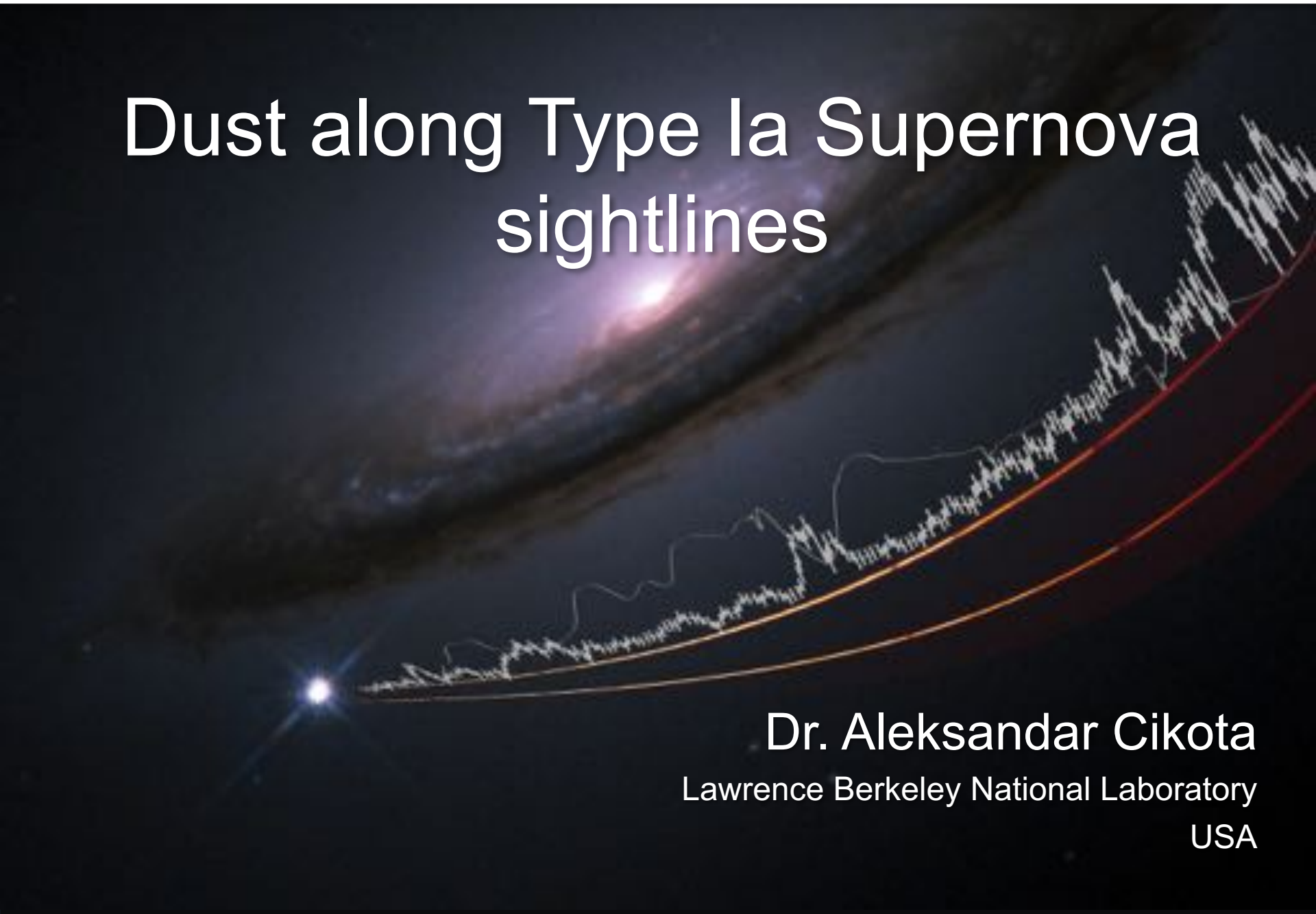
Dust along Type Ia Supernova sightlines



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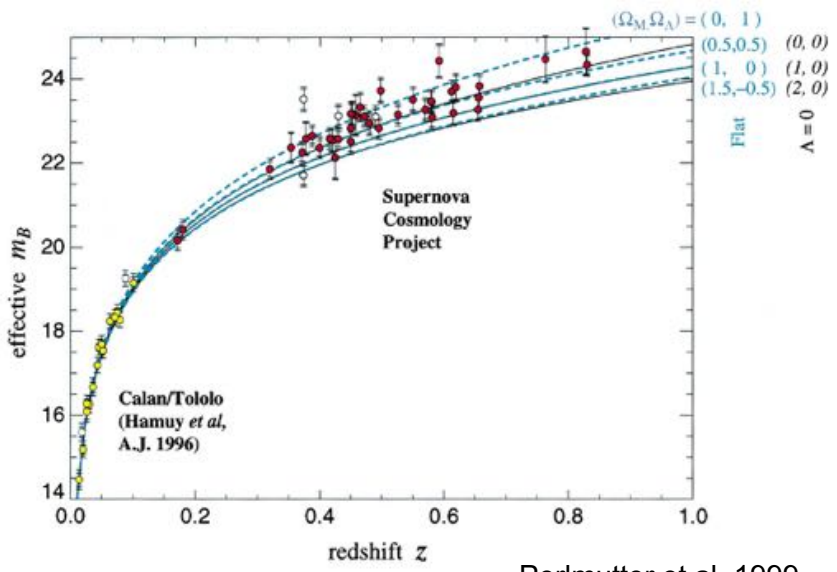
USA

