CRISP

CORRECTING REDDENING INTELLIGENTLY FOR COSMOLOGICAL SUPERNOVA PROBES

CRISPinho meeting,
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CORRECTING REDDENING INTELLIGENTLY FOR COSMOLOGICAL SUPERNOVA PROBES


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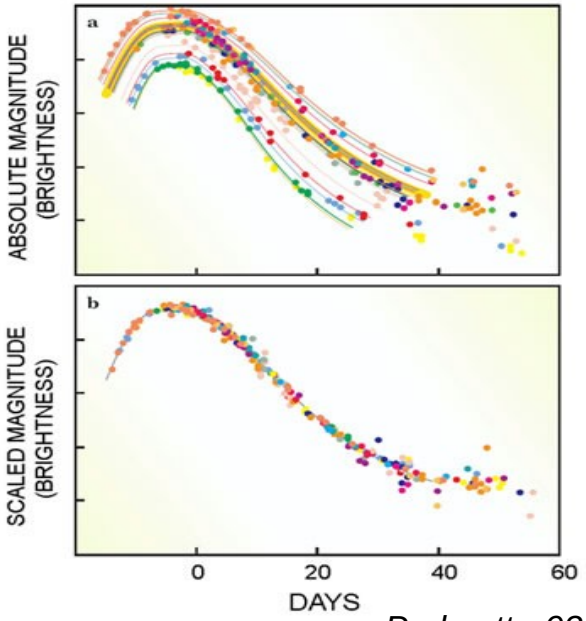
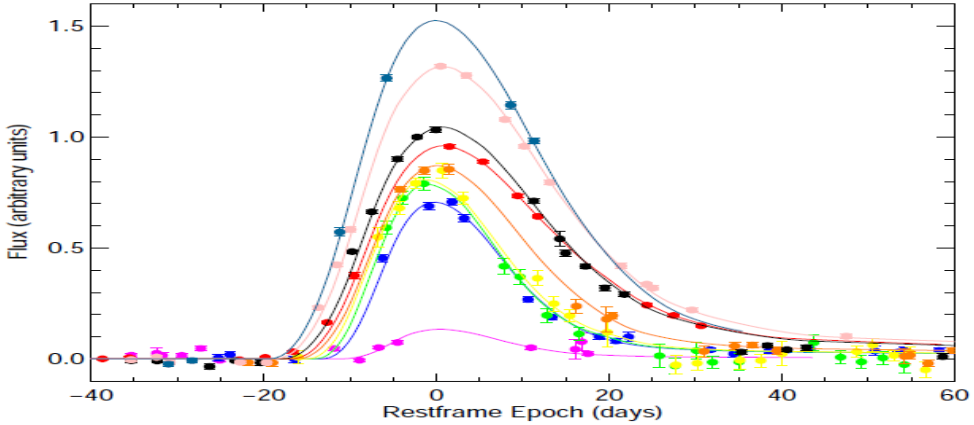
Motivation

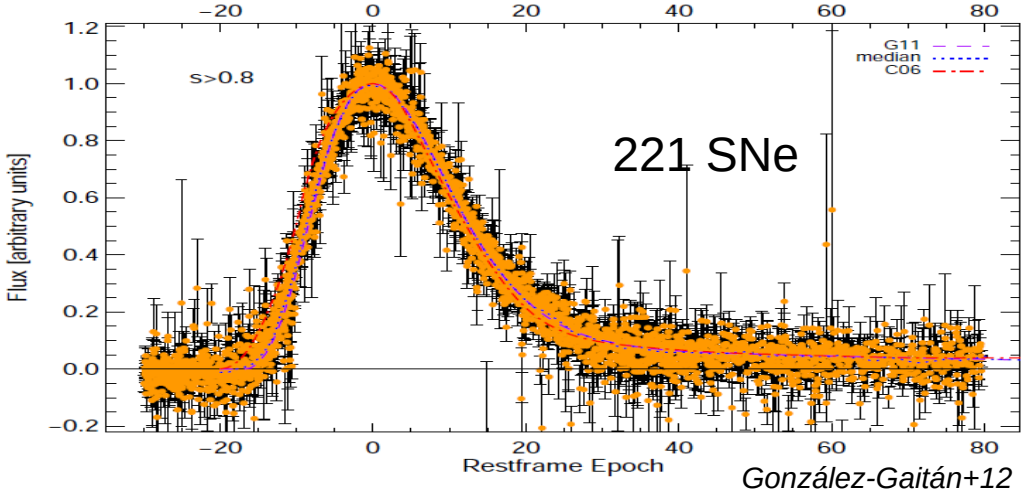
Supernova extinction and its effects on cosmology

SNe Ia: standardizable candles



Perlmutter03



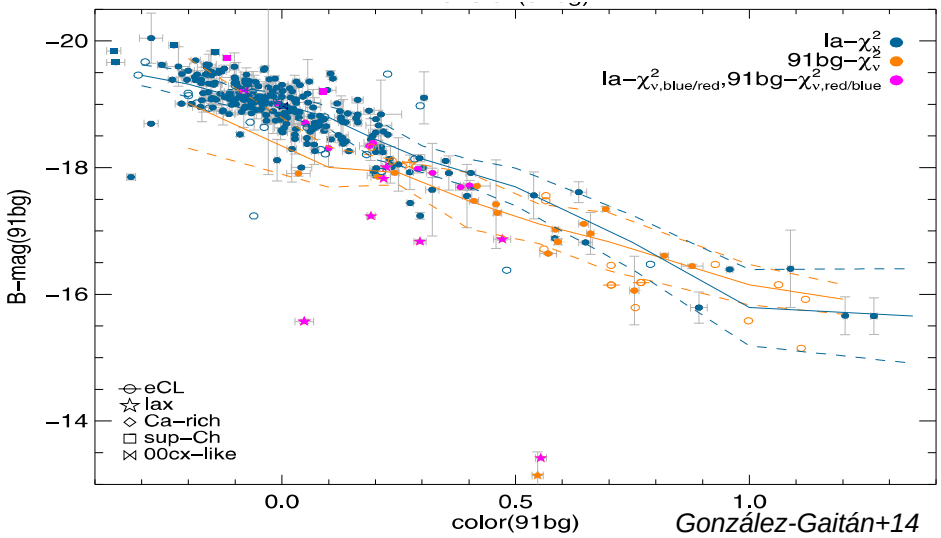


González-Gaitán+12

1. Light-curve morphology and brightness relation (Phillips93)

SNe Ia: standardizable candles

2. Color & brightness relation (Tripp98)



$$\mu = m_B^{\star} - (M_B - \alpha \times X_1 + \beta \times C)$$

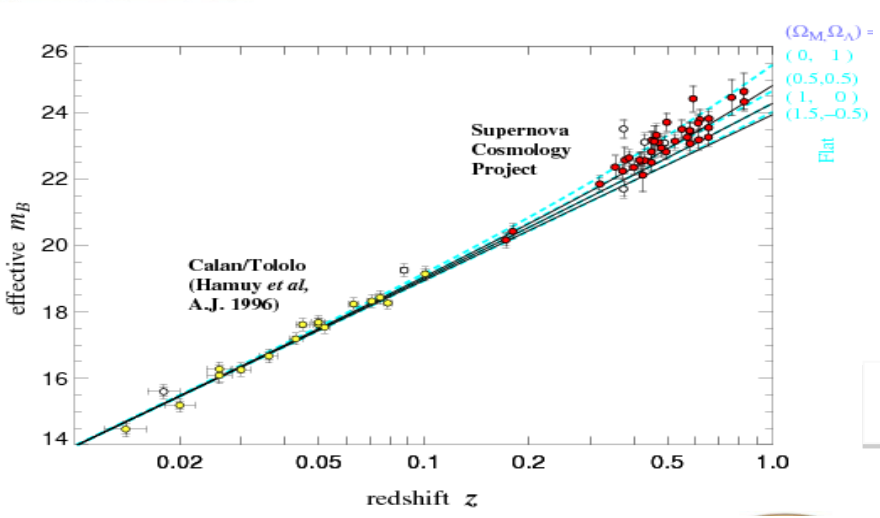
Light-curve shape

Color

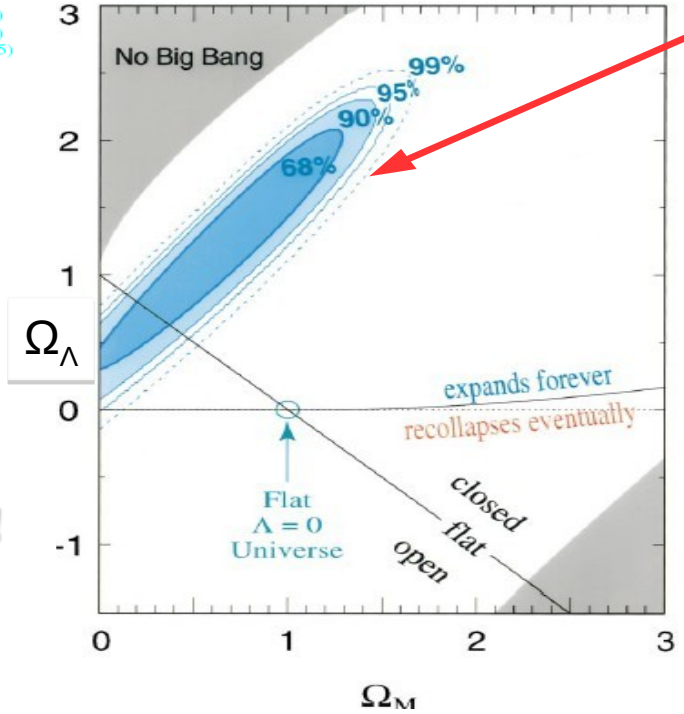
2% in *H0*

5.4% measure in *w*

A. The role of type Ia supernovae

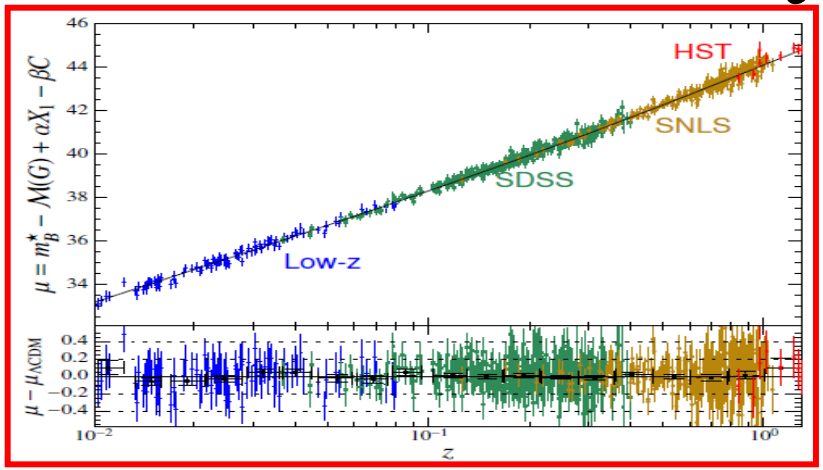


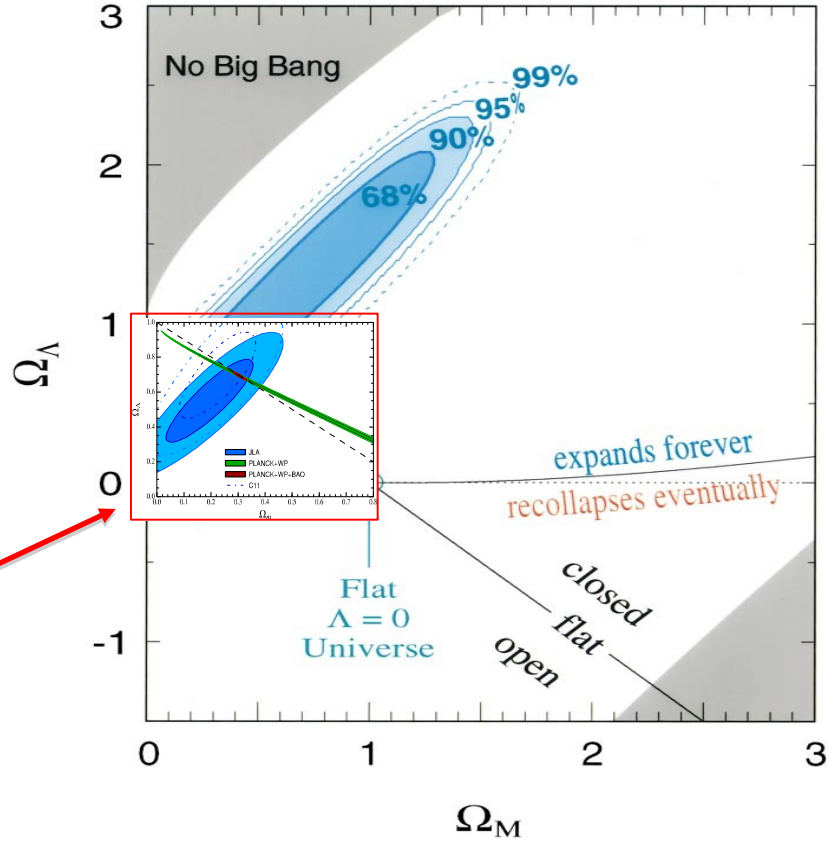
60 SNe Ia
Perlmutter
et al. 1998



ACCELERATING UNIVERSE!!!

