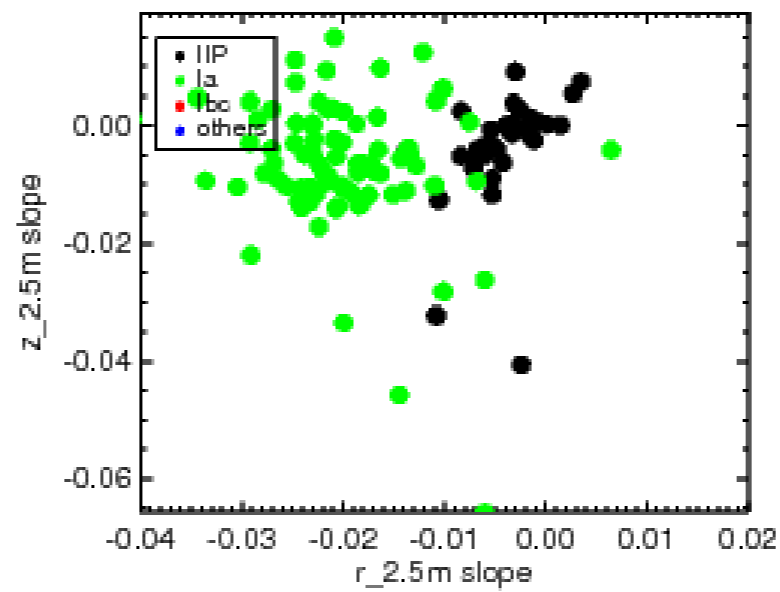# Non tag SNe IIP examples
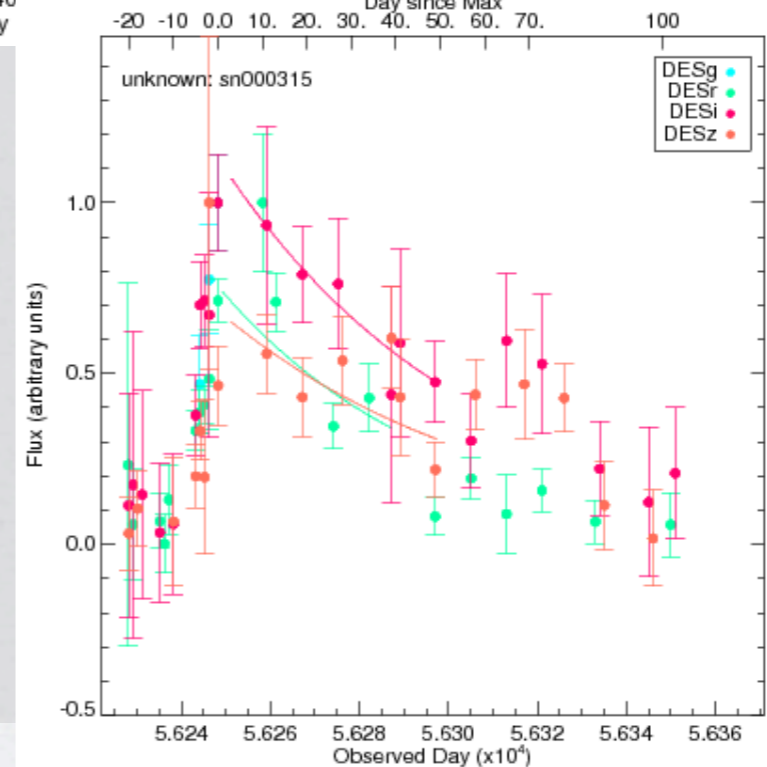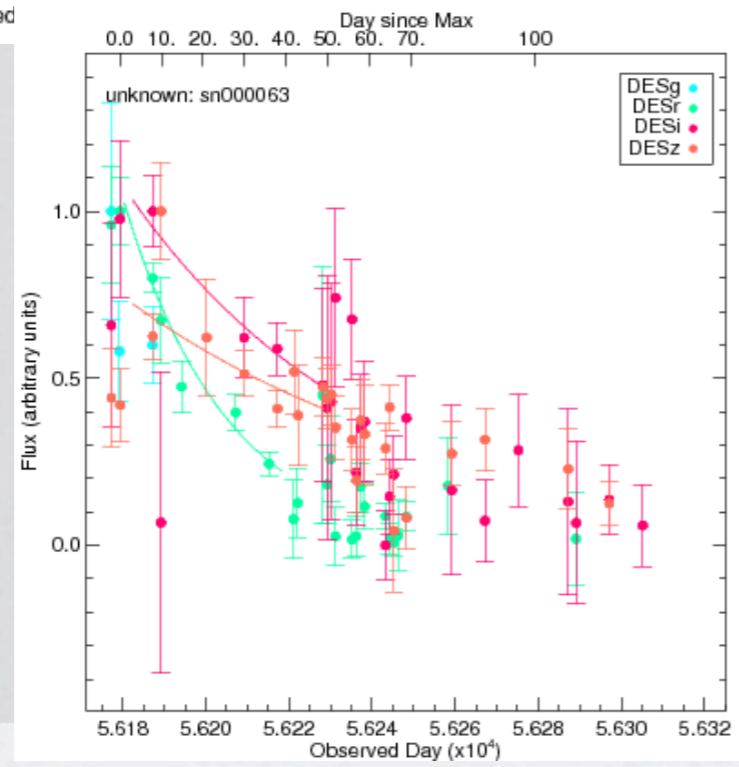