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The progenitor of Type Ia supernovae is largely expected as a close binary system of a carbon/oxygen white dwarf (WD) primary and its secondary non-degenerate (single degenerate; SD) or degenerate companion (double degenerate; DD). Here we present a high-cadence monitoring observation of SN 2021hpr in a spiral galaxy, NGC 3147. SN 2021hpr shows typical characteristics as a normal type Ia supernova from its photometric ( $\Delta m_{15}(B)=1.01 \pm 0.03$ , dust free  $M_{B,max}=-19.45 \pm 0.02$ ) and spectroscopic data. To investigate its progenitor system, we fit the early part of *BVR/I*-band light curve simultaneously with a combined version of ejecta-companion and simple power-law model. As a result, we found a significant feature of an early excess possibly from a  $7.63 \pm 0.52 R_{\odot}$ -sized companion at the optimal viewing angle while the fit is not successful at the common viewing angle. No possible red sources brighter than  $F555W=-7.01$  AB mag is detected at the SN location in Hubble Space Telescope (HST) pre-explosion images, excluding massive stars with initial mass of  $>16 M_{\odot}$  as companions. We suggest the progenitor system of SN 2021hpr can be a fairly large companion such as a main sequence, a low mass subgiant, and a helium giant star. In addition, a possibility of the ejecta-Disk Originated Matter (DOM) interaction for the DD scenario considering linearly-rising early flux still remains.

## 고에너지/이론천문학

### [구 HA-01] Preexisting Suprathermal Electrons and Preacceleration at Quasi-Perpendicular Shocks in Merging Galaxy Clusters

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Merger shocks with  $M_s < \sim 3-4$  have been detected in galaxy clusters through radio observations of synchrotron radiations emitted from cosmic-ray (CR) electrons. The CR electrons are believed to be produced by the so-called diffusive shock acceleration (DSA) at the merger shocks. To describe the acceleration of electrons, the injection into DSA has to be understood. Recent studies have showed that electrons could be energized through stochastic shock drift acceleration (SSDA), a mechanism mediated by multi-scale plasma waves at shock transition zone. However, such preacceleration process seems to be effective only at the supercritical shocks with  $M_s > \sim 2.3$ , implying that further studies should be done to explain radio relics with weaker shocks. In this talk, we present the results obtained by fully kinetic 2D particle-in-cell (PIC) simulations, which include pre-existing suprathermal electrons possibly ejected from active galactic nuclei (AGNs) or produced by previous episodes of turbulence/shocks. The simulations indicate that the pre-existing electrons enhance the upstream plasma waves in shocks with  $M_s < \sim 2.3$ . However, the wavelength of such waves is not long enough to scatter off suprathermal electrons and energize them to the injection momentum for DSA. Hence, we conclude that preexisting suprathermal electrons alone would not solve the problem of electron acceleration at radio relic shocks.

### [구 HA-02] Features in broadband SEDs of young pulsar wind nebulae: existence of two different electron populations

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Pulsar Wind Nebula(PWN)는 radio부터 TeV band 까지 넓은 파장에 걸쳐 복사를 하며 이 복사는 Spectral Energy Distribution(SED)으로 측정된다. 관측된 SED는 두 개의 주요한 bump를 보이는데 low-energy emission bump는 synchrotron radiation에 의해 만들어지고 high-energy emission bump는 inverse Compton scattering에 의해 만들어진다. 대부분 PWN들의 SED는 단일 전자 분포로 설명이 가능하지만 최근 연구 결과에 의하면 Crab nebula, G21.5-0.9 같은 일부 young pulsar wind nebula의 X-ray SED에서 단차나 기울기의 변화 등 단일 전자 분포로 설명하기 어려운 부분이 관측되기도

한다. 이런 PWN에 대하여 우리는 이중 전자 분포를 이용해서 broadband SED가 잘 설명이 되는지 확인하고 이를 통하여 PWN 입자 가속의 특성을 이해해보고자 한다.