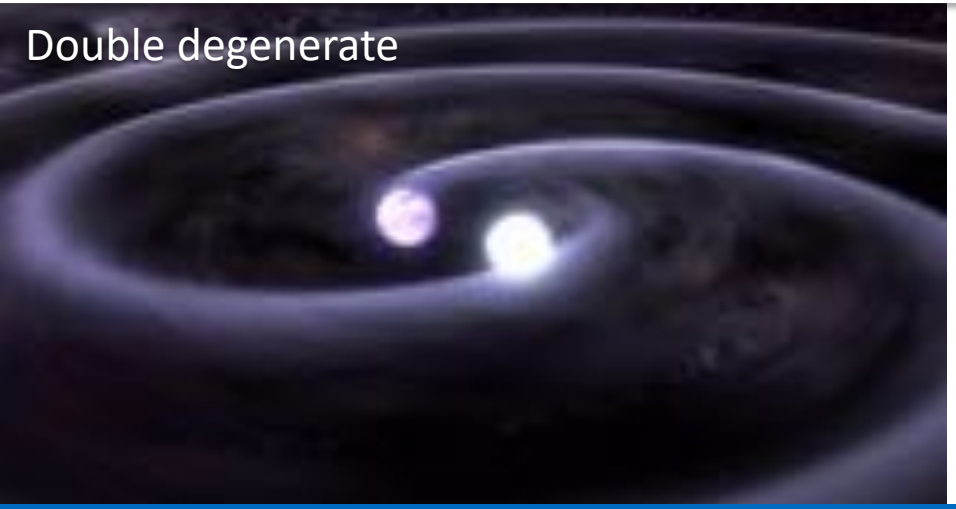
Type Ia Supernovae

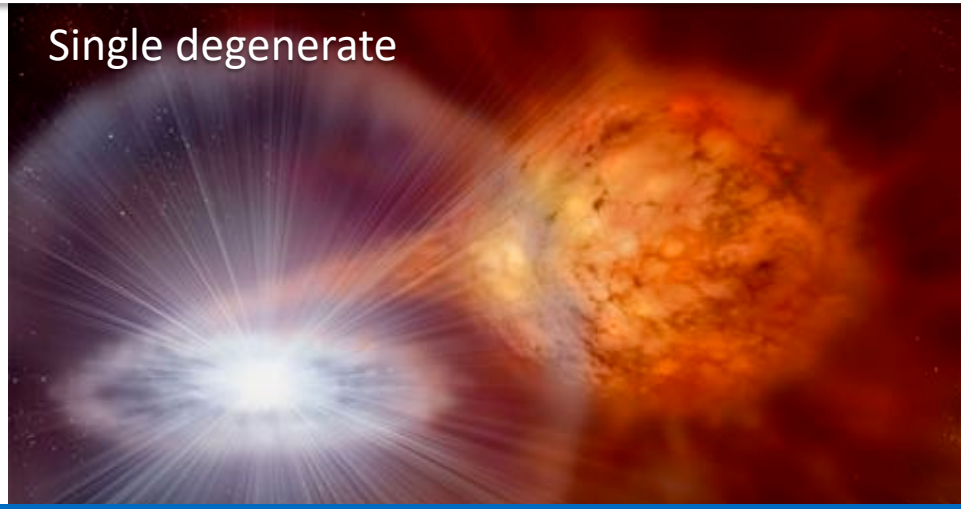
- SNe Ia are probably most accurate distance indicators on cosmological scales
- The progenitor system is still unknown
- We need to understand systematic errors in order to constrain dark energy