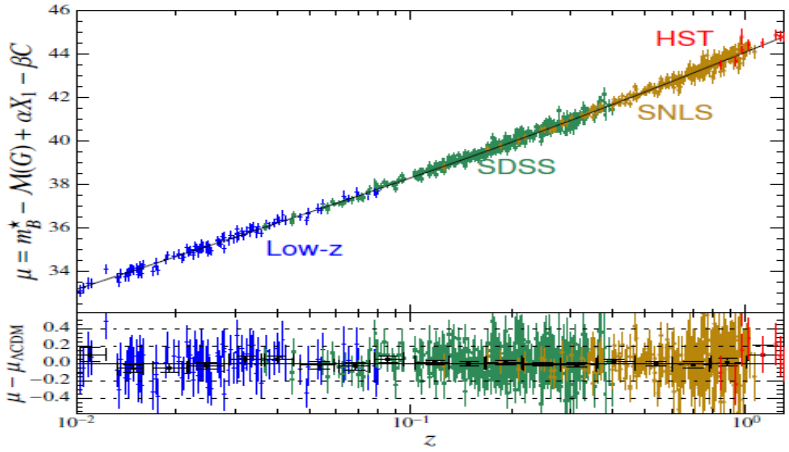
A. The role of type Ia supernovae





TODAY:
720 SNe Ia
Betoule et al. 2014

A. The role of type Ia supernovae



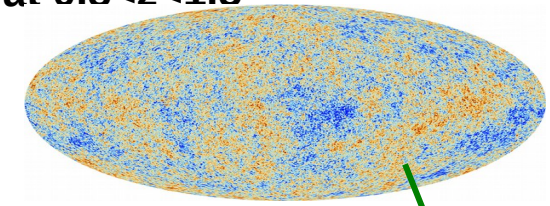
Surveys:

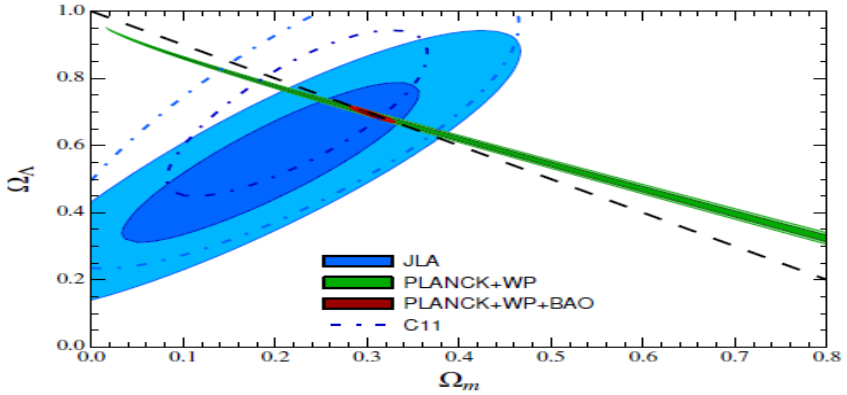
118 low-z: multiple datasets (CSP, CfA, Calan-Tololo) at z<0.1

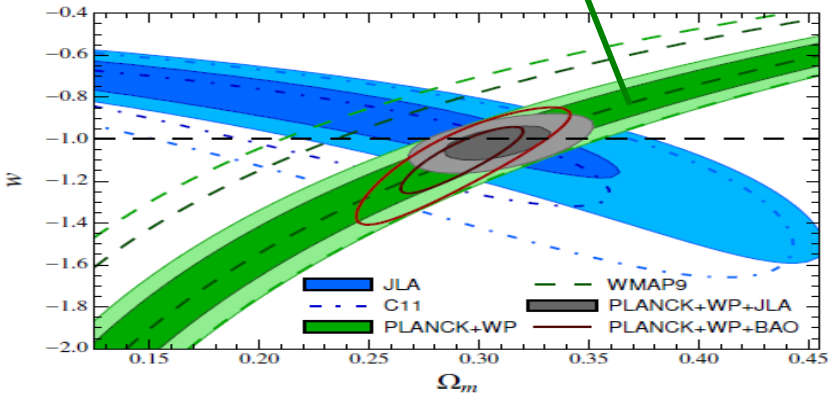
374 SDSS at 0.05<z<0.5

239 SNLS at 0.1<z<1.1

9 HST at 0.8<z<1.5







SNIa systematics

SNIa cosmology has reached a mature state in which systematic uncertainties are now larger than statistical uncertainties

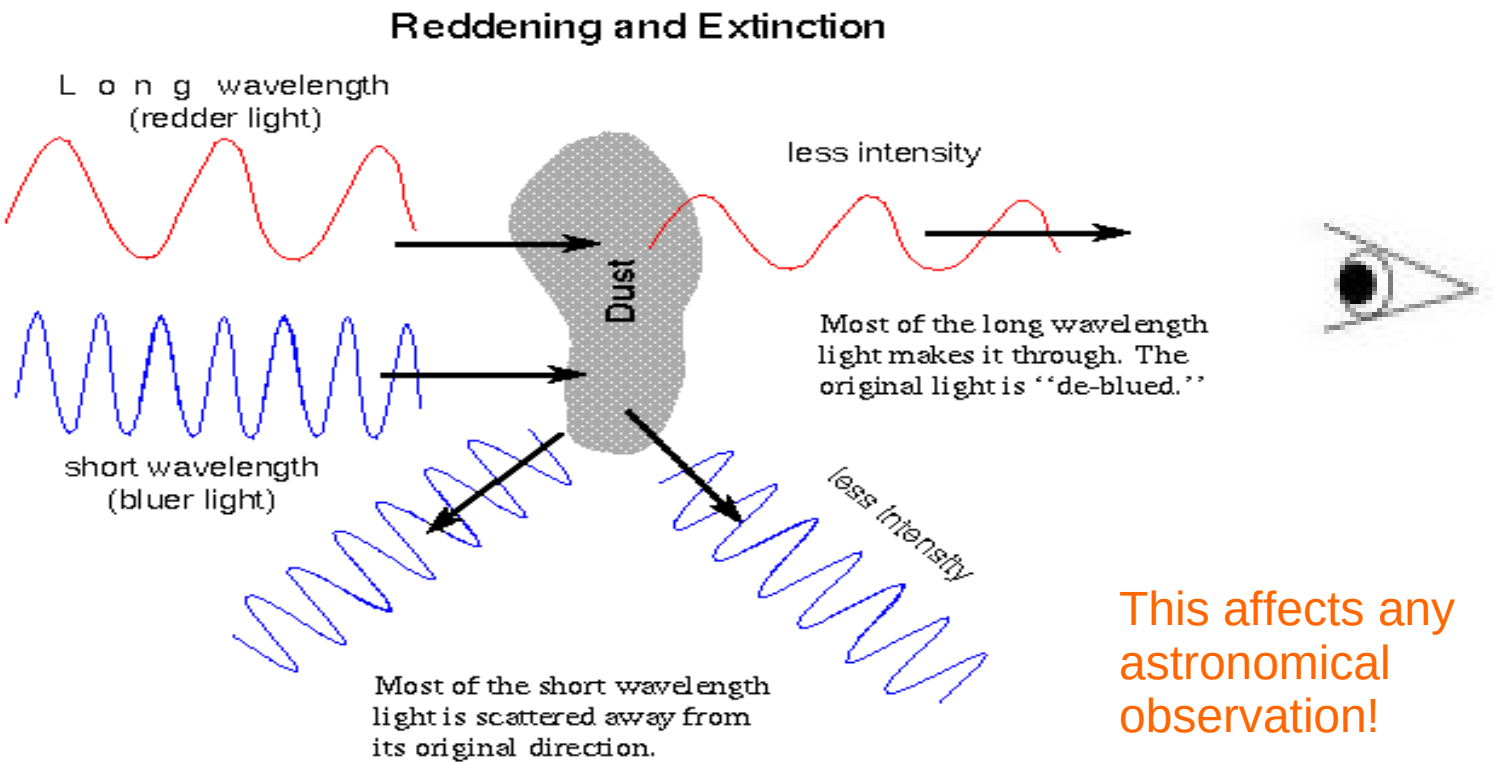
Conley+11

Table 7: Identified systematic uncertainties

Description	Ω_m	w	Rel. Area [a]	w for Ω_m=0.27	Section
Stat only	$0.19^{+0.08}_{-0.10}$	$-0.90^{+0.16}_{-0.20}$	1	-1.031 ± 0.058	
All systematics	0.18 ± 0.10	$-0.91^{+0.17}_{-0.24}$	1.85	$-1.08^{+0.10}_{-0.11}$	§4.4

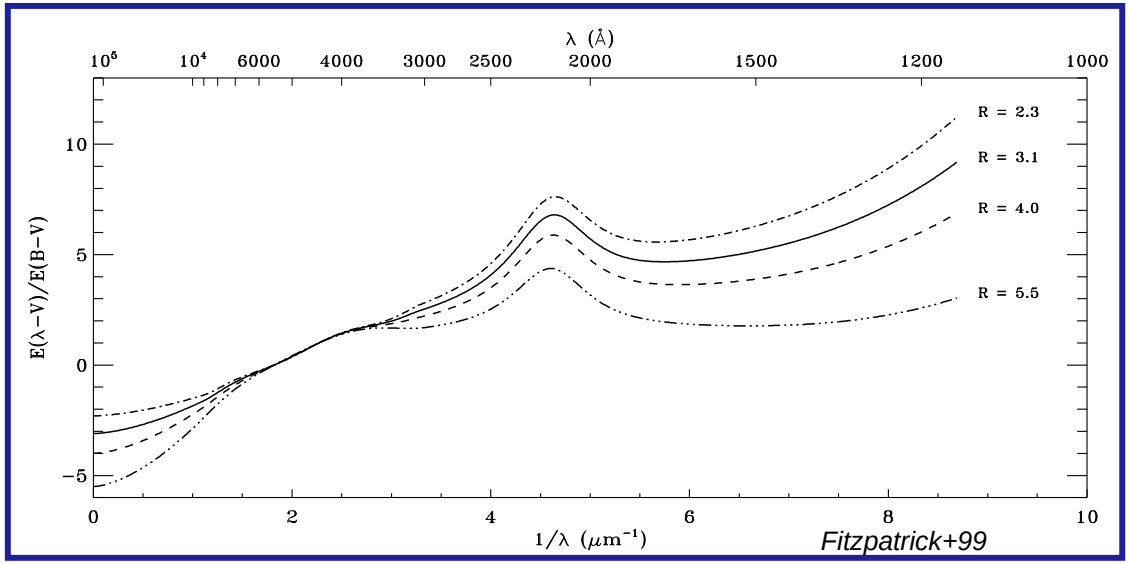
➔ Extinction is an important systematic

Reddening and extinction



This affects any astronomical observation!

Extinction/reddening law



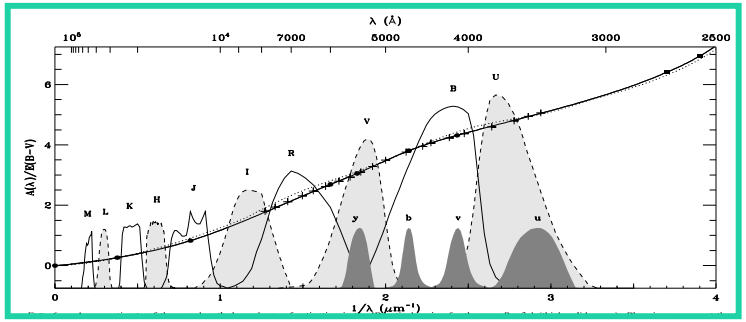
$$R \equiv A(V)/E(B-V)$$

Several parameterizations: Cardelli & O'Donnell (CCM), Fitzpatrick, etc.

In the Milky Way (MW) the average CCM measured from our position to other stars is

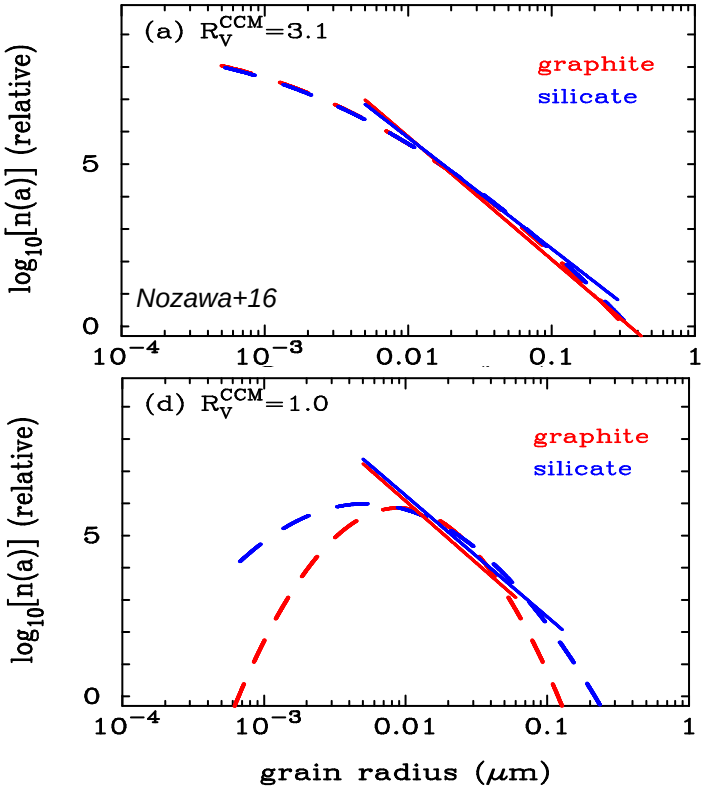
R=3.1 (2.5-5.5)

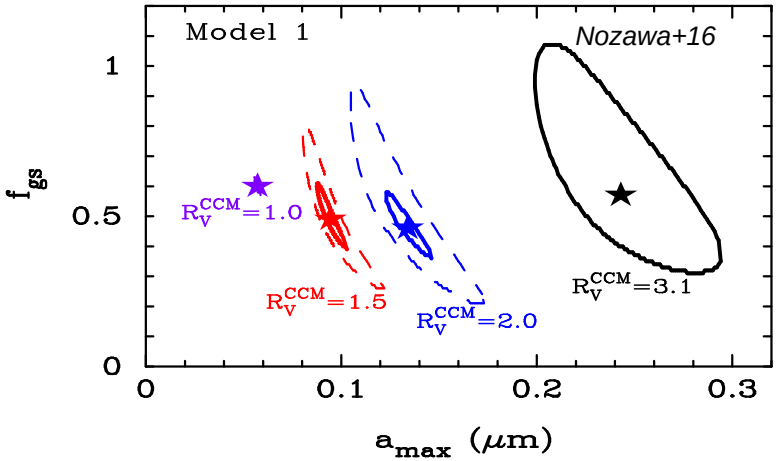
This value is generally assumed for other environments and galaxies.



