The AMUSING survey an update

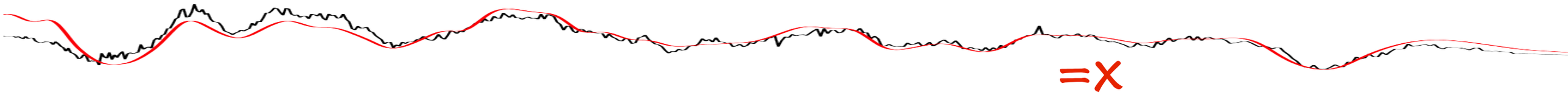
Lluís Galbany

MSCA fellow, U. Granada

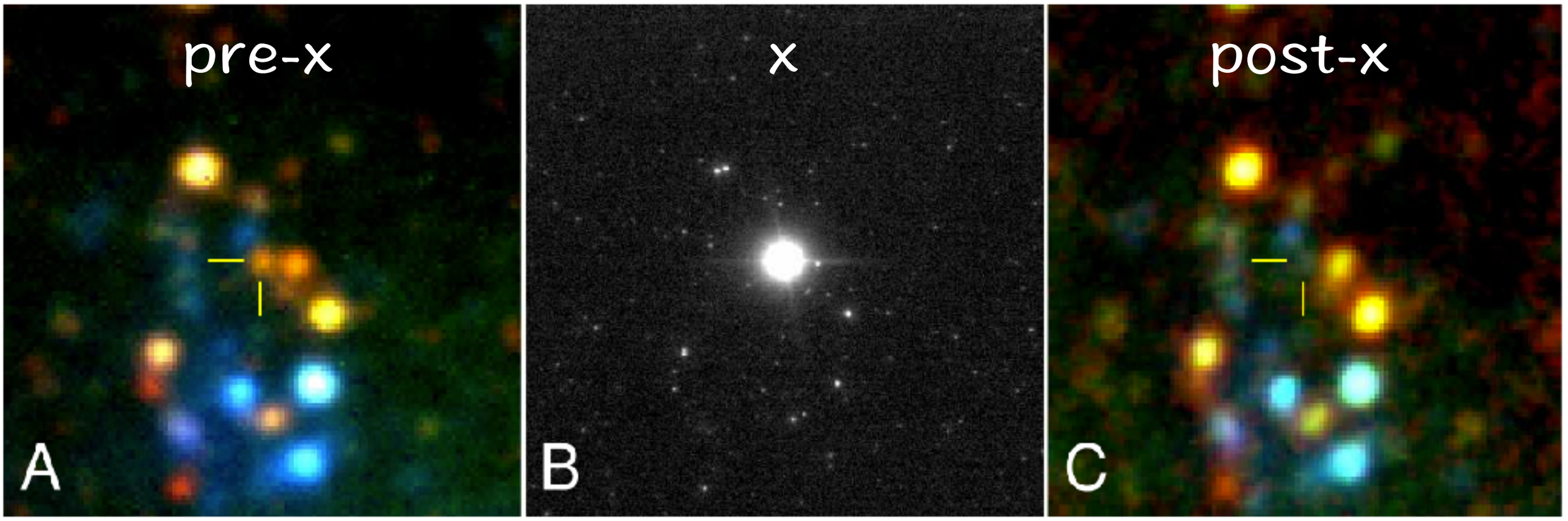
Palau de la Música Catalana, Antoni Rigalt i Blanch et al. 1908

Granada, Jan 27 2020

Direct progenitor detection in pre-explosion images



Around 30 direct detections of SN progenitors in HST pre-explosion images.



mattila+10 -> smartt15 -> van dyk17

All CCSNe (~80% SNII), and no SNIa detection (but 1 02cx-like?)

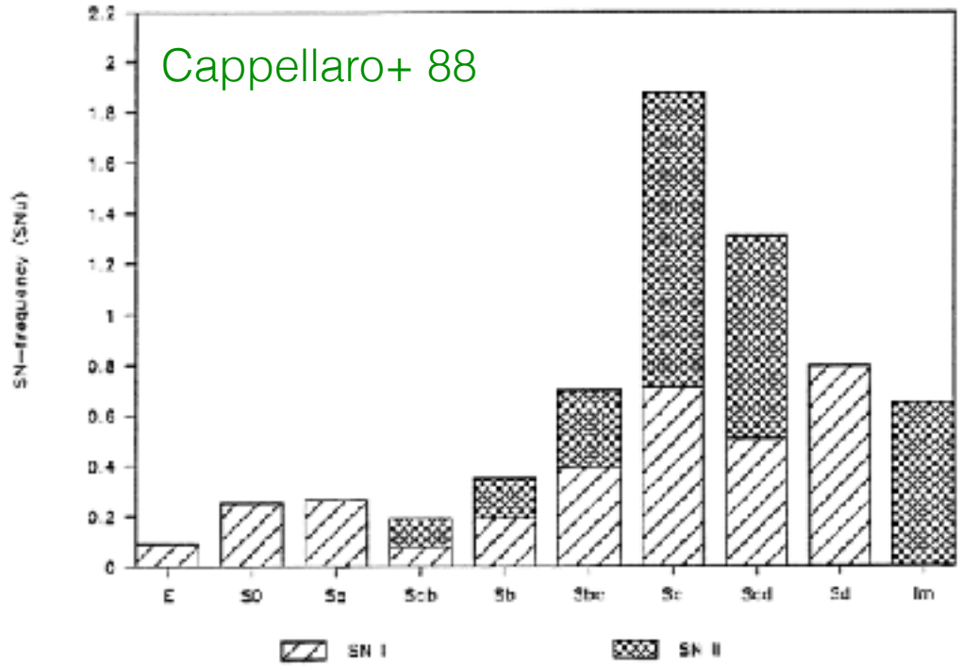
Low statistics, binarity, RSG problem, etc…

Alternative methods include studies of statistical samples of **SN environments**

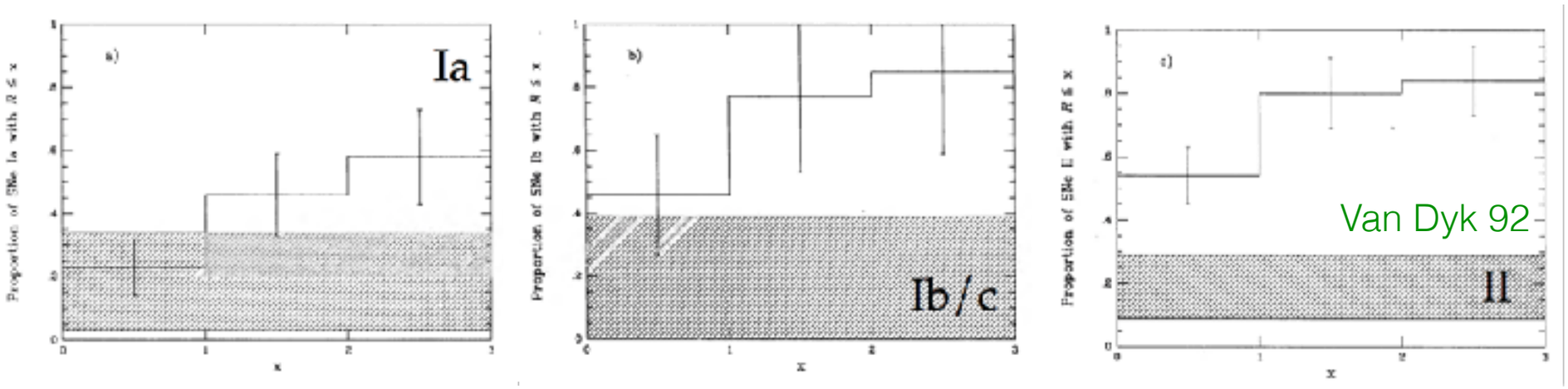
SN environmental studies examples

- **SNe II** only in SF galaxies

Frequency of SN I and
SN II per galaxy type



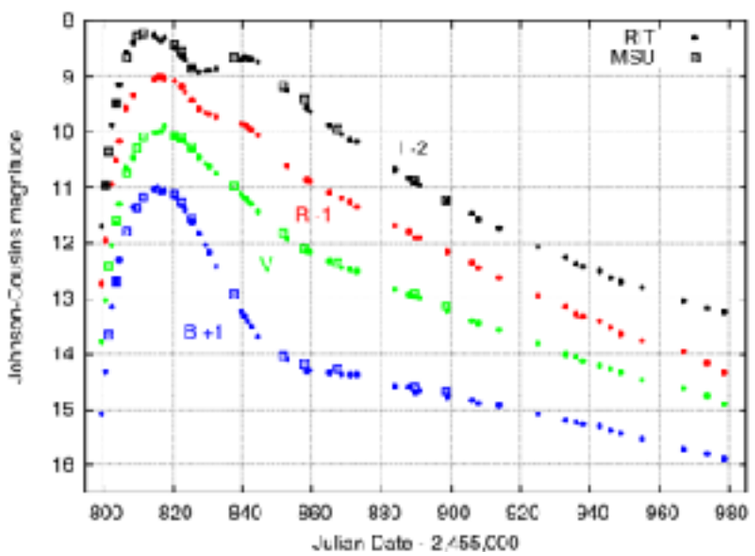
- **SN Ibc** and **SN II** more associated to SF regions than **SNe Ia**

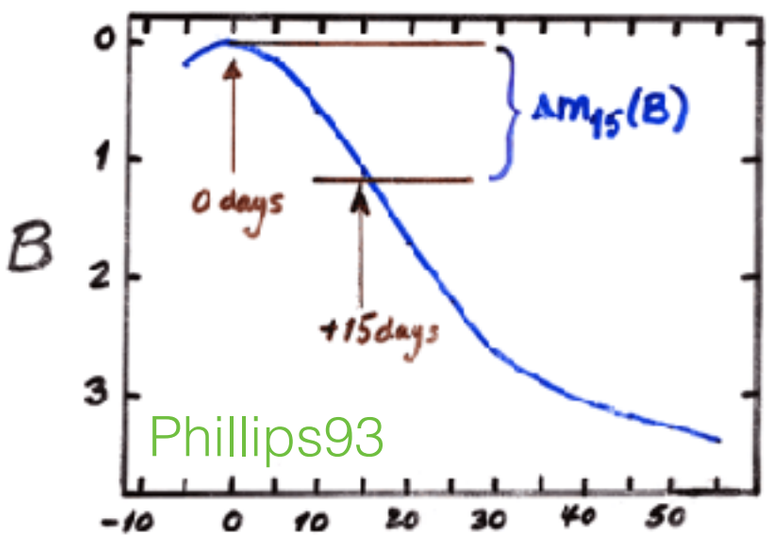


Cumulative distributions of distances to HII regions

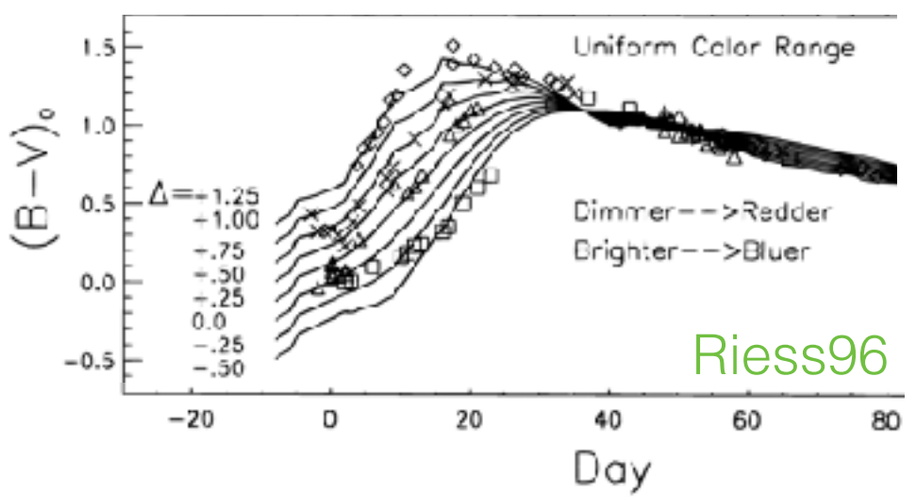
SNIa standardization

SNIa light-curve standardization origins from two empirical correlations:





m_{max} vs decline rate



m_{max} vs $color_{max}$

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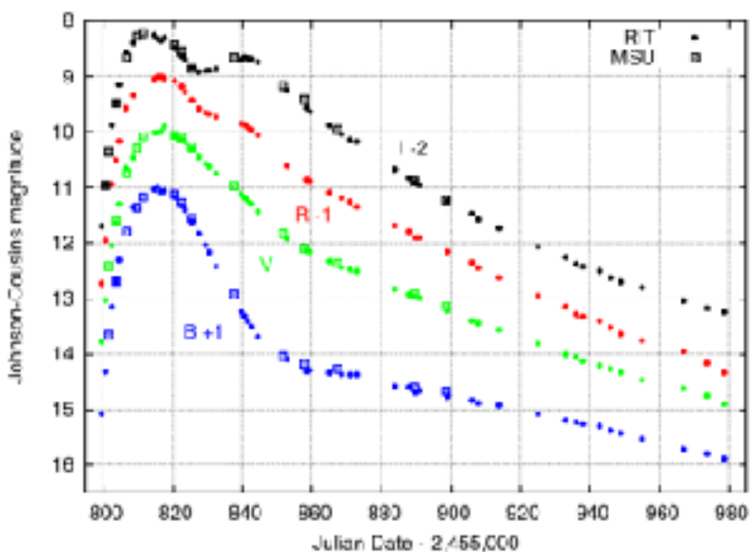
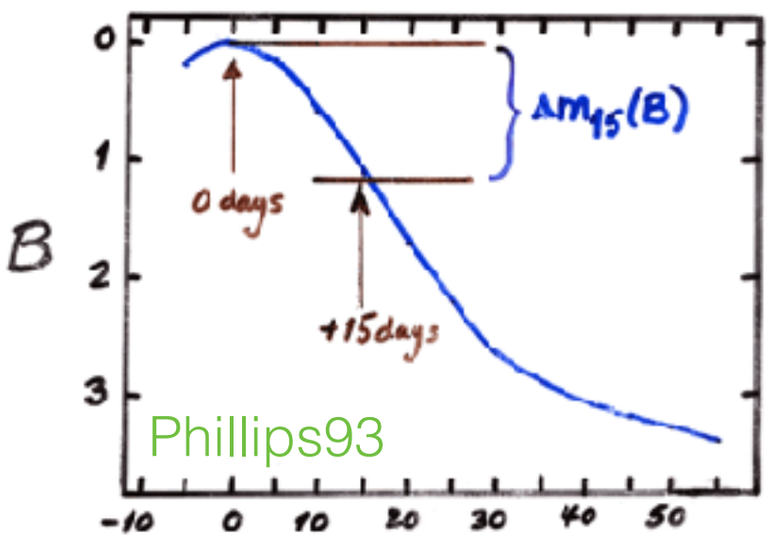
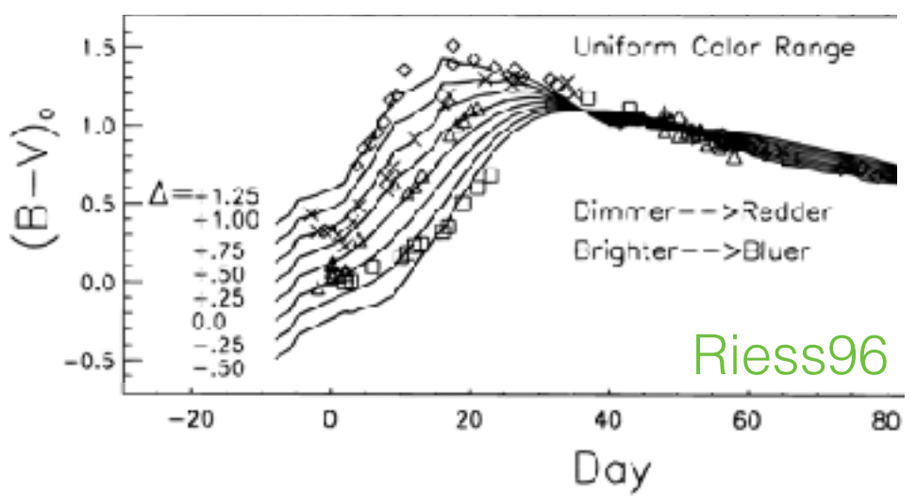






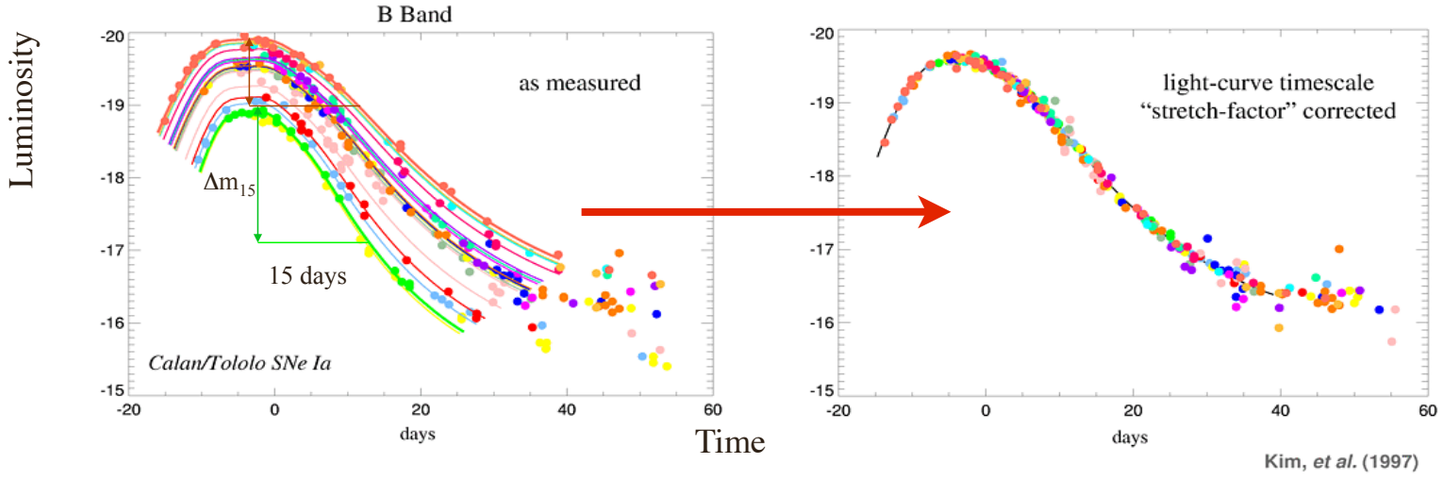
m_{max} vs decline rate m_{max} vs $color_{max}$

Parametrization has different *flavors*: Δm_{15},$E(B\text{-}V)_{max}$ Δ,A_V s,c x1,c s_{BV}

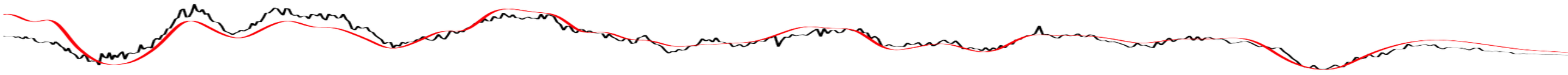
Standardization includes parameters from those 2 parameters (Tripp98):

$$m_{\rm cor} = m_{\rm obs} + \alpha x1 - \beta c$$

α,**β** correlation coeff.



SNIa cosmology 2nd order corrections: Environment



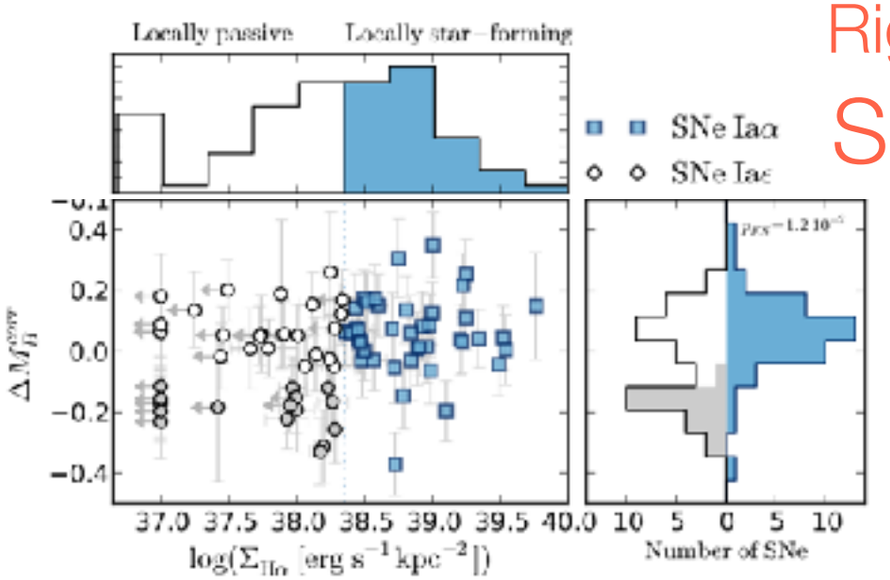
Look for dependences of the SN properties on the host galaxy properties (focused on global characteristics of the host)

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)	high-metallicity galaxies host SNe Ia with negative HR (after LC-corr)
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
Neill et al. (2009)	Older hosts produce less-extincted SNe Ia
Cooper et al. (2009)	SNIa are more luminous or more numerous in metal-poor galaxies
Brandt et al. (2010)	Luminous SNe associated with recent star-formation and young prog.
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
Konishi et al. (2011)	SNe Ia in host galaxies with a higher star formation rate show brighter events
Galbany et al. (2012)	SNe that explode further are less extinguished, and have lower metallicity
Childress et al. (2013)	correlation between SN Ia intrinsic color and host metallicity
Johansson et al. (2013)	more luminous SNe Ia appear in younger stellar progenitor systems
Rigault et al. (2013)	SNe Ia with local Hα emission are redder and drives the HR-mass relation
Pan et al. (2014)	fainter, faster declining SNe Ia are hosted by older/massive/metal-rich galaxies
Moreno-Raya et al. (2016)	SNe Ia luminosities tend to be higher for galaxies with lower metallicities
…	

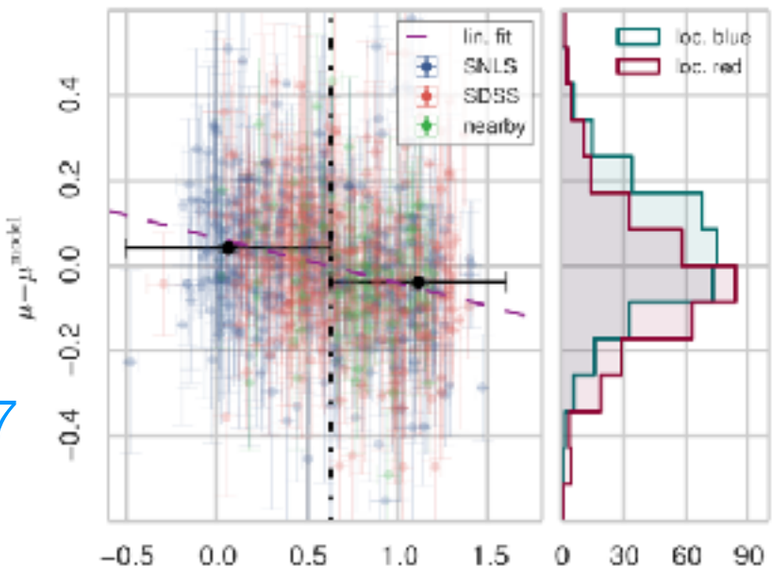
SNIa local environment

Just recently, some works have started looking at the LOCAL environment, finding some trends:



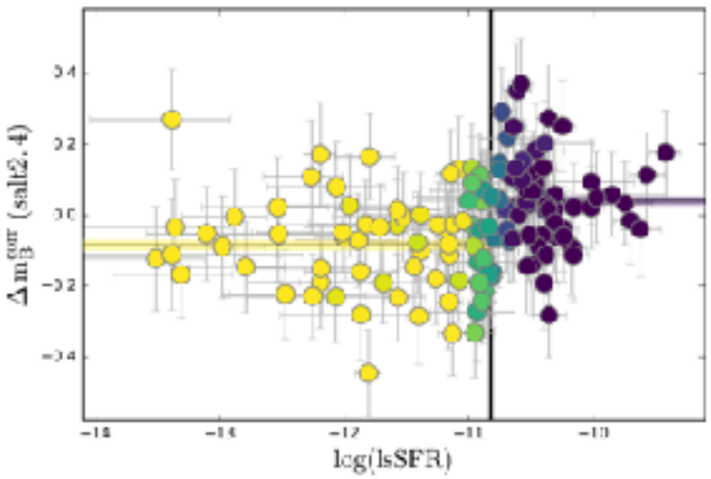
Rigault et al. 2013

SFR IFS ~1kpc



Roman et al. 2017

U-V Phot ~3kpc

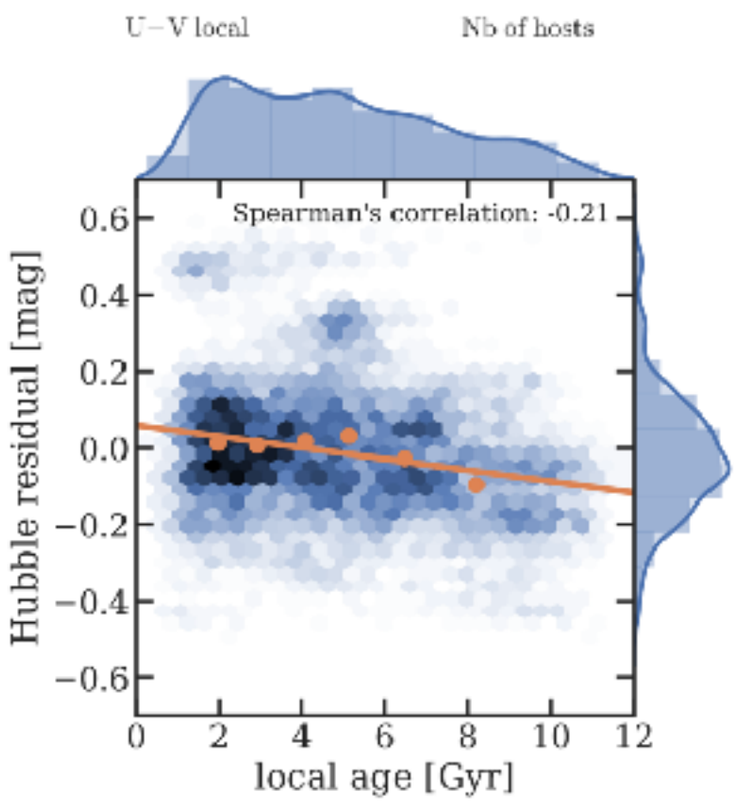


Rigault et al. 2018

lsSFR Phot ~5arcsec

Rose et al 2019

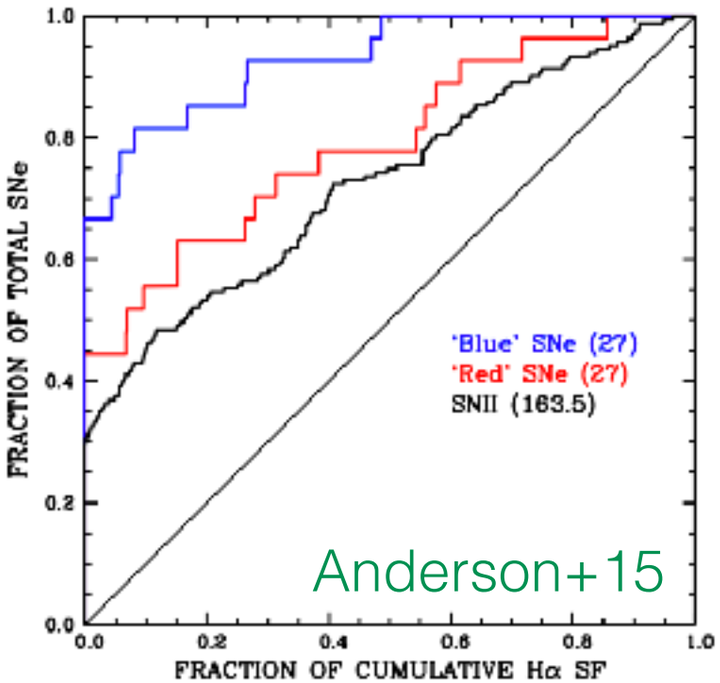
Age Phot ~1.5kpc

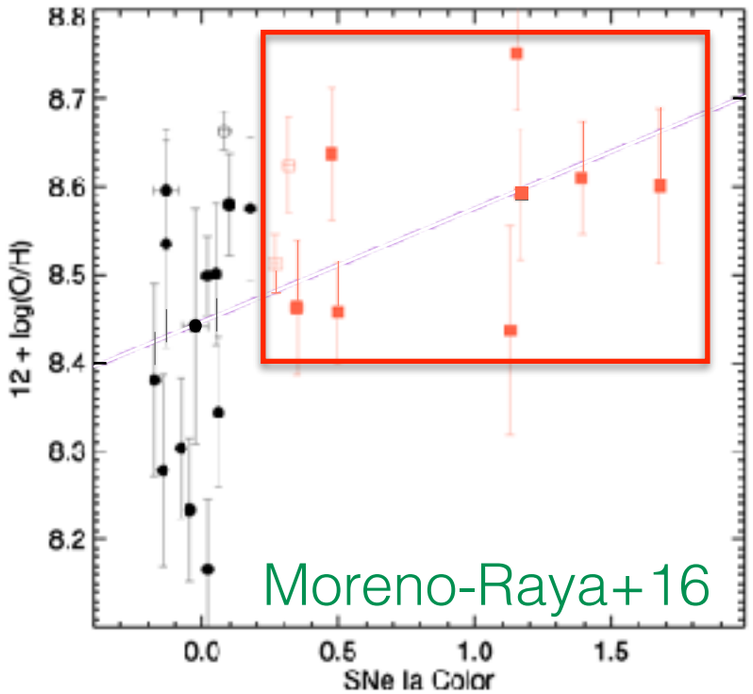


Although, it is interestingly disputed by Jones et al. (PS1)

