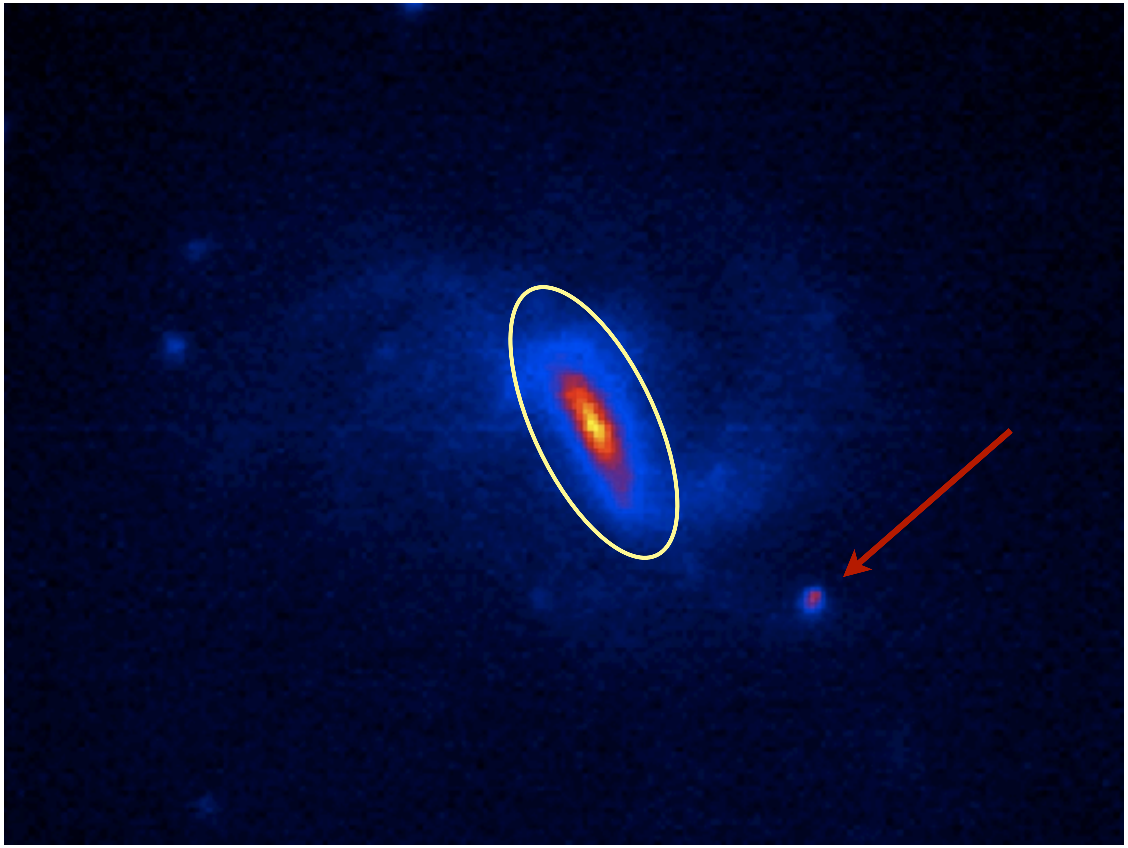
Using the environment to understand SNe properties

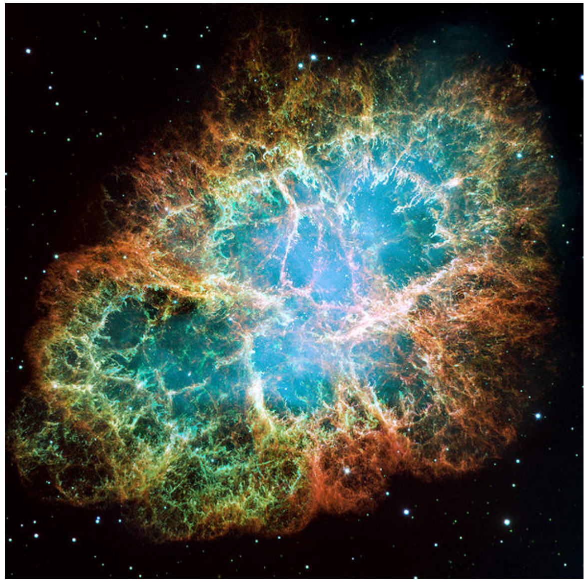
Lluís Galbany
CENTRA-IST, UTL, Lisbon



CIEMAT, 23 January 2013

Supernovae

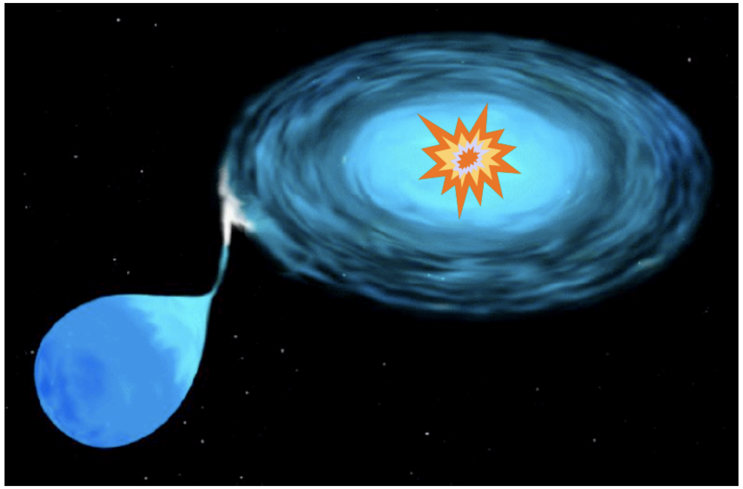
Crab nebula (SN1054)



- Stars that have reached the end of their lives in an explosion
- Two types of explosions:
  - *Core-collapse stars*: nuclear fuel exhausted, gravity not balanced, and the star collapses.
    - stellar evolution (progenitors)
  - *Thermonuclear explosions:* Low mass star that has evolved into a White Dwarf accretes mass from a companion until it reaches the Chandrasekhar mass ($M_{Ch}\sim 1.4\, M_{SUN}$)

    Details of explosion not well understood.

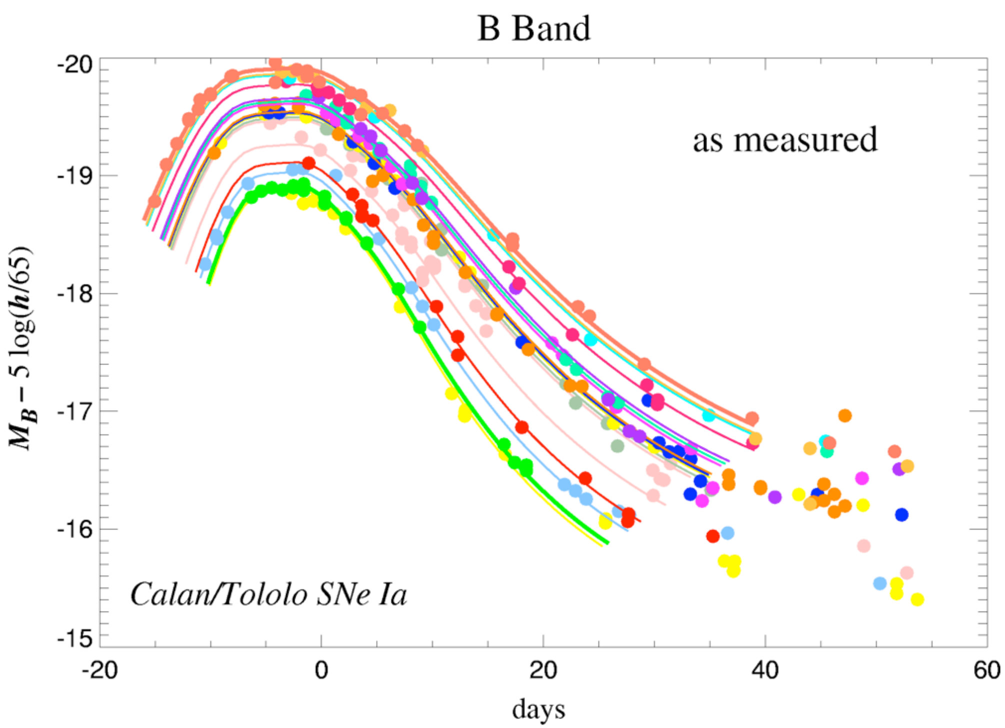
    Since the mass is fixed (M_{Ch}), they are expected to have similar absolute magnitudes, as well having homogeneous spectra and light curves



Type Ia SNe as standard candles

- Used as a cosmological probes because of their bright peak luminosities: useful distance indicators
- Thermonuclear explosions of ~1.4 M_{SUN} C/O White Dwarfs: similar peak luminosity and homogeneous light-curves (LC).

$$\mu(z) = m(z) - M = 25 + 5\log_{10} d_L(z) \qquad d_L = \frac{c}{H_0}(1+z)\int_0^z \frac{dz'}{\sqrt{\Omega_M(1+z')^3 + \Omega_\Lambda}}$$



- Different populations may be present:

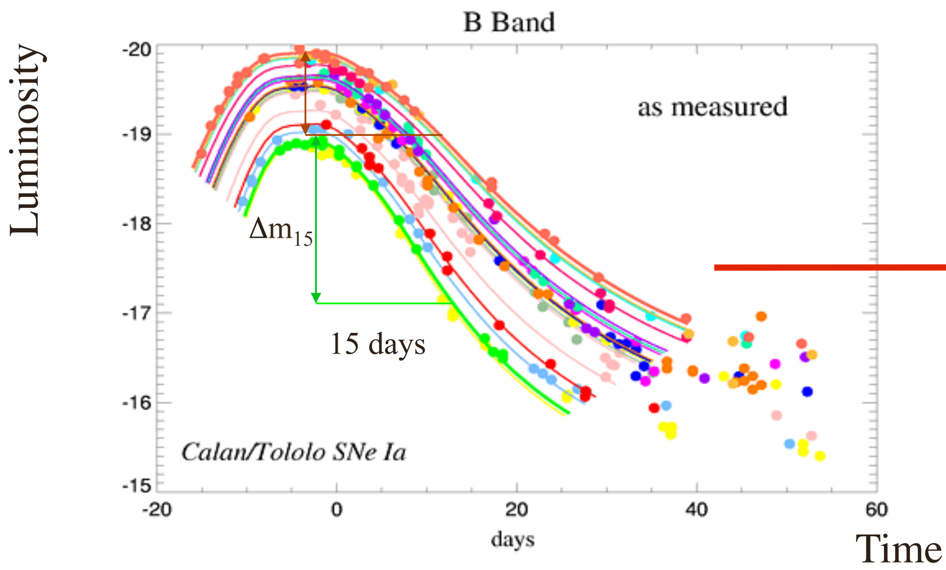
  2 channels: single degenerate (SD), double degenerate (DD)

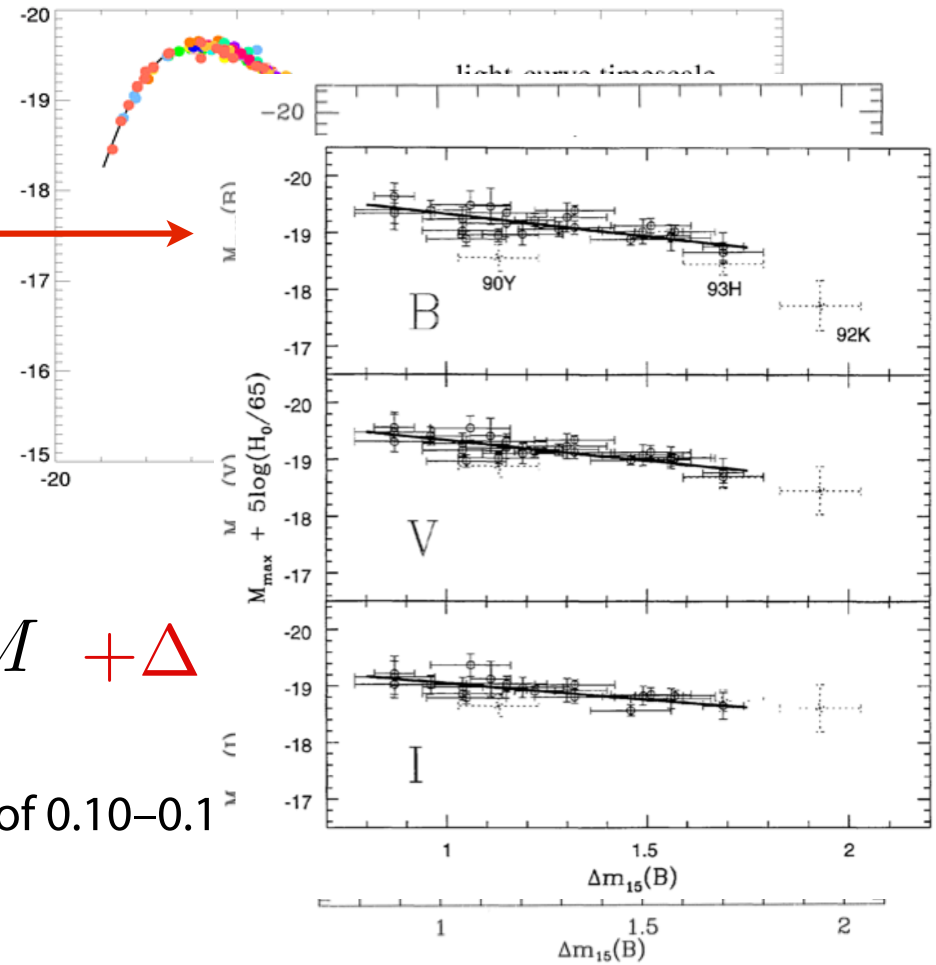
  Details of the physics of the explosion: deflagration, detonation, velocity of the burning front, rotation...

- Progenitors can be studied only indirectly

Type Ia SNe as standard(izable) candles

- Empirical correlation between the SN peak luminosity and LC decline rate (Phillips 1993).





$$\mu(z) = m(z) - M \quad +\Delta$$

- dispersion on their corrected peak magnitude of 0.10–0.1 precision of ~5%–7% in distance.

- Understanding systematic uncertainties in SN LC parameters can improve the determination of cosmological parameters

Second order corrections: Environment

Look for dependences of the SN properties on the host galaxy properties (focused on global characteristics of the host)

As they evolve with redshift, such dependences would impact the cosmological parameters

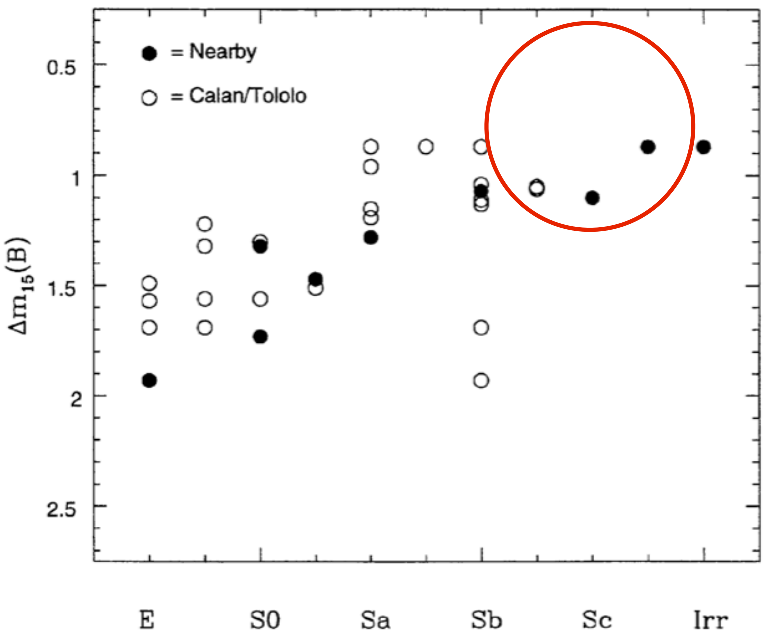
Hamuy et al. (1996)	Bright events occur preferentially in **young** stellar environments.
Hamuy et al. (2000)	Luminous SNe are produced in **metal-poor** neighborhoods
Gallagher et al. (2005)	**Age** is more likely to be the source of LC variability than **metallicity**
Sullivan et al. (2006)	Brighter events are found in systems with ongoing **star-formation**
Gallagher et al. (2008)	**Progenitor age** primarily determines the peak luminosity
Hicken et al. (2009)	SN Ia in **spiral** hosts are intrinsically fainter *(after LC-corr)*
Howell et al. (2009)	**more massive** progenitors give rise to less luminous explosions
Neil et al. (2009)	**Older** hosts produce less-extincted SNe Ia
Brandt et al. (2010)	Luminous SNe associated with recent **star-formation** and **young** prog.
Cooper et al. (2010)	SNIa are more luminous or more numerous in **metal-poor** galaxies
Sullivan et al. (2010)	SNIa are brighter in **massive** hosts (metal-rich) and with low **SFR** *(after LC-corr)*
Kelly et al. (2010)	SN Ia in physically **larger**, more **massive** hosts are ~10% brighter
Lampeitl et al. (2010)	introduce the stellar **mass** of the host in the parametrization
D'Andrea et al. (2011)	SNe are 0.1 mag brighter in **high-metallicity** hosts after corr.
Gupta et al. (2011)	**older** galaxies host SNe Ia that are brighter
Nordin et al (2011)	**passive** and **massive** galaxies host faint SNe
Konishi et al. (2011)	SNe in **metal-rich** hosts become brighter after corrections
Smith et al. (2012)	SNe rate is higher in **star-forming** galaxies

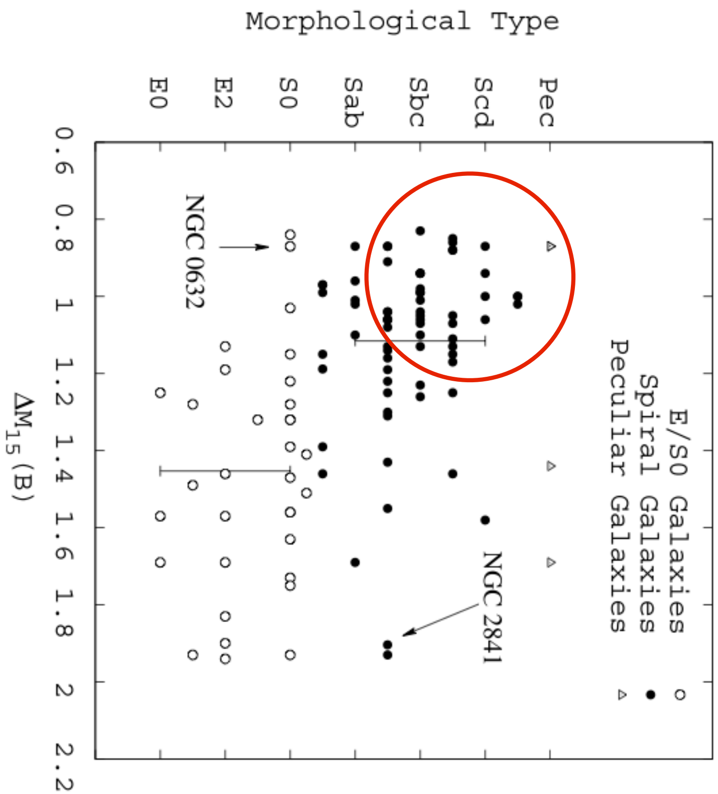
Second order corrections: Environment

Look for dependences of the SN properties on the host galaxy properties (focused on global characteristics of the host)

As they evolve with redshift, such dependences would impact the cosmological parameters

Hamuy et al. (1996)
Hamuy et al. (2000)
Gallagher et al. (2005)
Sullivan et al. (2006)
Gallagher et al. (2008)
Hicken et al. (2009)
Howell et al. (2009)
Neil et al. (2009)
Brandt et al. (2010)
Cooper et al. (2010)
Sullivan et al. (2010)
Kelly et al. (2010)
Lampeitl et al. (2010)
D'Andrea et al. (2011)
Gupta et al. (2011)
Nordin et al (2011)
Konishi et al. (2011)
Smith et al. (2012)





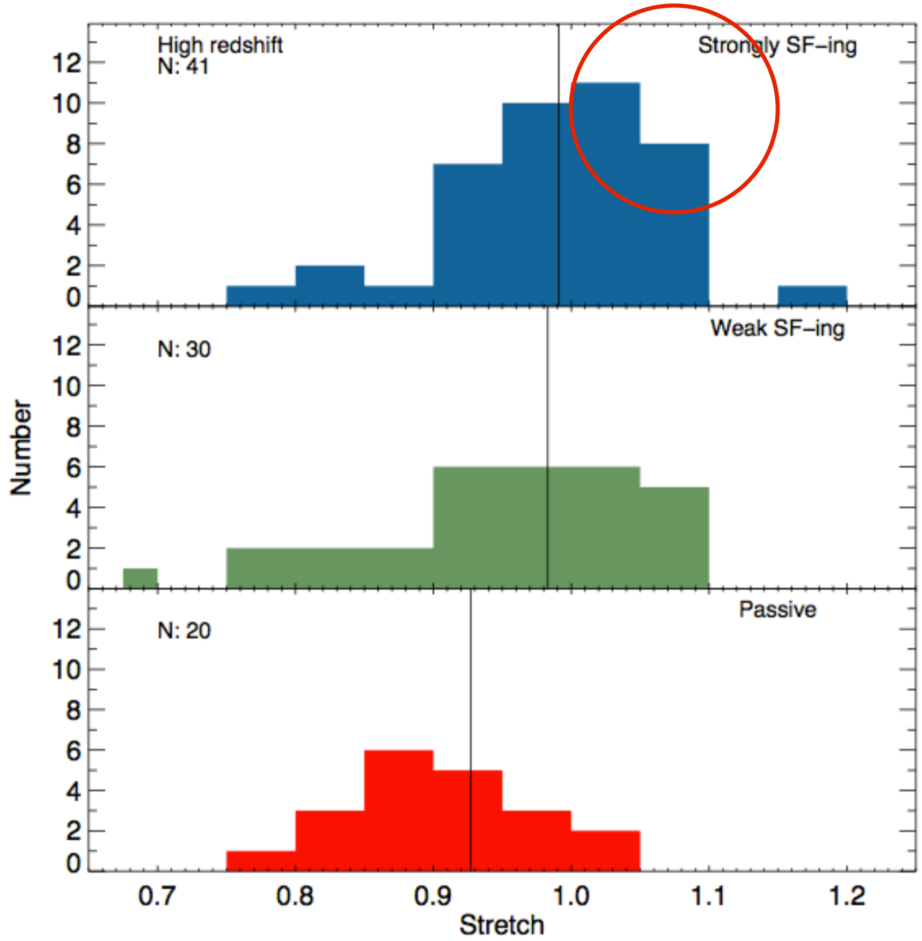
SN more luminous in late-type hosts

Second order corrections: Environment

Look for dependences of the SN properties on the host galaxy properties (focused on global characteristics of the host)

As they evolve with redshift, such dependences would impact the cosmological parameters

