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Planetesimal Dynamics in the Presence of a Massive Companion
連星系における微惑星の軌道進化

The standard models of planet formation explain well how planets form in axisymmetric, unperturbed disks in single star systems. However, it is possible that giant planets could have already formed when other planetary embryos start to grow. In other words, the early evolution of planetesimals can be affected by strong perturbations from the massive planets in the system, and thus deviate from the standard scenario. Using N-body simulations, we investigate the dynamics of planetesimals, including the distribution and evolution of their orbital elements, in a system with the presence of nebular gas and a giant planet perturber at 5.2 AU. We aim at finding out the impact of the perturber on the formation of giant planet cores exterior to the orbit of the perturber. While confirming the results from Kortenkamp and Wetherill (2000), we find that the orbits of particles distributed in ~ 9 − 11 AU and ~ 11 − 15 AU are generally aligned, and the typical velocity dispersions of identical-mass particles are ~25 m/s at ~10.4 AU, ~12 m/s at ~12 AU, and ~10 m/s at ~14 AU. While the mass-distribution generally imposes high relative velocities between different-massed bodies, the mass discrepancies between particles in different mass groups have smaller impact on relative velocities when $m1$ and $m2$ are both on the larger-end. These dynamical features of planetesimals displayed in certain parts of the disk can make them "accretion-friendly" regions which are favorable for planetary growth.

Observational Study of Magnetar Outburst in the Radio Bands: Re-activation of XTE J1810-197

(マグネターアウトバーストの電波域での観測的研究：XTE J1810-197の再活性化)

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Abstract

Magnetars are one group of pulsar population, showing relatively slow spin ($\sim$ seconds) and fast spin-down, thought as being young neutron stars with very strong magnetic fields (10^{14-15} G). They are distinguished from ordinary pulsars by intense short bursts, pulsations and outbursts in X-ray and soft gamma-ray which are too strong to be explained only with their spin-down energy. The decay of their ultra-strong magnetic field has been postulated to explain the emission from magnetars. However, the fundamental physics, especially regarding their origin and emission mechanism is still shrouded in mystery.

The detection of four radio-loud sources among the 23 confirmed magnetars shedded light on the puzzling magnetar physics. By enabling magnetar observations to spread out into radio band, radio-emitting magnetars hold the key to distinguish between them and ordinary radio pulsars and to explain the variety of emission mechanism within the magnetar population. Radio-loud magnetars show distinctive characteristics in their radio emission compared to ordinary pulsars: (i) the spectra of radio-emitting magnetars are flatter than those of ordinary pulsars, enabling them to be observable at higher radio frequencies, (ii) Magnetars' radio pulses vary in short and long timescales with regard to the flux density, the shape of pulse profiles, spectral index and polarization properties. What drives these features is still unclear.

We aim the comprehensive understanding of observational properties of radio-emitting magnetars in the multi radio bands, expecting to provide hints to elucidate the radio emission mechanisms and the origin of magnetars. We have developed a data pipeline for detecting radio pulsations of a pulsar. The procedures of our pipeline are presented in this thesis.

Very recently, a radio-loud magnetar, XTE J1810-197, restarted to emit radio pulsations after its secondly-observed X-ray outburst. The magnetar had been detected in 2003 in X-ray with the period of 5.54 seconds. Radio emission and pulsations were also detected about one year later its discovery. However, it suddenly stopped its emission and go into its quiescent state. After spending 10 years of dormancy, a radio outburst was reported on 8 December 2018, with significant flux density.

Right after the first detection, we organized radio observations using Japanese radio antennas aiming to figure out the multi-epoch, multi-frequency properties of the magnetar. Total seven radio antennas of four institutes have been involved in our observations for wide frequency coverage: Iitate antenna of Tohoku University, Kashima 34 m telescope of NICT , Hitachi 32 m telescope of Ibaraki University, and four stations of VERA VLBI (Very Long Baseline Interferometry) array of NAOJ at 0.3, 2, 6 & 8, and 22 GHz, respectively. Total 10 observations conducted from 14 December 2018 until June 2019 are discussed in this thesis.

Using our pipeline, we have successfully detected pulses from this magnetar. At 6 and 8 GHz the pulse intensities were so strong that the profile of each single pulse was visible with strong time variability. The pulse intensities at other frequencies were relatively weak (2 and 22 GHz), or only the upper limit has been obtained at 0.3 GHz. Also large variabilities over time are identified, as known for the common property of radio-emitting magnetar. We present this time/frequency-dependent properties of the reactivated magnetar. During our observation, the radio emission of the magnetar have generally become weaker as time goes in its intensity and in the signal-to-noise ratio distribution of single pulses.

We also measure the spin period using our independently developed pipeline. The estimated spin parameters are consistent with other studies, implying a characteristic age of $\sim$ 8 kyr. As a result, XTE J1810-197 seems to go into the radio-quiet period again, showing the similar but faster changes compared to 10 years ago.