Code Test of Radiative Transfer for Ionization

Seok-Jun Chang

MPA

RECAP
erc synergy grant

MAX-PLANCK-INSTITUT
FÜR ASTROPHYSIK

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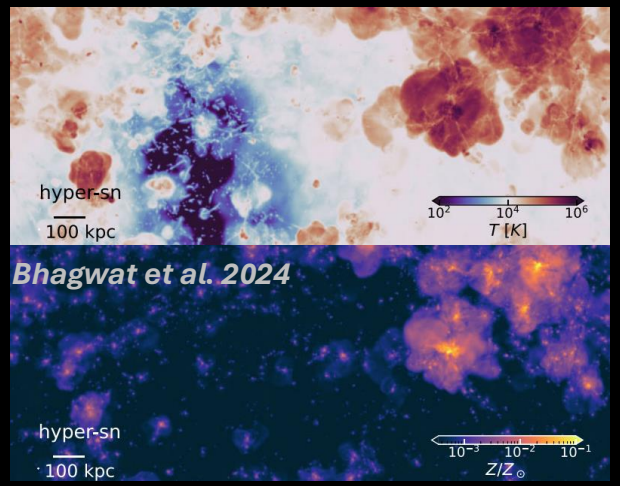
23 Jan 2026, 2nd RECAP online Meeting

My Role in RECAP

Development of Radiative Transfer Scheme for Post-Processing



Snapshots of hydrodynamic simulations

RT Codes for Post-Processing include

- Photoionization by Radiation from Stars & AGN
- Collisional Excitation & Ionization
- Recombination
- Continuum Pumping

Photoionization by UV and X-ray
Ray-tracing to estimate the ionization state in CGM/IGM and their temperatures

Non-Resonance Lines (ex., Hydrogen Balmer lines, [O III], [C II], [N II])
Peeling-Off Technique for mock observations

Resonance Lines (Lyα and metal resonance lines such as Mg II, C IV, O VI)
Ray-tracing for scattering + dust absorption & scattering

Mock Absorption Spectra
Sub-grid model for multiphase gas

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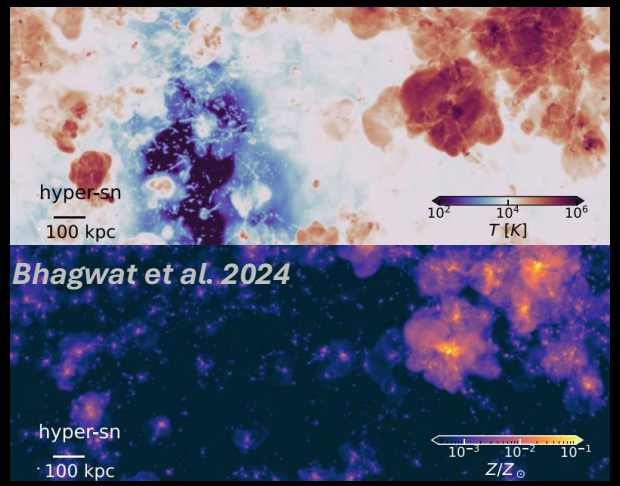

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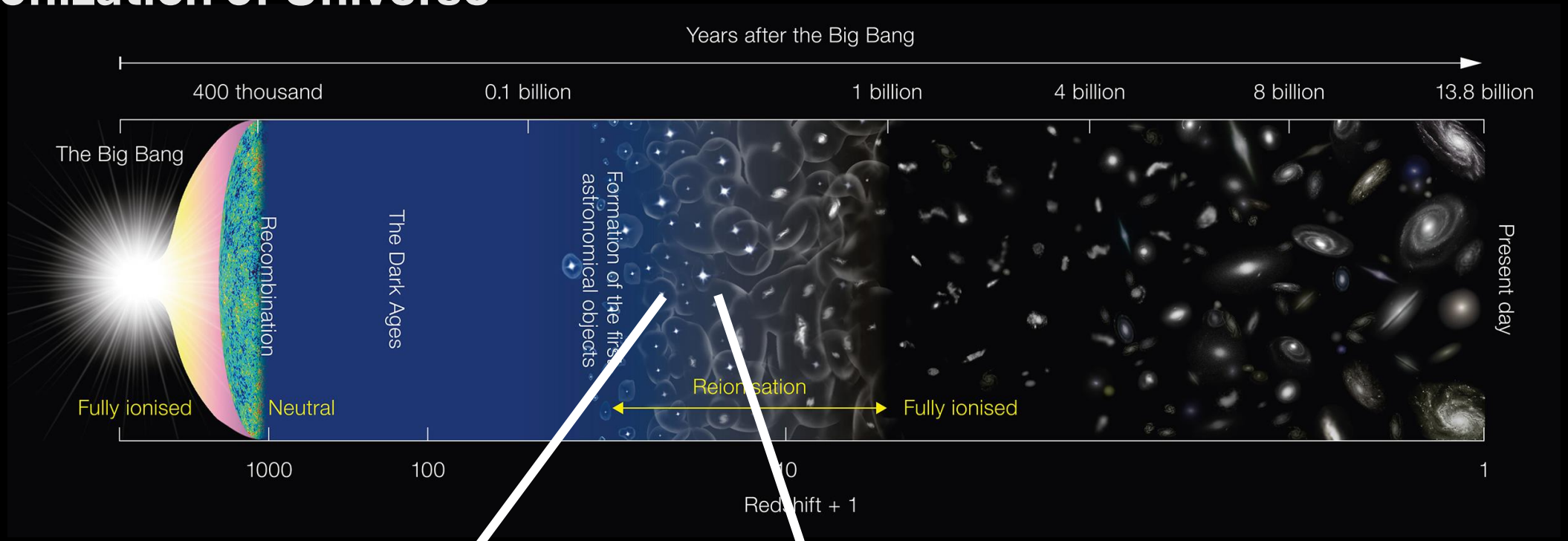
Reionization of Universe