  → Study explosion ejecta & supernova environment → progenitor system

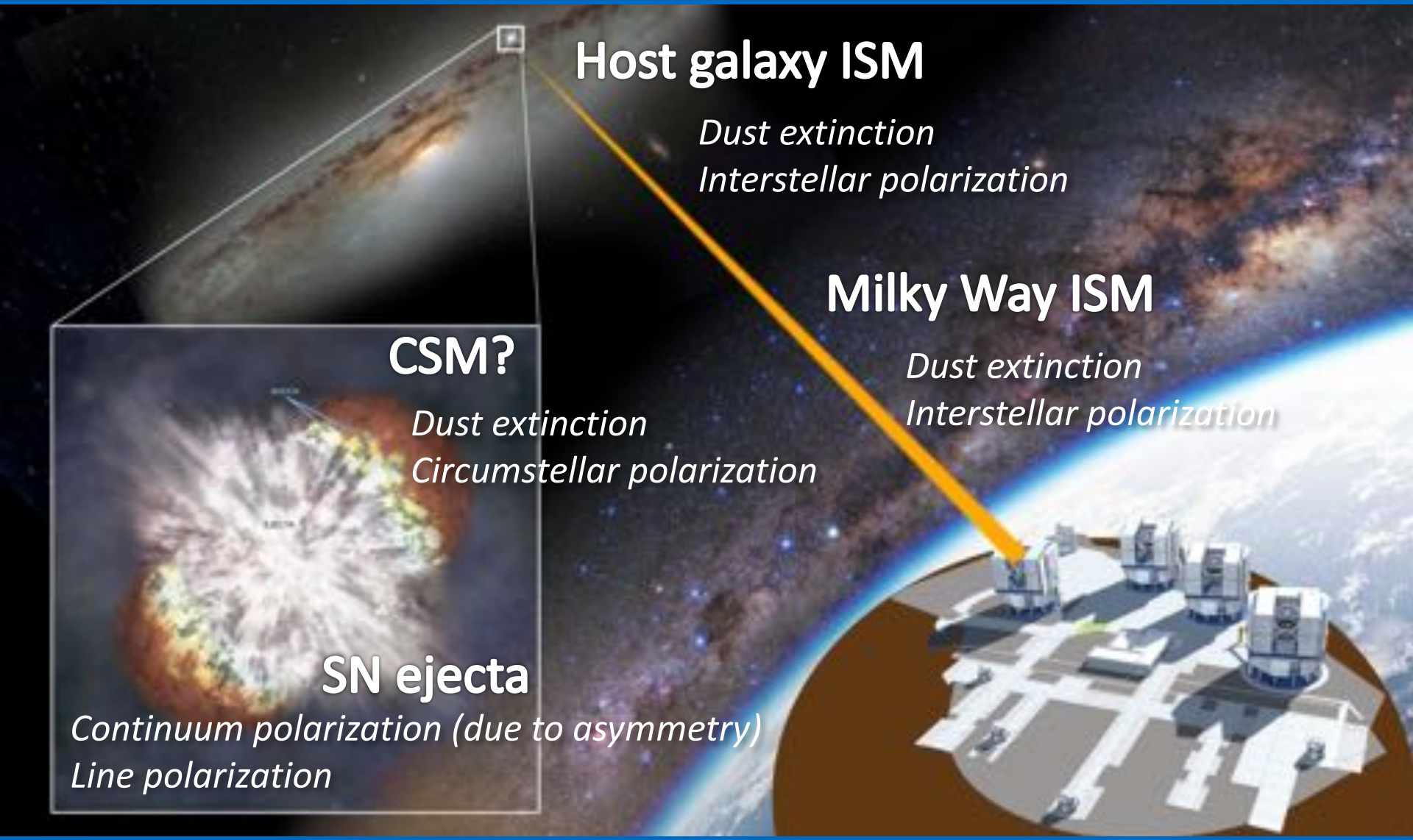


Perlmutter et al. 1999

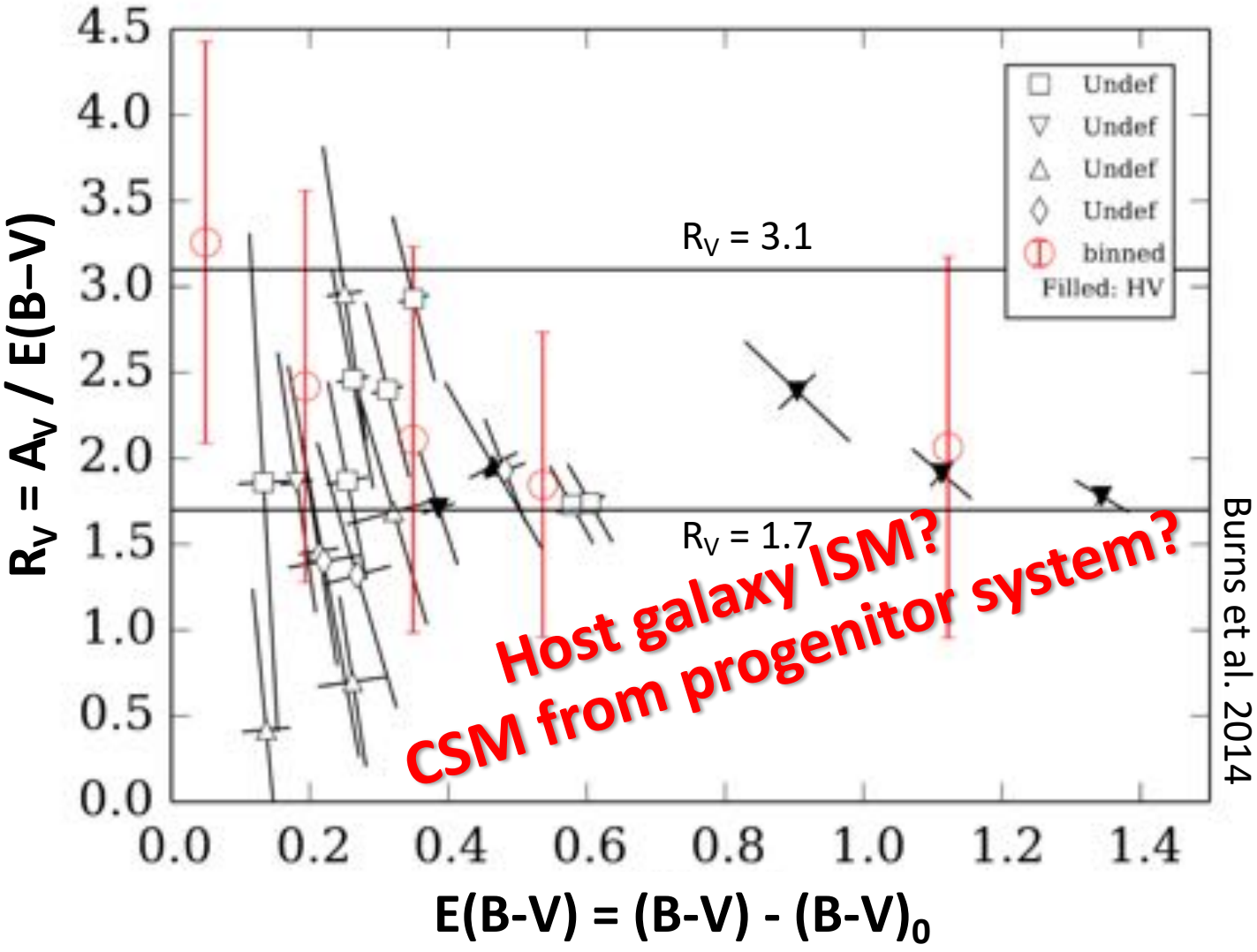




Sightlines toward SNe Ia

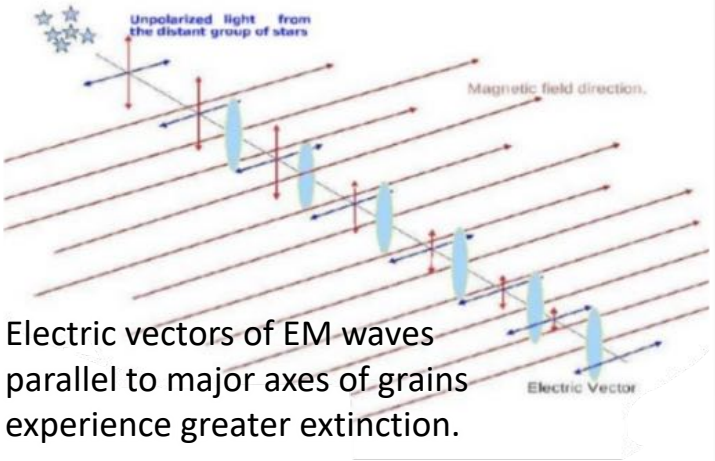


Dust extinction along SNe Ia

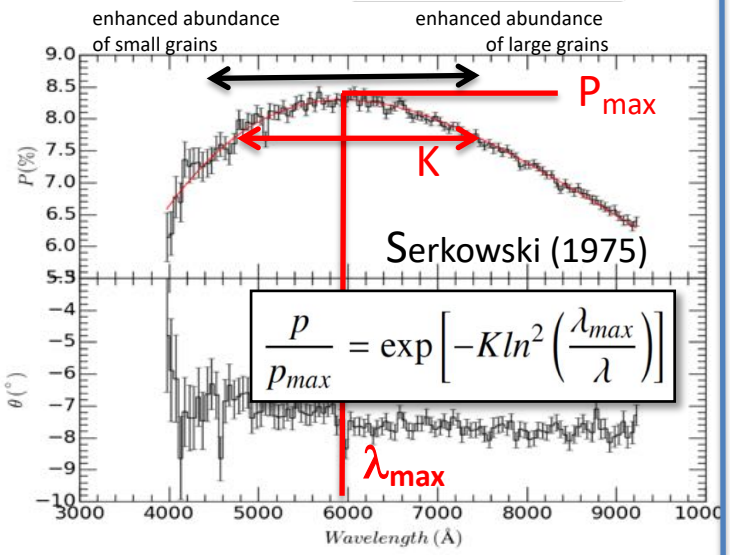


Continuum polarization mechanisms

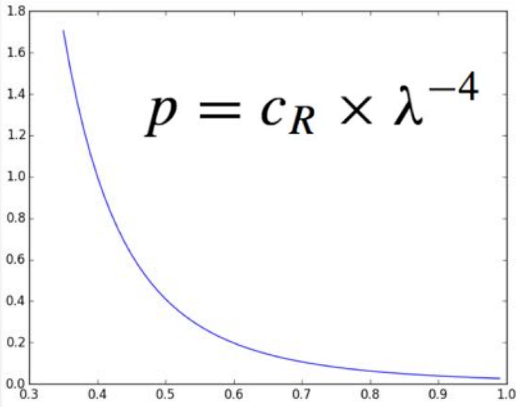
1. Result of "linear dichroism" in non-spherical grains

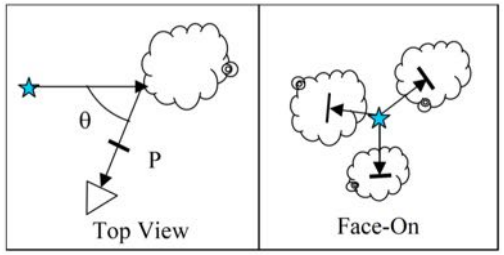


Electric vectors of EM waves parallel to major axes of grains experience greater extinction.

