VELOCITY CORRELATIONS IN TURBULENT MOLECULAR CLOUDS

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The observed widths of molecular lines indicate that molecular clouds are in a highly turbulent state with supersonic internal velocities. At the same time molecular clouds are highly fragmented into substructures exhibiting large density contrasts. These substructures seem to be arranged in a hierarchical order scheme where one can think of newly formed stars representing the smallest spatial scale of ordering. Stars, protostars and even dense clumps can be regarded as being hydrodynamically decoupled from the ambient gas. Thus, in an idealized way, one can think of molecular clouds as being a gravitationally coupled system consisting of gas (continuous component) and 'point-masses' (particle component) randomly moving through the gas. The random motion of these 'point-masses' is accompanied by spatial and temporal fluctuations of their gravitational potential which, in turn, induce velocity and density fluctuations of the gas [1],[2],[4],[5].

Using fluctuation theory we derived in quasilinear approximation analytical expressions for the resulting power spectrum of the velocity fluctuations V_k. To this end, the dynamics of the system of the 'point-masses' was described by a Vlasov equation; the gas was treated in two ways: (i) as a viscous, polytropic gas (ξ being the dynamical viscosity coefficient), and (ii) as a gas with finite cooling time τ_{cool} [1]. V_k was calculated in the time asymptotic limit, which means that we had to restrict ourselves to stable modes only. The respective shapes of the power spectra are sketched in fig.1. For a given physical situation V_k shows a maximum at a characteristic wavenumber k_g. For wavenumbers smaller than k_g Landau damping of the particle component is the relevant damping mechanism of the coupled system. For larger wavenumbers the spectrum is determined by the damping mechanisms of the gaseous component. Hence, that wavenumber where the fluctuation spectrum reaches a maximum depends on how the various damping effects of the gas vary with k. In example (ii) the damping effect due to heating and cooling is much stronger than that of purely visous damping (example (i)). Hence, $k_g' > k_g$ and $V_k(k_g') > V_k(k_g)$. The latter relation ensues from the fact that Landau damping of the particle component becomes increasingly inefficient for increasing k in damping fluctuations of the gas.

The two-point autocorrelation function $\alpha(x)$ is the Fourier transform of the power spectrum V_k. We were interested especially in the correlation function of the stationary stable velocity fluctuation field. Since k_g, and thus the maximum of V_k, lies within the stable mode regime, $\alpha(x)$ depends only weakly on the lower limit of the wavenumber integration. We approximated $\alpha(x)$ by extrapolating V_k to $k \rightarrow 0$ and integrated over the whole k axis

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[3]. From fig. 2 one finds for the correlation length, given as the usual e-fold length of $\alpha(x)$, $x_{correl} = 1.8\,k_g^{-1}$. Thus the largest turbulent eddies are of the order of the inverse of the characteristic wavenumber which, for cases (i) and (ii), is given by

$$k_g = \frac{1}{0.17pc}\exp\left\{-\frac{1}{5}\left(\frac{c_s}{\sigma}\right)^2\right\}$$
$$\times\left[\left(\frac{\rho_g}{10^{-21}g\,cm^{-3}}\right)\left(\frac{\rho_p}{10^{-22}g\,cm^{-3}}\right)\left(\frac{0.3km\,s^{-1}}{c_s}\right)^2\left(\frac{km\,s^{-1}}{\sigma}\right)^3\left(\frac{400yr}{\tau_{cool}}\right)\right]^{\frac{1}{5}}$$

and

$$k_g' = \frac{1}{0.06pc}\exp\left\{-\frac{1}{5}\left(\frac{c_s}{\sigma}\right)^2\right\}$$
$$\times\left[\left(\frac{\rho_g}{10^{-21}g\,cm^{-3}}\right)^2\left(\frac{\rho_p}{10^{-22}g\,cm^{-3}}\right)\left(\frac{0.3km\,s^{-1}}{c_s}\right)\left(\frac{km\,s^{-1}}{\sigma}\right)^3\left(\frac{c_s/\xi}{1.3\,10^{-9}g\,cm^{-2}}\right)\right]^{\frac{1}{5}}$$

respectively. ρ_g and c_s denote mean mass density and sonic velocity of the gas, and ρ_p and σ denote mean mass density and velocity dispersion of the particle component, respectively.

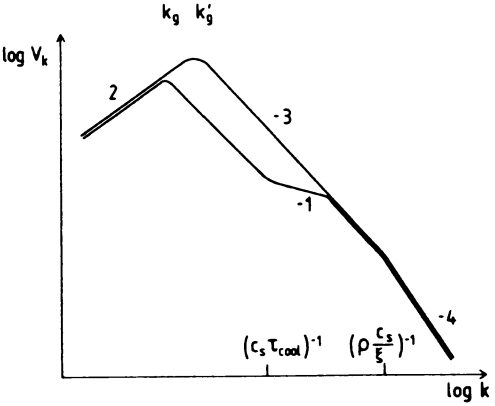

Fig.1: Power spectrum of velocity field (upper line: case i; lower line: case ii) Labels denote the respective power indices.

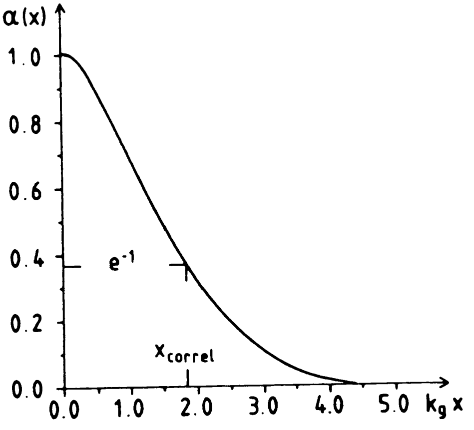

Fig.2: Two-point autocorrelation function of the velocity field

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