Extinction law: dust properties

The extinction law is determined by physical properties like composition (graphite and silicate grains) and size distribution



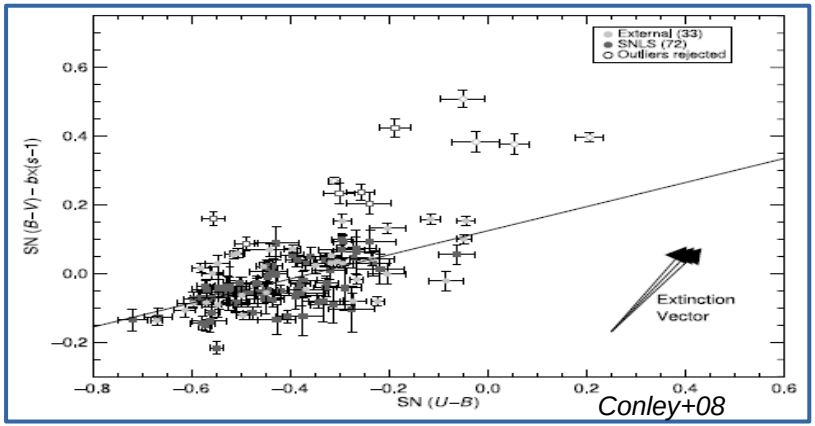


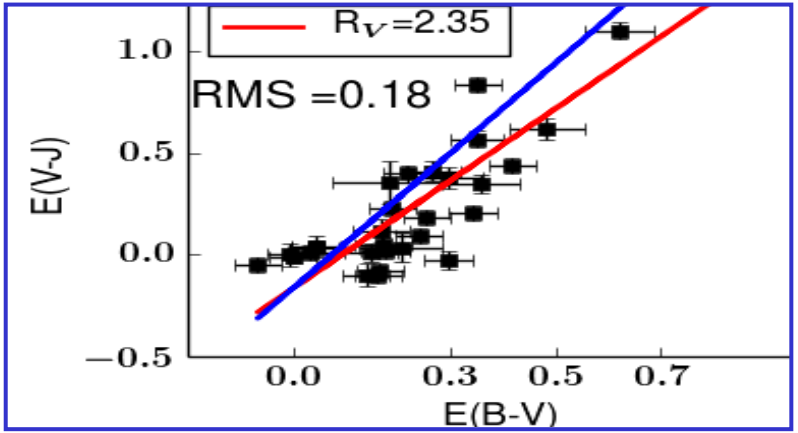
Smaller Rv is associated with smaller grain size!

Common SN color laws

$$\mu = m_B^{\star} - (M_B - \alpha \times X_1 + \beta \times C)$$

If β is assumed to be a general description of the reddening law, then the inferred extinction law is not common: R~2 for SNe Ia and for SNe II

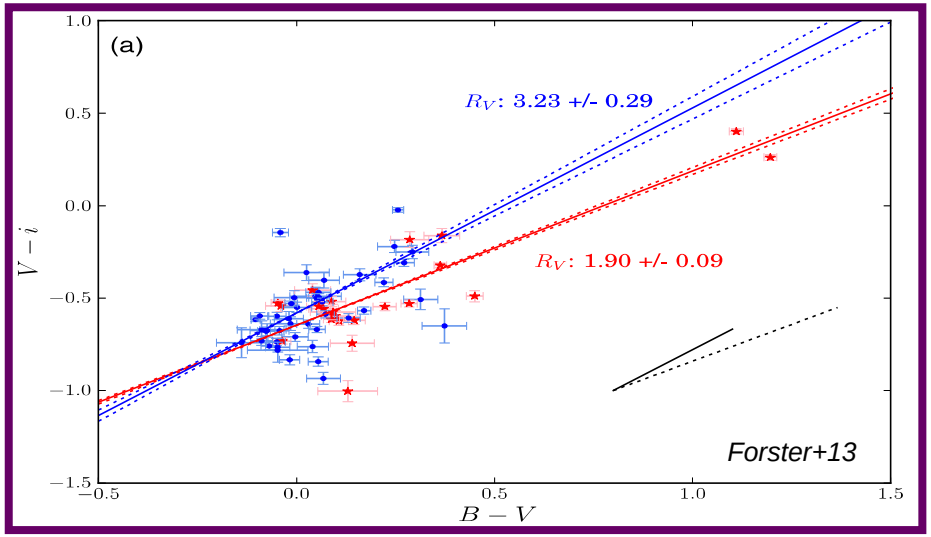


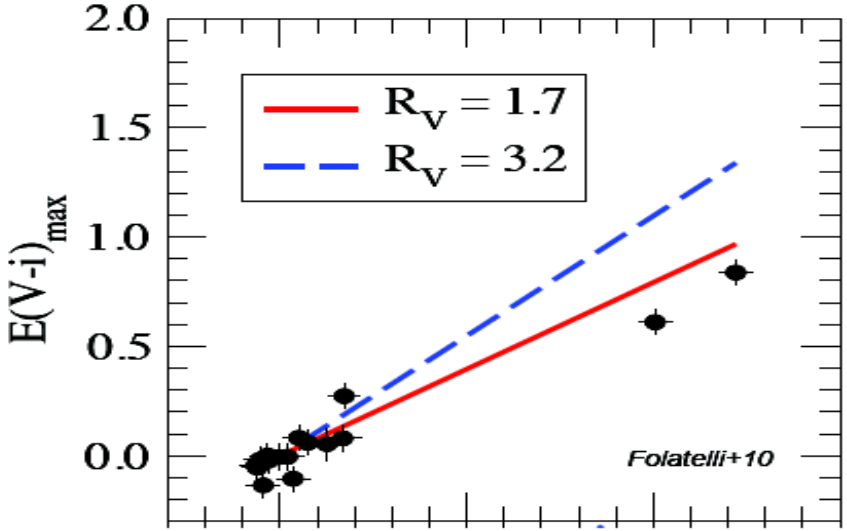


The magnitude-color relation of SNe in reality comes probably from two effects:

1) **intrinsic (temperature, ionization evolution)**
2) **extrinsic (dust in the ISM)**

Multiple SN color laws



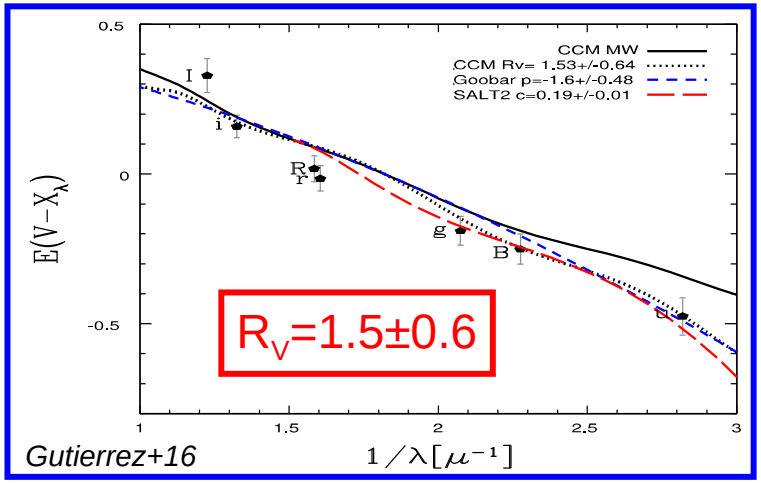


Although properly modeling colors reveals that most SNe are consistent with a normal Rv=3.1 reddening law (Chotard+11,Scolnic+14), there is diversity in SNe with different brightness-color relations.

«Either SN intrinsic colors are more complicated that can be described with a single light-curve shape parameter or dust around SN is very unusual»

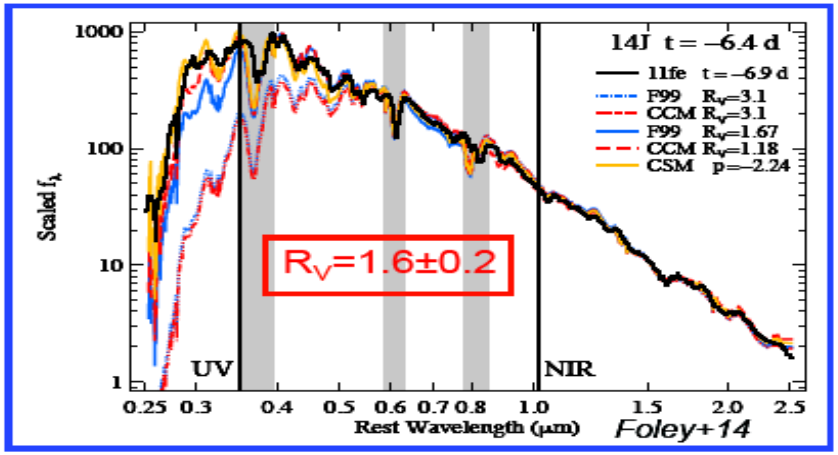
Conley+07

Individual SN color laws

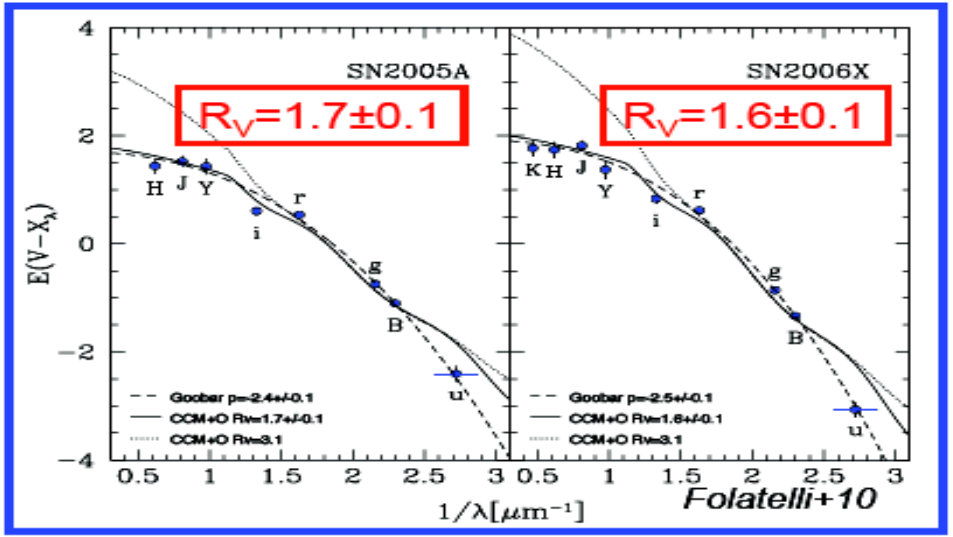


Gutierrez+16

Extremely peculiar extinction laws found towards some SNe!



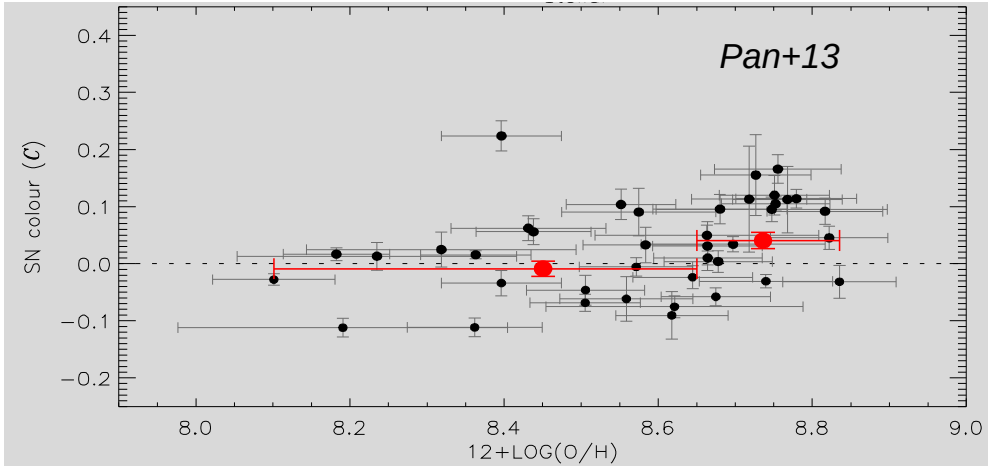
Foley+14

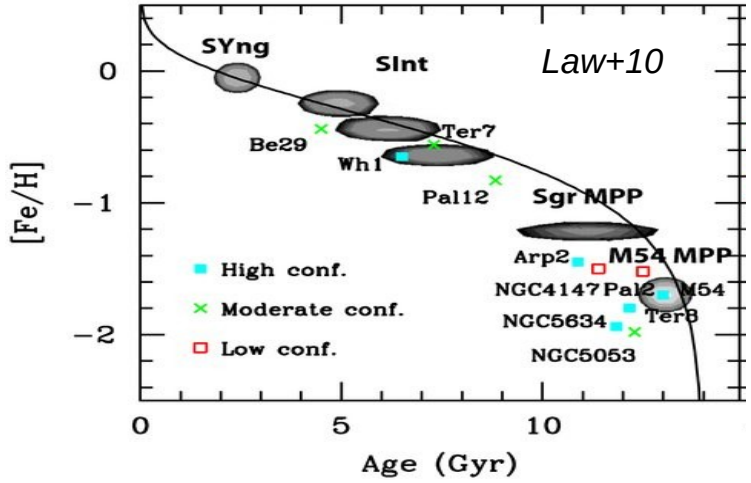


Folatelli+10

Effects on cosmology

Having multiple SN color laws affects cosmology, especially if there is a change of demographics with redshift





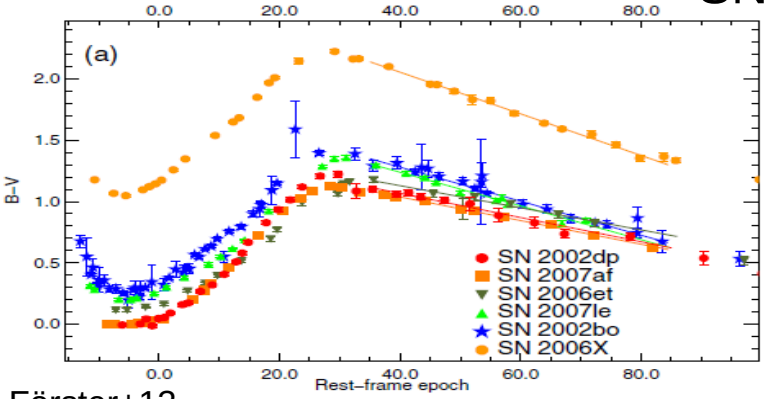
$$\mu = m_B^{\star} - (M_B - \alpha \times X_1 + \beta \times C)$$

evolves with time?

