

our 25 timing measurements, a total of 83 times of minimum light spanning about 66 yr were used for a period study. It was found that the orbital period of GX Aur has varied due to two periodic oscillations superposed on an upward-opening parabolic variation. The long-term period increase rate is deduced as  $+9.636 \times 10^{-10} \text{ d yr}^{-1}$ , which can be produced as a mass transfer from the secondary star to the primary at a rate of  $3.136 \times 10^{-6} M_{\odot} \text{ yr}^{-1}$ , among the largest rates for contact systems. The periods and semi-amplitudes of the two periodic variations are about  $P_3 = 8.7 \text{ yr}$  and  $P_4 = 21.2 \text{ yr}$ , and  $K_3 = 0.011 \text{ d}$  and  $K_4 = 0.017 \text{ d}$ , respectively. The most reasonable explanation for both cycles is a pair of light-travel-time effects driven by the possible existence of an unseen third and fourth components with projected masses of  $M_3 = 0.91 M_{\odot}$  and  $M_4 = 1.09 M_{\odot}$  in eccentric orbits of  $e_3 = 0.13$  and  $e_4 = 0.73$ . Because no third light was detected in the light curve synthesis, each circumbinary object could be a compact star or a binary itself.

#### [7 ST-04] Apsidal motions of 90 eccentric binary systems in the Small Magellanic Cloud

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We examined thousands of light curves of stars brighter than 18.0 mag in I band and less than mean magnitude error of 0.1 mag in V band from the OGLE-III eclipsing binary catalogue, and found 90 new binary systems exhibiting apsidal motion. In this study, the samples of apsidal motion stars in the SMC were increased by 250 percent than previously known. In order to determine the period of the apsidal motion for the binaries, we analysed in detail both light curves and eclipse timings using the MACHO and OGLE photometric database obtained for about 20 yrs. For the eclipse timing diagrams of the systems, new times of minimum light were derived from the full light curve combined at intervals of one yr from the survey data. The binaries presented in this paper have apsidal motion periods in the range of 12-918 yrs. An additional short-term oscillation was detected in five systems (OGLE-SMC-ECL-1634, 1947, 3035, 4946, and 5382), which most likely arise from the existence of a third body orbiting each eclipsing binary. All of the selected systems can be used for the statistical study of the interior structure of the stars in the SMC through their apsidal motions due

to the homogeneous data and consistent analysis methods.

#### [7 ST-05] Wolf-Rayet star evolution with clumpy envelope structure.

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It is well known that theoretical models of Wolf-Rayet stars are not consistent with observational data in terms of temperature and stellar radius. Recent study in analytical and numerical simulations show the importance of density inhomogeneity in stellar envelope. Using 1-dimensional numerical simulations, we study how such clumpiness arisen over convective surface of Wolf-Rayet stars affect their evolutionary path. Starting from pure helium star models, we constructed 21 different initial conditions by varying stellar mass, metallicity, and the clumpiness of the sub-surface convection zone. We run the simulations until the oxygen-burning is reached and find that the influence of the clumpiness is sensitive to the initial metallicity. Our models with high metallicity including the effect of the density inhomogeneity can roughly explain the observed properties of Wolf-Rayet stars such as stellar radius and temperature. By contrast, despite a considerable amount of density inhomogeneity is given, low metallicity models could not fully explain observations. To understand the inconsistency in low metallicity models, detailed study with improved model is required, taking account of the error range of the observations.

#### [7 ST-06] Infrared-Visible Photometric Analyses of Core-collapse Supernovae and Supernova Dust Formation

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We present multiband photometric analyses of

10 core-collapse supernovae in the near-infrared and visible wavebands. Our infrared data is from observations of the supernovae using the Wide Field Infrared Camera at the Palomar 5-m telescope as part of the Caltech Core-Collapse Supernova Program, while we obtain the visible data from publicly available data base. By fitting the broadband spectral energy distribution with a black body and, when necessary, modified black body component, we estimate physical parameters of the supernovae more accurately and also conduct a systematic investigation of when the supernovae show any indication of dust formation.

### [ㄱ ST-07] Time monitoring observations of H<sub>2</sub>O and SiO masers toward semi-regular variable star R Crateris

Dong-Jin Kim<sup>1,2</sup>, Se-Hyung Cho<sup>2</sup>, Young-Joo Yun<sup>2</sup>, JaeHeon Kim<sup>2</sup>, Yoon Kyung Choi<sup>2</sup>, Dong-Whan Yoon<sup>2</sup>, Suk-Jin Yoon<sup>1</sup>

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With the Korean VLBI Network (KVN), both single dish and VLBI monitoring observations of H<sub>2</sub>O and SiO masers were performed toward the semi-regular variable star R Crateris. In the case of 11 VLBI monitoring observations from Jan. 5, 2014 to Jan. 7, 2016, successful superposed maps of H<sub>2</sub>O and SiO masers were obtained at 7 epochs by adopting the Source Frequency Phase Referencing (SFPR) method. These results enable us to investigate the development of outflow and asymmetric motions from SiO maser to H<sub>2</sub>O maser regions according to stellar pulsation which are closely related with a mass-loss process. Single dish monitoring observations of H<sub>2</sub>O and SiO masers were also carried out from 2009 June to 2016 Feb. Intensity variations between H<sub>2</sub>O and SiO masers were investigated according to stellar optical phases together with peak velocity variations with respect to the stellar velocity. We will compare the VLBI results among different maser transitions with those of single dish.

### [ㄱ ST-08] Calibrator Survey for evolved stars using the KVN

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We present results of a calibrator search near twenty evolved stars using the Korean VLBI

Network (KVN). Our evolved star targets include candidate sources for a Key Science Project (KSP) of the KVN. The KSP plans to investigate the spatial structure and dynamical effects between SiO and H<sub>2</sub>O maser regions including mass-loss process and development of asymmetry in circumstellar envelopes of evolved stars. For these purposes, we need compact and strong extragalactic sources close to the evolved stars. We carried out 5 observations in order to detect radio continuum sources that can be used for source frequency phase-referencing (SFPR) -based analysis. We observed 153 sources, out of which we detected 29 at 22 GHz and 20 at 43 GHz at signal-to-noise ratios higher than 50 at all baselines. Therefore, we successfully found target and calibrator pairs for the KVN KSP.

### [ㄱ ST-09] Radial distribution of RGB stars in the Globular Clusters with multiple stellar populations

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Most globular clusters are now known to have two or more stellar populations with different chemical properties. In order to understand the origin and evolution of multiple stellar populations in these globular clusters, it is necessary to study not only the chemical property, but also the dynamical property. In our previous works (Lim et al. 2015; Han et al. 2015), we have shown that Ca narrow-band photometry can be combined with low-resolution spectroscopy to effectively study the chemical properties of globular clusters. In this talk, we will show our observations are also useful to study the radial distribution of stars in globular clusters with multiple stellar populations, and report our preliminary results.

### [ㄱ ST-10] Spectroscopic study of Planetary hosting star HD 20794

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We observed the high resolution spectra of a solar-neighborhood planetary hosting star HD 20794. The analysis of spectroscopic data was