博 士 論 文 公 聴 会

ご 案 内

下記の要領で博士論文公聴会を開催します。皆様のご来聴をお待ちしております。

記

日　時 ： ２０２６年５月２０日（水）　8：50　～ 10：20

場　所 ： Ｆ６０８号室

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題　目 ：From Cosmic Web to Supernova Remnants: Modeling Fast Radio Burst Dispersion Measures to Trace Baryons across Multiple Scales

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論文題目 ： From Cosmic Web to Supernova Remnants: Modeling Fast Radio Burst Dispersion Measures to Trace Baryons across Multiple Scales

論文要旨 ：

Background: Fast radio bursts (FRBs) provide a powerful probe of ionized baryons through their dispersion measures (DMs), but the observed signal is intrinsically multi-scale: it contains contributions from the intergalactic medium (IGM), circumgalactic gas and foreground halos, host galaxies, and source-local plasma. This thesis addresses the FRB DM problem from cosmic-web to source-local scales, with the dual goal of constraining the distribution of the missing baryons and determining how local environments can bias or enrich FRB-based cosmological inferences.

Method: I combine cosmological and zoom-in hydrodynamical simulations with detailed local-environment forward modeling. On large scales, I use the CROCODILE framework based on the {GADGET3/4-OSAKA} smoothed particle hydrodynamics code, including star formation, supernova feedback, and active galactic nucleus (AGN) feedback, to construct light cones, gas density profiles, and FRB DM statistics. These calculations are used to quantify the DM-z relation, the partition of diffuse baryons between the IGM and halos/CGM, and the host-galaxy contribution across dwarf, Milky Way-like, and cluster environments. On local scales, I model a young magnetar embedded in supernova ejecta using time-dependent one-dimensional hydrodynamical simulations with non-equilibrium ionization and radiative cooling, exploring both single-star and binary-stripped progenitors to follow shock structure, ionization evolution, radio transparency, and the time dependence of $\mathrm{DM_{source}}$ and $\mathrm{RM_{source}}$.

Results: The cosmological analysis shows that AGN feedback lowers central halo gas densities, reshapes the CGM-IGM transition, and significantly modulates foreground-halo DM along FRB sight lines. From the DM-z relation integrated to $z = 1$, I constrain the diffuse baryon fraction to $f_{\mathrm{diff}} = 0.865^{+0.101}_{-0.165}$ for the fiducial model and $0.856^{+0.101}_{-0.162}$ for the NoBH model, where $f_{\mathrm{diff}} \equiv f_{\mathrm{IGM}} + f_{\mathrm{halos}}$. I further quantify the redshift evolution of f_{CGM}, f_{IGM}, and $\langle f_{\mathrm{diff,obs}} \rangle$, showing that FRB-inferred baryon fractions depend on both physical gas partition and line-of-sight selection effects. Zoom-in simulations demonstrate that host contributions are strongly environment dependent, remaining typically below $100\,\mathrm{pc\,cm^{-3}}$ for central dwarf-galaxy cases but exceeding $1300\,\mathrm{pc\,cm^{-3}}$ in cluster environments. The local-environment study shows that the dominant time-variable DM component generally arises from the unshocked ejecta, whereas the shocked region contributes only $\lesssim 10\,\mathrm{pc\,cm^{-3}}$. At early times the ejecta contribution follows $\mathrm{DM} \propto t^{-\alpha}$ with $\alpha \simeq 1.8$-1.9. Binary-stripped progenitors generally yield lower DMs than single-star models at fixed initial mass, while composition-dependent mean molecular weights introduce non-monotonic mass trends. Matching the observed $\mathrm{dDM/d}t$ of FRB~20190520B and the late declining stage of FRB~20121102 implies source-local SNR contributions of tens to hundreds of $\mathrm{pc\,cm^{-3}}$. Most models become transparent to GHz

emission by $t_{\mathrm{esc}} \lesssim 70$ yr, and within the shock-only RM framework only the $11\,M_{\odot}$ single-star model reproduces the RM evolution of FRB~20121102.

Conclusions: This thesis shows that FRB dispersion measures must be interpreted as layered signals rather than as a single cosmological observable. Robust FRB cosmology requires explicit modeling of foreground halos, host environments, and source-local plasma, while physically consistent local-environment models are essential for separating cosmological and astrophysical DM components. FRBs are therefore best understood not only as distance indicators, but as multi-scale baryon probes linking the cosmic web, gaseous halos, host galaxies, and young compact-object environments within a unified framework.