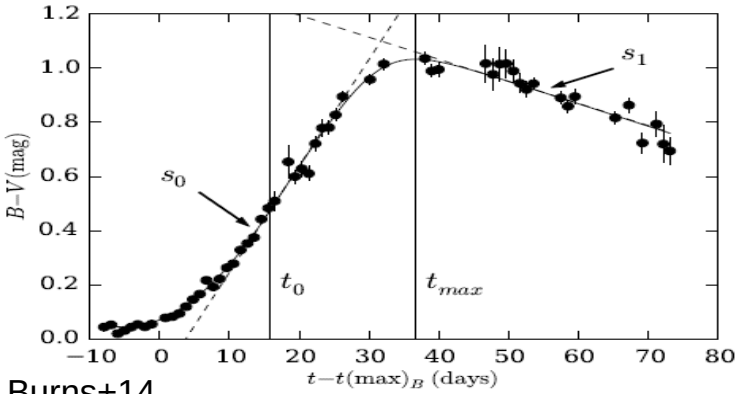
Methods

What to do? Find indivudal Rv?

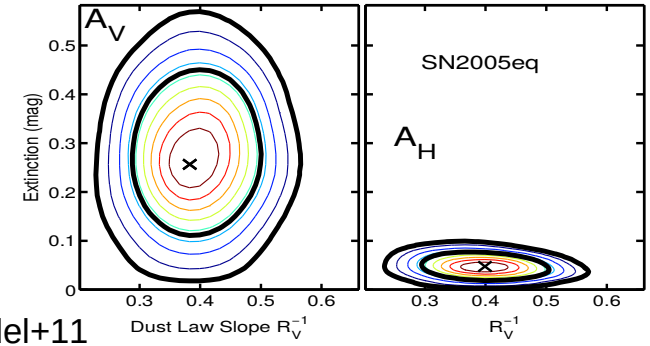
Fitters: Light-curve fitters based on color instead of brightness: CMAGIC, SNooPY2



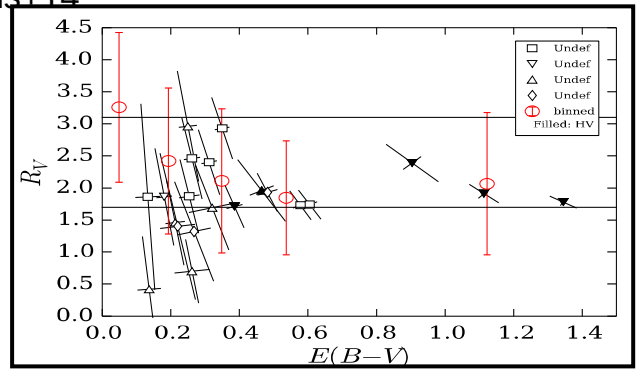
Förster+13



Burns+14

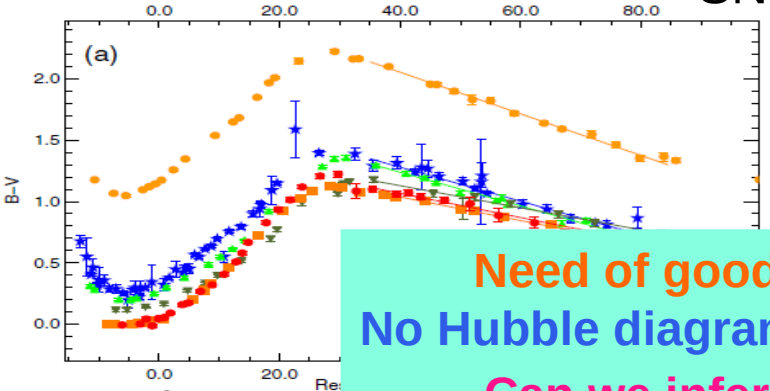


Mandel+11

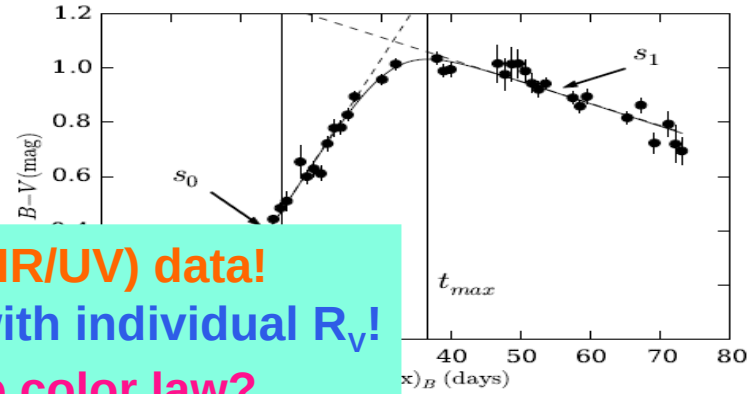


What to do? Find indivudal Rv?

Fitters: Light-curve fitters based on color instead of brightness: CMAGIC, SNooPY2



Förster+13

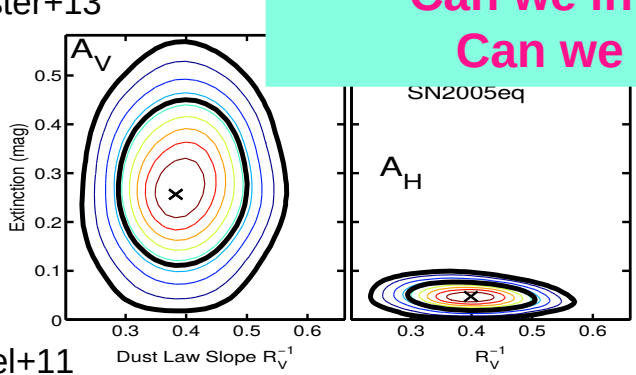


Need of good (NIR/UV) data!

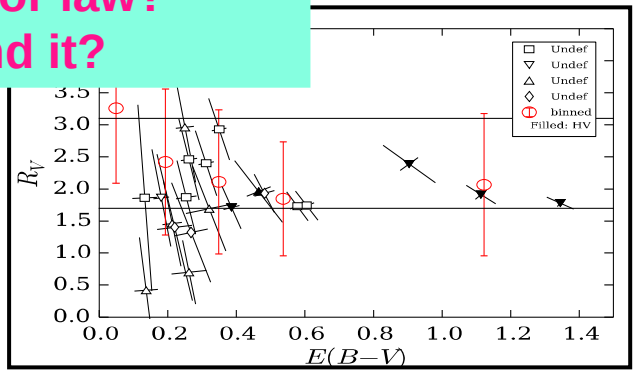
No Hubble diagram with individual R_V!

Can we infer the color law?

Can we understand it?

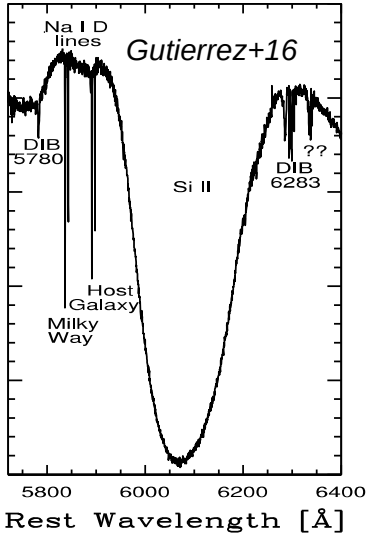


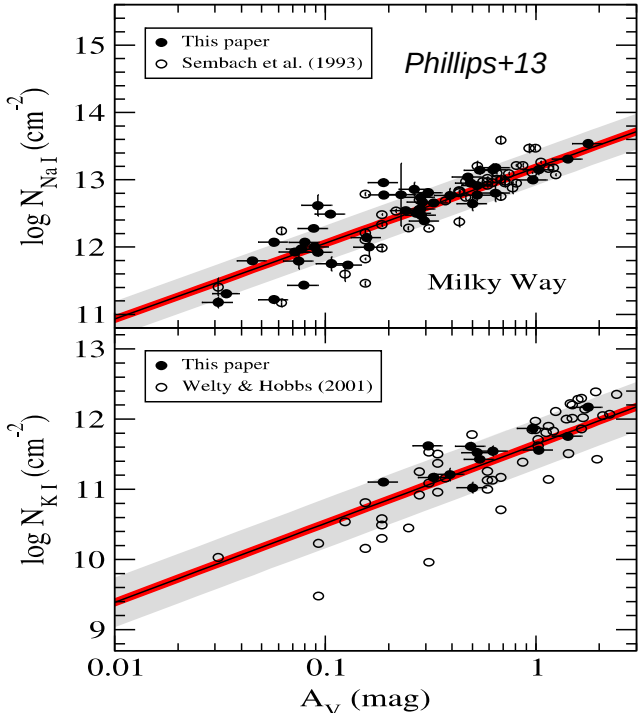
Mandel+11



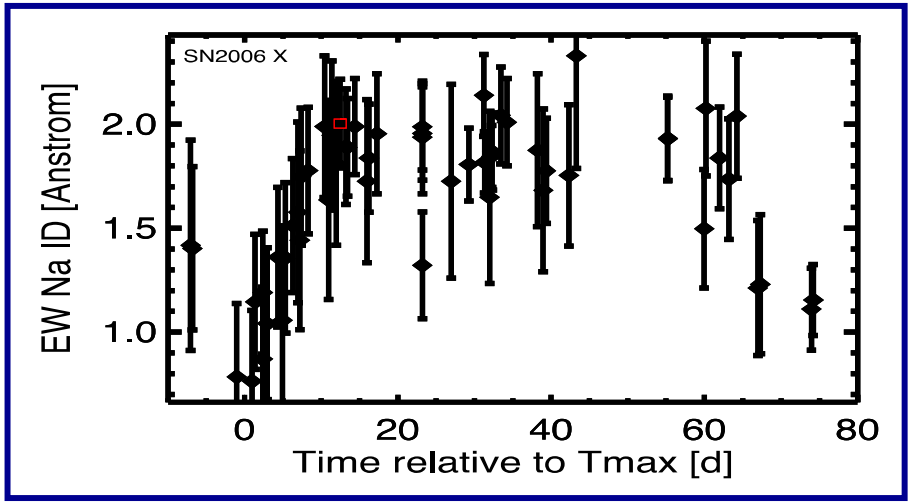
Other dust indicators

Other spectroscopic indicators of cold gas arise when the SN ionizes neutral atoms (like Na I D, Ca II H&K, DIBs) which later recombines and narrow absorption lines are seen.

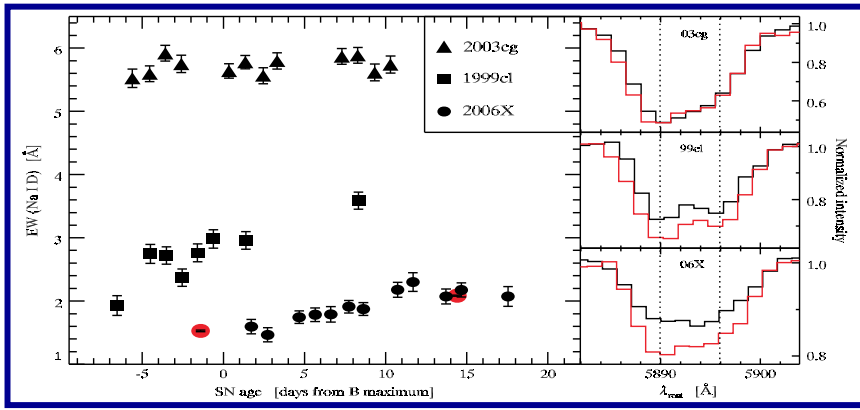




Also evolution!?

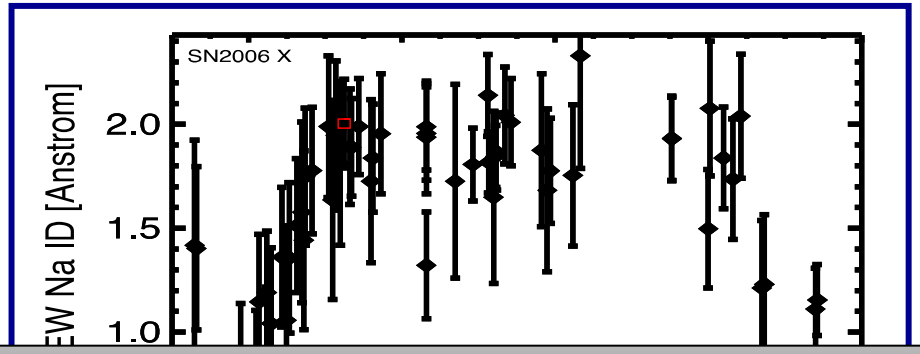


Some SNe have variability of their dust indicators!



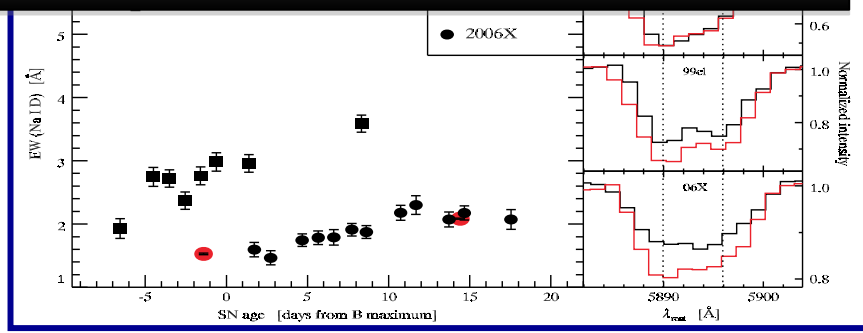
Blondin+09

Also evolution!?



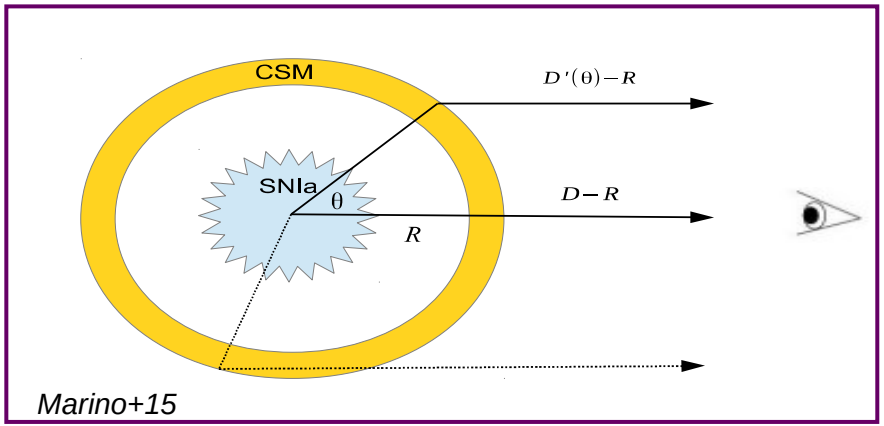
Some SNe have

Is there very nearby material, circumstellar material (CSM) near the SN?



