SN Polarization with CAFOS

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UCA
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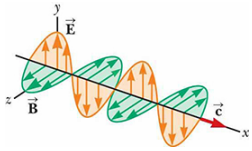
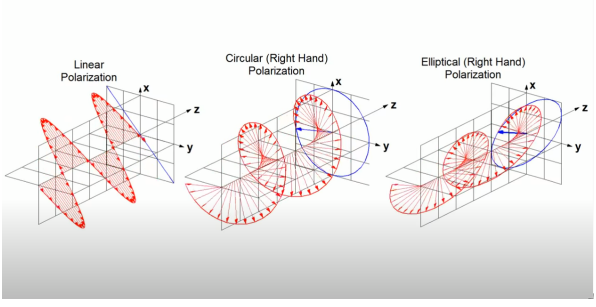
CRISP meeting

Peniche (we wish!), July 2020

Outline

1. Introduction
   - Polarization
   - Continuum Linear Polarimetry Mechanisms in Supernovae
2. Our project at CAHA
   - SN Imaging polarimetry with CAFOS
   - Future Prospects





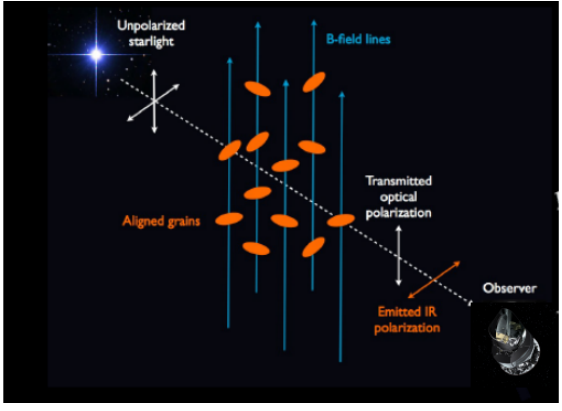
- Polarization State $\Longrightarrow$ I,Q,U,V
- Linear polarization degree and angle:

$$P = \frac{\sqrt{Q^2 + U^2}}{I} \equiv \sqrt{\bar{Q}^2 + \bar{U}^2},$$

$$\chi = \frac{1}{2} \arctan \frac{U}{Q},$$

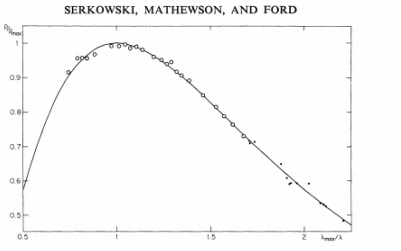
1. **Selective absorption** by interstellar non spherical dust grains
2. **Scattering** due to circumstellar material
3. Electron **scattering** in aspherical photospheres

1. Selective absorption by interstellar non spherical dust grains



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

- p_{max} is the peak degree of polarization
- λ_{max} is the wavelength of peak polarization
- K is a constant that depends on the width of the curve



1. Selective absorption by interstellar non spherical dust grains

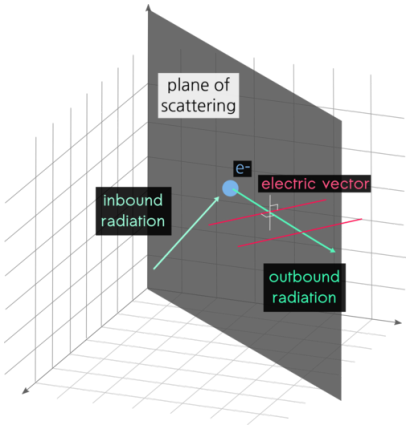
- λ_{max} depends on dust size
  - Smaller dust grains, shorter λ_{max}
  - Larger dust grains, longer λ_{max}