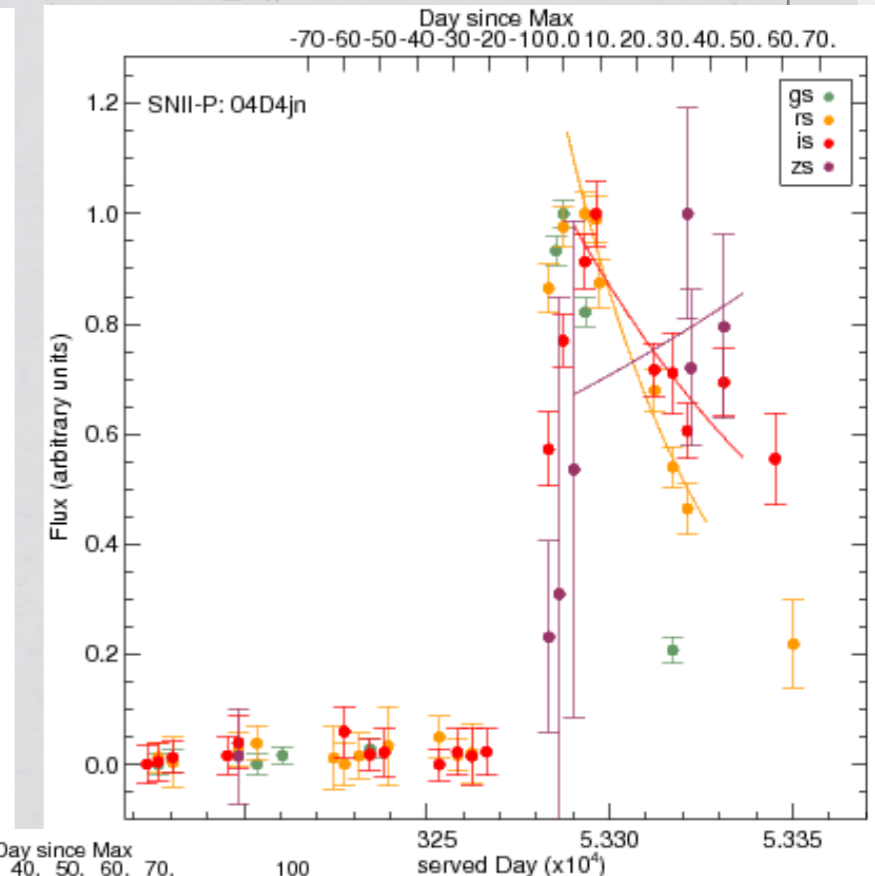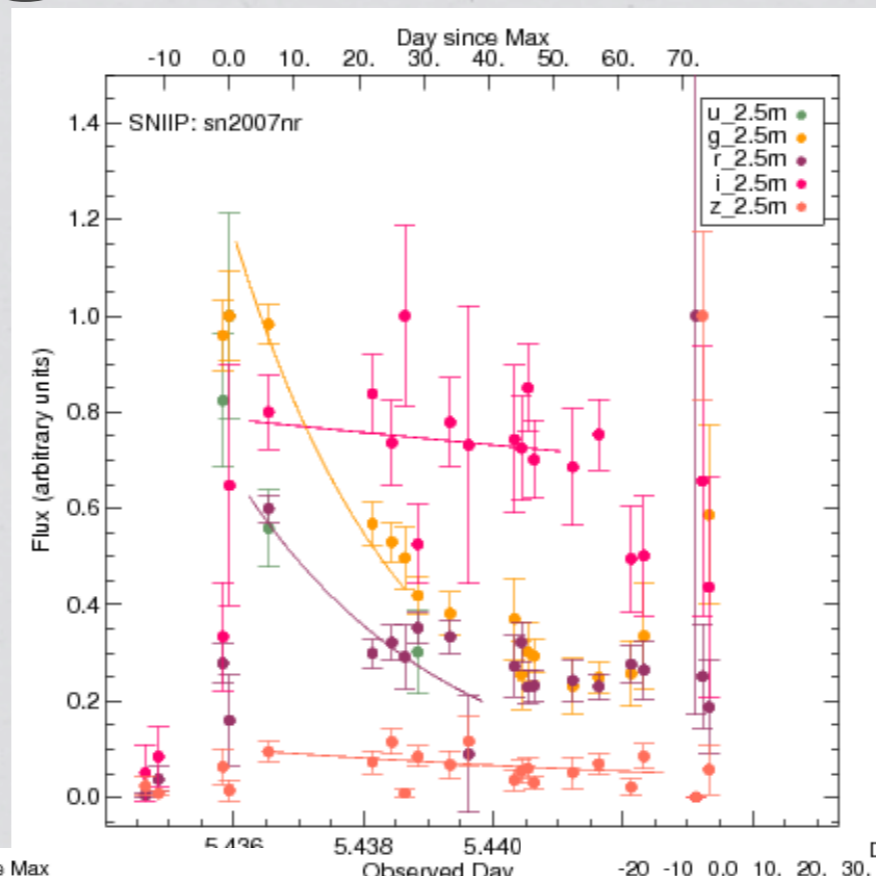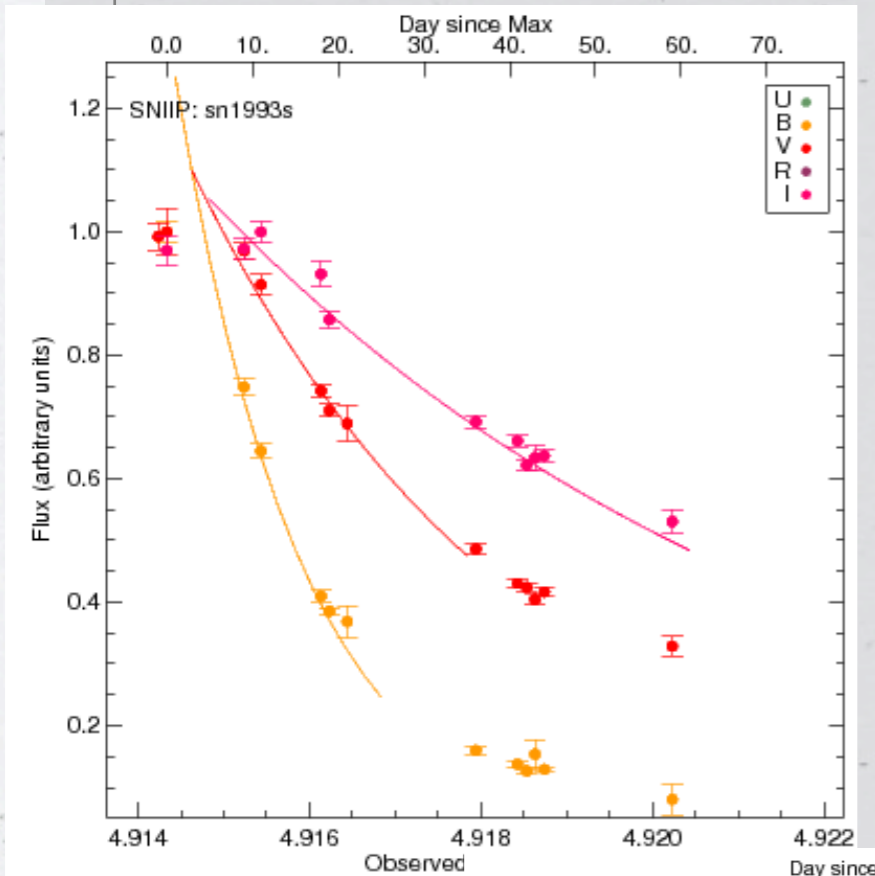
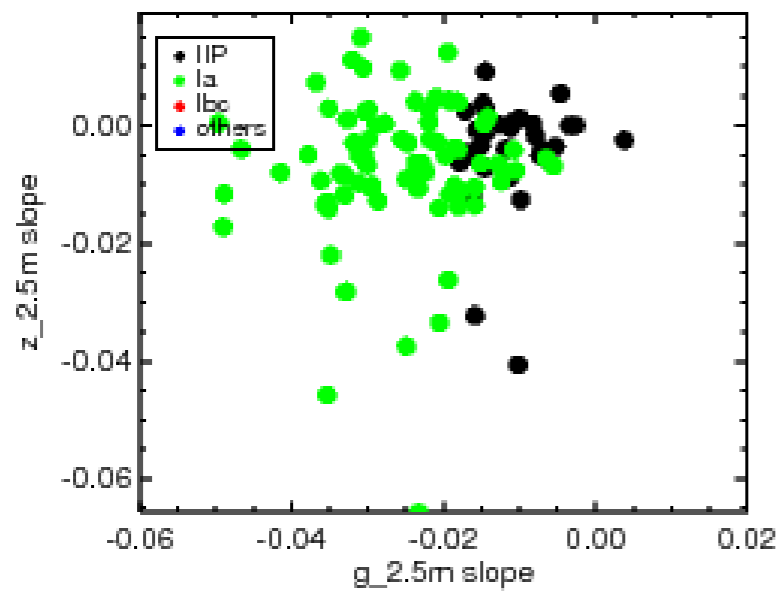# False