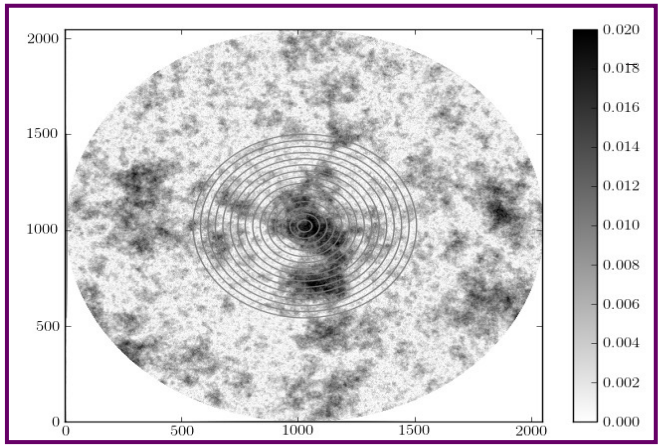
Blondin+09

CSM vs clumpy ISM



Marino+15

Multiple scattering or dust destruction from circumstellar material (CSM) (<1pc):
Can explain variations in Av, Rv and lines



Forster+13

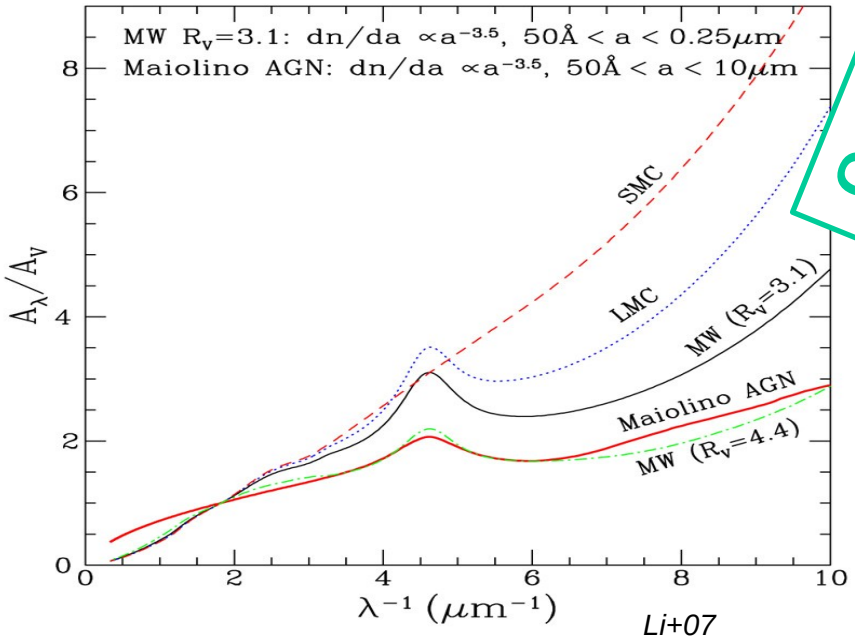
Inhomogeneous interstellar material (ISM) (>10pc):
Can explain variations in Av but cannot explain variation of Rv and lines

Another approach: host extinction

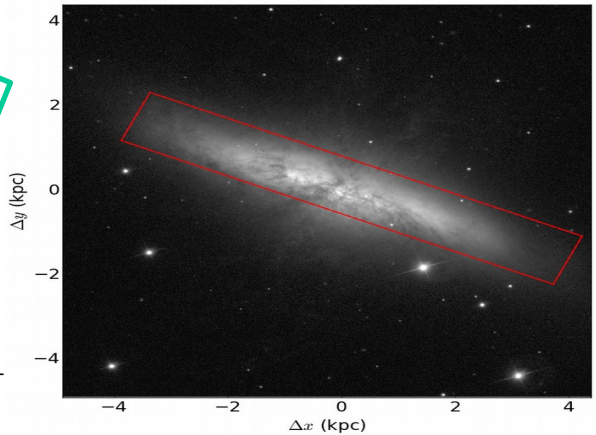
Can we measure extinction from the SN environment?

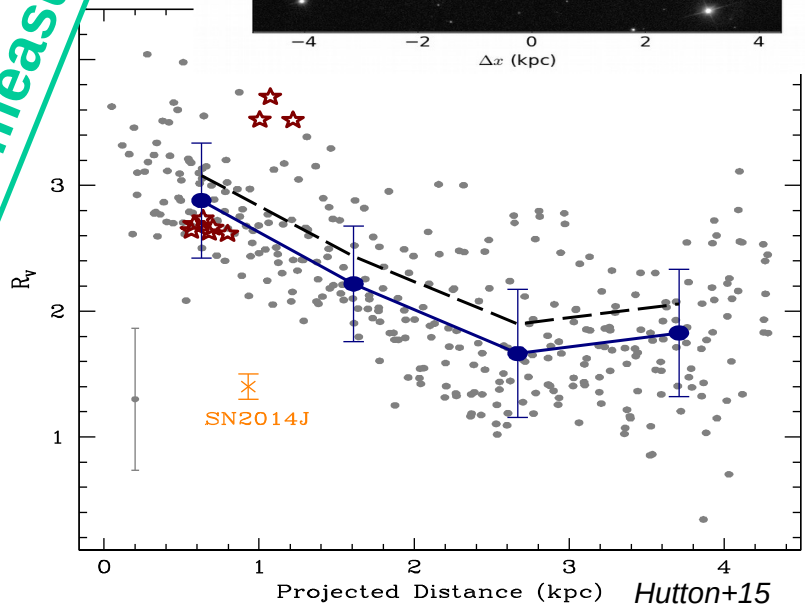
Normally only local extinction (Av) is measured b
a universal extinction law (Rv) is assumed, exc
for some parts of the MW, SMC and LMC.

Only SN local Rv measurement



Li+07

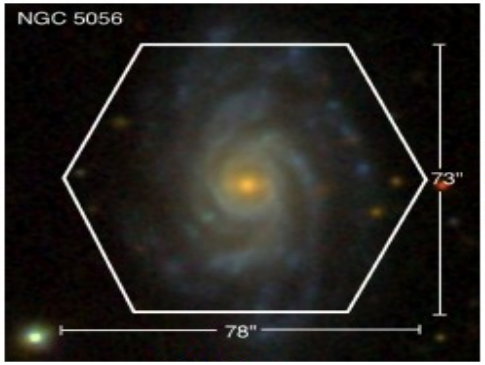


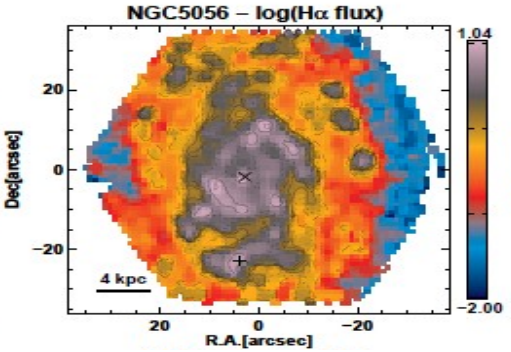


Hutton+15

Host extinction with CALIFA/AMUSING

Integral Field Unit (IFU) – images with spectra at each pixel – of 700+300 galaxies of CALIFA/MUSE:





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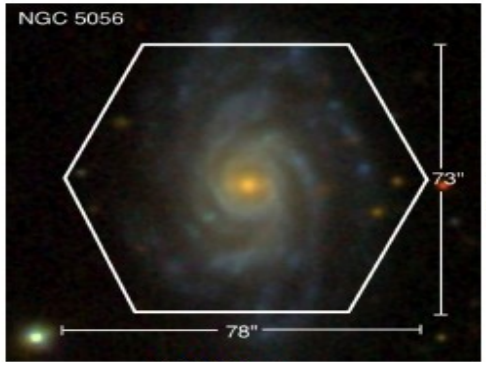
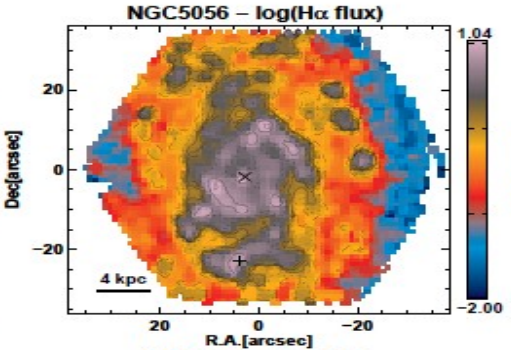
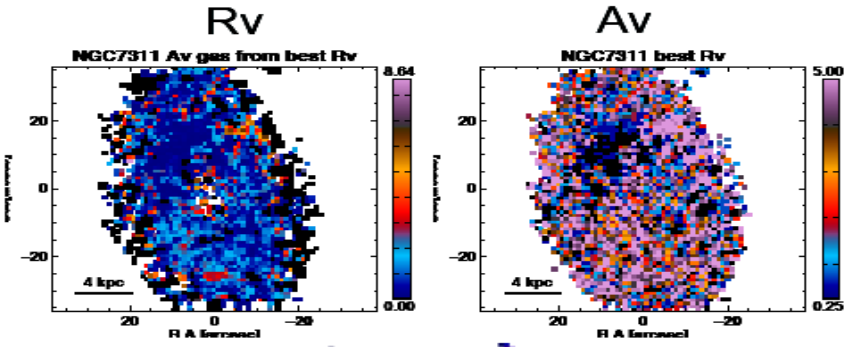




Host extinction with CALIFA/AMUSING

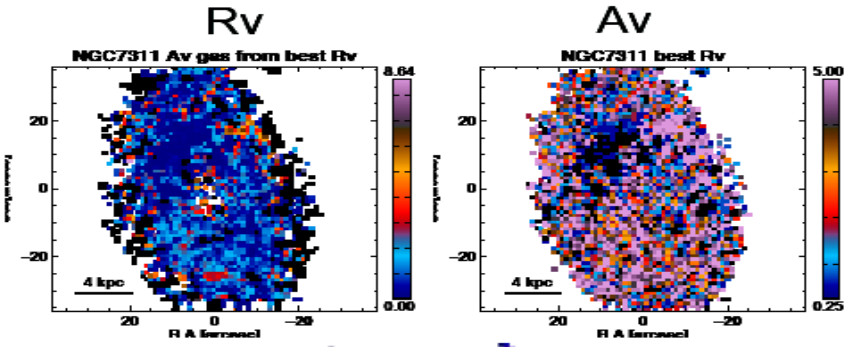
Fitting of SED with models to obtain Av,Rv at each position



Host extinction with CALIFA/AMUSING

Fitting of SED with models to obtain Av,Rv at each position


Alessandro Razza



Host extinction with CALIFA/AMUSING

Fitting of SED with models to obtain Av,Rv at each position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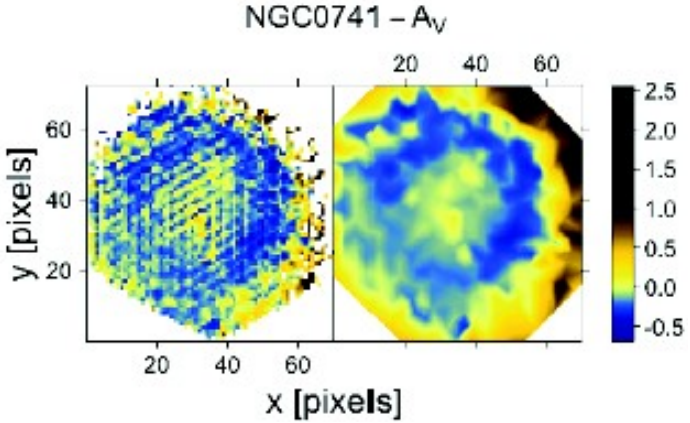
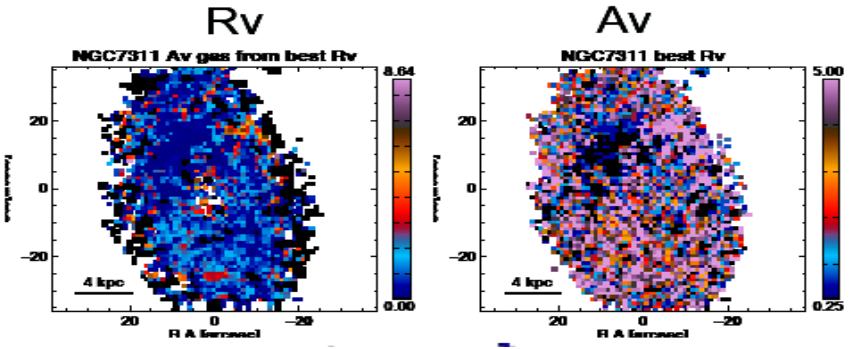


Develop an efficient fitting technique that takes spatial correlations into account: 1.5D fitting



