The molecular spiral arms of NGC 6946

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1. Introduction

High resolution observations of molecules in external galaxies are essential to understand the physical processes leading to the formation of stars. One question is that whether there is a spiral structure in the molecular gas, but it was not possible to resolve the spiral arms of external galaxies until the advent of large millimeter-wave telescopes.

With the IRAM 30 m telescope we are carrying through the mapping of NGC 6946 in the ^{12}CO(1-0) and (2-1) lines. This galaxy is a large, gas-rich Scd spiral with a strong star formation activity. NGC 6946 is well studied at radio and optical wavelengths, so that it is possible to compare the location of the spiral arms tracers : HI ridge, HII regions and molecular clouds.

2. Observations

They were collected with the IRAM 30m telescope between November 1987 and April 1989. Mapping is still in progress ; we have already observed 309 positions in the CO(1-0) line and 440 in the CO(2-1) one. We used a position-switching procedure with signal in both the ON and OFF positions, but at different velocities. The average time spent on each positions is six minutes yielding an r.m.s. noise of about 70 mK in the (CO1-0) line and 50 mK in the CO(2-1). The map sampling is 10" (the HPBW is 23" at 115 GHz and 14" at 230 GHz).

Figure 1 shows the two CO(2-1) maps that have been obtained simultaneously with this observing procedure in the inner regions of NGC 6946, at about 3.5 kpc from the nucleus. In CO(1-0) we have mapped only the southern half of these regions, but we also have about 100 spectra of the nuclear region (see Weliachew, Casoli and Combes, 1988, A.A. **199**, 29).

3. Results and discussion

The disk CO emission is very contrasted (no lines for some positions, 1 K in CO(1-0) for some others) and correlated with the optical spiral arms : this clearly shows up in figure 2 which presents superimposed contours of CO(2-1) integrated emissivity and of Hα line emission. The agreement is very good, and there is *no displacement across the arm* between the CO, HI and Hα ridges of emission. The arms are barely resolved by the 23" beam and the molecular contrast averaged over the map is about 4. The CO(2-1) maxima are closer to the position of the HII regions than those of CO(1-0), which could be due to variations of excitation conditions.

The CO excitation in the disk of NGC 6946 is *low* : when all data are convolved to the same resolution of 23" the CO(2-1) lines are about 0.45 times fainter than the CO(1-0) ones, while in the nucleus they have roughly the same intensity. This suggests that in the disk of NGC 6946

most of the CO emission comes from cold optically thick gas located in cloud envelopes rather than from cloud cores.

The molecular and atomic component in the observed regions of NGC 6946 seems to be organized in *large gaseous complexes*. One such complex is centered at offsets (150, -20) (figure 1). It contains 2.4 10^7 M_o of HI, 4.6 10^7 M_o of H_2 [using $N(H_2) = 2.6\ 10^{20}$ I(CO)] and several HII regions. It has an elongated shape with a length of 1.8 kpc and is in approximate virial equilibrium. The molecular mass fraction in the regions we have observed is typically 0.5 and reaches 0.8 at some positions.

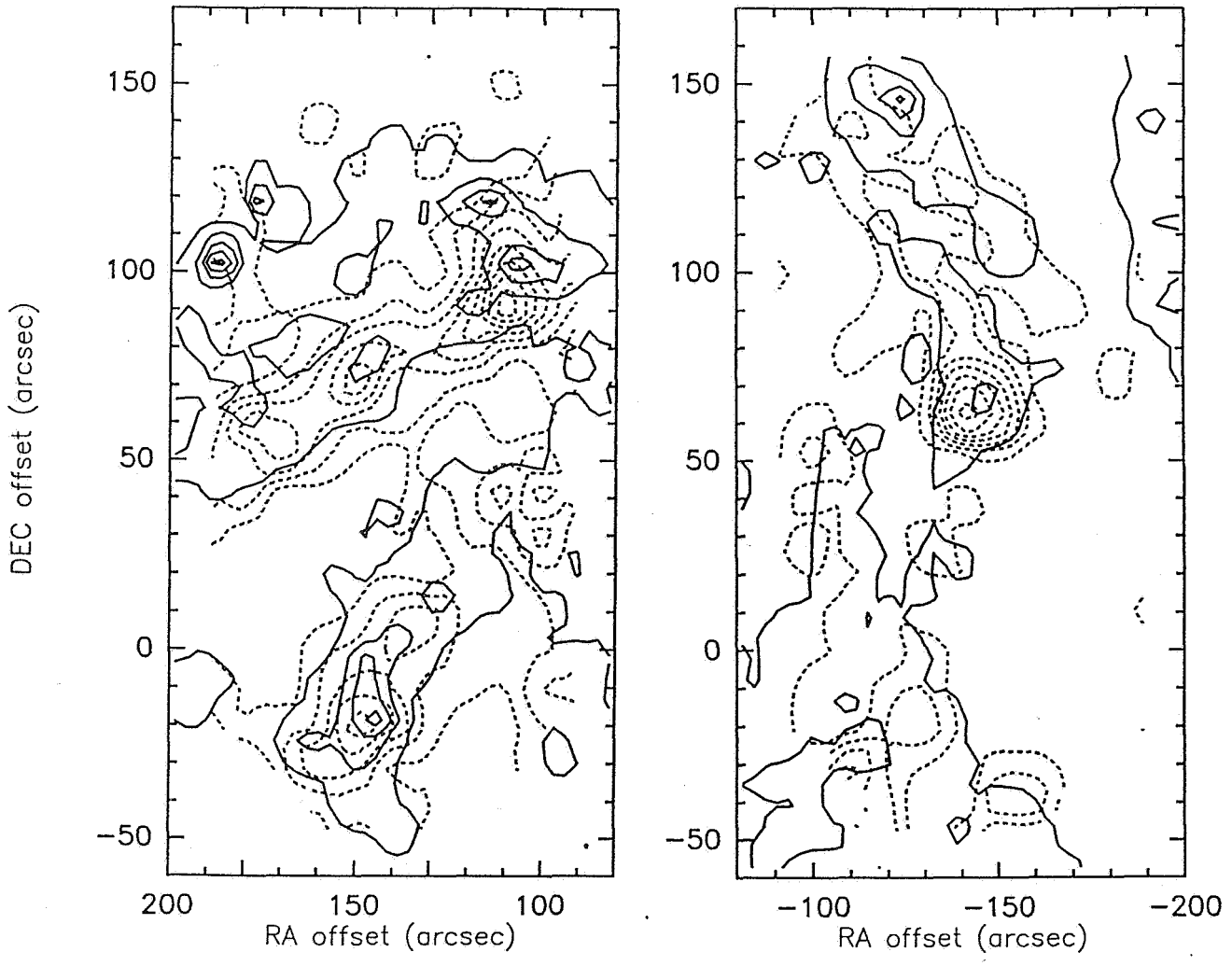

Figure 1 : superimposed Hα [full line] and CO(2-1) [dashed] line emission in two fields of NGC 6946. Both fields have been mapped simultaneously. Levels : 1.5 to 15.5 K kms^{-1} by 2 for CO(2-1), 8 to 48 10^{-26} erg s^{-1} cm^{-2} $arcsec^{-2}$ by 10 for Hα. The sampling of the CO observations is 10" and the beamsize 14".