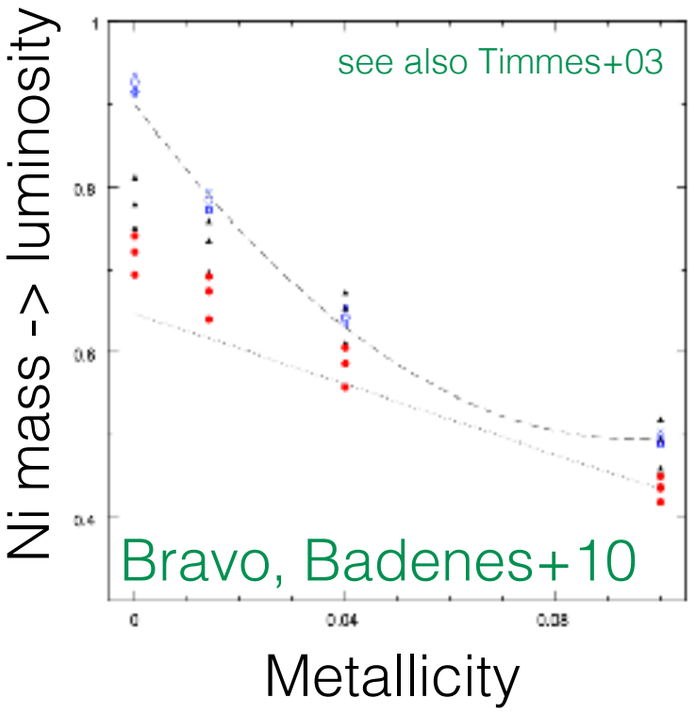
SNIa local environment

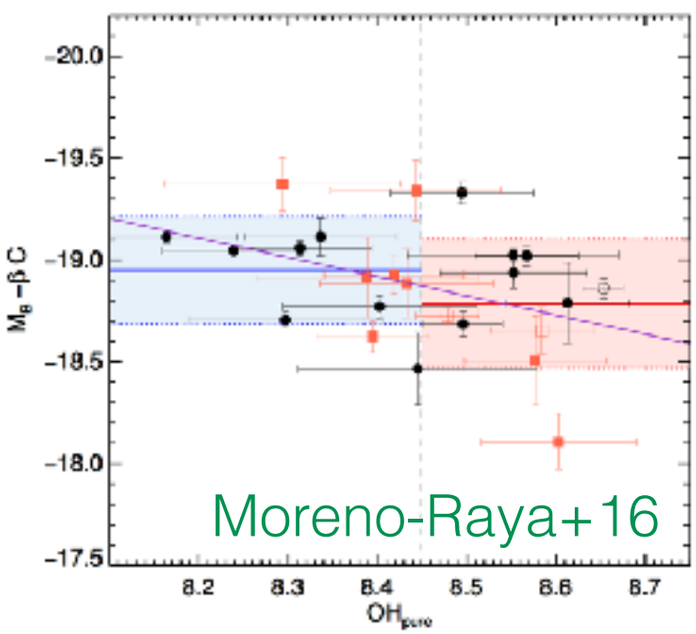
channel of SNe Ia. SNe Ia best trace the *B*-band light distribution of their host galaxies. This implies that the population within star-forming galaxies is dominated by relatively young progenitors. Splitting SNe by their *(B-V)* colours at maximum light, 'redder' events show a higher degree of association to H II regions and are found more centrally within hosts. We discuss





Red SNe in metal-rich environments





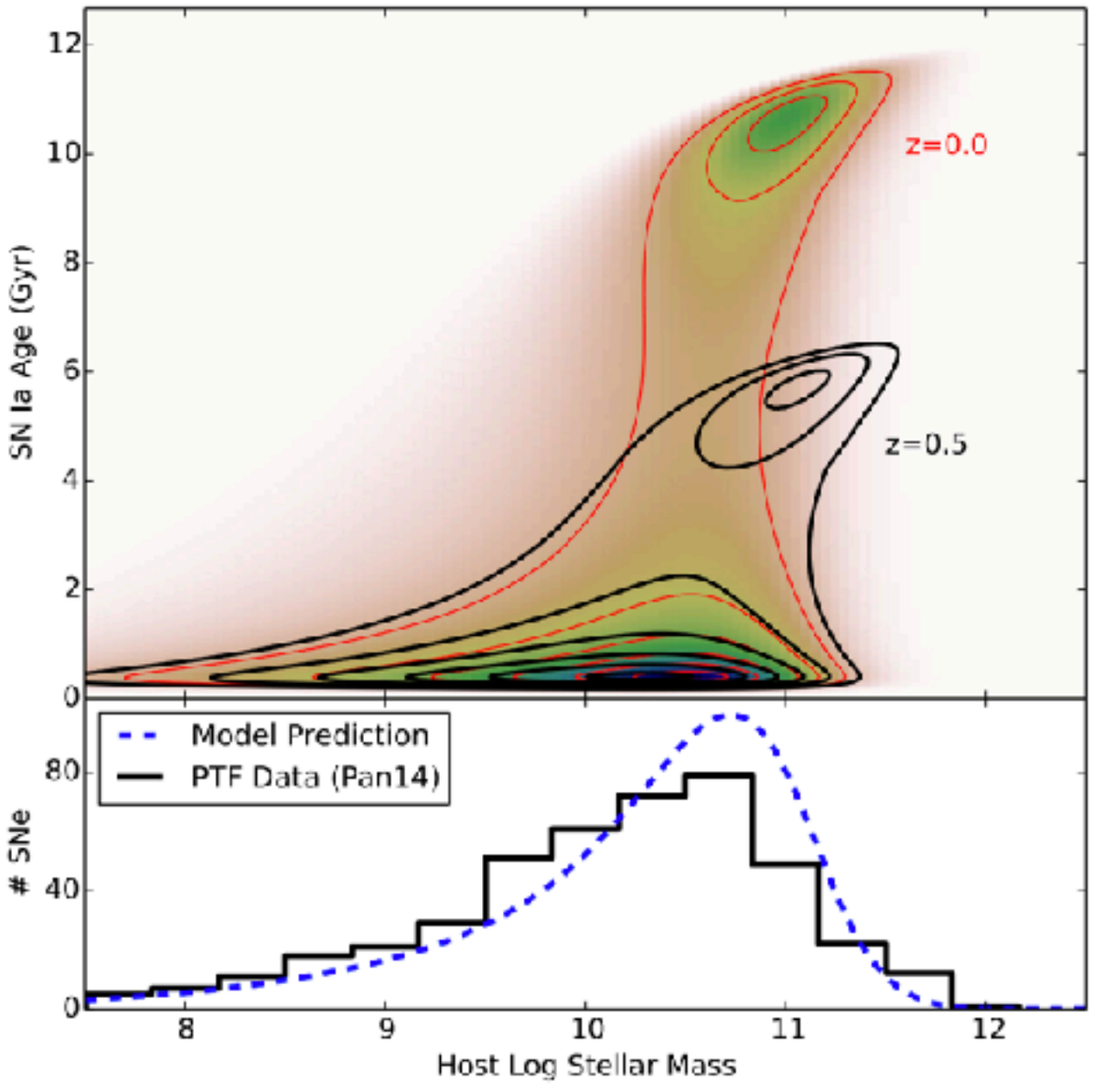
Color corrected magnitudes depend on local metallicity

Cosmology

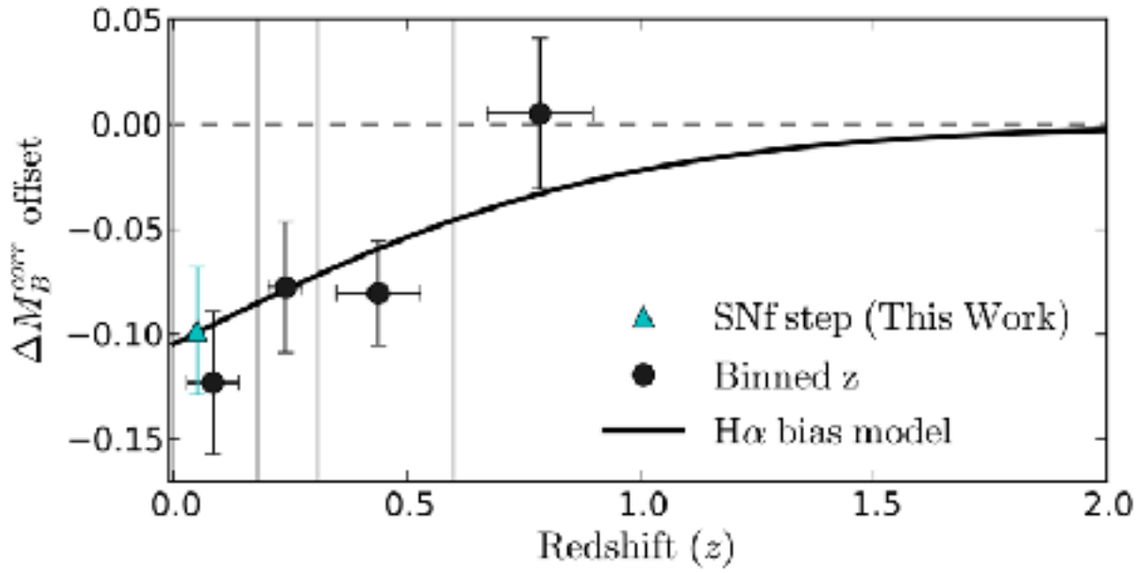
Local environment dependences disputed:

Rigault+13, Rigault+15, Jones+15, Roman+17,
Rigault+18, Jones+18, Rose+19, …

SNIa local environment: 2 populations

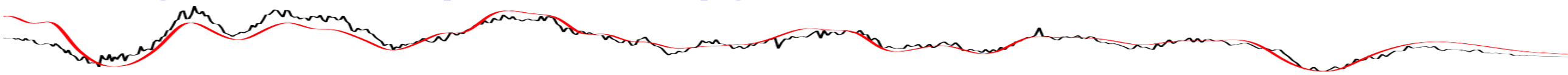


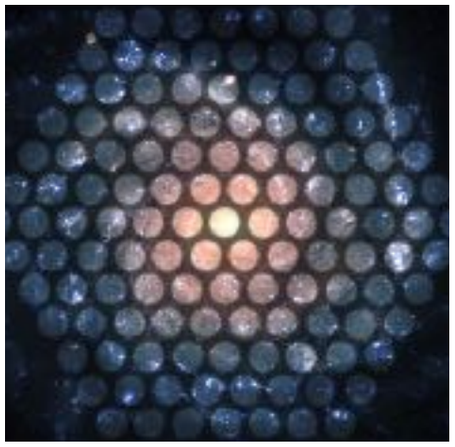
Childress et al. 2014



Rigault et al 2013

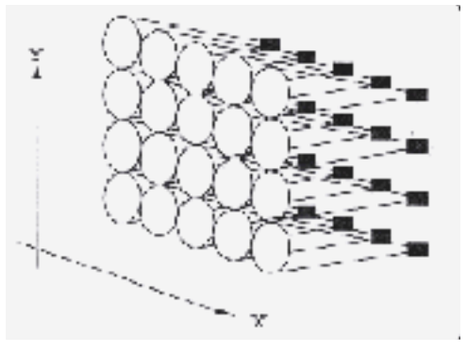
Integral Field Spectroscopy



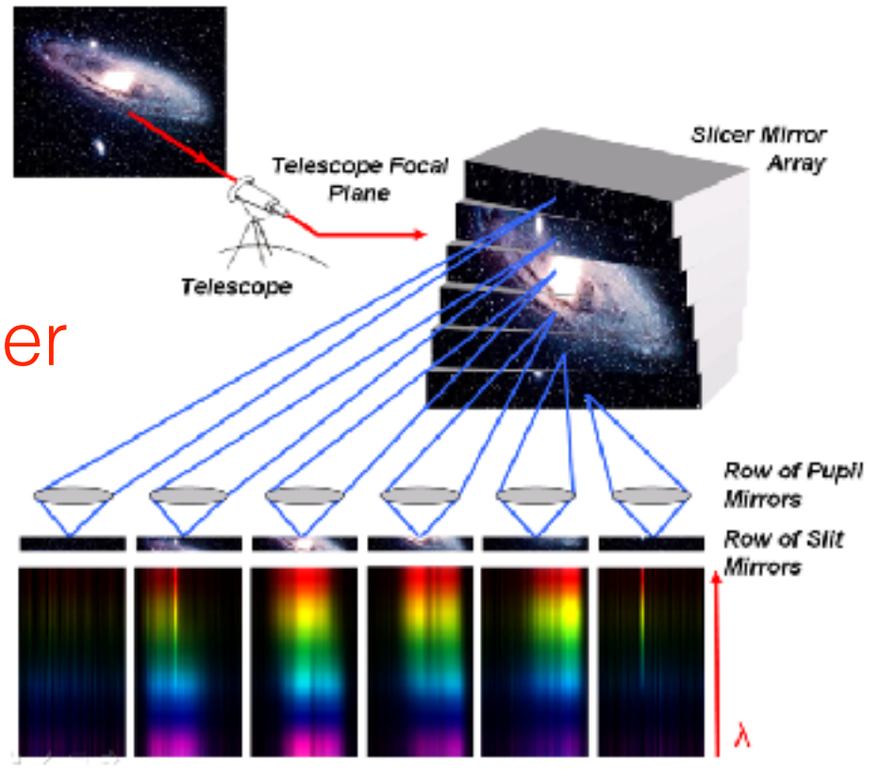


Fiber bundle

Lenslet



Slicer



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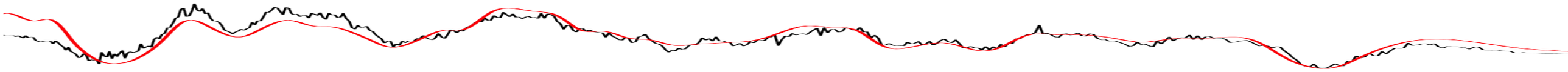

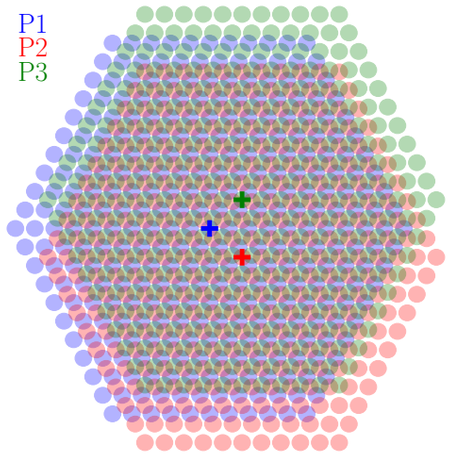

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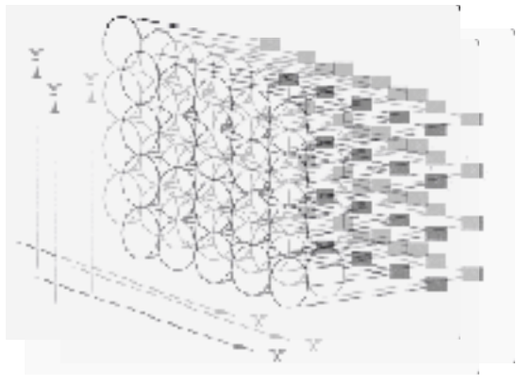

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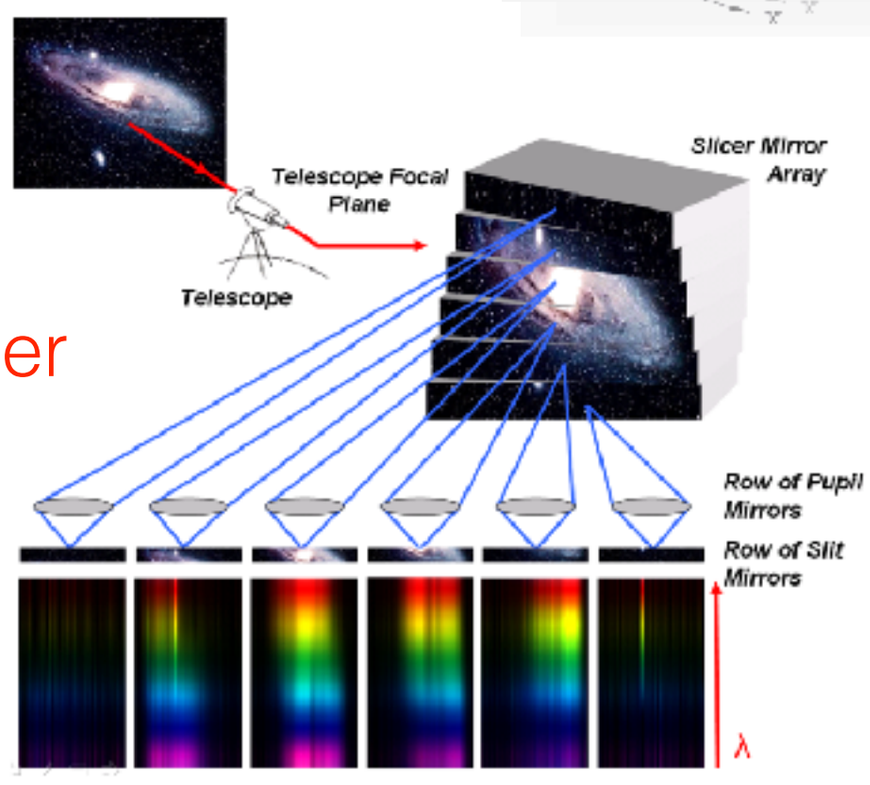

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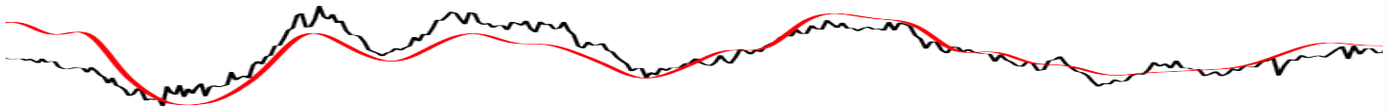

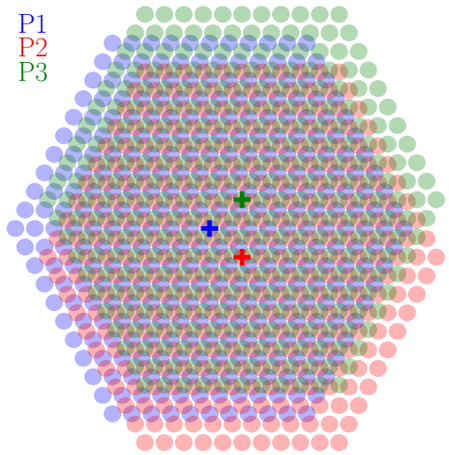

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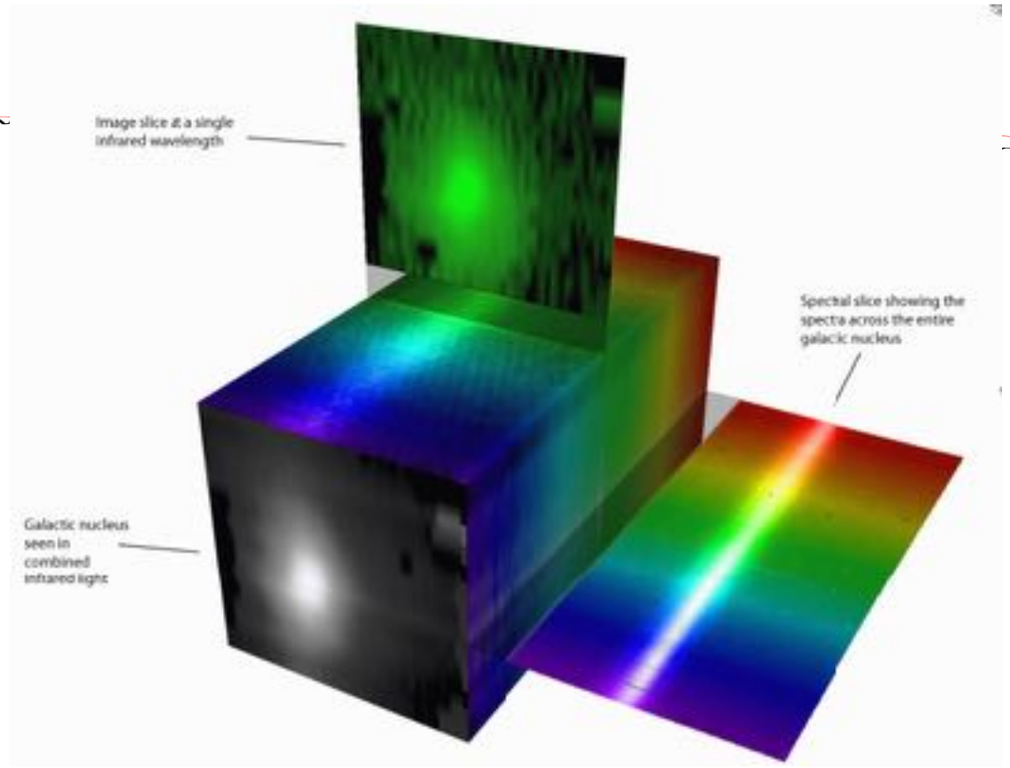

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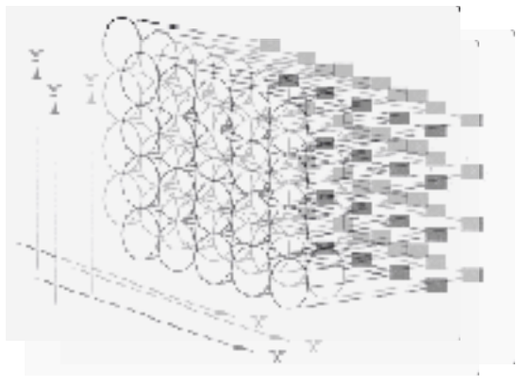

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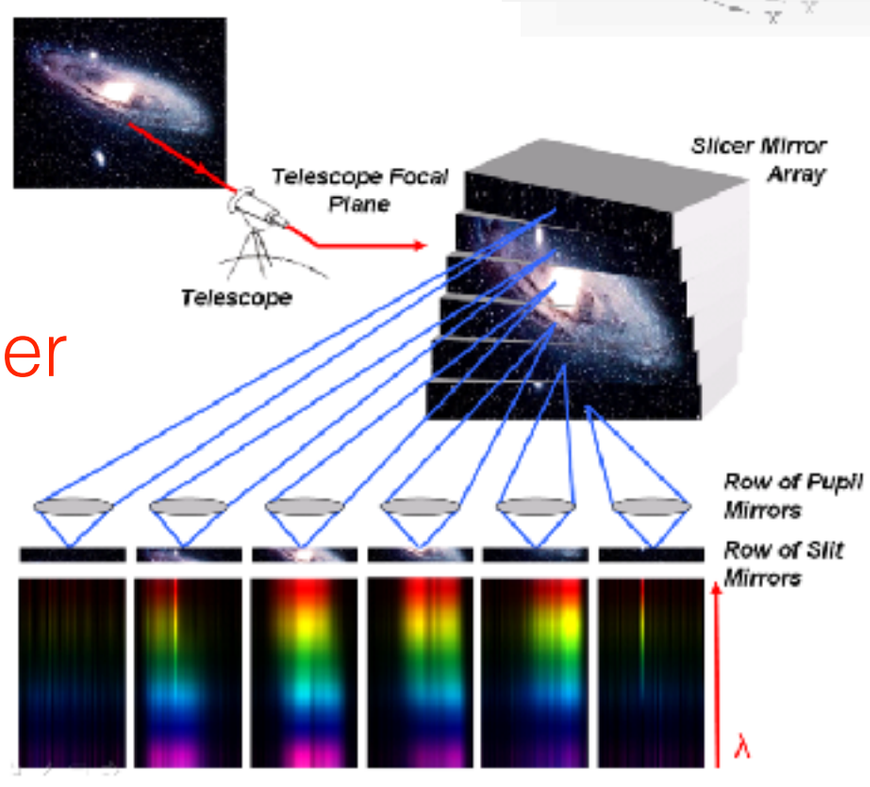

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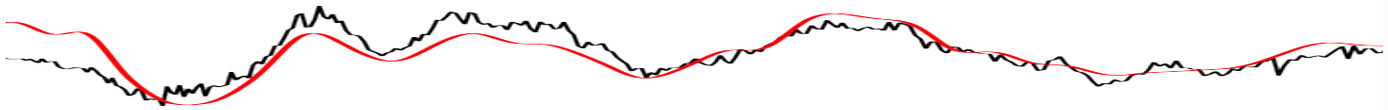

