Berkeley – Illinois – Maryland Array

Observing Proposal Cover Sheet

BIMA use
Recd.

Version 1.7 06/22/98

SEND TO: BIMA Time Allocation Committee, c/o Lew Snyder
Univ. of Illinois, 103 Astronomy Building
1002 W. Green Street, Urbana, IL 61801

DATE: 12 January 1999

TITLE: Imaging Infall Toward the S68N Protostar

KEY PROJECT: ____ Yes

Target of Opportunity: ____ Yes

Contact Email: awootten@nrao.edu

	Name	Affiliation	Inst. Code	Grad Student?	Thesis?
P.I:	Al Wootten	NRAO	V	n	n
2.	M. Barsony	UC-Riverside	V	n	n
3.	J. Mangum	NRAO	V	n	n
4.	G. Wolf-Chase	U. Chicago	V	n	n

TIME REQUEST

	Observe File Name	Array Config	Freq (GHz)	Source Name	R.A. HHMM	Dec DDMM	Track Hrs Min - Max	No. of mosaic fields	Filler Proj
1.	n###c218.s68n	C	218.3	S68N	1829	0116	14 - 23	1	

SCIENTIFIC CATEGORY: ____ planetary ____ solar ____ stellar _X_ galactic ____ extragalactic

TYPE OF OBSERVATION: ____ Continuum _X_ Spectral Line ____ Both

FREQUENCY BAND: ____ 3 mm _X_ 1 mm ____ 1 cm

CORRELATOR INPUT:

	Primary Species (& transition)	Rest Freq (GHz)	channel width (MHz)	Required rms [T(K) or S_ν(Jy/Beam)] per channel
1.	H2CO $J = 303 \rightarrow 202$	218.222191	0.25	0.25
2.	H2CO $J = 322 \rightarrow 221$	218.475639	0.25	0.25
3.	H2CO $J = 321 \rightarrow 220$	218.760068	0.25	0.25
4.	CH3C2H $J = 13* \rightarrow 12*$	222.15	0.25	0.25

NOTES AND SPECIAL REQUIREMENTS:

Help required: ____ None _X_ Consultation ____ Extensive

Special hardware, software, or operating requirements: ____ None ____ Some

Describe special notes or requirements (including required or unacceptable observation dates):

ADDITIONAL INFORMATION REQUIRED FOR A-ARRAY (1MM/3MM) AND B-ARRAY (1MM):

Target Source	Point Source?	Source has structure?	Can Self-cal?	Main-component Flux Density
1.S68N	no	yes	no	0.9

Phase Calibrator	Degrees away	Flux Density	Integration Time	Cal-repeat cycle time
1.1751+096	11.8	4 Jy	10 sec	1 min

UPDATE STATUS OF UNPUBLISHED BIMA DATA

Proj. #	Source	Line	Array	Year of observation	Status
t150	N1333-IRAS4A	NH2D-l	C	1998	abstract published, paper in preparation

ABSTRACT:

We are requesting 1 track of BIMA time to *simultaneously* observe three transitions of H_2CO (218.222, 218.475 and 218.760 GHz) towards the Serpens protostellar source, S68N. Although we have acquired single-dish spectra towards S68N in a dozen H_2CO transitions to date, spanning the 72 GHz–365 GHz frequency range, our recent 450 μm SCUBA and VLA NH_3 imaging results emphasize the need for high-spatial resolution H_2CO *imaging* to understand the gas dynamics and structure towards this infall/outflow source.

We will contrast our observations to our Shu model for the structure of the collapsing protostar in order to:

- establish the scale of the infall which we believe we have established to occur onto S68N,
- establish the role of angular momentum and of neighboring sources on the maintenance of the massive core.
- provide support for our model of the density structure of S68N, and particularly to identify and map the warm unresolved inner component seen in broad beam H_2CO maps and dust images,
- determine the state of the gas toward other nearby clumps along the submillimeter ridge through S68N,
- establish a temperature probe in the millimeter regime of similar usefulness to the NH_3 probe in the centimeter regime.

PLEASE ATTACH: !!! NEW ITEM 1 !!!