UV & X-ray

$\dot{n}_{\mathrm{Ionization}}$

$\dot{n}_{\mathrm{Recombination}}$

$$\dot{n}_{\mathrm{Ionization}} = n_{HI} \int_{\nu>\nu_{\mathrm{HI}}}^{\infty} \frac{4\pi J_\nu}{h\nu} \sigma_{\mathrm{HI}}(\nu) d\nu$$

$$\dot{n}_{\mathrm{Recombination}} = n_e n_{\mathrm{HII}} \alpha(T)$$

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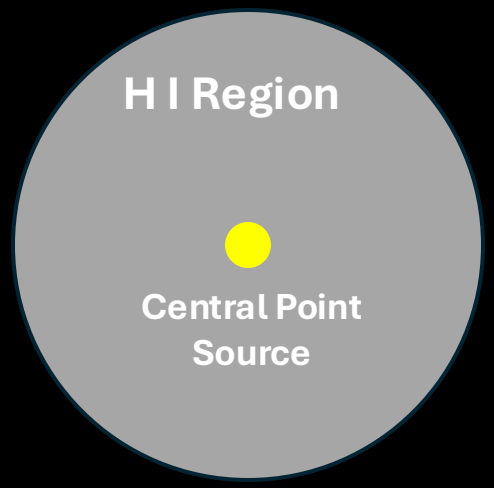
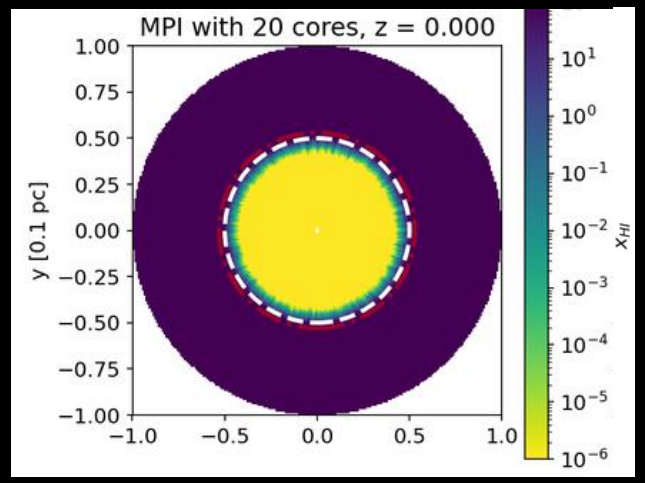
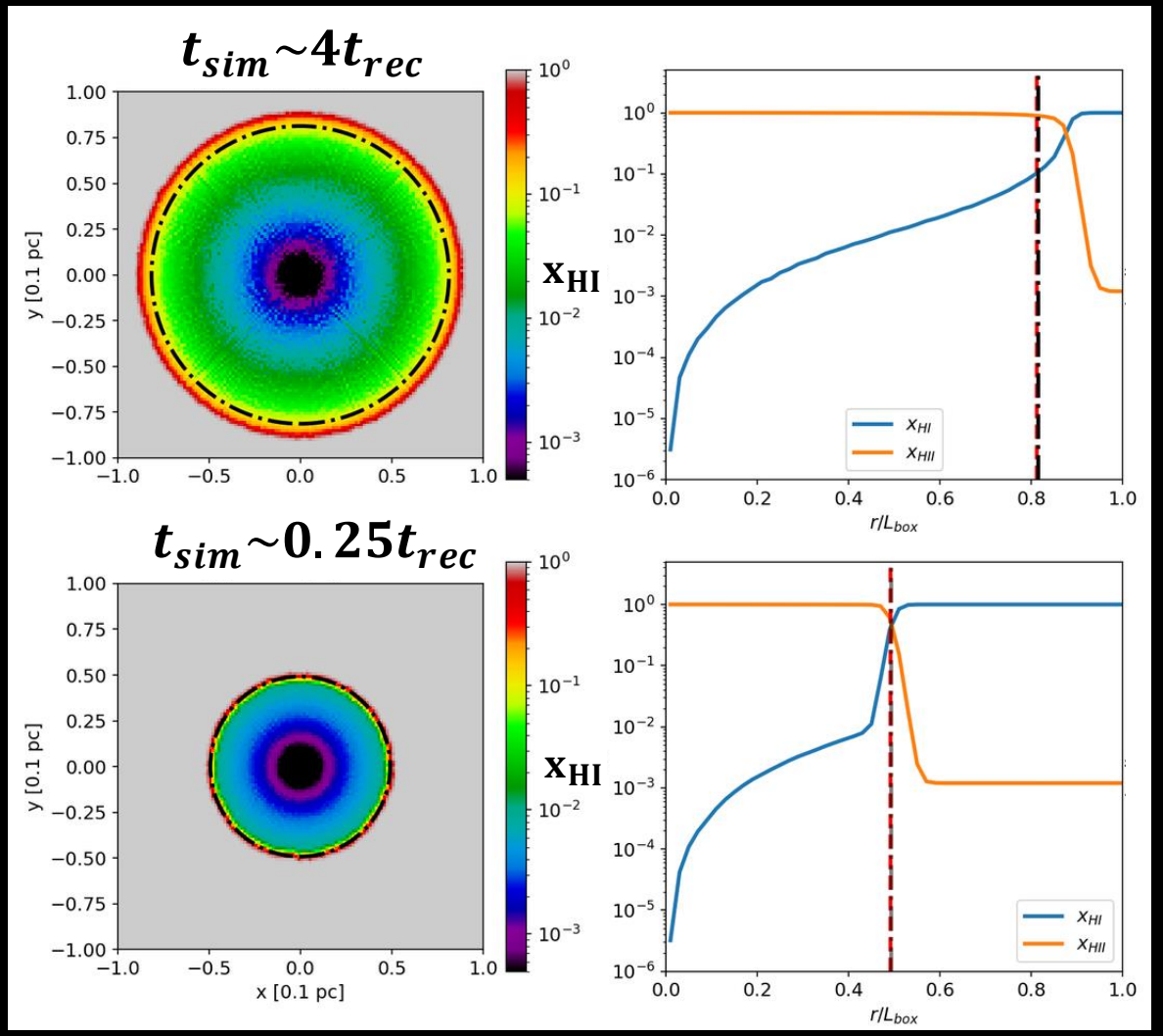
3D RT for Photoionization