$\Longrightarrow$ **grain size distribution**

- $R_V = A_V/E(B-V) \approx 5.5\lambda_{max}$

$\Longrightarrow$ **extinction in the line of sight**

2. Scattering due to circumstellar material



$$p(\lambda) = c_R \lambda^{-4}$$

3. Electron scattering in aspherical photospheres

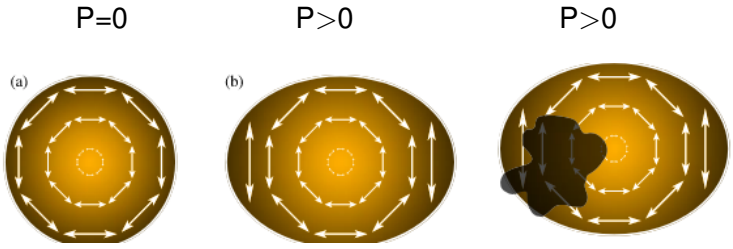


Figure: Cikota et al. 2019

$\Longrightarrow$ **asphericities**

Our SN polarimetry project at Calar Alto Observatory

Motivation

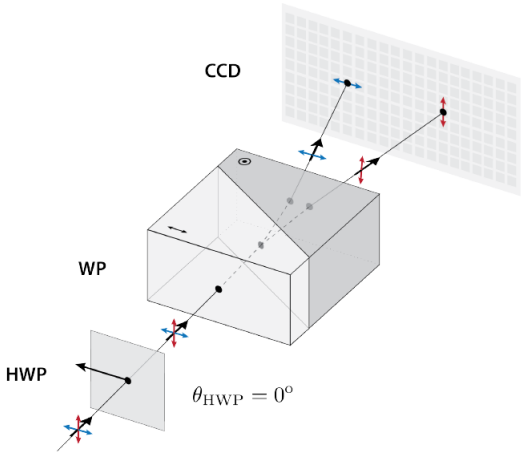
The POWER of SN polarimetry:

- Material in the line of sight
- Asphericities

Calar Alto

- @ the 2.2 m telescope CAFOS $\longrightarrow$ POLARIMETRY

How do we measure continuum polarization?



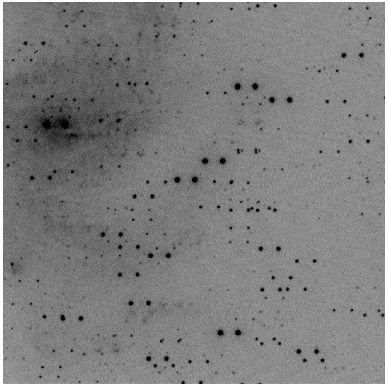


Figure: González-Gaitán et al., A&A 634, A70 (2020)

First Proposal: Autumm 2017

1. Telescope: 2.2-m [X] 3.5-m [ ]

2.1 Applicant	Dr. M. E. **Moreno-Raya**	CAHA
	Name	Institute
	Observatorio Astronómico Calar Alto	04550 Gergal (Almería)
	street	ZIP code - city
	Spain	mmoreno@caha.es
	country	e-mail
2.2 Collaborators	S. González-Gaitán, L. Galbany	U. Lisboa, U. Pitt
	name(s)	institute(s)
	M. Mollá, J. L. Prieto, J. M. Vílchez	CIEMAT, U. Diego Portales, IAA
	name(s)	institute(s)
2.3 Observers	M. E. Moreno-Raya	S. González-Gaitán
	name	name

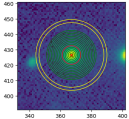
CAHA points out that by specifying the names under item 2.3 it is obligatory to also send out these observers to Calar Alto. Correspondence on the rating of this application will be sent to the applicant (P.I.) as quoted under 2.1 above.

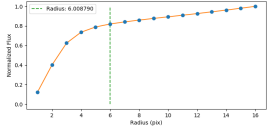
3. Observing programme and method: Category: [E]

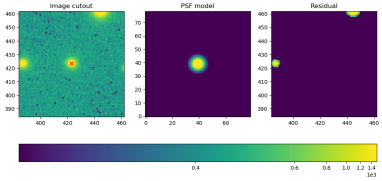
Title : **Revealing supernova explosions asymmetries and intervening dust with imaging linear polarimetry**

First Proposal: Autumn 2017

- 12 SNe observed
- Reduction Pipeline by Santiago
  - Bias
  - Flat
  - Aperture and PSF SN Photometry on ordinary and extraordinary beams
  - Interstellar polarization correction on Stoke parameters
  - *P* (Pol degree), χ (Pol angle)

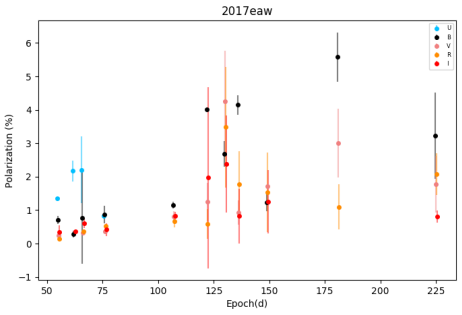


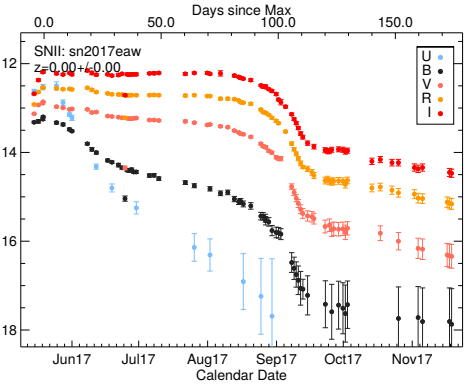




First Proposal: Autumm 2017

- An example: Type IIP SN 2017eaw (work in progress)



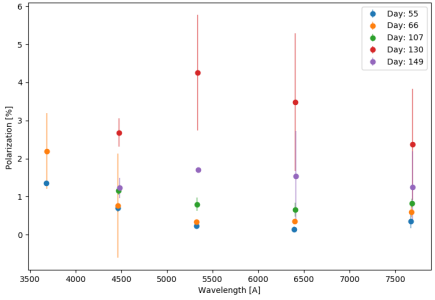


- SN 2017eaw: Polarization increase after plateau $\longrightarrow$ asphericities.

