Riccardo ("il Cesa") and IRAM

ROBERTO NERI

Villa Galileo, 4-6 May 2026

iram
Institut de
Radioastronomie
Millimétrique

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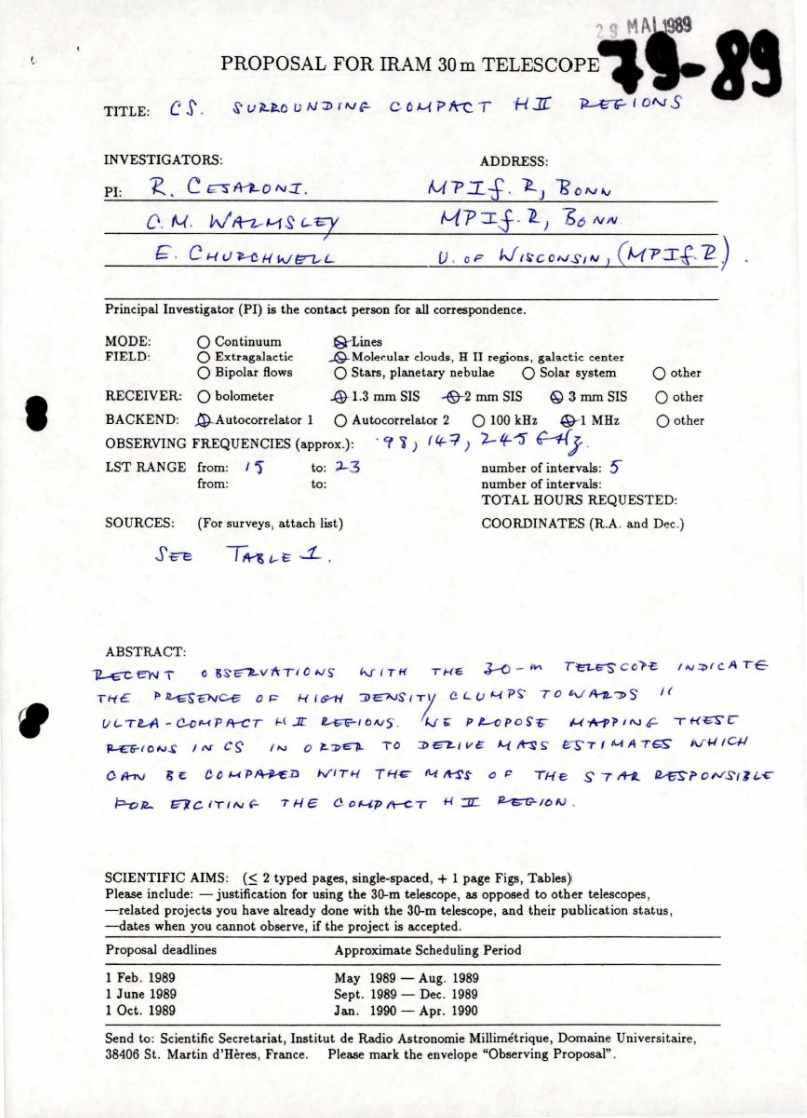


29 MAI 1989

79-89

PROPOSAL FOR IRAM 30 m TELESCOPE

TITLE: CS. SURROUNDING COMPACT HII REGIONS

INVESTIGATORS:	ADDRESS:
PI: R. CESARONI.	MPIf. R, BONN
C.M. WALMSLEY	MPIf. R, BONN
E. CHURCHWELL	U. OF WISCONSIN, (MPIf. R) .

Principal Investigator (PI) is the contact person for all correspondence.

MODE: ○ Continuum ⊗ Lines
FIELD: ○ Extragalactic ⊗ Molecular clouds, H II regions, galactic center
○ Bipolar flows ○ Stars, planetary nebulae ○ Solar system ○ other
RECEIVER: ○ bolometer ⊗ 1.3 mm SIS ⊗ 2 mm SIS ⊗ 3 mm SIS ○ other
BACKEND: ⊗ Autocorrelator 1 ○ Autocorrelator 2 ○ 100 kHz ⊗ 1 MHz ○ other
OBSERVING FREQUENCIES (approx.): 98, 147, 245 GHz.
LST RANGE from: 15 to: 23 number of intervals: 5
from: to: number of intervals:
TOTAL HOURS REQUESTED:
SOURCES: (For surveys, attach list) COORDINATES (R.A. and Dec.)

SEE TABLE 1.

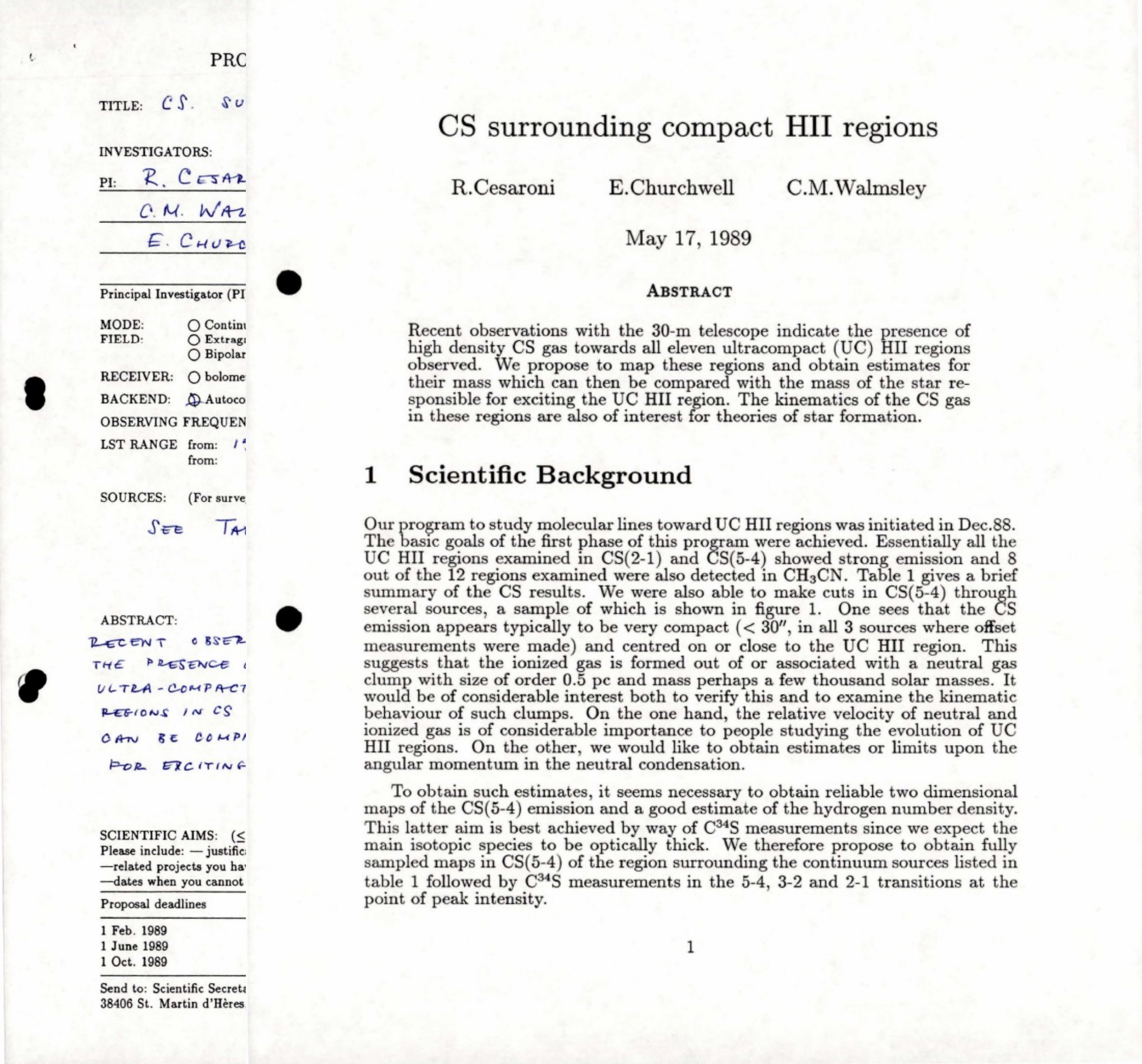
ABSTRACT:

RECENT OBSERVATIONS WITH THE 30-m TELESCOPE INDICATE THE PRESENCE OF HIGH DENSITY CLUMPS TOWARDS '' ULTRA-COMPACT H II REGIONS. WE PROPOSE MAPPING THESE REGIONS IN CS IN ORDER TO DERIVE MASS ESTIMATES WHICH CAN BE COMPARED WITH THE MASS OF THE STAR RESPONSIBLE FOR EXCITING THE COMPACT H II REGION.