Monochromatic source with $E_{photon} = 13.6\ eV$



without recombination



with recombination

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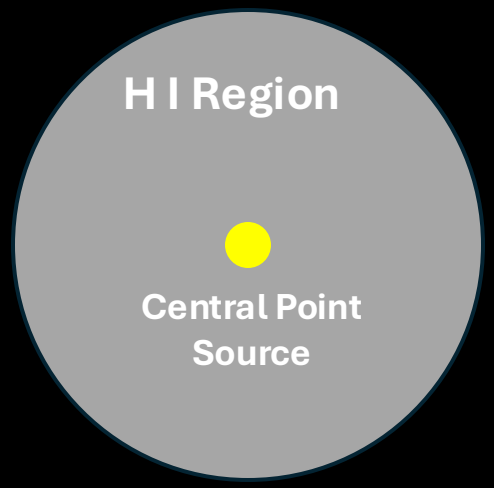
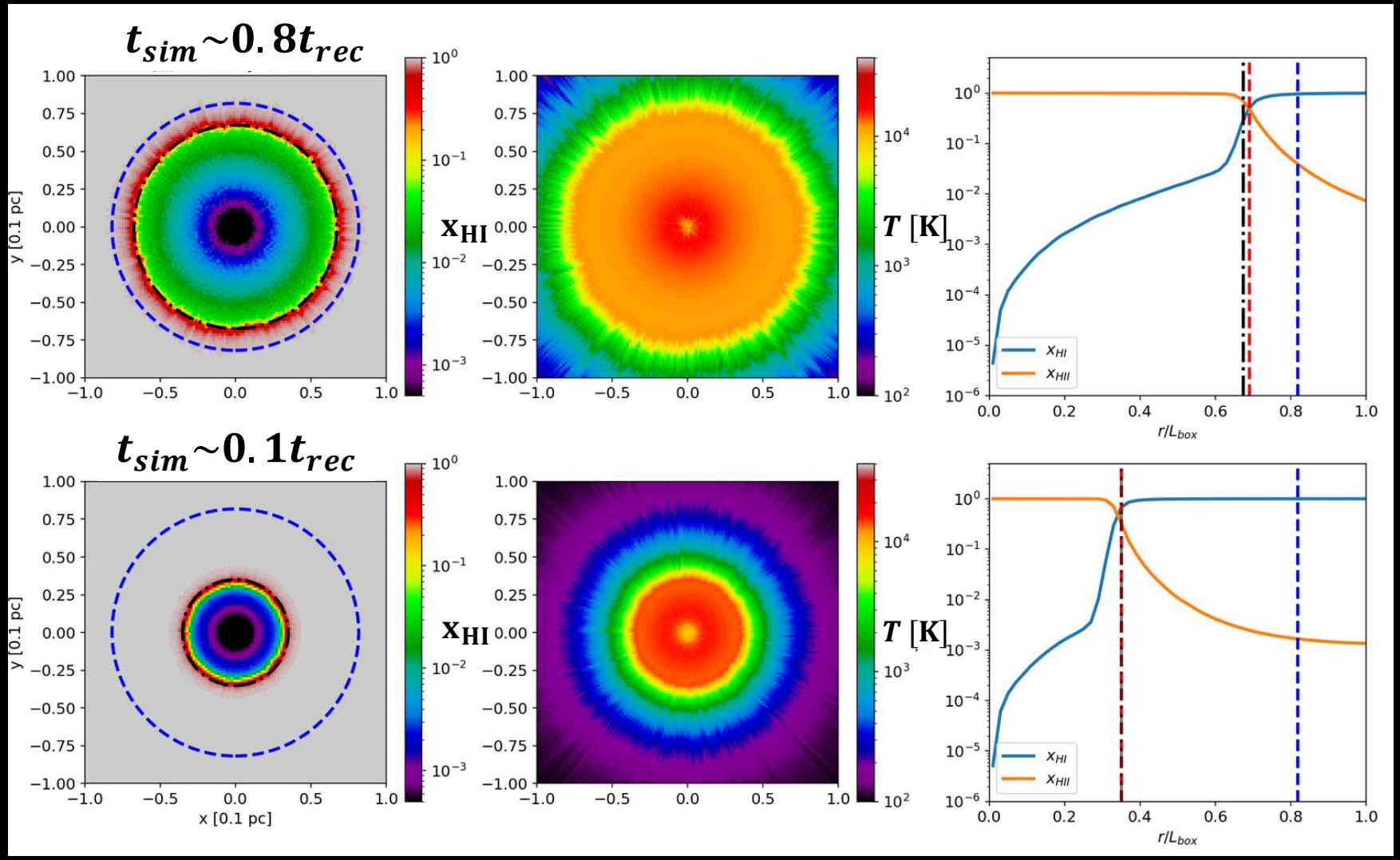
3D RT for Photoionization



Blackbody radiation at $T = 10^5$ K

+ heating & cooling



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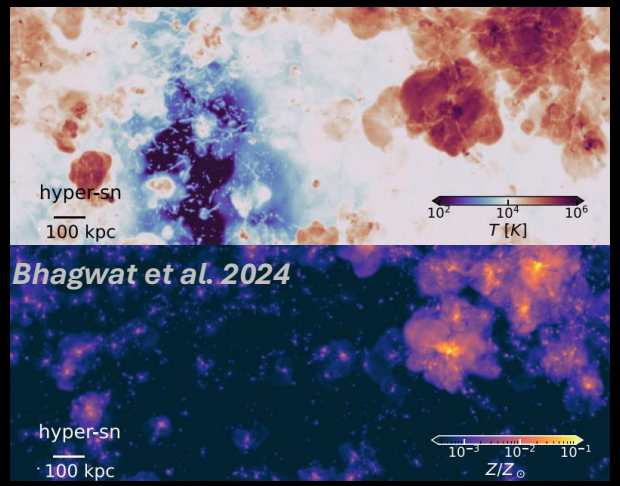