Hamuy et al. (1996)
Hamuy et al. (2000)
Gallagher et al. (2005)
Sullivan et al. (2006)
Gallagher et al. (2008)
Hicken et al. (2009)
Howell et al. (2009)
Neil et al. (2009)
Brandt et al. (2010)
Cooper et al. (2010)
Sullivan et al. (2010)
Kelly et al. (2010)
Lampeitl et al. (2010)
D’Andrea et al. (2011)
Gupta et al. (2011)
Nordin et al (2011)
Konishi et al. (2011)
Smith et al. (2012)



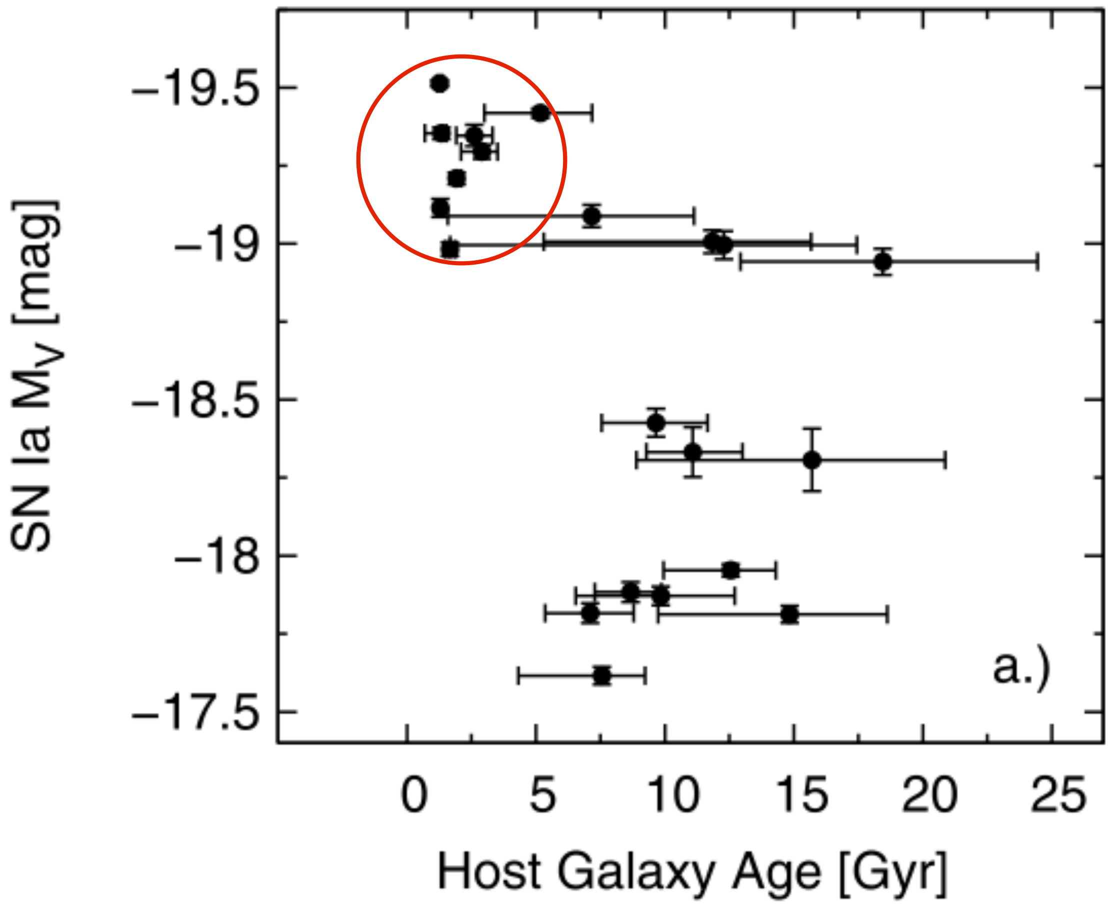
SN more luminous in late-type hosts

Second order corrections: Environment

Look for dependences of the SN properties on the host galaxy properties (focused on global characteristics of the host)

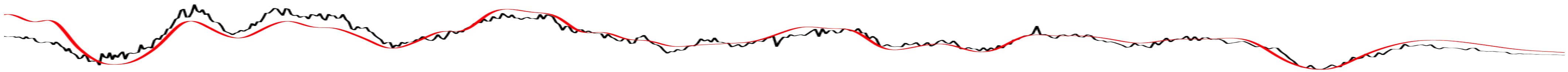
As they evolve with redshift, such dependences would impact the cosmological parameters

Hamuy et al. (1996)
Hamuy et al. (2000)
Gallagher et al. (2005)
Sullivan et al. (2006)
Gallagher et al. (2008)
Hicken et al. (2009)
Howell et al. (2009)
Neil et al. (2009)
Brandt et al. (2010)
Cooper et al. (2010)
Sullivan et al. (2010)
Kelly et al. (2010)
Lampeitl et al. (2010)
D'Andrea et al. (2011)
Gupta et al. (2011)
Nordin et al (2011)
Konishi et al. (2011)
Smith et al. (2012)



SN more luminous in late-type hosts

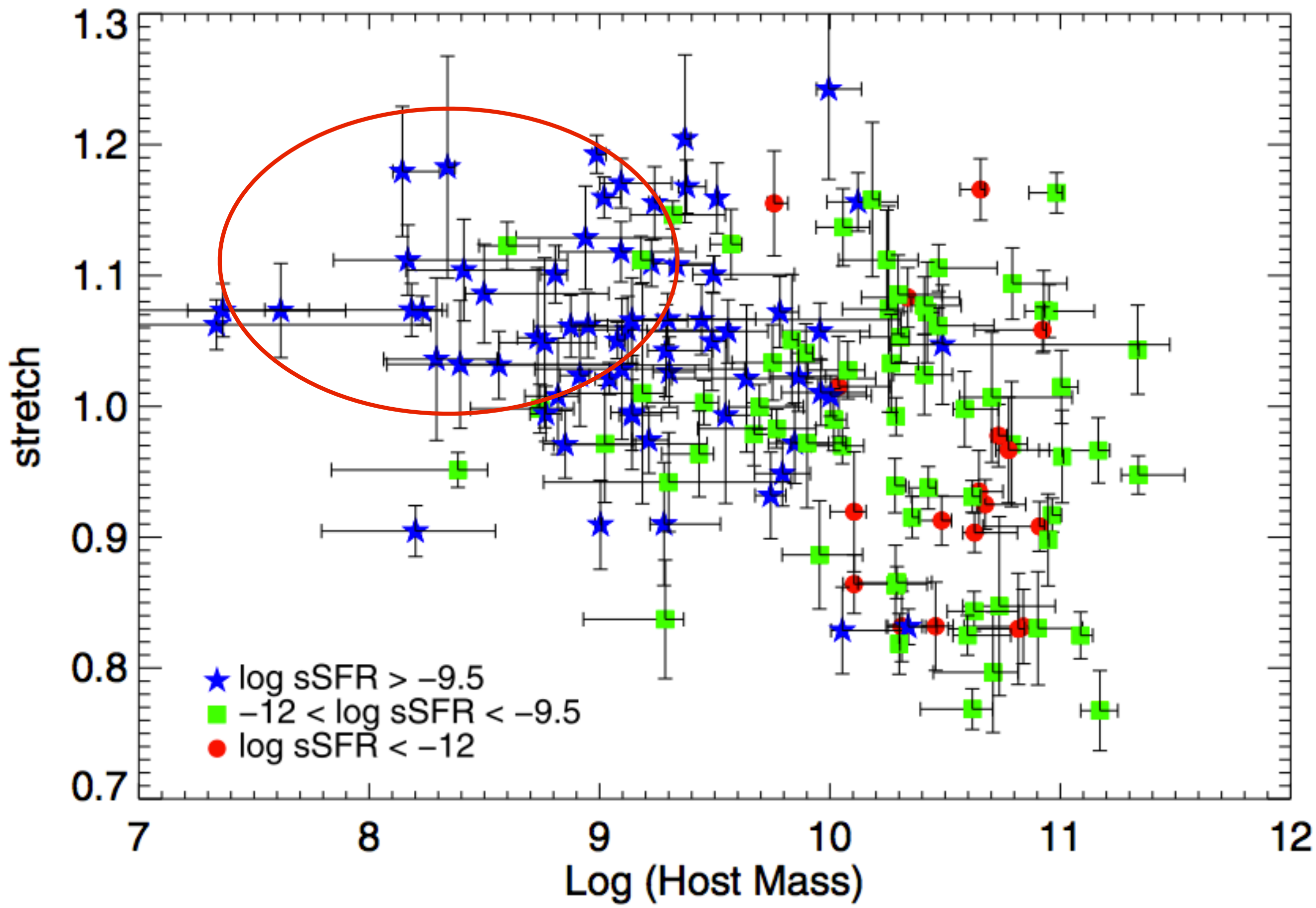
Second order corrections: Environment



Look for dependences of the SN properties on the host galaxy properties (focused on global characteristics of the host)

As they evolve with redshift, such dependences would impact the cosmological parameters

Hamuy et al. (1996)
Hamuy et al. (2000)
Gallagher et al. (2005)
Sullivan et al. (2006)
Gallagher et al. (2008)
Hicken et al. (2009)
Howell et al. (2009)
Neil et al. (2009)
Brandt et al. (2010)
Cooper et al. (2010)
Sullivan et al. (2010)
Kelly et al. (2010)
Lampeitl et al. (2010)
D'Andrea et al. (2011)
Gupta et al. (2011)
Nordin et al (2011)
Konishi et al. (2011)
Smith et al. (2012)



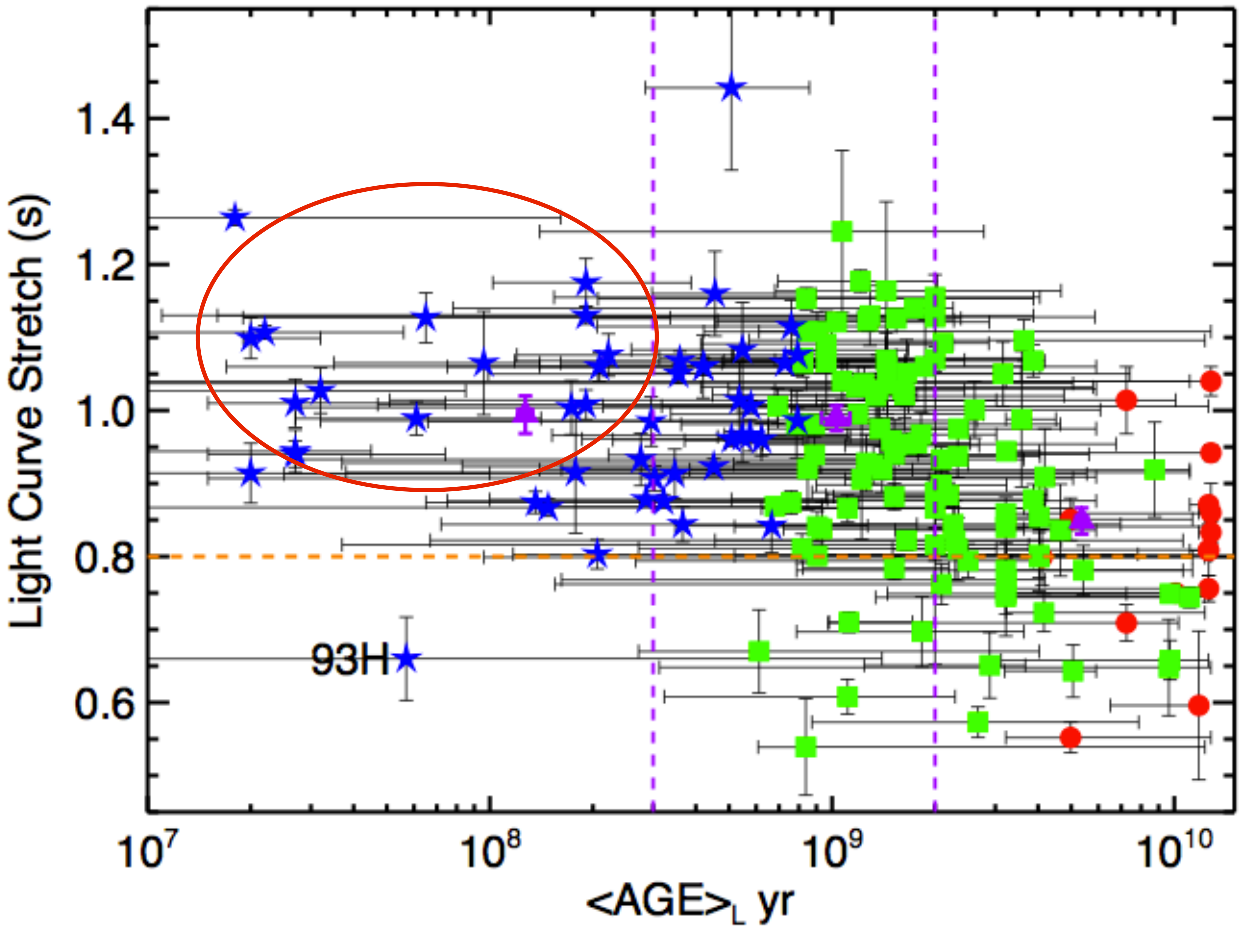
SN more luminous in late-type hosts

Second order corrections: Environment

Look for dependences of the SN properties on the host galaxy properties (focused on global characteristics of the host)

As they evolve with redshift, such dependences would impact the cosmological parameters

Hamuy et al. (1996)
Hamuy et al. (2000)
Gallagher et al. (2005)
Sullivan et al. (2006)
Gallagher et al. (2008)
Hicken et al. (2009)
Howell et al. (2009)
Neil et al. (2009)
Brandt et al. (2010)
Cooper et al. (2010)
Sullivan et al. (2010)
Kelly et al. (2010)
Lampeitl et al. (2010)
D'Andrea et al. (2011)
Gupta et al. (2011)
Nordin et al (2011)
Konishi et al. (2011)
Smith et al. (2012)



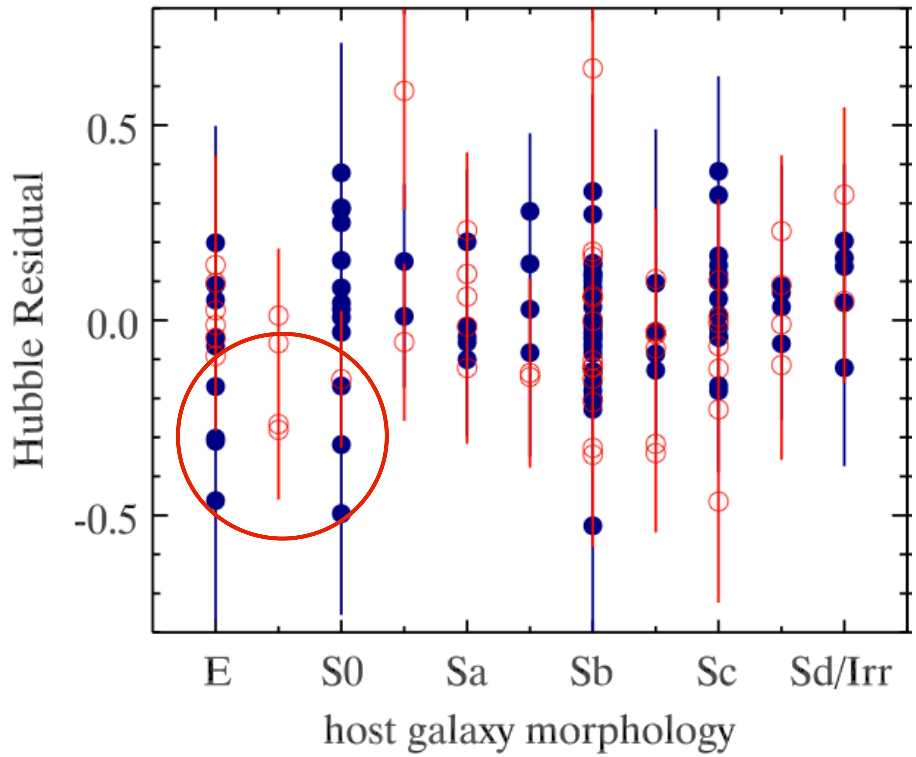
SN more luminous in late-type hosts

Second order corrections: Environment

Look for dependences of the SN properties on the host galaxy properties (focused on global characteristics of the host)

As they evolve with redshift, such dependences would impact the cosmological parameters

Hamuy et al. (1996)
Hamuy et al. (2000)
Gallagher et al. (2005)
Sullivan et al. (2006)
Gallagher et al. (2008)
Hicken et al. (2009)
Howell et al. (2009)
Neil et al. (2009)
Brandt et al. (2010)
Cooper et al. (2010)
Sullivan et al. (2010)
Kelly et al. (2010)
Lampeitl et al. (2010)
D'Andrea et al. (2011)
Gupta et al. (2011)
Nordin et al (2011)
Konishi et al. (2011)
Smith et al. (2012)



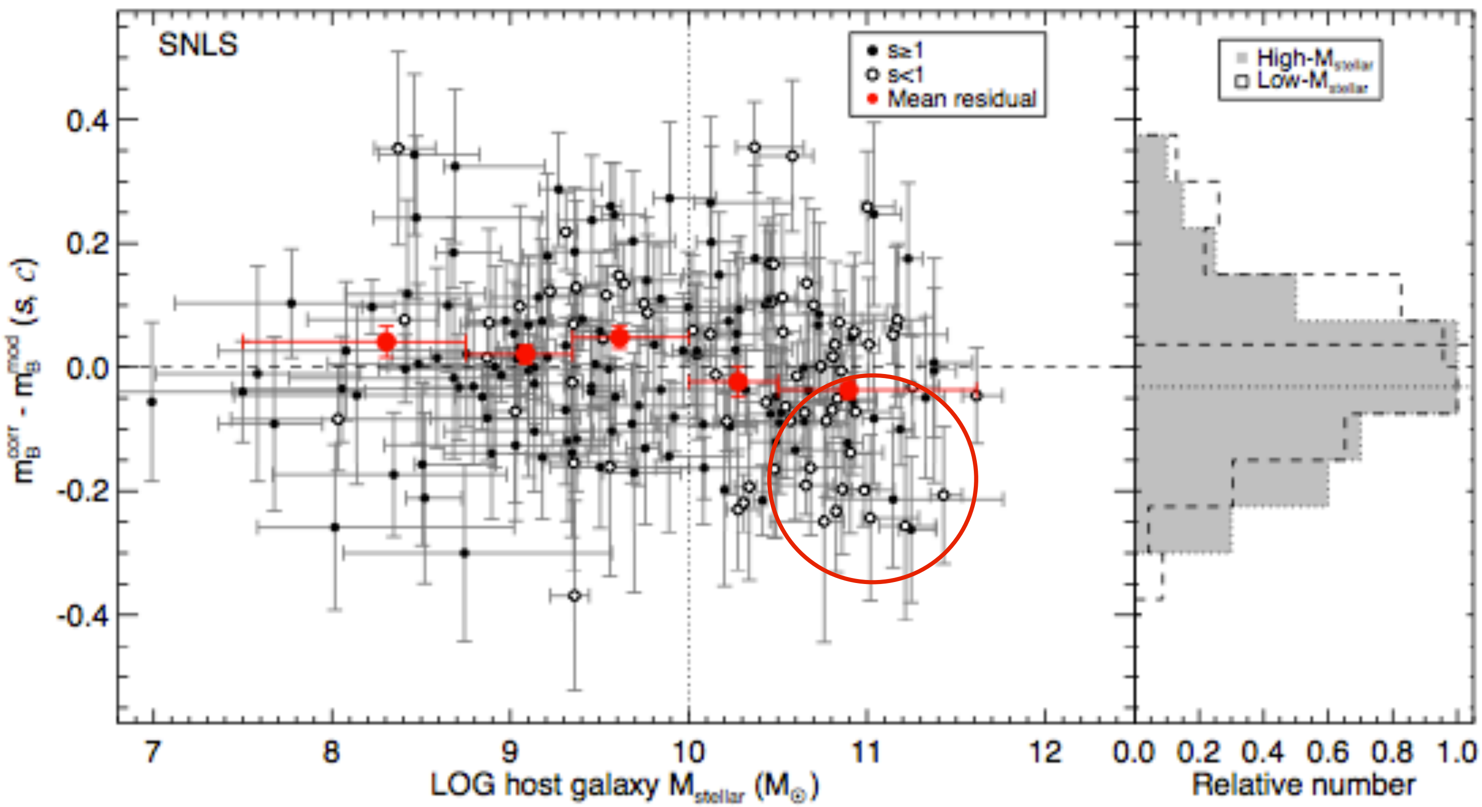
SN corrected magnitudes are higher in early-type hosts

Second order corrections: Environment

Look for dependences of the SN properties on the host galaxy properties (focused on global characteristics of the host)

As they evolve with redshift, such dependences would impact the cosmological parameters

Hamuy et al. (1996)
Hamuy et al. (2000)
Gallagher et al. (2005)
Sullivan et al. (2006)
Gallagher et al. (2008)
Hicken et al. (2009)
Howell et al. (2009)
Neil et al. (2009)
Brandt et al. (2010)
Cooper et al. (2010)
Sullivan et al. (2010)
Kelly et al. (2010)
Lampeitl et al. (2010)
D'Andrea et al. (2011)
Gupta et al. (2011)
Nordin et al (2011)
Konishi et al. (2011)
Smith et al. (2012)



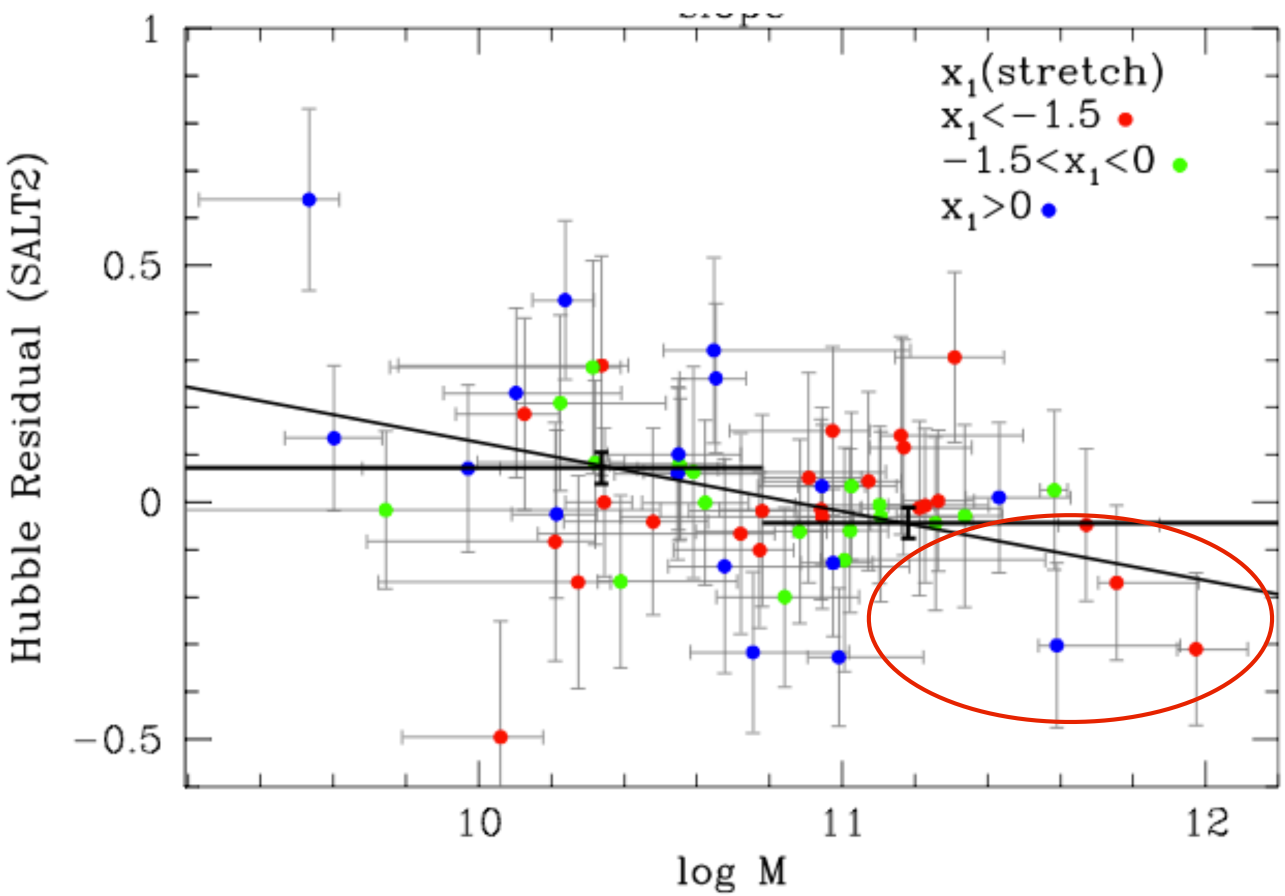
SN corrected magnitudes are higher in early-type hosts