tag SNe IIP examples
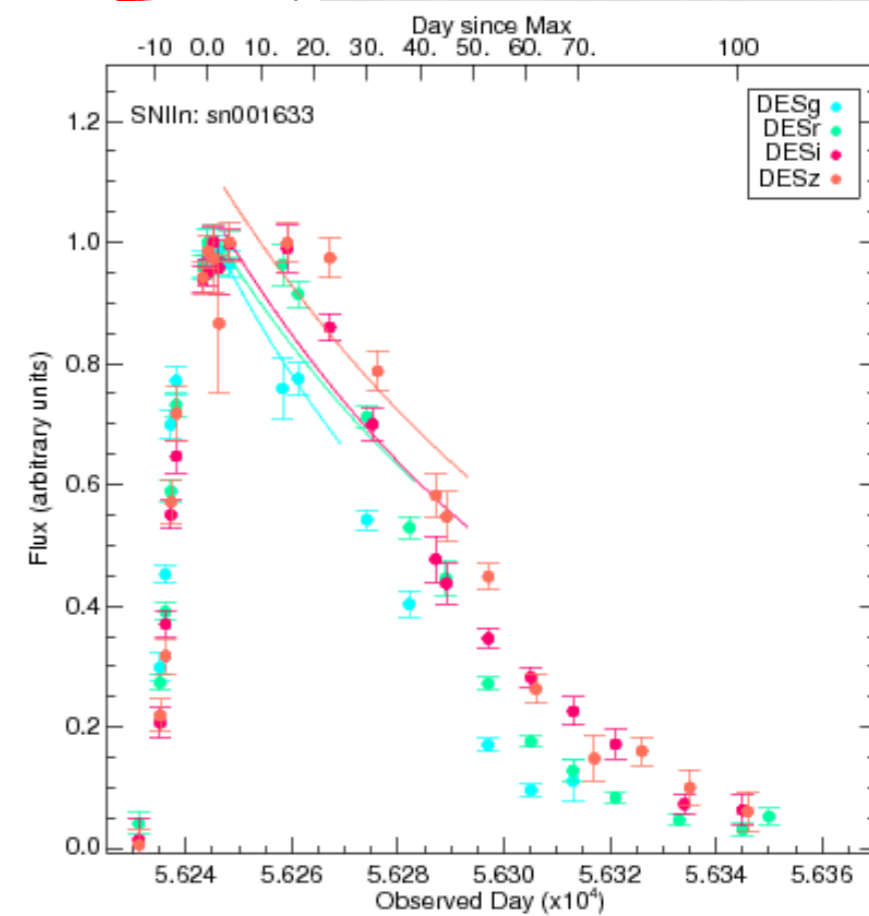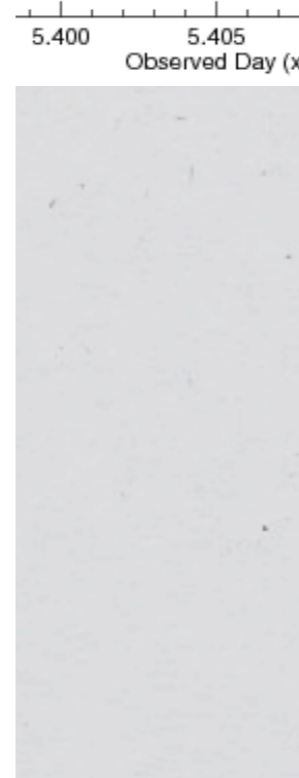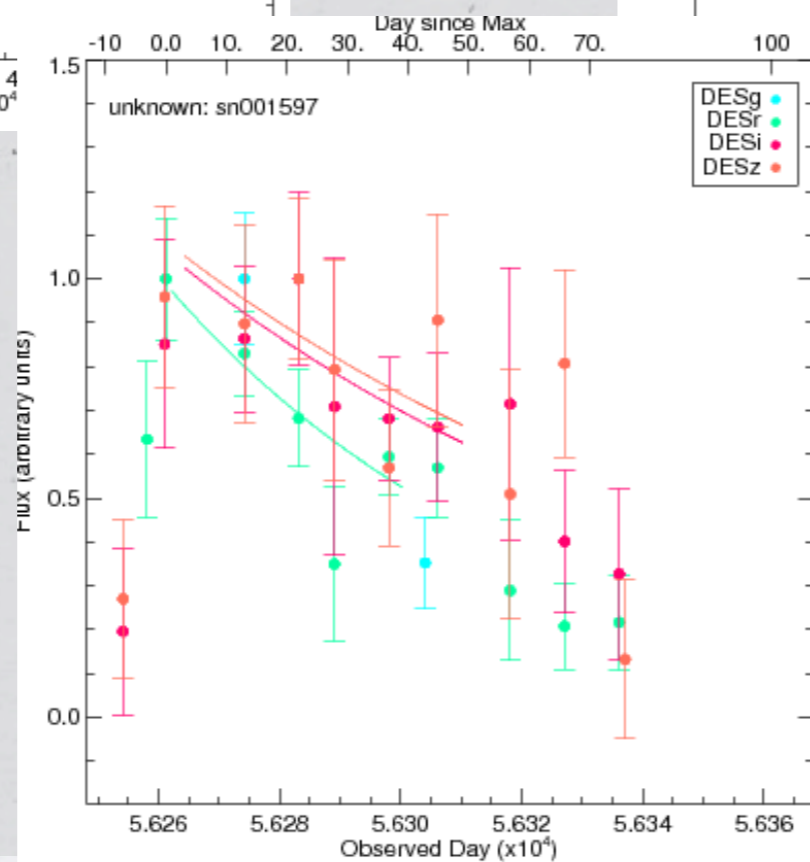