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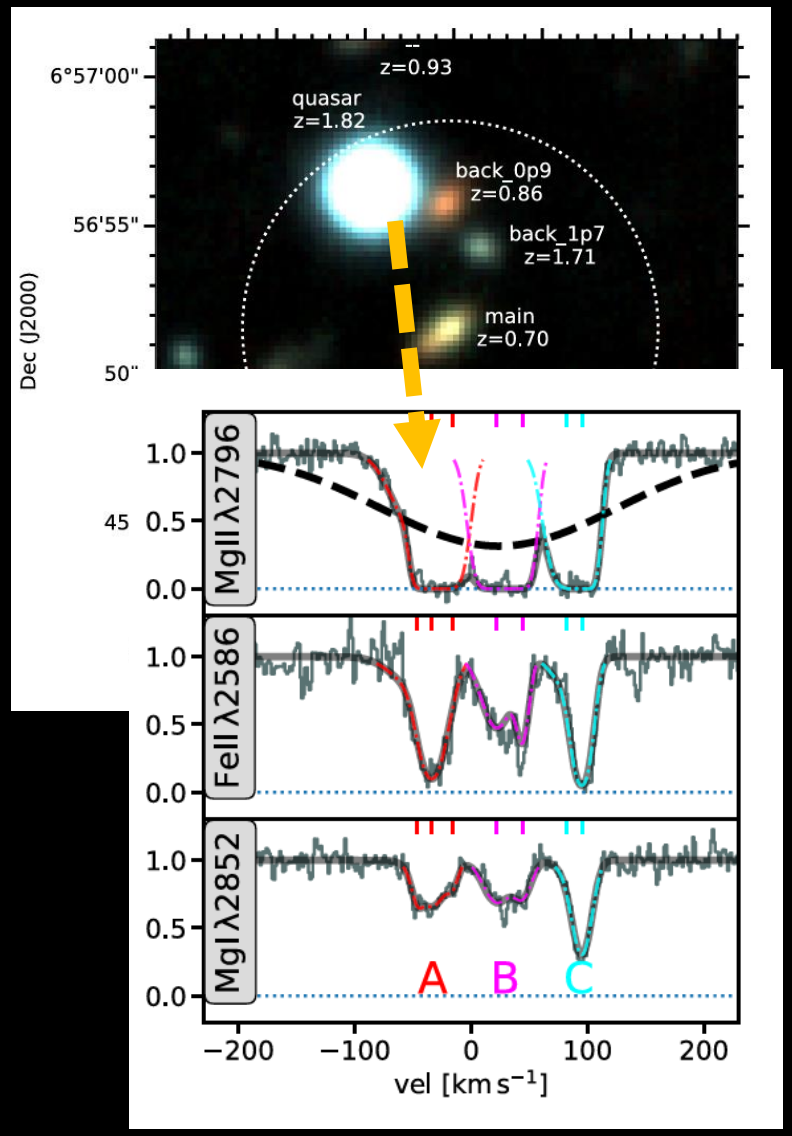