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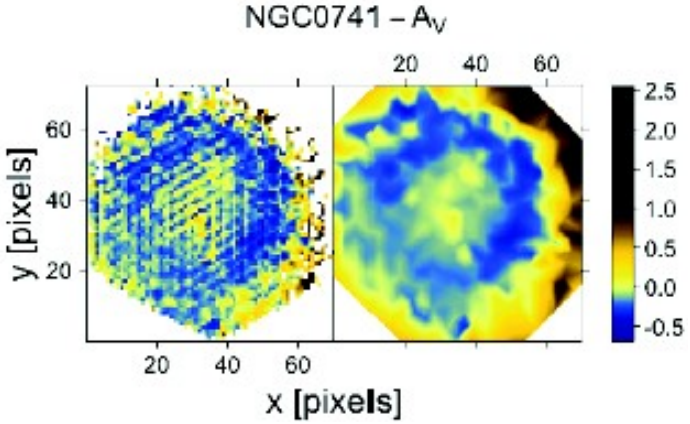
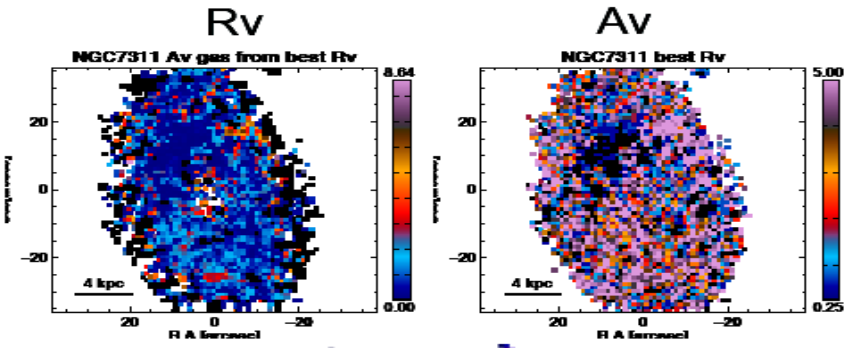




Develop an efficient fitting technique that takes spatial correlations into account: 1.5D fitting

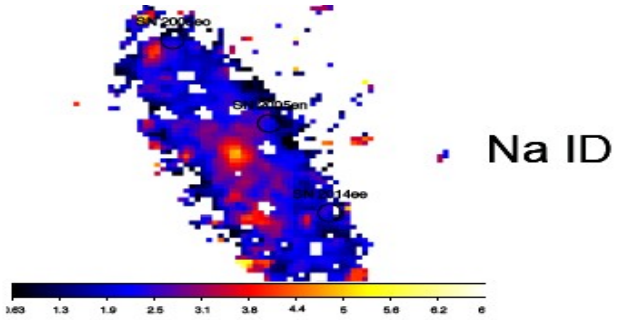
Santiago González

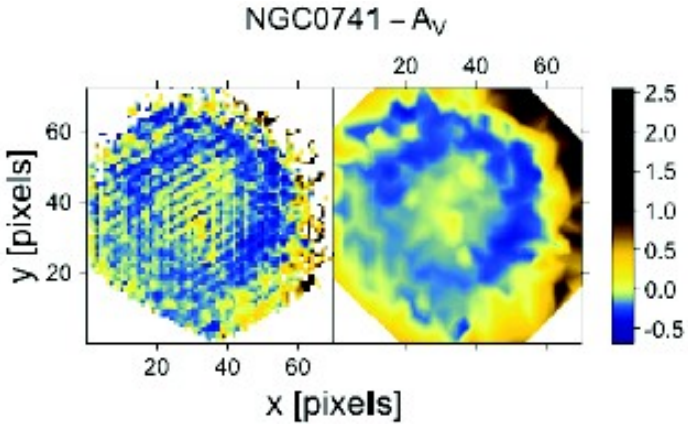
Alberto Krone-Martins

Pedro García

Host extinction with CALIFA/AMUSING

Investigate dust indicators in IFU like Na I D, K I, Balmer decrement





Develop an efficient fitting technique that takes spatial correlations into account: 1.5D fitting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Host extinction with CALIFA/AMUSING


Lluis Galbany

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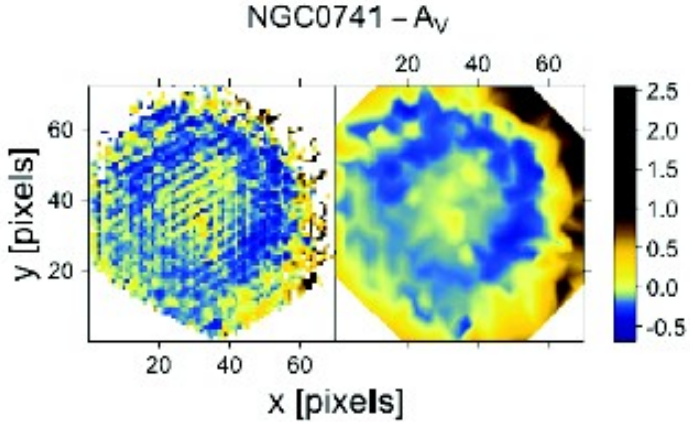

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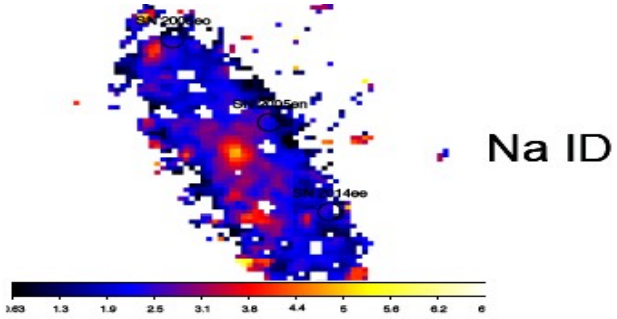


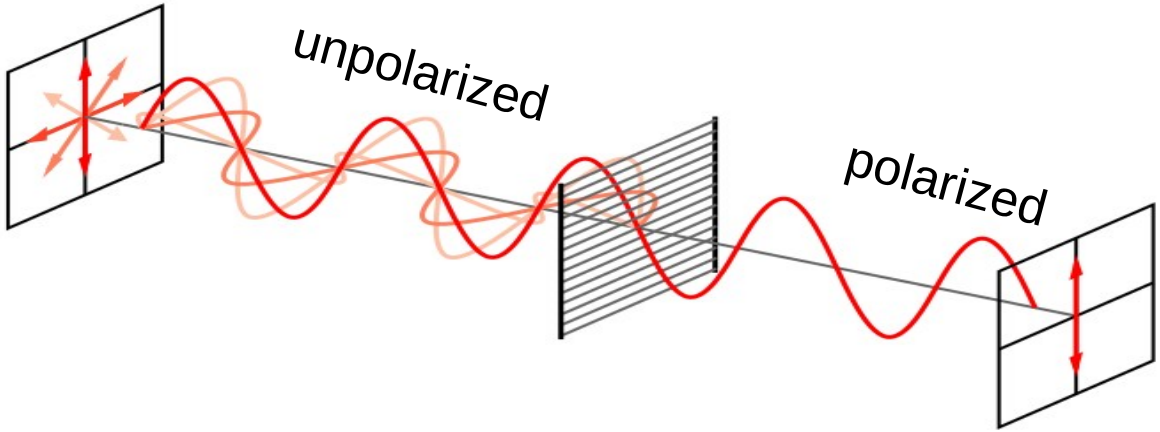

Santiago González


Alberto Krone-Martins


Pedro García

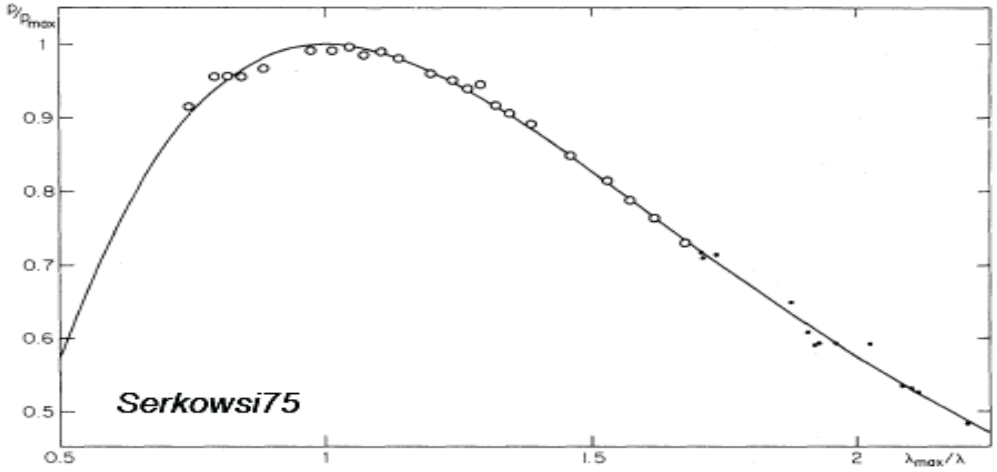
POLARIZATION

The measurement of differences in flux across different electric field orientations



SERKOWSKI LAW

Interstellar polarization of the MW: Maximum wavelength related to Rv and dust grain size.

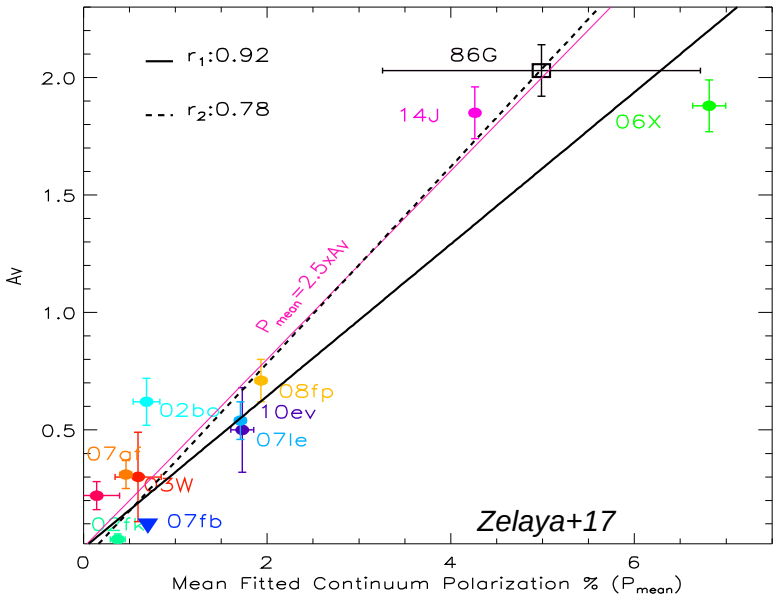


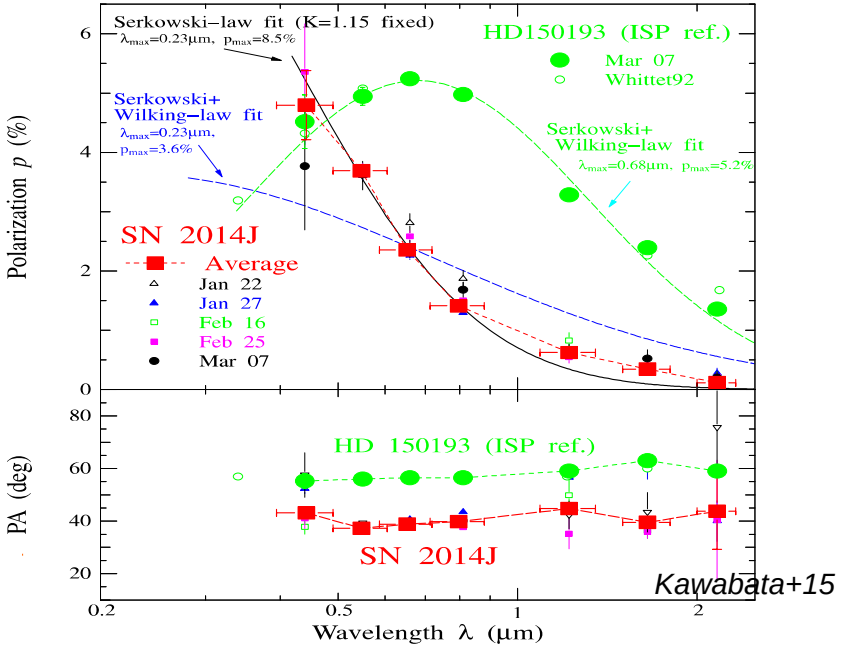
$$p(\lambda) = p_{max} \exp\left[-K \ln^2\left(\frac{\lambda_{max}}{\lambda}\right)\right]$$

$$R_V \simeq 3.67(\lambda_{max}/5500\mathring{A}) - 0.29$$

Polarization of SNe

- **Polarization degree related to extinction**
- **Highly extincted SNe have exotic Serkowski laws: low Rv!**





Not much data… and how about evolution?

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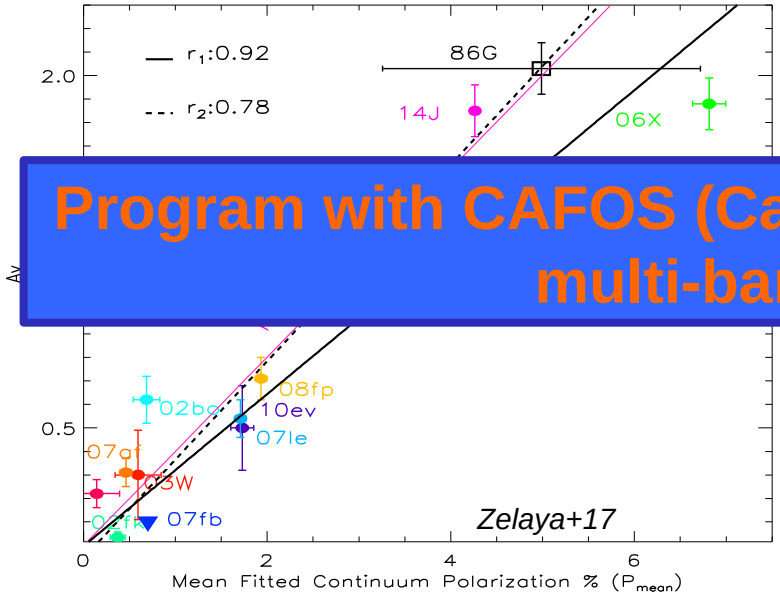
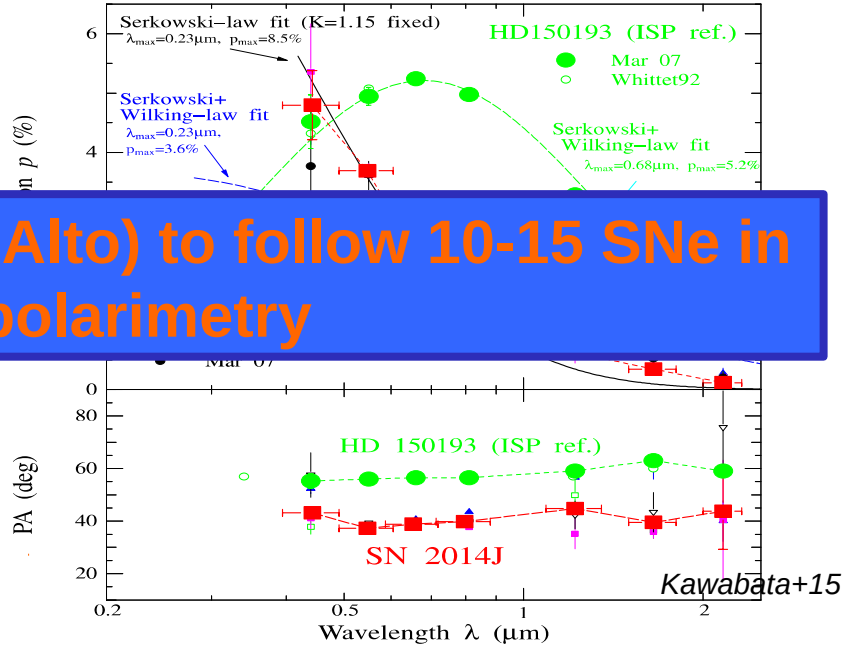