Second order corrections: Environment

Look for dependences of the SN properties on the host galaxy properties (focused on global characteristics of the host)

As they evolve with redshift, such dependences would impact the cosmological parameters

Hamuy et al. (1996)
Hamuy et al. (2000)
Gallagher et al. (2005)
Sullivan et al. (2006)
Gallagher et al. (2008)
Hicken et al. (2009)
Howell et al. (2009)
Neil et al. (2009)
Brandt et al. (2010)
Cooper et al. (2010)
Sullivan et al. (2010)
Kelly et al. (2010)
Lampeitl et al. (2010)
D'Andrea et al. (2011)
Gupta et al. (2011)
Nordin et al (2011)
Konishi et al. (2011)
Smith et al. (2012)



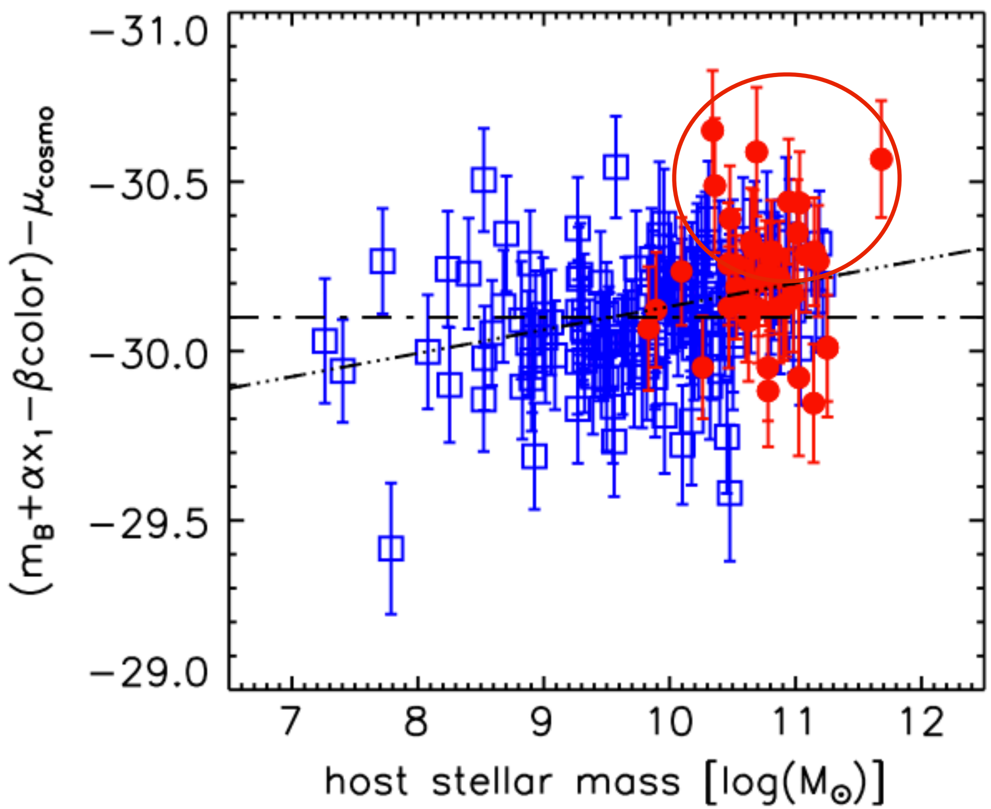
SN corrected magnitudes are higher in early-type hosts

Second order corrections: Environment

Look for dependences of the SN properties on the host galaxy properties (focused on global characteristics of the host)

As they evolve with redshift, such dependences would impact the cosmological parameters

Hamuy et al. (1996)
Hamuy et al. (2000)
Gallagher et al. (2005)
Sullivan et al. (2006)
Gallagher et al. (2008)
Hicken et al. (2009)
Howell et al. (2009)
Neil et al. (2009)
Brandt et al. (2010)
Cooper et al. (2010)
Sullivan et al. (2010)
Kelly et al. (2010)
Lampeitl et al. (2010)
D'Andrea et al. (2011)
Gupta et al. (2011)
Nordin et al (2011)
Konishi et al. (2011)
Smith et al. (2012)



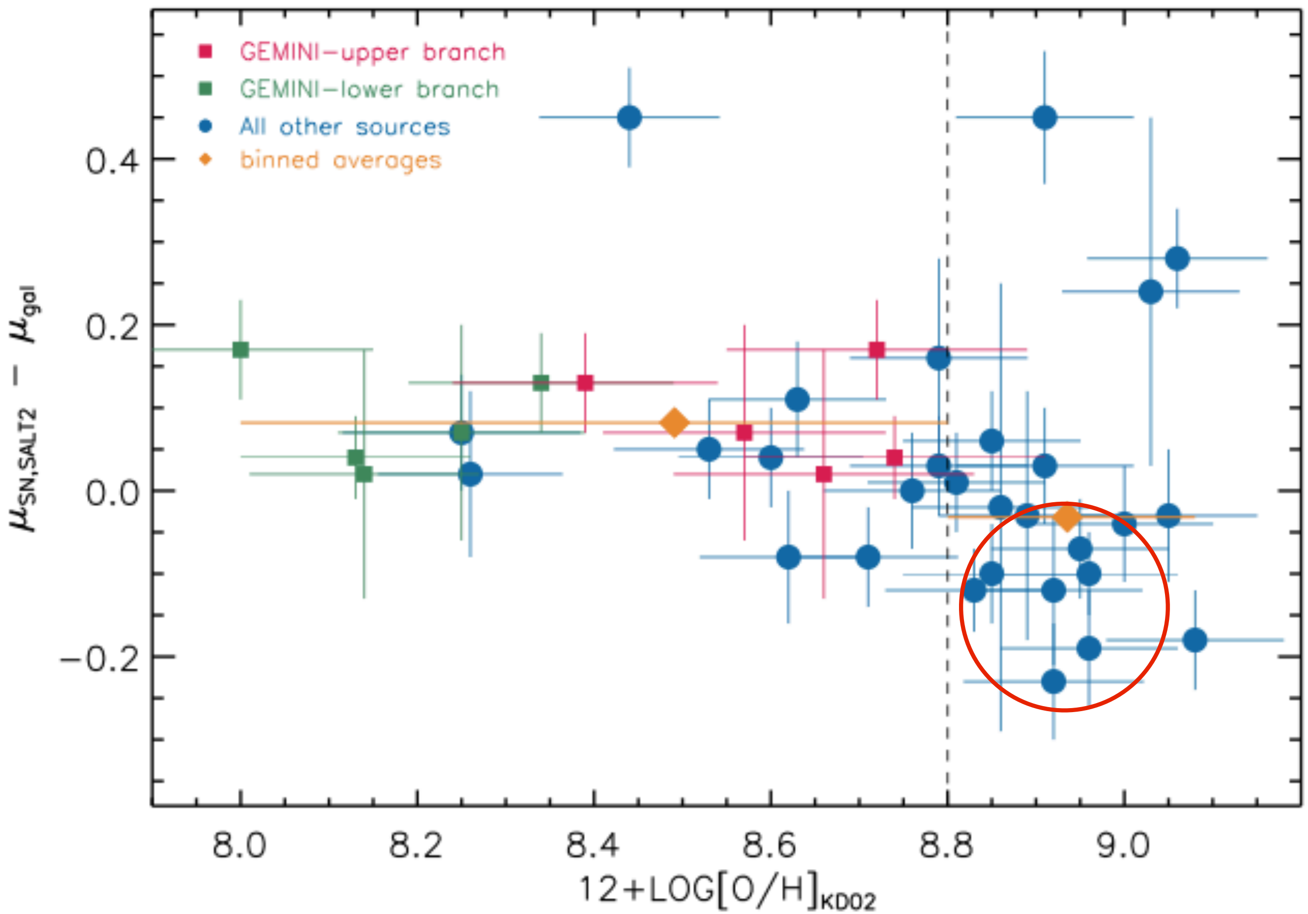
SN corrected magnitudes are higher in early-type hosts

Second order corrections: Environment

Look for dependences of the SN properties on the host galaxy properties (focused on global characteristics of the host)

As they evolve with redshift, such dependences would impact the cosmological parameters

Hamuy et al. (1996)
Hamuy et al. (2000)
Gallagher et al. (2005)
Sullivan et al. (2006)
Gallagher et al. (2008)
Hicken et al. (2009)
Howell et al. (2009)
Neil et al. (2009)
Brandt et al. (2010)
Cooper et al. (2010)
Sullivan et al. (2010)
Kelly et al. (2010)
Lampeitl et al. (2010)
D'Andrea et al. (2011)
Gupta et al. (2011)
Nordin et al (2011)
Konishi et al. (2011)
Smith et al. (2012)



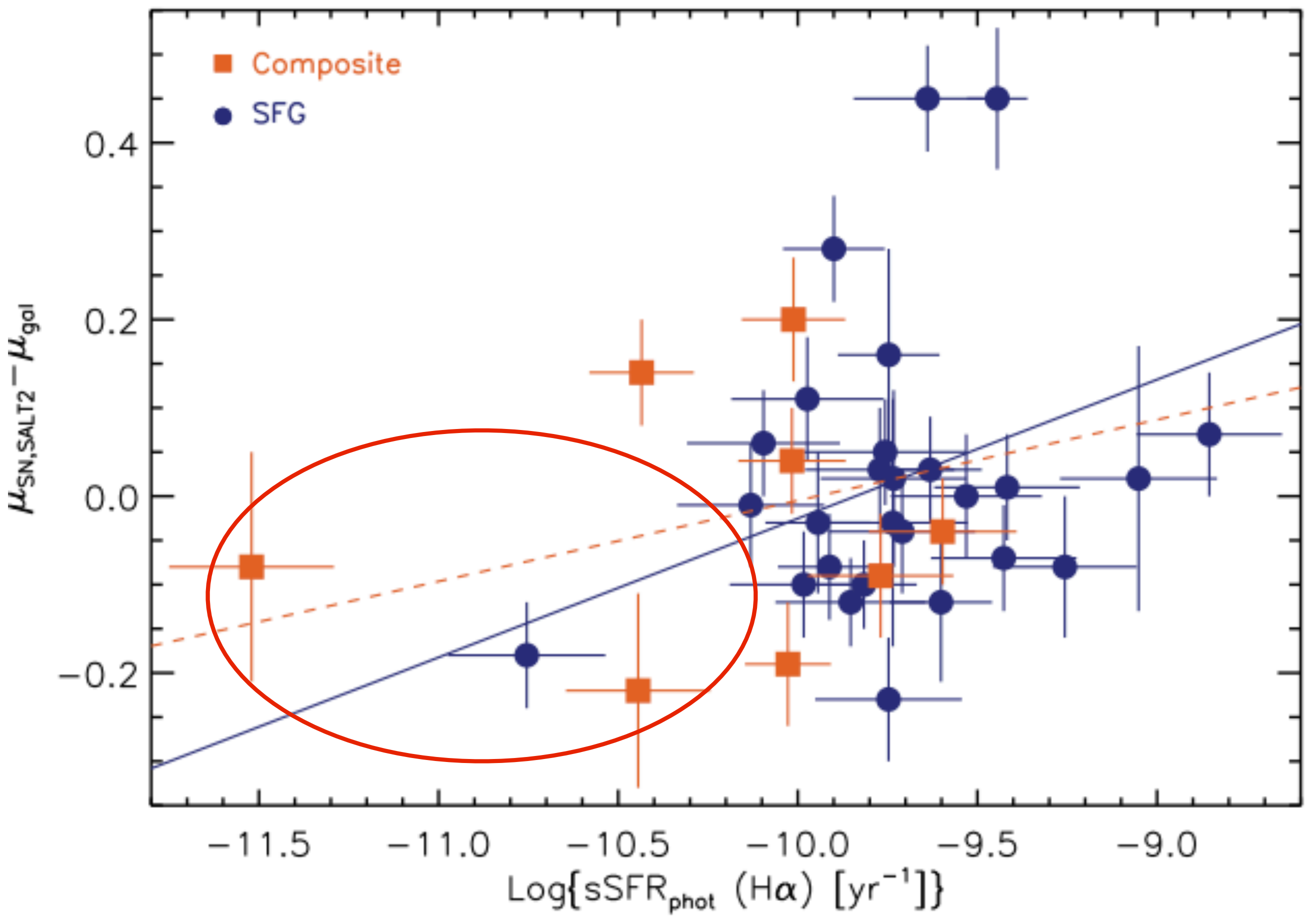
SN corrected magnitudes are higher in early-type hosts

Second order corrections: Environment

Look for dependences of the SN properties on the host galaxy properties (focused on global characteristics of the host)

As they evolve with redshift, such dependences would impact the cosmological parameters

Hamuy et al. (1996)
Hamuy et al. (2000)
Gallagher et al. (2005)
Sullivan et al. (2006)
Gallagher et al. (2008)
Hicken et al. (2009)
Howell et al. (2009)
Neil et al. (2009)
Brandt et al. (2010)
Cooper et al. (2010)
Sullivan et al. (2010)
Kelly et al. (2010)
Lampeitl et al. (2010)
D'Andrea et al. (2011)
Gupta et al. (2011)
Nordin et al (2011)
Konishi et al. (2011)
Smith et al. (2012)



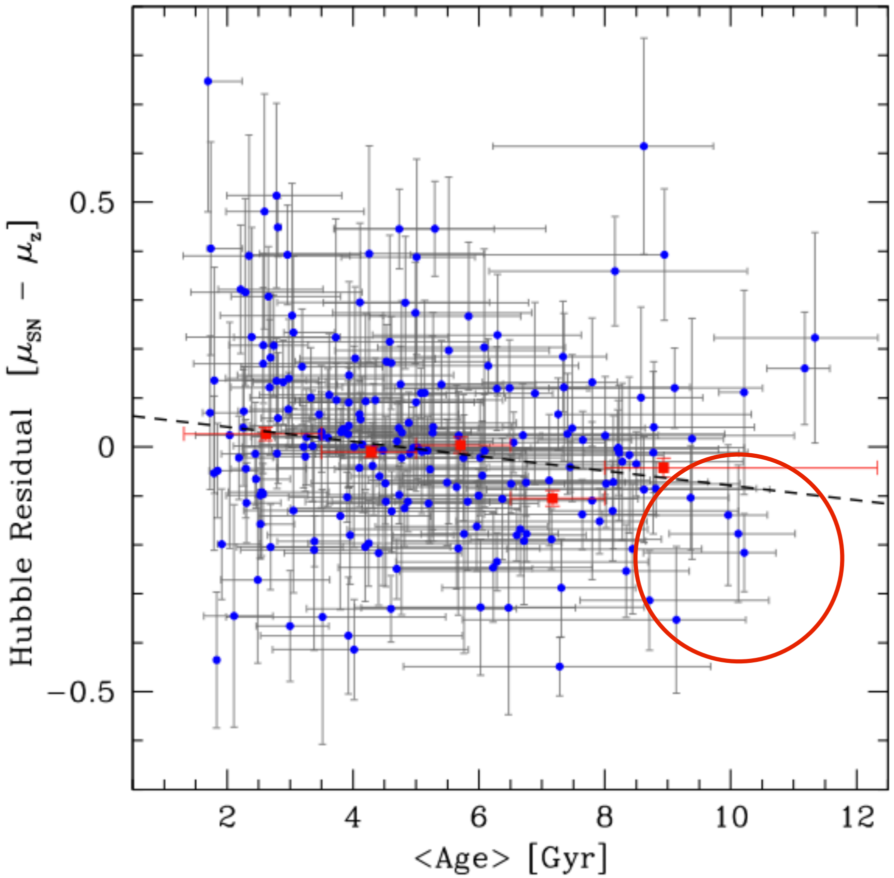
SN corrected magnitudes are higher in early-type hosts

Second order corrections: Environment

Look for dependences of the SN properties on the host galaxy properties (focused on global characteristics of the host)

As they evolve with redshift, such dependences would impact the cosmological parameters

Hamuy et al. (1996)
Hamuy et al. (2000)
Gallagher et al. (2005)
Sullivan et al. (2006)
Gallagher et al. (2008)
Hicken et al. (2009)
Howell et al. (2009)
Neil et al. (2009)
Brandt et al. (2010)
Cooper et al. (2010)
Sullivan et al. (2010)
Kelly et al. (2010)
Lampeitl et al. (2010)
D'Andrea et al. (2011)
Gupta et al. (2011)
Nordin et al (2011)
Konishi et al. (2011)
Smith et al. (2012)



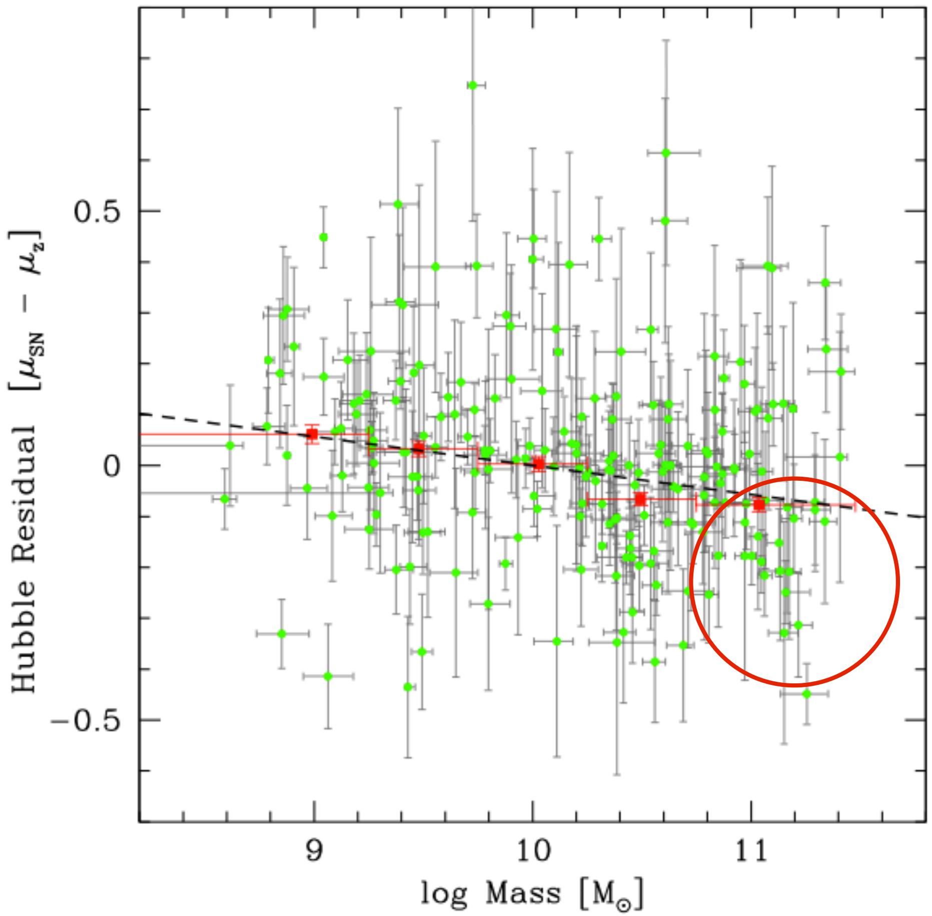
SN corrected magnitudes are higher in early-type hosts

Second order corrections: Environment

Look for dependences of the SN properties on the host galaxy properties (focused on global characteristics of the host)

As they evolve with redshift, such dependences would impact the cosmological parameters

Hamuy et al. (1996)
Hamuy et al. (2000)
Gallagher et al. (2005)
Sullivan et al. (2006)
Gallagher et al. (2008)
Hicken et al. (2009)
Howell et al. (2009)
Neil et al. (2009)
Brandt et al. (2010)
Cooper et al. (2010)
Sullivan et al. (2010)
Kelly et al. (2010)
Lampeitl et al. (2010)
D'Andrea et al. (2011)
Gupta et al. (2011)
Nordin et al (2011)
Konishi et al. (2011)
Smith et al. (2012)



SN corrected magnitudes are higher in early-type hosts

SNe Ia properties as a function of the GCD

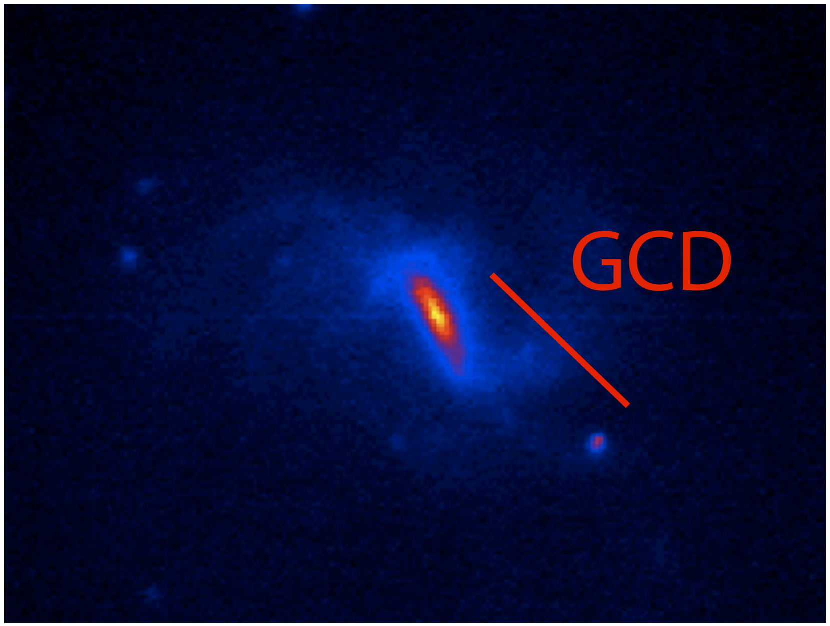
The Astrophysical Journal, 755:1 (14pp), 2012 ??? doi:10.1088/0004-637X/755/1/1