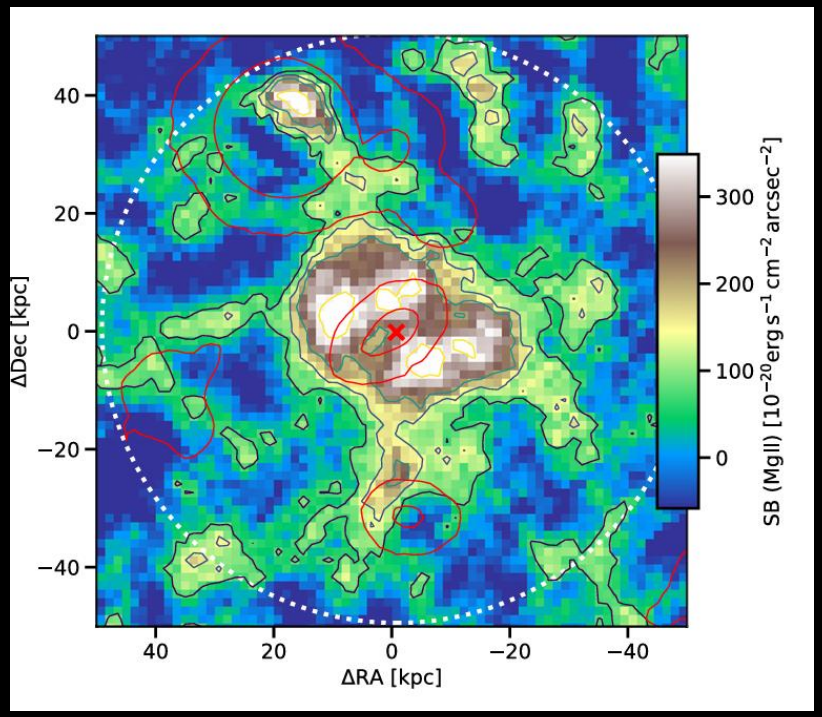
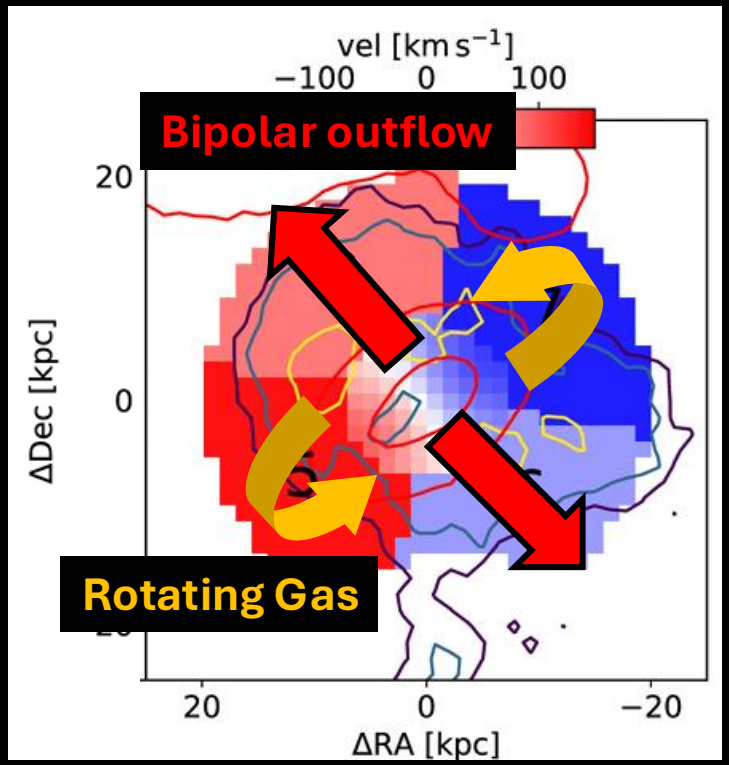
Extended Mg II halo in Zabl et al. 2021