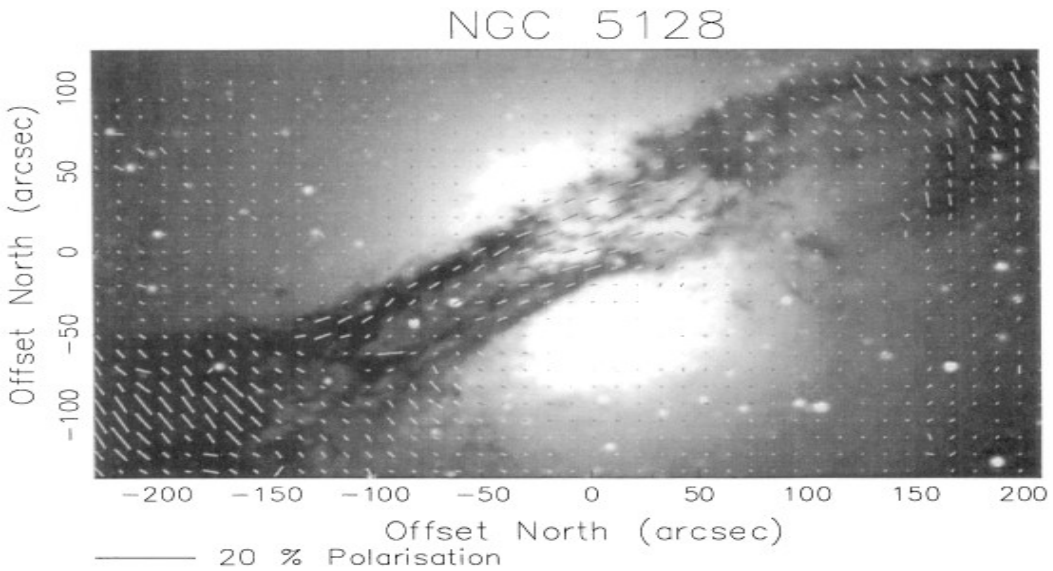


Program with CAFOS (Calar-Alto) to follow 10-15 SNe in multi-band polarimetry

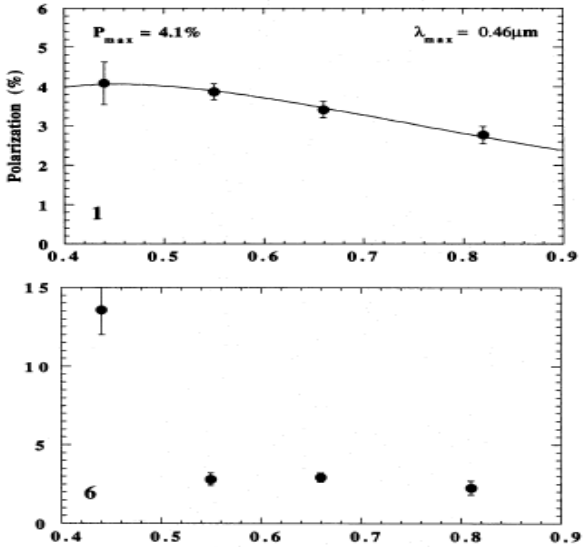
Not much data… and how about evolution?

Polarization of SN hosts

What about continuum polarization in galaxies?
→ very few studies!!



Scarrott+96



Varying Rv's and other things

How do values at SN position compare with SN measurements?

Santiago González

Polarization of SN hosts

Ana Mourão

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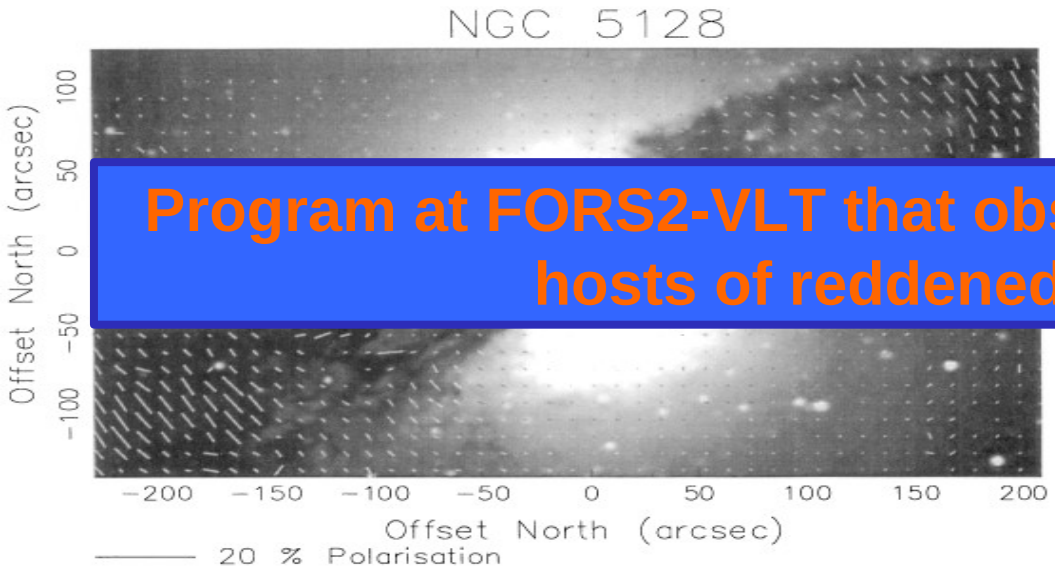
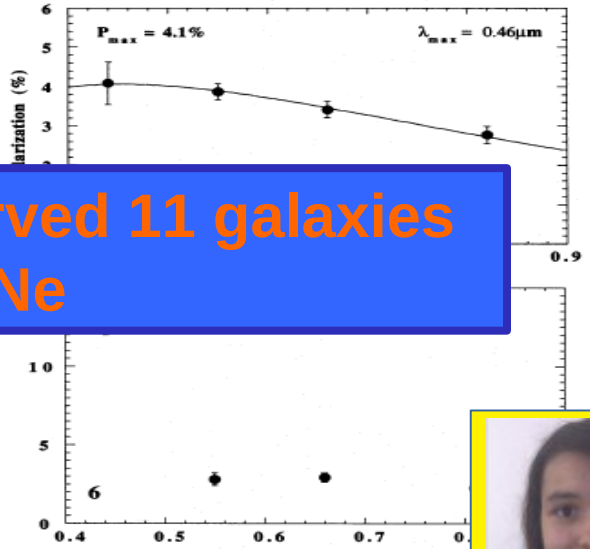


Program at FORS2-VLT that observed 11 galaxies hosts of reddened SNe



Varying Rv's and other t

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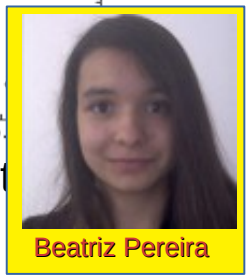
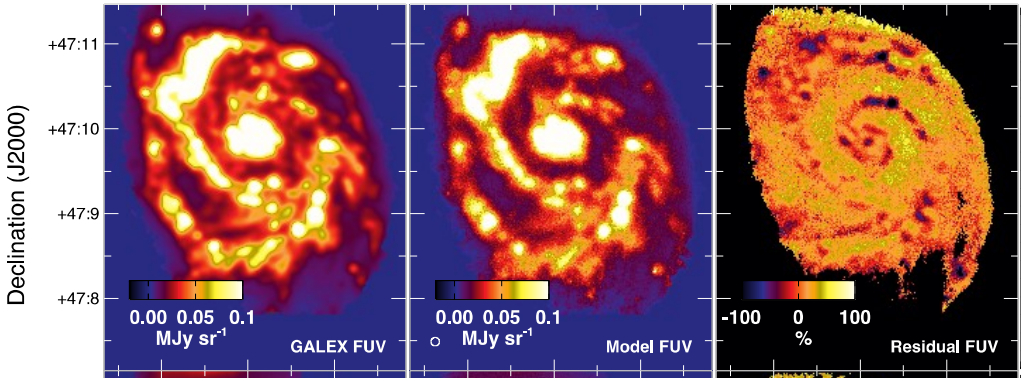


Beatriz Pereira

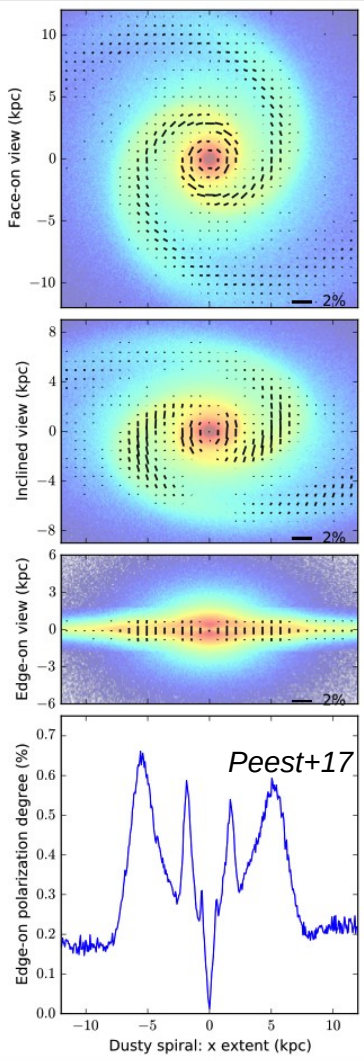
How do values at SN position compare with SN measurements?

Modeling of galaxies

- 3D Monte Carlo hydrodynamical radiative transfer codes
- Modeling of galaxy: brightness, temperature, Sérsic profile, number of spiral arms, etc.
- Modeling of dust composition, grain size distribution, mass and geometry
- Generate multi-wavelength maps of intensity and polarimetry



De Looze+14



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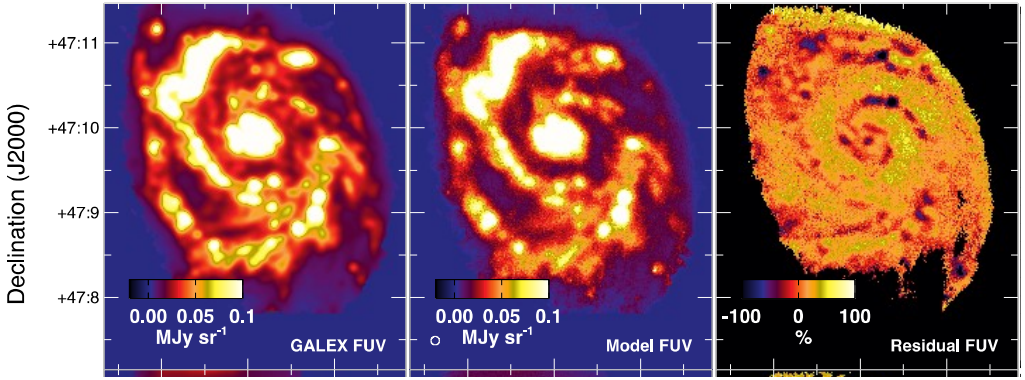

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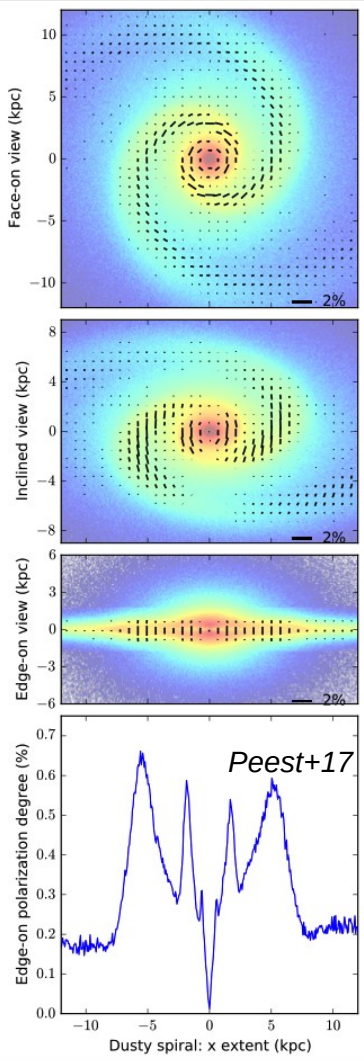
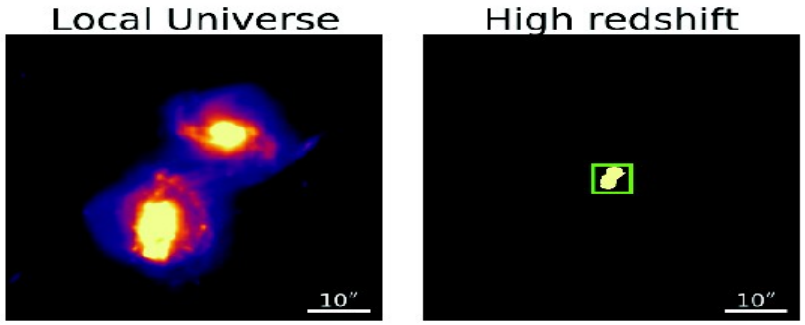
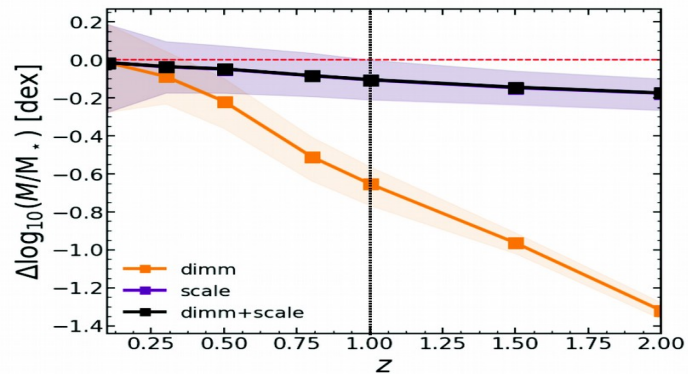


How do we extrapolate ot high-z?