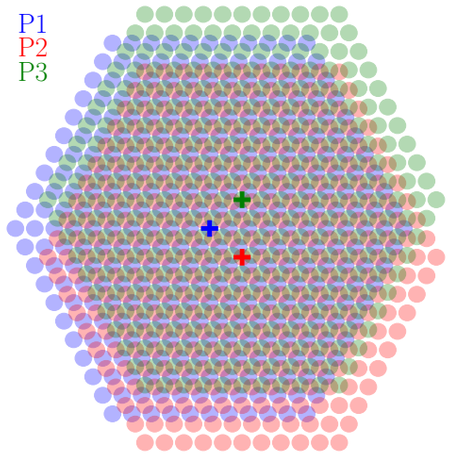

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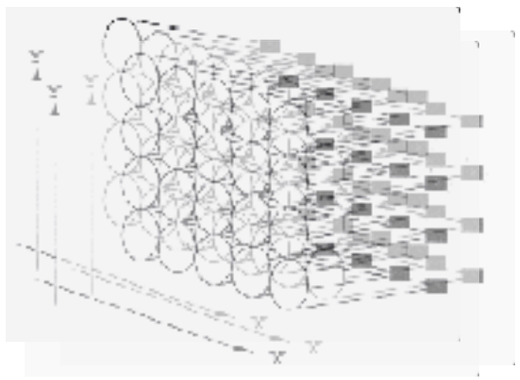

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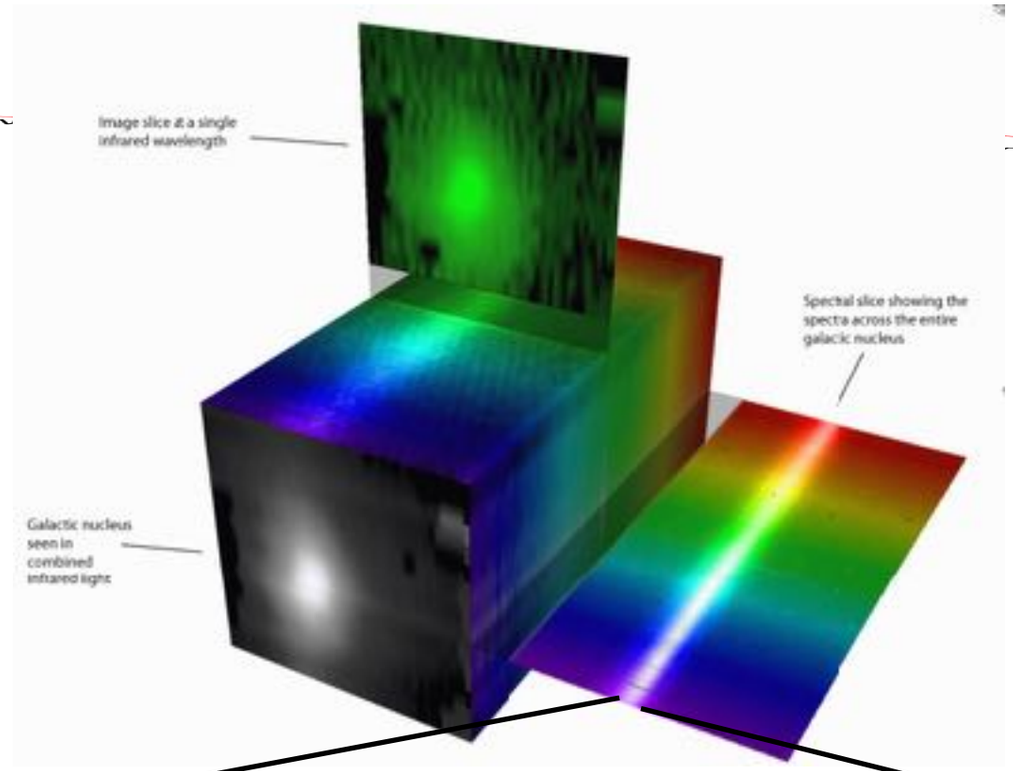

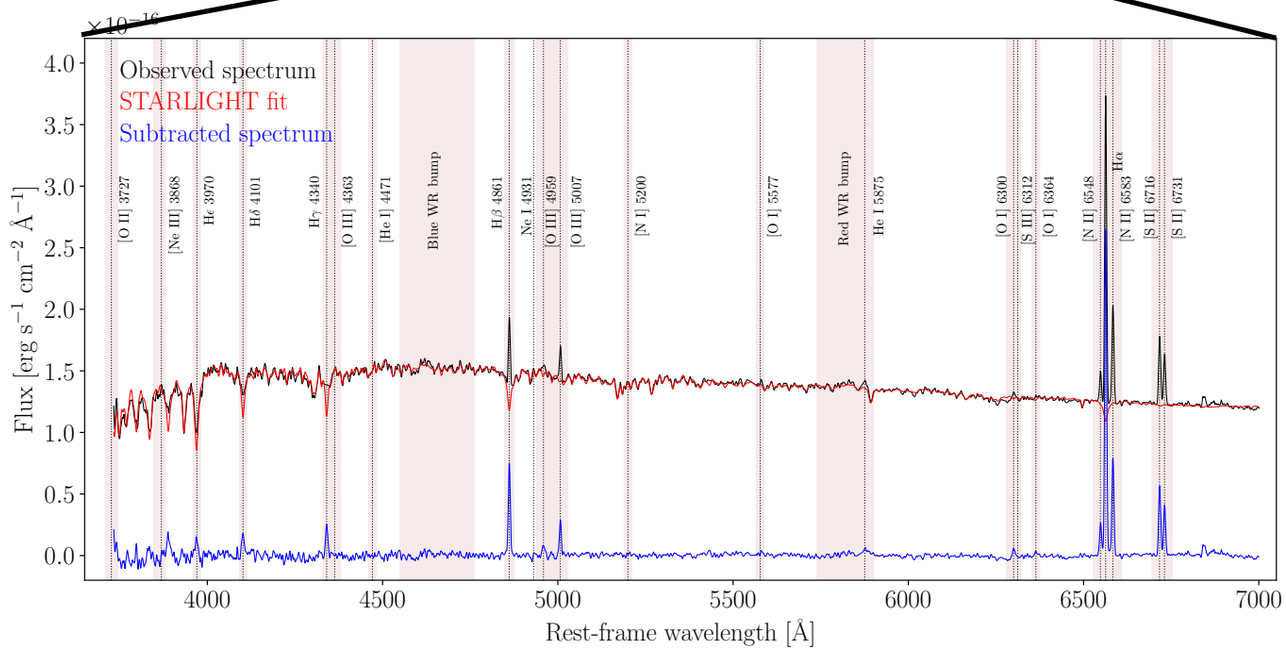

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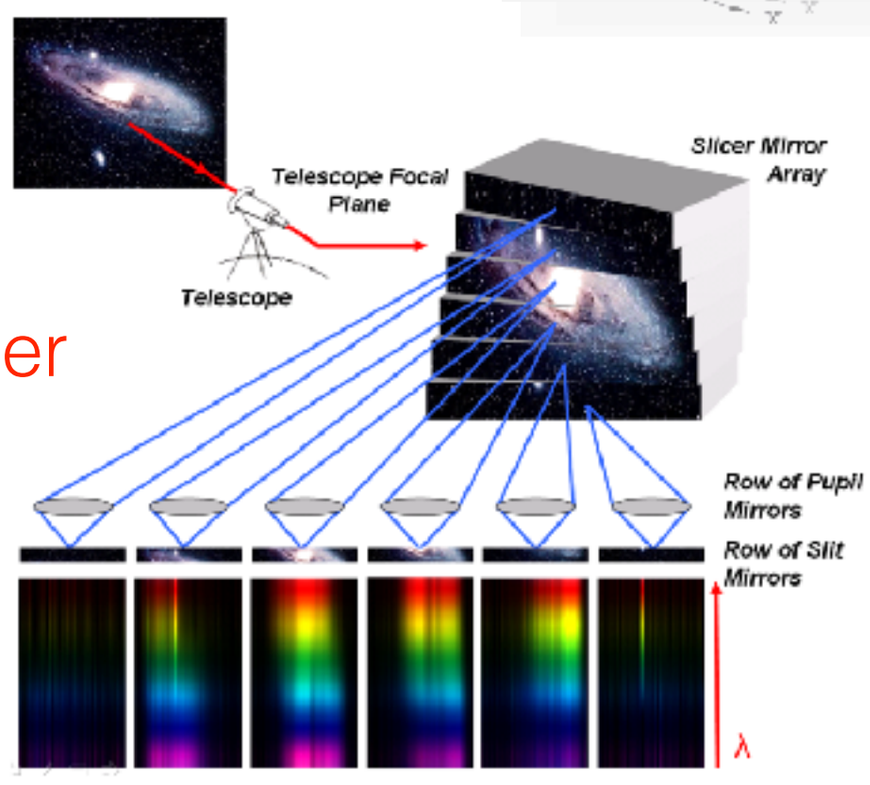
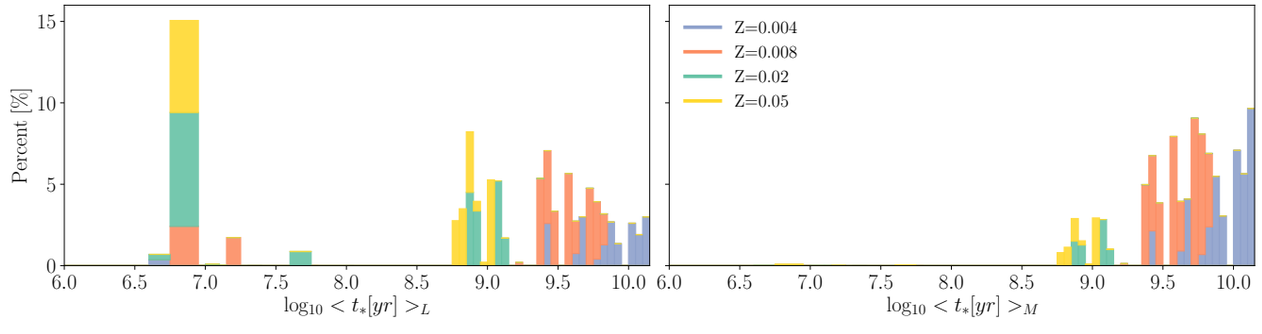


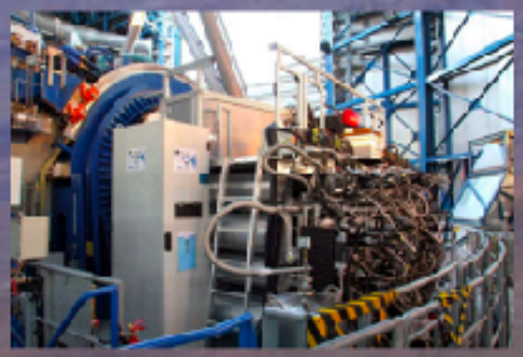


BOSS

APO 2.5m

PMAS

Calar Alto 3.5m

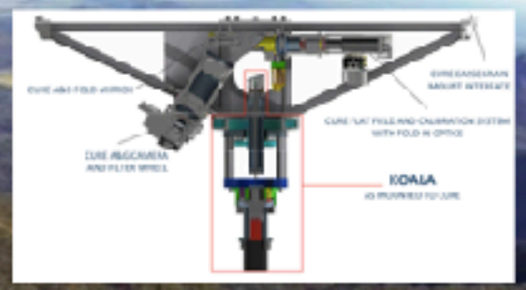


MUSE

KMOS

Paranal 8.2m

KOALA



Siding Spring 3.9m

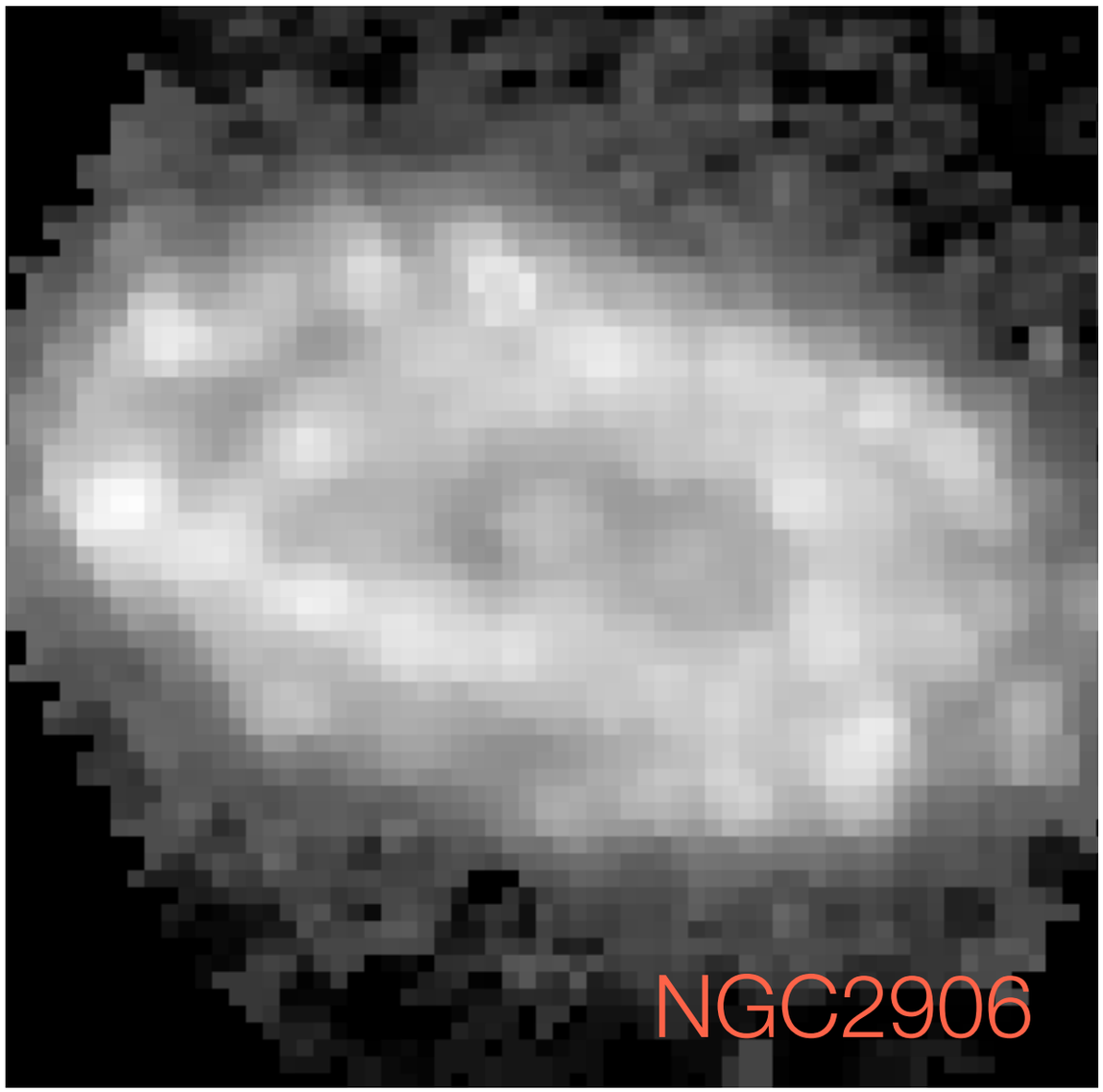
THE AMUSING SURVEY

PIs: Anderson (ESO) & Galbany (Pitt)

- All-weather: using non-optimal weather of Paranal (avg. seeing 1.1", from 0.7" to 1.5").
- MUse: very efficient instrument. 3GB per cube, >4800 A. Basis for driving big data spectroscopic astronomy.
- Supernova: Overall aim is to further understand supernova progenitors/explosions. Study SN environment and all other regions within the host.
- Integral-field: 1'x1' FoV, 0.2" pixel scale. Image-like resolution but with 'spaxels'.
- Nearby: Allows in-depth study of gas and stellar populations.
- Galaxies: Allows cross-field collaborations. Galaxy studies: evolution, dynamics, stellar populations…

10 semesters: P95 to P104

530 SN hosts (561 SNe)



Aimed to be an open collaboration with regular data releases including all kinds of data products

1st data release expected for 2020! Will include ~250 cubes

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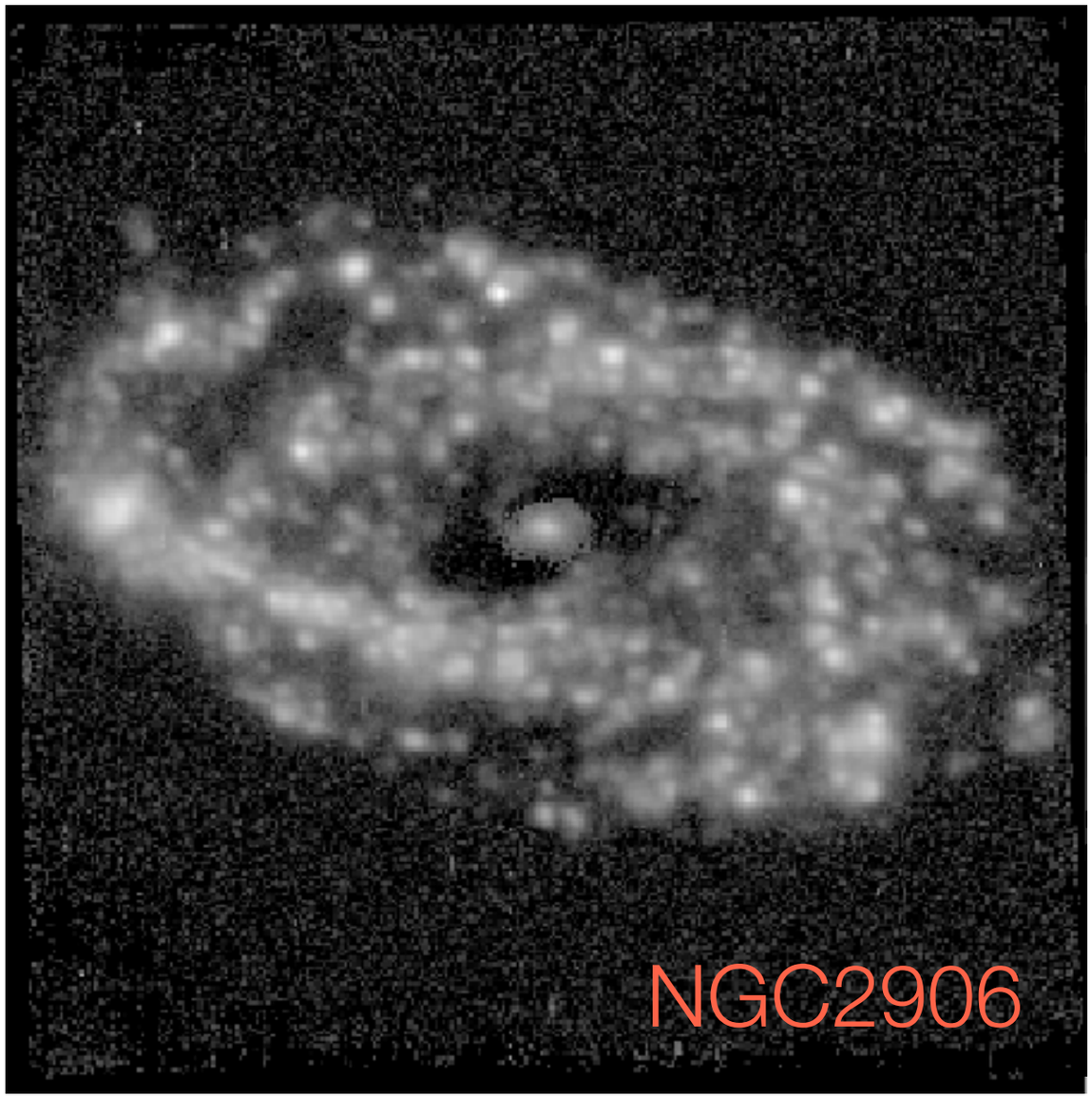

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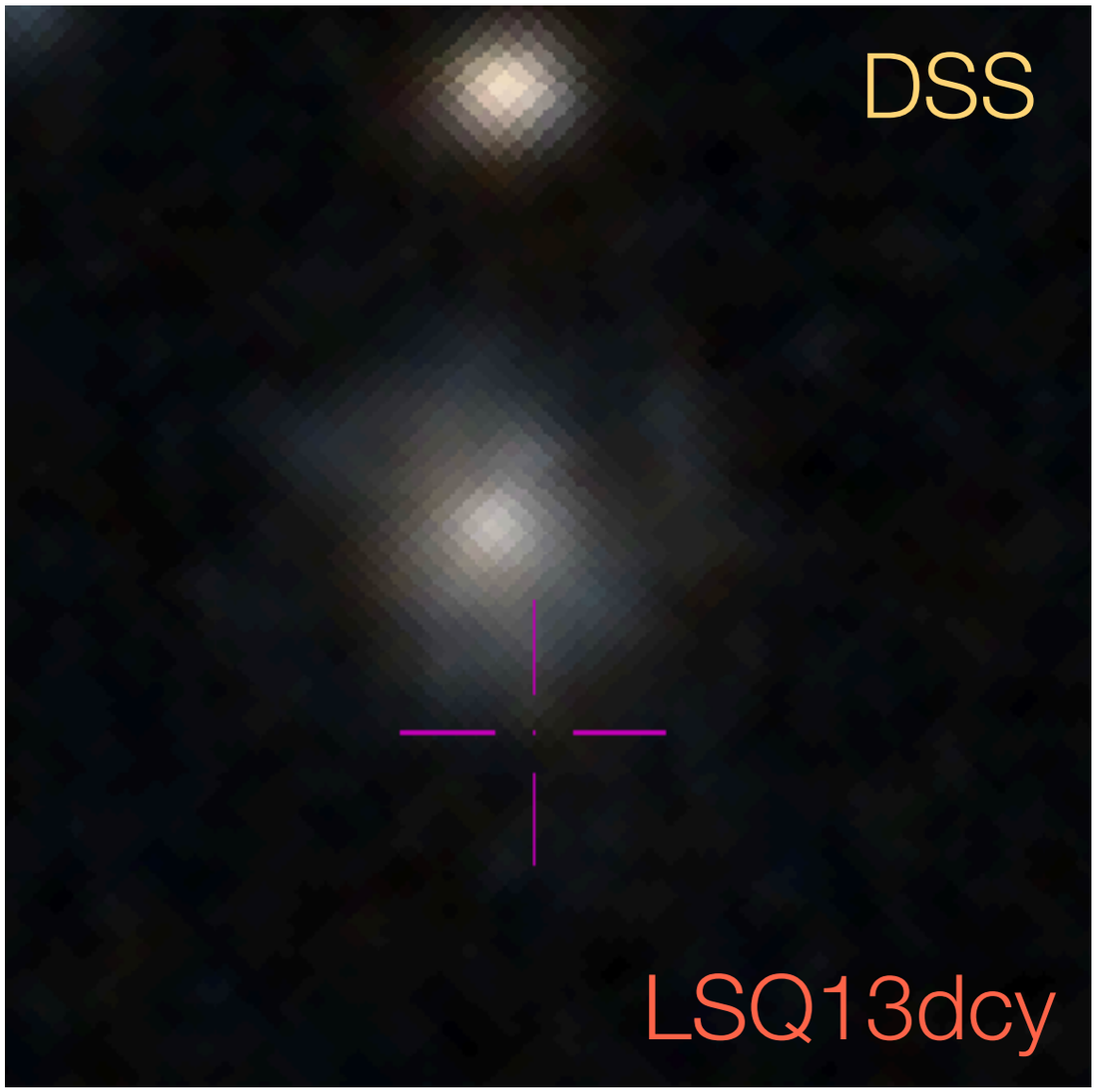

Aimed to be an open collaboration with regular data releases including all kinds of data products

1st data release expected for 2020! Will include ~250 cubes

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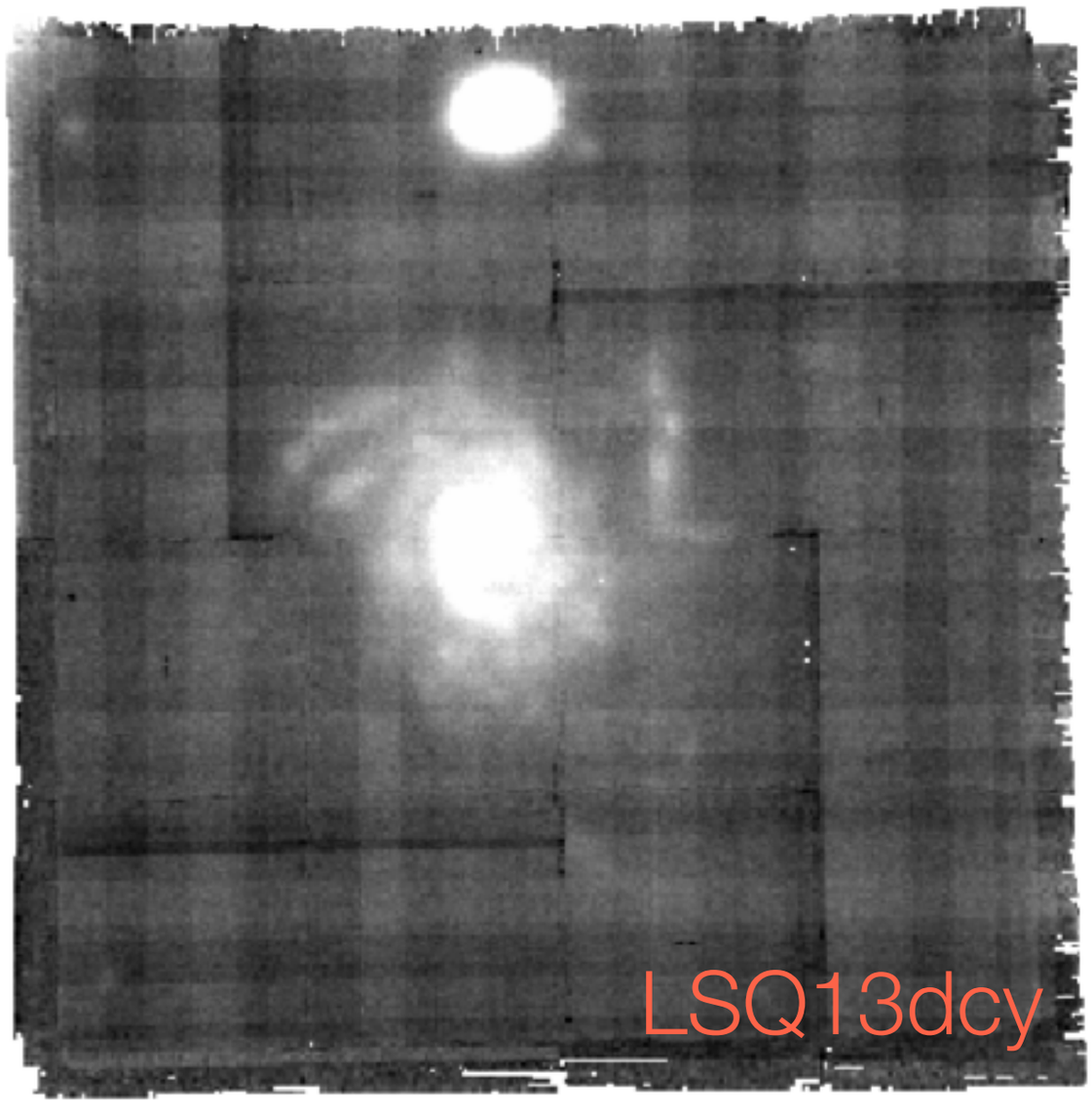