Mg II Narrow Band Image



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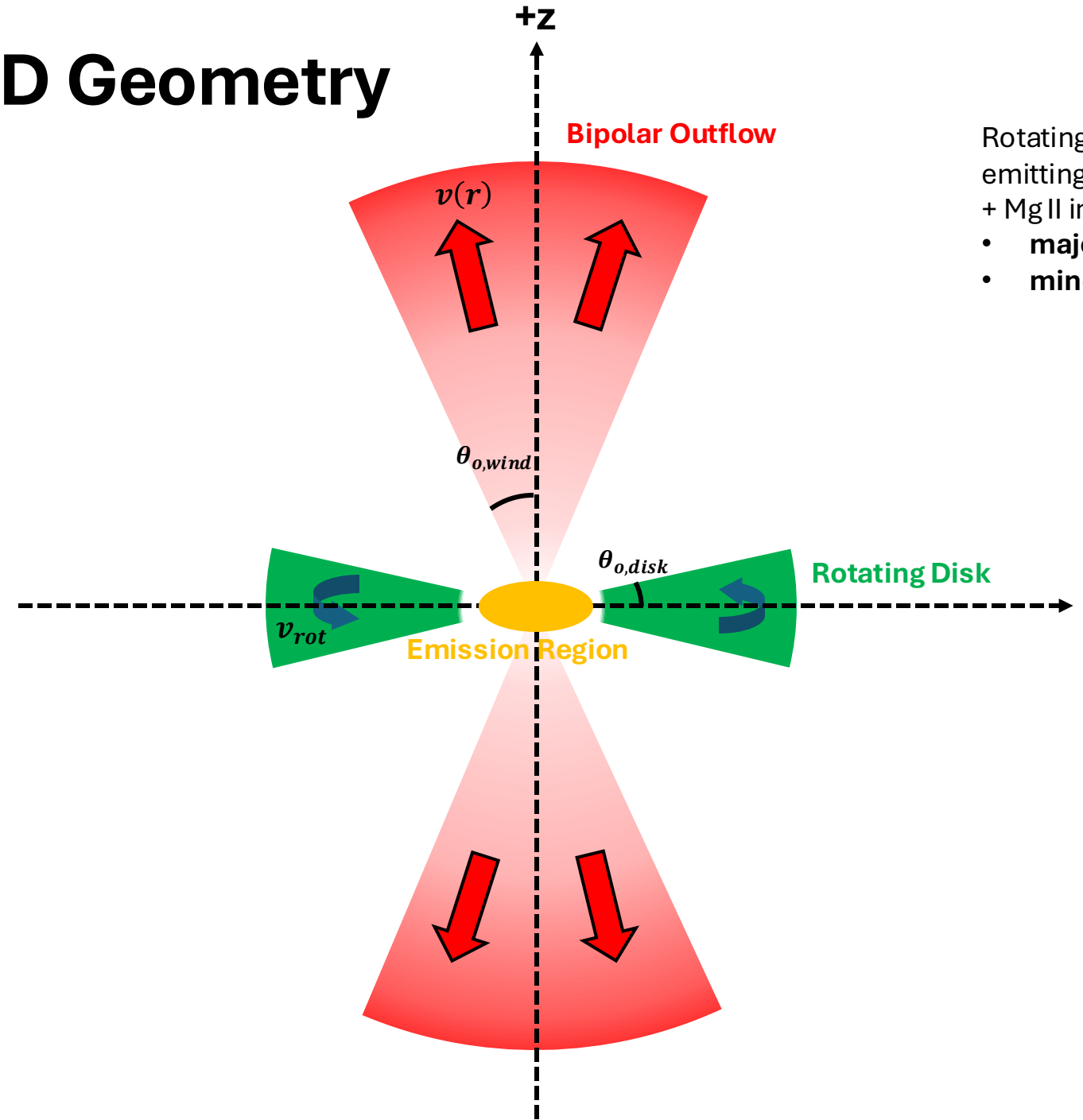
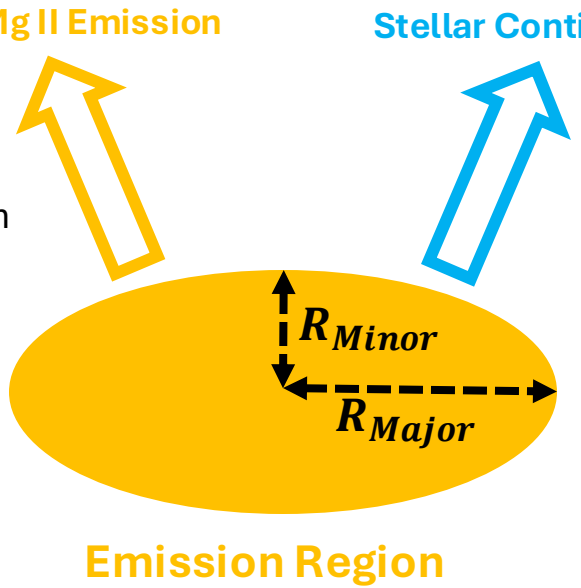
3D Geometry