SCIENTIFIC AIMS: (≤ 2 typed pages, single-spaced, + 1 page Figs, Tables)
Please include: — justification for using the 30-m telescope, as opposed to other telescopes,
—related projects you have already done with the 30-m telescope, and their publication status,
—dates when you cannot observe, if the project is accepted.

Proposal deadlines	Approximate Scheduling Period
1 Feb. 1989	May 1989 — Aug. 1989
1 June 1989	Sept. 1989 — Dec. 1989
1 Oct. 1989	Jan. 1990 — Apr. 1990

Send to: Scientific Secretariat, Institut de Radio Astronomie Millimétrique, Domaine Universitaire, 38406 St. Martin d'Hères, France. Please mark the envelope "Observing Proposal".



PRC

TITLE: CS. SU

INVESTIGATORS:
PI: R. CESAR
C.M. WAL
E. CHURC

Principal Investigator (PI

MODE: ○ Contin
FIELD: ○ Extrag
○ Bipolar
RECEIVER: ○ bolome
BACKEND: ☒ Autoco
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ABSTRACT:
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1 June 1989
1 Oct. 1989

Send to: Scientific Secret
38406 St. Martin d'Hères

CS surrounding compact HII regions

R.Cesaroni E.Churchwell C.M.Walmsley

May 17, 1989

Abstract

Recent observations with the 30-m telescope indicate the presence of high density CS gas towards all eleven ultracompact (UC) HII regions observed. We propose to map these regions and obtain estimates for their mass which can then be compared with the mass of the star responsible for exciting the UC HII region. The kinematics of the CS gas in these regions are also of interest for theories of star formation.

1 Scientific Background

Our program to study molecular lines toward UC HII regions was initiated in Dec.88. The basic goals of the first phase of this program were achieved. Essentially all the UC HII regions examined in CS(2-1) and CS(5-4) showed strong emission and 8 out of the 12 regions examined were also detected in CH_3CN. Table 1 gives a brief summary of the CS results. We were also able to make cuts in CS(5-4) through several sources, a sample of which is shown in figure 1. One sees that the CS emission appears typically to be very compact ($< 30''$, in all 3 sources where offset measurements were made) and centred on or close to the UC HII region. This suggests that the ionized gas is formed out of or associated with a neutral gas clump with size of order 0.5 pc and mass perhaps a few thousand solar masses. It would be of considerable interest both to verify this and to examine the kinematic behaviour of such clumps. On the one hand, the relative velocity of neutral and ionized gas is of considerable importance to people studying the evolution of UC HII regions. On the other, we would like to obtain estimates or limits upon the angular momentum in the neutral condensation.

To obtain such estimates, it seems necessary to obtain reliable two dimensional maps of the CS(5-4) emission and a good estimate of the hydrogen number density. This latter aim is best achieved by way of $C^{34}S$ measurements since we expect the main isotopic species to be optically thick. We therefore propose to obtain fully sampled maps in CS(5-4) of the region surrounding the continuum sources listed in table 1 followed by $C^{34}S$ measurements in the 5-4, 3-2 and 2-1 transitions at the point of peak intensity.

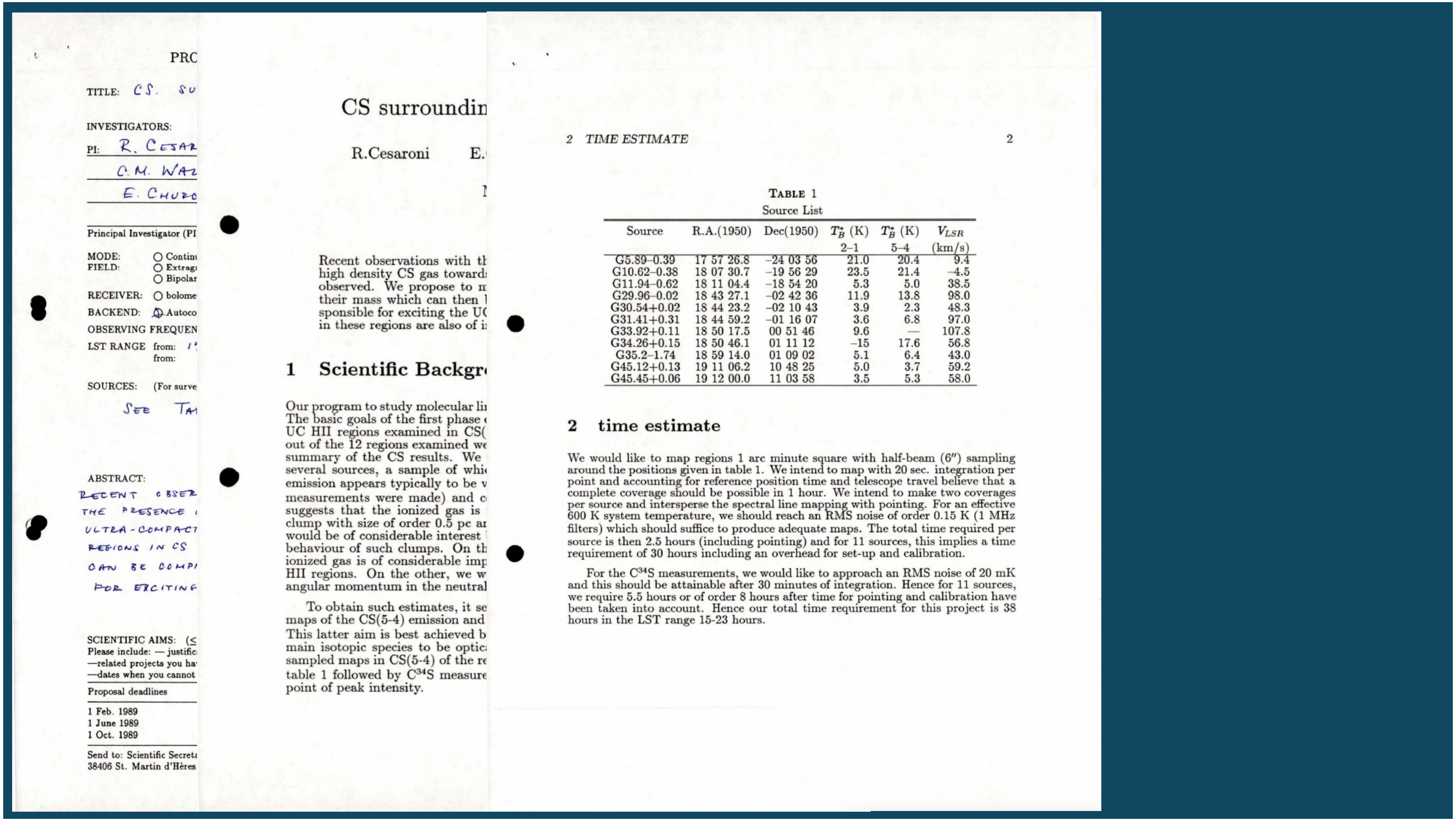

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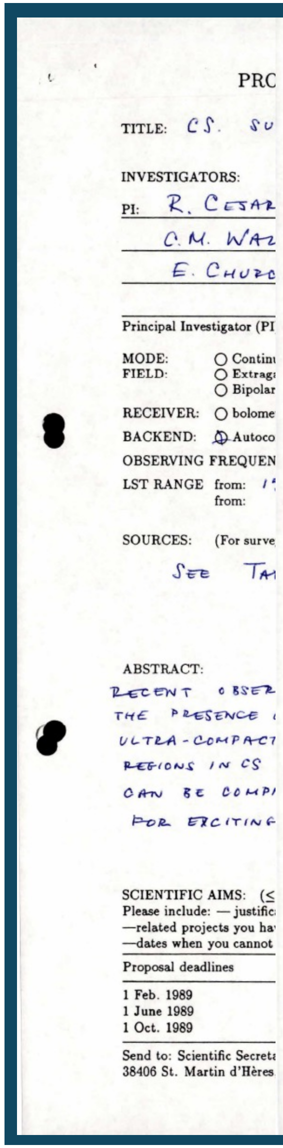
TABLE 1
Source List

