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THE NOBEYAMA MILLIMETER ARRAY SURVEY FOR PROTOPLANETARY DISKS AROUND PROTOSTAR CANDIDATES AND T TAURI STARS IN TAURUS

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ABSTRACT

The Nobeyama Millimeter Array Survey for protoplanetary disks has been made for 19 protostellar IRAS sources in Taurus; 13 were invisible protostars and 6 were youngest T Tauri stars. We observed the 98 GHz continuum and CS(J=2– 1) line emissions simultaneously with spatial resolutions of $2.8''- 8.8''$ (360 AU–1,200 AU). Unresolved continuum emission was detected from 5 of 6 T Tauri stars and 2 of 13 protostar candidates. The continuum emission arose from compact circumstellar disks. Extended CS emission was detected around 2 T Tauri stars and 11 protostar candidates. There is a remarkable tendency for the detectability for the 98 GHz continuum emission to be small for protostar candidates. This tendency is explained if the mass of protoplanetary disks around protostars is not as large as that around T Tauri stars; the disk mass may increase with the increase of central stellar mass by dynamical accretion in the course of evolution from protostars to T Tauri stars.

1. Introduction

Recent observations have revealed that T Tauri stars often show evidence of compact and dense circumstellar dust disks, and their physical properties have become clear by some millimeter and submillimeter observations (e.g. Beckwith *et al.*1990). Evolution of circumstellar disks as well as their physical properties is of great importance to understand the mechanism of planetary system formation and, hence, is now in the field of active investigation. It is conceivable that the formation of the disk precedes the T Tauri phase, namely in the embedded protostar phase. There were some observations of compact disks around optically invisible protostar candidates (e.g. L1551-IRS5; Keene & Masson 1990). Because such observations are limited in number, it is very important to make survey observations for disks around protostar candidates to derive their physical properties and to understand the evolution of protoplanetary disks by comparing the results with those for T Tauri stars.

We have been carrying out survey observations for protoplanetary disks around protostar candidates and T Tauri stars with the Nobeyama Millimeter Array (NMA)

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to compare the total mass within $\lesssim$500AU in radius between the two types of objects. The initial results of the survey were reported for 6 embedded sources and 5 youngest T Tauri stars (Ohashi *et al.*1991). By increasing the number of samples up to 19, we have covered most of the invisible sources detected by IRAS toward the Taurus molecular cloud. In this article we report the latest results of the NMA survey.

2. Results and Discussion

We observed 19 low mass protostellar IRAS sources associated with Taurus in 98 GHz continuum and CS (J=2–1) emission. The 19 sources consist of 13 optically invisible protostar candidates and 6 young T Tauri stars. Unresolved compact continuum emission was detected from 5 of 6 T Tauri stars (83%), and from only 2 protostar candidates out of 13 (15%). Most of the detected continuum emission was thermal emission arising from dust grains. Though the T Tauri stars detected in the continuum are optically visible, the flux density of the continuum emission shows that the T Tauri stars are surrounded with a large amount of dust grains. This means that dust grains distribute not spherically but like a disk, i.e., the continuum emission arises from protoplanetary disks. The continuum emission around the two protostar candidates also arises from protoplanetary disks (Keene & Masson 1990; Adams *et al.*1987). The total mass (H_2 and dust) of the protoplanetary disks was estimated to be $\sim$0.1 $M_\odot$ for 5 T Tauri stars and $\sim$0.07 $M_\odot$ for 2 protostar candidates under the assumption that the dust emissivity law index (β) is 1.

On the other hand, CS emission was detected from 11 of 13 protostar candidates (85%), and 2 of 6 T Tauri stars (33%). The CS emission was spatially extended compared with the continuum emission; FWHM size of the CS emission $\sim$1000–2000 AU. The detected CS emission probably arises from inner parts of extended molecular envelopes surrounding the central sources.

Our results clearly show a remarkable difference in detectability of 98 GHz continuum emission between the protostar candidates and T Tauri stars; i.e.,the detectability of the 98 GHz continuum emission is higher toward the T Tauri stars than the protostar candidates. The 98 GHz continuum detectability basically depends on the total amount of circumstellar matter within the NMA beam of $\sim$500 AU in radius because: (1) the 98 GHz continuum emission is optically thin, and (2) dust temperatures are coincident among the observed sources within a factor of 2. Thus, our results show that the sources without detectable continuum emission do not have enough circumstellar matter within the NMA beam to be detected with NMA. The upper limit of total mass within the NMA beam size around the sources not detected in continuum is estimated to be $\sim$0.03 $M_\odot$. On the contrary, the sources detected in continuum have circumstellar matter of $\sim$0.1 $M_\odot$ within the NMA beam size as disks of $\sim$100 AU in radius.

The difference in total mass within the NMA beam size between the two types of objects is equivalent to the difference in mass of protoplanetary disks between them; i.e., disk mass around the protostar candidates is smaller than that around the T Tauri stars. Since the protostar candidates must be younger than the T Tauri stars, the difference in disk mass may result from the difference in evolutional stage between them. Our results suggest that disk mass increases by dynamical mass accretion when the protostar candidates evolve into the T Tauri stars.

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