

sources lensed by QSO hosts, i.e. the number of lensing QSO host galaxies (hereafter QSO lenses).

SMBH masses in the literature are transformed into the velocity dispersions of their host galaxies using the  $M_{BH}$ - $\sigma$  relation, and in turn the Einstein radii for each QSO-source redshift combination is calculated, assuming singular isothermal spherical mass distributions. Using QSOs and galaxies as potential sources, the probability of a QSO host galaxy being a QSO lens is calculated, as a function of limiting magnitude. The expected numbers of QSO lenses are estimated for ongoing and future wide-imaging surveys, and the Hyper Suprime-Cam Wide survey is illustrated as an example.

## 우주론

### [구 GC-22] Impact of Massive Neutrinos and Dark Radiation on the High-Redshift Cosmic Web

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With upcoming high-quality data from surveys such as eBOSS or DESI, improving the theoretical modeling and gaining a deeper understanding of the effects of neutrinos and dark radiation on structure formation at small scales are necessary, to obtain robust constraints free from systematic biases. Using a novel suite of hydrodynamical simulations that incorporate dark matter, baryons, massive neutrinos, and dark radiation, we present a detailed study of their impact on Lyman-Alpha forest observables. In particular, we accurately measure the tomographic evolution of the shape and amplitude of the small-scale matter and flux power spectra and search for unique signatures along with preferred scales where a neutrino mass detection may be feasible. We then investigate the thermal state of the intergalactic medium (IGM) through the temperature-density relation. Our results indicate that the IGM at  $z \sim 3$  provides the best sensitivity to active and sterile neutrinos.

### [구 GC-23] Graphical study of cosmic inhomogeneity using CMASS galaxy sample

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Sloan Digital Sky Survey 12번째 Data release의 CMASS catalog를 이용하여 우주의 균일, 등방성 여부를 조사하였다. Redshift 범위에 따라 얻은 2차원 영역들을 조사한 결과, CMASS 은하들은 통계조사가 가능한 최대 규모인 반지름 300Mpc/h에서도 여전히 Random catalog에 비해 불균일하게 분포하고 있음을 보였다. 결과를 더 명확하게 보여주기 위해 은하의 분포가 불균일함을 나타내는 통계량을 여러 방법으로 시각화하는 연구를 진행하였다. 밀도 분포를 입체적으로 나타낸 그림에서 최대, 최소 밀도의 차이는 300Mpc/h 규모에서 약 27%에 달한다. 이는 같은 규모에서 최대 약 4.5%의 차이만이 나타나는 Random catalog의 밀도 분포와는 상이한 결과로, 이 규모에서조차 우주에서 은하는 균일하게 분포하고 있지 않다는 것을 밝혔다.

### [구 GC-24] Understanding reionization and cosmic dawn with galaxies and 21-cm

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The properties of unseen high-redshift sources (and sinks) are encoded in the 3D structure of the cosmic 21-cm signal. Here I introduce a flexible parametrization for high- $z$  galaxies' properties, including their star formation rates, ionizing escape fraction and their evolution with the mass of the host dark matter halos. With this parametrization, I self-consistently calculate the corresponding 21-cm signal during reionization and the cosmic dawn. Using a Monte Carlo Markov Chain sampler of 3D simulations, 21CMMC, I demonstrate how combining high- $z$  luminosity functions with a mock 21-cm signal can break degeneracies, resulting in  $\sim$  percent level constraints on early universe astrophysics.

### [석 GC-25] Regional anomalies of cosmic microwave background power spectrum

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We analyze the Planck 2015 cosmic microwave background temperature fluctuation data to find any anomaly in the angular power spectra