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Constraining Protoplanetary Disk Midplane Heating Mechanism Using Analytically Derived Wavelength-Dependent Radial Intensity Profile

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The temperature structure of a protoplanetary disk plays an important role in determining the physical and chemical conditions for planetary formation. The midplane serves as a crucial environment where dust settles and later coagulates into pebbles and planetesimals. A key component in understanding this environment is modeling the internal heating mechanisms acting within it. It is still unclear whether efficient midplane heating occurs in protoplanetary disks in general. Recent findings on Magnetohydrodynamics (MHD) suggest that accretion happens in disk without actually heating the midplane. This further suggests that the midplane temperature in the inner region of the protoplanetary disk is only determined by stellar irradiation. Constraining the midplane temperature through observation is not straightforward, as typical observations would trace the layers above the midplane. Therefore, determining at which wavelength we could observe the midplane effectively is an important step needed to constrain the heating mechanism inside.

To investigate the mechanism, we use the IM Lup system as a case study. We model the temperature structure using two distinct models, one with irradiation heating only and the other with midplane viscous heating. The resulting temperature profiles are then used to calculate the emerging intensity coming from the disk at various wavelengths using an analytic formulation of the radiative transfer equation. Assuming azimuthal symmetry of the disk, we then derive the radial intensity profile of the disk. We include wavelength-dependent dust opacities from 0.1 to 10,000 micron in the calculation. Our results successfully capture the overall temperature structure, distinctly differentiating the accretion-heated midplane and irradiation-heated surface region. Based on the wavelength-dependent radial intensity profiles, we will discuss which wavelengths are most useful for discriminating between different internal heating mechanisms.