Source	R.A.(1950)	Dec(1950)	T_B^* (K) 2–1	T_B^* (K) 5–4	V_{LSR} (km/s)
G5.89–0.39	17 57 26.8	–24 03 56	21.0	20.4	9.4
G10.62–0.38	18 07 30.7	–19 56 29	23.5	21.4	–4.5
G11.94–0.62	18 11 04.4	–18 54 20	5.3	5.0	38.5
G29.96–0.02	18 43 27.1	–02 42 36	11.9	13.8	98.0
G30.54+0.02	18 44 23.2	–02 10 43	3.9	2.3	48.3
G31.41+0.31	18 44 59.2	–01 16 07	3.6	6.8	97.0
G33.92+0.11	18 50 17.5	00 51 46	9.6	—	107.8
G34.26+0.15	18 50 46.1	01 11 12	–15	17.6	56.8
G35.2–1.74	18 59 14.0	01 09 02	5.1	6.4	43.0
G45.12+0.13	19 11 06.2	10 48 25	5.0	3.7	59.2
G45.45+0.06	19 12 00.0	11 03 58	3.5	5.3	58.0

2 time estimate

We would like to map regions 1 arc minute square with half-beam (6″) sampling around the positions given in table 1. We intend to map with 20 sec. integration per point and accounting for reference position time and telescope travel believe that a complete coverage should be possible in 1 hour. We intend to make two coverages per source and intersperse the spectral line mapping with pointing. For an effective 600 K system temperature, we should reach an RMS noise of order 0.15 K (1 MHz filters) which should suffice to produce adequate maps. The total time required per source is then 2.5 hours (including pointing) and for 11 sources, this implies a time requirement of 30 hours including an overhead for set-up and calibration.

For the $C^{34}S$ measurements, we would like to approach an RMS noise of 20 mK and this should be attainable after 30 minutes of integration. Hence for 11 sources, we require 5.5 hours or of order 8 hours after time for pointing and calibration have been taken into account. Hence our total time requirement for this project is 38 hours in the LST range 15-23 hours.



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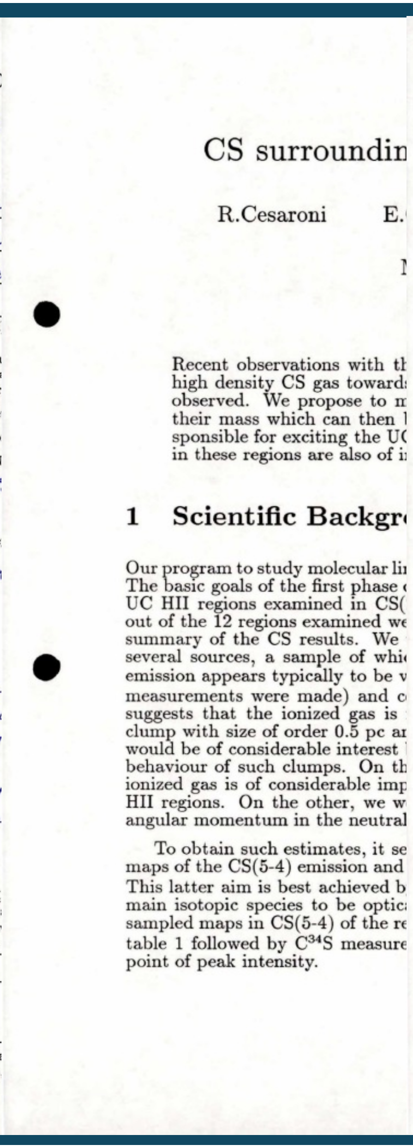

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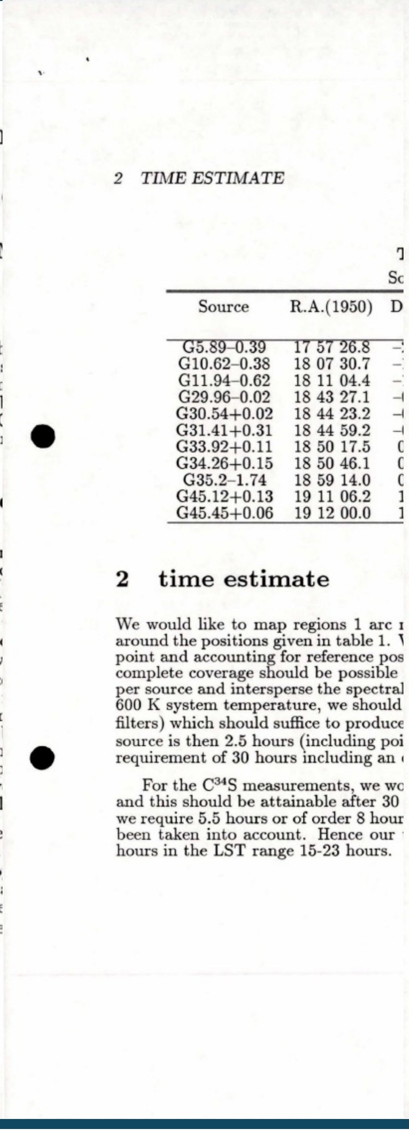

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G29.96–0.02	18 43 27.1	–
G30.54+0.02	18 44 23.2	–
G31.41+0.31	18 44 59.2	–
G33.92+0.11	18 50 17.5	0
G34.26+0.15	18 50 46.1	0
G35.2–1.74	18 59 14.0	0
G45.12+0.13	19 11 06.2	1
G45.45+0.06	19 12 00.0	1

