Yi Yang

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December 15, 2016

Prof. Eli Waxman
Benoziyo Center for Astrophysics, Head
Weizmann Institute of Science, Dept of Particle Physics and Astrophysics
234 Herzl St., Rehovot
Rehovot, 7610001, Israel

Dear Prof. Eli Waxman, Dear Review Committee:

Please find the enclosed application for the Benoziyo Postdoctoral Fellowship - JRID56700. I expect to complete my Ph.D. at Texas A&M University in May 2017 under the supervision of Prof. Lifan Wang.

My current research is focused on our ongoing polarimetric monitoring at both early and late phases of Type Ia supernovae with the *HST* and VLT to study their progenitor systems. I also probe the optical properties of dust in nearby extragalactic environments using the light echoes resulted in the supernova-lit interstellar matter. My polarimetric studies also include other types of transients like superluminous supernovae. Apart from supernova-related research, I am also working on the Antarctic site testing surveys by leading the reduction and analysis of large photometric and spectroscopic datasets obtained by small aperture survey telescopes.

My proposed research aims to reduce the systematical errors from extragalactic extinction and progenitor systems and improve the study of cosmology using Type Ia supernovae as standard candles. I will study the light echoes in the nearby galaxies to provide a systematic and more universal characterization of the optical properties of the dust. This provides a better understanding of the dust extinction and reduces the systematic error in extinction corrections of Type Ia supernovae. Additionally, my polarimetric studies of Type Ia supernovae at both early and late times will put strong constraints on their circumstellar environments, helping to explore the mysterious explosion physics of Type Ia supernovae.

I am also particularly interested in working with Prof. Avishay Gal-Yam and Prof. Eran Ofek on understanding the physics of various types of transients. I would greatly appreciate the opportunity to work at Weizmann Institute of Science. I believe my proposed study and my experience on photometric, spectroscopic, and polarimetric studies with *HST*, VLT, and LCOGT will contribute to the Type Ia supernovae cosmology and the understanding towards interstellar dust grains, as well as enhancing the scientific goals of the experimental astrophysics group at the Weizmann Institute. I have attached a single PDF file including a cover letter, my CV, a list of my publications, a 2-page summary of my previous research and a 2-page research statement for your further consideration. If you have any questions or would like to discuss my application further please do not hesitate to contact me at yiyangtamu@gmail.com.

Thank you very much for your time and consideration. I look forward to hearing from you soon.

Sincerely,

Yi Yang

Yi Yang

Contact Information

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Research Interests

• Type Ia and Superluminous Supernovae • Light Echoes as a probe of Interstellar and Circumstellar Medium • Imaging Polarimetry • Spectropolarimetry • Antarctica Site Survey • Small Aperture Survey Telescopes

Education

Texas A&M University, College Station, TX, U.S.A

Ph.D., Physics, *Expected:* May 2017

- Advisor: Lifan Wang, Ph.D

Beijing Normal University, Beijing, P.R.China

B.S., Astronomy, July 2012

- Advisor: Jianning Fu, Ph.D

Research Programs

1. Imaging Polarimetry of Light Echoes around SN 2014J — 2015-2017
   Co-I – Hubble Space Telescope #14139, Cycle 23, PI – L. Wang (Texas A&M)
2. Observations of Young Supernovae for Precision Cosmology — 2016-2017
   Co-I – Las Cumbres Observatory, 2016B, PI – X. Wang (Tsinghua University)
3. Spectroscopy of Very Early Supernovae — 2016
   Co-I – Very Large Telescope 098.D-0780, PI – F. Patat (ESO)
4. Polarimetry of ASASSN-15lh as a probe of explosion physics of the most luminous supernova ever discovered — 2015
   PI – Hubble Space Telescope #14348, Directors Discretionary Time
5. Post-blackout spectropolarimetric typing of bright Type Ia Supernovae — 2015
   Co-I – Very Large Telescope 096.D-0144, PI – L. Wang (Texas A&M)
6. Antarctica Gattini-UV South Pole experiment — 2014-present
   Data reduction, PI – AM. Moore (Caltech)
7. Antarctica Gattini-Dome A experiment — 2012-present
   Data reduction, PI – AM. Moore (Caltech)

