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Transonic analysis of galactic outflows and its application

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Abstract

We examine transonic galactic outflows using a steady and spherically symmetric model with both the isothermal and polytropic assumption. The gravitational potentials of dark matter halo (DMH) and super-massive black hole (SMBH) are incorporated in our model. In this model, we classify transonic solutions according to their topological features. We mainly find two types of transonic solutions: one has only a transonic point, and the other has two transonic points with an O-point.

In addition, we estimate the parameter ranges of actual galaxies by referring to previous studies. We found that, in quiescent galaxies, there is a possibility of slowly accelerating outflows having a transonic point generated by the DMH gravity in the distant region (~100kpc). In star-forming galaxies, transonic galactic outflow has a transonic point generated by the SMBH gravity in the inner region (~0.01kpc).

We apply the isothermal model to the Sombrero galaxy and find the possibility of a slowly accelerating outflow in this galaxy. In this galaxy, the *Chandra* X-ray observatory shows a trace of galactic outflows by widely spread hot gas, while the observed gas density distribution is similar to that of the hydrostatic state. This discrepancy can be solved by the slowly accelerating outflow because this outflow has a wide subsonic region having similar gas density distribution to that of the hydrostatic state. However, the estimated mass flux is much larger than that supplied from stellar components. This may be due to the unlimited energy in the isothermal assumption. Therefore, we apply the polytropic model to this galaxy with mass flux estimated by observed stellar components. Because the polytropic model can reproduce the observed gas density and temperature distributions well with this mass flux, the polytropic model is more realistic than the isothermal one.

Moreover, we prove that the entropy of the transonic solution is maximum for every possible solution. This property is independent of the functional form of gravitational potentials. Therefore,

we conclude that galactic outflows must become transonic, although actual galaxies have complicated mass distributions.

We estimate mass fluxes and mass loading rates in star-forming galaxies. When the observed stellar mass (and star formation rate) increase, the estimated mass loading rates decrease. Because the entrainment of interstellar medium with outflowing gas increases mass loading rates, these results reveal that the entrainment more strongly influences less massive galaxies. We also calculated the loci of transonic points in these galaxies. The more massive galaxies can have only the inner transonic point, while the less massive galaxies can have both the inner and outer transonic points. This shows that the outflow in more massive galaxies is driven by concentrated star formation and that in less massive galaxies is driven by concentrated or diffuse star formation.