Figure: From Tsvetkov et al. 2018

First Proposal: Autumm 2017

- SN 2017eaw Serkowski curves:



- Early$\longrightarrow$blue λ_{max} smaller dust (CSM?)
- Late$\longrightarrow$red λ_{max} (asphericities)

Second Proposal: Spring 2020 (ongoing)

1. Telescope: 2.2-m [X] 3.5-m [ ] H17-2.2-023 [C]

2.1 Applicant

Antonia Morales-Garoffolo	University of Cádiz
Name	Institute
Department of Applied Physics	11510 Puerto Real (Cádiz)
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Spain	antonia.morales@uca.es
country	e-mail

2.2 Collaborators S. González-Gaitán, A. Mourao, J. Silvestre — Instituto Superior Técnico Lisboa (1)
name(s) institute(s)

L. Galbany, I. Domínguez — University of Granada
name(s) institute(s)

2.3 Observers L. Galbany, S.González-Gaitán, A. Morales-Garoffolo, J. Silvestre, MSc/PhD students
name name

CAHA points out that by specifying the names under item 2.3 it is obligatory to also send out these observers to Calar Alto. Correspondence on the rating of this application will be sent to the applicant (P.I.) as quoted under 2.1 above.

3. Observing programme and method: Category: [E]

Title : **Exploring Supernova explosion asymmetries and line of sight dust through imaging linear polarimetry**

Second Proposal: Spring 2020 (ongoing)

Date	Observer 1	Observer 2
April 7 (0.5N)	(CANCELLED)	(CANCELLED)
April 16(0.75N)	(CANCELLED)	(CANCELLED)
April 28 (0.75N)	(CANCELLED)	(CANCELLED)
May 5 (0.5N)	(CANCELLED)	(CANCELLED)
May 13 (0.75N. Last 3/4)	BAD WEATHER	BAD WEATHER
May 25 (0.75N. Last 3/4)	BAD WEATHER	BAD WEATHER
May 25-26 (PMAS)	BAD WEATHER	BAD WEATHER
June 1 (0.75N)	EXTRA	EXTRA
June 9 (0.5N)	service	service
June 18 (0.75N)	BAD WEATHER	BAD WEATHER
July 17 (1N)	service	service
July 27 (1N)	service	service
August 14 (0.5N)	service	service

CANDIDATE SELECTION:
Transient Name Server: https://wis-tns.weizmann.ac.il/search
Alerce ZTF: https://alerce.online/ y https://snhunter.alerce.online/
PESSTO Marshal: http://www.pessto.org/marshall/

Second Proposal: Spring 2020 (ongoing)

Increase precision in our polarization measurements

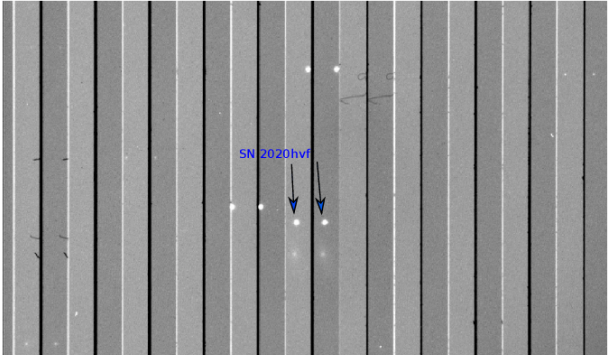
- Mask.
- Increase exposure times.

$$\sigma_P = \frac{1}{\sqrt{N/2}(\mathrm{S/N})}$$

- Bright objects: $\sigma_P = 0.001 \Longrightarrow \frac{S}{N} \sim 700$
- Faint objects : $\sigma_P = 0.006 \Longrightarrow \frac{S}{N} \sim 200$

Second Proposal: Spring 2020 ongoing

- To achieve the S/N desired we compared the S/N measured with the pipeline and the CAFOS exposure calc and compared.
- We found $\sim$ constant differences in each filter.
- We correct the exposure times given by the calc by taking into account those differences.



- Finish the analysis on SN 2017eaw and publish our results + amateur phot.
- 3 runs left within our current proposal.
- We have applied for more time in the Fall semester (fingers crossed!).

Thank you!!