Conferences & Presentations

- Talk: AAS Winter Meeting Dissertation Talk, Grapevine, TX, USA — Jan 2017
- Talk: The Physics and Chemistry of the Interstellar Medium Chengdu, P.R.China — Jul 2016
- Poster: The Transient Sky, The Ninth Harvard-Smithsonian Conference on Theoretical Astrophysics, Cambridge, MA, USA — May 2016
- Talk: Carnegie Supernova Project II Meeting, Cooks Branch, TX, USA — Apr 2016
- Talk: Third Workshop of the SCAR AAA, Hilo, HI, USA — Aug 2015
- Talk: 3rd International Collaboration Meeting on Antarctic Survey Telescopes, Nanjing, P.R.China — Jun 2014
- Poster: 223rd Annual AAS Meeting, Washington, DC, USA — Jan 2014
- Talk: IAU XXVIII General Assembly, Beijing, P.R.China — Aug 2012

Skills, Observation, & Data Reduction Experience

- Spectropolarimetry: VLT (5 nights ToO)
  Observation planning & data reduction & data analysis
- Imaging polarimetry: *HST* (19+ orbits)
  Observation planning & data reduction & data analysis
- *HST* ACS/WFC polarimeter calibration
  Shown in the appendix of Brown et al. 2016, ApJ, 828, 3B
- Optical Imaging and Spectroscopy: LCOGT (15+ triggering)
  Data reduction & data analysis
- Small Aperture Survey Telescopes: Gattini Dome A (FOV: $90° \times 90°$, 60K+ raw frames)

Computer Skills: IDL, Python, LaTex, UNIX shell scripting, Matlab, IRAF

Awards

- Travel Award: Third Workshop of the SCAR AAA, Hilo, HI, USA — Aug 2015
- National Astronomical Observatories Scholarship, Chinese Academy of Science — Oct 2010
- NMOE (National Ministry of Education) Fellowship
  for the National Undergraduates Innovating Experiment — Sep 2009
- Beijing Normal University Undergraduates Research Fellowship — Mar 2009

Teaching Experience

- Astronomy 101: Overview of Modern Astronomy, Teaching Assistant — 2012, 2013, 2015
- Astronomy 111: Overview of Modern Astronomy, Lab instructor — 2014
- Caltech Summer Undergraduate Research Fellowships (SURF) — Summer 2014
  Co-Mentor: Yichen Chen
- Teaching the exercise classes for the members — 2010, 2012
  of Chinese Team for Astronomy Olympiad

Outreach

- Texas A&M Physics and Astronomy Festival, Presenter — 2012 - present
- Texas A&M Star Parties, Organizer — 2012 - 2015

References

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Peter J. Brown
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Samuel T. and Fern Yanagisawa Regents Professor of Astronomy
Department of Astronomy — Phone: 1-512-471-6407
The University of Texas at Austin — E-mail: wheel@astro.as.utexas.edu

List of Publications

First-author Refereed Publications

1. "Interstellar-Medium Mapping in M82 through Light Echoes around Supernova 2014J"
   Accepted for publication in the *ApJ*; arXiv:1610.02458
   Yang, Yi; Wang, Lifan; Baade, Dietrich; Brown, Peter; Cracraft, Misty; Höflich, Peter; Maund, Justyn R.; Patat, Ferdinando; Sparks, William B; Spyromilio, Jason; Stevance Heloise F.; Wang, Xiaofeng; Wheeler, J. Craig

2. "Constraints from a Polarized Light Echo on the Circumstellar Matter around Supernova 2014J"
   To be submitted to *ApJ*
   Yang, Yi; Wang, Lifan; Baade, Dietrich; Brown, Peter; Clocchiatti, Alejandro; Cracraft, Misty; Höflich, Peter; Maund, Justyn R.; Patat, Ferdinando; Sparks, William B; Spyromilio, Jason; Wang, Xiaofeng; Wheeler, J. Craig

3. "The Winter Sky Brightness and Transparency in Multiple Bands at Dome A, Antarctica"
   Submitted to *AJ*, arXiv:1610.10094
   Yang, Yi; Moore, Anna M.; Wang, Lifan; Krisciunas, Kevin; Ashley, Michael C. B.; Fu, Jian-Ning; Suntzeff Nicholas B.; Cui, Xiangqun; Feng, Long-Long; Gong, Xuefei; Hu, Zhongwen; Lawrence, Jon S.; Luong-Van, Daniel; Riddle, Reed L.; Shang, Zhaohui; Sims, Geoffrey; Storey, John W. V.; Tothill, Nick; Tavouillon, Tony; Yang, Huigen; Yang, Ji; Zhou, Xu; Zhu, Zhenxi