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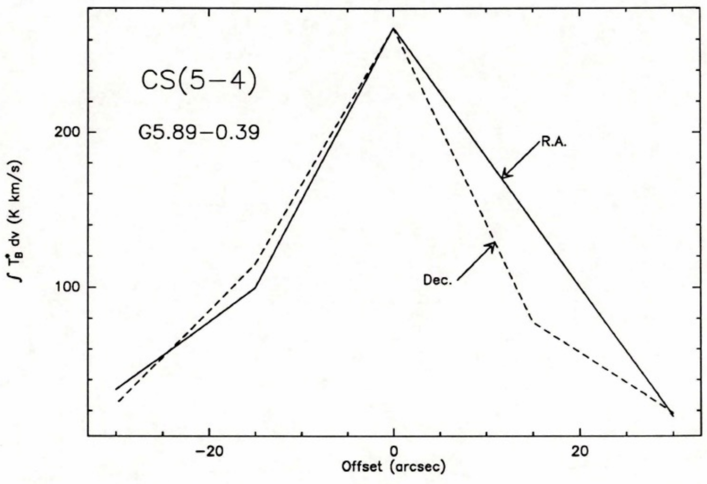
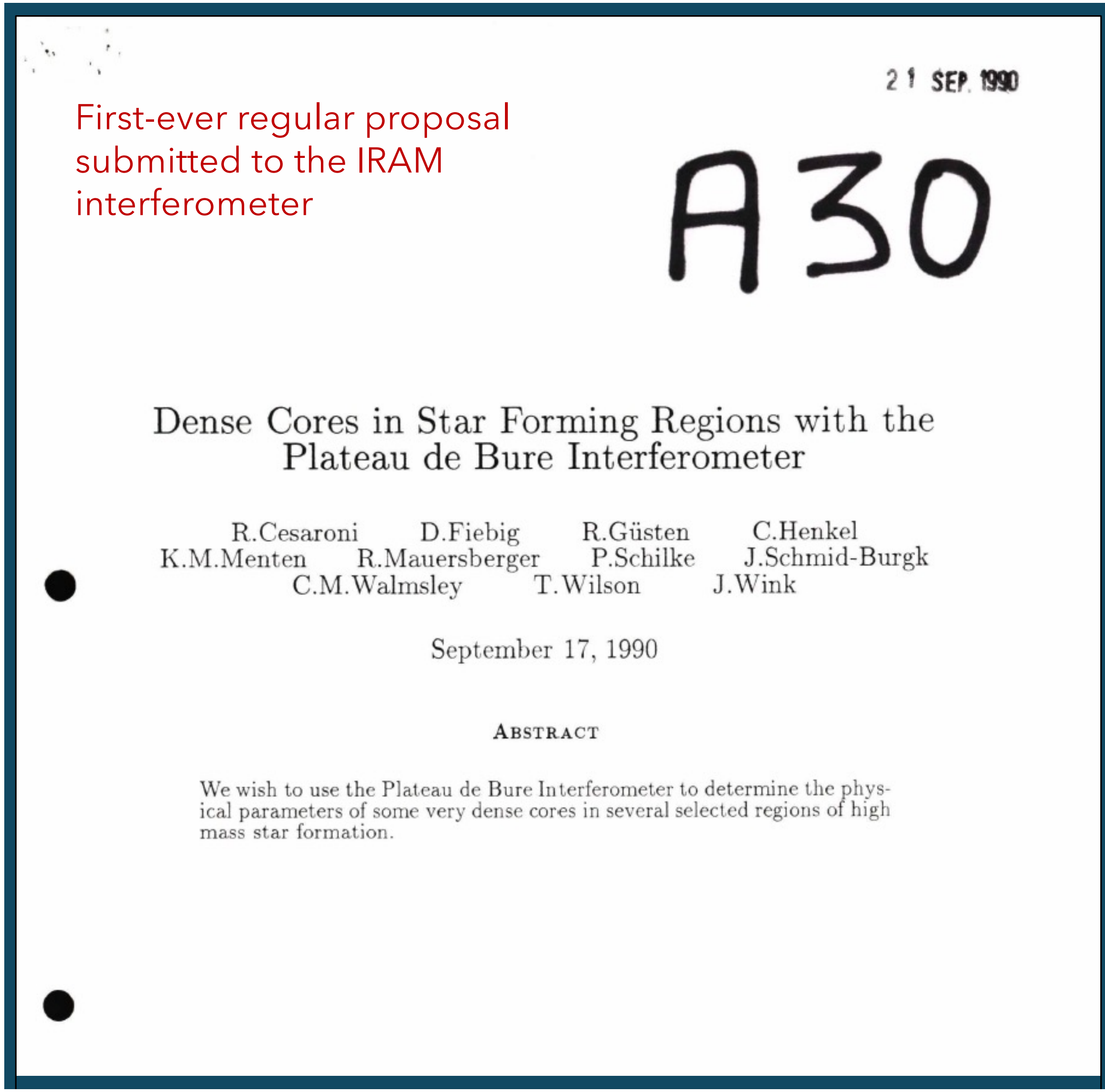


First-ever regular proposal submitted to the IRAM interferometer



21 SEP. 1990

A30

Dense Cores in Star Forming Regions with the Plateau de Bure Interferometer

R.Cesaroni D.Fiebig R.Güsten C.Henkel
K.M.Menten R.Mauersberger P.Schilke J.Schmid-Burgk
C.M.Walmsley T.Wilson J.Wink

September 17, 1990

ABSTRACT

We wish to use the Plateau de Bure Interferometer to determine the physical parameters of some very dense cores in several selected regions of high mass star formation.

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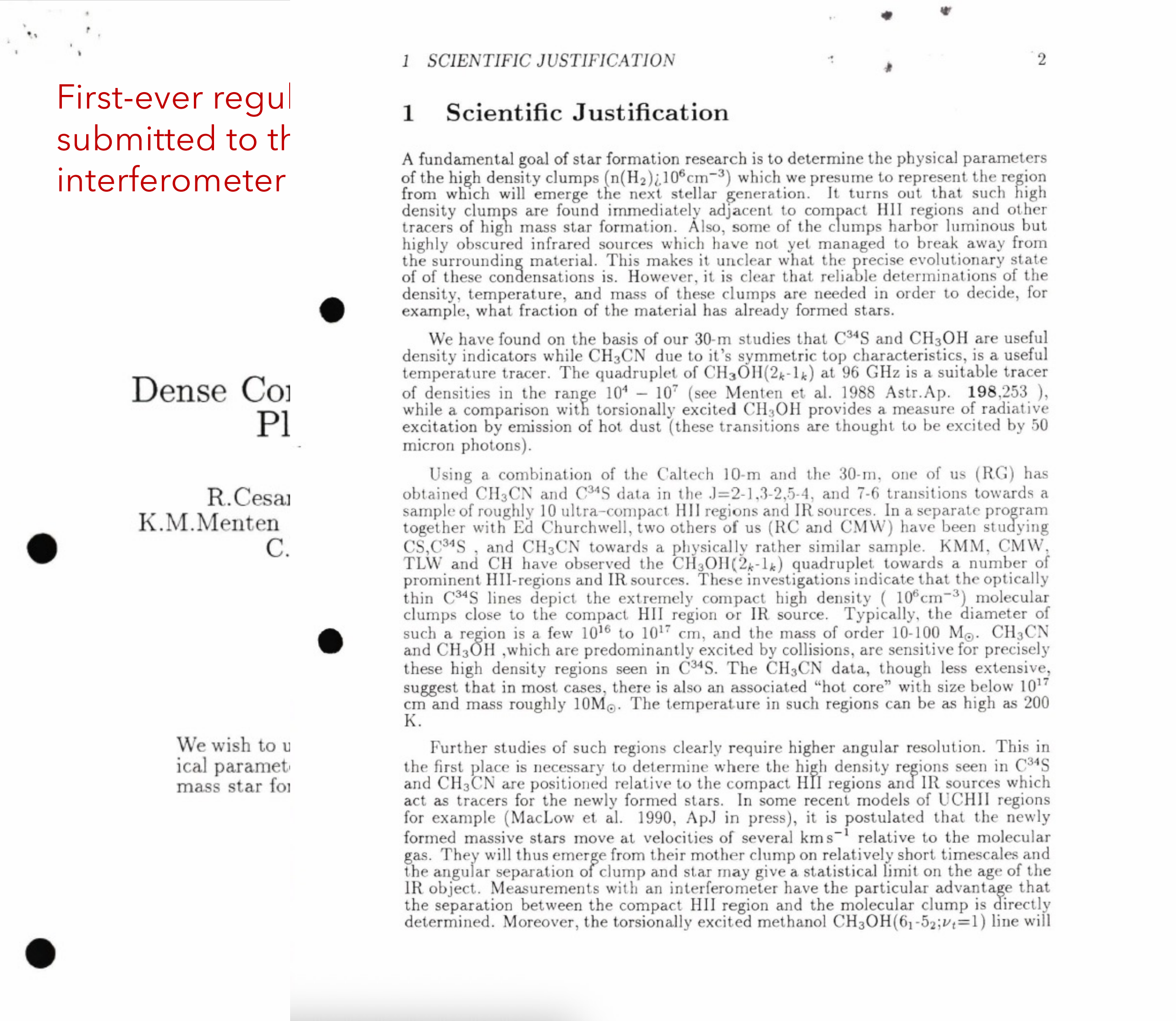

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1 Scientific Justification

A fundamental goal of star formation research is to determine the physical parameters of the high density clumps (n(H_2)¿10^6cm^{-3}) which we presume to represent the region from which will emerge the next stellar generation. It turns out that such high density clumps are found immediately adjacent to compact HII regions and other tracers of high mass star formation. Also, some of the clumps harbor luminous but highly obscured infrared sources which have not yet managed to break away from the surrounding material. This makes it unclear what the precise evolutionary state of of these condensations is. However, it is clear that reliable determinations of the density, temperature, and mass of these clumps are needed in order to decide, for example, what fraction of the material has already formed stars.

