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Preface: Frontiers in Astrophysics (II) — A special issue dedicated to the 20th anniversary of RAA (2001–2020)

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Abstract On the arrival of the 20th anniversary of the journal, Research in Astronomy and Astrophysics (RAA), we see rapid progress in the frontiers of astronomy and astrophysics. To celebrate the birth and growth of RAA, a special issue consisting of 11 invited reviews from more than 30 authors, mainly from China, has been organized. This is the second volume of the special issues entitled Frontiers in Astrophysics published in RAA. The publication aims at evaluating the current status and key progress in some frontier areas of astronomy and astrophysics with a spirit of guiding future studies.

Key words: galaxies: statistics — Galaxy: structure — stars: binaries, black holes — planetary systems — Sun: CMEs, filaments, magnetic fields — astronomical instrumentation, methods and techniques

As an international journal, Research in Astronomy and Astrophysics (RAA) was established in 2001 as a continuation of Acta Astrophysica Sinica (1981–2000, in Chinese). From its launch, RAA has aimed at exhibiting the latest advancements in astronomy and astrophysics in China as well as around the world, driving original research in astronomy, and promoting academic exchanges between Chinese scholars and international fellow scientists. RAA devotes itself to developing a fine style of study and cultivating outstanding research talents.

As we ushered in the 20th anniversary, we witnessed the great and astonishingly rapid progress in the frontiers of astronomy and astrophysics, as well as the growth of RAA. Astronomy and astrophysics remain rich, vigorous and flourishing in many frontiers with scientific challenges and esthetical beauty. It is great to see that since the dawn of the new millennium, there have been 19 scientists working on astronomy and astrophysics who won seven sets of Nobel Prizes for Physics, including the one from 2020. Great advances in astronomy and astrophysics have also been seen in China in quite many branches of astrophysics.

During the XXVIIIth IAU General Assembly in Beijing (2012 August 20–31), a special issue entitled Frontiers in Astrophysics was published in RAA, which is now listed as the first in the series of special issues with this title. It was declared that the special issue was aimed at a timely, in-depth evaluation of the current status and key progress, with suggestions for future directions (Yan et al. 2012). Although the current volume is published in the same spirit, it focuses more on studies in a few frontier areas with more involvements of Chinese colleagues. As we will see, the authors of this volume have been trying to synthesize the vast amount of primary research literature and identify the principal advances in astronomy and astrophysics. We introduce their contributions in the following.

1 GALAXIES AND COSMOLOGY

Galaxy redshift surveys have provided a fundamental data base to map and probe the structure and evolution of the Universe. In addition, galaxy redshift surveys are of particular importance for investigating the origin of cosmic acceleration. Wang & Zhao (2020) provide a very careful and concise review on cosmological analysis of galaxy surveys with multiple tracers. The authors first point out the limitation on the precision of the data analysis if only one tracer is observed, and, then, present the idea of the multi-tracer method by which this limitation can be relaxed. In addition, they have outlined the key steps in practical data analysis and provided a few worked examples based on the GAMA, BOSS and eBOSS galaxy surveys.

The Milky Way is a normal spiral galaxy, and is the home galaxy of human beings. The earliest drawing of the Milky Way structure was made in 1785 based on astronomical observations. However, as noted by Shen & Zheng (2020), the real appearance of the Milky Way remains elusive nowadays. They present a careful review on the known structure and kinematics of the Galaxy so far, and show us an updated picture that the Galaxy consists of a large peanut-shaped bar, four major spiral arms, and a local arm likely to be longer than previously thought. Shen and Zheng list the key open questions for future studies and look forward to the next generation of major instrumentation and more sophisticated chemo-dynamical modeling.

2 SUPERMASSIVE BLACK HOLES AND GRAVITATIONAL WAVES

Close binaries (CBs) of supermassive black holes (SMBHs) are those binaries with separations less than $\sim$0.1 pc. Nano-Hz gravitational waves (GWs) are expected to be radiated by CB-SMBHs that formed during galaxy mergers and are detectable with the Pulsar Timing Array (PTA) technique. So far, unfortunately, there have been no Nano-Hz GWs detected and no CB-SMBHs definitively identified. In an in-depth review, Wang & Li (2020) focus on the observational signatures of CB-SMBHs from theoretic expectations, numerical simulations and observations. They review in great detail the likely observational signatures of CB-SMBHs and list key open questions that are relevant. As they have concluded, systematic searches and careful studies of CB-SMBH candidates based on electromagnetic observations are necessary and important, moreover, a combination of reverberation mapping applying spectro-astrometry with high spatial resolution will further reinforce the capability for discovering CB-SMBHs.

3 STARS AND EXOPLANETS

Stars are the elementary building blocks of galaxies and the universe; more than half of the stellar population appears in binaries. To understand the evolution of the binary population and the consequent object formation, a fundamental theoretical approach, named binary population synthesis (BPS), was initiated and has been developed since early 1990s. In this special issue, Zhanwen Han and his former students make a thorough and concise review on the general picture and key ingredients of BPS, and the widespread use of BPS in many areas in astrophysics (Han et al. 2020). The authors demonstrate the extraordinary expansion of the Tree of Life grown from BPS with its fruits, such as compact binaries, supernovae, γ-ray bursts, X-ray binaries (XRBs), pulsars, novae, cataclysmic variables, hot subdwarf stars, barium stars and blue stragglers (see Fig. 2 in the paper).

