eDisk Modeling of a Protostellar Disk: Viscous Accretion Heating and Dust and Gas Radii

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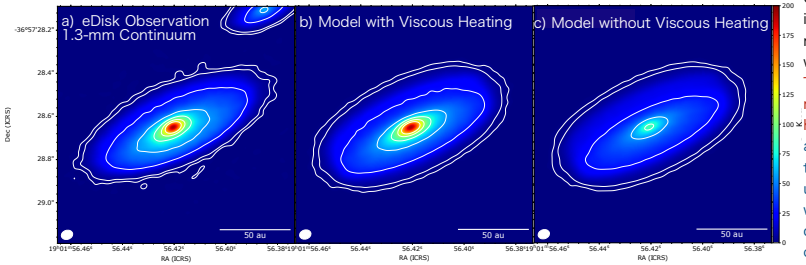
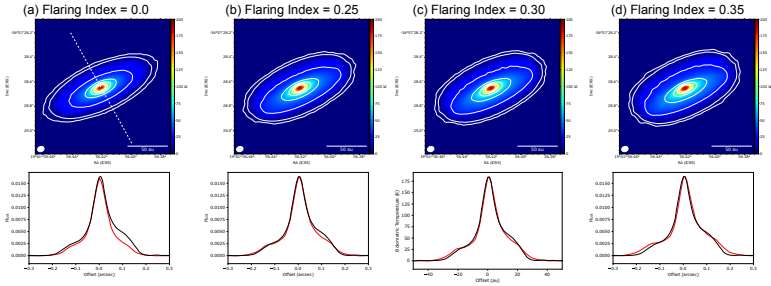
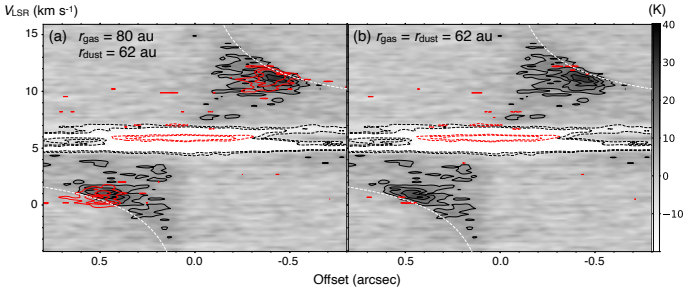
We have conducted radiative transfer modeling using RADMC3d combined with the eDisk observing simulations to reproduce the eDisk results of the 1.3-mm dust-continuum and $C^{18}O$ (2-1) emission. The target source here is R Cr A IRS7B. We found that inclusion of viscous accretion heating is required to reproduce the high peak brightness temperature (~190 K) of the observed 1.3-mm dust-continuum emission. In other words, the disk is self-luminous. Furthermore, dust flaring and optical thickness of the 1.3-mm emission are necessary to reproduce the observed asymmetric intensity distribution along the disk minor axis. We also realized that a gas radius larger than the dust radius is required to reproduce the observed $C^{18}O$ (2-1) emission. Please check Takakuwa et al. 2024, ApJ, 964, 24.



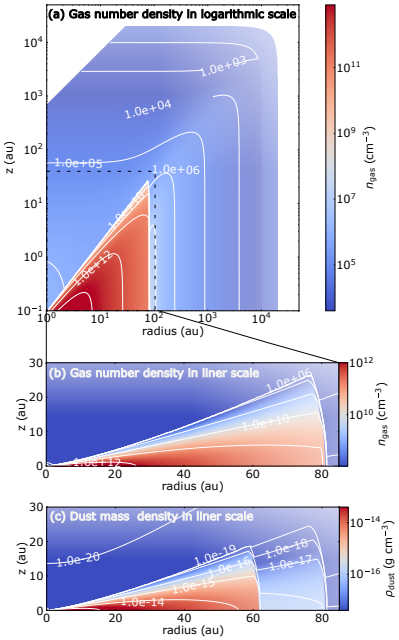
Comparison of the observed 1.3-mm image in R Cr A IRS7B (left) to the model images with (middle) and without the viscous heating (right). The internal heating in the disk is required to reproduce the observed high peak brightness temperature. We attempted different dust opacities (in these images the DSHARP opacity is used.) and dust mass in the disk, but we confirmed that the self-luminous disk is necessary to reproduce the observations.



Effect of the dust flaring on the images. The upper panels show the model 1.3-mm images with different dust flaring indices. The lower panels show observed (black lines) and model (red) intensity profiles along the minor axis (while dashed line in the upper-left panel). The flaring index p is defined as $H(r)/r \propto r^p$. Thus p=0 denotes that the scale height increases linearly with radius. The flaring index of ~0.3 is required to reproduce the observed asymmetric intensity distribution along the minor axis.



(Top) Observed (black contours and gray scale) and model P-V diagrams (red) of the $C^{18}O$ (2-1) emission along the major axis of the disk around IRS 7B. White dashed curves show the Keplerian rotation curve with the central stellar mass of 2.9 $M_\odot$. The left panel shows the model with the gas radius of 80 au, larger than the dust radius of 62 au. The right panel shows the model with the gas radius same as the dust radius. The model with a larger gas radius reproduces the observed $C^{18}O$ P-V diagram. On the other hand, the model with the gas radius same as the dust radius predicts very low $C^{18}O$ intensities due to the dust absorption, and cannot reproduce the observations.



(Right) Distributions of molecular gas and dusts in the fiducial model. The dust and gas disk is embedded in the infalling envelope.