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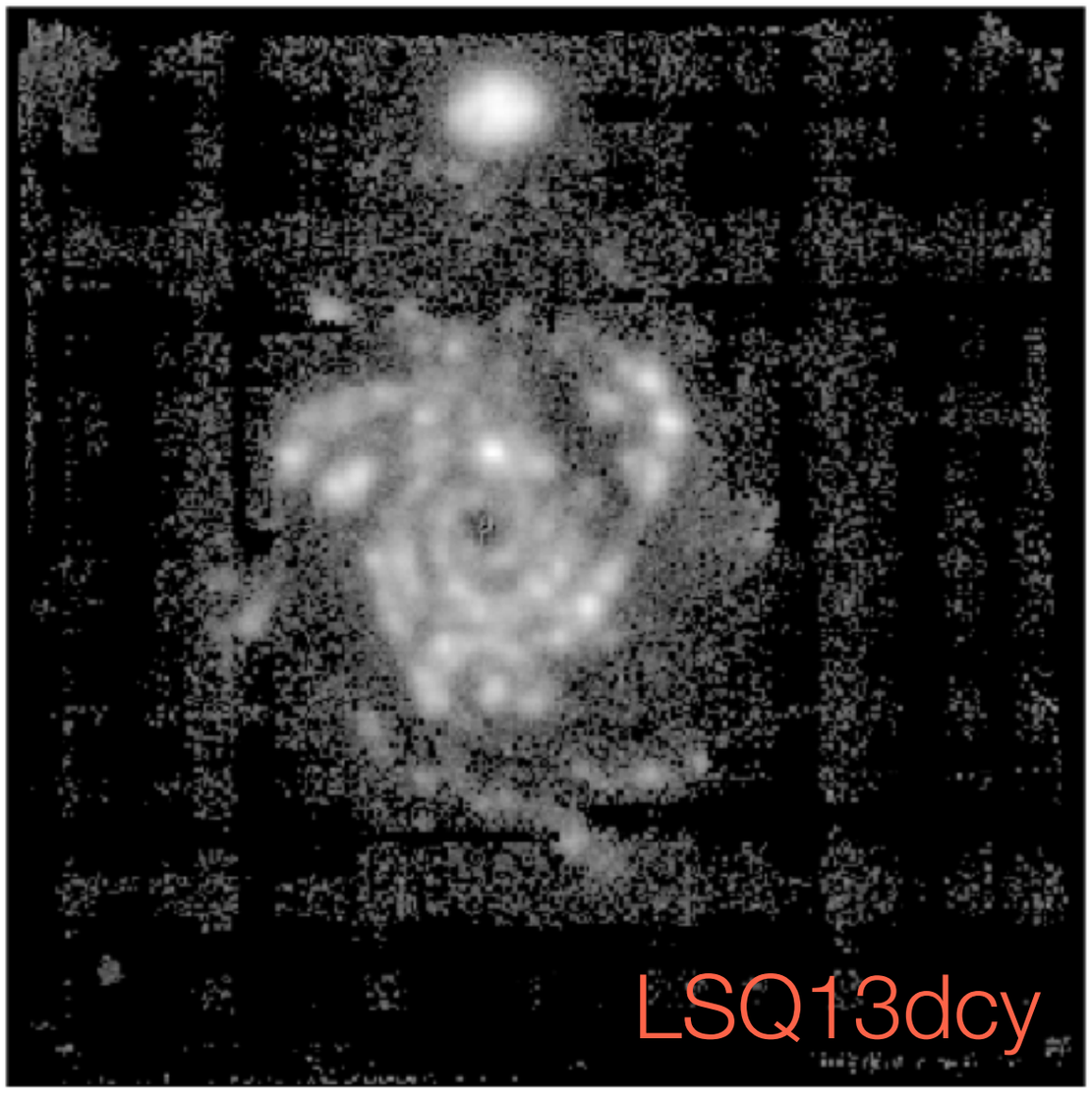

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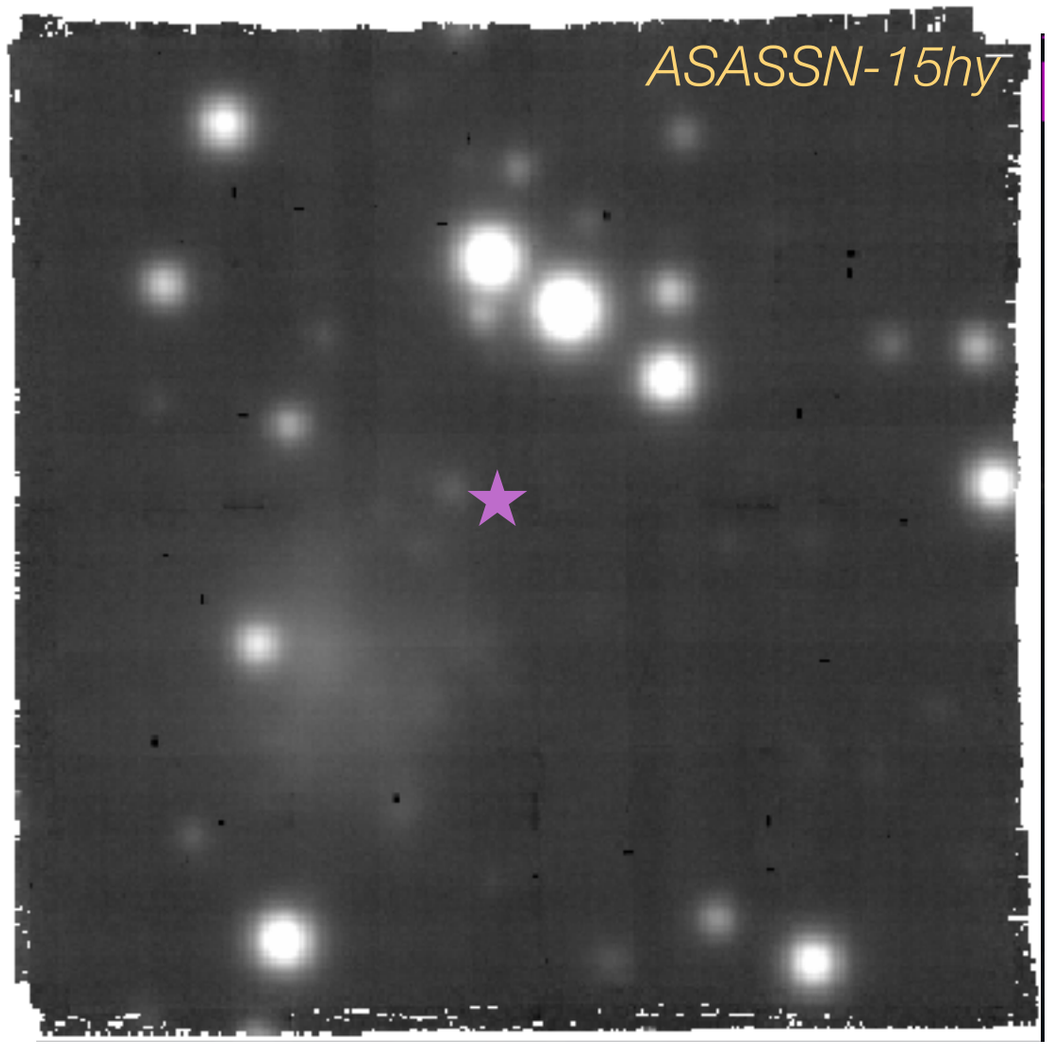

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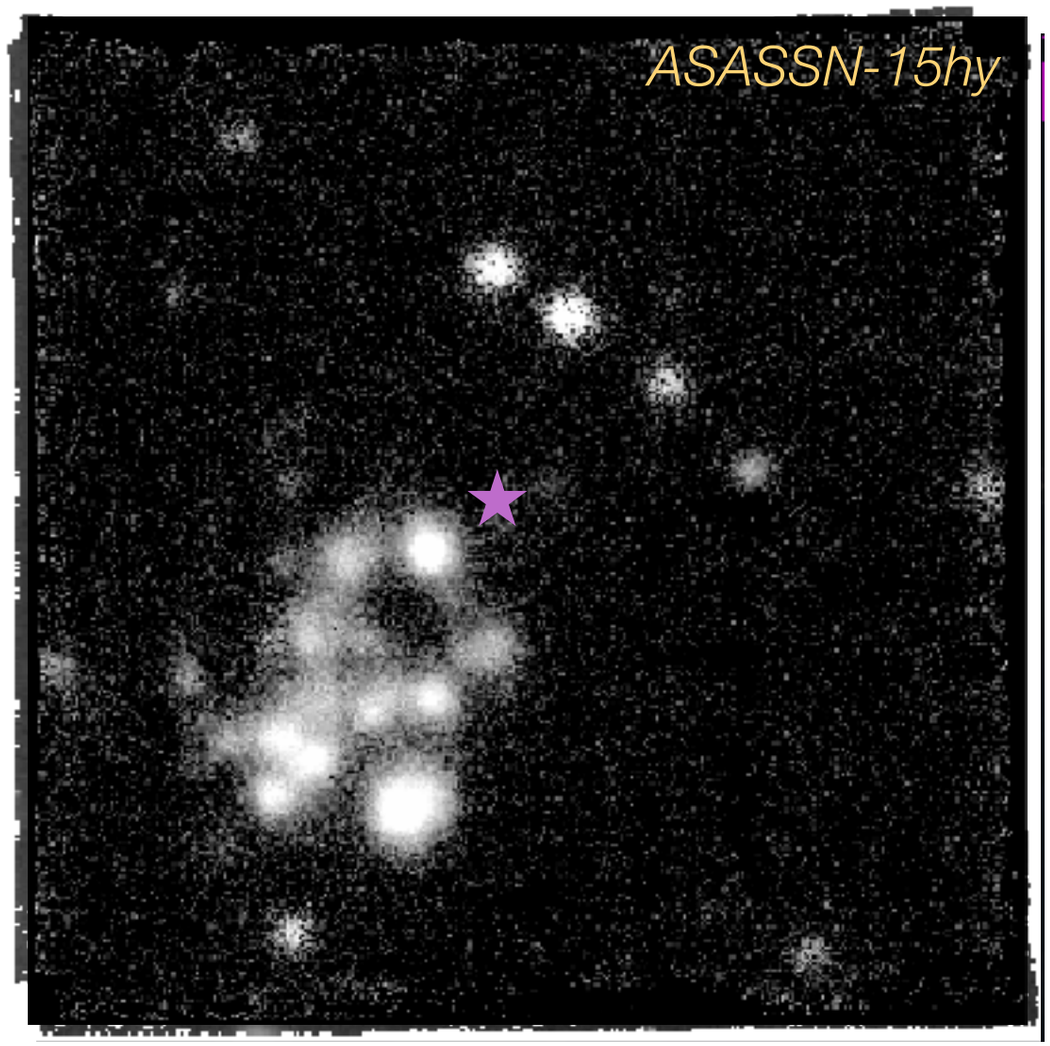

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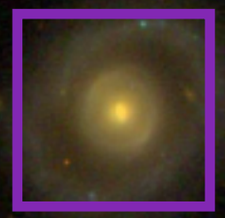
THE AMUSING SURVEY TEAM

- CORE: Joseph P. Anderson (ESO-Chile, PI), Lluís Galbany (Granada, PI), Hanin Kuncarayakti (Turku), Thomas Kruehler (left to a happier life), Sebastián Sánchez (UNAM), Joe Lyman (UWarwick).

- INV. (alph.): Ana S. Afonso (CENTRA), Yago Ascasibar (UAM), Chris Ashall (FSU), Carles Badenes (Pitt), Chris Burns (Carnegie), Luc Dessart (UMI), Inma Dominguez (Granada), Subo Dong (Kavli Institute Beijing U.), Jesús Falcón-Barroso (IAC), Francisco Förster (CMM/UChile), Santiago González-Gaitán (CENTRA), Claudia Gutiérrez (Soton), Mario Hamuy (UChile), Peter Hoeflich (FSU), Tom Holoien (OSU), Eric Hsiao (FSU), Phil James (ARI, LJMU), Tuomas Kangas (STScI), Erkki Kankare (Turku), Christopher Kochanek (OSU), Seppo Mattila (Turku), Ana Mourão (CENTRA), Enrique Pérez (IAA), Isabel Pérez (U. Granada), Mark Phillips (LCO), Jose-Luis Prieto (UDP), Alessandro Razza (ESO/UChile), Fabián Rosales-Ortega (INAOE), Tomás Ruiz-Lara (IAC), Patricia Sánchez-Blázquez (UCM), Laura Sánchez-Menguiano (IAC), Patricia Schady (Bath), Ben Shapee (Hawaii), Mat Smith (Soton), Kris Stanek (OSU), Maximilian Stritzinger (Aarhus U.), Mark Sullivan (Soton), Lingzhi Wang (CASSACA/UChile),…

People from both supernova and galaxy communities and continuously increasing…

PROGRESS SO FAR...



MUSE FoV

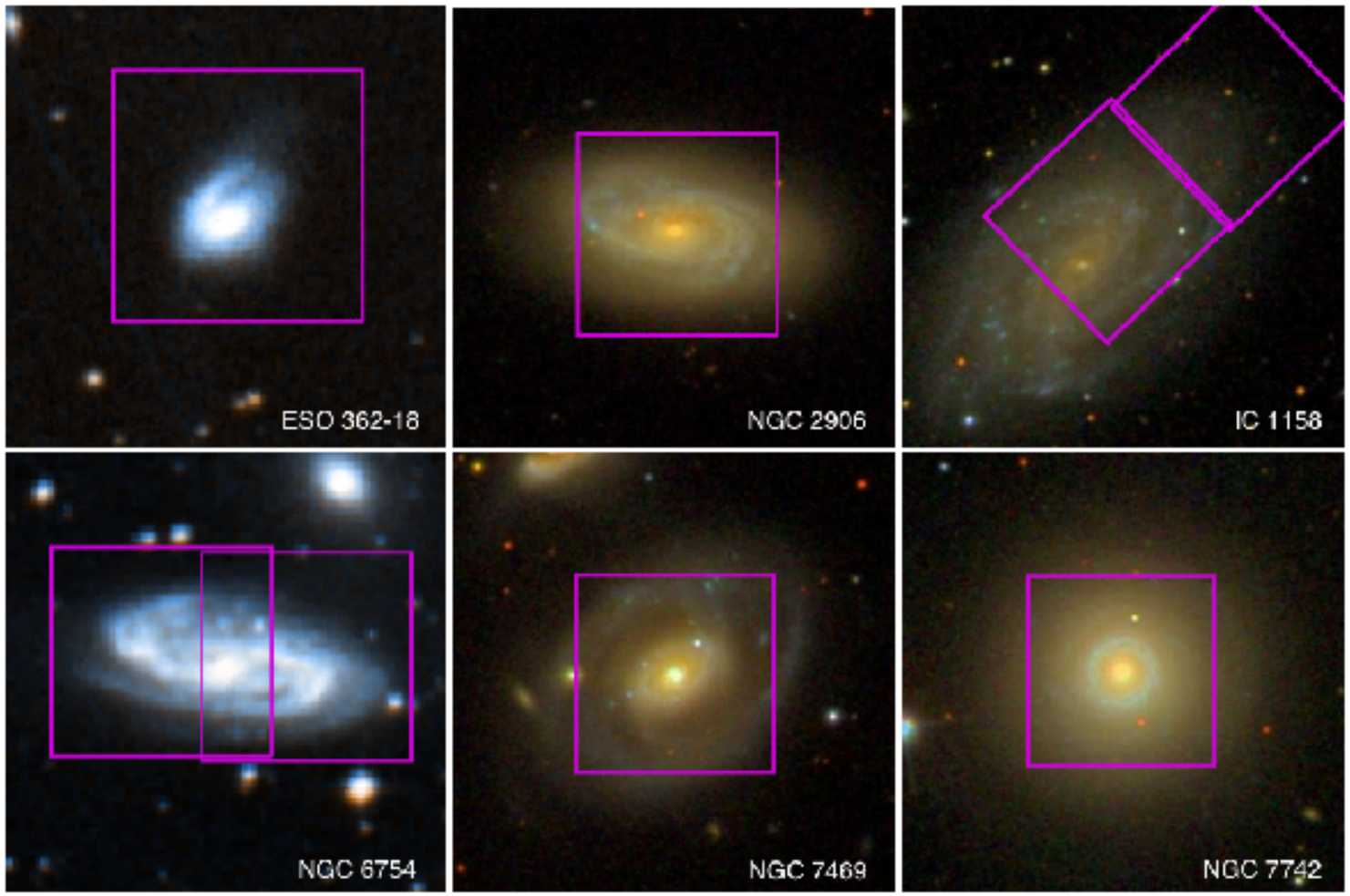
- **SV**: 6 galaxies with 11 SNe. HII region parameter statistics for different SN types.
- **P95**: 87 galaxies. CSP SNe Ia environments and dependence with Hubble residuals.
- **P96**: 49 galaxies. SN rates w.r.t. environmental parameters of transients discovered by ASASSN hosts:.
- **P97**: 64 galaxies. Hosts of SNe that have been observed with high-res. spectra and showed strong NaD absorptions.
- **P98**: 28 galaxies. SweetSpot SNe Ia observed in the NIR, to study Hubble residual dependences.
- **P99**: 37 galaxies. SweetSpot SNe Ia observed in the NIR, to study Hubble residual dependences.
- **P100**: 25 late-time CC and Ia SN nebular spectra + host.
- **P101**: (A; 80%) 55 late-time CC and Ia SN nebular spectra + host. + (B; 20%) 17 CSP I+II host galaxies
- **P102**: 45 galaxies. Continuing CSP I+II host galaxies
- **P103**: 84 galaxies *(so far)*. ASAS-SN CCSN hosts + TDE hosts
- **P104**: **<<ON-GOING>> ~50** low-mass CCSN hosts
- **OTHER**: 151 galaxies from other projects (+1 DDT).

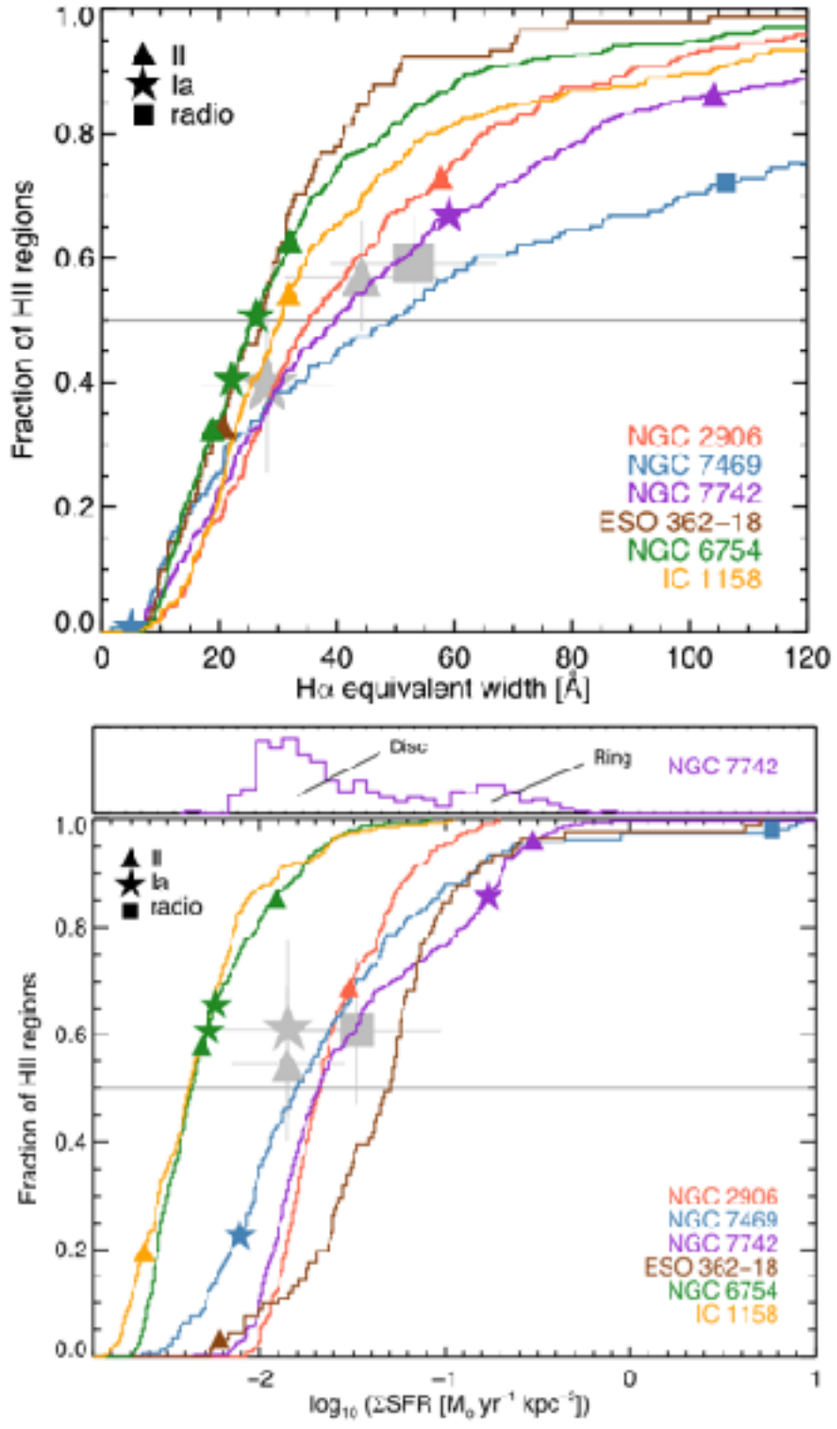
681 nearby SN local environments

So far 18 articles from AMUSING, but more coming… **+Stritzinger,+Hsiao**

Sánchez15, Galbany16, Kuncarayakti16, Prieto16, Sánchez-Menguiano16, Kruehler17, López-Cobá17, Sánchez-Menguiano18, Kuncarayakti18, Anderson18, Galbany18, Boselli18, Phillips19, Bellochi19, Meza19, Schady19, Bostroem19, Tucker19…

MUSE-SV: Pilot study of 6 galaxies that hosted 11 SNe





- ***HII region statistics:*** Distributions of SFR, oxygen abundance, Av extinction, and EW(Ha) measured in ALL HII regions in the galaxy, and characterization of the SN parent HII region.

LG et al. 2016b, MNRAS, 455, 4099

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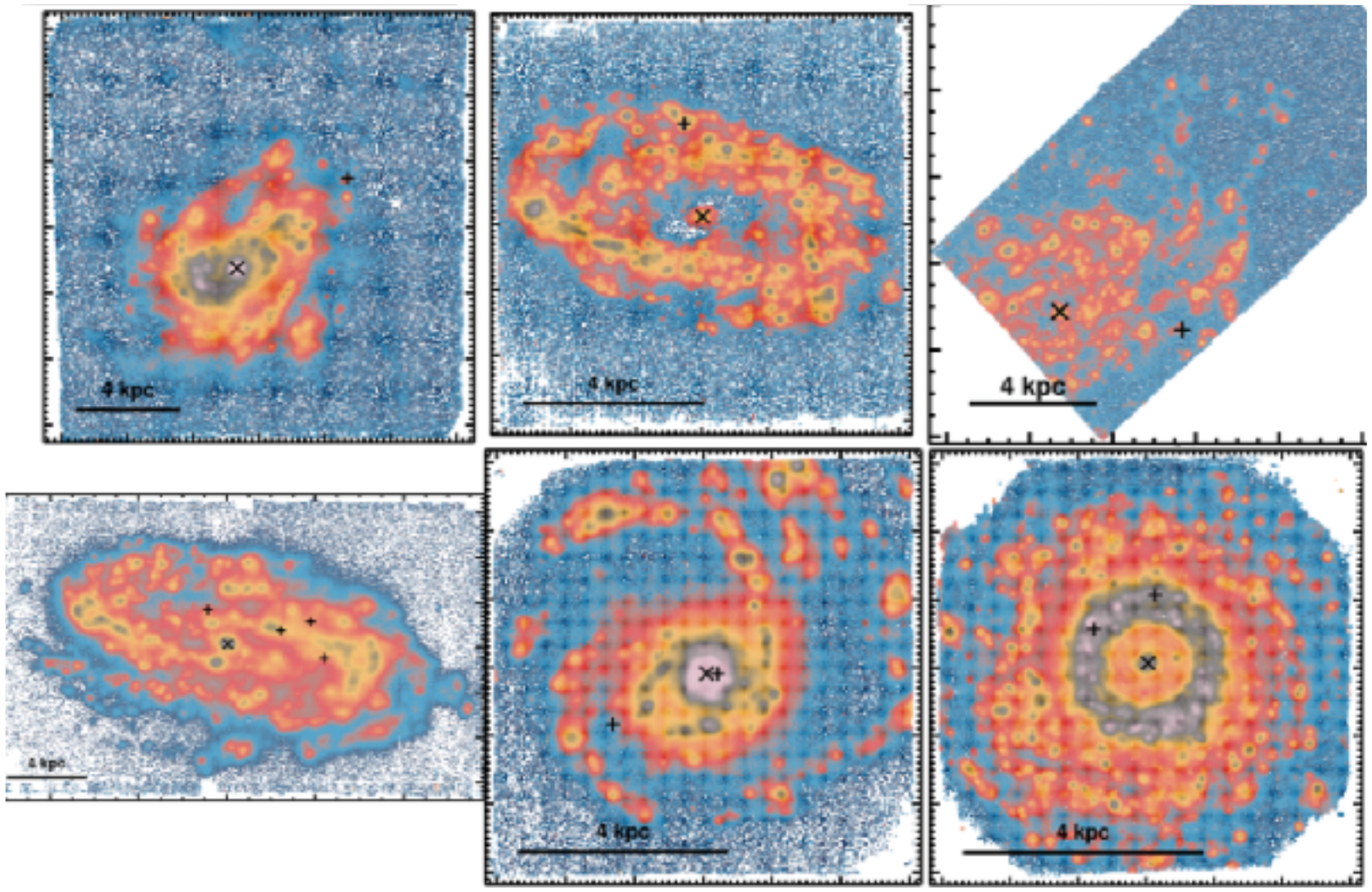