TYPE Ia SUPERNOVA PROPERTIES AS A FUNCTION OF THE DISTANCE TO THE HOST GALAXY IN THE SDSS-II SN SURVEY

Lluís Galbany[1,18], Ramon Miquel[1,2], Linda Östman[1], Peter J. Brown[3], David Cinabro[4], Chris B. D'Andrea[5], Joshua Frieman[6,7,8], Saurabh W. Jha[9], John Marriner[8], Robert C. Nichol[5], Jakob Nordin[10,11], Matthew D. Olmstead[3], Masao Sako[12], Donald P. Schneider[13,14], Mathew Smith[15], Jesper Sollerman[16], Kaike Pan[17], Stephanie Snedden[17], Dmitry Bizyaev[17], Howard Brewington[17], Elena Malanushenko[17], Viktor Malanushenko[17], Dan Oravetz[17], Audrey Simmons[17], and Alaina Shelden[17]

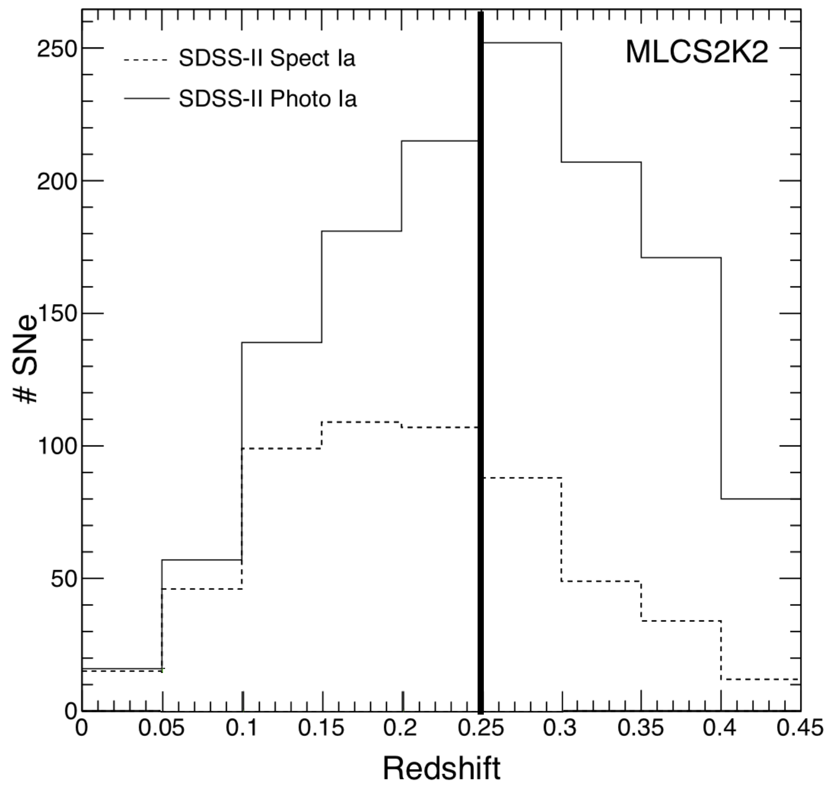
Galbany et al., 2012, ApJ, 755, 125

- Look for dependencies between SN Ia properties and its projected distance to the host galaxy center, using the distance as a proxy for **local** galaxy properties (star-formation rate, local metallicity, etc.).
- Use SDSS-II/SNe Survey 3-year sample
- Fit LCs using both MLCS2k2 and SALT2. Determine:
    - Color (A_V, c)
    - Decline rate (Δ, x_1)
    - Residuals in the fit to the Hubble diagram ($\delta\mu$).
- Correlate these parameters with several definitions of the distance of the SN to the center of the host galaxy



Sample

- The SDSS-II SN sample consists of 1318 SNe Ia in the range 0<z<0.45
    - 559 SNe Ia confirmed spectroscopically (*Spec-Ia* sample)
    - 759 SNe photometrically classified as Type Ia from their LCs (*Photo-Ia* sample)
- We restrict the sample to redshifts z<0.25 where the completeness is still relatively high



- The closest galaxy within an angular separation of 20″ was matched using the SDSS DR7

17 no host

	Spec-Ia	Photo-Ia	Total
SN Ia sample ($z < 0.45$)	559	759	1318
Redshift < 0.25	376	232	608
Identified host galaxy	363	228	591

Light-curve fitters

- LC fitted through MLCS2k2 and SALT2. Parameters obtained:
  - LC shape (Δ and x_1)
  - SN color (A_V and c)
  - Hubble residual (μ_{MLCS} and $\mu_{SALT2}=m_B-M+\alpha x_1-\beta c$) ➞ $\delta\mu = \mu_{LC} - \mu_{TH}$

From full SDSS-II/SNe sample

$M = -19.41 \pm 0.04$
$\alpha = 0.131 \pm 0.052$
$\beta = 3.26 \pm 0.49$
ΛCDM: $\Omega_M = 0.274 = 1 - \Omega_\Lambda$

- We apply LC quality cuts *(MLCS, SALT2)*
  - 5 obs between $t_{max}-20<t_{obs}<t_{max}+$*70 (60)* days
  - 1 obs $t_{obs}<t_{max}$ - *2 (0)* days
  - 1 obs $t_{obs}>t_{max}$ +*10 (9.5)* days
  - 1 obs with S/N > 5 in *gri*
  - Probability of LC fit > 0.001

- And Parameter cuts
  - Δ >-0.4
  - $-4.5<x_1<2.0$
  - $-0.3<c<0.6$

	Spec-Ia		Photo-Ia		Total	
	MLCS	SALT2	MLCS	SALT2	MLCS	SALT2
SN Ia sample ($z < 0.45$)	559		759		1318	
Redshift < 0.25	376		232		608	
Identified host galaxy	363		228		591	
LC quality cuts	228	217	115	125	343	342
LC parameter cuts	203	209	110	111	313	320

Galactocentric distances (GCD)

- Measurement of the angular separation (θ) between the host galaxy center and the SN, and physical (projected) distance using z

$$PGCD = d_A \times \theta$$

$$d_A = \frac{c}{H_0} \frac{1}{(1+z_{host})} \int_0^{z_{host}} \frac{dz'}{\sqrt{\Omega_M (1+z')^3 + \Omega_\Lambda}}$$

$$H_0 = 70.4 \pm 1.4 \text{ km s}^{-1} \text{ Mpc}^{-1}$$

- Due to different sizes of the host galaxies we use 3 distance normalization methods to allow comparisons

  - Petrosian radius 50 (P50): radius of a circle that contains 50% of the galaxy flux
  - Sérsic profile (SER): distance to the center of the ellipse containing half the luminosity
    - de Vaucouleurs (DEV) profile (n=4, for ellipticals)
    - exponential (EXP) profile (n=1, for spirals)

$$I(r) = I_0 \exp\left[-a_n (r/r_e)^{1/n}\right]$$

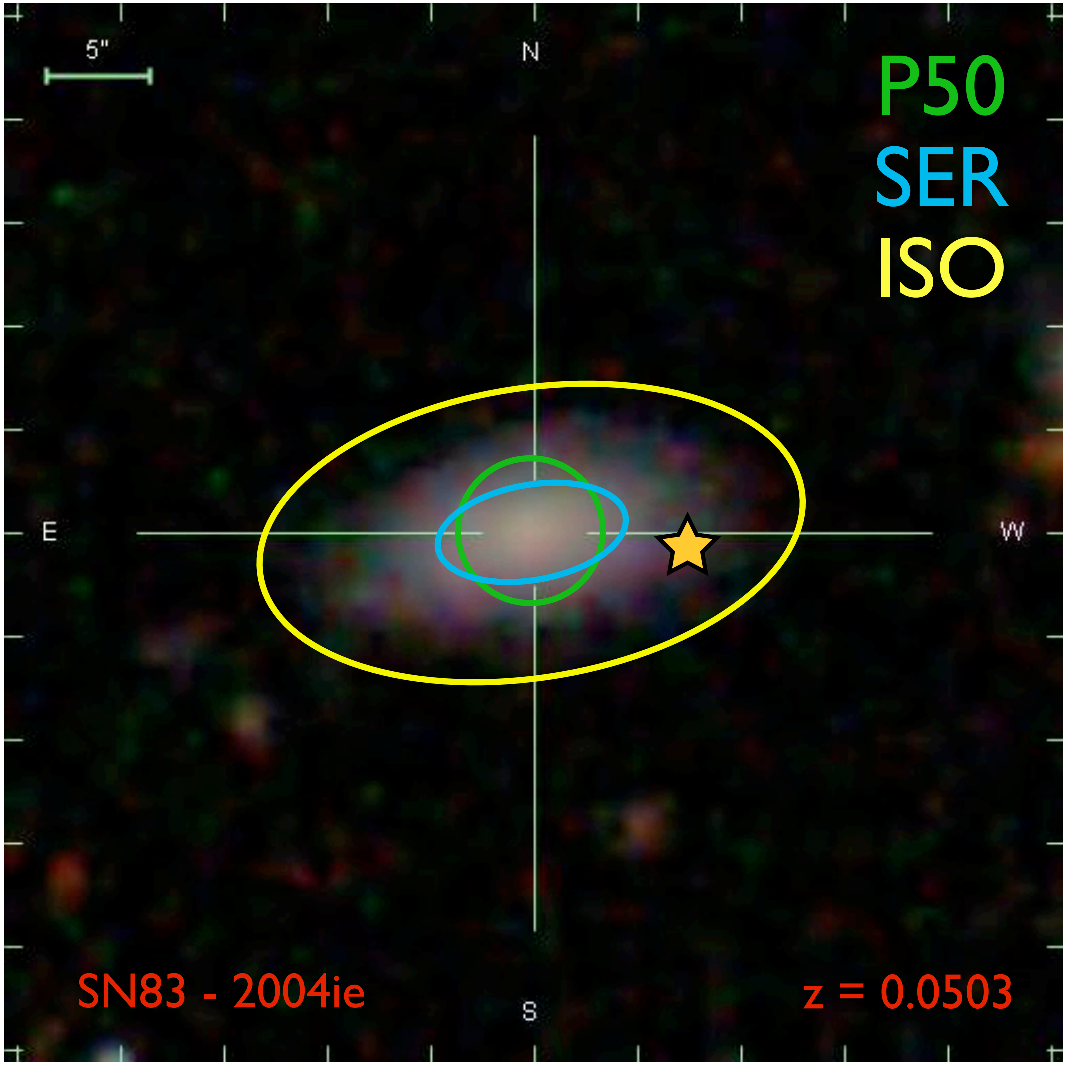
  - Isophotal ellipse (ISO): distance to the center of the ellipse containing 25 mag/arcsec^2

- We then apply cuts on distance measurements:

  - σ(θ) < 0.5″
  - σ(PGCD) < 1kpc
  - σ(R) < 0.5″
  - σ(R)/R < 1
  - NGCD ≡ θ/R < 10

	Spec-Ia		Photo-Ia		Total	
	MLCS	SALT2	MLCS	SALT2	MLCS	SALT2
SN Ia sample ($z < 0.45$)	559		759		1318	
Redshift < 0.25	376		232		608	
Identified host galaxy	363		228		591	
LC quality cuts	228	217	115	125	343	342
LC parameter cuts	203	209	110	111	313	320
Distance cuts	171	177	95	94	266	271

Galactocentric distances (GCD)



$d_{kpc} = 7.293 \pm 0.162$

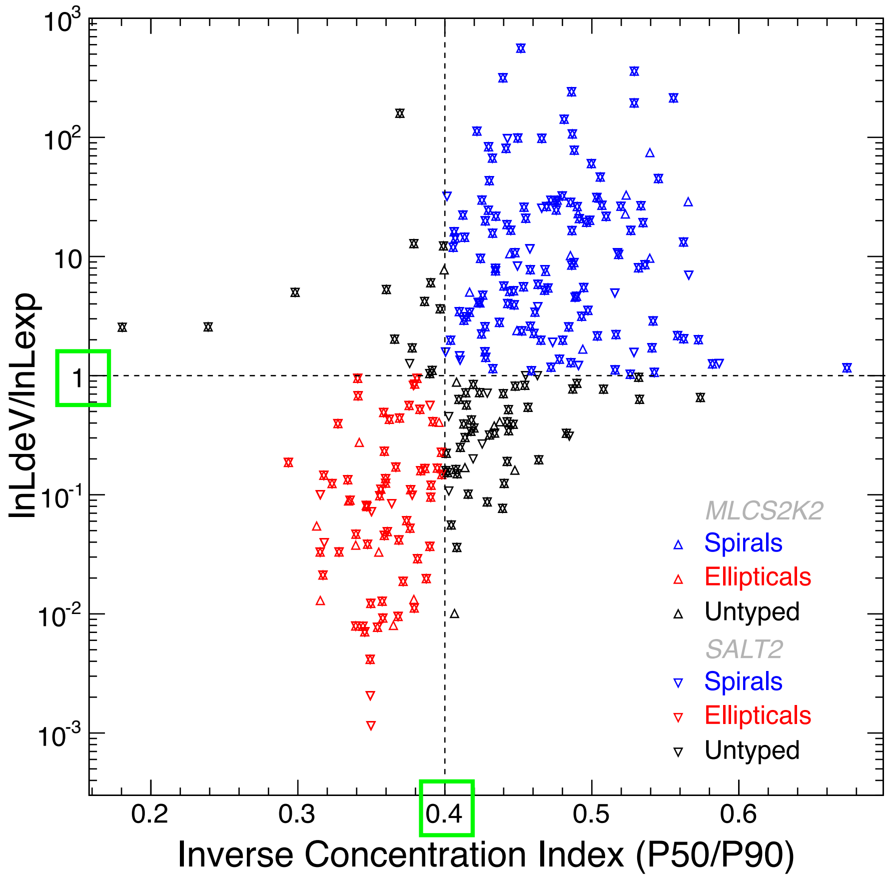
$d_{P50} = 2.137 \pm 0.032$

$d_{SER} = 1.754 \pm 0.033$

$d_{ISO} = 0.307 \pm 0.003$

Host typing

- 2 criteria used in order to separate the hosts in elliptical and spiral
  - Inverse concentration index (P50/P90)
  - Best brightness profile fit (DEV/EXP)
- Selection made on agreement on both criteria



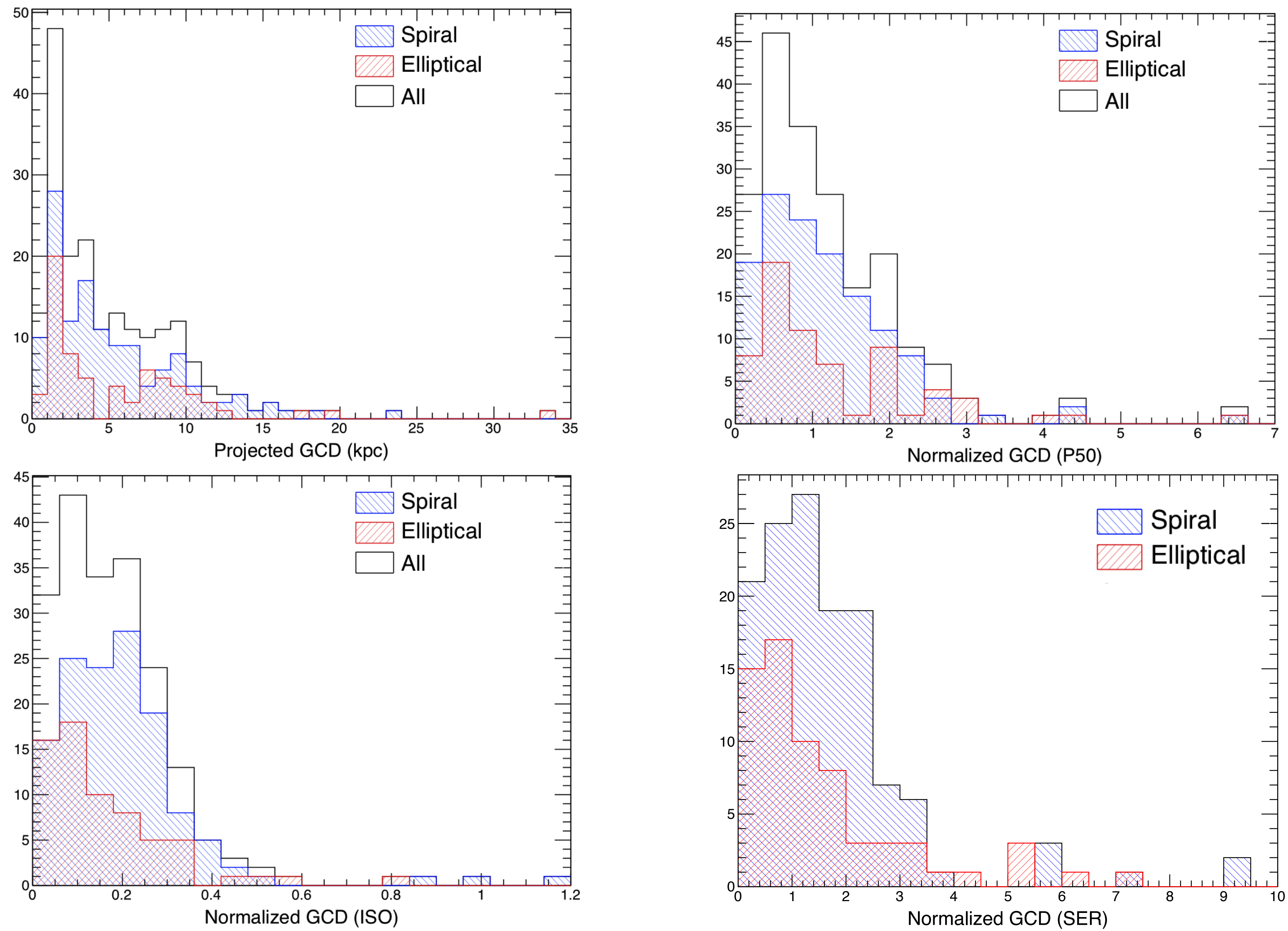
	Spec-Ia		Photo-Ia		Total	
	MLCS	SALT2	MLCS	SALT2	MLCS	SALT2
SN Ia sample ($z < 0.45$)	559		759		1318	
Redshift < 0.25	376		232		608	
Identified host galaxy	363		228		591	
LC quality cuts	228	217	115	125	343	342
LC parameter cuts	203	209	110	111	313	320
Distance cuts	171	177	95	94	266	271
Consistent host type	128	132	64	65	192	197

MLCS: 127 spirals
65 ellipticals

SALT2: 131 spirals
66 ellipticals

GCD distributions

(SALT2 plots)



Distributions

- $\langle c \rangle_{ell} = 0.015 \pm 0.013$

  $\langle c \rangle_{spi} = 0.043 \pm 0.011$
- $\langle AV \rangle_{ell} = 0.252 \pm 0.031$

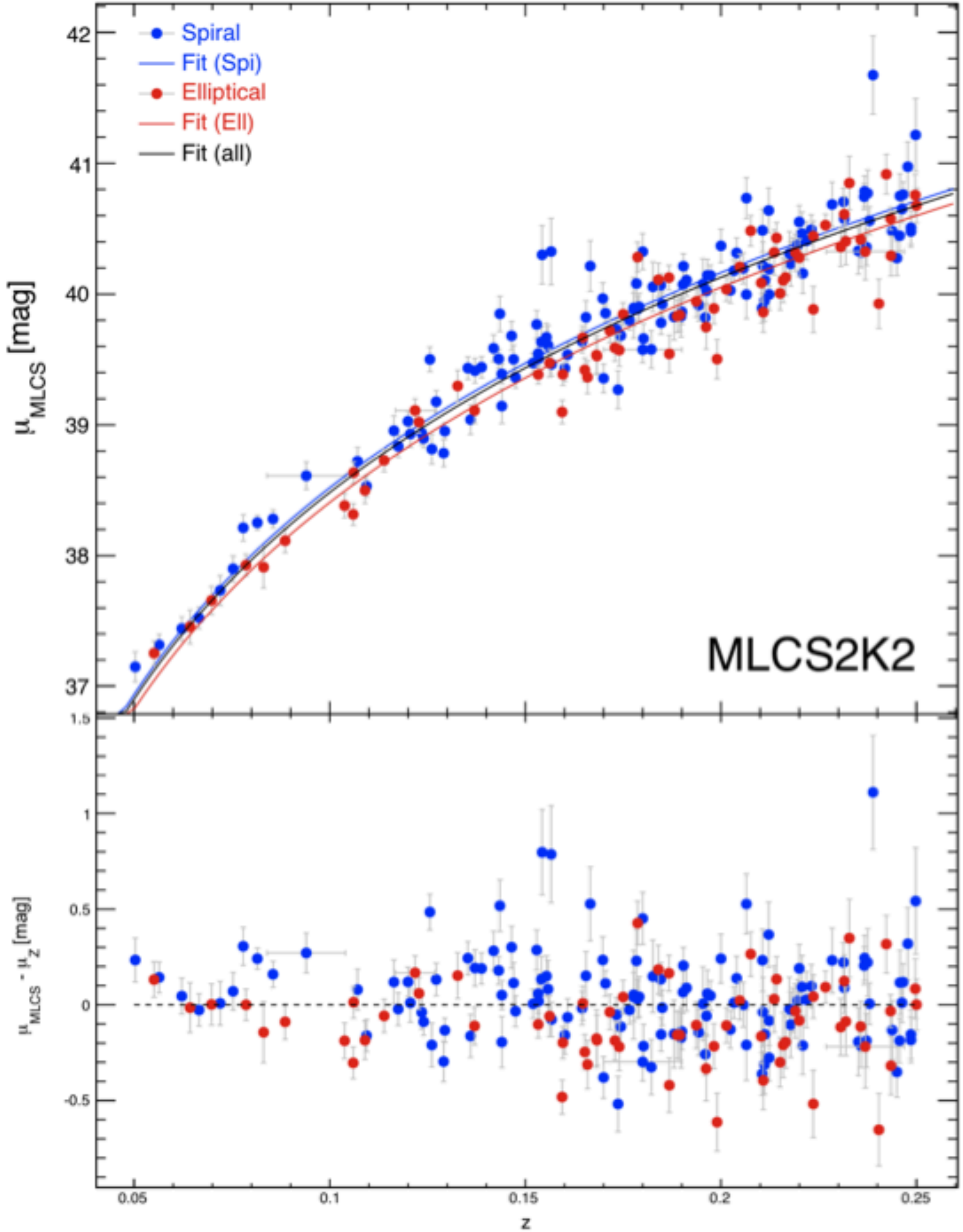
  $\langle AV \rangle_{spi} = 0.363 \pm 0.024$
- $\langle \Delta \rangle_{ell} = 0.162 \pm 0.049$

  $\langle \Delta \rangle_{spi} = -0.078 \pm 0.031$
- $\langle x1 \rangle_{ell} = -0.780 \pm 0.129$