4. "A search for variable stars in the open clusters NGC7209, NGC1582 and Dolidze 18"
   2013, New Astronomy, Volume 23, p. 67-72
   Yang, Yi; Fu, Jian-Ning; Chen, Xiao-Dian; Yu, Mo; and Zhang, Yan-Ping

Co-author Refereed Publications

1. "ASASSN-15lh: A Superluminous Ultraviolet Rebrightening Observed by Swift and Hubble"
   2016, ApJ, 828, 3B
   Brown, Peter. J.; **Yang, Yi**; Cooke, Jeff; Olaes, Melanie; Quimby, Robert M.; Baade, Dietrich; Gehrels, Neil; Höflich, Peter; Maund, Justyn R.; Mould, Jeremy; Wang, Lifan; Wheeler, J. Craig

2. "Spectropolarimetry of the Type IIb SN 2008aq"
   2016, MNRAS, 461, 2019S
   Stevance, H. F.; Maund, J. R.; Baade, D.; Höflich, P.; Patat, F.; Spyromilio, J.; Wheeler, J. C.; Clocchiatti, A.; Wang, L.; **Yang, Y.**; Zelaya, P

Non-Refereed Publications

1. ATeL 8668: ESO VLT Spectropolarimetry of AT 2016adj in NGC 5128 (Centaurus A) and other 7 Astronomer's Telegrams including
   ATeL: 8807, 8774, 8748, 8679, 8623, 8611, 8021

STATEMENT OF PREVIOUS AND CURRENT RESEARCH

Yi Yang, Texas A&M University Department of Physics and Astronomy

Light attenuated by dust limits our ability to interpret the local and distant universe, i.e., the Type Ia supernova (SN) cosmology, which uses Type Ia SNe as the most accurate distance indicators at redshifts out to $\sim$2. Amazingly, this accuracy is achieved without knowing even approximately the distribution of various progenitors. My thesis work is focused on our ongoing polarimetric monitoring at both early and late phases of Type Ia SNe with the *HST* and VLT to study the progenitor system and probe the optical properties of dust in nearby extragalactic environments using the light echoes resulted in the supernova-lit interstellar material (ISM).

Resolved Interstellar Echoes through multi-band imaging: testing the optical properties of the dust. Light echoes are the light of a transient event scattered off dust clouds. These 'astronomical time machines' preserve the information of the original explosion (Davidson & Humphreys, 2012; Rest et al., 2008, 2012). Moreover, they also reveal the light-scattering properties of the dust since photons scattered by the dust reach the observer through multiple slightly different paths. This opportunity of determine extinction and scattering separately, however, can be raredly offered by a second, nearby object of suitable brightness.

Based on our *HST* observations of the SN 2014J in M82, I have detected different wavelength-dependencies of scattering in different ISM components: a small $R_V \sim 1.4$ in a dense layer of dust and a Milky Way-like $R_V \sim 3$ in a diffuse, tenuous dust cloud. This suggests that these two different ISM components exhibit different grain size distributions (Yang et al., 2016a), and this is consistent with a correlation between the host galaxy extinction A_V and their measured R_V (Mandel et al., 2011). The dense layer of dust may also be responsible for most of the extinction towards the SN 2014J. This study reveals the R_V fluctuation of the extragalactic dust on parsec scales. We deduce that systematically steeper extinction laws towards Type Ia SNe do not have to represent the average behavior of the extinction law in the host galaxy.

Unresolved Circumstellar Echoes through late-time polarimetry: Probing the pre-explosion evolution. Observations of the polarized scattered light and its time evolution can be an effective way of studying the circumstellar material (CSM). Type Ia SNe are intrinsically very little polarized in broad-band observations ($\lesssim 0.2\%$, Wang & Wheeler, 2008), but the scattered light from CSM can be highly polarized. As a SN fades, the portion of the scattered light coming from CSM increases and can contribute significantly to the total flux observed from the SN. Light scattered at large angles can be polarized at $\sim 50\%$. For a spatially unresolved source, the scattered light can contribute significantly to the total integrated light and the polarization of the integrated light can evolve rapidly with time after the supernova evolves past optical maximum (Wang & Wheeler, 1996).

