国立天文台天文シミュレーションプロジェクト 成果報告書

Protoplanetary Disk Substructure and Dusty Winds from Non-ideal MHD Simulations

Scott Suriano (University of Tokyo)

利用カテゴリ ・ XC-B

We now know that detailed substructure (both radial and azimuthal) is commonplace in protoplanetary disks (Andrews et al. 2019). We also that the disks around young protostars actively launch outflows perpendicular to the plane of the disk. Recent observations suggest that slow, wide-angle disk winds are magnetic in origin (e.g., Tabone et al. 2020). In this project we surmise the connection between small-scale disk substructure, MHD disk winds, and the intrinsic photometric variability of classical T Tauri stars, as it is presumed that some class of variable young stellar objects (YSOs) arises obscuration of the central protostar by circumstellar dust (e.g., Cody et al. 2014). We do this by analyzing the results of non-ideal 3D MHD simulations of circumstellar disks in which the processes of disk wind launching and substructure formation are inextricably linked by large-scale poloidal magnetic field lines.

First, using the resulting gas density and velocity obtained from the 3D MHD simulations of structure formation in disks (Suriano et al. 2019), we simulate the types (sizes) of dust grains that can be launched or lifted by the gaseous wind. These one-dimensional simulations are solved along the magnetic flux tubes that launch the disk wind and result in characteristic vertical locations where small dust grains float above the disk (see Miyake et al. 2016). For example, grains of order 10 microns can still be launched over 20 scale-heights above the disk midplane by the slow magnetic disk winds, even at their furthest radial extent of tens of au. Next, we use the results of the vertical dust grain profiles as the input to radiative transfer simulations using the RADMC-3D code (Dullemond et al. 2012). These radiative transfer simulations calculate the dust temperature of the disk/wind and allow us to construct photometric light curves and near-infrared scattered light images. We show that for low inclination angles where the line-of-sight intercepts the floating dust grains, dusty MHD disk winds from structured disks could be responsible for the class of variable YSOs known as “dippers”. Finally, this work has potentially important implications of how dust entrained in disk winds can affect dust stirring vs. settling, radial dust circulation and transport, and the local dust-to-gas mass fraction. More broadly, the dynamical processes of dust grains in protoplanetary disks control where and how grains grow to form planetesimals and set the global planetary mass budget.