  $\langle x1 \rangle_{spi} = 0.189 \pm 0.080$
- $\langle \delta\mu_{MLCS} \rangle_{ell} = -0.093 \pm 0.026$

  $\langle \delta\mu_{MLCS} \rangle_{spi} = 0.051 \pm 0.022$
- $\langle \delta\mu_{SALT2} \rangle_{ell} = -0.025 \pm 0.023$

  $\langle \delta\mu_{SALT2} \rangle_{spi} = 0.048 \pm 0.019$



Analysis procedure

bin width	
PGCD	0.5 kpc
P50	0,25
SER	0,25
ISO	0,05

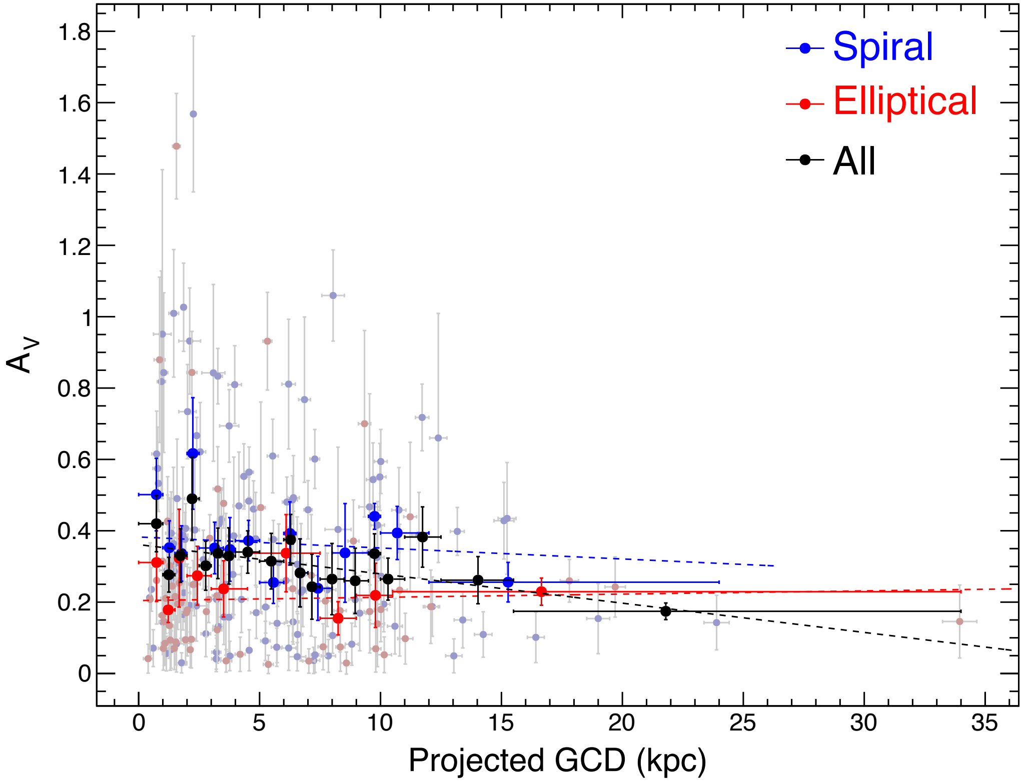
- We correlate A_V, Δ, c, x_1 and Hubble residuals with the PGCD and the 3 normalized distances

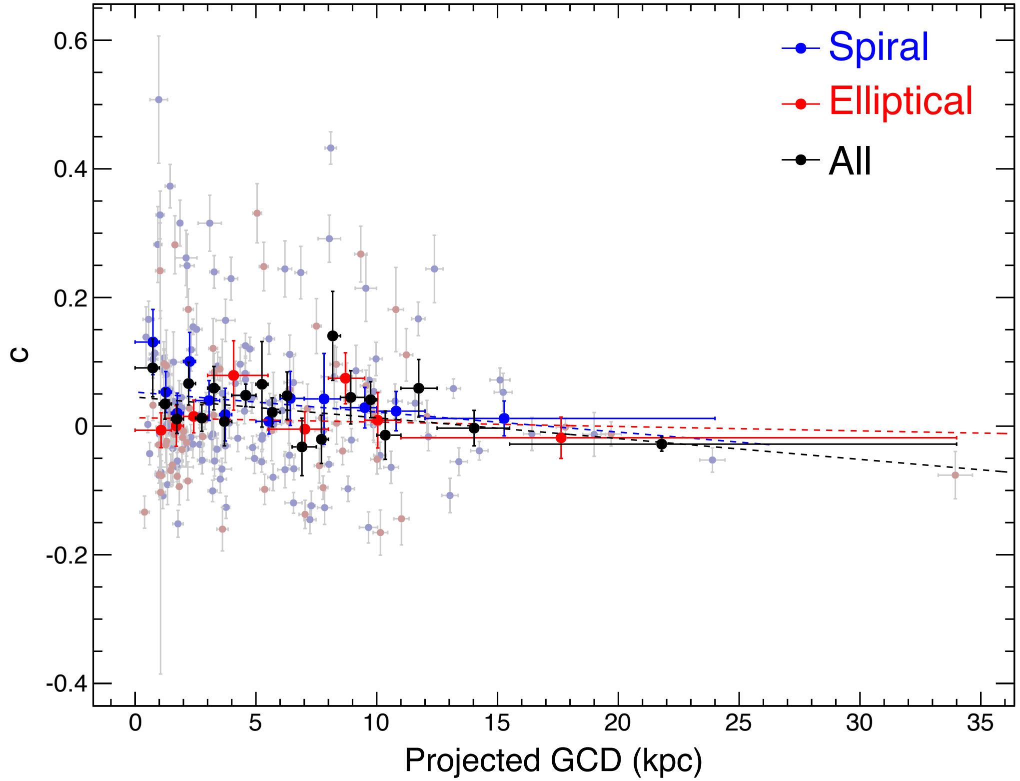
- For every combination of LC parameter and distance measurement, SNe are binned in distance (at least 5 SNe per bin, or joined), for all the SNe, and separating host types
  - Measurement of the mean value in each bin, for both LC parameter and distance
  - Linear fit of all the SNe, and separating host types
    - Compute reduced χ^2 and significance of the slope are calculated
  - We focus on results with slope different from 0 with more than 2σ significance and reduced $\chi^2 < 2$

- We also split the sample in 2 bins (Near-Far) with same #SNe in each bin
  - Measurement of the mean and the scatter, and calculate the significance in the difference between the 2 bins
  - We focus on results with a difference with more than 2σ significance

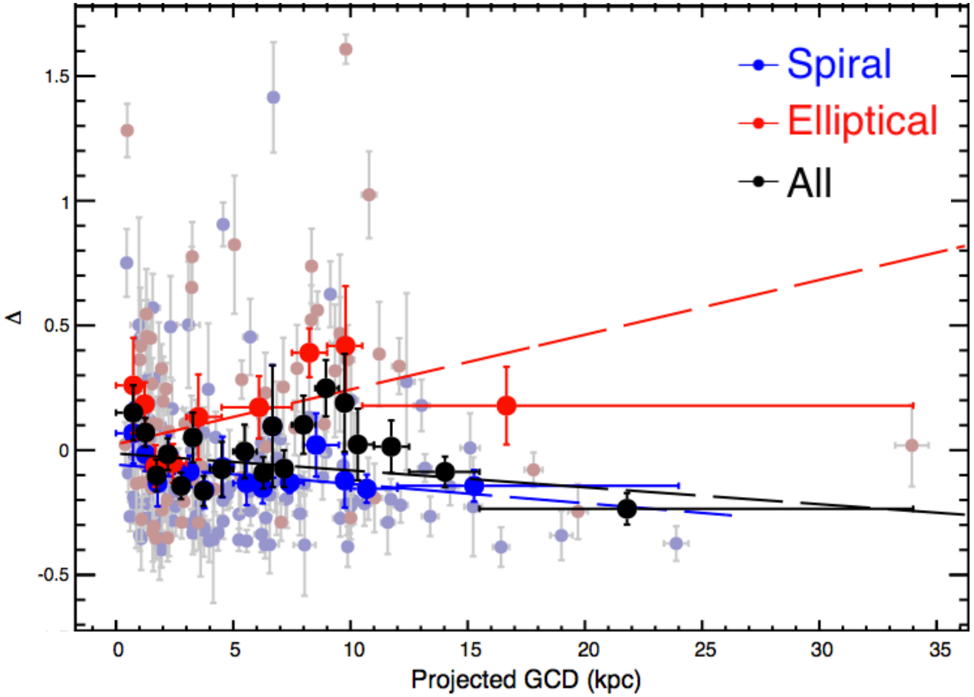
Results (I)

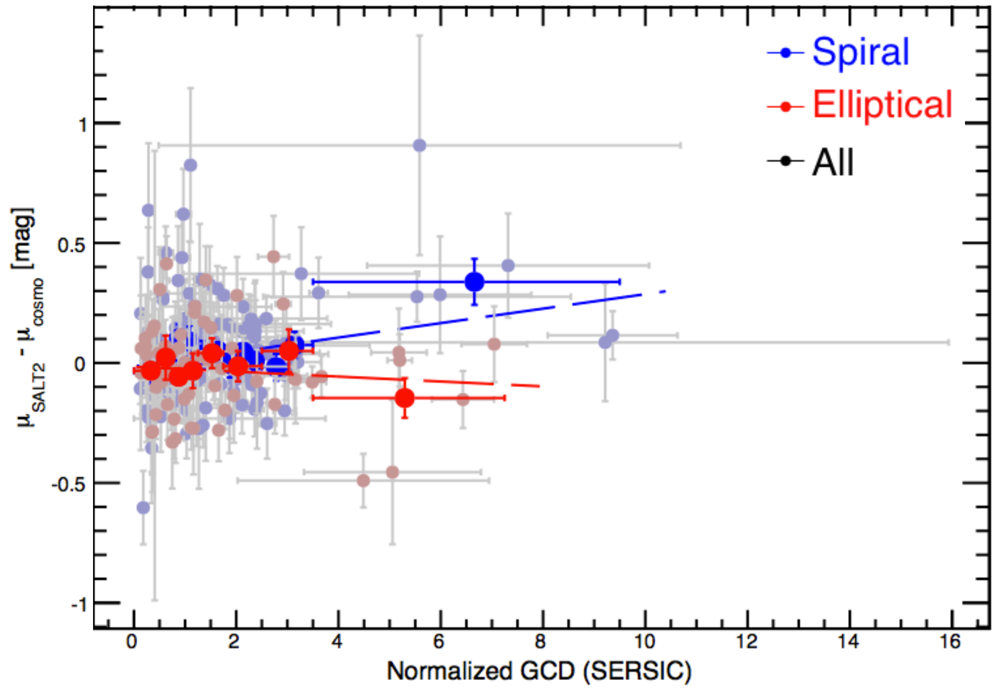
- We find 2 (related) trends with very high significance and good fit quality:
    - A_V and c decrease with physical GCD with significant slopes (4.9 and 4.4σ), and good reduced χ^2/dof (0.6 and 0.9), when consider the whole sample
- Av and c decreases with distance. Most extinguished explosions occur close to the center of the host galaxies





Results (II)





Linear fit: we find weak correlation in ellipticals, larger Δ (dimmer SNe) are found at large GCD

Distance unit	Host type	Slope	Sig.[a]	χ^2/dof
kpc	Elliptical	0.0220 ± 0.0092	2.4	2.1
P50	Elliptical	0.092 ± 0.050	1.9	0.7
ISO	Elliptical	0.81 ± 0.45	1.8	1.1
deV	Elliptical	0.103 ± 0.043	2.4	1.4

- Linear fit: we only find a weak correlation between $\delta\mu_{SALT2}$ and EXP normalization. $\delta\mu_{SALT2}$ in spirals increases with distance

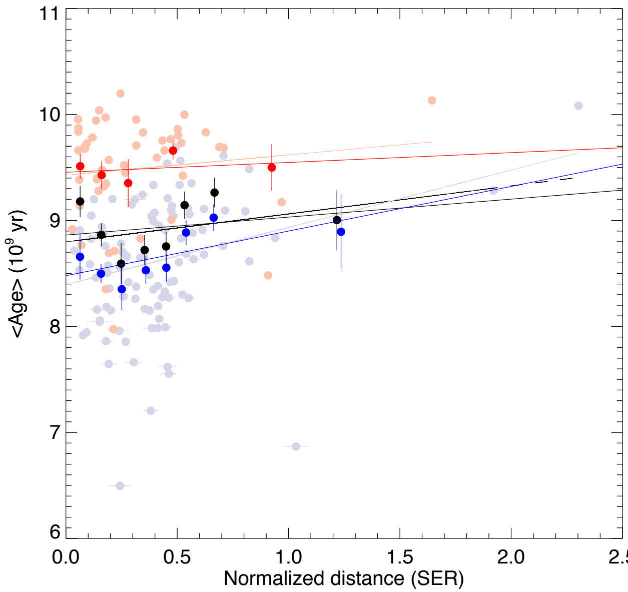
Distance unit	Host type	Slope	Sig.[a]	χ^2/dof
exp	Spiral	0.030 ± 0.014	2.2	1.1

Conclusions (1st)

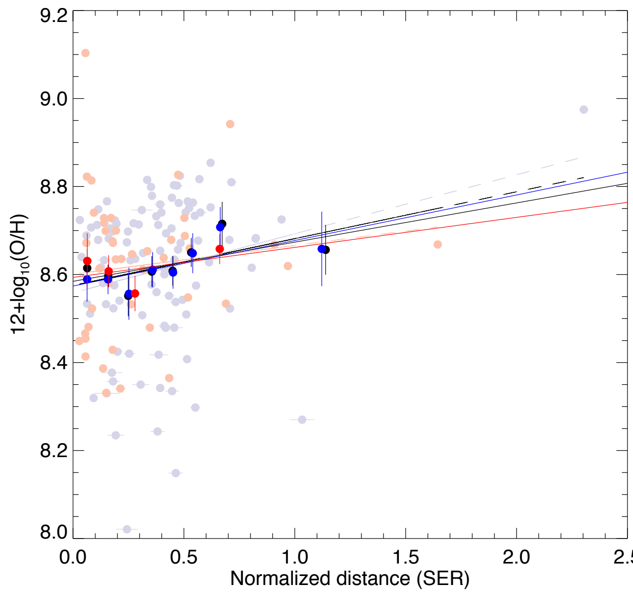
- We find some indications that SNe in elliptical galaxies tend to have narrower LC (larger Δ, fainter SNe) if they explode farther from the galaxy core
    - This could be explained by the difficulty to detect faint SNe close to the galaxy center, where the galaxy light is stronger (selection effect)
- We find strong indications of a decrease in color with distance
    - If most of the variability in color is due to dust, and dust is expected to decrease with distance from the center, this would be expected
    - Due to the difficulty to observe faint SNe close to the galaxy center, we would expect fewer dust extincted SNe (with high A_V) at small distances. However, this is opposite of what we find, so maybe the selection effect is not too large
- We do not find any correlation between the Hubble residuals and the GCD
    - Since GCD can be used as a proxy for the local metallicity, this can be seen as an indication of a limited correlation between Hubble residuals and local metallicity.
    - This does not confirm the result in D'Andrea et al. , which finds a correlation between Hubble residuals and global metallicity

Correlating host galaxy parameters with distance

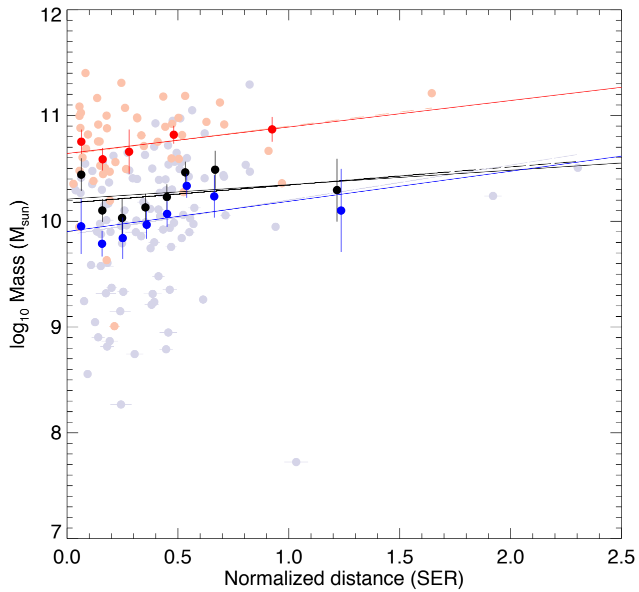
We measure galaxy parameters, such as the **age**, the **mass**, the **metallicity**, the **Hα emission,** and the **specific star formation rate** from the spectra of the host galaxies of those SNe in the sample used in Galbany+12 that have the host galaxy spectrum available in SDSS Data Release 9 (153 MLCS, 157 SALT2). We look for correlations between these host galaxy parameters and the galactocentric distances.



$y = 8.565\ (0.030) + 0.135\ (0.067)$ NGCD



$y = 9.755\ (0.118) + 0.736\ (0.265)$ NGCD



$y = 8.378\ (0.095) + 0.738\ (0.213)$ NGCD

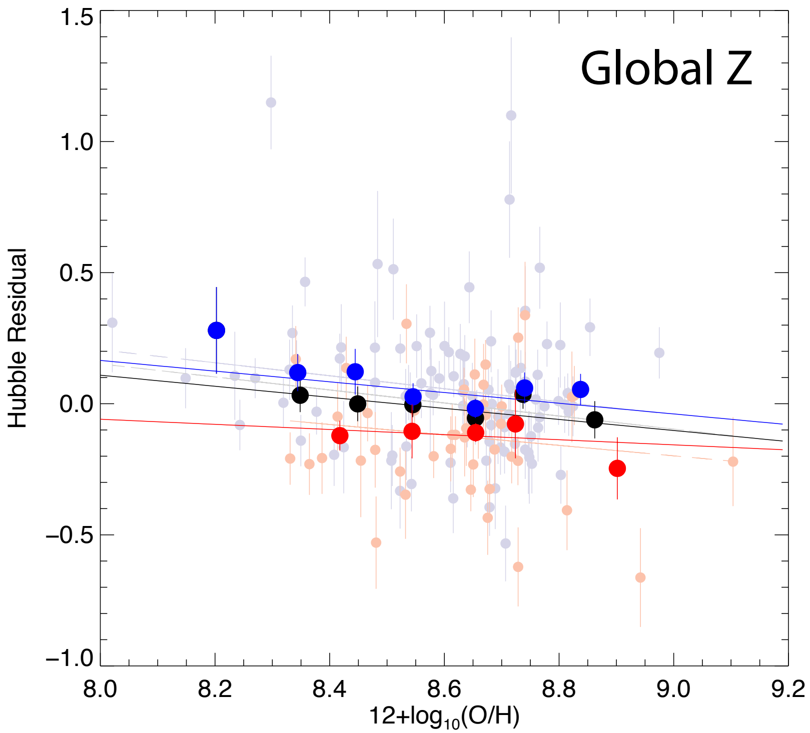
We find that **SNe in more massive, old, and more metallic galaxies, tend to explode farther for the center** (significance > 2 sigma).

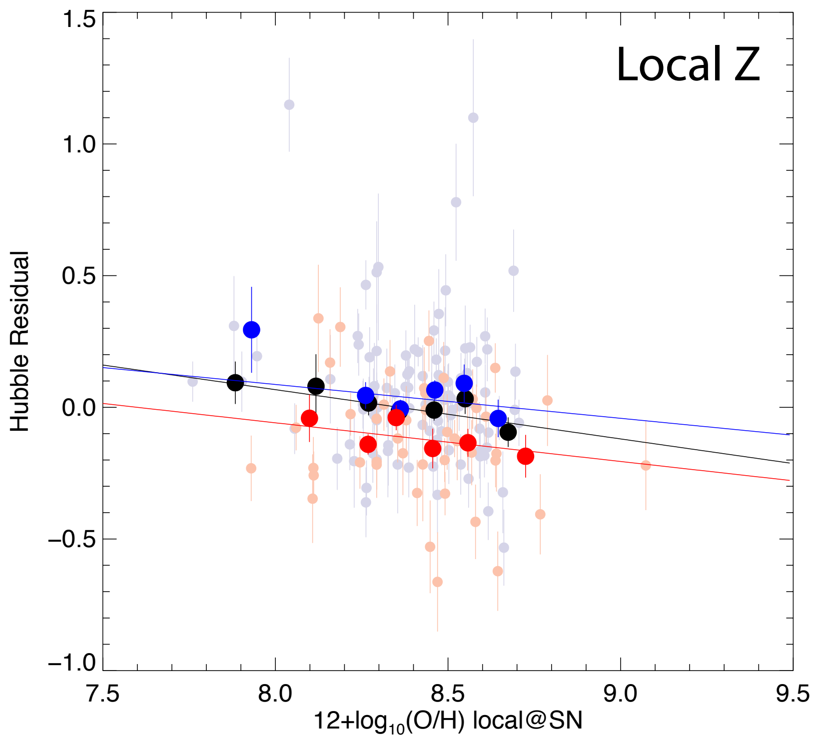
Metallicity gradients

We also considered the use of metallicity gradients as a better approximation to the local value at the SN position. We combine the expression in Boisser+09 with our own measurement of the NGCD.

gradient in Boissier+09

$$[12 + \log(O/H)](\mathrm{NGCD}) = Z_{\mathrm{CORE}} + (0.204 + 0.04\ \mathrm{M_B})(\mathrm{NGCD})$$