Rotating ellipsoidal shape
emitting stellar continuum
+ Mg II intrinsic emission

- **major radius 5 kpc**
- **minor radius 2 kpc**



Bipolar Outflow

- opening angle = 45°
- outflow velocity is constant
- Inner 5 kpc, outer 50 kpc.

Rotating Disk

- opening angle = 10-20°
- rotating velocity = 100 km/s
- inner 5 kpc, outer 15 kpc

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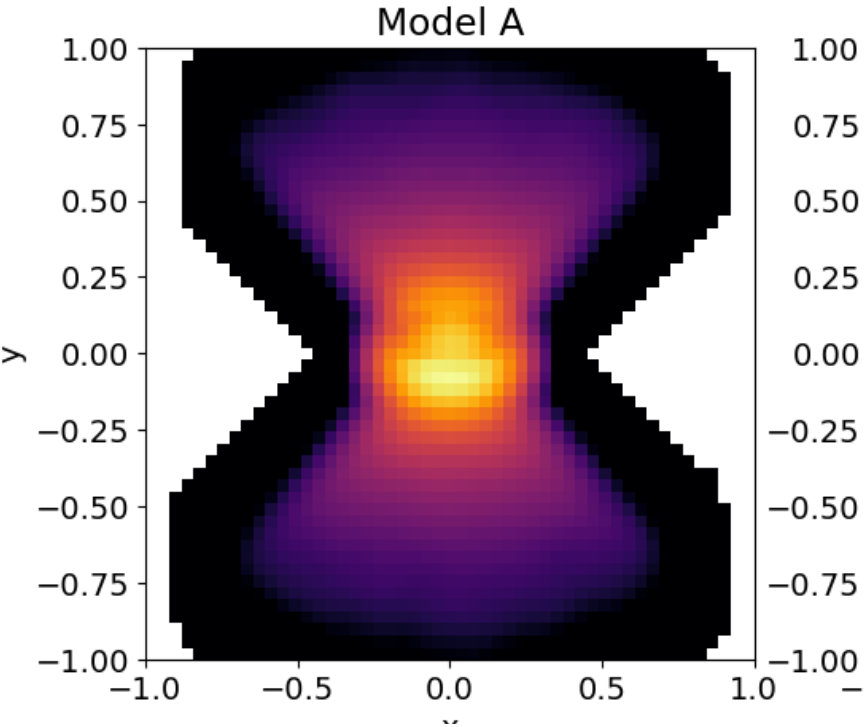