### [석 HA-03] Applying intrabinary shock model to various X-ray observation data

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Low mass X-ray binary(LMXB) 중 accretion disk가 존재하지 않으며 매우 작은 질량 ( $1 \ll M_{\odot}$ )의 동반성을 가지는 pulsar binary system에서 중성자별과 동반성의 항성풍은 상호작용하여 intrabinary shock(IFS)을 형성한다. 이곳에서 입자들은 상대론적으로 가속되어 싱크로트론 복사를 방출한다고 생각된다. 이 복사는 X-선 영역으로 관측되며 이때 관측된 X-선 궤도 광도곡선은 IFS의 모양에 따라 달라진다. 우리는 IFS의 X-선 복사 과정을 모델화하여 shock의 모양과 내부의 전자 특성을 파악하고, 광학 관측을 통해 얻은 orbital parameter와 비교하며 binary의 geometry를 보다 정확히 이해하고자 한다. 이 발표에서는 다양한 pulsar binary system의 Chandra, XMM 그리고 NuSTAR의 X-선 관측 데이터에 IFS 모델을 적용해보고 IFS와 binary의 geometry를 분석한 결과를 제시한다.

### [구 HA-04] A correlation analysis about properties of quiescence magnetar

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우리는 quiescent state magnetar의 물리적 특성을 연구하기 위해 복사특성이 잘 알려진 24개의 대상을 선정하였고 가장 어두운 시기(quiescent state)의 Chandra와 XMM-Newton의 X-ray 관측 데이터를 분석하여 복사특성과 시간 특성을 측정하였다. 이 측정을 이용하여 복사특성과 시간 특성 사이의 여러 경우에 대해 상관관계를 분석하였다. 그 결과 기존에 높은 상관관계를 갖는 것으로 알려진 표면 자기장( $B_s$ )과 흑체복사 광도( $L_{BB}$ ),  $B_s$ 와 X-ray photon index ( $\Gamma_X$ ) 관계를 더 많은 magnetar에 대하여 재확인하였으며, spin-down rate ( $\dot{P}$ )와  $L_{BB}$ , characteristic age ( $\tau_c$ )와  $L_{BB}$ 의 새로운 유의미한 관계를 찾았다. 또한 magnetar의 pulsed fraction ( $PF$ )과 흑체복사 반경( $R_{BB}$ ),  $PF$ 와  $\Gamma_X$ , 그리고  $\dot{P}$ 와  $\Gamma_X$ 가 서로 상관되어 있다는 단서를 확인하였다.

### [석 HA-05] An Investigation of X-ray pulsation searches: Weighted vs unweighted H test

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Timing analysis에서 pulsar 또는 magnetar의 pulsation 측정은 background 또는 주변의 다른 source의 영향으로 매우 세밀하게 측정을 진행해야 할 수 있다. 하지만 gamma-ray 영역에서는 instrument의 낮은 imaging resolution으로 인해 likelihood 분석법을 사용하며, pulsation측정의 sensitivity를 향상시키기 위해 weighted H-test를 적용하고 있다. weighted H-test는 Instrument의 responses와 source, background의 radiational properties를 이용하여 각 photon의 probability를 계산하고 이를 weight하여 pulsation detection의 sensitivity를 향상시키는 방법으로 이번 연구를 통해 이를 X-ray에서 적용할 수 있도록 확장하였다. 이번 발표에서는 X-ray 데이터 중 상대적으로 낮은 imaging resolution을 갖는 XMM-Newton data에 weighted H-test를 적용하여 기존의 H-test와의 차이를 비교해보고, weighted H-test가 갖는 이점에 대하여 논의하고자 한다.

## 천문우주관측기술

### [구 AI-01] 7-Dimensional Telescope (7DT) for multi-messenger astronomy

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The 7-dimensional Telescope (7DT) is an innovative multiple telescope system that can perform a rapid identification of optical counterparts of gravitational-wave (GW) sources and a wide variety of other astronomical projects. This telescope is being developed as a part of the recently approved National Challenge program, the GW Universe project, with a full operation planned at the end of 2023. The word 7-dimension stands for x, y, z positions, the radial velocity, the time, the wavelength, and the flux of astronomical sources, implying the telescope's capability of performing time-series wide-field, IFU-type spectroscopic observations. The 7DT is composed of about twenty 0.5-m wide-field telescopes, and it can obtain spectral-imaging data at 40 different wavelengths to the depth of 20 AB mag with 3 min exposure for a given epoch. In this talk, we will introduce the telescope system, and outline its scientific capabilities with an emphasis on multi-messenger astronomy and a few other key science topics.