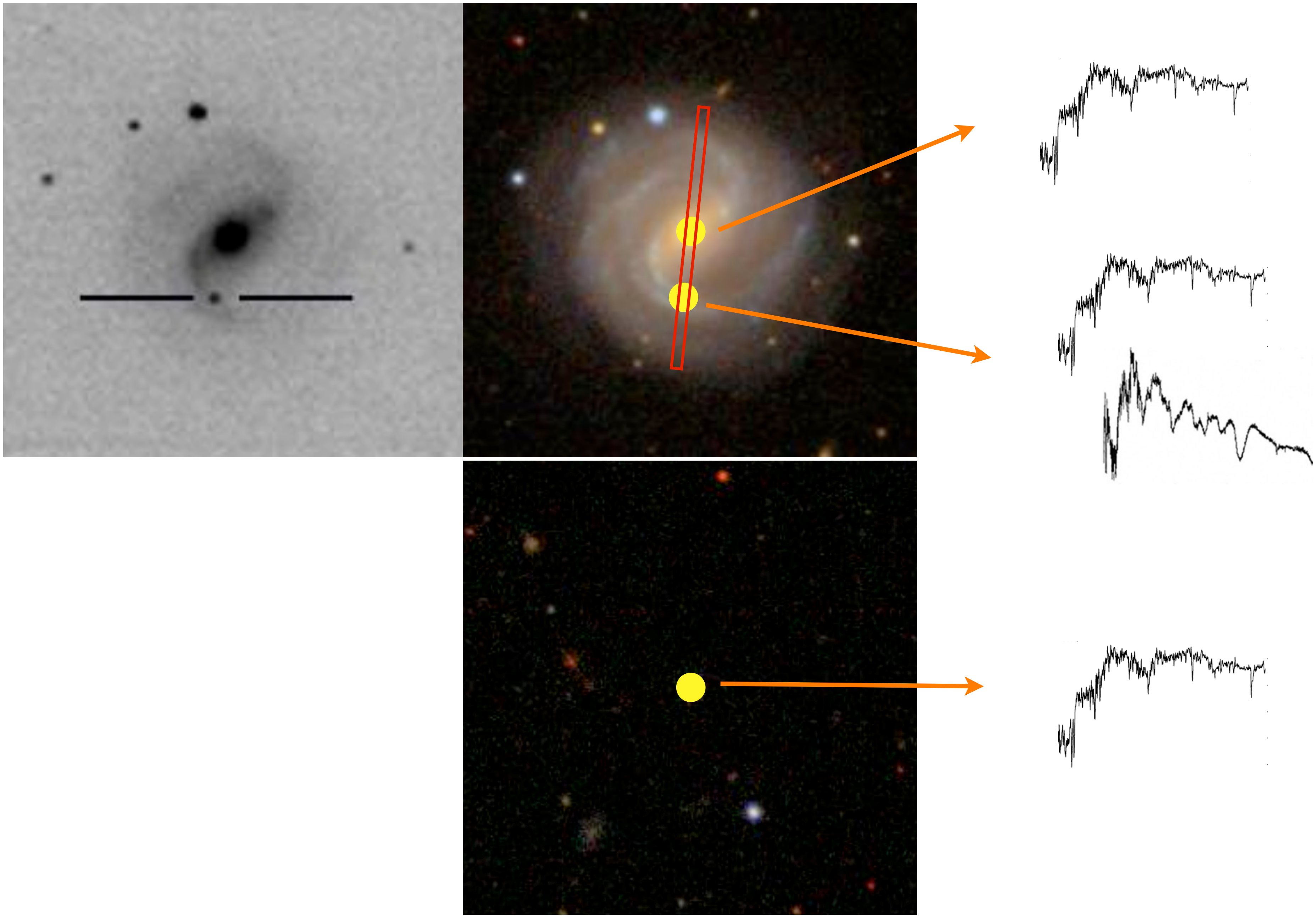


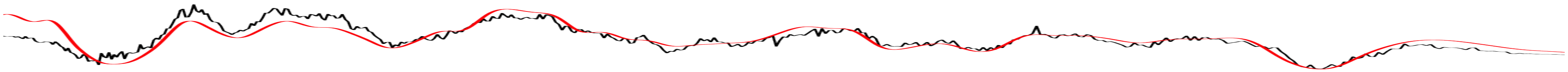
We **do not find any significant** (> 2 sigma) **slope** when using a metallicity gradient as an approximation to the local metallicity @SN position

Broad-band photometry Fiber / slit spectroscopy

z=0.016

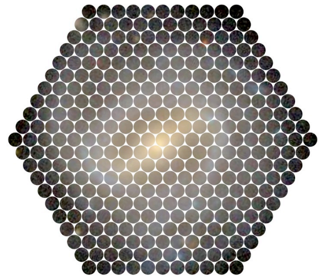
z=0.25



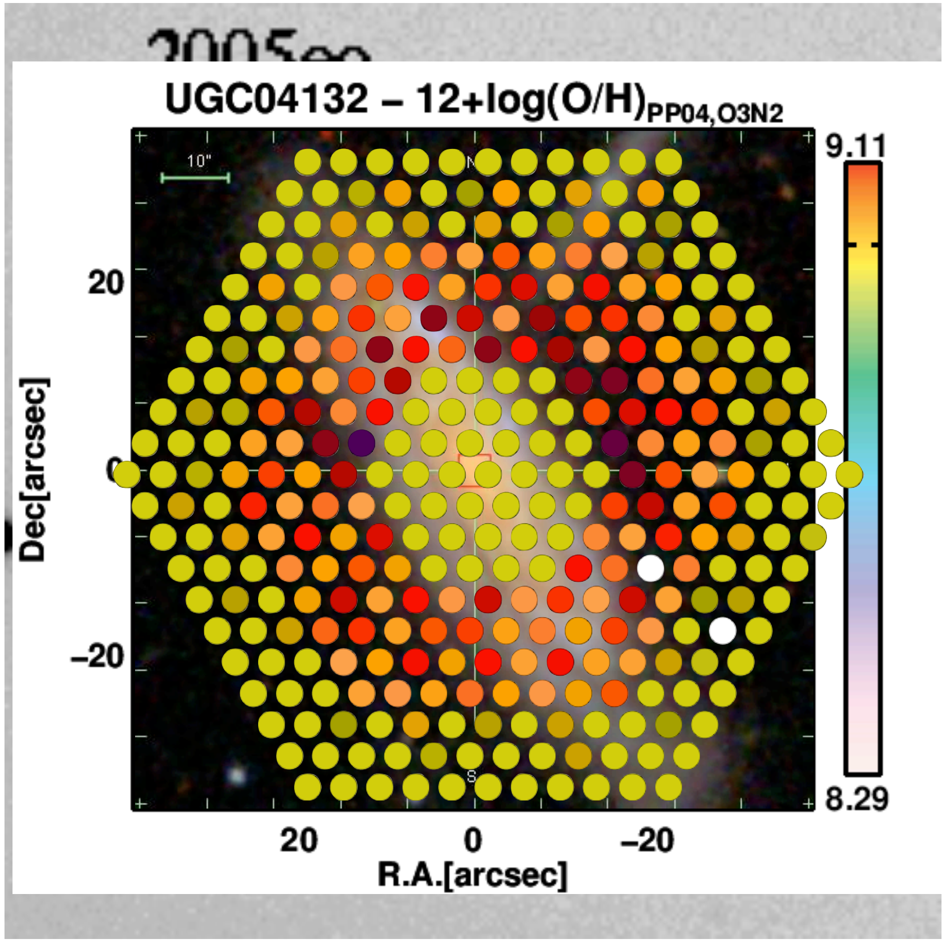


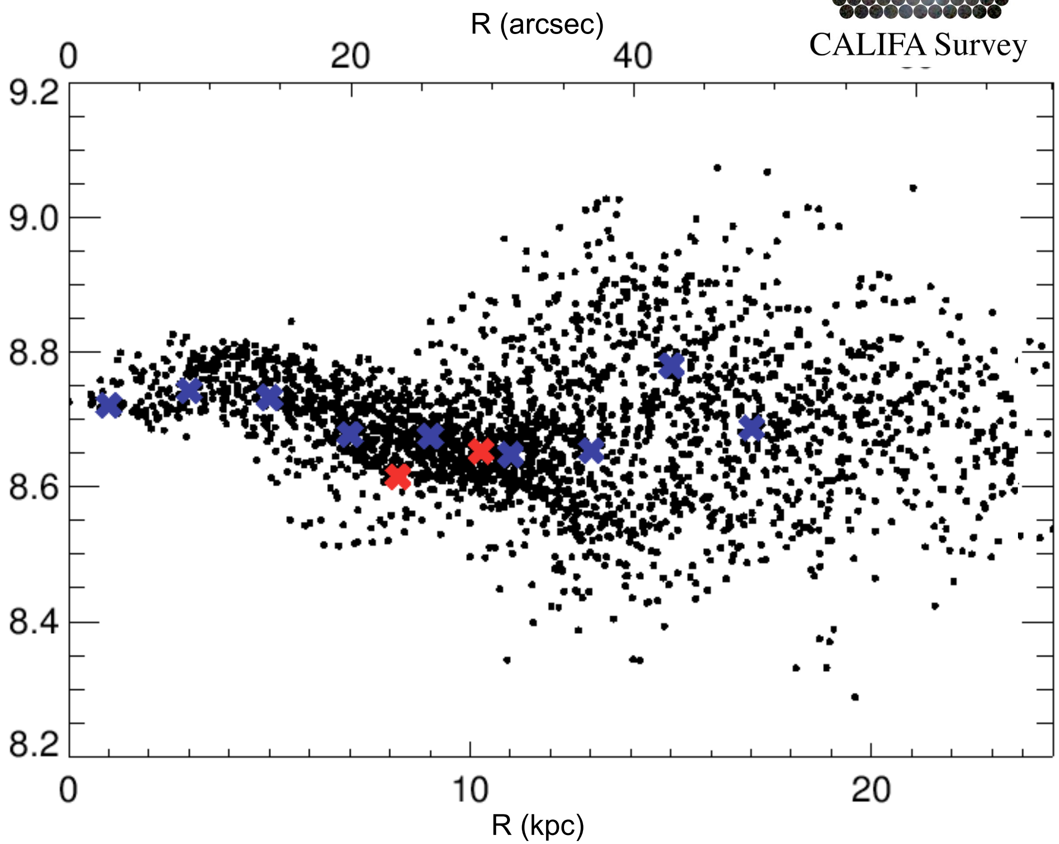
do the correlations found from global galaxy properties hold when using the local ones?

Integral spectroscopy



CALIFA Survey





Sample selection

- Cross-Check for SNe in both NED database (by name) and IAU list (by coordinates)

  266 galaxies observed (at least with one grating)

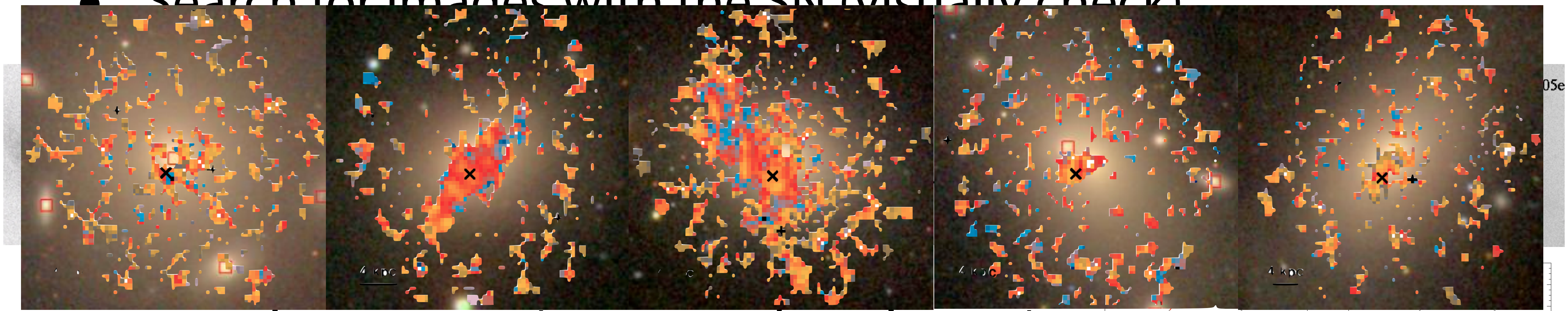
  56 hosted **67** SNe (9 with 2 SNe,1 with 3 SNe) (35 COMB, 21 only V500)

  44 in the field of view: **12** SNIa, **9** SNIbc, **17** SNII (2 b, 1 P, 4 n), **6** untyped

  5 SNIa hosts with no emission lines:

  Sample, 33 SNe: 17 II, 9 Ibc, 7 Ia

- Search for images with the SN (visually check)

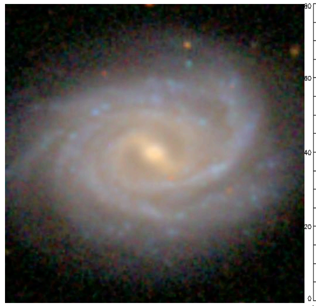


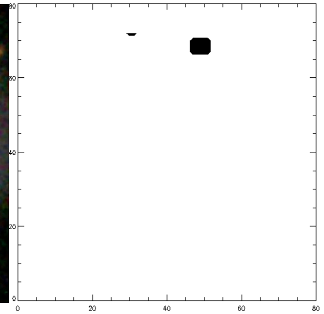
- Fit galaxy center (Σrows and Σcolumns)

NGC4784 UGC10097 NGC6146 NGC6166 NGC6173

- Determine SN position from offset (IAU, literature...)

Reduction





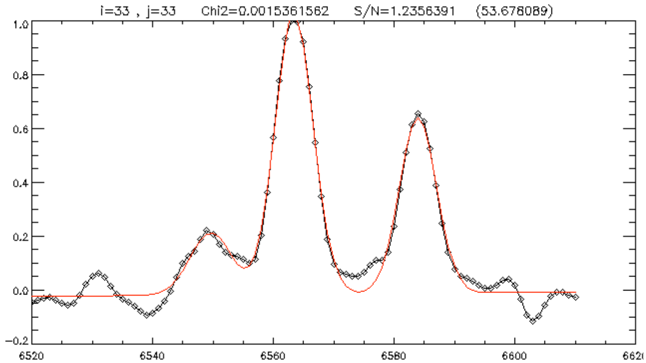
- Use Rubén (et al.) masks when available
- Resample to 1Å, remove sky lines and shift to the rest-frame
- Fit all spectra with STARLIGHT

CB07: 17 Ages 10^6 to $1.8\ 10^{10}$ M$_\odot$

4 metallicities 0.004, 0.05, 0.2, 2.5 Z$_\odot$ (Z$_\odot$=0.02)

S/N window: [4580:4640] Å

Fit range: [3660:7000] Å



- Subtract continuum and fit emission lines with MPFIT

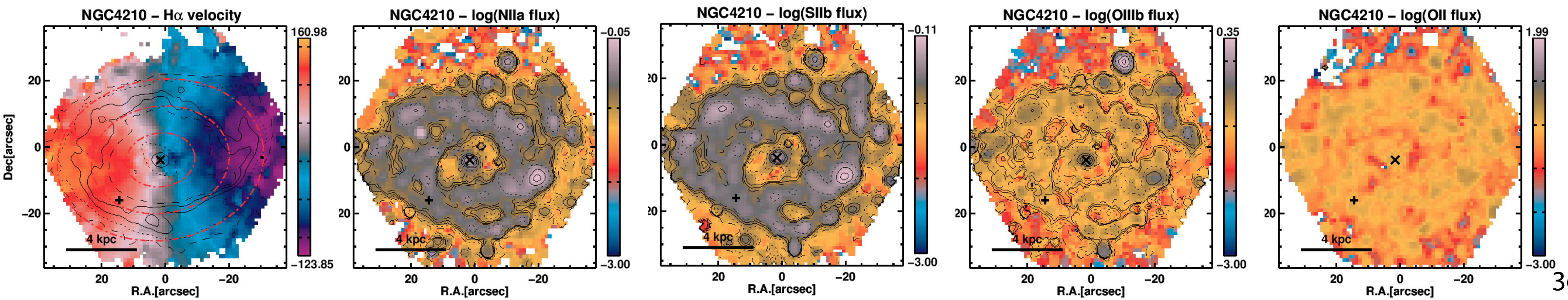
[O II] λ3727	[Ne I] λ4931	[O I] λ6364
[Ne III] λ3868	[O III] λ4959	[N II] λ6548
Hϵ λ3970	[O III] λ5007	Hα λ6563
Hδ λ4102	[O I] λ5577	[N II] λ6583
Hγ λ4340	[He I] λ5875	[S II] λ6716
[O III] λ4363	[O I] λ6300	[S II] λ6731
Hβ λ4861	[S III] λ6312	

Hα velocity to shift whole spectrum

Balmer decrement to correct for extinction → E(B-V)

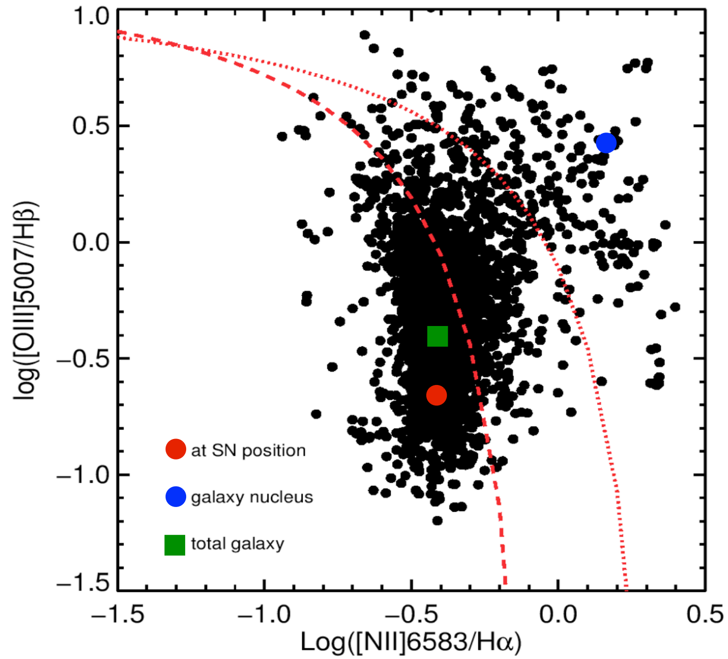
Line flux, line velocity, gaussian fit parameters

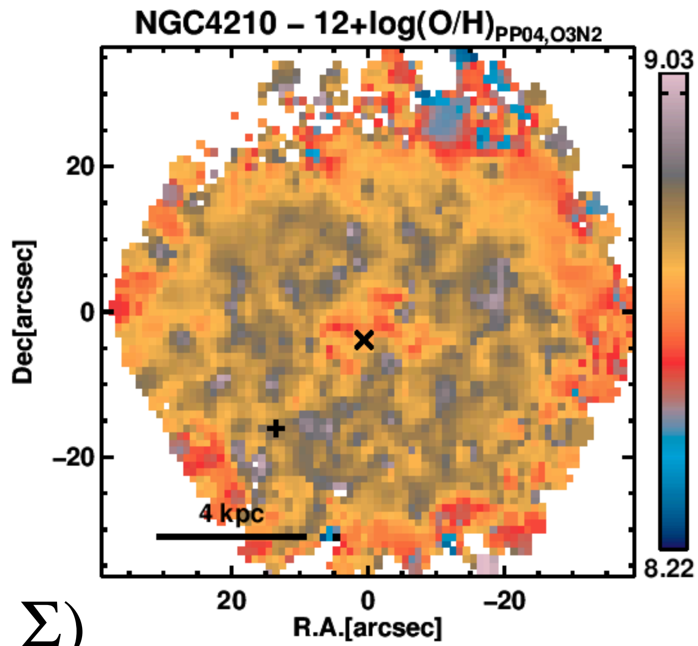
Produce 2D maps for each line



Measurements

- Electronic density (N_e=SIIa/SIIb)
- Diagnostic diagram (BPT)
- Several metallicity calibrations
    - Pettini & Pagel 04 (PP04): N2, O3N2
    - Perez-Montero & Contini 09 (PC09): O3N2_NO
    - Kobulnicky & Kewley 04 (KK04): R23
    - Tremonti+04 (T04): R23_T
    - Pilyugin+10: P10
    - Pilyugin+11: P11





- Ionization parameter
- Star formation rate (sqarcsec, sqkpc, Σ)
- Stellar populations parameters from STARLIGHT

