Yi Yang

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January 10, 2017

Maryam Modjaz
Center for Cosmology and Particle Physics, New York University
Meyer Hall of Physics, 4 Washington Place, room 529
New York, NY 10003, USA

Dear Prof. Maryam Modjaz:

Please find the enclosed application for the data science/SN-related postdoctoral research opportunity at NYU. 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 Antarctic site testing programs by leading the reduction and analysis of large photometric and spectroscopic datasets obtained by small aperture survey telescopes.

In addition to work with you on various observational projects in transient astrophysics and cosmology, I am also be able to carry out my own research programs on studying the light echoes in the nearby galaxies to provide a systematic and more universal characterization of the optical properties of the dust. This research aims to reduce the systematical errors from extragalactic extinction and improve the study of cosmology using Type Ia supernovae as standard candles. This will provide a better understanding of the dust extinction and reduces the systematic error in extinction corrections of various types of transient. 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 their mysterious explosions.

I am particularly interested in joining the SNYU group and working with you on understanding the physics of various types of transient. I would greatly appreciate the opportunity to work at NYU. 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. I have attached a single PDF file including a cover letter, my CV, a list of my publications, a one-page summary of my research experience, and a two-page plan of my future research 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)

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

Yi Yang

Conferences & Presentations

- Talk: AAS Winter Meeting Dissertation Talk **(410.03D)** — Jan 2017
  Grapevine, TX, USA
- Talk: The Physics and Chemistry of the Interstellar Medium — Jul 2016
  Chengdu, P.R.China
- 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: 3^{rd} International Collaboration Meeting on Antarctic Survey Telescopes, Nanjing, P.R.China — Jun 2014
- Poster: 223^{rd} Annual AAS Meeting, Washington, DC, USA — Jan 2014
- Talk: IAU XXVIII General Assembly, Beijing, P.R.China — Aug 2012

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 of Chinese Team for Astronomy Olympiad — 2010, 2012

Outreach

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

References

Lifan Wang
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Texas A&M University

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J. Craig Wheeler
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*; 2016, 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; Stevance Heloise F.; Wang, Xiaofeng; Wheeler, J. Craig

3. "Late-time Photometry of Type Ia Supernova 2014J"
   To be submitted to *ApJL*
   Yang, Yi; Wang, Lifan; Baade, Dietrich; Brown, Peter; Clocchiatti, Alejandro; Cracraft, Misty; Höflich, Peter; Maund, Justyn R.; Patat, Ferdinando; Sparks, William B; Spyromilio, Jason; Stevance Heloise F.; Wang, Xiaofeng; Wheeler, J. Craig

4. "The Winter Sky Brightness and Transparency in Multiple Bands at Dome A, Antarctica"
   Submitted to *AJ*, 2016, 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

5. "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

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 Supernovae (SNe) 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. I have been focusing 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 SN-lit 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 is rarely offered by nearby objects of suitable brightness. Our *HST* observations of the SN 2014J detected different wavelength-dependencies of scattering in different ISM components: a small R_V in a dense dust layer and a Milky Way-like R_V in a diffuse cloud (Yang et al., 2016a). This reveals the R_V fluctuation of the extragalactic dust on parsec scales, and we consider 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. Type Ia SNe are intrinsically very little polarized (Wang & Wheeler, 2008) but the scattered light from circumstellar matter (CSM) can be highly polarized, and as a SN fades, they can contribute significantly to the total flux from the SN (Wang & Wheeler, 1996). I found the polarization of Type Ia SN 2014J shows conspicuous deviations at day 277 from other epochs. 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 most double-degenerate scenarios (see Margutti et al., 2014). To summarize, Late-time polarimetry constrains the CSM effectively since the fraction of polarized flux from any asymmetric CS dust increases substantially as 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. My efforts include Target of Opportunity programs using the VLT to obtain spectropolarimetric data for Type Ia SNe at very early phases. 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 (Yang et al, 2017 in prep). Moreover, I requested *HST* Directors Discretionary Time observations and measured the polarization of ASASSN-15lh - the most luminous supernova ever discovered (Dong et al., 2015, 2016). I conducted independent calibrations of the associated *HST* ACS polarimeters and found low polarizations for this event, indicating a small asymmetry on the sky (Brown et al., 2016). The uniqueness of polarimetry makes it a promising tool in understanding the progenitor system.

Antarctic site testing as pathfinders for further astronomical studies. Antarctica offers a uniquely long 'winter night' and is proving to have excellent astronomical sites. 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). 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.

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., 2016a).