Observationally, Li (2020) has paid special attention to the youngest XRBs which are suggested to be associated with supernova remnants (SNRs), and thus are short-lived (with ages $<\sim10^5$ yr). The author has carefully reviewed the detailed observational characteristics of all the six known youngest XRBs and explored their implications on the formation and evolution of compact stars. The author particularly reviewed the most recent BPS modeling (Han & Li 2020; Xing 2020) on two of the youngest XRBs with an emphasis on the formation of Roche-lobe overflow XRBs within the SNR's lifetime.

Qian et al. (2020) present a careful review on contact binaries which consist of two strongly interacting component stars which fill their critical Roche lobes and share a common envelope. The authors have introduced and cataloged the stellar atmospheric parameters for more than nine-thousand EW-type CBs based on low- and medium-resolution spectroscopic surveys by LAMOST. Several particular groups of contact binary systems are reviewed in great detail. They are marginal, deep and low-mass ratio, near or below the short-period-limit, and advanced evolved contact binaries. The authors present several important statistical relations, e.g., period-temperature relation for normal EW CBs, which was obtained by applying LAMOST data. They also propose a new period cut-off at around 0.15 d and predict that more and more contact binaries with periods between 0.15 d and 0.2 d will be detected in the future.

An entire new era in astronomy and astrophysics has been opened following the historic discovery of the first exoplanet by Mayor & Queloz (1995). In a well-organized review, Liu & Ji (2020) summarize the whole story about planet formation in a vivid way. They describe each step of the scenario of modern core accretion planet formation, i.e., dust growth and radial drift, planetesimal formation by streaming instability, core growth by planetesimal accretion, and pebble accretion (see Fig. 4 in the review). Liu and Ji discuss all the key theoretical concepts in the physical processes and list a few of the ultimately important questions that are open for future considerations.

4 SOLAR MAGNETIC ACTIVITY

Magnetic flux ropes are referred to as a group of helical field lines collectively winding around a common axis. This typical magnetic pattern or topology has been suggested to be a central engine in driving plasma activity in the solar atmosphere and planetary magnetospheres, as well as in other cosmic plasma environments. Studies of magnetic flux rope have been an extremely active area in solar physics, particularly in the last 20 years. In an

extraordinarily careful review, Liu (2020) presents quantitative descriptions on magnetic flux ropes from different perspectives, and summarizes the current observations of flux rope structure and evolution toward solar eruptions, in combination with results from numerical simulations and theoretical considerations. The author highlights an initiation mechanism for coronal mass ejections (CMEs) with a key scenario in which plasmoids coalesce into "seed" flux ropes in current sheets, and poses some key questions, in particular, on the formation of large-scale flux ropes and the interactions among flux ropes and ambient magnetic fields.

As is well known, solar filaments (prominences) are one of the basic forms of solar activity, and it is intrinsically associated with two other forms of activity, solar flares and CMEs, which appear to be more violent and potentially disastrous. Understanding filaments would provide a key in learning the physics of general plasma activity. An interesting review on some interesting aspects in solar filament studies has been presented by Chen et al. (2020). The authors present their review in three sections: what we already know, new or controversial topics, and prospects for other topics. In the review, Chen et al. list seven new or controversial topics, including the fine structures in filaments, filament chirality and magnetic helicity, magnetic field configuration, counterstreaming flows in filaments, tornado-like structures and so on. They are looking forward to more innovative studies on solar filaments and predict a boom in research on solar filaments in the coming decade.

5 PROJECTS

The LAMOST-Kepler (LK) project, initiated from 2010, is a flourishing international collaboration program. Fu and his collaborators (Fu et al. 2020) have brought us an excellent overview of the project in light of the potentiality and productivity in scientific research. They divided the project into Phase I and Phase II. The former (LK) is highlighted by LAMOST low-resolution spectroscopic observations for 155 623 stars in the Kepler field; while the latter (LK-MRS, beginning from September 2018) is characterized by LAMOST time-domain medium-resolution spectroscopic observations for about 12 000 stars in four central plates of the Kepler field. The huge amount of qualified data has been widely applied in scientific research in frontier areas, such as stellar pulsations and astero-seismology, exoplanets, stellar magnetic activity and flares, peculiar stars and the Milky Way, binary stars, etc. It is very encouraging that more astronomers actively use the LK and LK-MRS data to advance scientific progress.

The Antarctic plateau has long been dreamed of and explored for advanced ground-based astronomical observations; while over more than ten years, Dome A has been gradually confirmed to be the best site on Earth for optical, infrared, and terahertz (THz) astronomical observations. This highest location on the polar ice cap was first visited by humans in January 2005 by the 21st Chinese National Antarctic Research Expedition (CHINARE). In chronological order, Shang (2020) carefully summarizes all the concrete efforts in astronomical campaigns at Dome A, including all the experiments and instrument developments. He has comprehensively reviewed the time-domain research conducted at Dome A and the results for site testing. The author looks forward to the major instrumentation at Dome A, among which the Kunlun Dark Universe Survey Telescope (KDUST, a 2.5 m optial/infrared telescope) and Dome A TeraHertz Explorer (DATE5, 5 m at wavelengths $\sim$ 350 μm) seem to characterize the not-far future of Dome A astronomy.

We expect that the special issues in Frontiers of Astrophysics will continue to highlight newly established achievements, new ideas and new methods in this ever growing field.

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