I tested the circumstellar environment of SN 2014J by monitoring its late-time polarization with the imaging polarimetry mode of the *HST* ACS/WFC. I found the polarization of Type Ia SN 2014J shows conspicuous deviation at day 277 from other epochs (Kawabata et al., 2014; Patat et al., 2015). This can result from light scattered by a silicate dust ejecta of $\gtrsim 10^{-6} M_\odot$ located 0.5 light years to the SN. The location of this matter then constrains the time history of the mass ejection and is consistent with an episode of nova-like ejection $\sim$160 years before the SN explosion for a typical speed of 1,000 km/sec. The mass of ejecta and the time-delay between the mass ejection and the explosion of the SN are consistent with most of the double-degenerate scenarios discussed in Margutti et al. (2014) and references therein. To summarize, the principle fact enabling late-time polarimetry as an effective tool to constrain the CSM is that the fraction of polarized flux from any asymmetric CS dust increases substantially as the the SN dims sufficiently.

Polarimetry as a unique tool to study the progenitor system. Early observations before the ejecta wipe out most of the traces of the pre-explosion configuration is critical to study the progenitor systems, especially for Type Ia SNe. Polarimetry probes the mass-loss history and the geometrical asymmetry. If the footprint on the photosphere of the distribution of the dust particles is asymmetric, the integrated polarization can be quite large.

My efforts include Target of Opportunity programs using the VLT to obtain spectropolarimetric data for Type Ia SNe at very early phases (VLT 096.D-0144, PI: Wang). My discovery of a low level of continuum polarization ($<0.2\%$) of SN 2015ak as early as 11 days before the maximum is inconsistent with the merger-induced explosion scenario (Bulla et al., 2016). Moreover, intrigued by the explosion mechanism of ASASSN-15lh - the most luminous supernova ever discovered (Dong et al., 2015, 2016), I requested *HST* Directors Discretionary Time observations to obtain imaging polarimetry of this target. Three orbits for a single visit in multi-band were awarded (*HST* 14348 PI: Yang). My measurement suggests that this hydrogen-poor superluminous supernova event at z$\sim$0.23 has a small asymmetry on the sky (Brown et al., 2016). Current and the next generation surveys probe the time-domain universe in unprecedented cadence, depth, and sky coverage. The uniqueness of polarimetry makes it a promising tool in understanding the progenitor system.

Antarctic site testing as pathfinders for further astronomical studies. Antarctic sites are proving to be excellent sites for optical, NIR, and THz astronomical observations. To understanding and make the use of the long 'winter night' as well as other remarkable observation conditions is one of the essential topics for future astronomy.

I am leading two data reduction and analysis programs on Antarctic site testing. From continuous monitoring data at the highest point on the Antarctic plateau in a $90^\circ \times 90^\circ$ FOV with a fisheye lens, I calibrated the BVR sky brightness, the cloud coverage, and estimated the aurorae statistics from 60,000 raw frames (Yang et al., 2016b). Given the nature of the wide-field design and combined with no sidereal tracking system, non-negligible effects needed to be modeled to effectively process the data. Light curves of ~ 2600 stars brighter than 7.5 in V for a consecutive 120 days have also been obtained. My work on Antarctic site testing will be continuing in the future.

References

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Dong et al. 2015, ATEL, 7774
–. 2016, Science, 351, 257
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Yang et al. 2016b, arXiv:1610.10094

Research Proposal: Physics of Supernovae and Interstellar Matter: a Disentangling Effort

Incomprehensive knowledge on dust is hindering our study of the universe. For example, the Type Ia supernovae (SNe) cosmology requires better estimation of interstellar extinction to reduce systematic uncertainties. The extinction properties measured towards Type Ia SNe suggest the properties of extragalactic dust may be incompatible with the Galactic dust, resulting in a systematic uncertainty in the intrinsic luminosity and distances to the Type Ia SNe. Additionally, the exact progenitor systems of Type Ia SNe and explosions remain unknown. Comprehensive understanding of **(1) the extinction and optical properties of the extragalactic dust grains**, and **(2) the mechanism and the progenitor for Type Ia SN explosions**, are both essential. The scattering properties of dust will be imprinted on the light scattered by the ISM, and the mass-loss history of the progenitor before the final explosion can be revealed by the scattered light from ejecta close to the SN. These principles motivate me to take advantage of the interstellar light echoes to probe the optical properties of the ISM and the circumstellar light echoes to constrain the circumstellar matter (CSM) and hence the progenitor system of the Type Ia SNe. The major task of this proposal is to investigate the light echoes in nearby galaxies to probe the optical properties of the echoing material. Additionally, the circumstellar environment will be examined through the search and study of the echoing dust and our on-going *HST* imaging polarimetry campaign.