Kinemetry

Deprojection

Azimutal average

Voronoi binning

Integrated spectrum

3” aperture spectrum

Kinemetry

Fit ellipses using Krajnovic et al. 2006

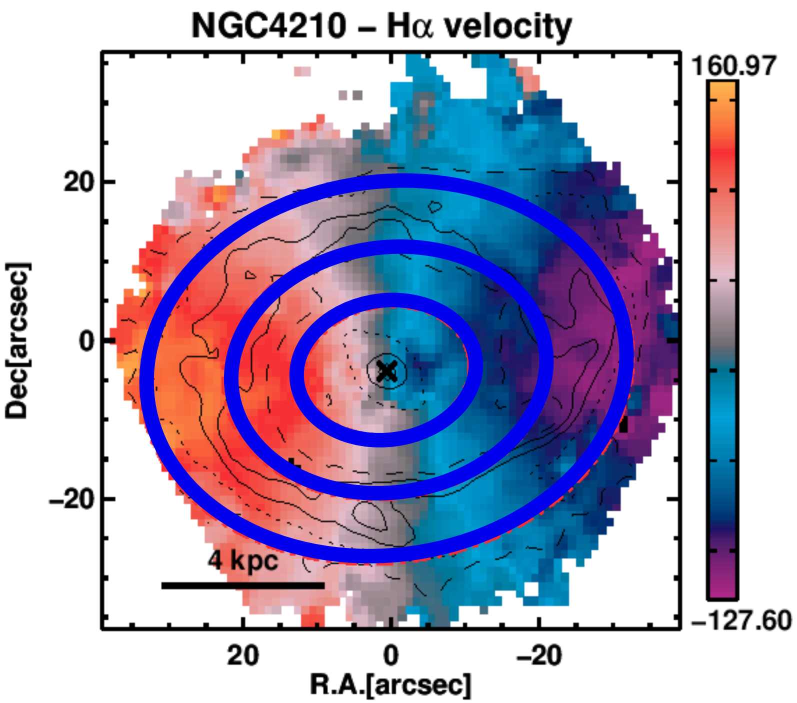
Deprojection

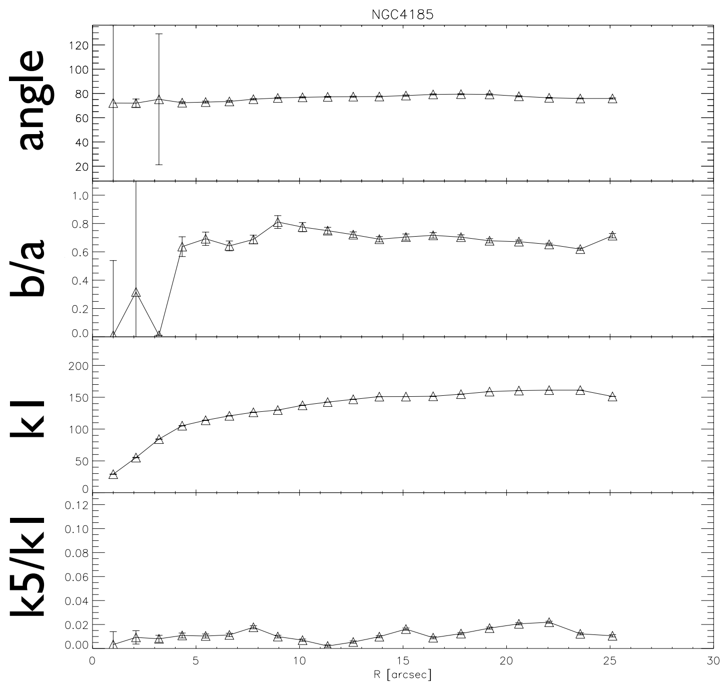
Azimutal average

Voronoi binning

Integrated spectrum

3" aperture spectrum





Kinemetry

Deprojection

Azimutal average

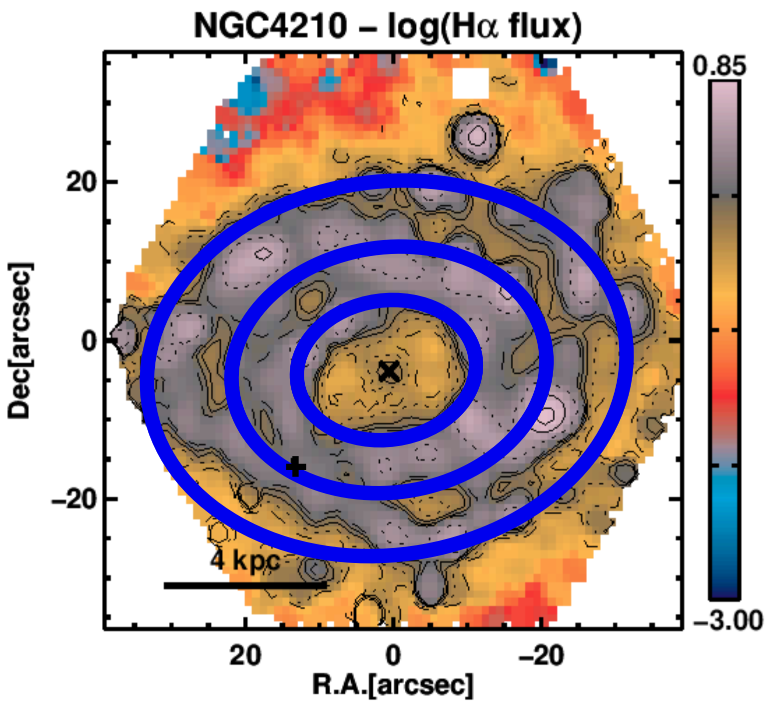
Voronoi binning

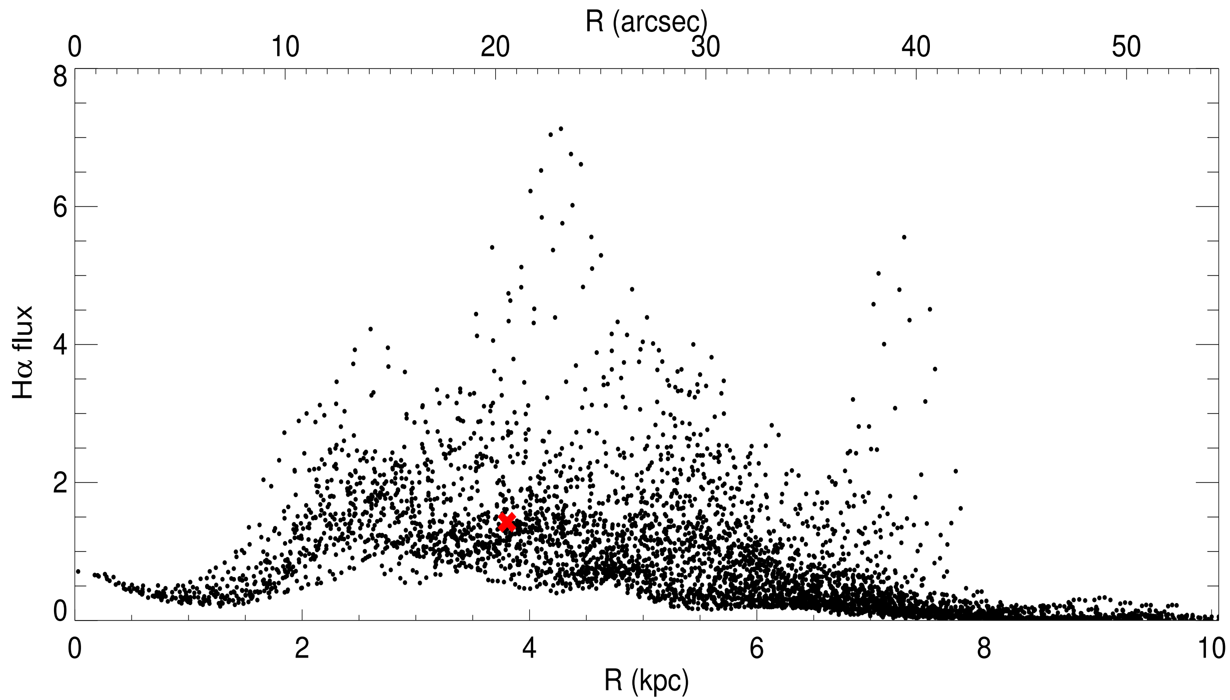
Integrated spectrum

3" aperture spectrum

Fit ellipses using Krajnovic et al. 2006

Measure distances in the galactic plane





Kinemetry — Fit ellipses using Krajnovic et al. 2006

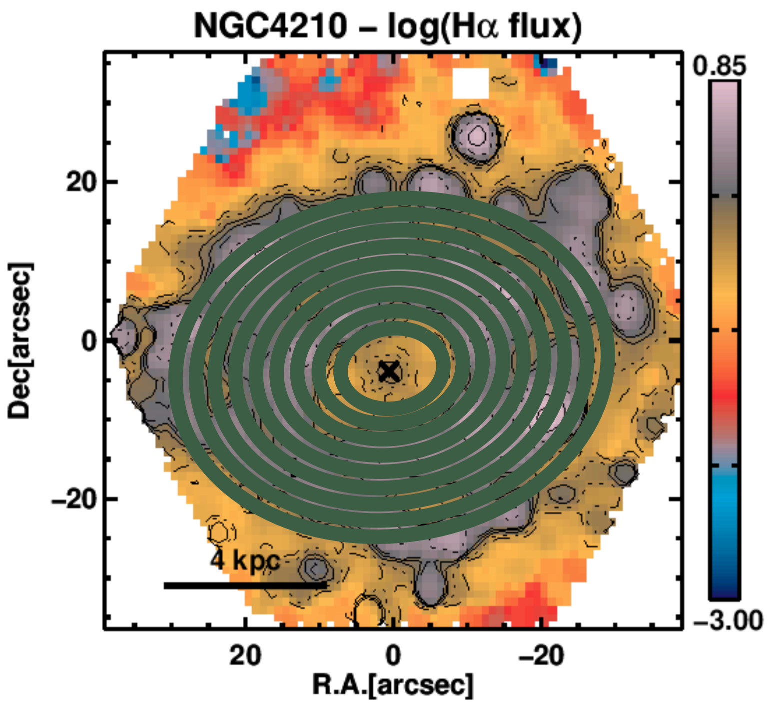
Deprojection — Measure distances in the galactic plane

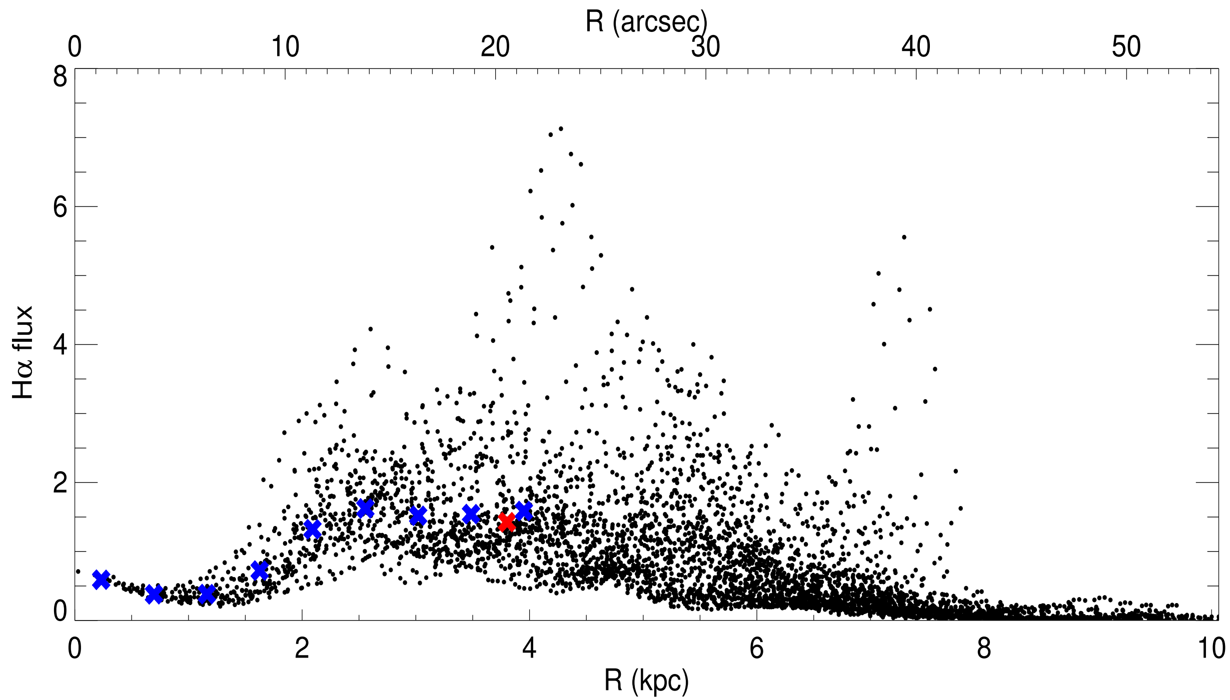
Azimutal average — Co-add ell. rings centered in the core

Voronoi binning

Integrated spectrum

3" aperture spectrum





Kinemetry — Fit ellipses using Krajnovic et al. 2006

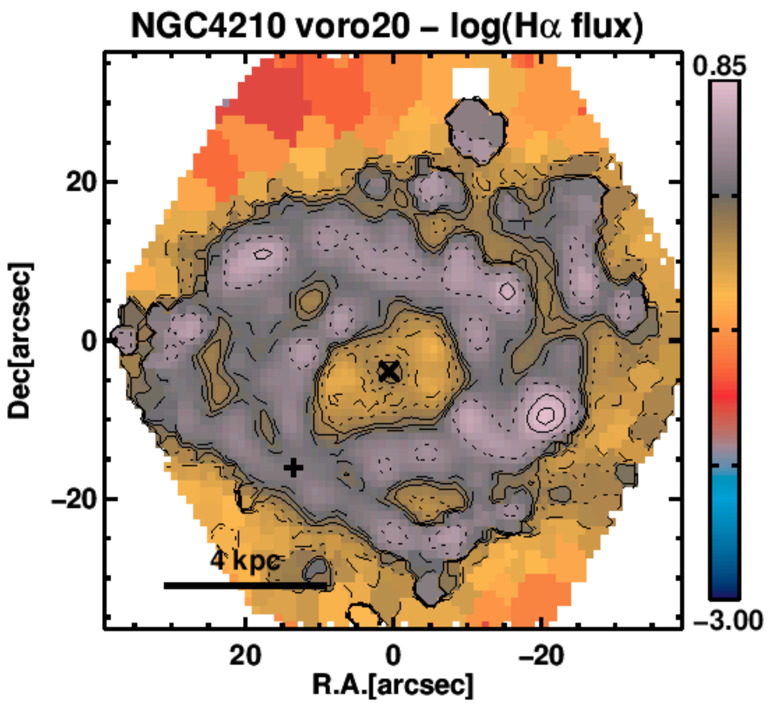
Deprojection — Measure distances in the galactic plane

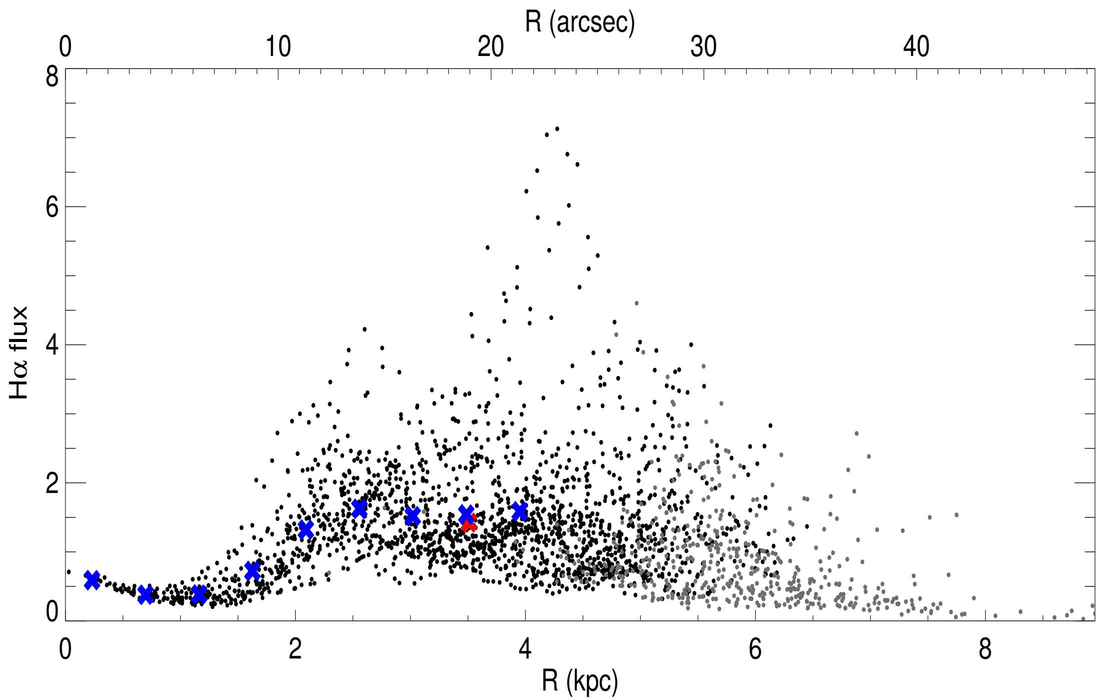
Azimutal average — Co-add ell. rings centered in the core

Voronoi binning — Requiring S/N > 20

Integrated spectrum

3" aperture spectrum





Kinemetry — Fit ellipses using Krajnovic et al. 2006

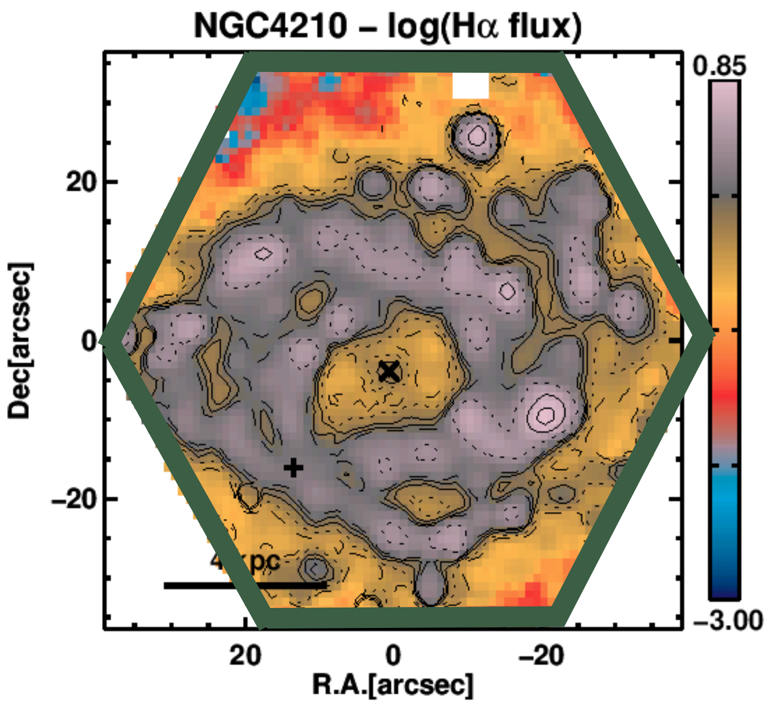
Deprojection — Measure distances in the galactic plane

Azimutal average — Co-add ell. rings centered in the core

Voronoi binning — Requiring S/N > 20

Integrated spectrum — For high-z (aperture effects)

3″ aperture spectrum



Kinemetry — Fit ellipses using Krajnovic et al. 2006

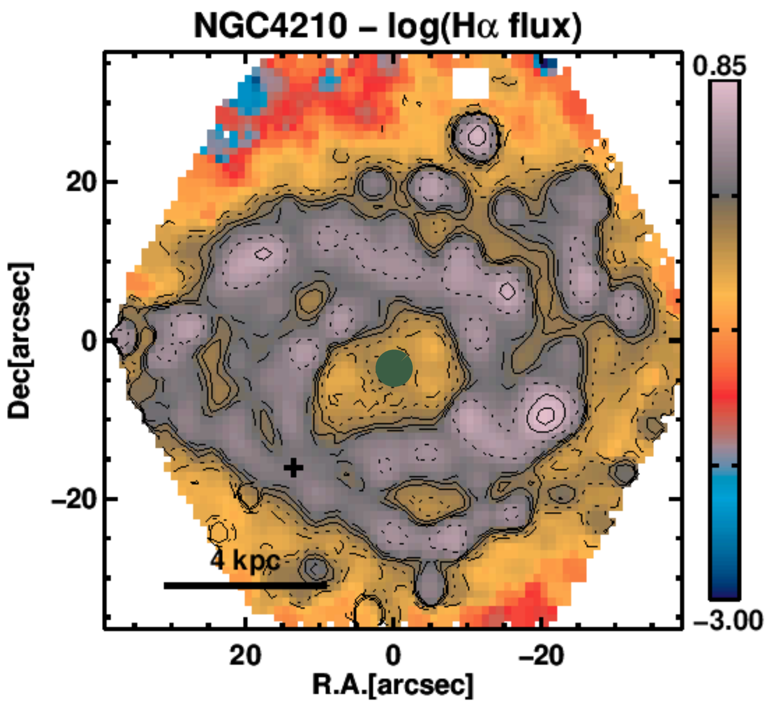
Deprojection — Measure distances in the galactic plane

Azimutal average — Co-add ell. rings centered in the core

Voronoi binning — Requiring S/N > 20

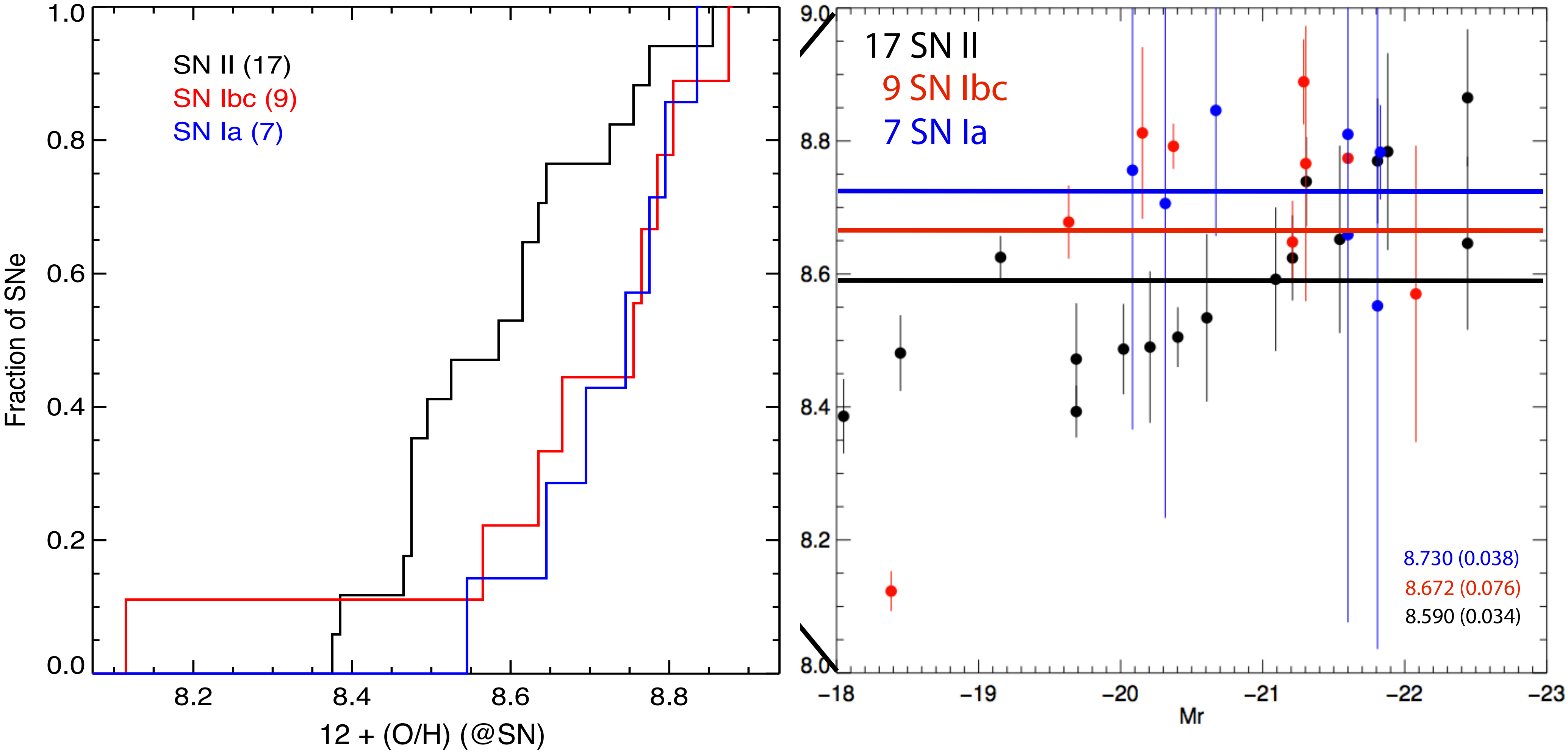
Integrated spectrum — For high-z (aperture effects)

3" aperture spectrum — Allow comparisons (SDSS + fiber)



Results...