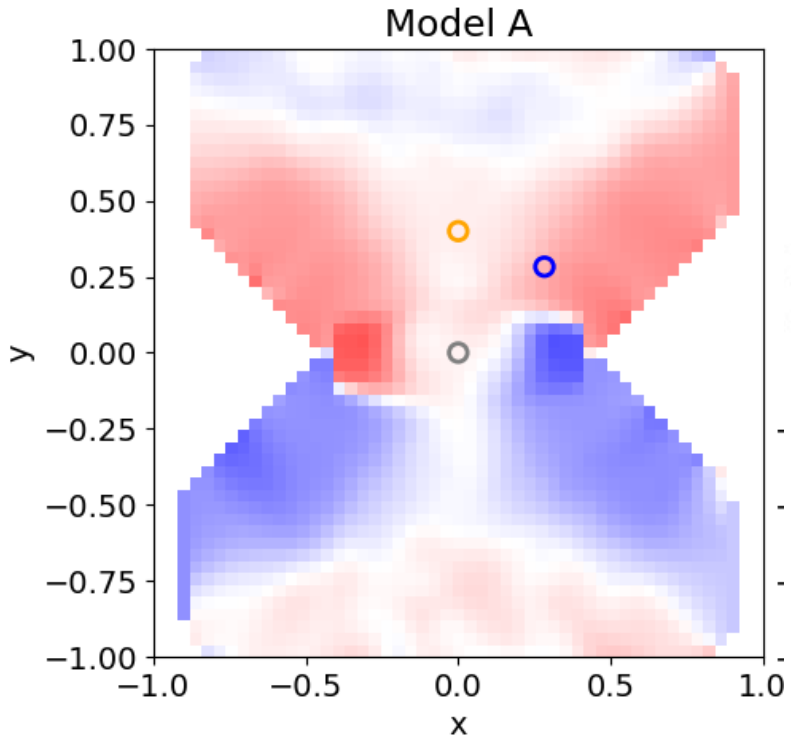
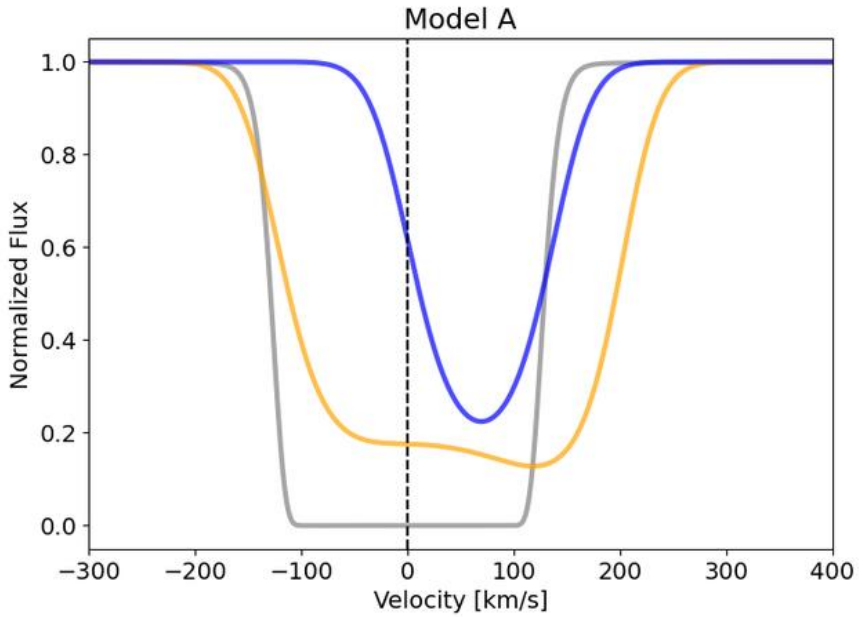
Mock Observations of Mg II halo







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Acknowledgement & Disclaimer

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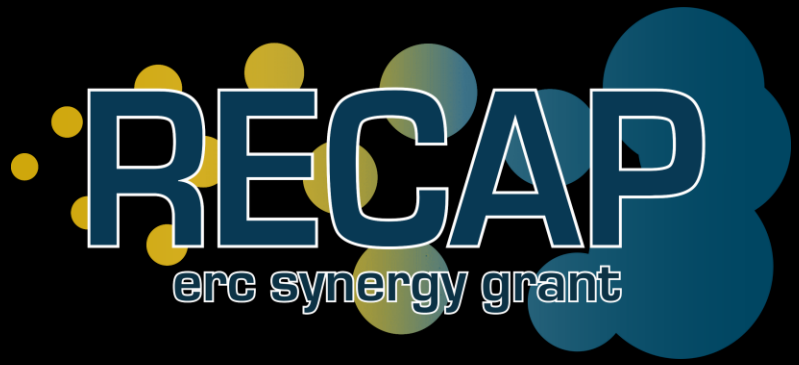

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