1) LIST OF PAPERS involving BIMA data published by PI and co–investigators. Of the published papers, List any data observed since 1994 that has NOT been deposited in the NCSA Astronomy Digital Image Library.
2) SCIENTIFIC justification not to exceed 1000 words.
3) TECHNICAL justification including expected signal strength

For further information, send e–mail to lanie@astro.uiuc.edu

BIMA observing proposal LaTeX macros v1.7.

Imaging the Infall Toward the S68N Protostar

A. Wootten (NRAO), M. Barsony (UCR), J. Mangum (NRAO) and G. Wolf-Chase (U. Chicago)

SCIENTIFIC BACKGROUND & JUSTIFICATION

S68N was first identified by its strong CS 2$\rightarrow$1 emission (McMullin et al. 1994 Ap. J.424 222), appearing merely as an anonymous clump, lacking a near-infrared counterpart, in the millimeter continuum (Casali, Eiroa, & Duncan 1993 A& A 275, 195). Our study of this object has shown it to be a nearby (310 pc) *bona fide* protostar of 5 $L_\odot$ with $\sim$ 2.5 $M_\odot$ of gas in its infall envelope (Hurt, Barsony, & Wootten 1996 Ap. J.456 686; Hurt & Barsony 1996 Ap. J.460 L45). The compact bipolar flow driven by S68N was imaged by us for the first time, by combining single-dish (Haystack 37-m) and interferometric (BIMA) data (Wolf-Chase et al. 1998 Ap. J.501 L193). Until now, only high-luminosity sources were known to drive outflows visible in CS. S68N is also the site of water maser emission.

Observations with SCUBA at submillimeter wavelengths (see Figure 1), and with the VLA of ammonia emission, show a dominant point source, the star forming core of S68N, with additional close clumps surrounding S68N, forming a ridge perpendicular to the flow. Our focus will be to determine the structure of gas in this core. An ancillary focus will be to determine the evolutionary state of the nearby clumps.

To date, we have observed S68N in a myriad of H_2CO transitions, lying between 72 GHz and 365 GHz, in order to constrain its gas properties. In the lowest excitation line, a layer of cool (T$\sim$20K) gas at moderate densities is seen, accounting for most of the total gas column density. In slightly more excited lines, such as the 145 GHz line, this gas is seen in absorption against a warmer background gas. As we climb the ladder of rotational excitation to the 218.222 GHz H_2CO $3_{03} \rightarrow 2_{02}$ line, which we are requesting to image with BIMA, we find only a narrow absorption from the foreground gas. The foreground gas is moving away from the observer; that is, it is falling inward upon the central heating source (see Figure 2). At this excitation (22K) and higher, the source is barely resolved or unresolved to the beams which have been employed (>18"), about the size of the primary beam at BIMA. Examination of models fitting the data, and of NRAO-12m emission maps (including the lines we will image at BIMA, which will provide small spacing information), shows that only about a third of the total column density toward S68N emits in these higher excitation lines. At even higher energies, e.g., the 365 GHz line, no absorption is seen in spectra taken at the CSO. The origin of this warm gas remains unclear but, centered on the protostar, it is most likely closely associated with it.

The SCUBA maps offer higher resolution, though they lack information on gas structure and dynamics. We have extrapolated the H_2CO model inwards, using the SCUBA maps and H_2CO observations as constraints. This has resulted in a model for the density and temperature structure for the source which can reproduce the formaldehyde profiles observed in eight transitions by Hurt et al. (1996) as well as the deconvolved, azimuthally averaged 450μm flux density distribution to better than 10% out to a radius of 20$''$. Inside a radius of 10$''$ we have no dynamical information. However, the line asymmetry which we have noted suggests that infall occurs onto the central warm region. Beyond this radius, neighboring sources start to contribute to the observed flux. What is the role of these sources? The strong velocity gradients in this region suggest that rotation may be important–is the substantial mass in the core prevented from falling onto the protostar by an excess of angular momentum?

Maps of emission in the H_2CO $2_{02} \rightarrow 1_{01}$ and H_2CO $5_{05} \rightarrow 4_{04}$ lines, taken with 20$''$ beams, are shown in Figure 3; the BIMA beam is clearly appropriate for resolving the central emission feature.