We have found on the basis of our 30-m studies that $C^{34}S$ and CH_3OH are useful density indicators while CH_3CN due to it's symmetric top characteristics, is a useful temperature tracer. The quadruplet of $CH_3OH(2_k$-$1_k)$ at 96 GHz is a suitable tracer of densities in the range $10^4 - 10^7$ (see Menten et al. 1988 Astr.Ap. **198**,253), while a comparison with torsionally excited CH_3OH provides a measure of radiative excitation by emission of hot dust (these transitions are thought to be excited by 50 micron photons).

Using a combination of the Caltech 10-m and the 30-m, one of us (RG) has obtained CH_3CN and $C^{34}S$ data in the J=2-1,3-2,5-4, and 7-6 transitions towards a sample of roughly 10 ultra-compact HII regions and IR sources. In a separate program together with Ed Churchwell, two others of us (RC and CMW) have been studying CS,$C^{34}S$, and CH_3CN towards a physically rather similar sample. KMM, CMW, TLW and CH have observed the $CH_3OH(2_k$-$1_k)$ quadruplet towards a number of prominent HII-regions and IR sources. These investigations indicate that the optically thin $C^{34}S$ lines depict the extremely compact high density (10^6cm^{-3}) molecular clumps close to the compact HII region or IR source. Typically, the diameter of such a region is a few 10^{16} to 10^{17} cm, and the mass of order 10-100 $M_\odot$. CH_3CN and CH_3OH ,which are predominantly excited by collisions, are sensitive for precisely these high density regions seen in $C^{34}S$. The CH_3CN data, though less extensive, suggest that in most cases, there is also an associated "hot core" with size below 10^{17} cm and mass roughly 10$M_\odot$. The temperature in such regions can be as high as 200 K.

Further studies of such regions clearly require higher angular resolution. This in the first place is necessary to determine where the high density regions seen in $C^{34}S$ and CH_3CN are positioned relative to the compact HII regions and IR sources which act as tracers for the newly formed stars. In some recent models of UCHII regions for example (MacLow et al. 1990, ApJ in press), it is postulated that the newly formed massive stars move at velocities of several km s^{-1} relative to the molecular gas. They will thus emerge from their mother clump on relatively short timescales and the angular separation of clump and star may give a statistical limit on the age of the IR object. Measurements with an interferometer have the particular advantage that the separation between the compact HII region and the molecular clump is directly determined. Moreover, the torsionally excited methanol $CH_3OH(6_1$-$5_2;\nu_t$=1) line will

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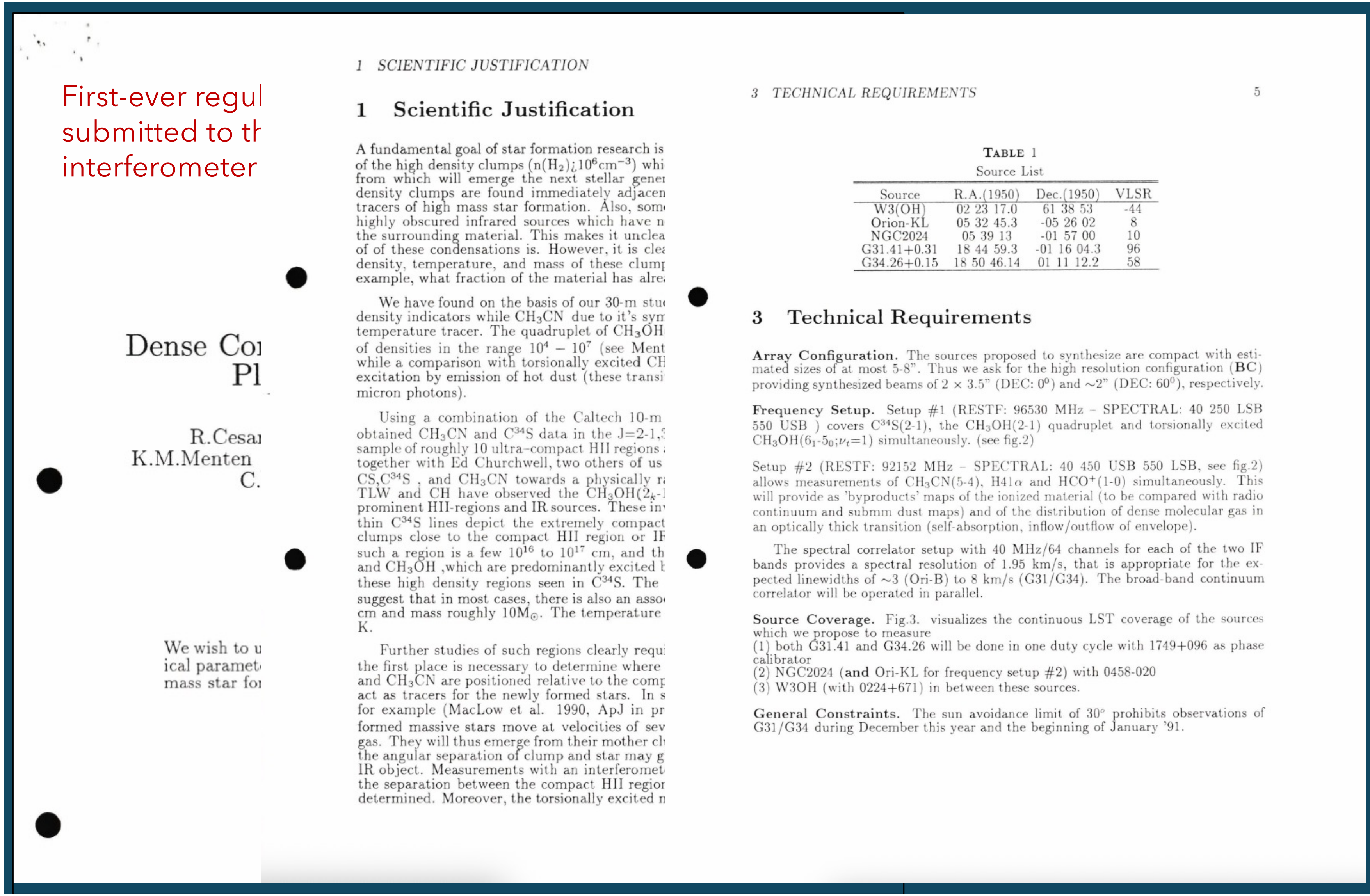

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3 TECHNICAL REQUIREMENTS 5

TABLE 1
Source List

Source	R.A.(1950)	Dec.(1950)	VLSR
W3(OH)	02 23 17.0	61 38 53	-44
Orion-KL	05 32 45.3	-05 26 02	8
NGC2024	05 39 13	-01 57 00	10
G31.41+0.31	18 44 59.3	-01 16 04.3	96
G34.26+0.15	18 50 46.14	01 11 12.2	58

3 Technical Requirements

Array Configuration. The sources proposed to synthesize are compact with estimated sizes of at most 5-8". Thus we ask for the high resolution configuration (**BC**) providing synthesized beams of 2 × 3.5" (DEC: 0^0) and ∼2" (DEC: 60^0), respectively.

Frequency Setup. Setup #1 (RESTF: 96530 MHz – SPECTRAL: 40 250 LSB 550 USB) covers $C^{34}S$(2-1), the CH_3OH(2-1) quadruplet and torsionally excited $CH_3OH(6_1\text{-}5_0;\nu_t=1)$ simultaneously. (see fig.2)

Setup #2 (RESTF: 92152 MHz – SPECTRAL: 40 450 USB 550 LSB, see fig.2) allows measurements of CH_3CN(5-4), H41α and HCO^+(1-0) simultaneously. This will provide as 'byproducts' maps of the ionized material (to be compared with radio continuum and submm dust maps) and of the distribution of dense molecular gas in an optically thick transition (self-absorption, inflow/outflow of envelope).