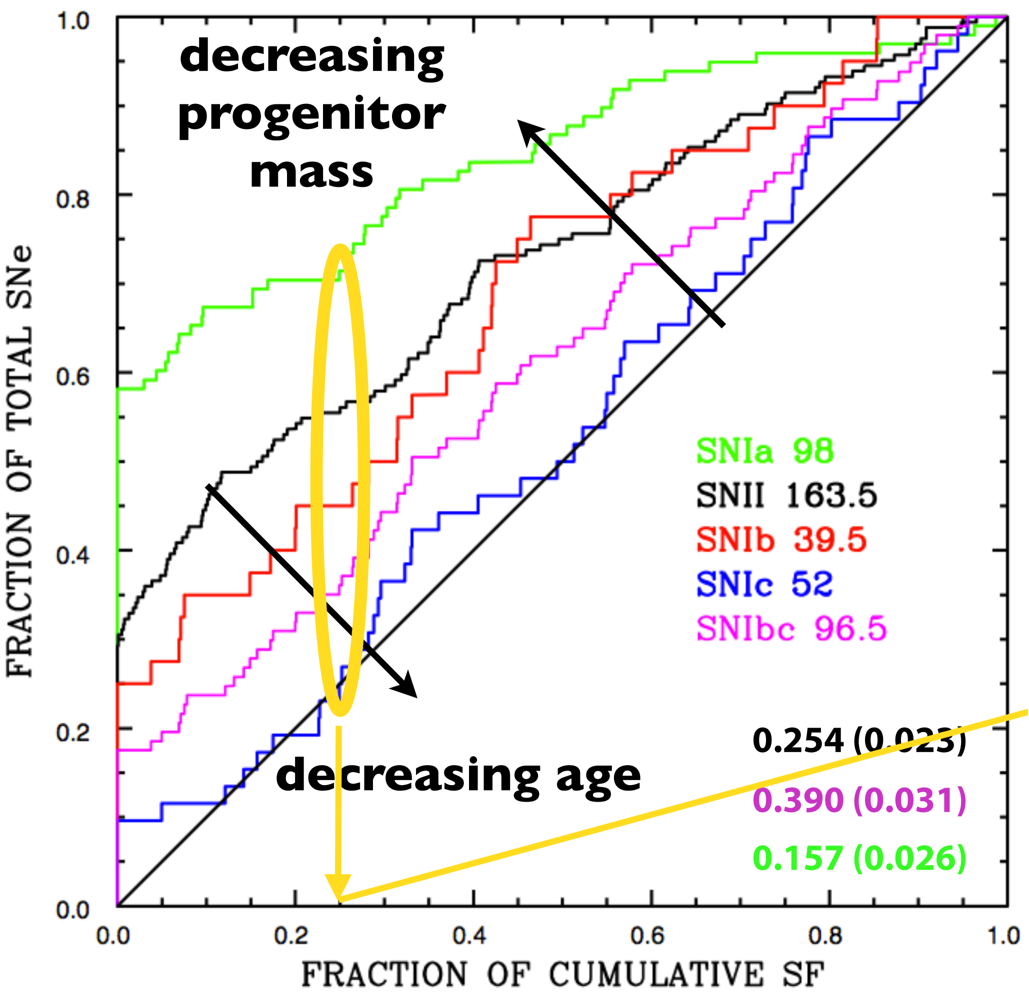
$Z_{Ia} > Z_{Ibc} > Z_{II}$



SN II (17)
SN Ibc (9)
SN Ia (7)
Fraction of SNe
12 + (O/H) (@SN)
17 SN II
9 SN Ibc
7 SN Ia
8.730 (0.038)
8.672 (0.076)
8.590 (0.034)
Mr

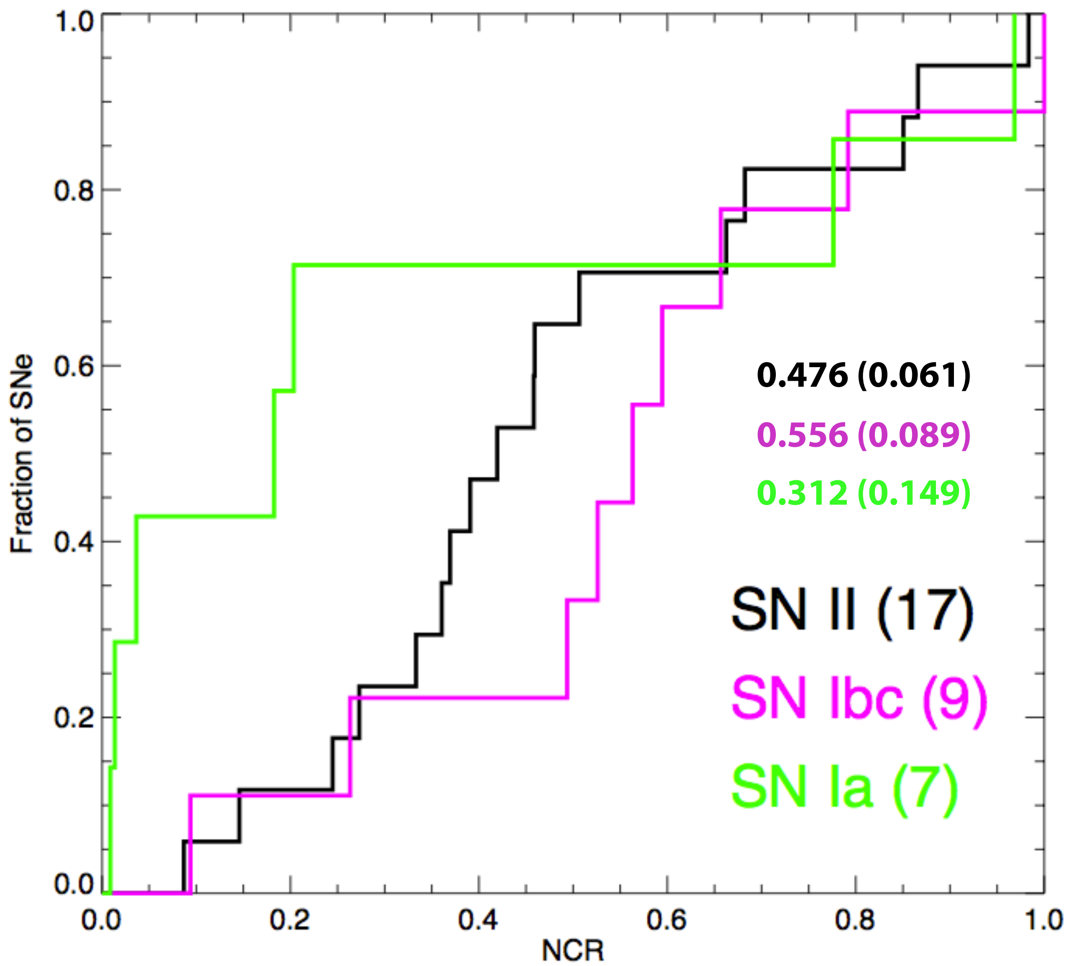
Hα emission (SF)

Hα imaging



Anderson+12

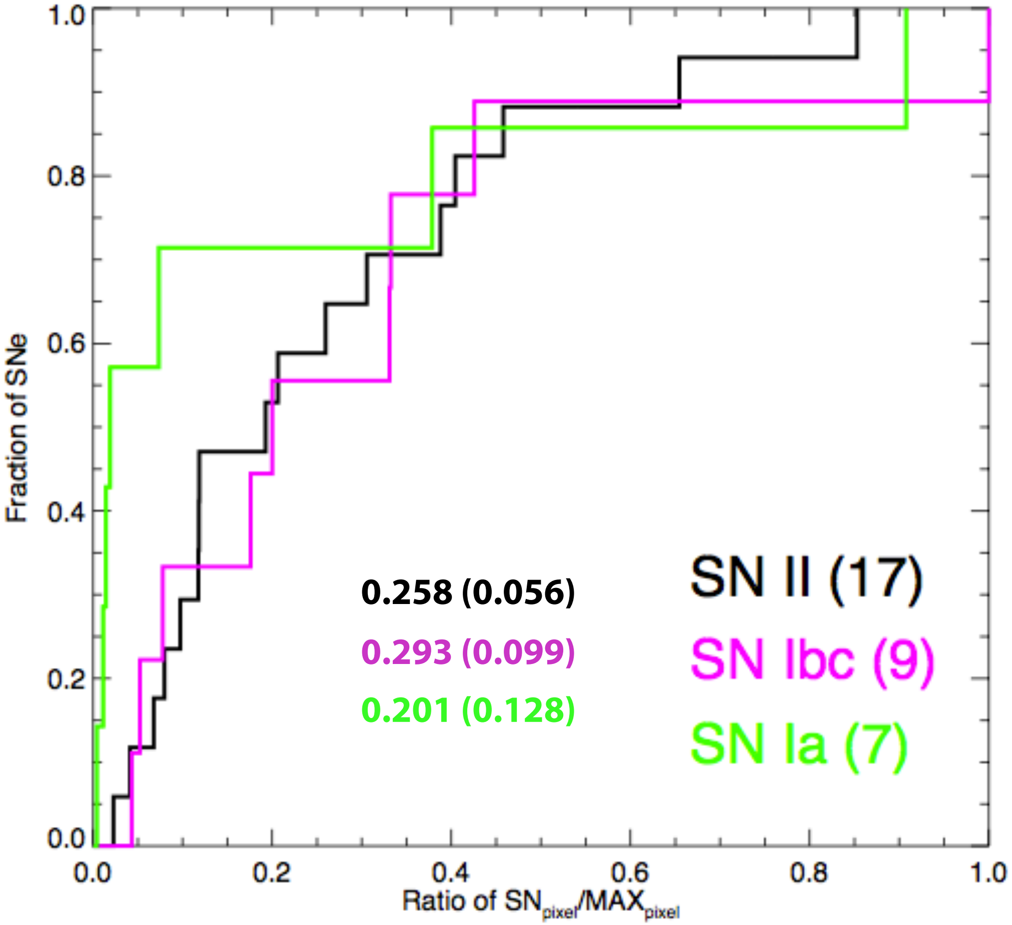
NCR result



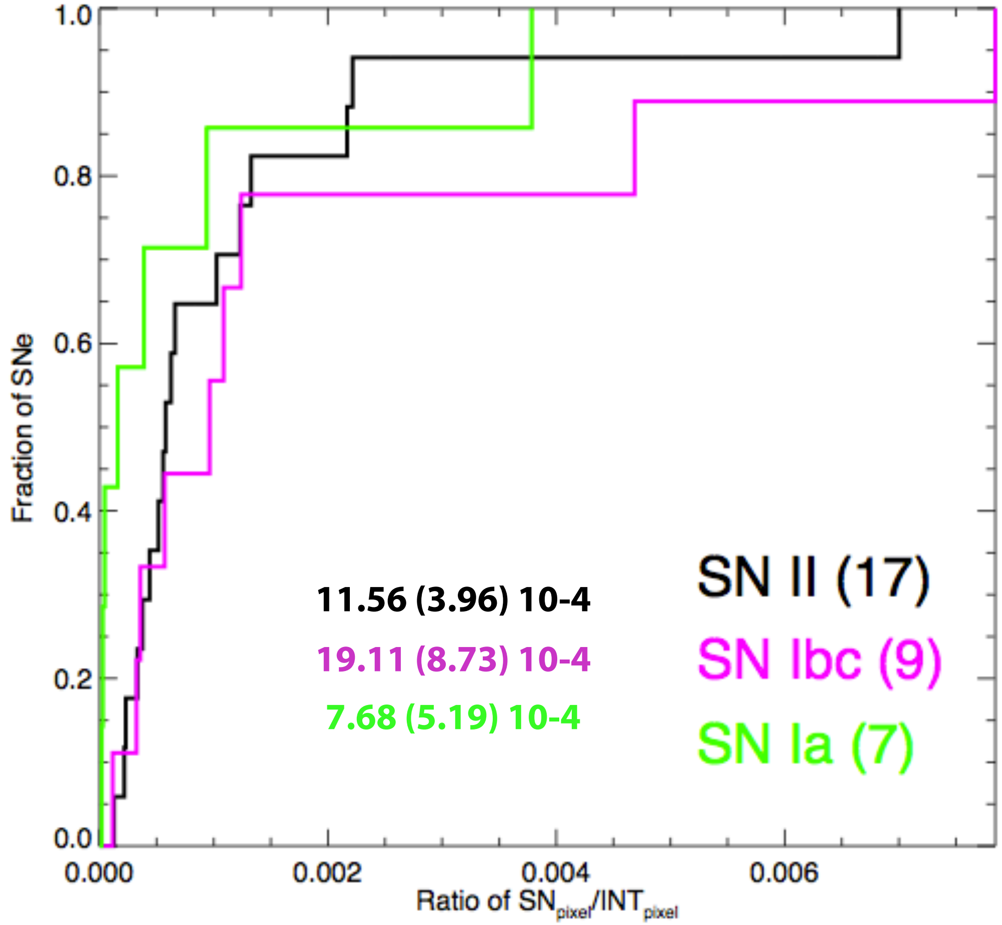
pixels

Hα emission (SF)

@SN/MAX

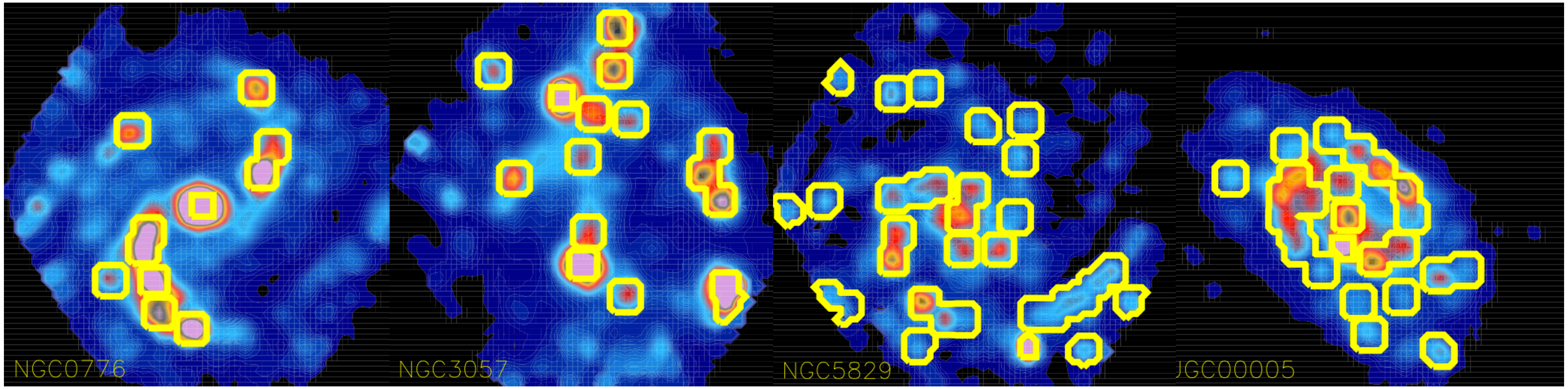


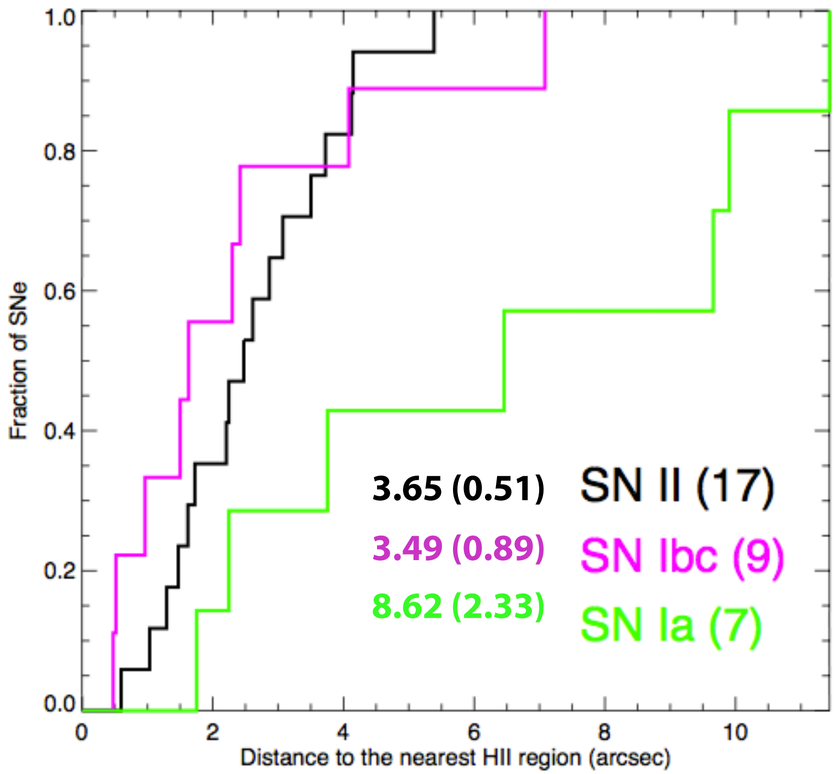
@SN/TOTAL

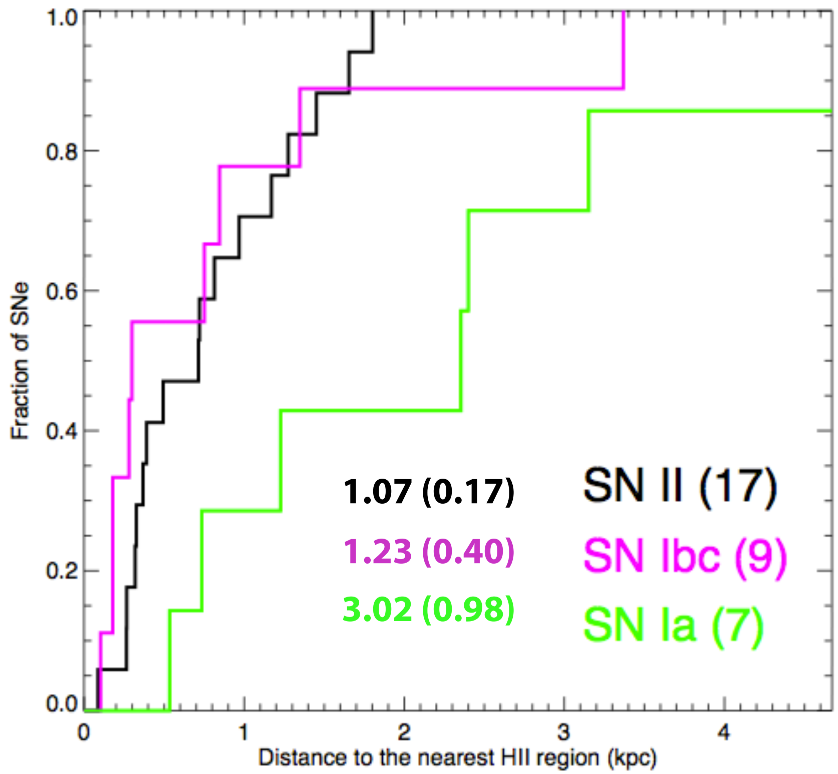


Hα emission (SF)

HIIexplorer

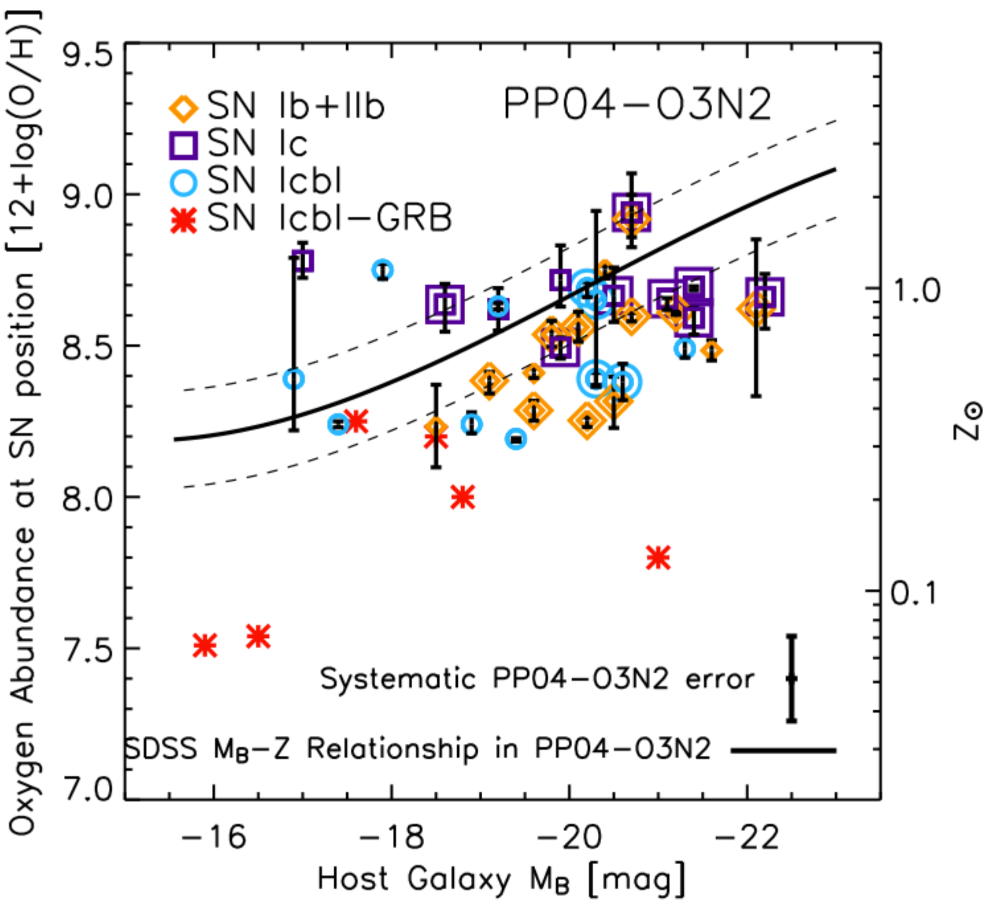




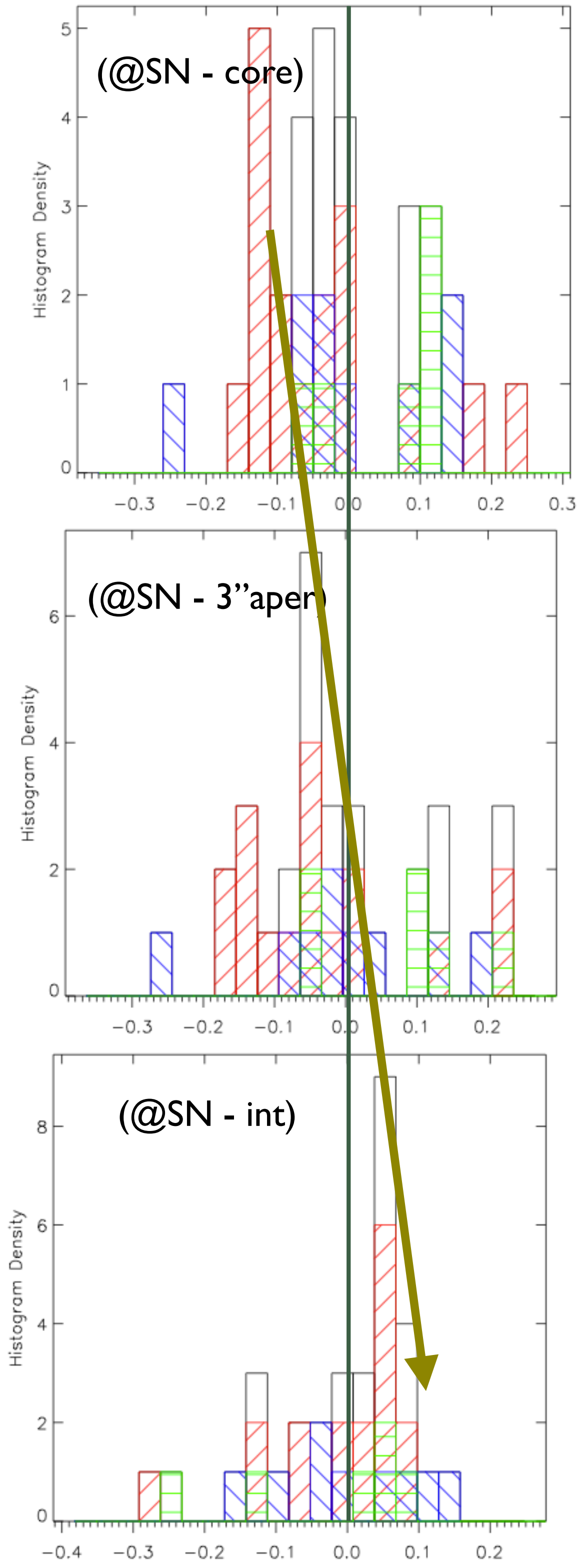


global Z Vs Local Z

long slit @SN



Modjaz+11



II -0.034
Ibc -0.011
Ia 0.111

II -0.034
Ibc -0.009
Ia 0.107

II -0.013
Ibc 0.004
Ia 0.027

Conclusions (2nd)

- We found some indications on differences between type II, Ibc and Ia SNe
  - mass, age, metallicity
  - progenitors
- we found differences between global and local metallicities
  - ...cosmology (aperture, gradients...)
- Need of more statistics to make strong conclusions
- Need to correlate other parameters