外　国　語　要　旨

Radiation Hydrodynamic Studies of Line-Driven Disk Wind in Active Galactic Nuclei
Mariko NOMURA

We research the dynamics of the line-driven disk wind in the active galactic nuclei (AGNs) by radiation hydrodynamic calculations and compare them to the X-ray observations of broad absorption line (BAL) quasars and ultra-first outflow (UFO) in Seyfert galaxies. The observations of blueshifted absorption lines by metals suggest the outflow with the large velocity $\sim 10,000\,\mathrm{km\,s^{-1}}$–$90,000\,\mathrm{km\,s^{-1}}$ $(0.3c)$ in the active galactic nuclei, where c is the velocity of the light. The origin of the outflow is still unknown and the existing phenomenological model for AGNs cannot reproduce these outflows, since the obscuring torus that is the absorber assumed in the model is just rotating around the nuclei and cannot explain the large blueshifted speed.

Our aim is to investigate the dynamics and structure of the outflow, to explain the origin of the absorption lines, and furthermore, to establish the theoretical model of the AGN including the outflow. We focus on the plausible model for the outflows, the line-driven disk wind model, in which the radiation force due to spectral lines (line force) accelerates the matter on the surface of the accretion disk and induces the disk wind.

First we investigate the steady structure of the line-driven disk wind by calculating streamlines of the wind and compare with X-ray observation. We found the funnel-shaped winds with a half opening angle of $\sim 50^\circ$ in the wide parameter space, $\varepsilon = 0.3$–0.9 and $M_{\rm BH} = 10^7$–$10^{8.5} M_\odot$, where ε is the Eddington ratio and $M_{\rm BH}$ is the black hole mass. The BAL features appear when the system is observed from an observer with the viewing angle, $\sim 50^\circ$. A resulting probability of detecting BAL is ~ 7–11%, which is roughly consistent with the abundance ratio of BAL quasars, ~ 10–15%.

Second we perform the two-dimensional radiation hydrodynamic simulations of line-driven disk wind to investigate more realistic structure of the wind. We find that the funnel-shaped disk wind is basically consistent with the calculation of the streamlines as we have mentioned above, and newly find the time variation of the column density, velocity, and ionization degree. In the upper region of the funnel (typically $\lesssim 70^\circ$), the matter is powered by the line force near the disk surface and is not accelerated at the higher latitude. Therefor the terminal velocity of the wind is relatively small, $v_r \lesssim 0.1c$, and a part of the matter returns to the disk. In the equatorial region (typically $\gtrsim 70^\circ$), the wind continues to be accelerated even after the launching, and the outflow velocity reaches 0.3–$0.4c$. As a result, for $\varepsilon = 0.3$–0.9 and $M_{\rm BH} = 10^8$–$10^9 M_\odot$, the UFO features are observed in the direction of $\sim 70^\circ$ and come and go at the time scale from ~ 20 days to several months. The resulting short

timescale (~ 20 days) is similar to the rapid variability (~ 7 days) reported by the X-ray observations. The time-averaged UFO probability is 20–30%, which is comparable to or slightly smaller than that estimated by the observation, $\sim 50\%$. For $\varepsilon \lesssim 0.1$ and $M_{\rm BH} \lesssim 10^{7.5} M_{\odot}$, the disk wind is launched, but the UFO probability is pretty small or null, since the column density of the matter of which the ionization state is suited for producing the metal absorption lines are small.

We conclude that the disk wind is successfully launched by the line force and the line-driven disk wind model can reproduce the absorption features of the BAL and UFO. In addition, the detection of the absorption lines are depend on not only the viewing angle but also the Eddington ratio and the black hole mass.