CO(J=2-1) OBSERVATIONS OF THE EDGE-ON GALAXY NGC 4631

Y. SOFUE[1], T. HANDA[1], G. GOLLA[2], and R. WIELEBINSKI[2]
[1] *Institute of Astronomy, University of Tokyo, Mitaka, Tokyo 181*
[2] *Max-Planck-Institut f"ur Radioastronomie, Bonn 1, FRG*

ABSTRACT: The interacting edge-on galaxy NGC 4631 has been observed in the ^{12}CO($J = 2-1$) line emission using the IRAM 30-m telescope with a resolution of 13″ (330 pc). The molecular gas is strongly concentrated in a ring-like disk of 1 kpc radius, which is rotating rigidly. Line proriles show several velocity components, which are attributable to spiral arms. Although the J=2-1 to l-0 transition line ratio indicates that the gas is generally opaque against the lines, we find some optically thinner regions, as well.

1. INTRODUCTION

NGC 4631 (Arp 281) is an Sc/SBd edge-on galaxy interacting with NGC 4627 and NGC 4656, and is IRAS bright. HI filamentary features extending for tens of kiloparsecs are found bridging NGC 4631 and NGC 4656 (Weliachev et al 1978). Radio continuum bright nuclear disk exists, which is resolved into several complexes (Bruyn 1977; Klein et al 1984). Nonthermal halo of a few kpc thickness exists, being dominated by a large-scale vertical magnetic field (Hummel et al 1988). Nuclear molecular gas disk was found in the ^{12}CO($J = 1 - 0$) line emission with the Nobeyama 45-m telescope. The central molecular disk composes rings with radius of 250 pc and 1 kpc (Sofue et al 1989).

In order to get information about physical conditions like optical depth and temperature, we need another transition observations. Observations of the ^{12}CO($J = 2 - 1$) line of NGC 4631 were made in January, 1990 using the 30-m telescope of IRAM. The antenna had a HPBW of 13″ at 230 GHz, corresponding to a linear scale of 330 pc (see for detail, Sofue et al 1990).

3. MOLECULAR GAS IN NGC 4631

Rigidly rotating ring: The position-velocity diagrams along the major axis indicates a rigid rotation of the central molecular disk (Fig. 1). There are two concentrations of gas toward $X = \simeq \pm 42''$ (1 kpc), which appear symmetric with respect to the center. The prominent CO(2-1) peak at $X = +42''$ suggests some compact, high temperature complex toward this +42″ peak.

J=2-1/1-0 ratio: The ratio of the ^{12}CO($J = 1 - 0$) and ^{12}CO($J = 2 - 1$) line intensities is nearly equal to unity as a whole, except toward the 42″ peak, where

F. Combes and F. Casoli (eds.), Dynamics of Galaxies and Their Molecular Cloud Distributions, 329–330.

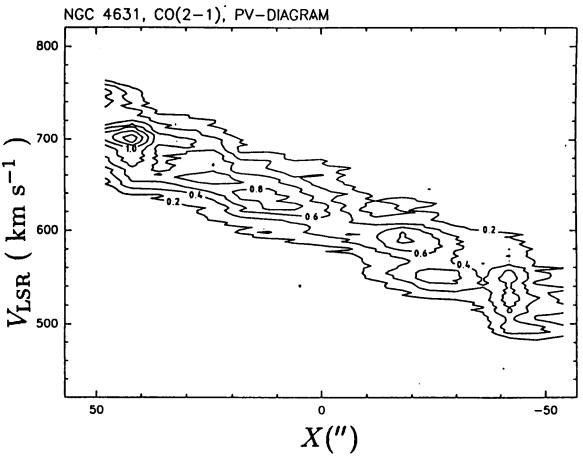

Fig.1: Position-velocity diagram of CO (2-1) line emission for NGC 4631. Note a ring at $X = 1$ kpc and its rigid rotation.

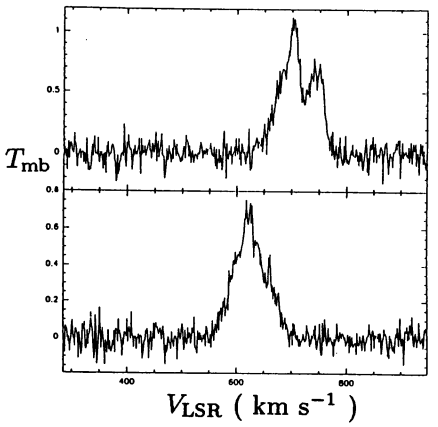

Fig.2: Line profiles toward $X = 48''$ (1.2 kpc: upper panel) and toward the center (lower). Note several velocity components indicating spiral arms.

we find a larger ratio of 1.5. Thus the line ratio of unity on average indicates that the gas in the disk is generally optically thick, as is usually the case for molecular clouds in normal galaxy disks. However, we find that the gas is optically thin (or at least less opaque) toward the outer $+42''$ peak.

Disk inclination: The weighted $^{12}CO(J = 2 - 1)$ intensity is shifted toward the north in the eastern half, while it is shifted toward the south in the western half. This indicates that the nulcear molecular disk is inclined by a few degrees from the optical major axis.

Spiral arms: Line profiles are composed of several velocity components (Fig. 2). Each velocity component involves a considerable portion of the total emission (mass) of gas, they are most likely arms.

Slow rotation in halo: The maximum velocity decreases with Y or with the height from the plane at $X \sim \pm 42''$. This indicates that the rotation of molecular gas in the halo is slower than in the disk plane.

References

de Bruyn, A.G. 1977, *Astron. Astrophys.*, **58**, 221.

Hummel, E., Lesch, H., Wielebinski, R., Schlickeiser, R. 1988, *Astron. Astrophys.*, **197**, L29.

Klein, U., Wielebinski, R., and Beck, R. 1984, *Astron. Astrophys.*, **133**, 19.

Sofue, Y., Handa, T. , Golla, G., Wielebinski, R. 1990, *Publ. Astron. Soc. Japan*, No. 3, in press.

Sofue, Y., Nakai, N., and Handa, T. 1989, *Publ. Astron. Soc. Japan*, **41**, 937.

Weliachew, L., Sancisi, R., and Guélin, M., 1978, *Astron. Astrophys.*, **65**, 37.