The spectral correlator setup with 40 MHz/64 channels for each of the two IF bands provides a spectral resolution of 1.95 km/s, that is appropriate for the expected linewidths of ∼3 (Ori-B) to 8 km/s (G31/G34). The broad-band continuum correlator will be operated in parallel.

Source Coverage. Fig.3. visualizes the continuous LST coverage of the sources which we propose to measure
(1) both G31.41 and G34.26 will be done in one duty cycle with 1749+096 as phase calibrator
(2) NGC2024 (**and** Ori-KL for frequency setup #2) with 0458-020
(3) W3OH (with 0224+671) in between these sources.

General Constraints. The sun avoidance limit of 30° prohibits observations of G31/G34 during December this year and the beginning of January '91.

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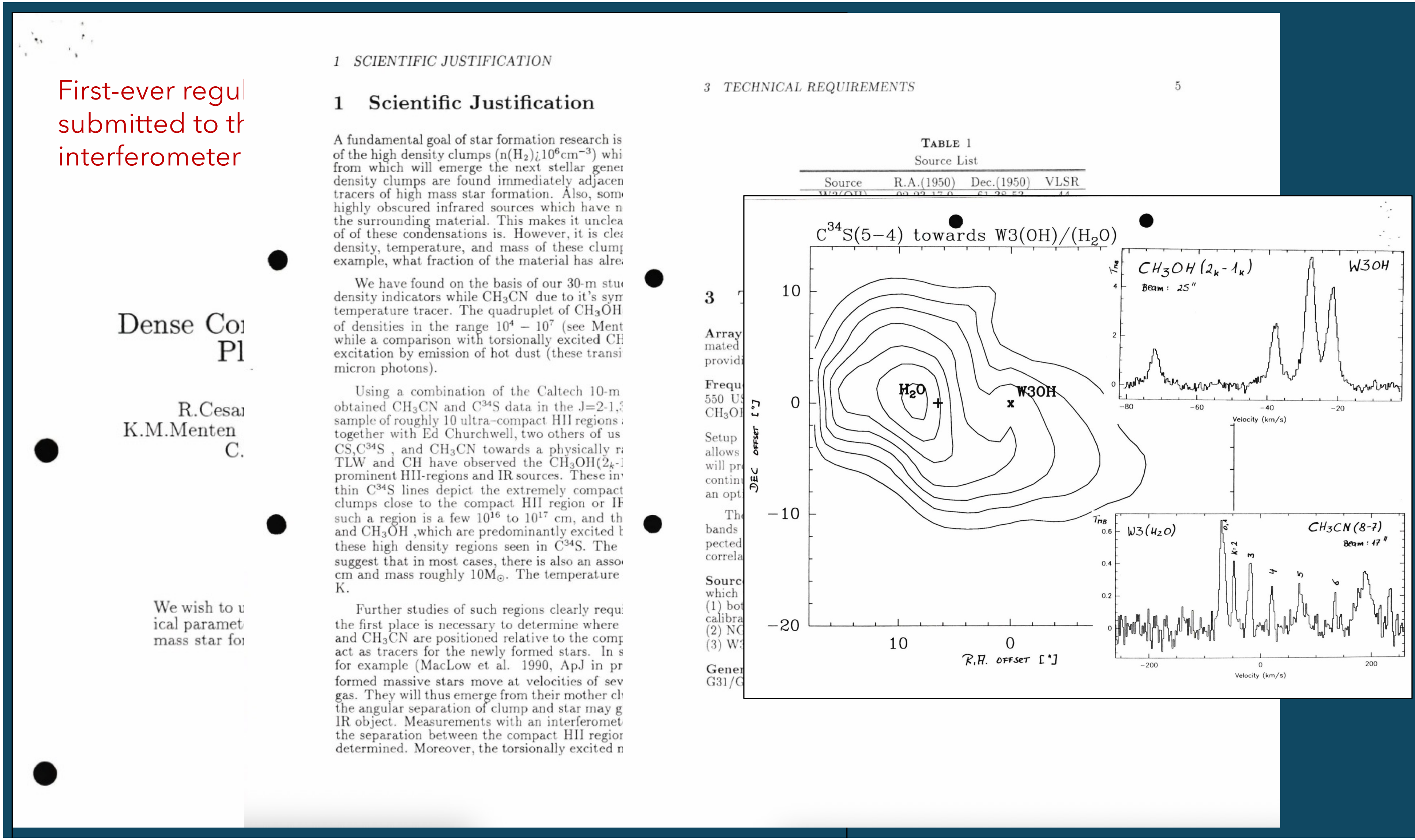

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Am: Rel.(A)
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CLIC − 14−APR−2026 12:57:37 *N001N005W005 N01−N05−W05*
85 7803 A032 ORION−KL O CORR C34S N01−N05−W05 05−FEB−1993 18:21 −1.8
406 8098 A032 ORION−KL O CORR C34S N01−N05−W05 05−FEB−1993 23:34 3.5

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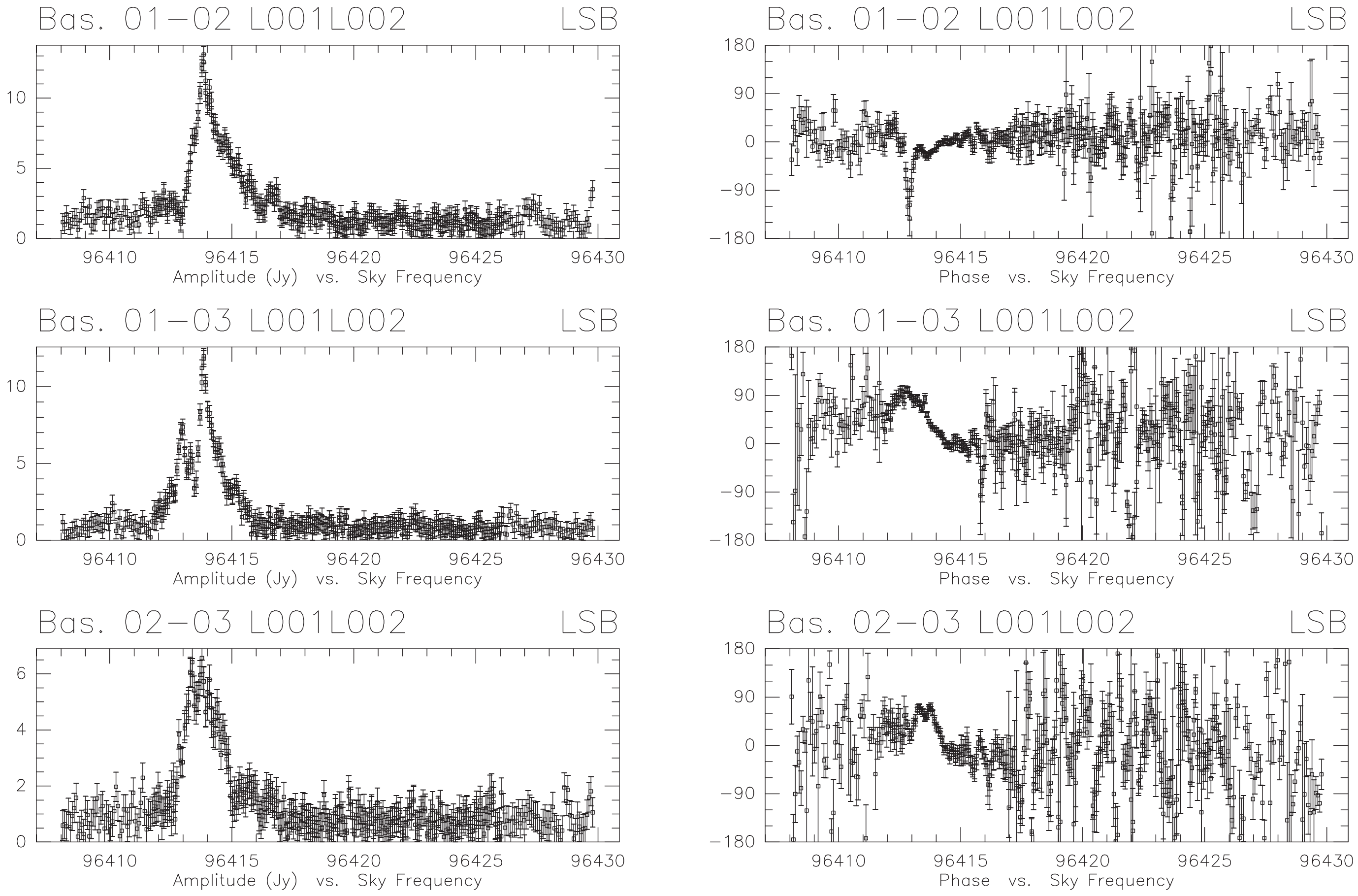

since 2000 …

- ~100 proposals submitted to IRAM facilities
- ~3500 hr requested, ~2000 hr recommended