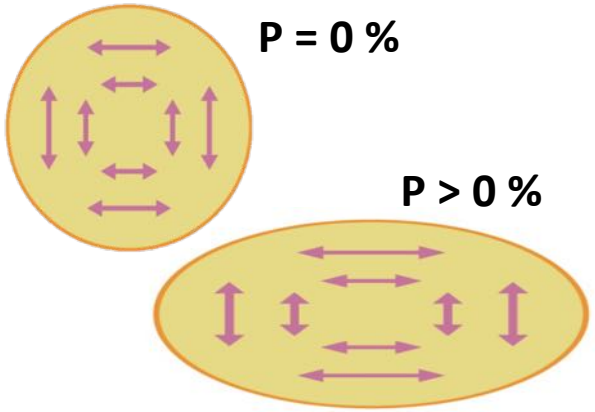


2. Scattering polarization





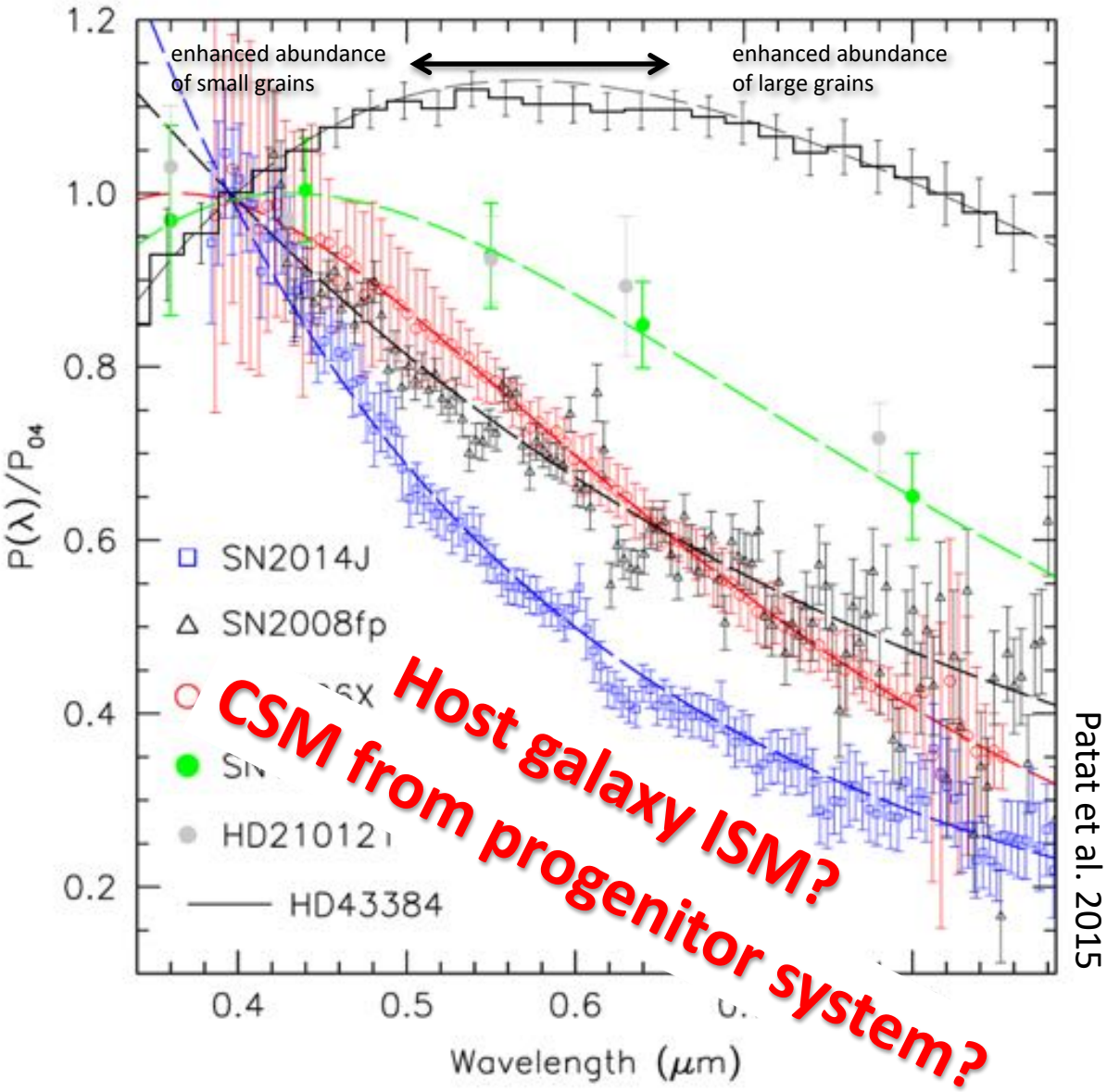
3. Electron scattering in globally aspherical photospheres



- is induced by electron scattering in globally aspherical photospheres (e.g. Hoeflich 1991)

- Intrinsic continuum polarizaiton typically <~0.4%; consistent with global asphericities at the ~10% level (Chornock & Filippenko 2008).
- SN 1999by (Howell et al. 2001), showed 0.7% polarization → could be modeled by an oblate spheroid with an axial length ratio of 1.17.

SNe Ia polarization curves



SNe Ia polarization curves

- The reasons why all SN in the sample show a behaviour so different from that seen in the Galaxy are unclear

Possible explanations:

→ The chemical/physical evolution of the hosts may be playing a relevant role.

→ Scattering? (Patat+ 2015)

→ Enhanced abundance of small grains produced by cloud collisions, or RATD (Hoang+ 2015, 2018)

→ We investigated untypical Galactic objects to establish possible connections to what is seen in extragalactic environments (Cikota+2017, Cikota+2018)