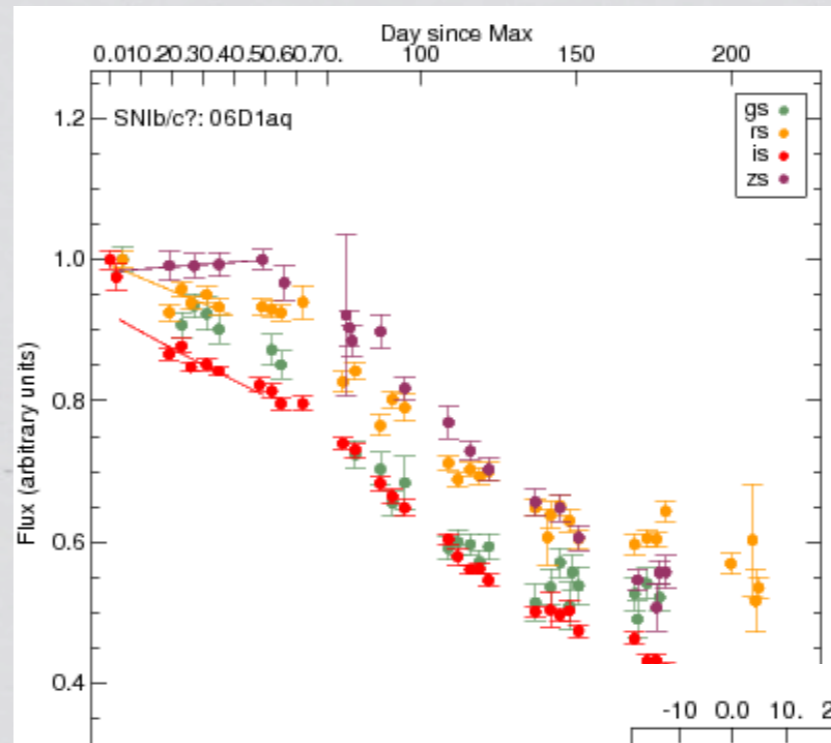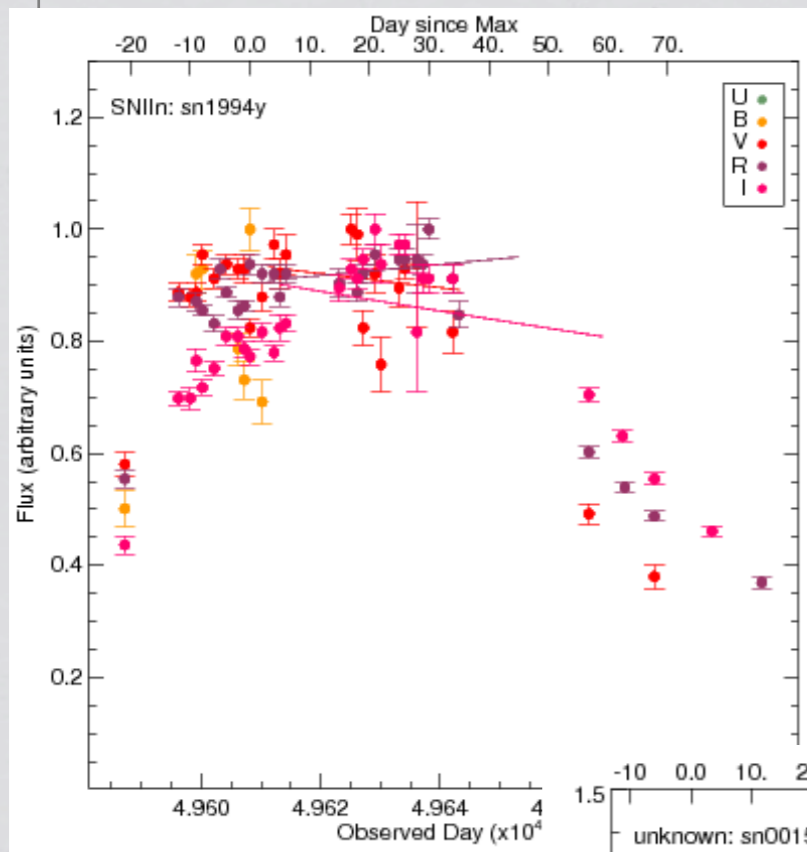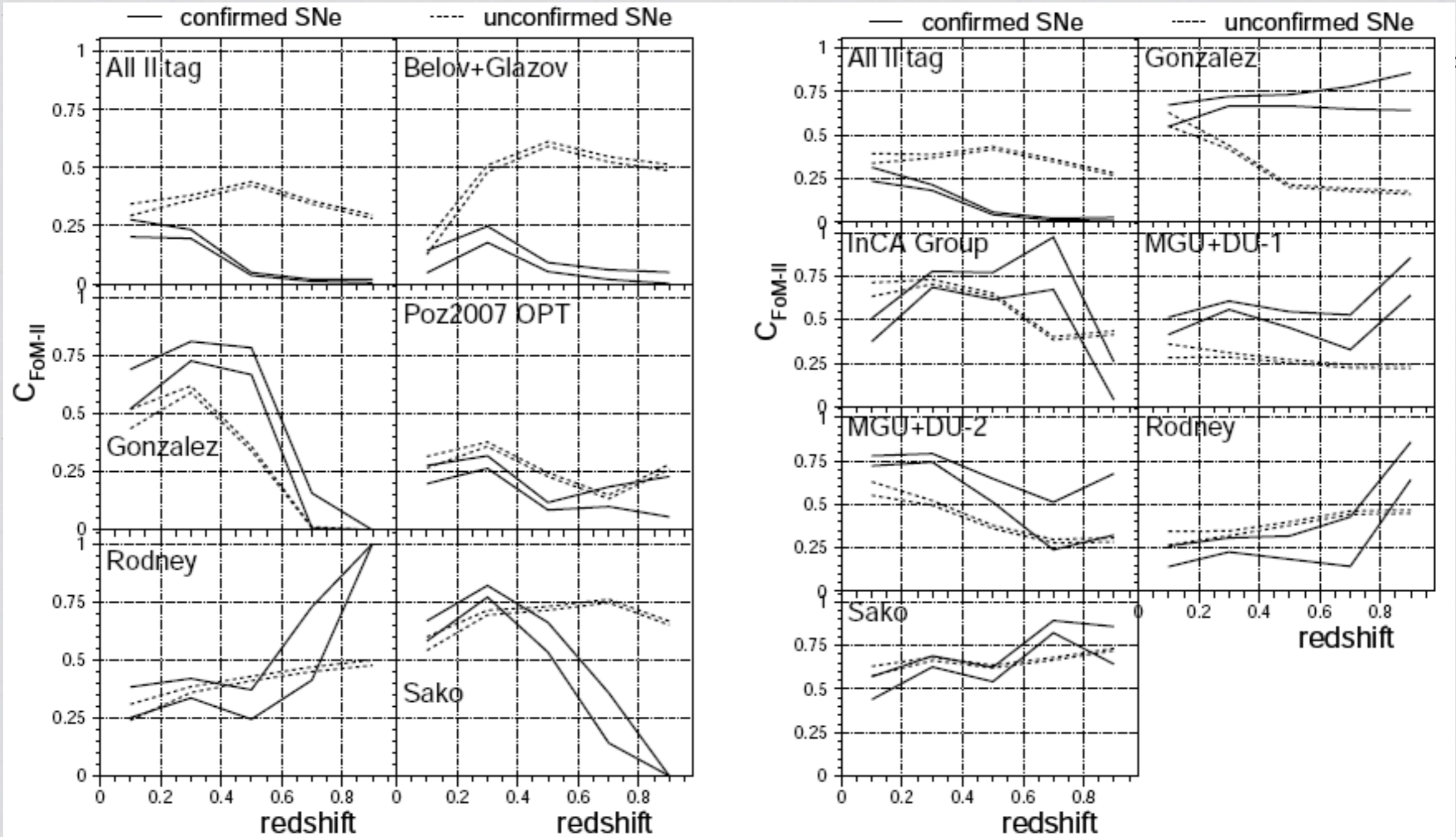
Low-z slope-slope regions