Peculiar extinction laws towards Type Ia SNe: how well do we know the interstellar dust? The characterization of dust in the diffuse ISM relies heavily on the observed wavelength dependencies of extinction and polarization (Patat et al., 2015). There is increasing evidence that extinction curves towards Type Ia SNe systematically favor a steeper law (R_V<3, see a summary from Cikota et al., 2016). This discrepancy has remained unexplained. Does the deduced R_V represent the average properties of the dust? Exploiting the high spatial resolution of *HST* and employing our method to calculate the optical properties and scattering wavelength dependence of the spatially resolved dust components, I will conduct a more universal test to the ISM in the local group and the nearby extragalactic environments. I will use the new method I developed to focus on **(1) the spatial variation**, and **(2) the scattering wavelength dependence** of the light echoes. This has been triggered by our recent discovery that different components of the ISM can exhibit different R_V towards the Type Ia SN 2014J in the nearby starburst galaxy M82 within only a few parsecs on the plane of the sky (see Figure 1, and Yang et al., 2016).

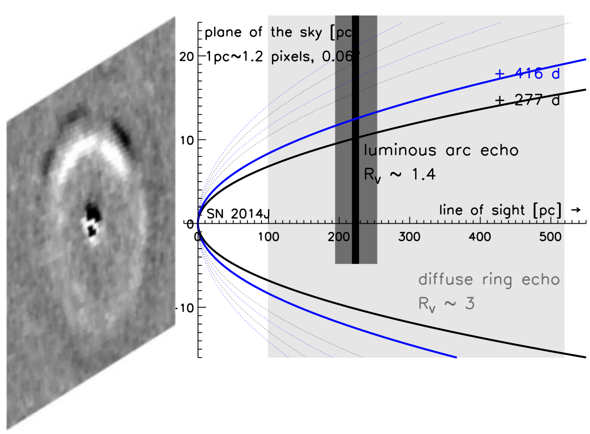

Fig 1. **Resolved Interstellar light echoes:** Schematic view of SN 2014J and light echoes showing the **thin dense dust slab** resulting in the luminous arc (R_V ∼1.4) and the **diffuse dust cloud** rising the diffuse ring (R_V ∼3) which are found to have different dust grain properties. Paraboloids represent the iso-delay light surfaces at different epochs. Dashed paraboloids indicate our future constraints on day 649, 796, 985, 1170, from inner to outer, respectively.

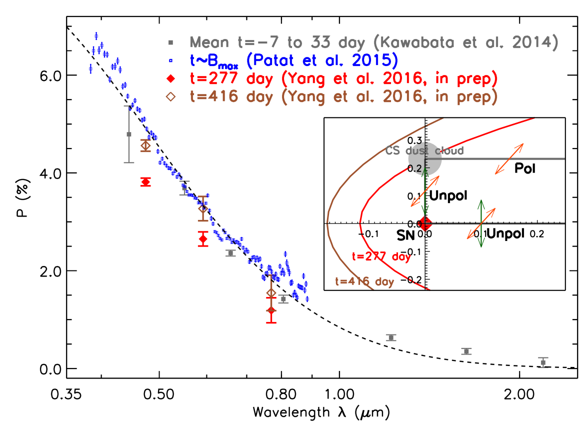

Fig 2. **Unresolved Circumstellar light echo:** Polarimetry of SN 2014J at different epochs. Conspicuous deviations of polarization at day 277 from the interstellar polarization can be due to the presence of CSM. The inset diagram shares the coordinates with Fig 1 and explains photons can be polarized by a circumstellar dust cloud at a large scattering angle. Contribution from the polarized flux will cause the time-variant polarization measured from the SN.