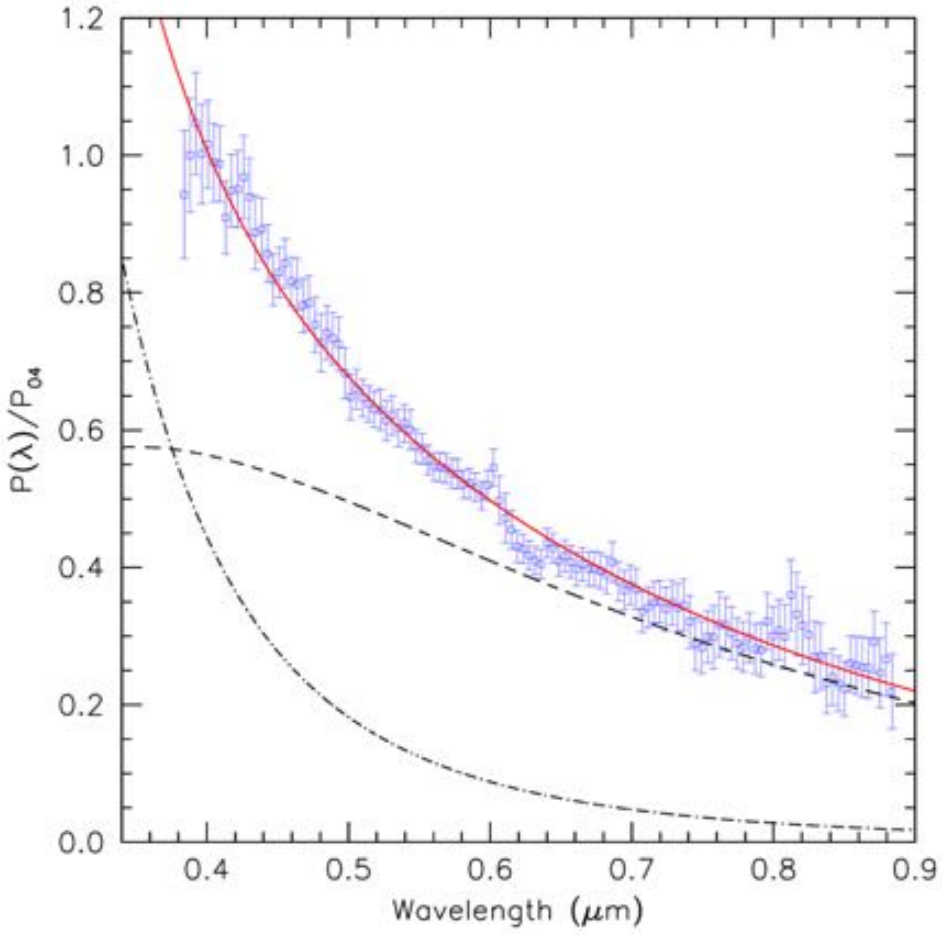
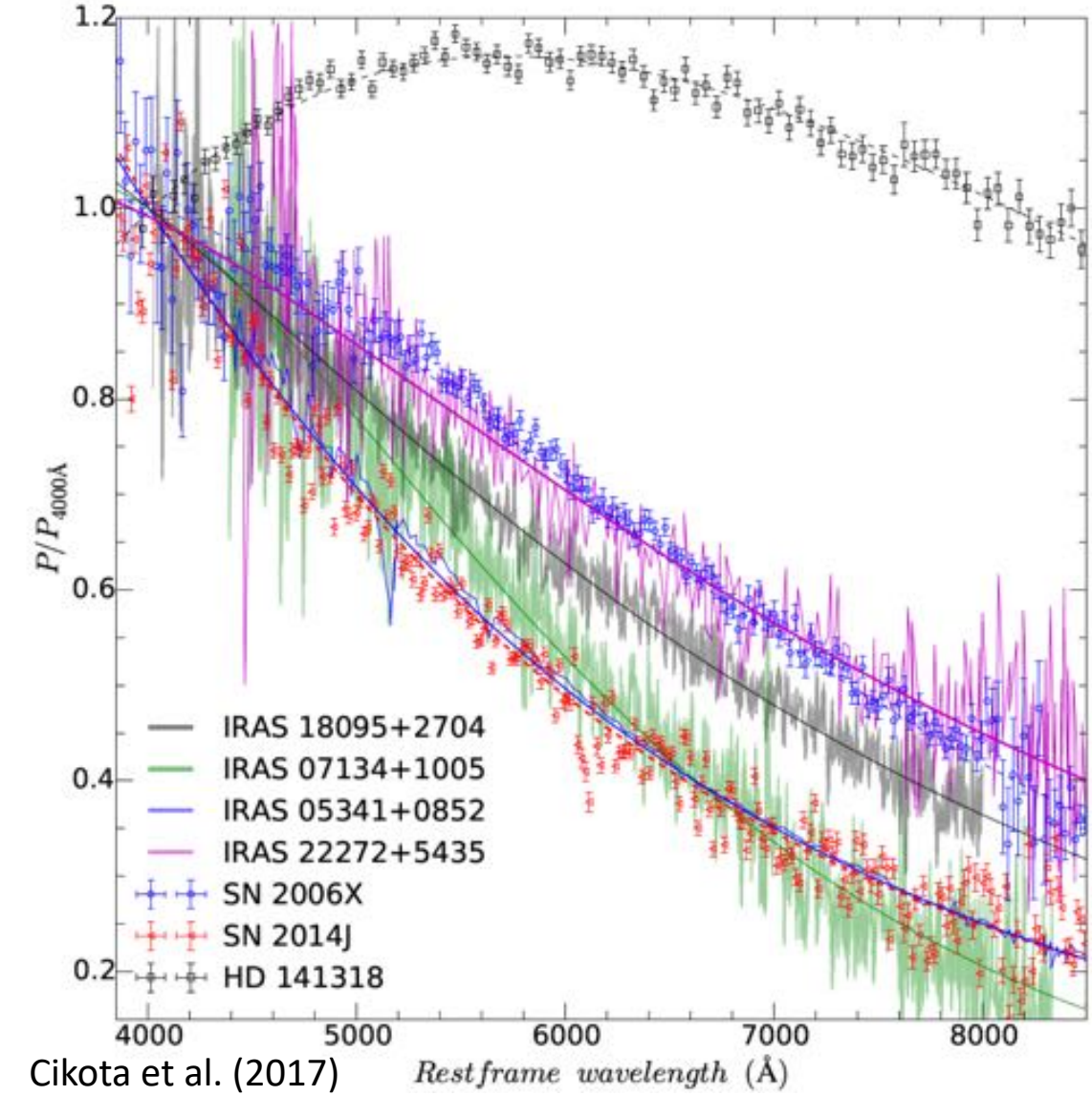


Fig. 6. Illustrative decomposition of the observed polarization in SN 2014J using a Serkowsky law (dashed) and a Rayleigh law (dotted-dashed). The solid line fitting the data traces the sum of the two (see text).

Patat+ 2015

Similarity to proto-planetary nebulae



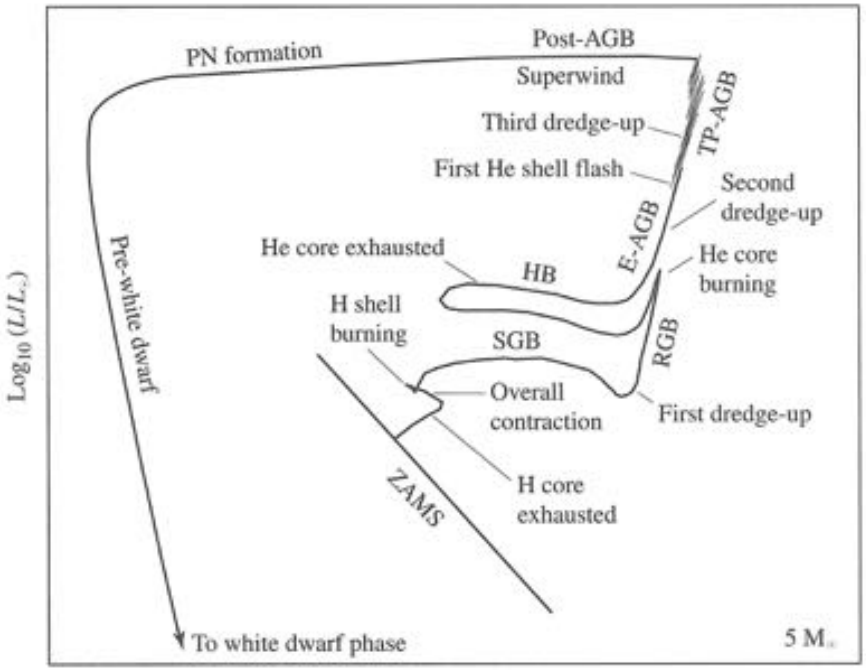
Cikota et al. (2017)

We examined spectropolarimetric data for a sample of 21 AGB and 13 post-AGB stars presented in **Bieging et al. (2006)**.

PPNe → Oppenheimer et al. (2005):

- dust-scattering Monte Carlo code DIRTY and the dust emission code 2Dust
- evidence for evacuated lobes cleared by collimated fast winds
- suggest that the polarization curves in those PPNe **can be explained in terms of scattering on CS dust grains**.