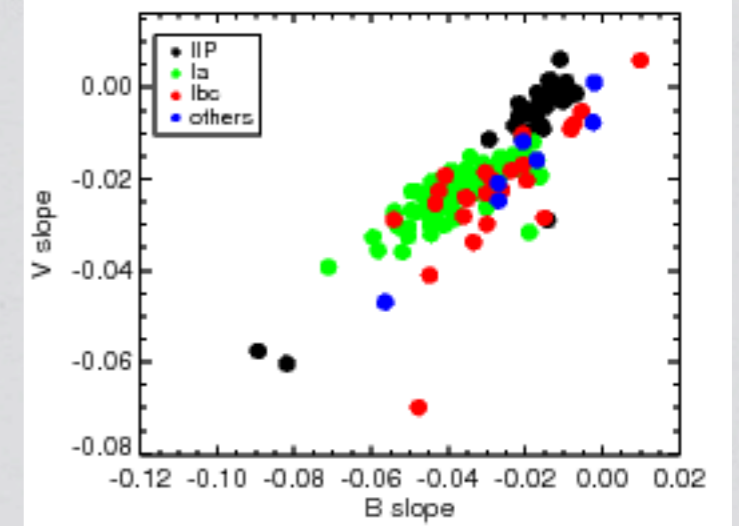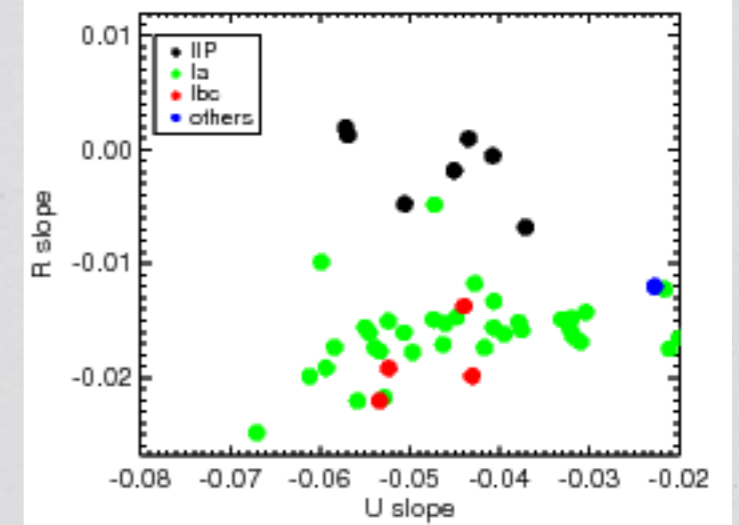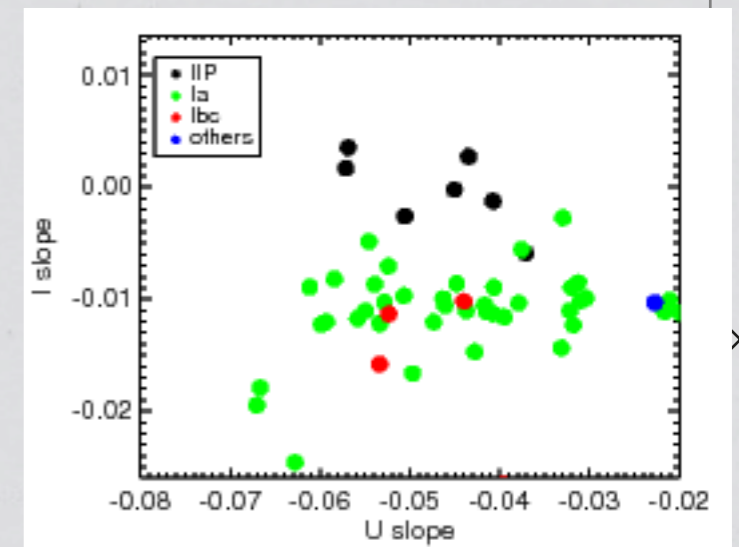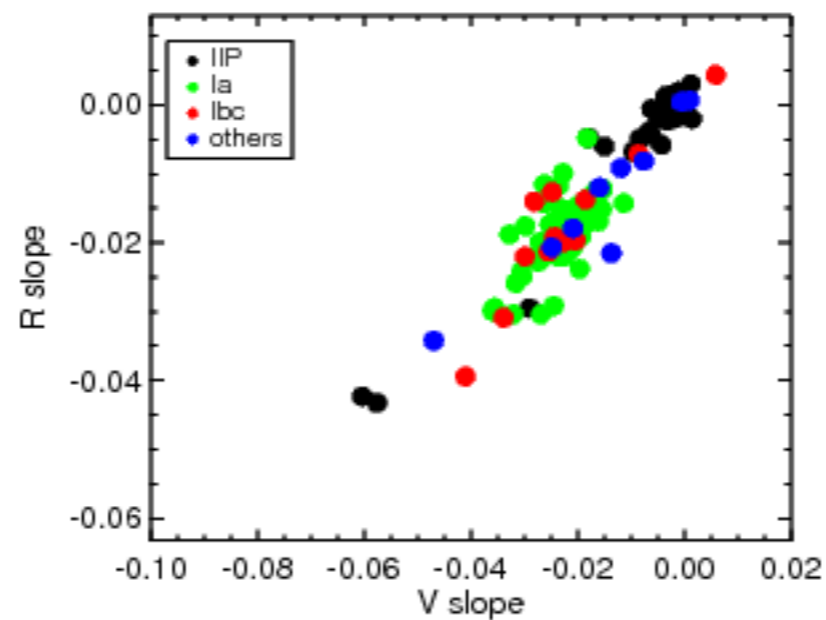