The multi-color, multi-epoch, and high-resolution *HST* images establish the feasibility of this study (see Table 1 of Yang et al., 2016 for a summary of resolved extragalactic echoes). I propose to use the *HST* archival data of nearby SNe with both **(1) multi-color information**, and **(2) well-resolved spatial profiles**. Difference imaging will be performed to better reveal the faint and time-variant echo signals thanks to the frequent visits of these nearby galaxies by *HST*. Additionally, studying the light echo evolution in multiple epochs will measure the optical properties and wavelength dependence of extragalactic ISM in 3D. Milky Way and LMC echoes are also important to improve our understanding of the ISM in the local group. I will revisit the echoing medium around the galactic variable V838 Monocerotis (Sparks et al., 2008; Tylenda & Kamiński, 2012) and in the LMC (Davidson & Humphreys, 2012; Rest et al., 2008, 2012) using the *HST* archive and ground-based observations with our method and also examine the polarization wavelength dependency to better characterize the different dust components in our Milky Way. I will also propose to *HST* to observe new light echoes of future SNe in nearby galaxies.

I also propose a two-pronged observational approach to constrain the Type Ia progenitor system through inner echo detection and polarimetric follow-up at extremely late and early phases, respectively. Our ongoing *HST* imaging polarimetry campaign will monitor the SN 2014J to at least 3.3 years and will map out any significant CSM at $\leqslant$3.3 light years perpendicular to the plane of the sky (1.2 ACS pixels). The detection of echoes close to the SN at very late times will be an unambiguous signature of the CSM, while a non-detection will yield an unprecedented constraint. The polarimetric properties of a Type Ia SN at late nebular phase will also be examined for the first time. I have detected the late-time light curve flattening of the SN 2014J, which can be due to the reprocessing of electrons and X-rays emitted by the decay of ^{57}Co (Figure 3, also Seitenzahl et al., 2009 and Graur et al., 2016 for SN 2012cg), or a faint echo caused by CSM within 1 light year. Our future data will distinguish these two possible scenarios. These proposed studies aim to reduce the systematical errors from Type Ia SNe progenitor systems.

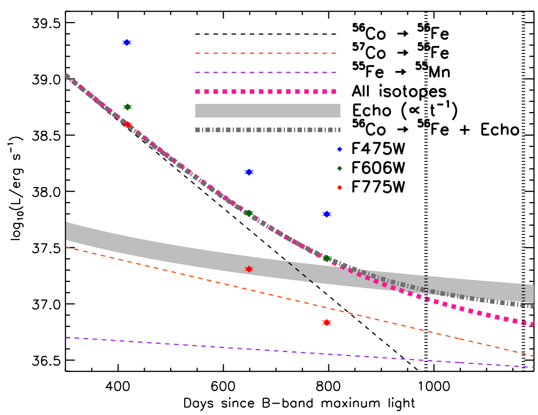

Fig 3. Possible mechanisms explaining the late time flattening light curves of SN 2014J (Yang et al. 2016, in prep). Isotope models from Graur et al. (2016) are used. F606W data $\gtrsim 500$ days have been assumed to be proportional to the bolometric light curves (Milne et al., 2001) and free from possible γ-ray photons. Only F606W observations after 500 days have been fitted with models counting in multiple isotopes and ^{56}Co plus a faint unresolved light echo. Isotope fitting requires a $\sim$3 times the solar ^{57}Ni/^{56}Ni ratio. Two more epochs will be obtained (the scheduled date of observations are marked by vertical dotted lines) to distinguish the two possible scenarios.

For the early epochs, I will continue our efforts on the spectropolarimetric follow-up of Type Ia SNe at extremely early phases to catch the pre-explosion configuration before it is wiped out by the ejecta. Traces of interactions between ejecta and a separate companion may be detected at $\lesssim$5 days past explosion (Kasen, 2010). A significantly higher degree of polarization around this epoch would be a strong indication of the highly asymmetric process between two white dwarfs. However, spectropolarimetry keeps finding very low degree of continuum polarization (Maund et al., 2013; Wang & Wheeler, 2008), incompatible with the double-degenerate scenario. I will trigger our VLT spectrophotometry campaign to expand the sample of early SNe and understanding better the progenitor mechanisms of Type Ia SNe.

To summarize, the expected scientific results of this proposal include (1) A systematic and more universal characterization of the optical properties and associated size distributions and compositions of the interstellar dust in the Milky Way, the LMC, and nearby extragalactic environments; (2) Strong constraints on the circumstellar environment around a few nearby type Ia SNe. I will compile our new understanding of the dust into the current method of extinction correction for SN cosmology. The constraints on the CSM will further help to explore the mysterious explosion physics of Type Ia SNe.

References

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