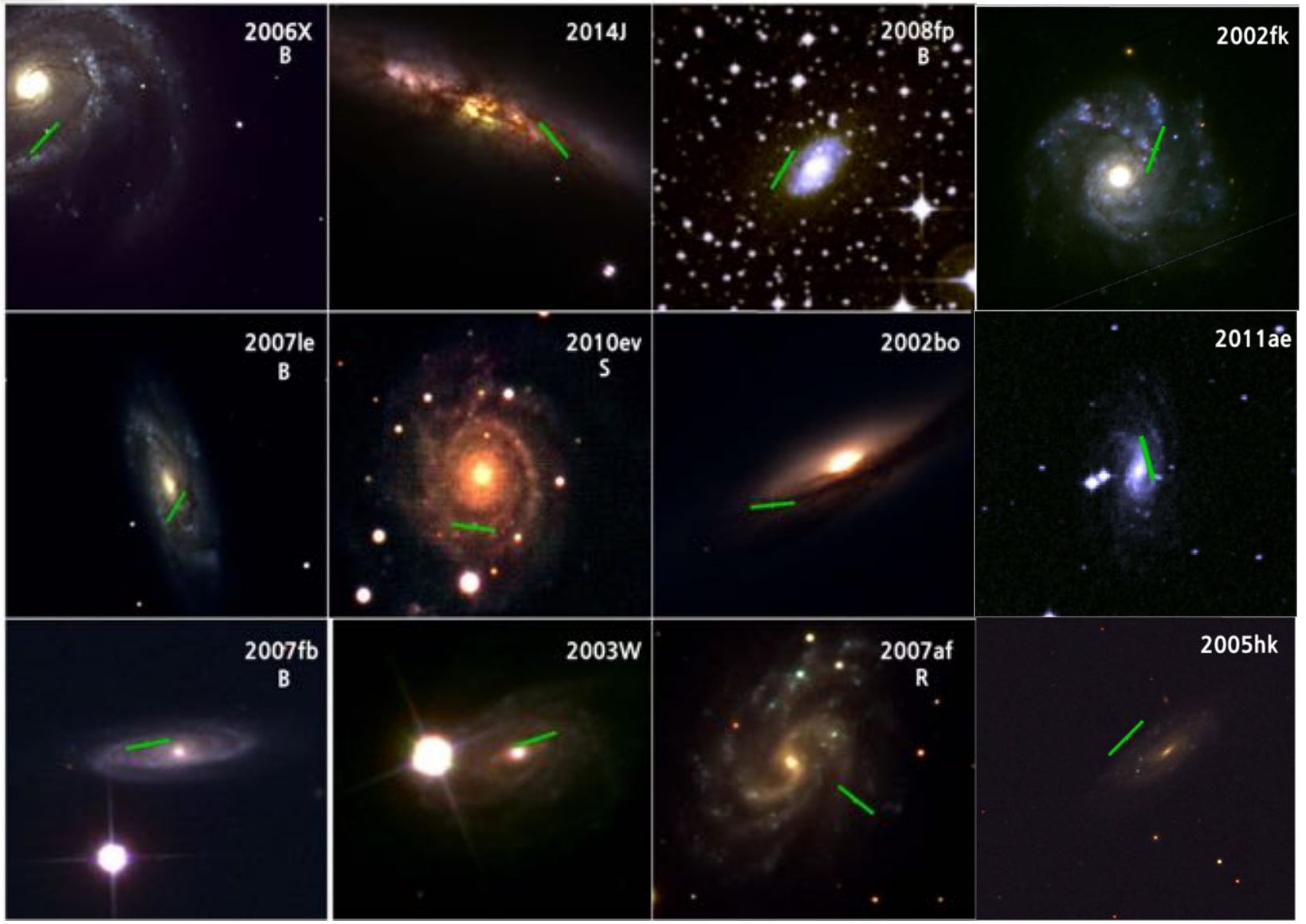
Possible implications



Carroll & Ostlie book

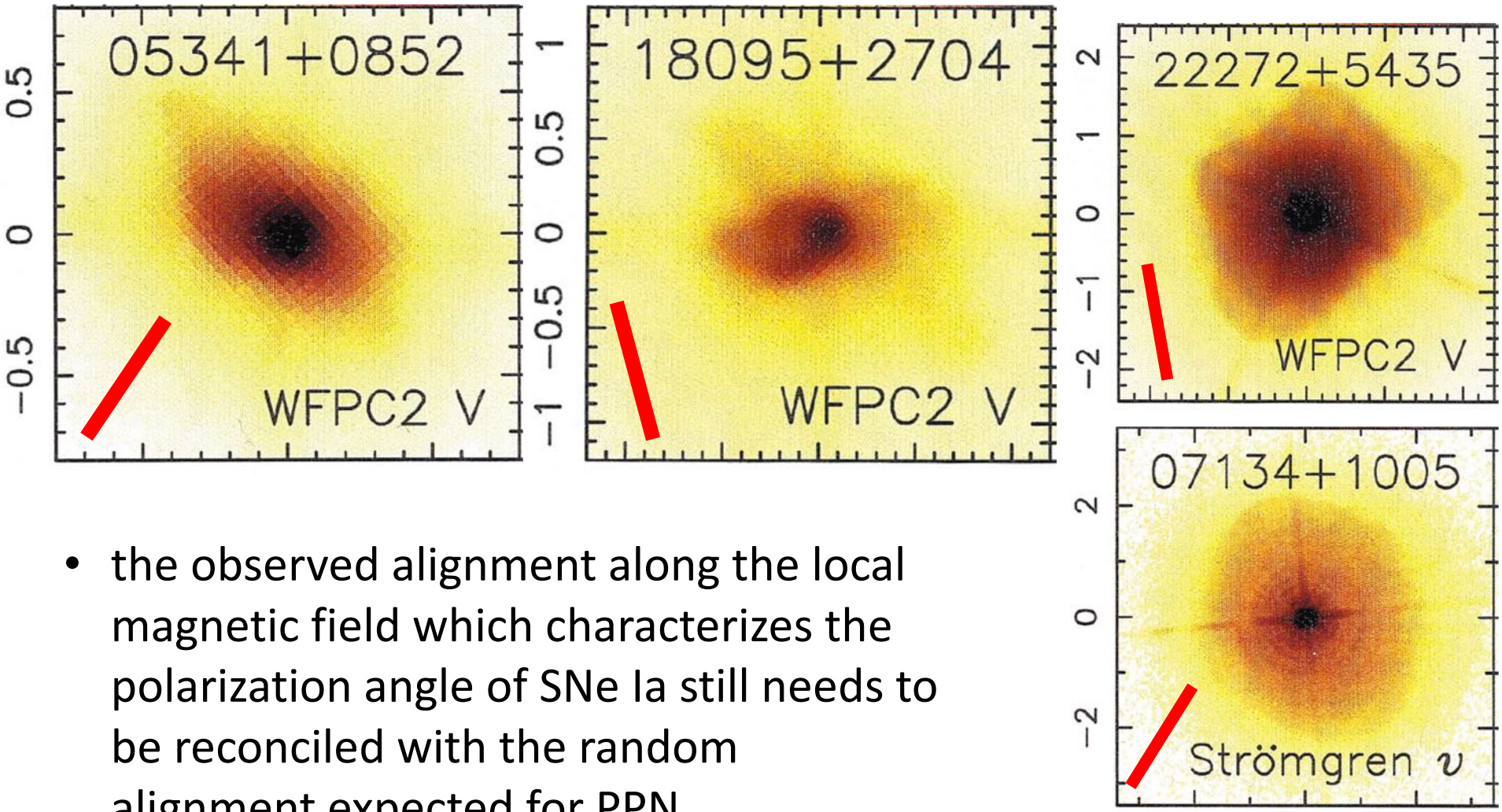
- PPNe may play role in evolutionary path of SNe Ia.
- The velocity of the CSM ejected during the AGB phase is slow (> 10 km s^{-1}). Given an AGB lifetime of ~1 Myr, the material can spread up to 10 pc.
- PPN phase: fast collimated winds shape the nebula (>150 km s^{-1})
- Jones & Boffin 2017: morphologies hard to explain → binary systems might play key role → form common envelope → formation of SNe Ia → core-degenerate progenitor model (Kashi & Soker 2011)