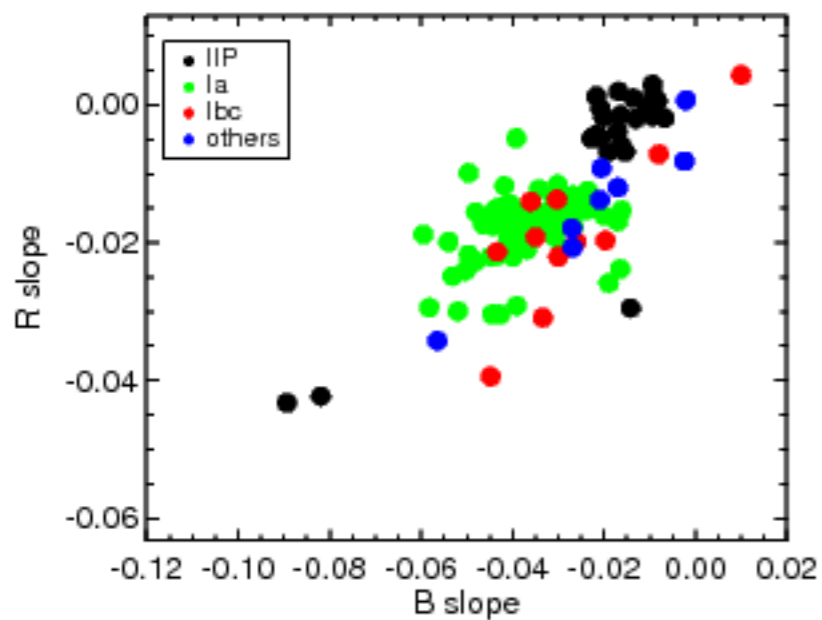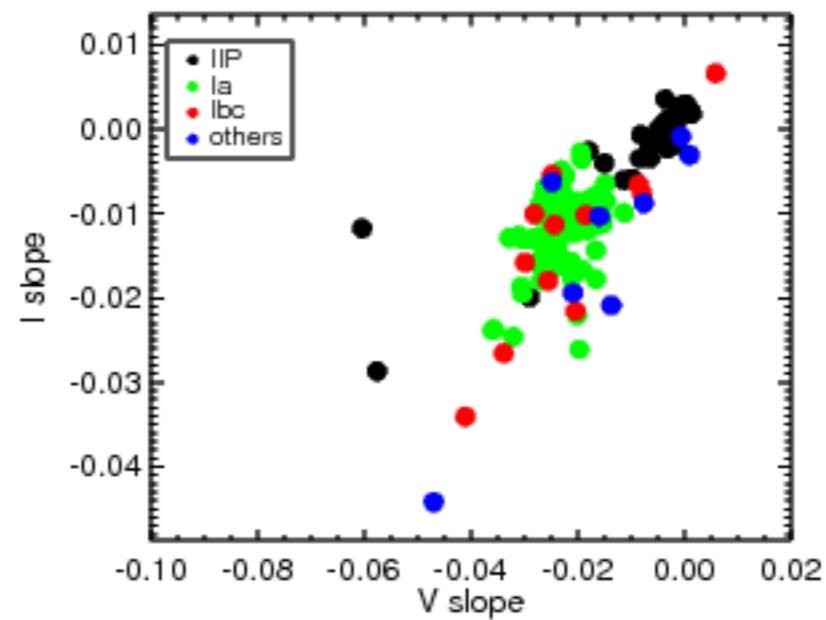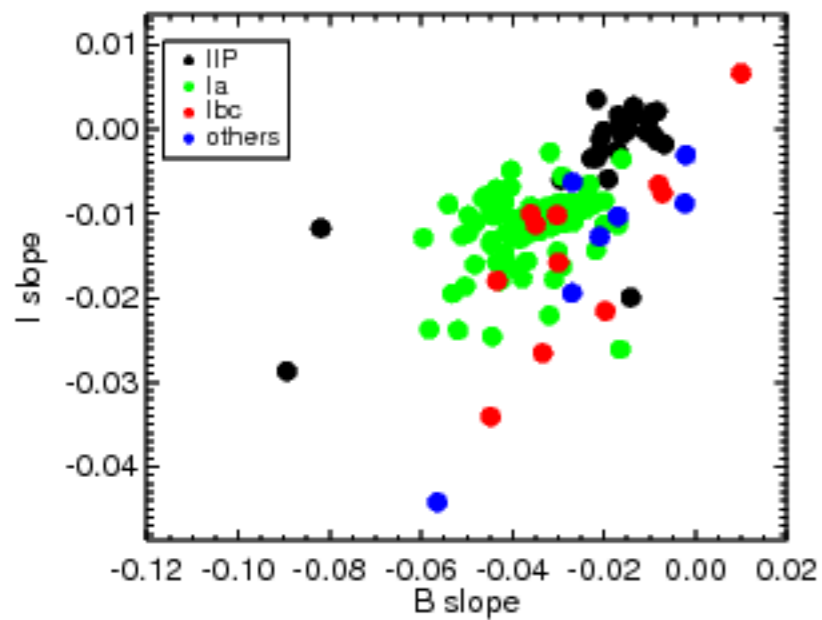
SNLS flux-flux/slope-flux regions