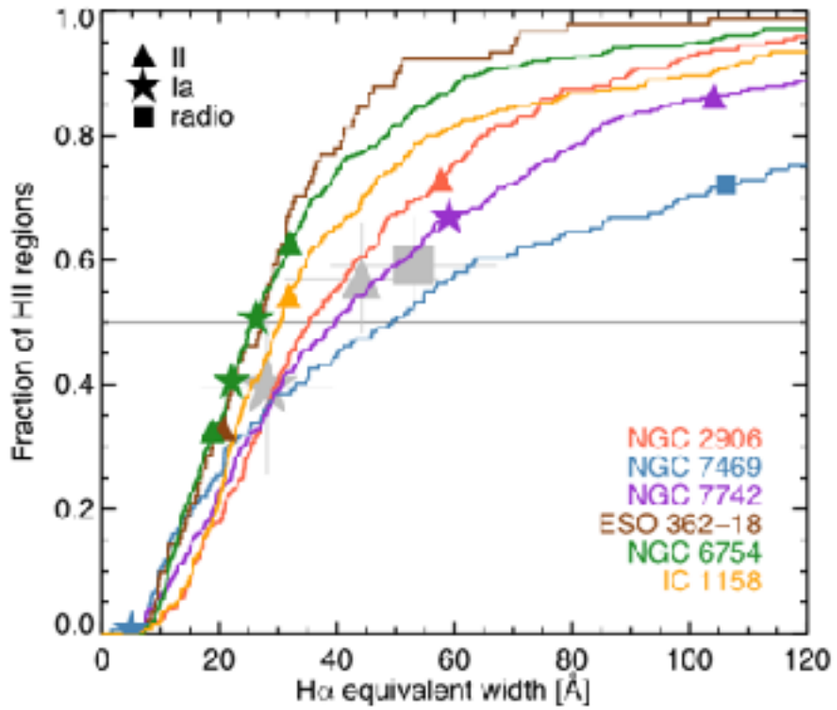

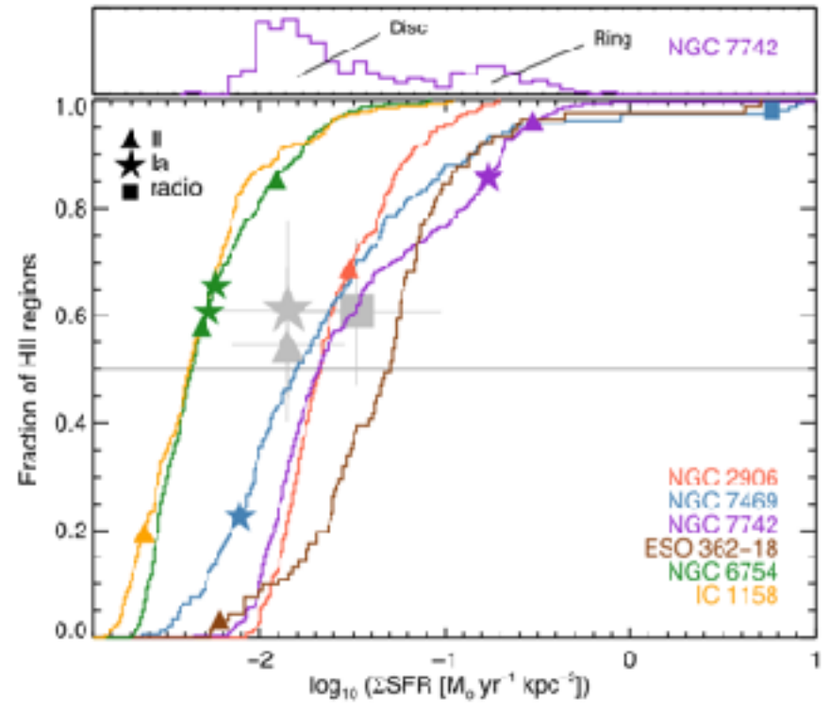

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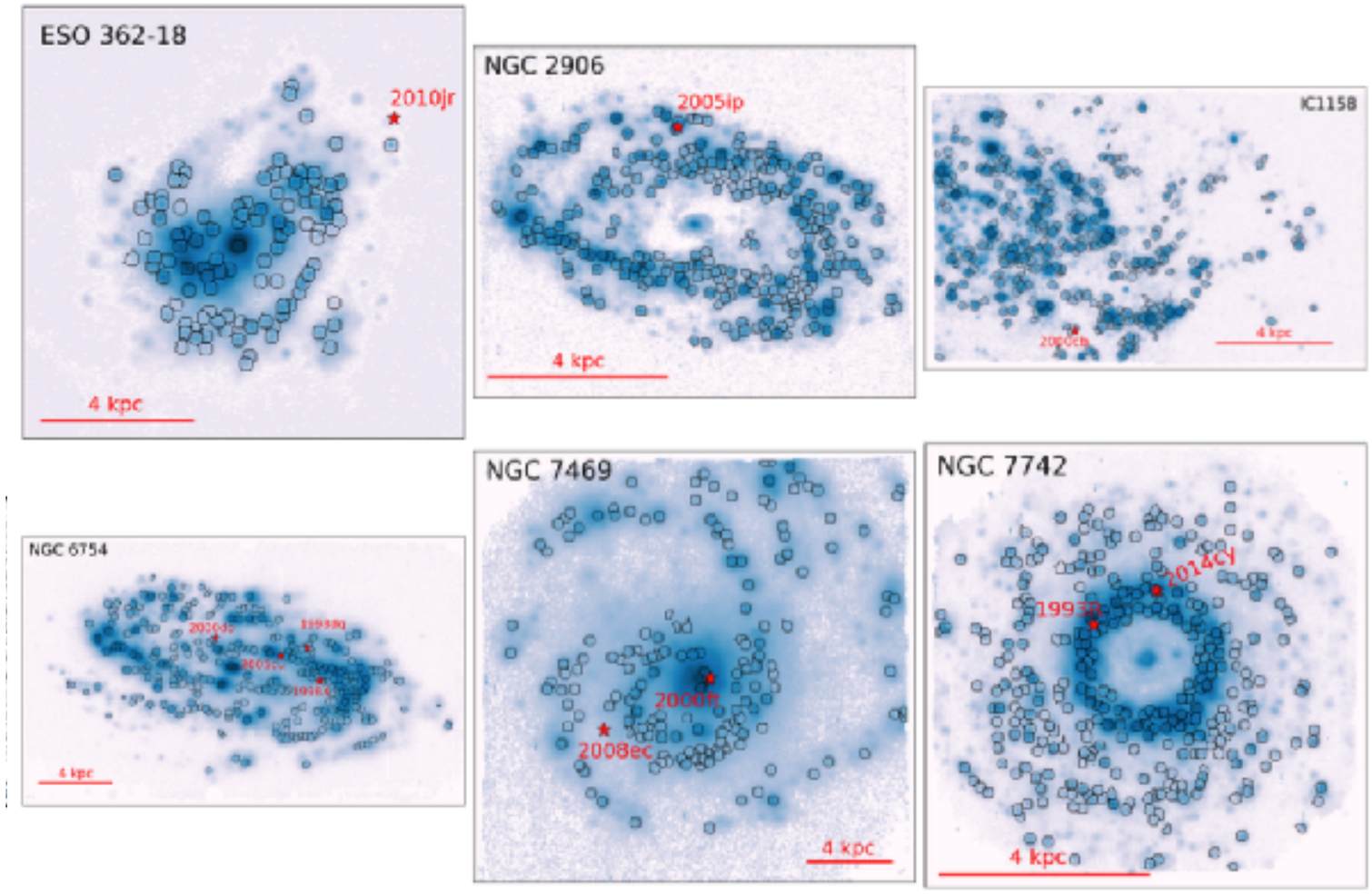

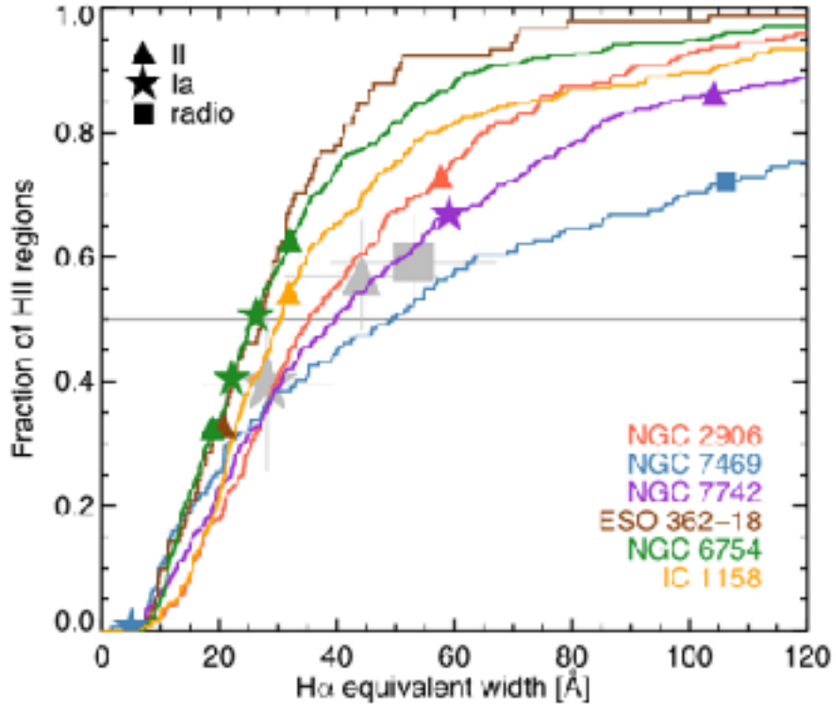

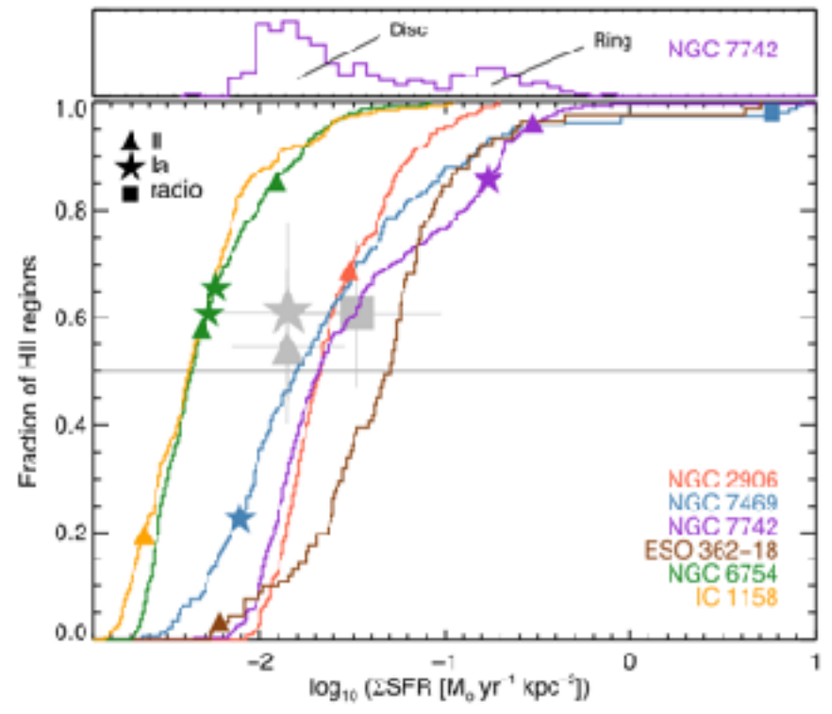

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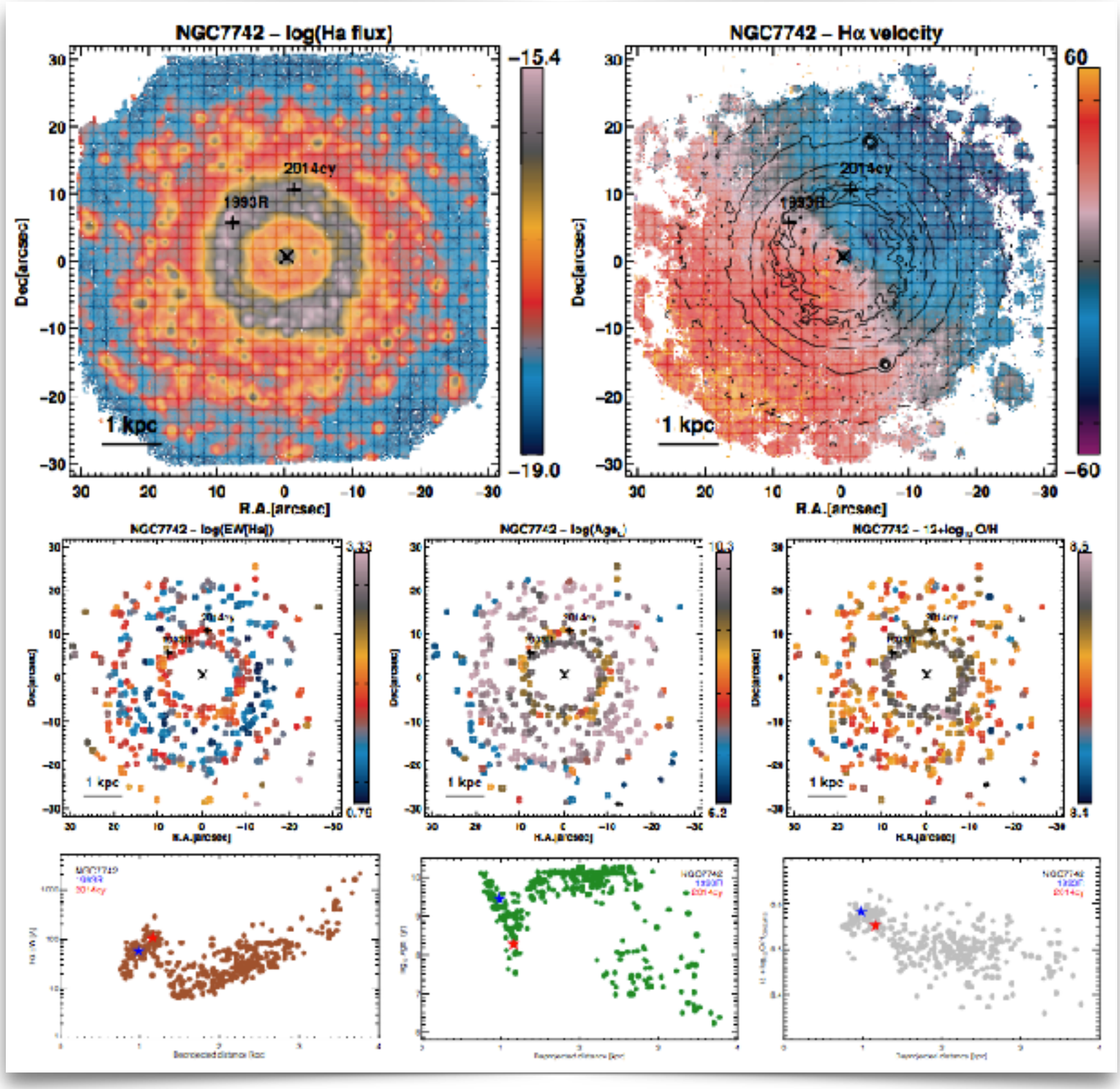
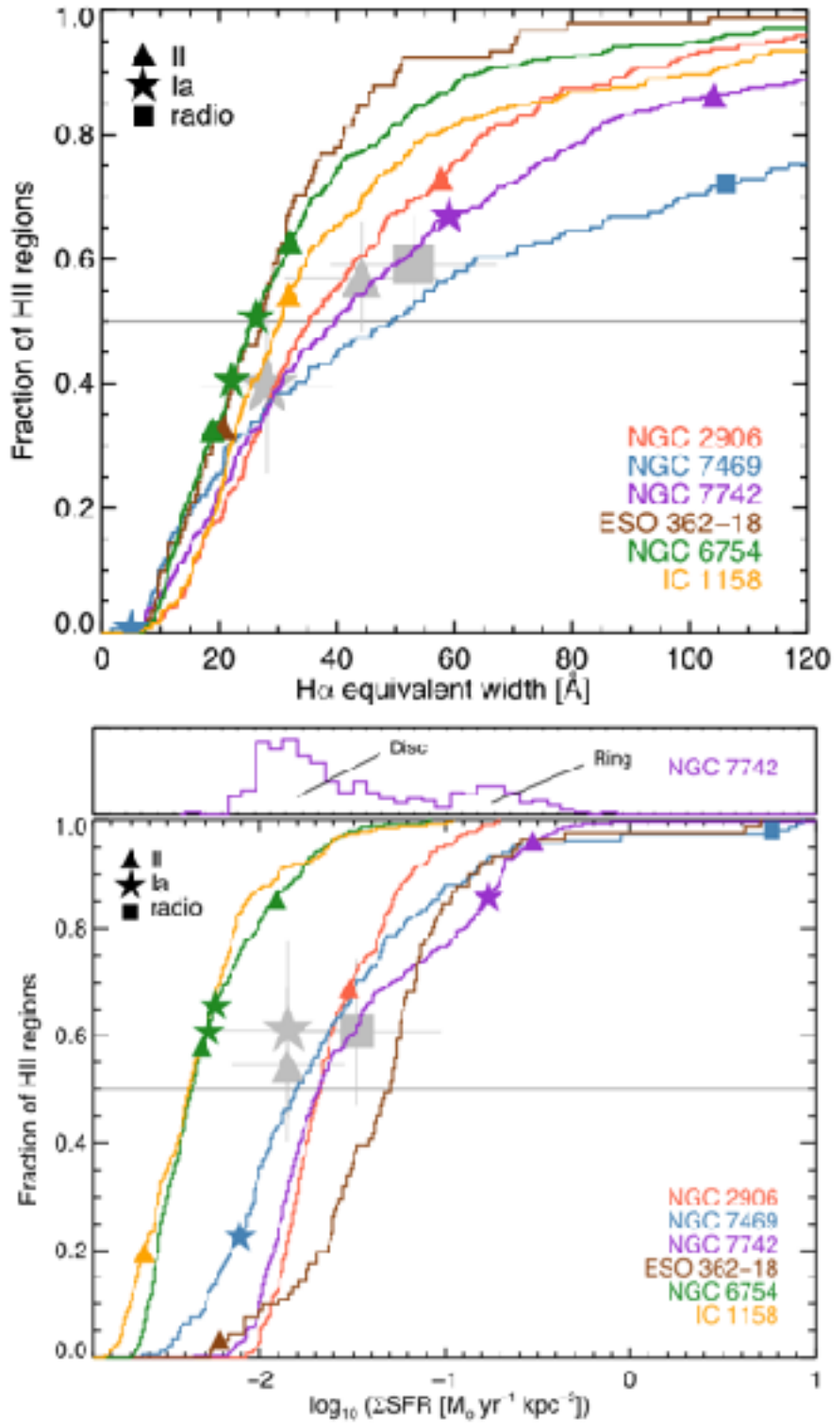
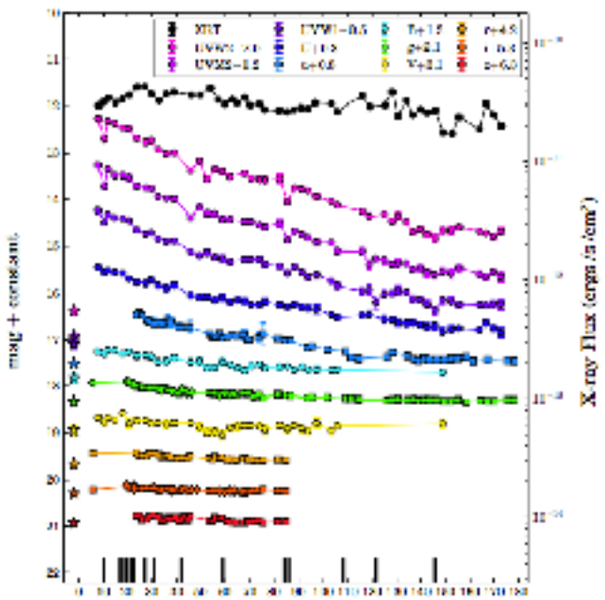