Caveats



Zelaya et al. 2017

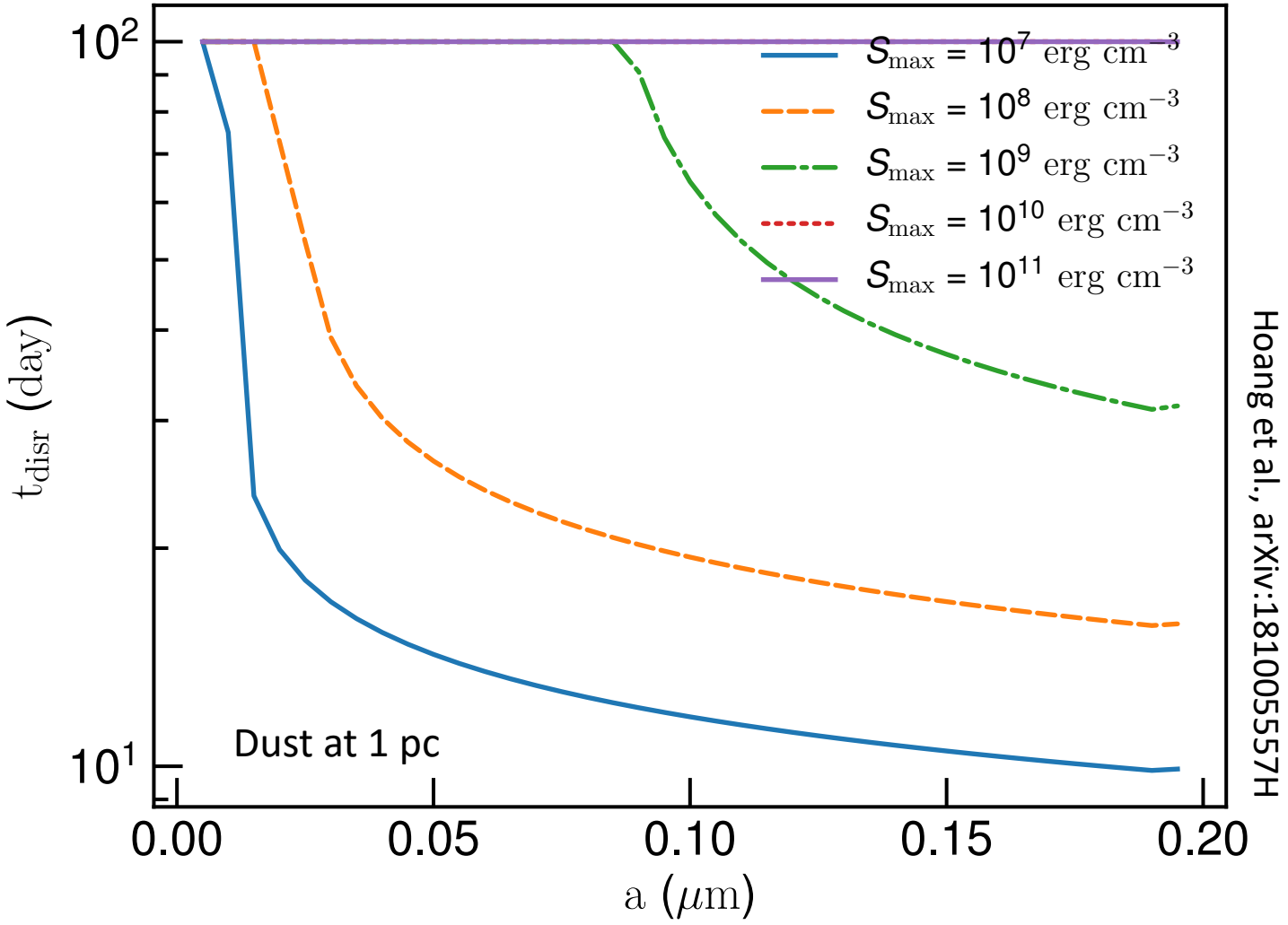
Caveats



- the observed alignment along the local magnetic field which characterizes the polarization angle of SNe Ia still needs to be reconciled with the random alignment expected for PPN.

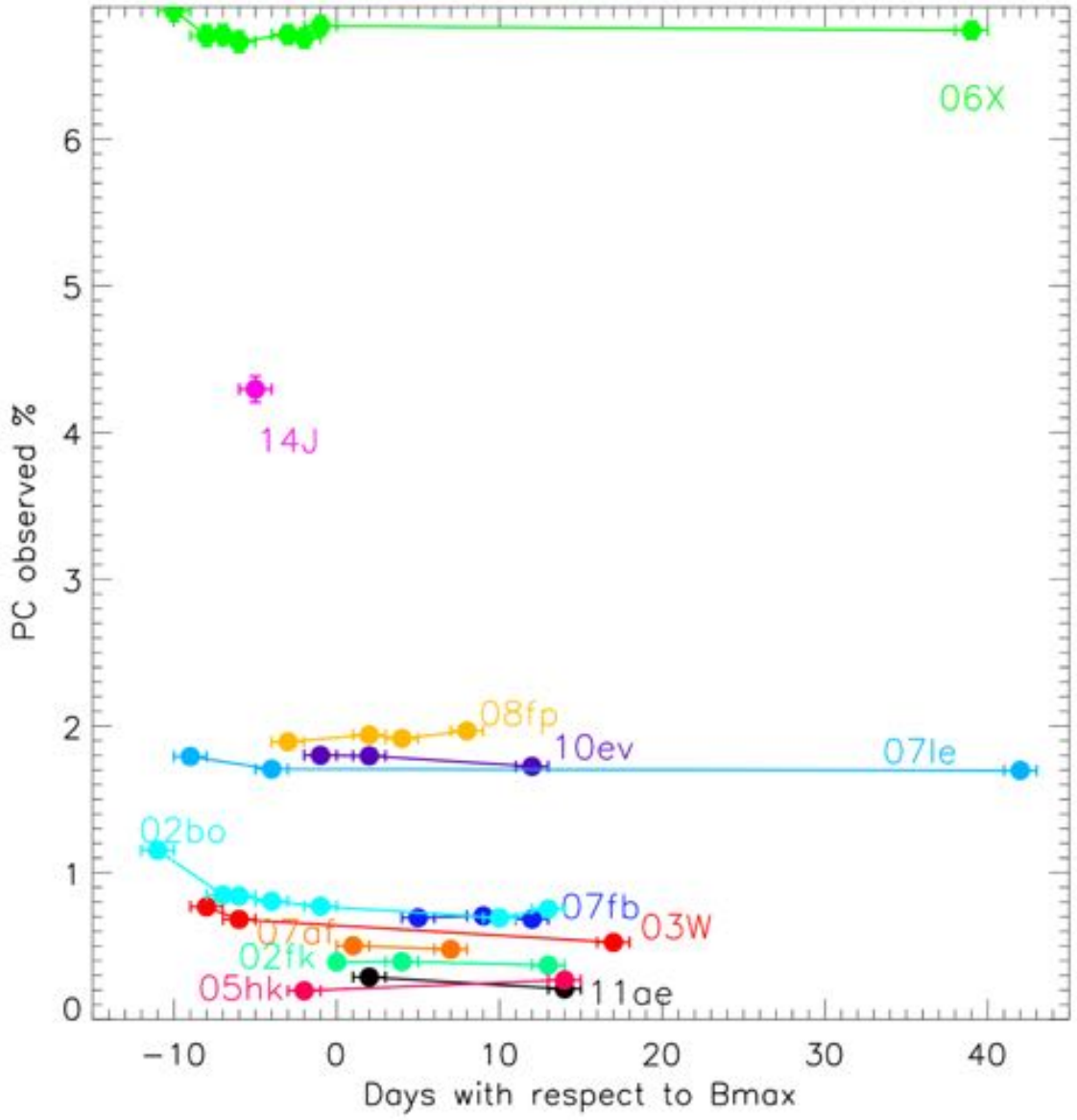
Ueta et al. 2000

Radiative Torque Disruption mechanism



- the disruption time can be within 10 days if the cloud is < 1 pc.
- the disruption time decreases as r^2