Looking for pre-stellar massive cores with nd/nh observations
C2H as magnetic field probe in star-forming clouds
Probing the latest high-mass star formation models
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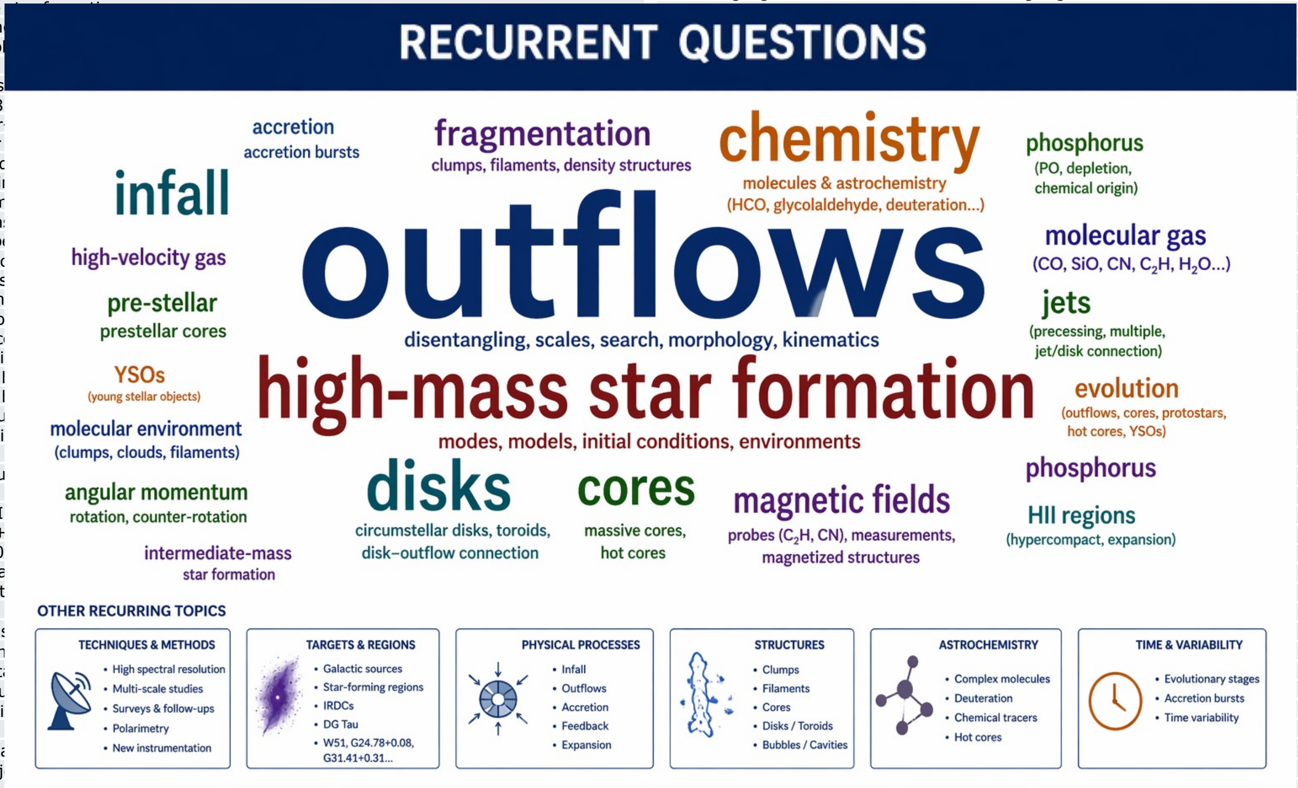


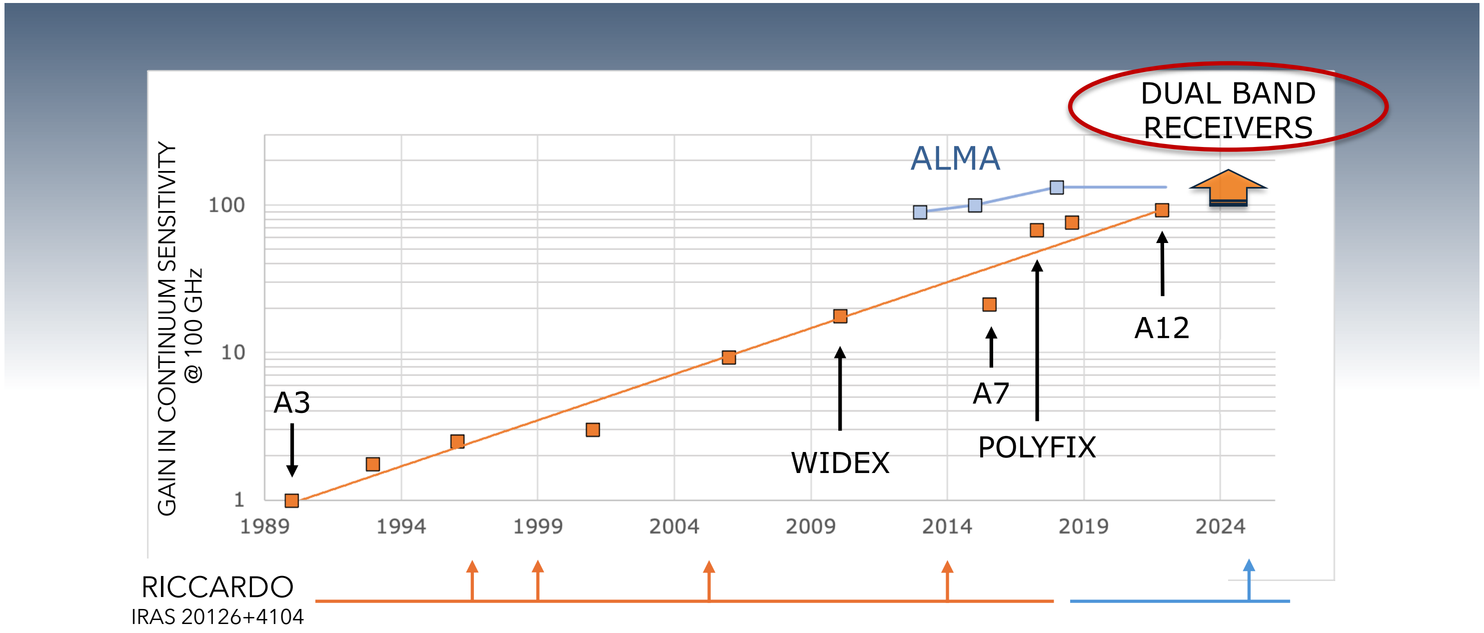
RECURRENT QUESTIONS

From the earliest (core, filaments) to the more evolved stages (outflows, jets, HII regions),
our collaboration returned regularly to question how massive stars form and evolve