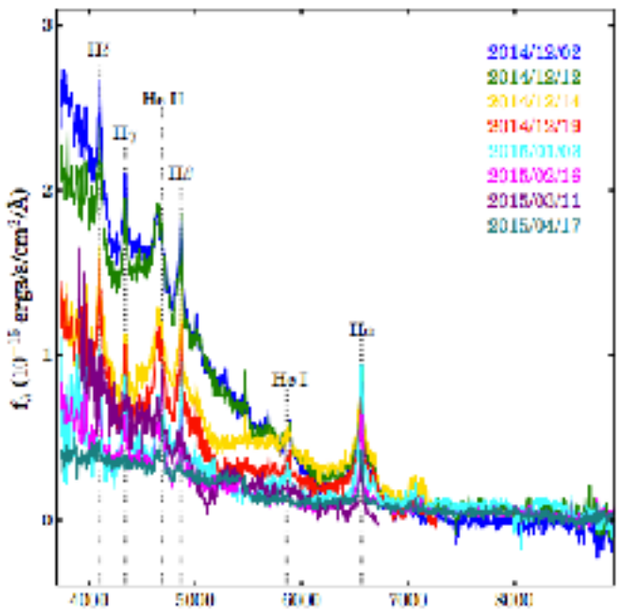


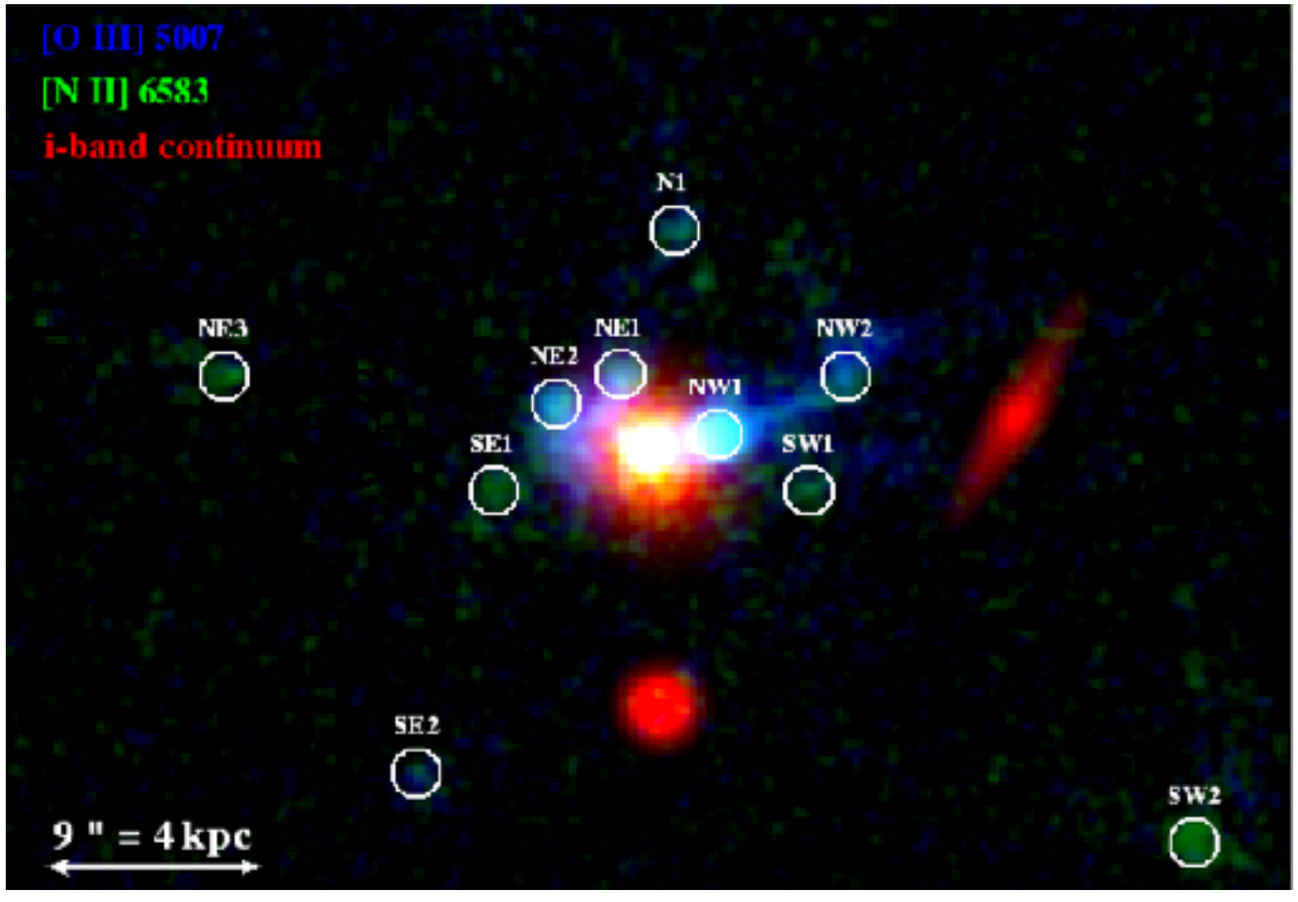
LG et al. 2016b, MNRAS, 455, 4099

José L. Prieto

ASASSN-14li: a nearby Tidal Disruption Event

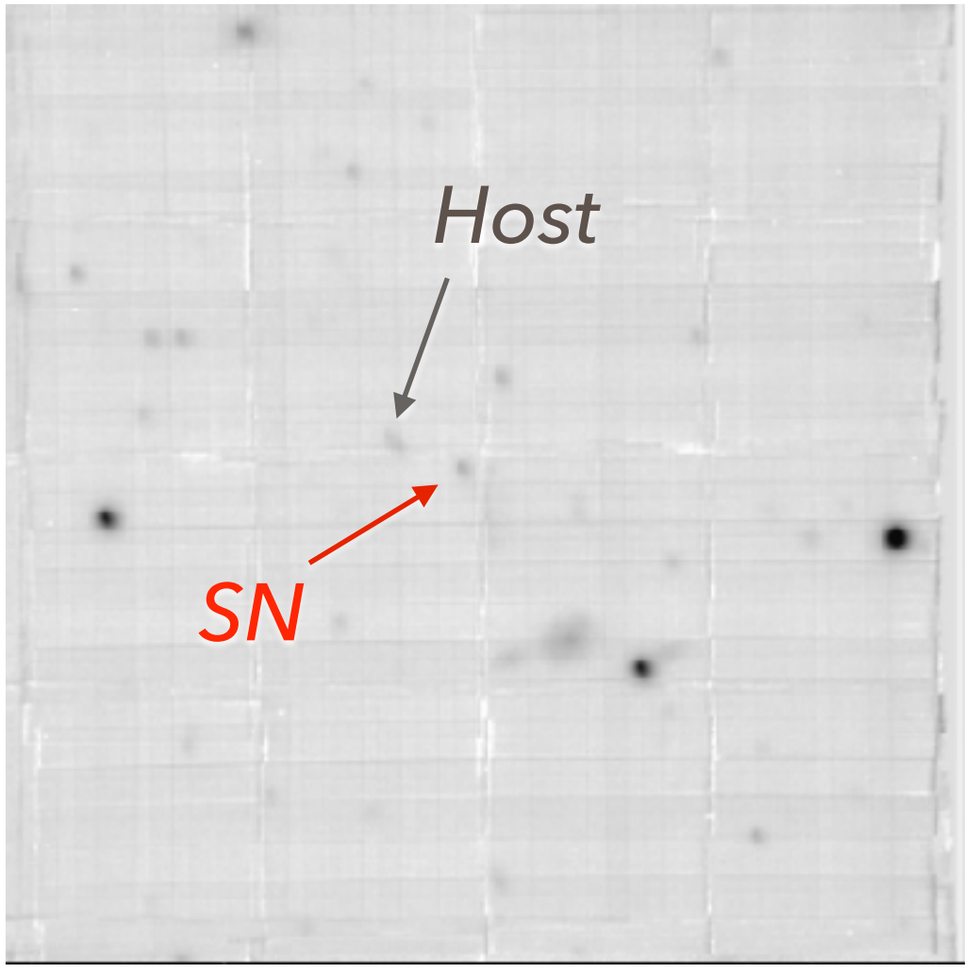




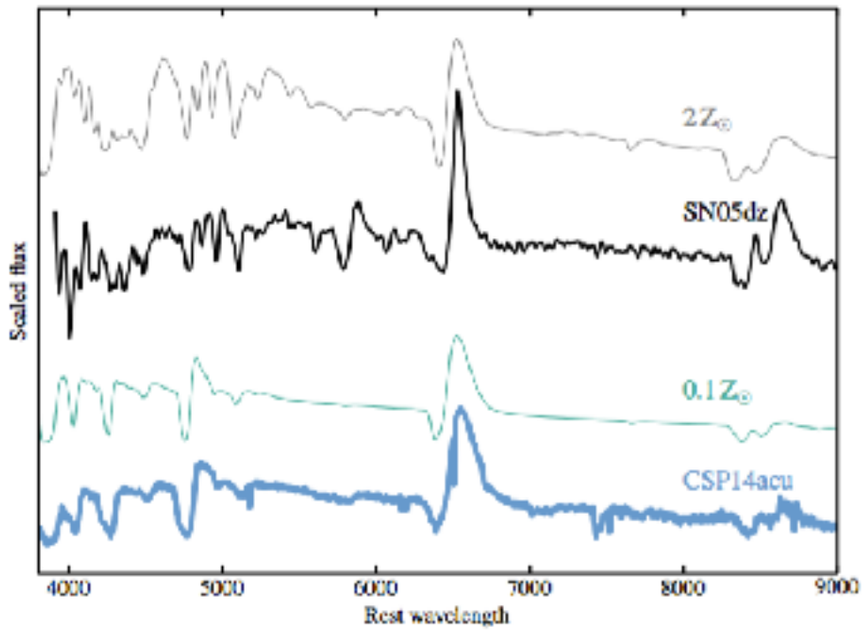


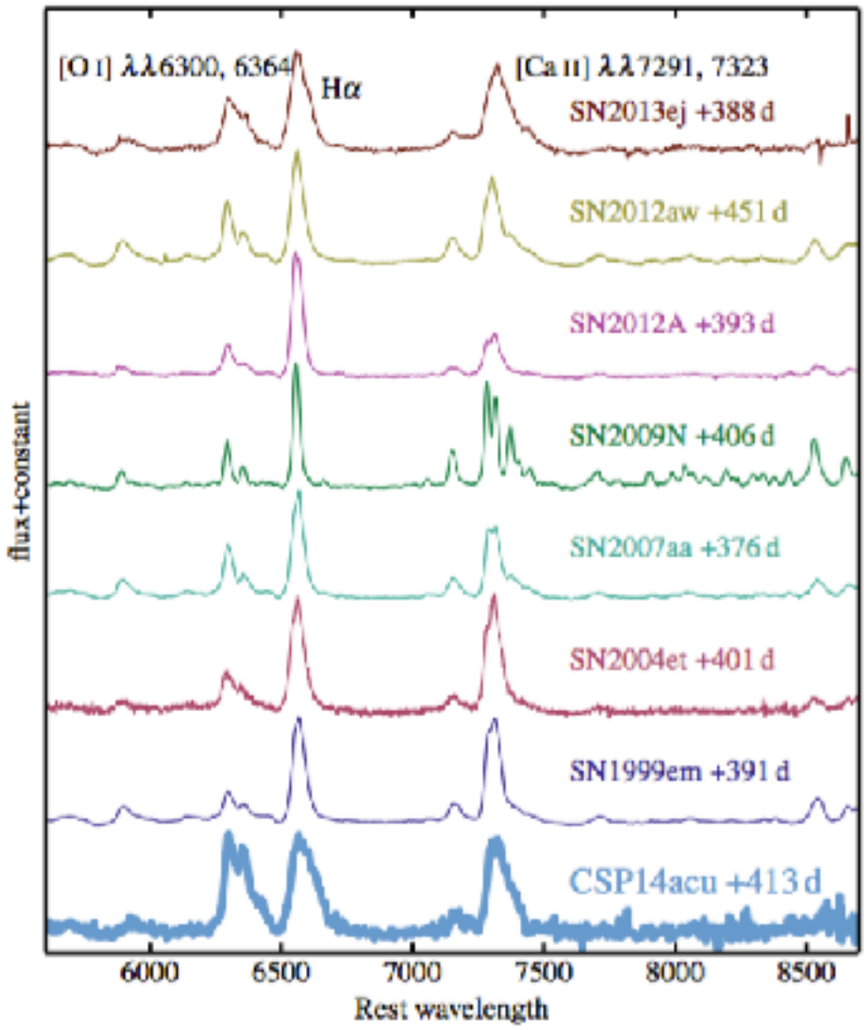
- One of the closest TDE, and the best studied ever (from X-ray to radio)
- post-starburst galaxy (TDE rate is 30 times higher in E+A galaxies)
- Recent interaction (merger triggered the starburst)
- Gas ionized by an AGN

SN2015bs: high-M low-Z progenitor



- MUSE constrained its host galaxy
- the SNII with the lowest Z to date
- strong [OI] w.r.t Ha (very broad) and [CaII], which means means more massive Helium core and more massive initial progenitor mass





Joseph P. Anderson

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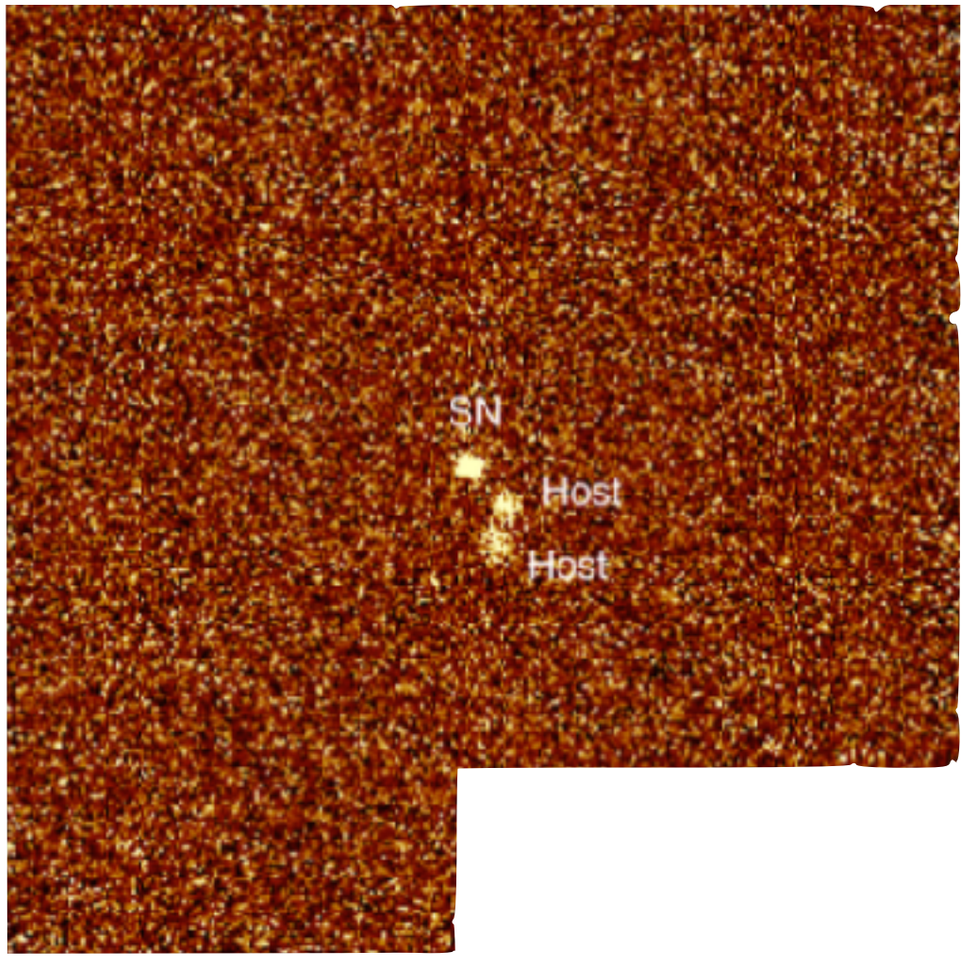

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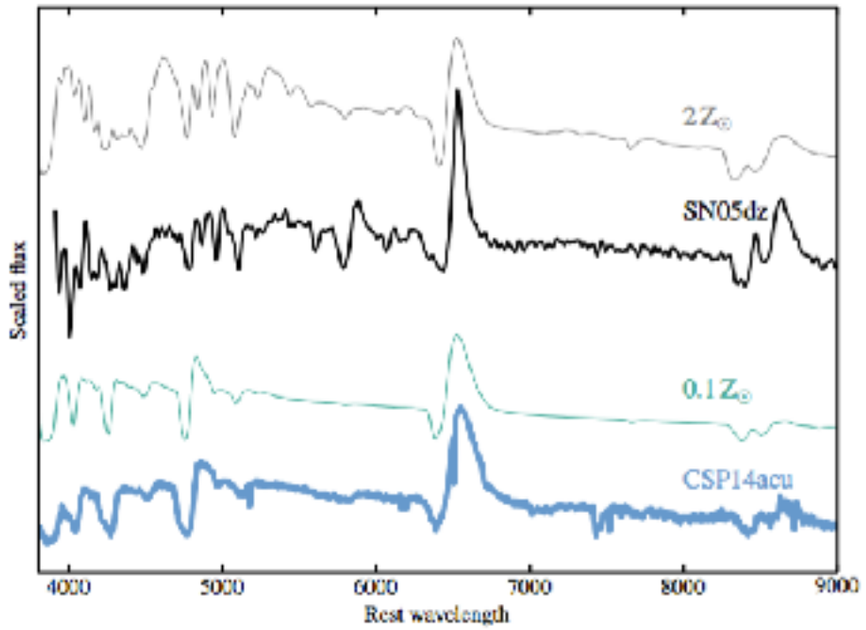
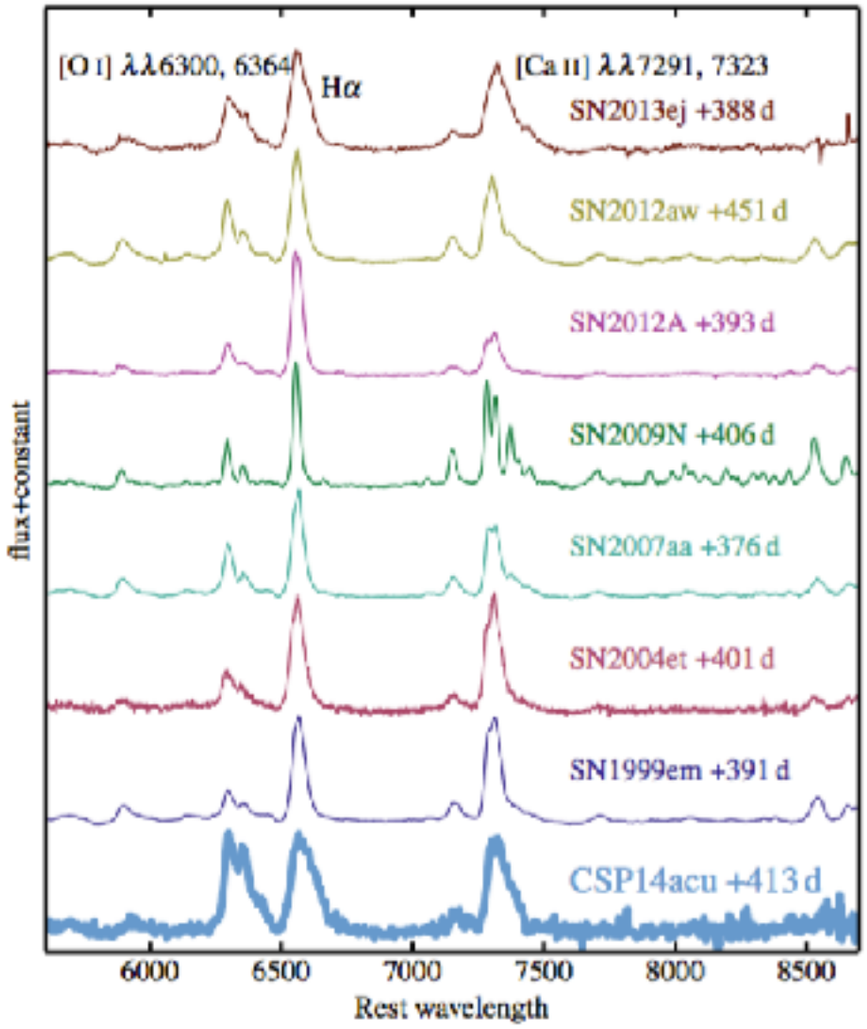
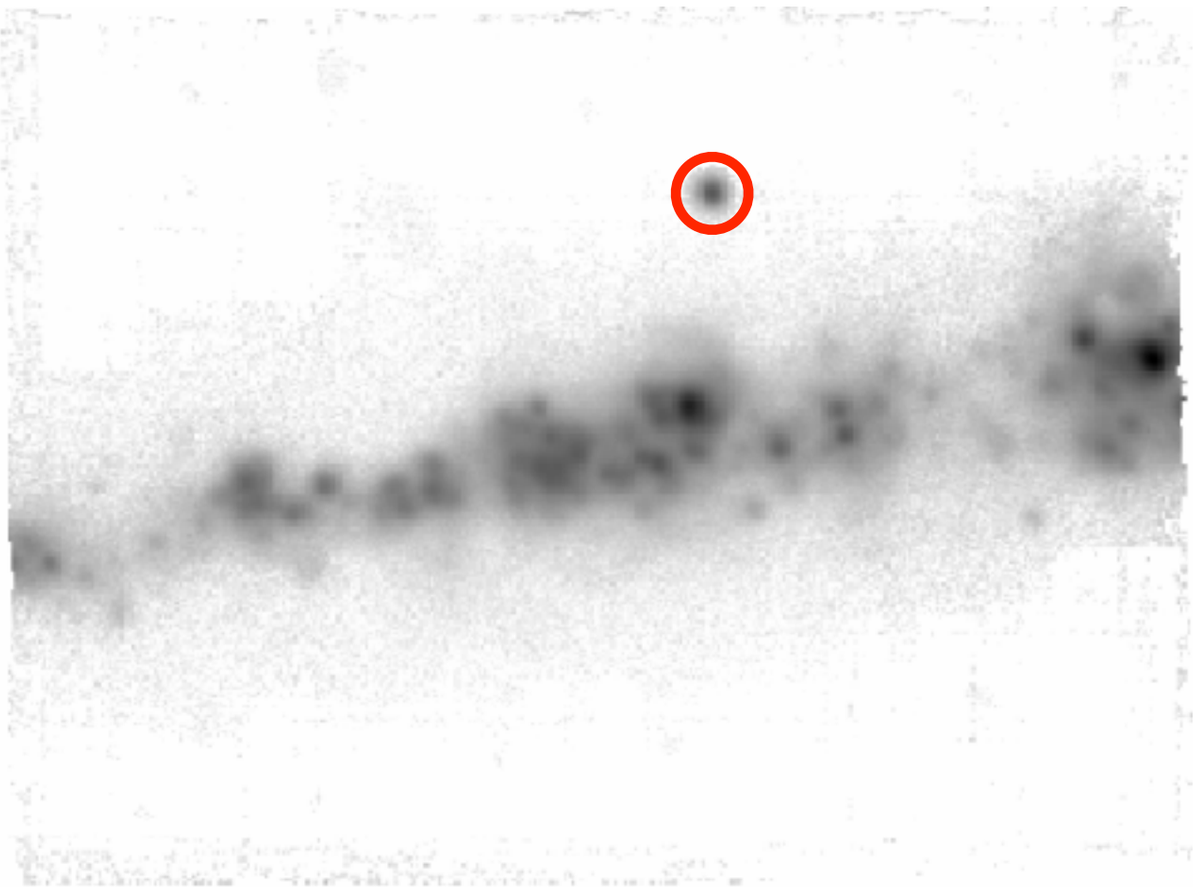
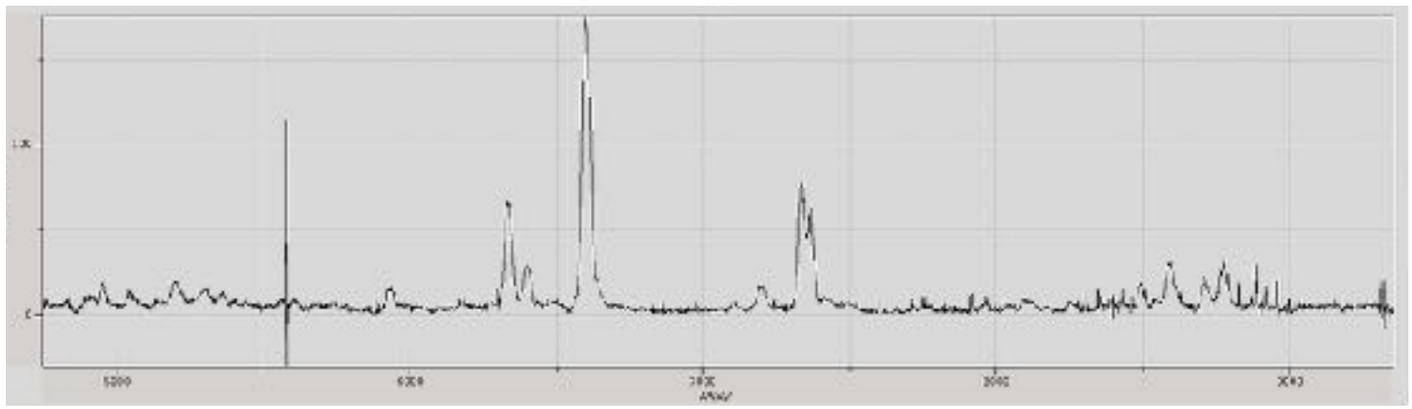




ASASSN-14jb: normal SNII very far from any SF region





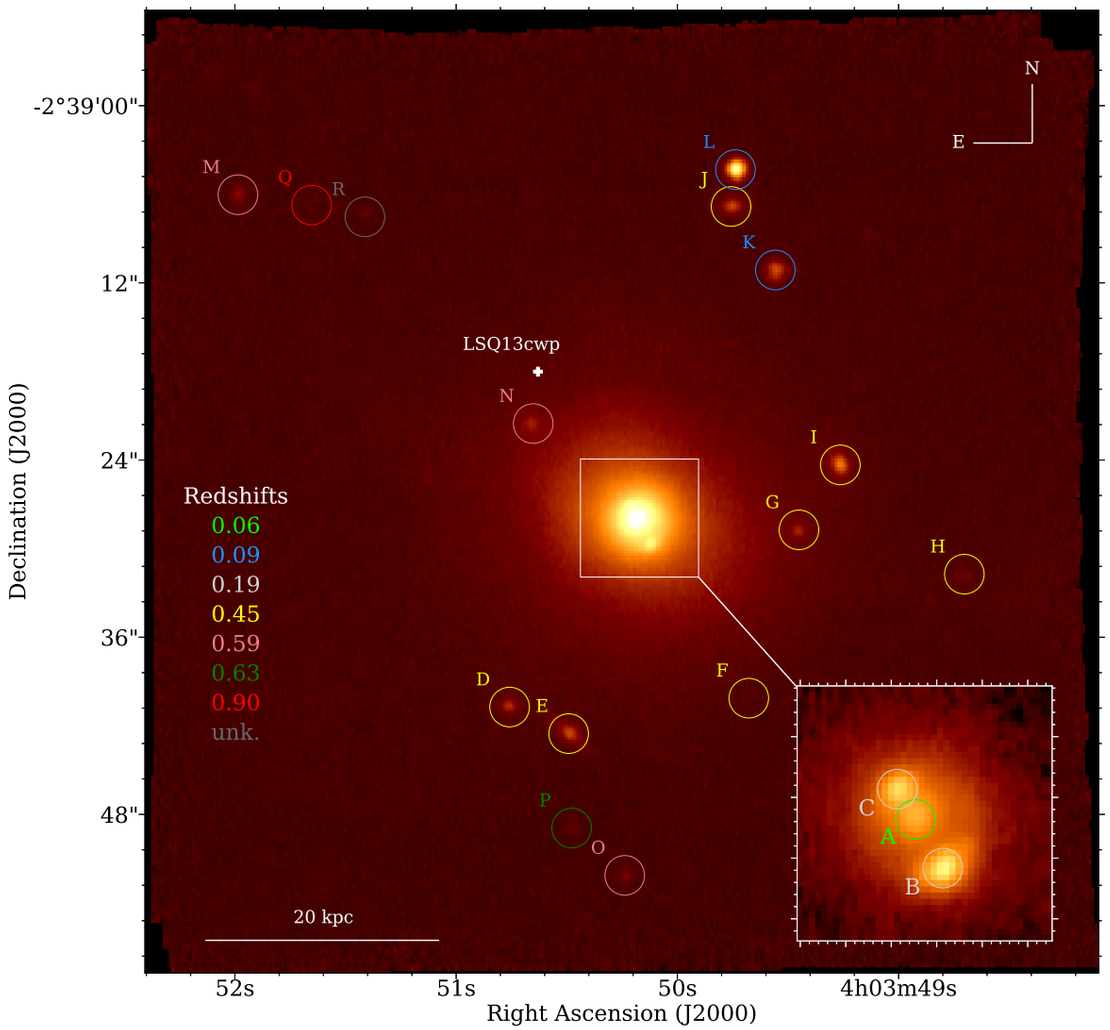
- Edge-on galaxy (scale height ~400pc)
- SN progenitor exploded at >2kpc (lifetime of ~10Myr)
- needs a pec. vel. of 50 km/s

- Options?
  - kick from a SN in a binary system
  - triple interaction
  - …
- It also has low Z

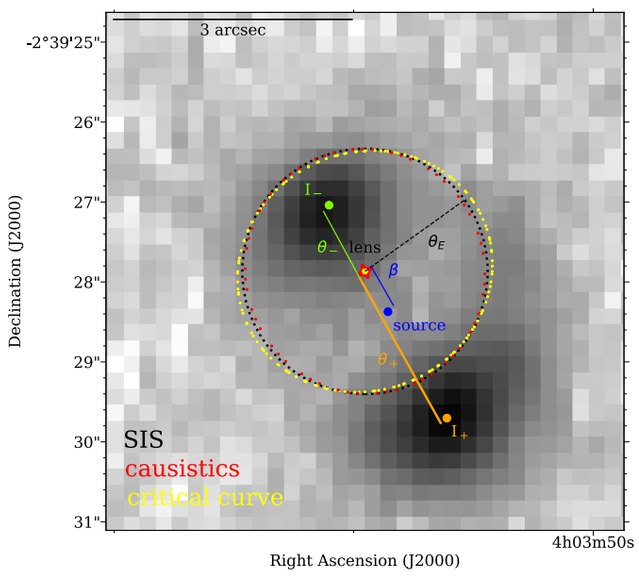
Nico Meza

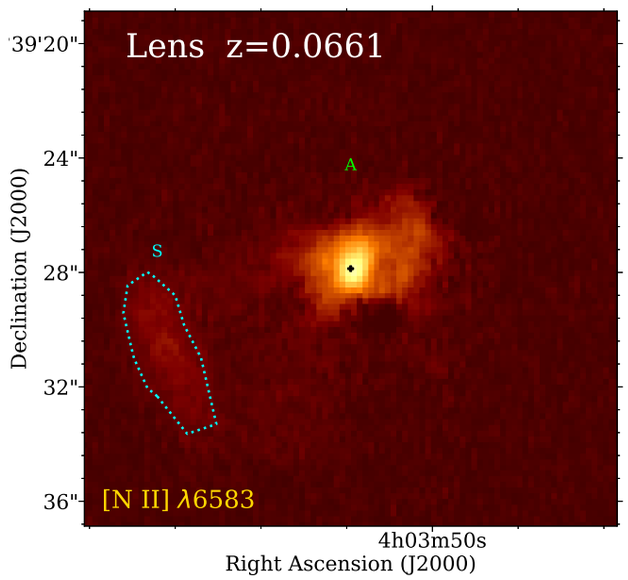
LG+ 2018, MNRAS, in press

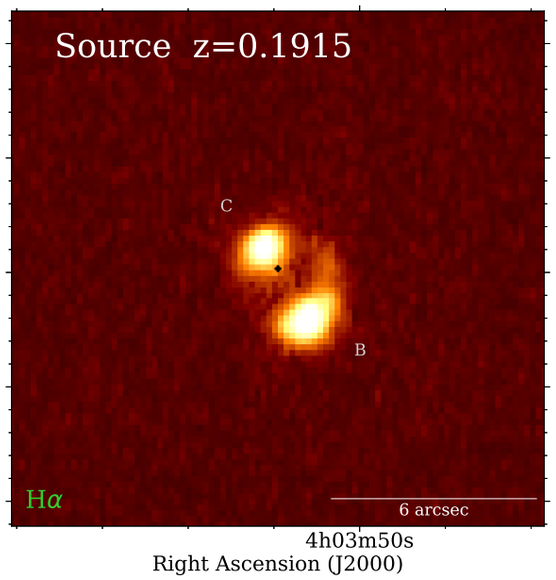
Discovery of a strong lensed galaxy in IFS data

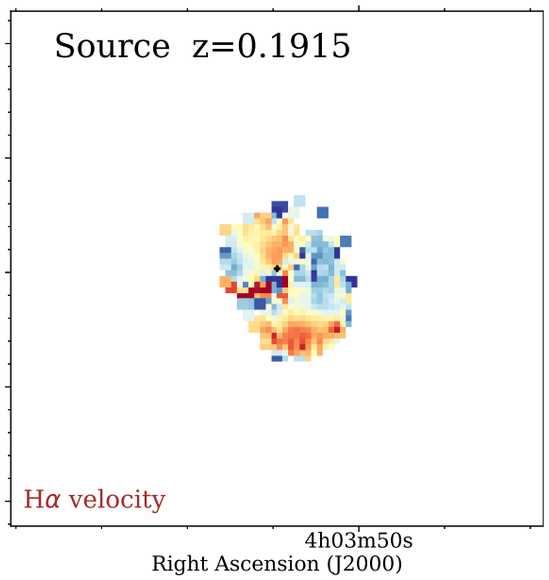


- Report the discovery of a background lensed galaxy at redshift 0.1915
- plus other 15 background galaxies at redshifts ranging from z=0.09 to 0.9
- Einstein radius of 1. 45±0. 04“, which corresponds to 1.9 kpc
- dark matter fraction of 18 ± 8 % within the Einstein radius.