SNe Ia polarization curves



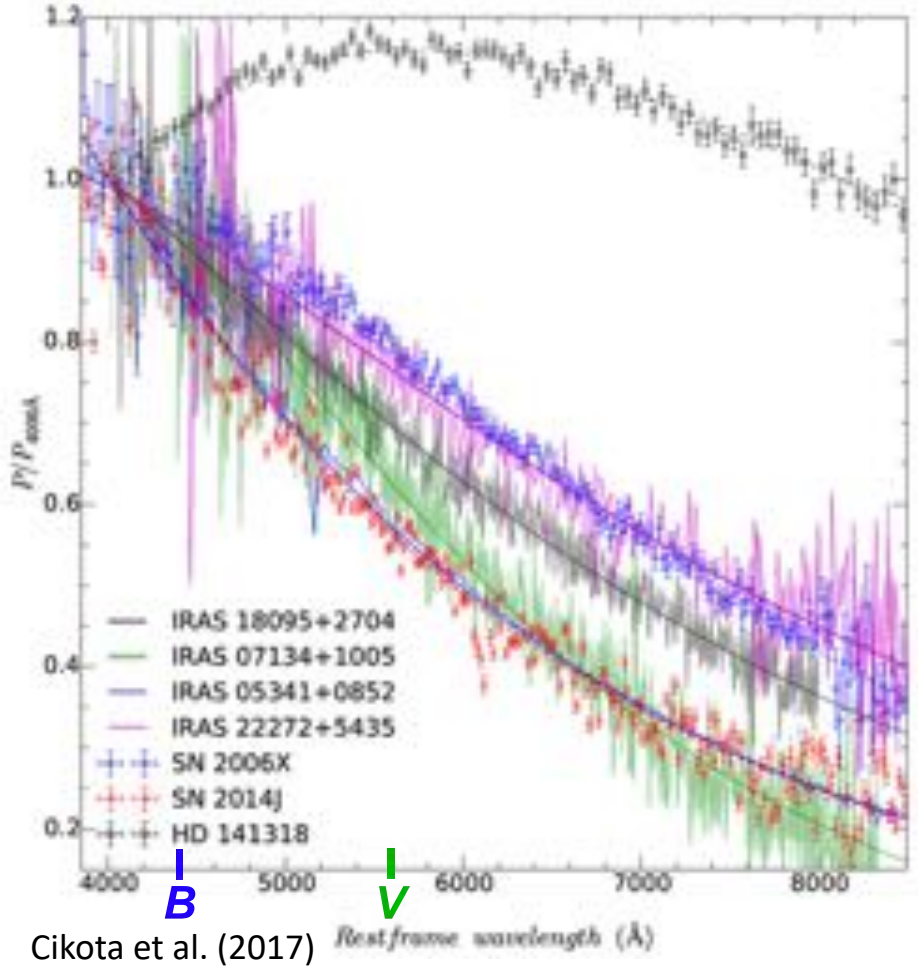
- The polarization varies by less than 0.05% on average.
- The exception is SN 2011ae, which shows a variation of 0.08%.

Zelaya et al. 2017

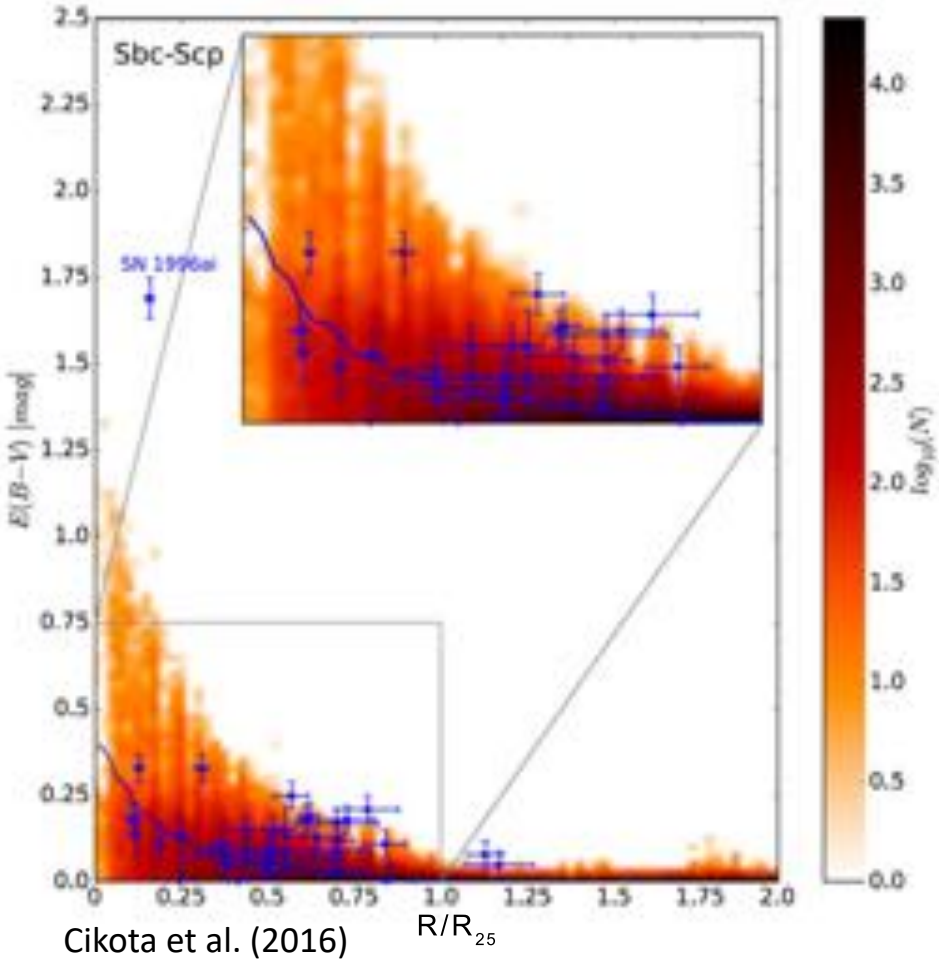
How to test the CS dust hypothesis?

ToO proposal: An imaging-polarimetry survey of Type Ia Supernovae: Is the nature of the progenitors encoded in the peculiar line-of-sight dust properties?

- 28+28 hours in P101 and P102, FORS2 @ VLT, PI: Cikota.
- Total required time: ~96 hours.



Cikota et al. (2017)



Cikota et al. (2016)

Summary & conclusions

- Studying CS environment (continuum polarization) may lead to implications on the progenitor system and explosion mechanism.
- We found a remarkable similarity in polarization between a group of four PPNe and the continuum polarization curves observed in highly reddened Type Ia SNe. The polarization curves rising towards the blue wavelengths in those PPNe are explained in terms of scattering on CS dust grains (Oppenheimer et al. 2005). Thus, we speculate that also some SNe Ia might explode during the post-AGB phase of their binary companion (Cikota et al. 2017).
- However, another possibility is that the abundance of small grains becomes enhanced through RATD mechanism, which produces steeply rising polarization curves, and extinction curves with low R_V .

Thank you for your attention!

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