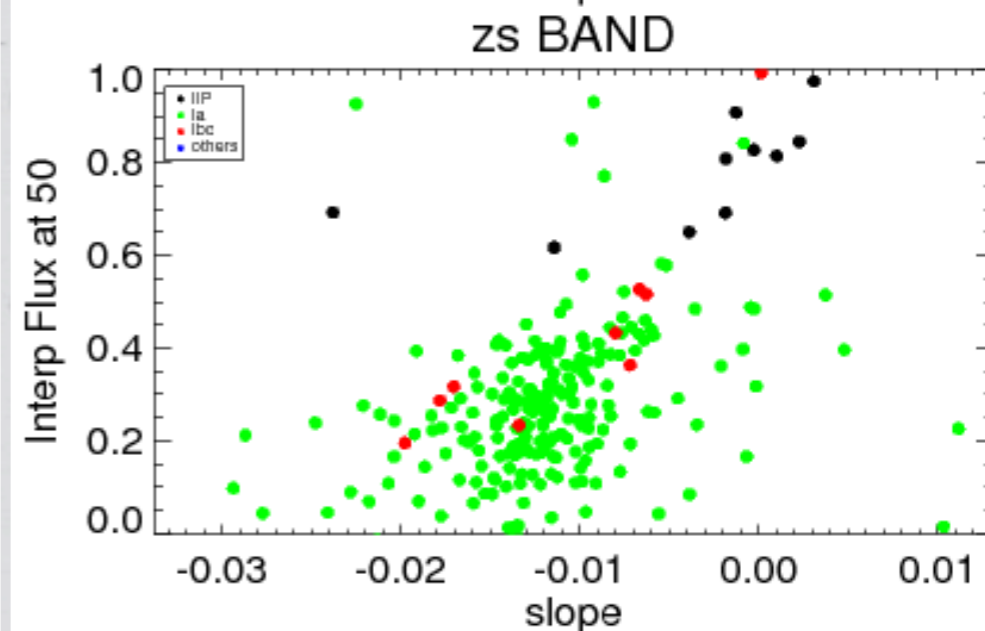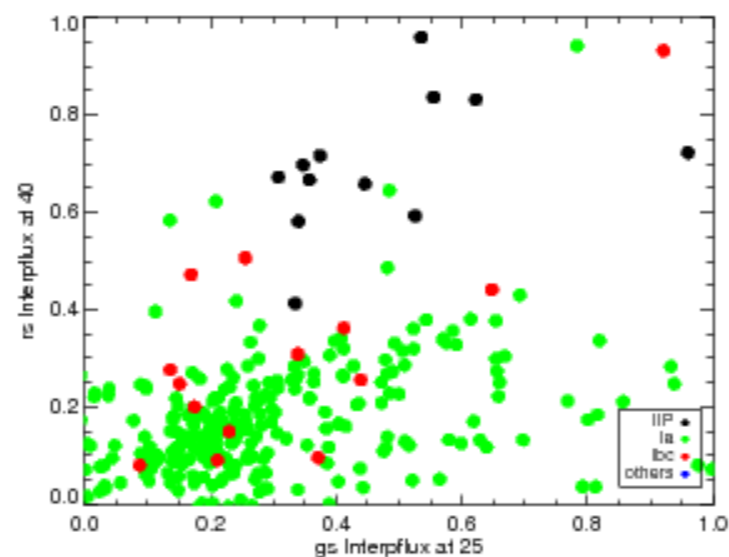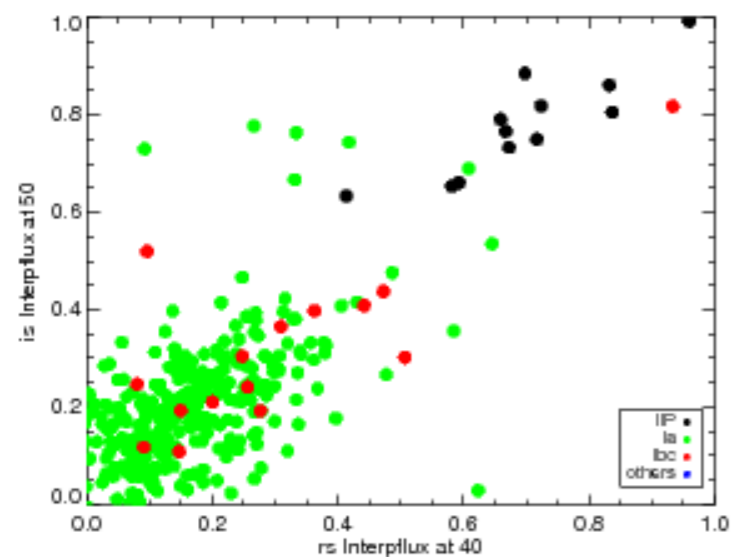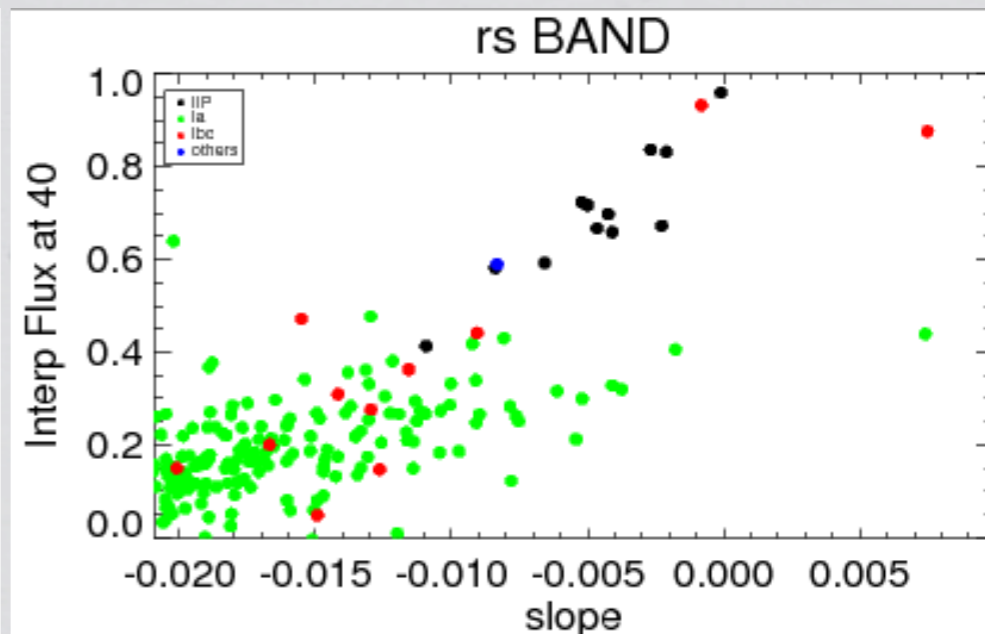