Background and Motivation

The cosmic star formation rate (SFR) density, and the cosmic activity of active galactic nucleus (AGN), both shows a notable increase over time, peaking during the era referred to as Cosmic Noon, followed by an exponential decline. AGN feedback is widely postulated to regulate star formation and mass accretion of its host galaxy, called 'co-evolution'.

However, due to cosmic dimming and intrinsic compact size, observing these galaxies at and beyond Cosmic Noon requires high angular resolution and deep sensitivity, which is either impossible or expensive. Therefore I use strong gravitational lensing as a primary tool, to witness how AGN jets feed back on star formation in sub-kpc (kilo-parsec) or even tens of pc scales at high-z.

Research Objectives

I have already preformed comprehensive studies in the case of Cloverleaf system—a lensed starburst quasar at $z = 2.558$—in the source plane (Zhang et al. 2023, Zhang et al. submitted). My research plan basically is to perform my previous studies as a novel method, on larger gravitationally lensed samples, with the observations by VLA, ALMA, and VLBI facilities.

- **Imaging star formation region and AGN jet in sub-kpc scale in radio wavelengthes:** Radio emission derived from free-free emission in star formation is widely believed as a tracer for SFR. By previous multi-band radio studies, I have found that **star formation region and localized AGN radio jet can be distinguished in sub-kpc scale in radio wavelengths,** (Zhang et al. 2023) and that **spatially resolved bremsstrahlung in radio wavelength can trace SFR quantitatively** (Zhang et al. submitted). With de-lensing technology, we can study the intrinsic star formation regions and AGN jet in hundreds or even tens of pc scales at high-z.
- **AGN Jet feedback:** For lensed star-forming galaxies hosting AGNs jets with high inclination angles, overlapping of skewed SFR map, enhanced velocity dispersion, and jet path can indicate AGN-jet feedback. As a 30% star formation efficiency suppression by an AGN jet was found in Cloverleaf (Zhang et al. submitted), the role of AGN-jet feedback in galaxy quenching in the early universe could be re-estimated by larger samples.
- **Resolving star formation region and jet sub-structure in tens of pc scale with VLBI facilities:** Based on the proposed observation conducted by VLBA (project ID: BZ105), with a beam size of $0''.03$, I revealed two knot-structure radio components at L-band near the caustics in the source plane with the spatial resolution of ~ 30 pc, indicating tens-pc scale jet-ISM interaction. Thus, with the observation by EAVN, VLBA, and other VLBI facilities, 10-pc scale imaging can provide detailed star formation and jet feedback information for comparison with nearby galaxies, therefore can update our understanding of the AGN activity across cosmic time.

Methodology

Strong lensing modelling is build with `PyAutoLens` for galaxy-galaxy lensing, plus `Lenstool` for cluster lensing. Data is mainly from archival VLA, ALMA, and VLBI data. I will write proposals for follow-up observations. Target selection could start from the PASSAGES program.

Expected Outcomes

In the first year I will start with about 5 sources. Reliable mass models, reconstructed source plane morphology and kinematics should be solid results. Discovery of AGN localized jet feedback on star formation, jet-ISM interaction, and jet substructures could be promising if the sources are unique.

In the extended years, follow-up observations with radio interferometer (e.g. VLA, VLBA) are very likely to be conducted, based on my previous awarded observational experiences. More lensed sources will be analyzed and localized AGN jet feedback could be revealed at 100-, even 10-pc scales at high-z.

Timeline (first year)

- Month 1–4: Data reduction, source investigation, and lensing model
- Month 5–9: Source plane reconstruction and analysis; Writing follow-up observational proposals
- Month 10–12: Paper writing