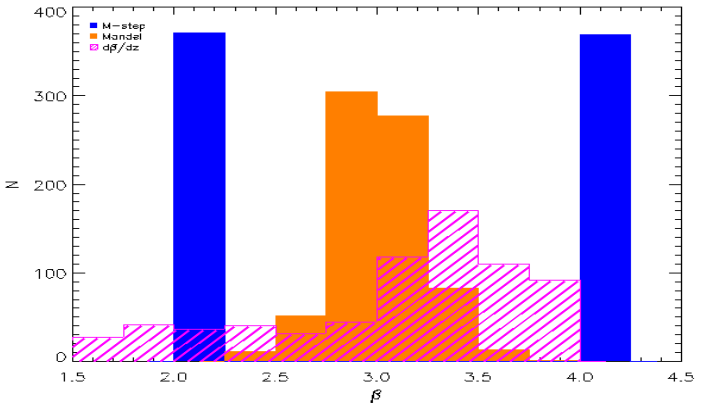
Artificial redshifting

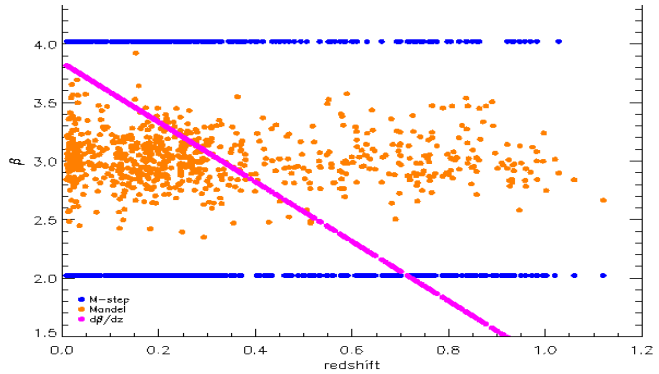




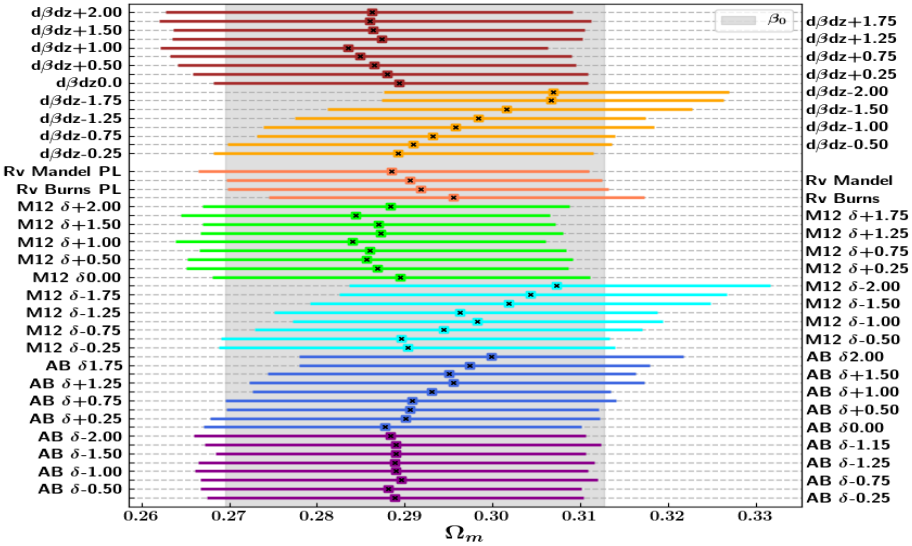
What are the effects on cosmology?

Having multiple SN color laws affects cosmology, especially if there is a change of demographics with redshift





$$\mu = m_B^{\star} - (M_B - \alpha \times X_1 + \beta \times C)$$



Thomas de Jaeger

Not large effects on cosmology BUT precision cosmology

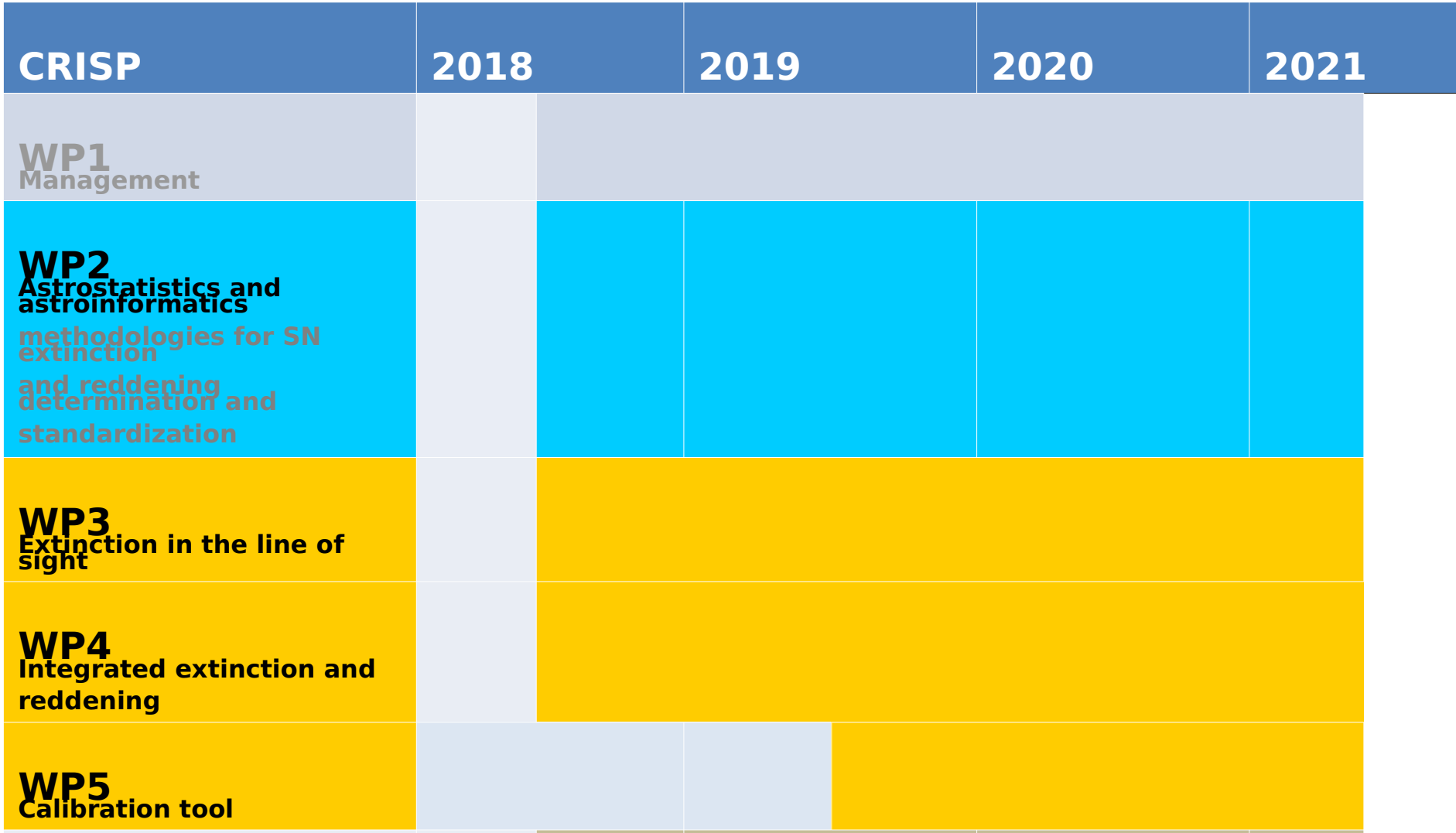
Summary

Supernova cosmology:

Type Ia are precise standard candles: systematic uncertainties are larger than statistical

Extinction:

- Reddening laws vary among SNe and cannot be assumed universal → affect cosmology
- Need to understand its origin: intrinsic, CSM and/or ISM
- Comprehensive effort to study SN and host reddening better than ever with SN/host photometry, spectroscopy and polarimetry ➔ vital in many fields!


CRISP
2018
2019
2020
2021
WP1
Management
WP2
Astrostatistics and astroinformatics
methodologies for SN extinction
and reddening
determination and
standardization
WP3
Extinction in the line of sight
WP4
Integrated extinction and reddening
WP5
Calibration tool

CRISP

TEAM:

Alberto Krone-Martins, co-PI, CENTRA, Ciências, ULisboa
Alessandro Razza (3,4)
Ana Afonso (1)
Ana Mourão, PI, CENTRA, Instituto Superior Técnico, ULisboa
Beatriz Dos Santos Pereira (1)
Francisco Förster (3)
João Silvestre (1)
Myriam Rodrigues (5)
Pedro Guilherme Garcia (2)
Santiago González-Gaitán (1)

(1) CENTRA, Instituto Superior Técnico, ULisboa
(2) CENTRA, Fac Ciências, Ulisboa
(3) Univ. Chile, Santiago de Chile
(4) ESO Chile
(5) Observatoire Paris-Meudon

CRISP

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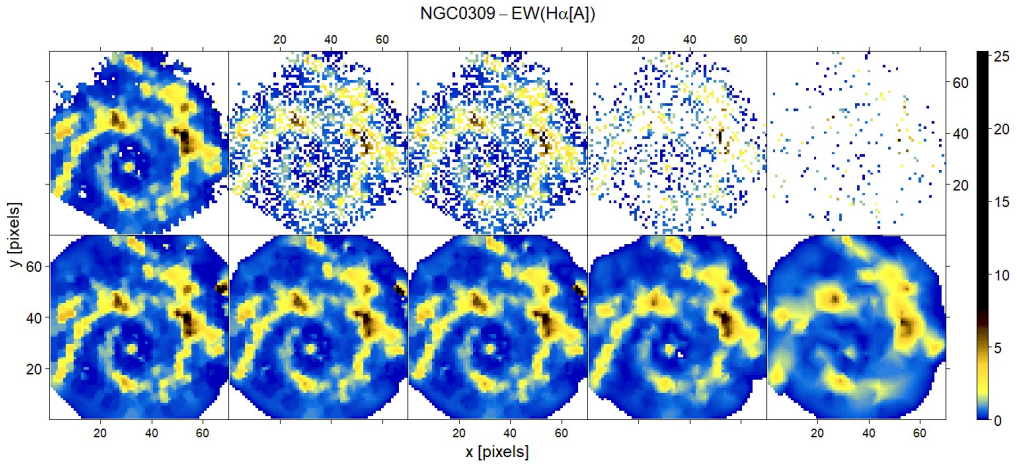
LARGE TEAM:

Lluis Galbany, UGR
Claudia Gutiérrez, Southampton
Thomas de Jaeger, UC Berkley
Joseph Anderson, ESO

Marko Stalevski, Belgrade Observatory

Antonia Morales Garoffolo, Univ Cadiz

CRISP: RESULTS in ASTROSTATISTICS



INLA

Statistical methods in astrophysics to infer/map the properties of galaxies
MNRAS, 2029 (Here: Gonzalez-Gaitan, Krone-Martins, Galbany) +
+ Silvestre, Garcia

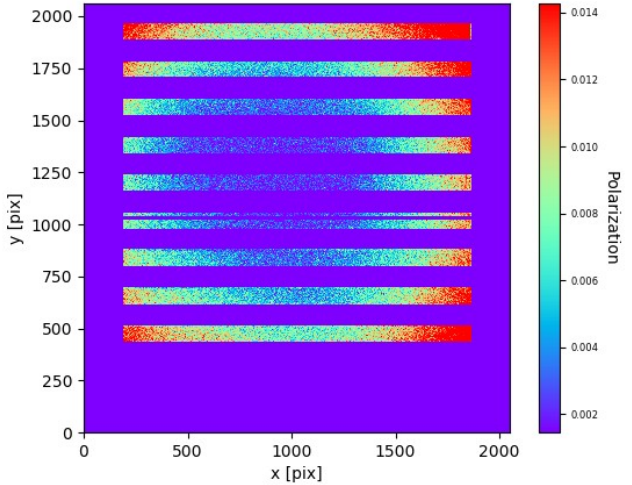
CRISP: RESULTS in HOST GALAXY STUDIES

Getting closer to the progenitor of SN 2016hnk

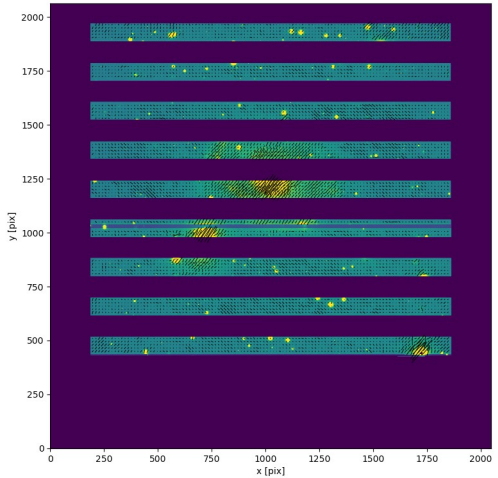
With Photometry+Spectroscopy+IFS

Galbany et al, with Gonzalez-Gaitan and Gutierez

CRISP: RESULTS in POLARIMETRIC STUDIES



Understand the FORS2 VLT



Goal: infer dust properties
from polarization data

Gonzalez-Gaitan, Mourão, Patat et al A&A 2020

CRISP: in PROGRESS

SN host properties and implications: local versus global

The “mass step” calibration *versus*
Can we trust the galaxy masses

By Ana Paulino-Afonso

CRISP

NEW OBSERVING PROJECTS:

Antonia Morales Garoffolo: Calar Alto, SN polarimetric evolution,
7 nights (April-June, to discuss implementation)

Santiago GG: FORS2-VLT Calibration of the moon background
In polarimetric studies (2 nights in June)

PI Cikota with Mourão, Gonzalez-Gaitan: calibration of the FORS2-VLT