Asymmetries in random motions of gas in spiral galaxies

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ABSTRACT

Context.
Aims. The velocity ellipsoid of gas in galactic discs is usually assumed isotropic because the gaseous component dissipates energy through collisions between clouds in all directions. Under this approximation, no projection effect occurs in the random motions of gas, as traced by the line-of-sight velocity dispersion, unlike that of collisionless stars, and the velocity dispersion can be used directly to study galactic dynamics. However, it has been recently shown that random motions of the neutral Hydrogen gas of the Triangulum galaxy (M33) exhibit a bisymmetric perturbation which is perfectly aligned with the minor axis of the galaxy, suggesting the stigma of a clear projection effect.
Methods. We study velocity asymmetries by performing Fourier transforms of high-resolution velocity dispersion maps corrected from beam smearing effects, and measure the amplitudes and phase angles of the Fourier harmonics.
Results. In all velocity dispersion maps, we evidence strong perturbations of first, second and fourth orders. The strongest asymmetry is the bisymmetry, and the total asymmetries are, on average, as important as the axisymmetric random motions, except in the innermost disc regions where the axisymmetric mode dominates. The probability distribution of phase angles of perturbations varies with the Fourier mode. We find larger probabilities of (1) lopsidedness asymmetries directed near the disc major axis, (2) bisymmetric perturbations outside the major axis, and (3) fourth order asymmetries at intermediate directions between the major and minor axes of the discs. These findings are tentatively more pronounced for the most massive spirals. These results are evidence that strong projection effects shape the velocity dispersion maps. The most likely source of systematic orientations is the anisotropy of velocities, through the projection of ordered velocity streaming motions more important in one of the planar direction in the discs than the other direction. We also show that systematic phase angles in the velocity dispersion could arise from a tilted velocity ellipsoid, with specific coefficients of correlation between the radial and tangential velocities, and between the vertical and planar velocity components. We predict a larger incidence of correlation between the radial and tangential velocities of gas with a coefficient of $|\rho_{R\theta}| \sim 0.6$, which could be tested against the kinematics of the youngest stellar populations of the Milky Way.
Conclusions. Velocity dispersions of gas can no longer be considered devoid of projection effects. The systematic orientations of asymmetries found in the gas random motions are naturally explained by the projection effects of perturbed ordered motions. Our methodology reveals to be a powerful tool to constrain the direction in the galaxy plane towards which velocity streamings are weaker or stronger, thus the shape of the velocity ellipsoid of gas, which is de facto anisotropic at the angular scales probed by the observations. This work is a step towards a more systematic search of asymmetries in the velocity dispersion of the neutral, molecular and ionised gaseous media of galactic discs. Observations of larger samples of galaxies, at higher sensitivity and resolution are also necessary to evaluate more precisely the relations between gravitational perturbations, velocity anisotropy and galaxy properties.

Key words. galaxies: fundamental parameters; galaxies: kinematics and dynamics; galaxies: spiral structure; galaxies: cold interstellar medium