Table 1: S68N Properties

Property	Value S68N	Reference
Position (1950.0)	$18^h\ 27^m\ 15^s.63\ 01^o\ 14'42''.3$	cm source
Distance (pc)	310	
Dust Size (AU)	7000 ×4500	450 μm
Dust Temperature (K)	20K	Wolf-Chase et al. 1998
Dust Mass ($M_\odot$)	1	within r=6000AU
Luminosity ($L_\odot$)	5	Wolf-Chase et al. 1998
Collapse Model		
Expansion wave radius (cm)	9.1×10^{16}	uncertain
Kinetic Temperature (K)	$50\ (R_T/r)^{-0.4}$	$R_T=10^{15}$cm,T(r) above 15K, assumed for fit
Density (cm^{-3})	$n(r)=1.7 \times 10^6 (R_0/r)^{-2}$	$R_0=9.1\times10^{16}$cm,this paper
	$n(r)=2.0 \times 10^6 (R_0/r)^{-1.5}$	inside R_{infall}

The model which reproduces both the flux distribution shown in the Figure, and the single antenna H_2CO spectra, is described in Table 1.

The model requires the existence of a warm inner region containing about one-third of the total column density toward the source, which we know from our SCUBA observations to subtend an angle $\leq 7''$. This would appear to be well within the infall radius. The structure of objects with cold energy distributions is not well-known; our modelling suggests that this small warm core subtends an angle of about $5''$, just resolved in the $3''$ BIMA beam. In some part of the envelope, material appears to be falling inward onto the core.

We propose to obtain high resolution observations of the H_2CO $3_{03} \rightarrow 2_{02}$, $3_{22} \rightarrow 2_{21}$ and $3_{21} \rightarrow 2_{20}$ transitions in order to:

• establish the scale of the infall which we believe we have established to occur onto S68N,

• establish the role of angular momentum and of neighboring sources on the maintenance of the massive core.

• provide support for our model of the density structure of S68N, and particularly to identify and map the warm unresolved inner component seen in broad beam H_2CO maps and dust images,

• determine the state of the gas toward other nearby clumps along the submillimeter ridge through S68N.

• establish a temperature probe in the millimeter regime of similar usefulness to the NH_3 probe in the centimeter regime.

OBSERVING STRATEGY AND TIME REQUIREMENTS

Our primary aim is to image *simultaneously* the $3_{03} \rightarrow 2_{02}$, $3_{22} \rightarrow 2_{21}$ and $3_{21} \rightarrow 2_{20}$ transitions of H_2CO, lying at 218.222, 218.475, and 218760.068 GHz, respectively, toward S68N and its environs at 2-3$''$ resolution. The former line is best to trace the infall motions of the cooler, dense foreground gas onto the centrally heated protostellar core, which will be best delineated in the latter transitions. At a resolution of $2''$, gas bound to a central object of 1 $M_\odot$ should show velocity excursions of ±1.7 km s^{-1} for Keplerian motion.

The mode 4 correlator mode with a bandwidth of 25 MHz over 256 channels will provide a velocity resolution of $\sim$ 0.13 km s^{-1} and a total velocity coverage of 34 km s^{-1} for each transition, both of which will be sufficient to probe the velocity structure over the entire range of the single antenna spectrum (see Figure 3).

As the signal-to-noise obtained in our weakest line will dictate how well we can measure the kinetic temperature structure, we would like to obtain at least 5:1 S/N in the $3_{22} \rightarrow 2_{21}$ transition. This will also provide excellent sensitivity to the source kinematics in the K=0 line. Our single antenna measurements likely suffer from beam dilution, so we will assume a conservative factor of 6 (from our model) to account for this in our sensitivity calculations. Hence we expect a line of at least 1 K intensity across 4 km/s. From "Technical Description of the BIMA Array" we assume the following: ten interferometer elements, $\tau_0 = 0.3$ (6mm of PWV), $T_{sys} = 500$ K DSB, $\eta_{cor} = 0.88$, and $\theta_A = \theta_B = 3''$. Therefore, for 4 - 1 km/s resolution elements across the line we achieve 0.14 K per channel in a single transit using configurations capable of providing good *u*-*v* coverage for a source at 0^o declination, and complete the proposed experiment. Recall that two K=2 lines of very similar excitation characteristics may be observed simultaneously with the flexible BIMA correlator, in addition to the K=0 line, which is expected to be stronger, allowing us to more easily reach our sensitivity goals.