SIMULATIONS OF MOLECULAR CLOUDS IN M51

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We present simulations of the gas behaviour in the M51 spiral potential, perturbed by the tidal field of NGC5195. These 3D computations are very helpful to interprete the molecular observations (arm-interarm contrast, Z-behaviour, map of velocity dispersion, kinematics, streaming motions) and in particular to guess the pattern speed of the spiral.

Techniques

We simulate the gas as a non self-gravitating component, streaming in the potential produced by the old stars. This potential is deduced from red (digitised red plate by the automatic machine MAMA) and near-IR pictures (CCD image from Gatley, 1990, priv. comm.). These two images gave very complementary information (high signal-to-noise in the red image, but saturation of the plate in the center).The potential is obtained numerically by a Fourier transform on 256x256 pixels of 1"x1" size after deprojection on the plane of the galaxy (β=-20°).The z-component of the force is obtained by the plane-parallel approximation, with a density varying in $sech^2(z/H)$. A small spherical bulge is added in the center, to fit the observed rotation curve.

The companion is schematised by a spherical potential, corresponding to a mass ratio of 1/3; its orbit has been fitted with a 3-body code to be an ellipse of excentricity e=0.8, an inclination i=-70° (a pericenter angle of ω = -15° and a viewing parameter of λ = 65°), parameters very close to that from Toomre and Toomre (1972).

The hydrodynamics of the gas was simulated with the collisionnal model from Combes and Gerin (1985), extended to 3D dynamics. Clouds are distributed according to a mass spectrum from 10^3 to 10^6 Mo. They interact via collisions, that can result in coalescence, mass exchange or fragmentation. Clouds over 3 10^5 Mo are GMCs: they can be dispersed by star formation after a life-time of 4 10^7 yrs. When a GMC is dispersed, its mass is re-injected in small clouds, with a velocity dispersion of 10km/s.

Results

We have tried simulations with different values of the pattern velocity. The resulting morphology is very sensitive to this parameter. We only find a spiral structure similar to the observed pattern for Ω_p = 31km/s/kpc (fig.1). For 25 and 71 km/s/kpc, the gas distribution was not consistent with the stellar potential. Simulations with Ω_p = 31km/s/kpc reveals the right morphology, with even a "crooked" northern arm.

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The resulting arm-interarm contrast is very similar to what is observed in CO with the IRAM telescope, from 4 up to 10 in some regions.

The measured velocity dispersion is enhanced in the arms, as in the observations.

The simulations show that there is no Z or Vz perturbations in the arms (only in the center, because of the spherical bulge).There are indeed non-circular motions: elliptical streamlines in the center (as in the observations); and streaming motions in the arms.

It is interesting to note the position of corotation, in the middle of the disk (fig.2): the dust-lanes inside the NW arm are not revolving around the center in the pattern frame. The associated gas remains in the same arm.

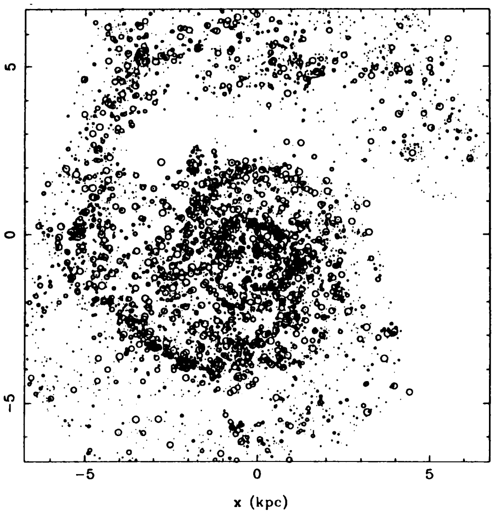

Fig 1:

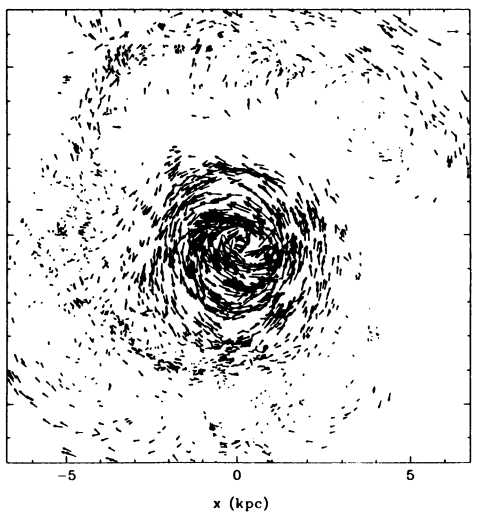

Fig 2:

Fig 1: Cloud distribution in the Ω_p= 31km/s/kpc simulation.
Fig 2: Velocity distribution in the rotating frame.

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