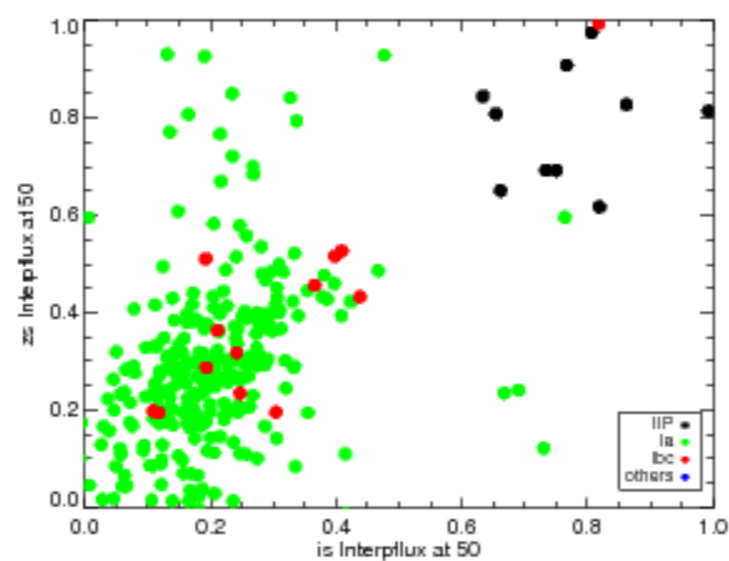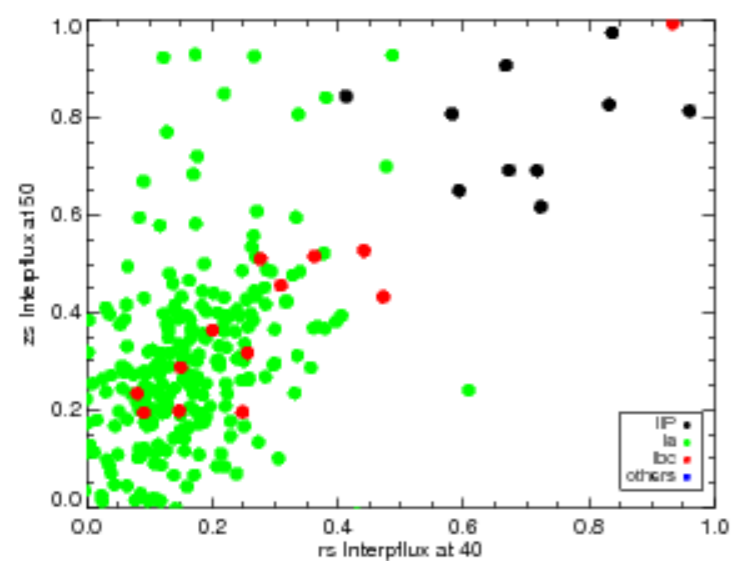
SDSS Slope-slope

DES challenge results

Kessler et al. 2010