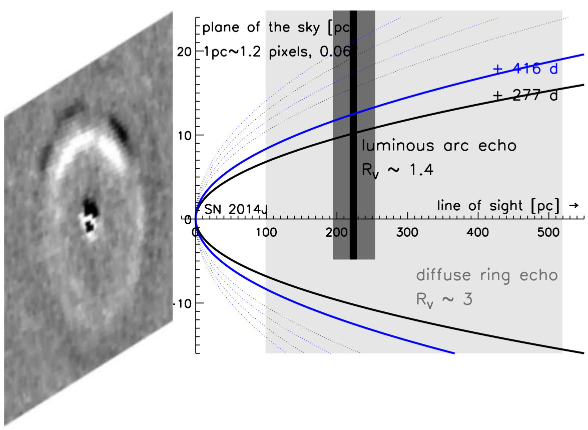

Fig 1. **Resolved Interstellar light echoes:** Schematic view of SN 2014J and light echoes showing the **thin dense dust slab** resulting in the luminous arc (R_V ~1.4) and the **diffuse dust cloud** rising the diffuse ring (R_V ~3) which are found to have different dust grain properties. Paraboloids 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.

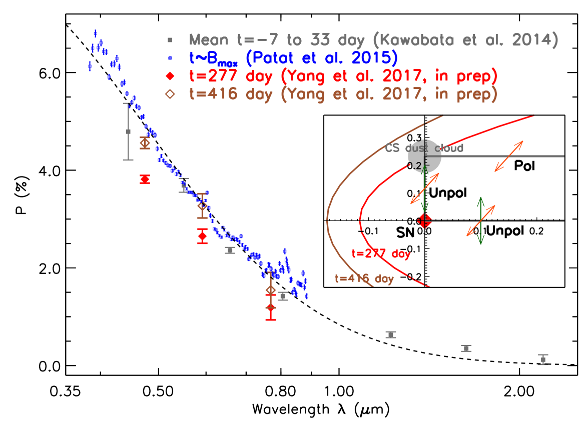

Fig 2. **Unresolved Circumstellar light echo:** Polarimetry of SN 2014J at different epochs. Conspicuous deviations of polarization at day 277 from the interstellar polarization can be due to the presence of CSM. The inset diagram shares the coordinates with Fig 1 and explains photons can be polarized 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., 2016a 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. This study characterizing the optical properties of the interstellar dust will contribute to the scientific goals of the SN research group at NYU, i.e., by providing more comprehensive extinction corrections to panchromatic observations of various types of SNe.

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.

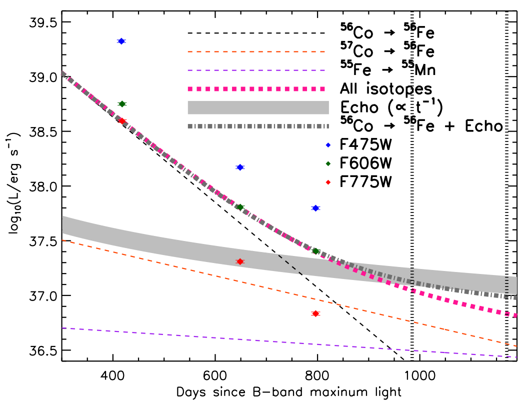

Fig 3. Possible mechanisms explaining the late time flattening light curves of SN 2014J (Yang et al. 2016, in prep). Isotope models from Graur et al. (2016) are used. F606W data $\gtrsim 500$ days have been assumed to be proportional to the bolometric light curves (Milne et al., 2001) and free from possible 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}Co/^{56}Co 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: Brown et al. 2016, ApJ, 828, 3; Cikota et al. 2016, ApJ, 819, 152; Davidson et al. 2012, Nature, 486, E1; Dong et al. 2015, The ATEL, 7774; Dong et al. 2016, Science, 351, 257; Graur et al. 2016, ApJ, 819, 31; Kasen 2010, ApJ, 708, 1025; Margutti et al. 2014, ApJ, 790, 52; Maund et al. 2013, MNRaS, 433, L20; Milne et al. 2001, ApJ, 559, 1019; Patat et al. 2015, A&A, 577, A53; Rest et al. 2008, ApJ, 680, 1137; Rest et al. 2012, Nature, 482, 375; Seitenzahl et al. 2009, MNRaS, 400, 531; Sparks et al. 2008, AJ, 135, 605; Tylenda et al. 2012, A&A, 548, A23; Wang et al. 1996, ApJL, 462, L27; Wang et al. 2008, ARAA, 46, 433; Yang et al. 2016a, arXiv:1610.02458; Yang et al. 2016b, arXiv:1610.10094