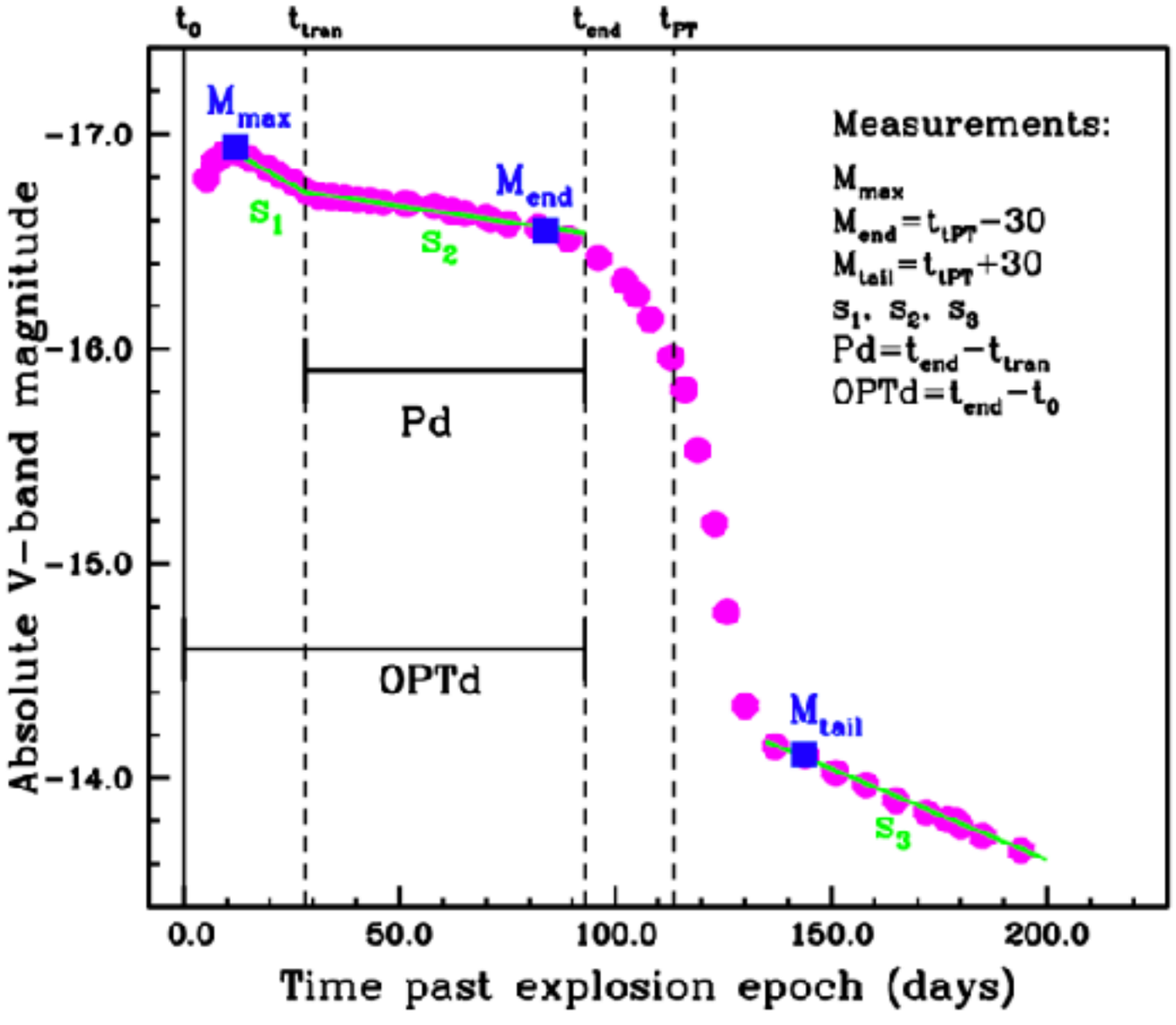


SNII local environments

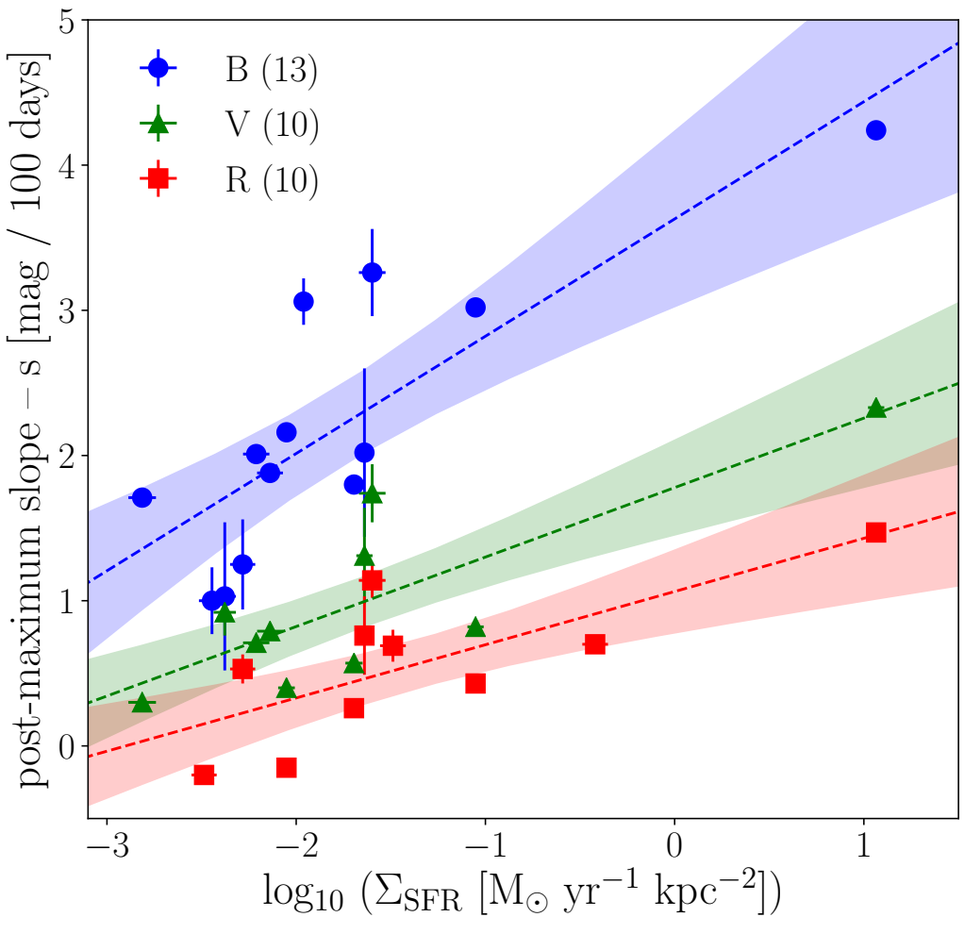
Post-maximum slope correlates with local SFR

Extend to AMUSING SNII environments (x4 in size)

Isaac Lozano (UIValencia)



LG, PISCO paper

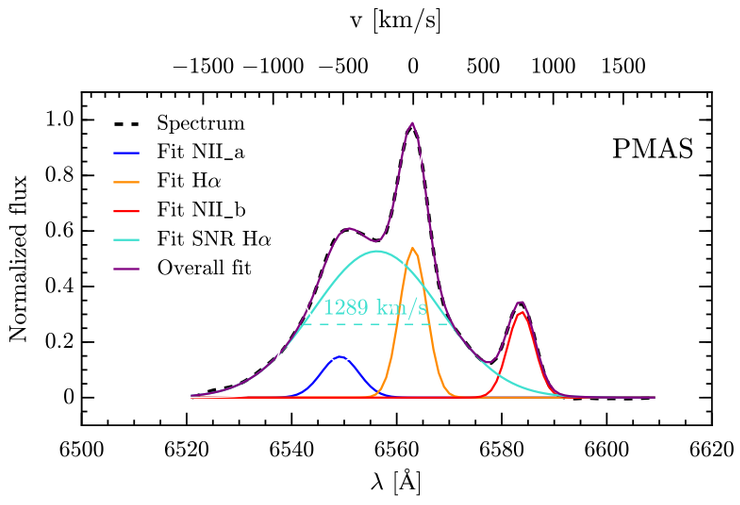


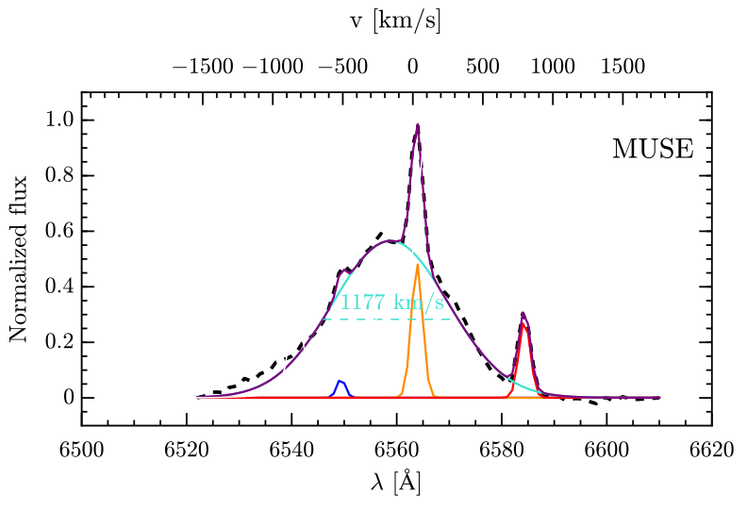
Young SN remnant detection/discovery

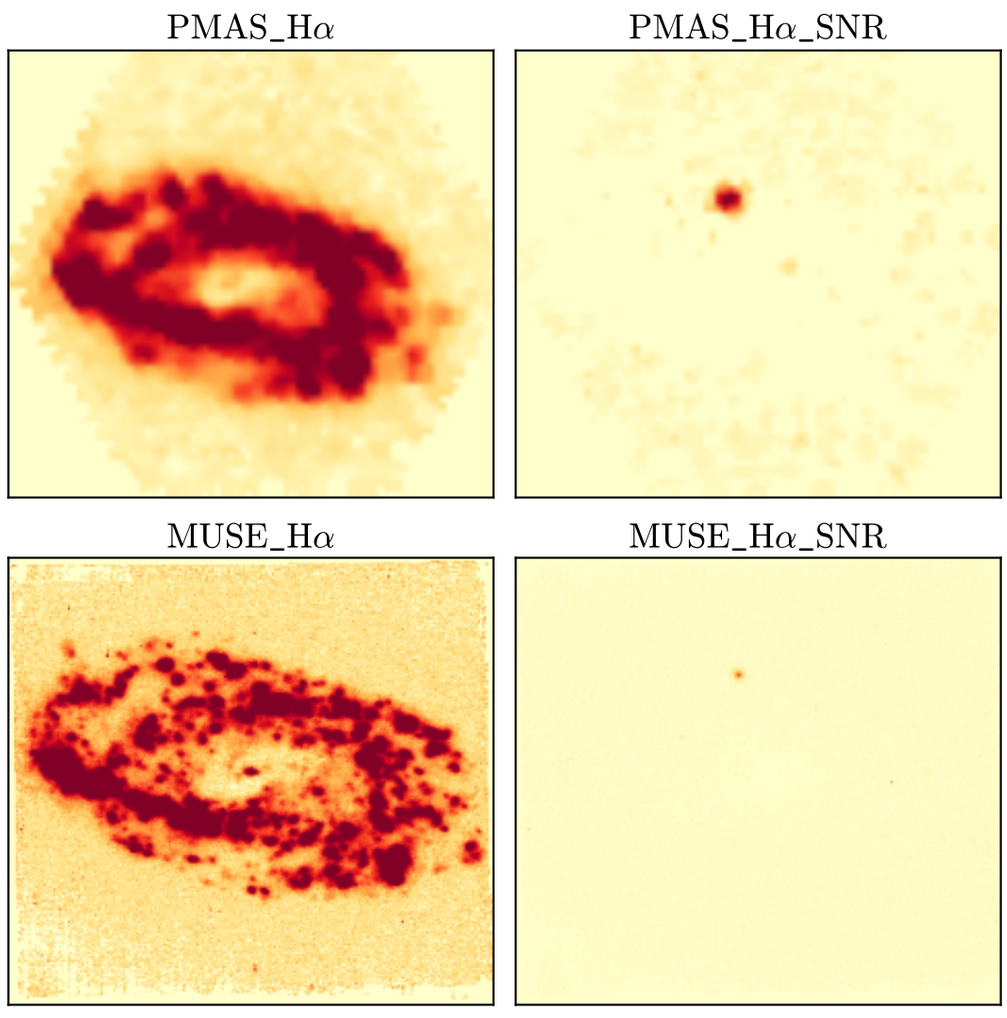
Héctor Martínez Rodríguez

2 methods:

- H_{alpha} broad component (4th gaussian)
- SNR cross-correlation:
  4700-5300 / 6100-6500 / 6500-6620 / 6620-6900 / 700-7600







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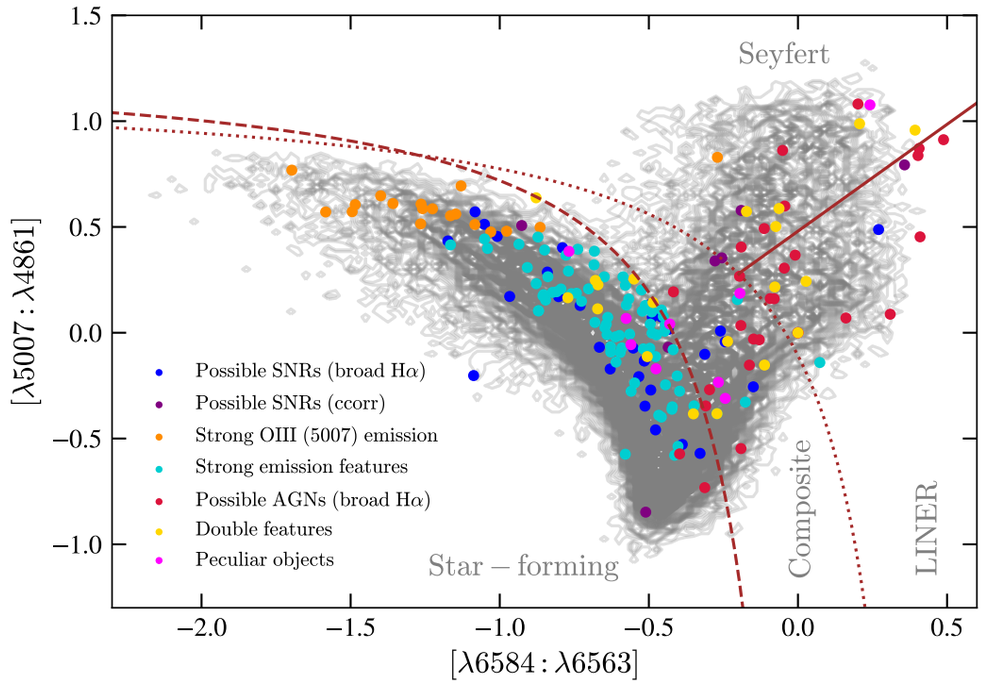
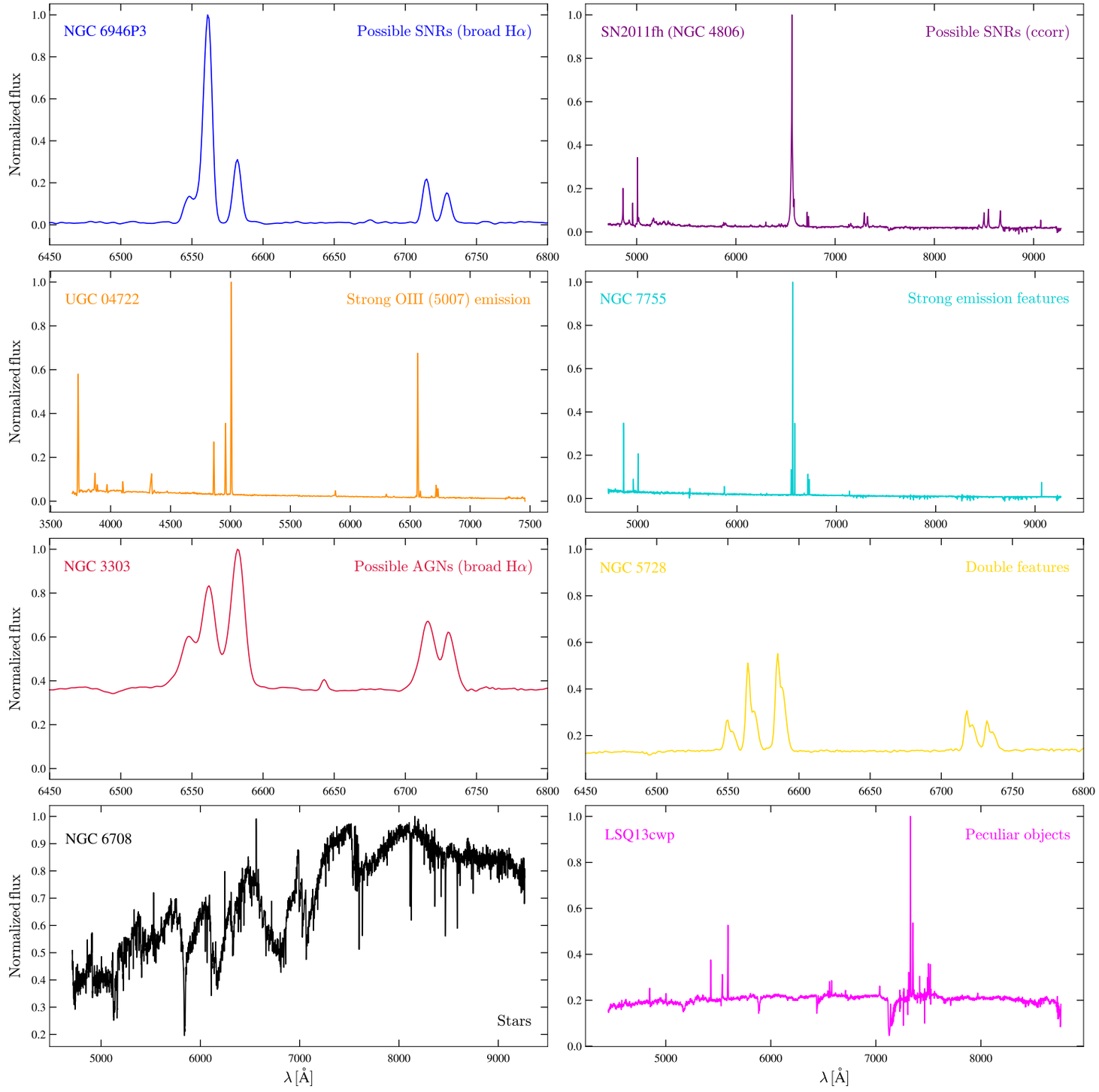
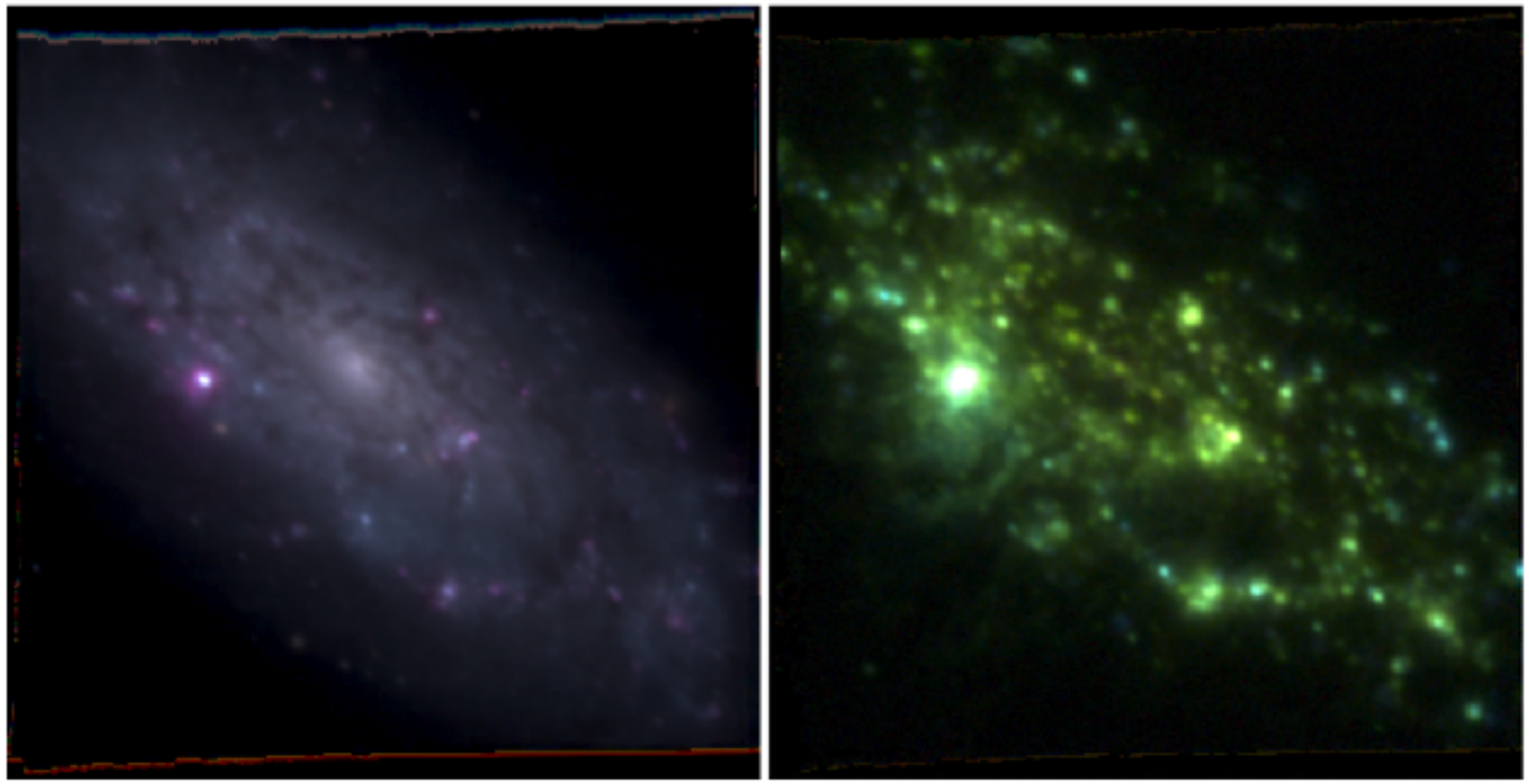
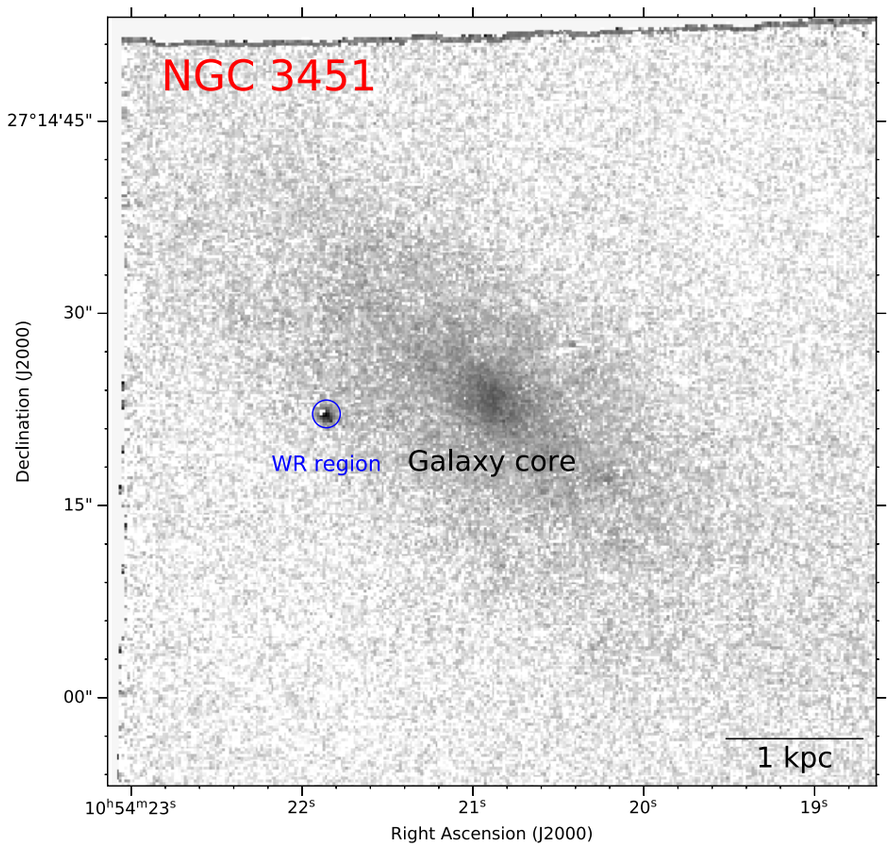


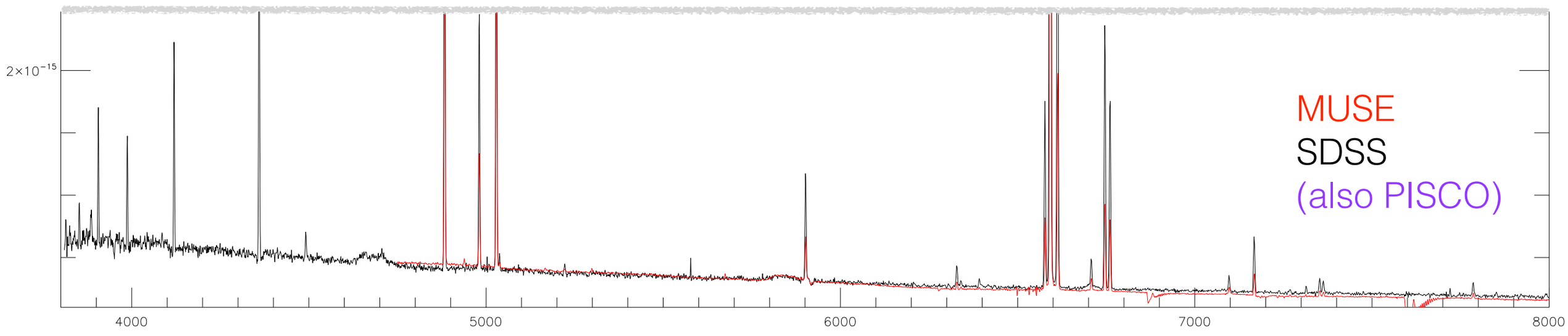


WR regions in AMUSING

Carolina Kheriig

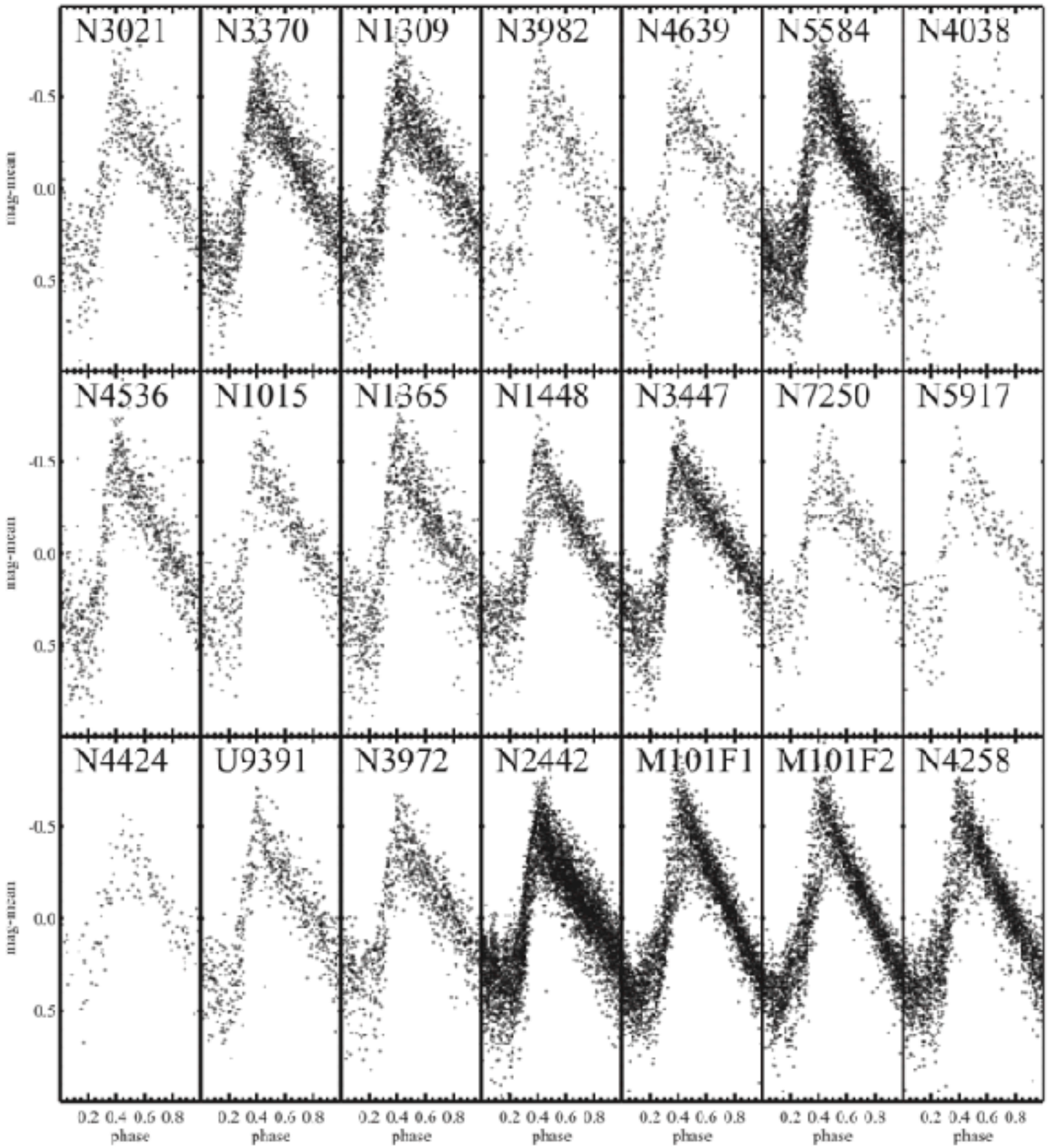






Cepheids metallicity calibration in SHOES

Sara Muñoz Torres



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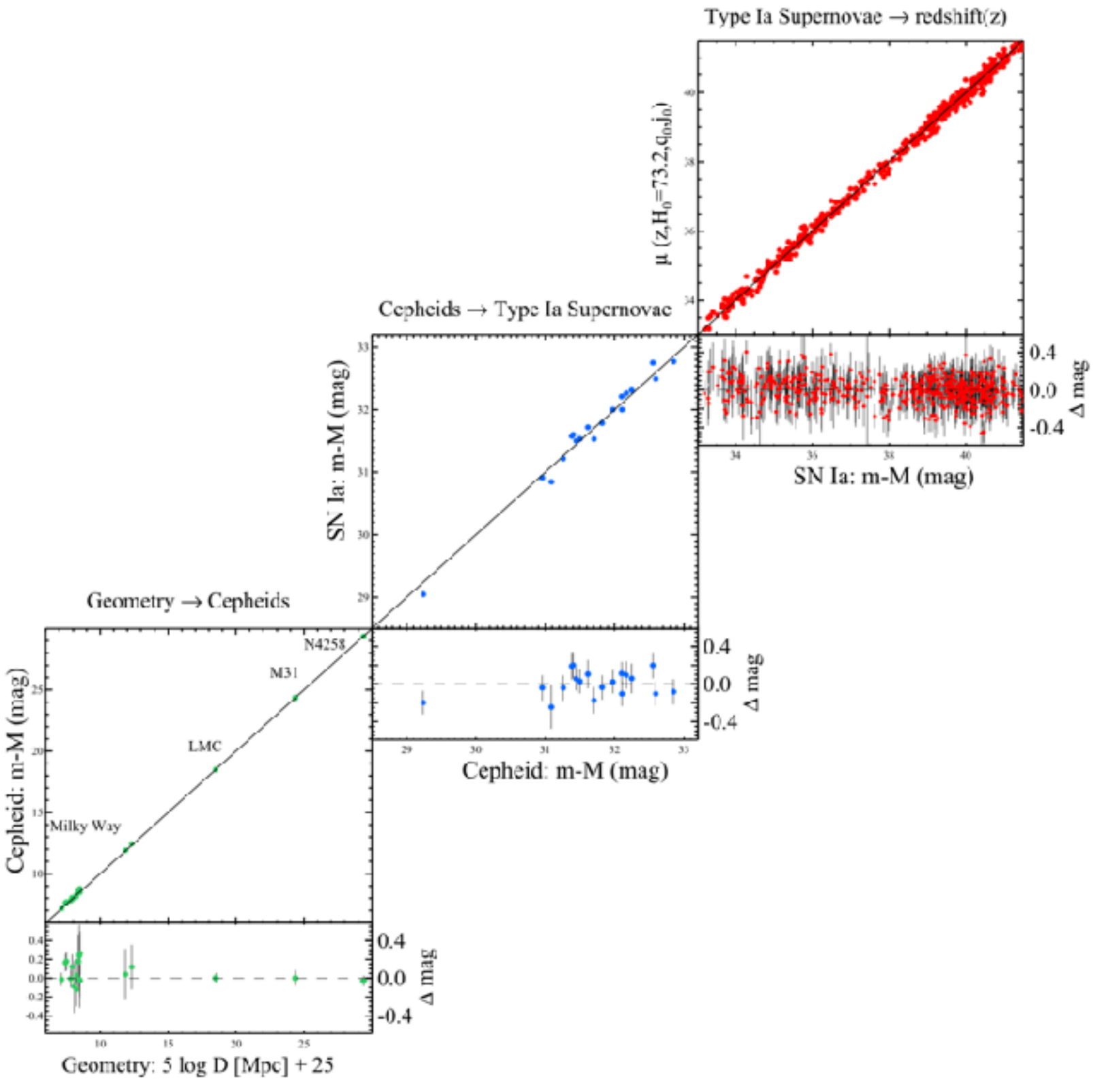

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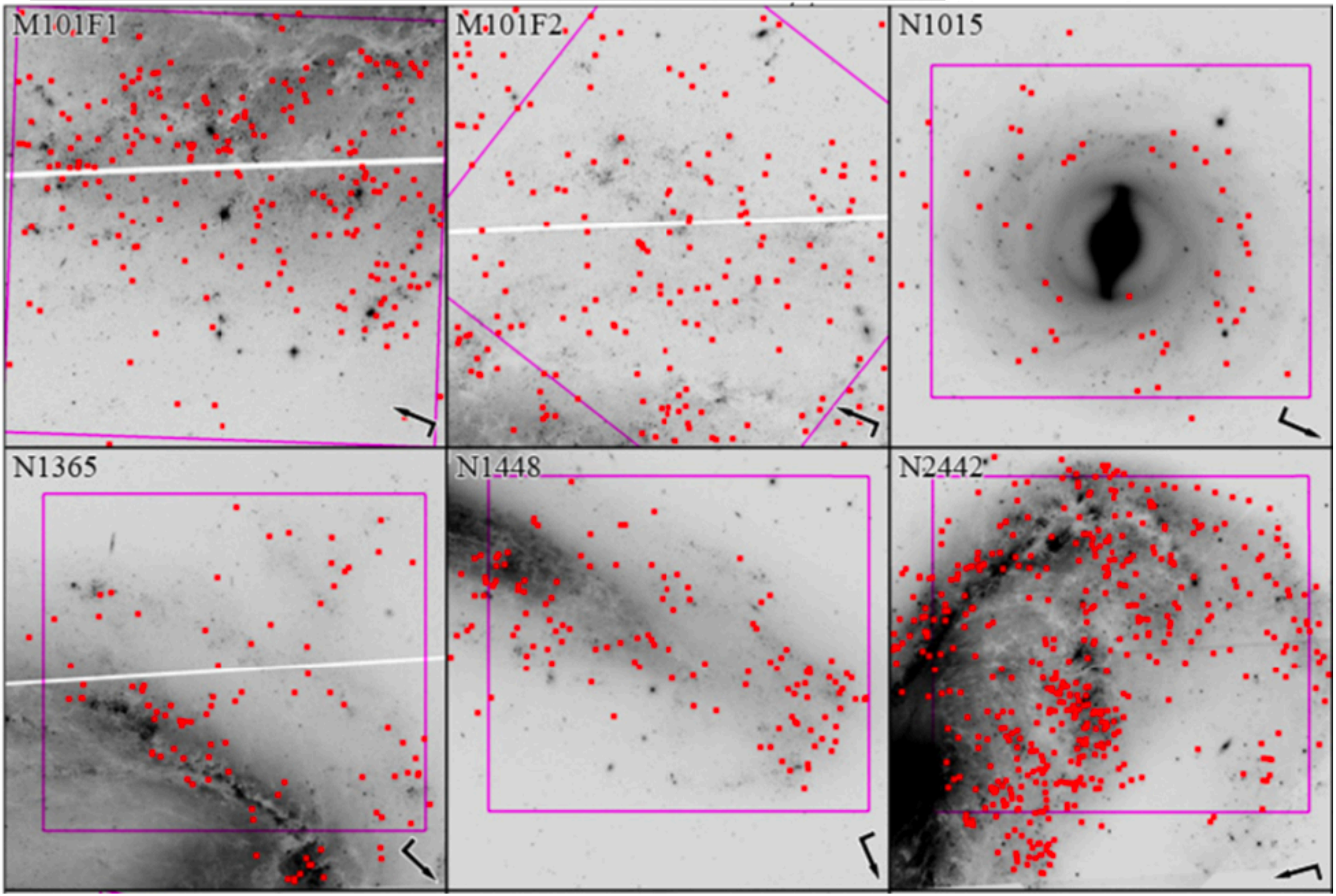


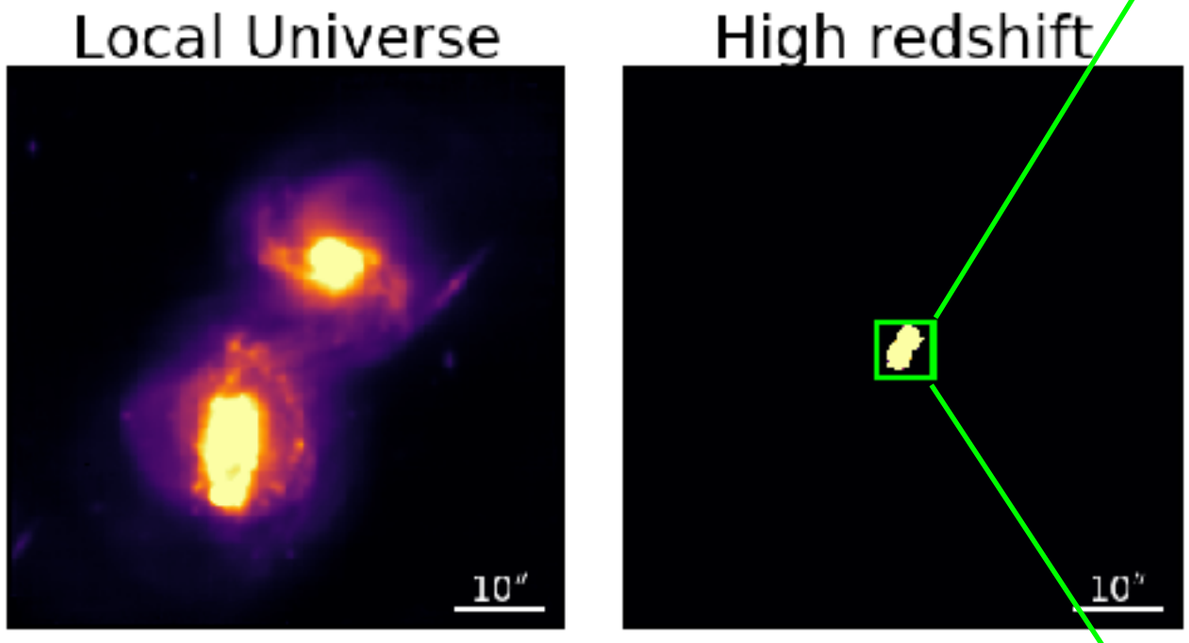
Simulating galaxies at high-z

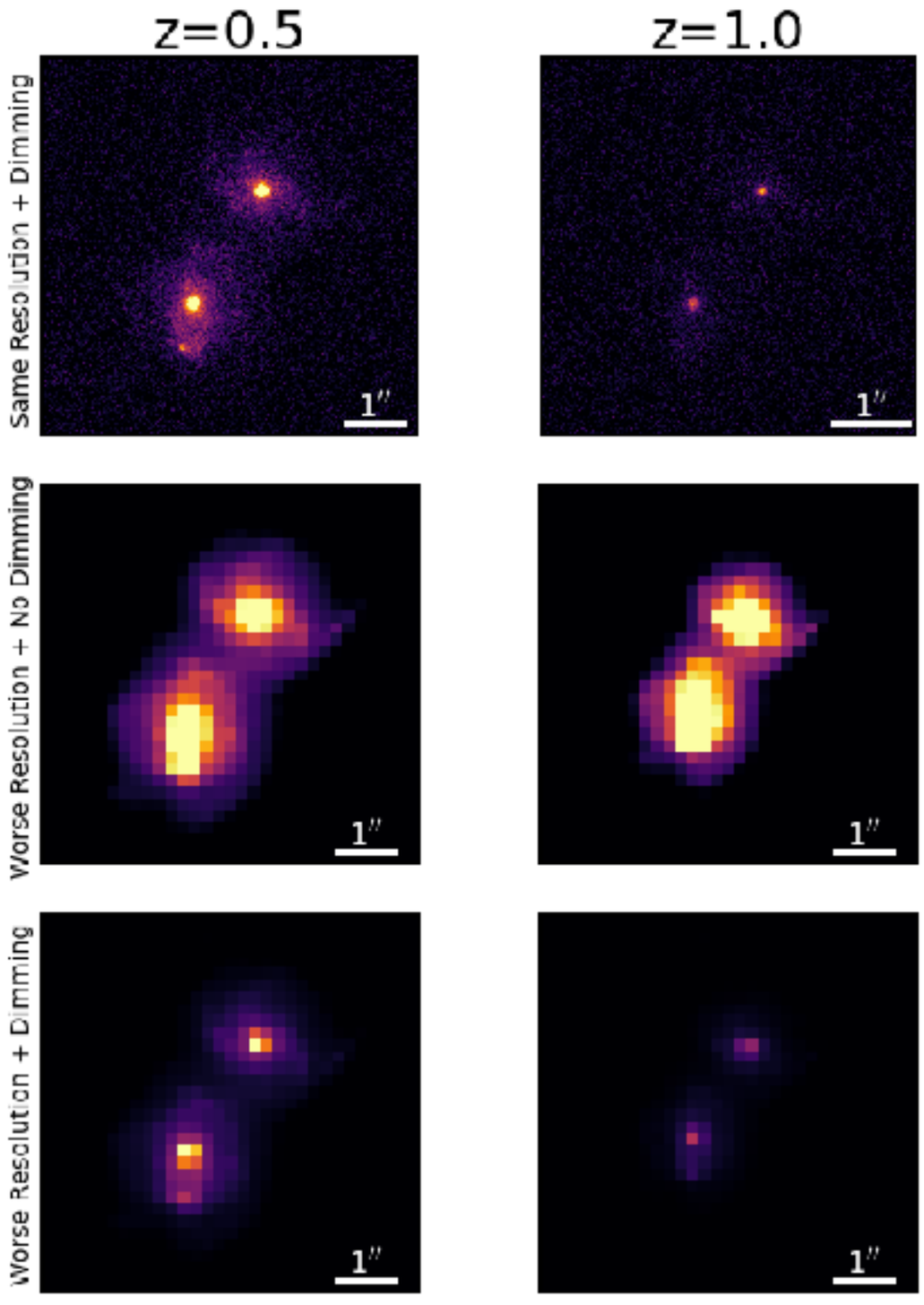
CRISP: Correcting Reddening Intelligently for cosmological Supernova Probes

Ana S. Paulino-Afonso (ULisboa)

in prep.

See also Paulino-Afonso+17
MNRAS 465.2717





Determine biases in galaxy properties when working in a wide range of redshifts

e.g. host galaxy dependencies in SNIa cosmology

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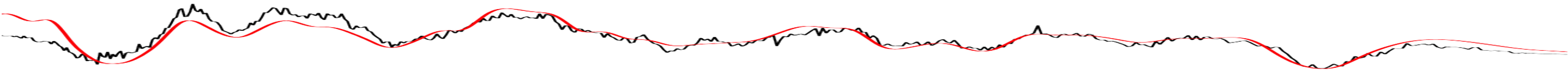

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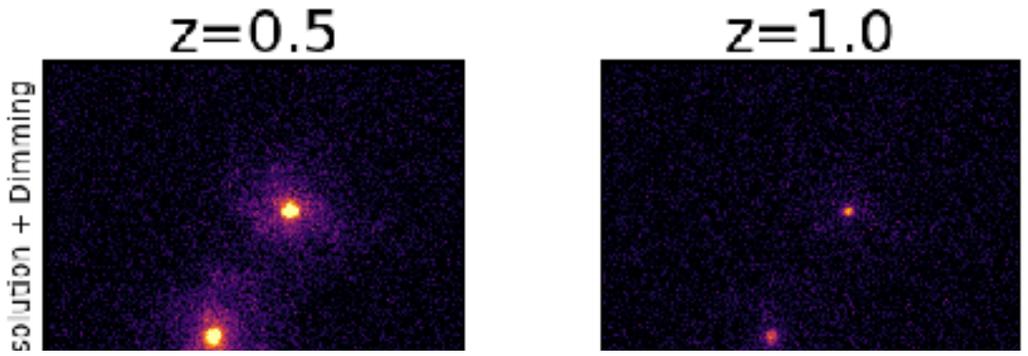

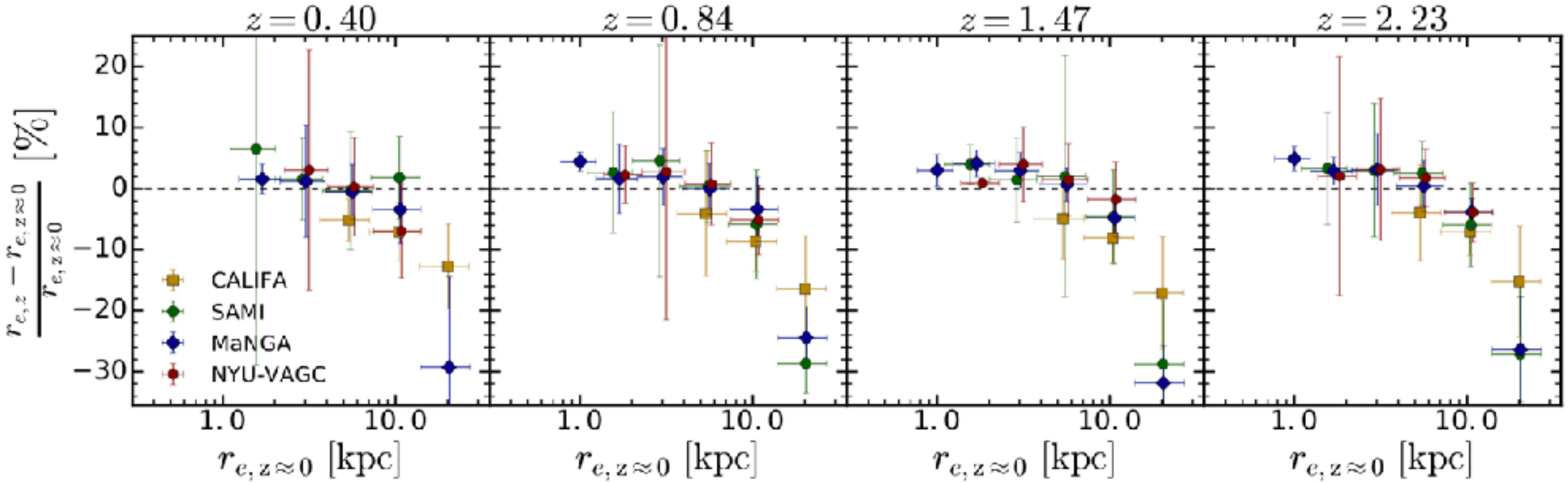

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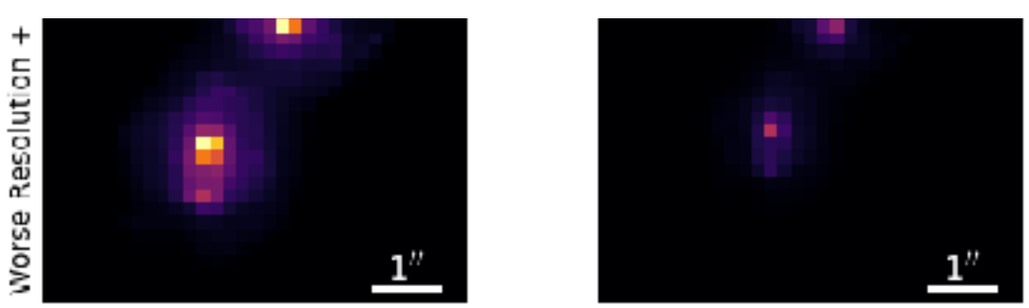
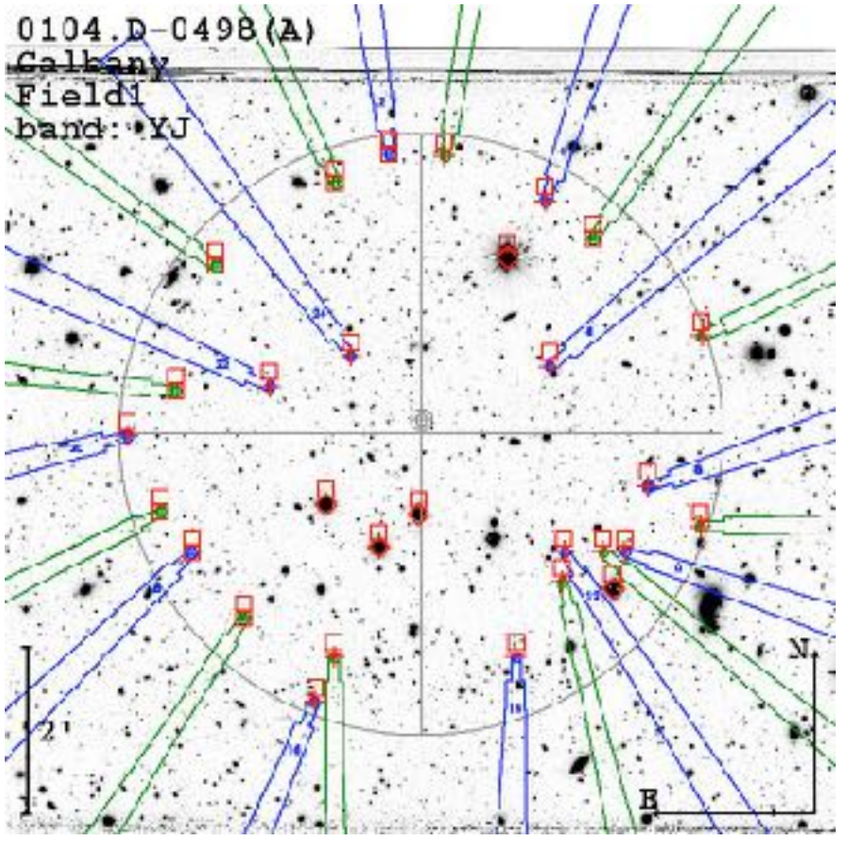


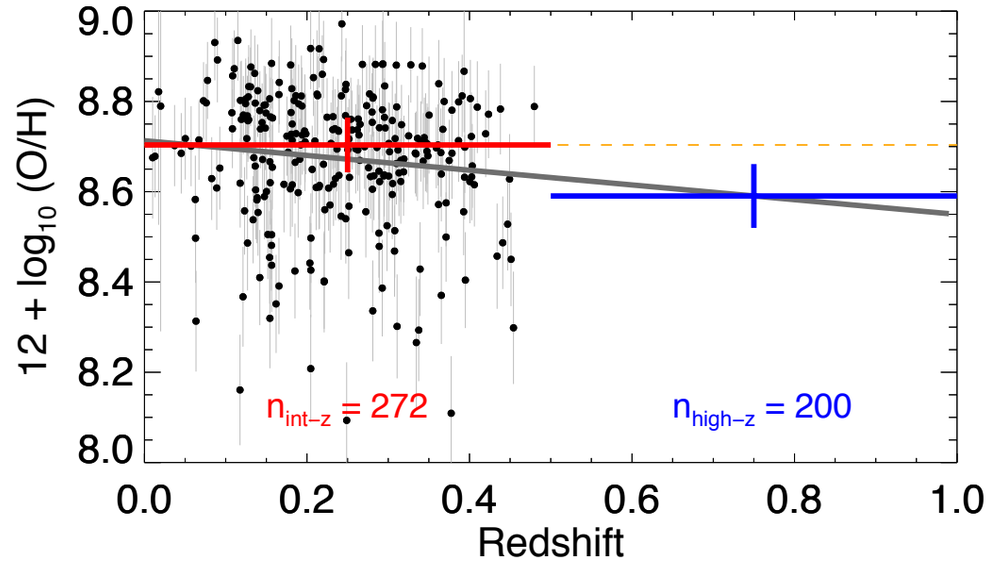
What about high-z?

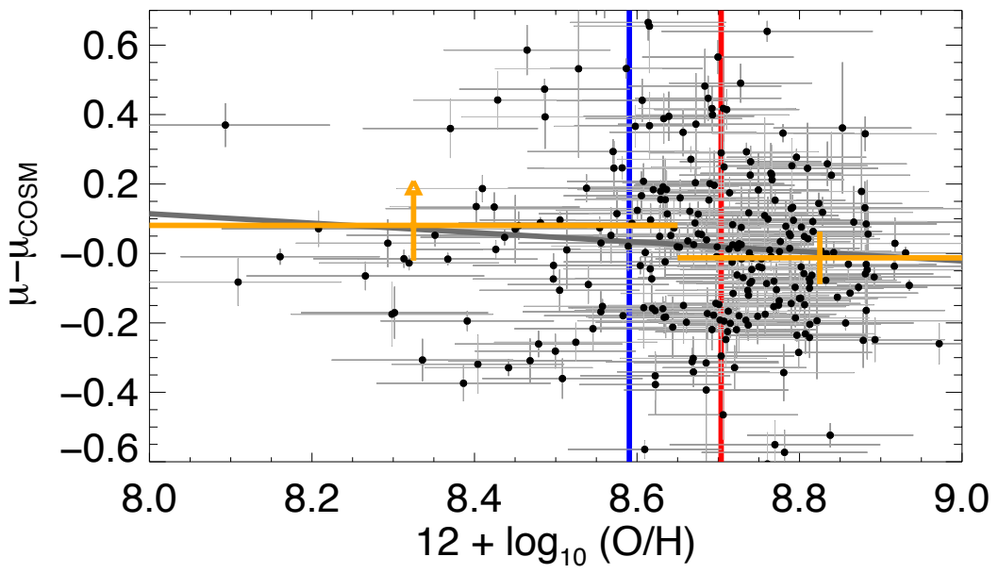
@ UT1 Very Large Telescope

DARK ENERGY SURVEY

- 24 arm spectrograph, 7.2’ diameter
- 24 ~3”x3” IFU (0.2” spx)
- >200 SN hosts at z>0.5 from DES







Observations finished! (Jan 2020)

Marie Skłodowska-Curie Actions

(SNDTD) Resolving the origins of SNe: constraining progenitors with integral field spectroscopy