PdBI’s evolution that made Riccardo’s science possible

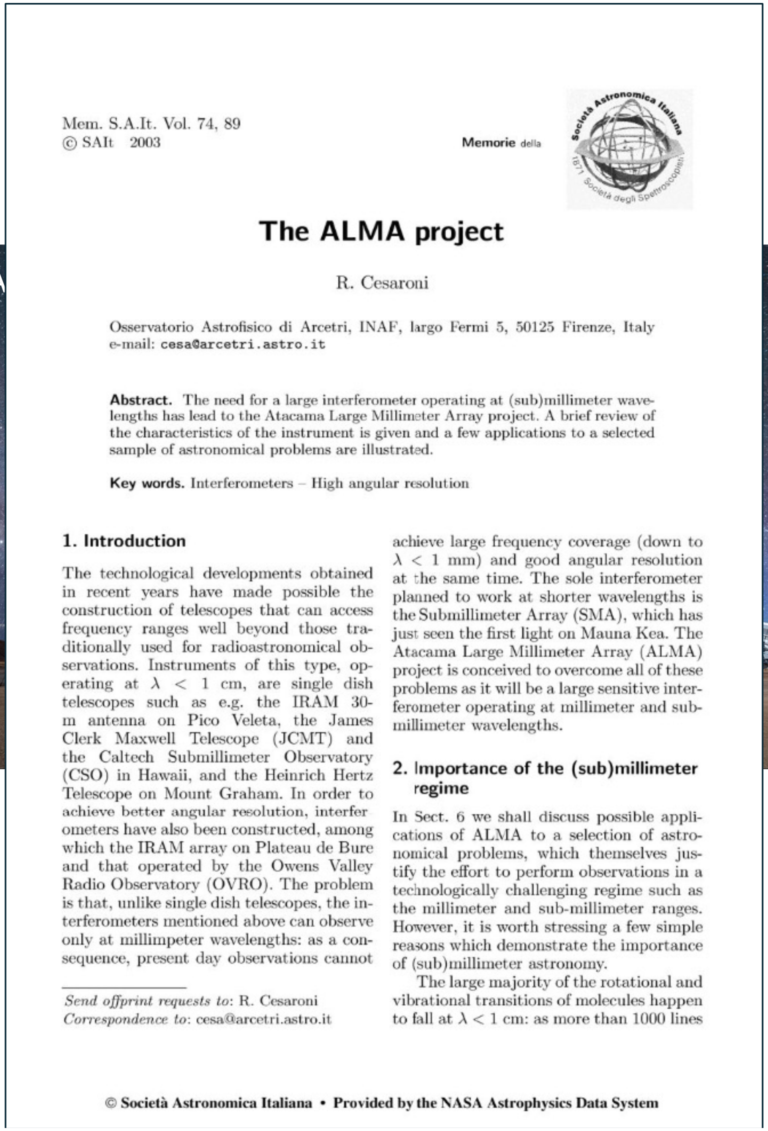
outflows → resolution   chemistry → bandwidth   surveys → sensitivity

The main interest in observing IRAS 20126+4104 was to establish the “missing link” between low- and high-mass star formation




ALMA 2040


NOEMA 20??



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The ALMA project

R. Cesaroni

Osservatorio Astrofisico di Arcetri, INAF, largo Fermi 5, 50125 Firenze, Italy
e-mail: `cesa@arcetri.astro.it`

Abstract. The need for a large interferometer operating at (sub)millimeter wavelengths has lead to the Atacama Large Millimeter Array project. A brief review of the characteristics of the instrument is given and a few applications to a selected sample of astronomical problems are illustrated.

Key words. Interferometers – High angular resolution

1. Introduction

The technological developments obtained in recent years have made possible the construction of telescopes that can access frequency ranges well beyond those traditionally used for radioastronomical observations. Instruments of this type, operating at $\lambda < 1$ cm, are single dish telescopes such as e.g. the IRAM 30-m antenna on Pico Veleta, the James Clerk Maxwell Telescope (JCMT) and the Caltech Submillimeter Observatory (CSO) in Hawaii, and the Heinrich Hertz Telescope on Mount Graham. In order to achieve better angular resolution, interferometers have also been constructed, among which the IRAM array on Plateau de Bure and that operated by the Owens Valley Radio Observatory (OVRO). The problem is that, unlike single dish telescopes, the interferometers mentioned above can observe only at millimpeter wavelengths: as a consequence, present day observations cannot achieve large frequency coverage (down to $\lambda < 1$ mm) and good angular resolution at the same time. The sole interferometer planned to work at shorter wavelengths is the Submillimeter Array (SMA), which has just seen the first light on Mauna Kea. The Atacama Large Millimeter Array (ALMA) project is conceived to overcome all of these problems as it will be a large sensitive interferometer operating at millimeter and submillimeter wavelengths.

2. Importance of the (sub)millimeter regime

In Sect. 6 we shall discuss possible applications of ALMA to a selection of astronomical problems, which themselves justify the effort to perform observations in a technologically challenging regime such as the millimeter and sub-millimeter ranges. However, it is worth stressing a few simple reasons which demonstrate the importance of (sub)millimeter astronomy.

The large majority of the rotational and vibrational transitions of molecules happen to fall at $\lambda < 1$ cm: as more than 1000 lines

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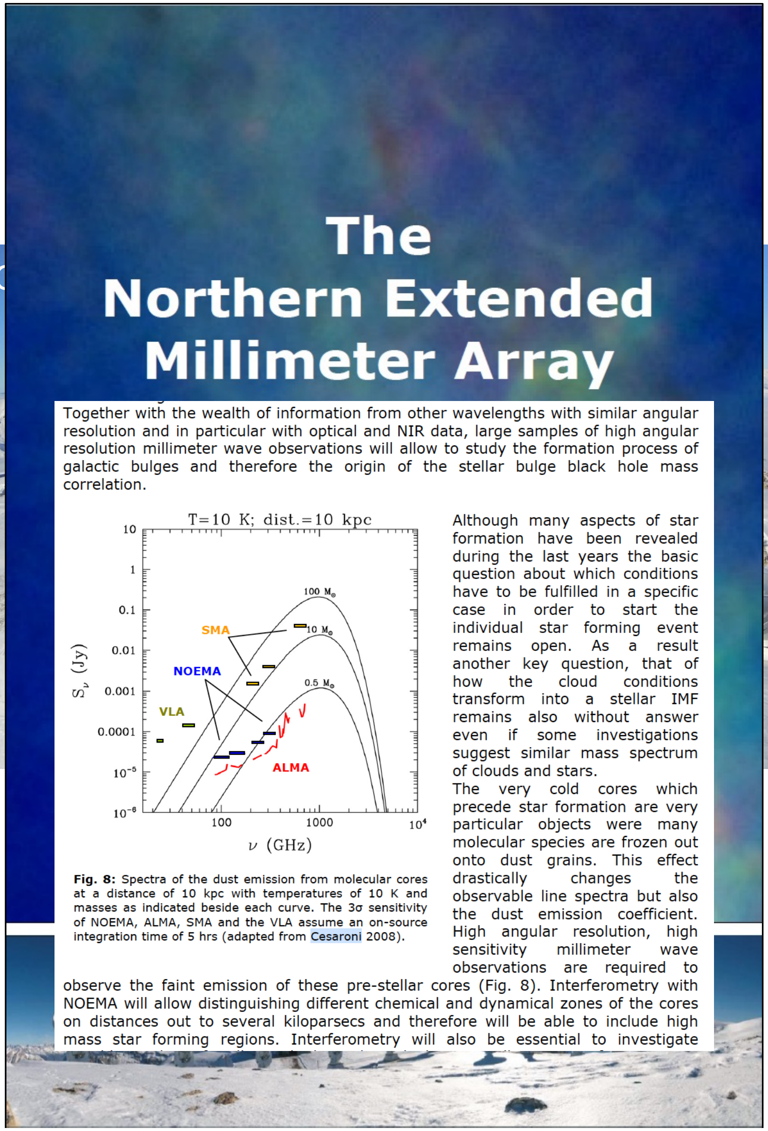
Send offprint requests to: R. Cesaroni
Correspondence to: cesa@arcetri.astro.it



The Northern Extended Millimeter Array

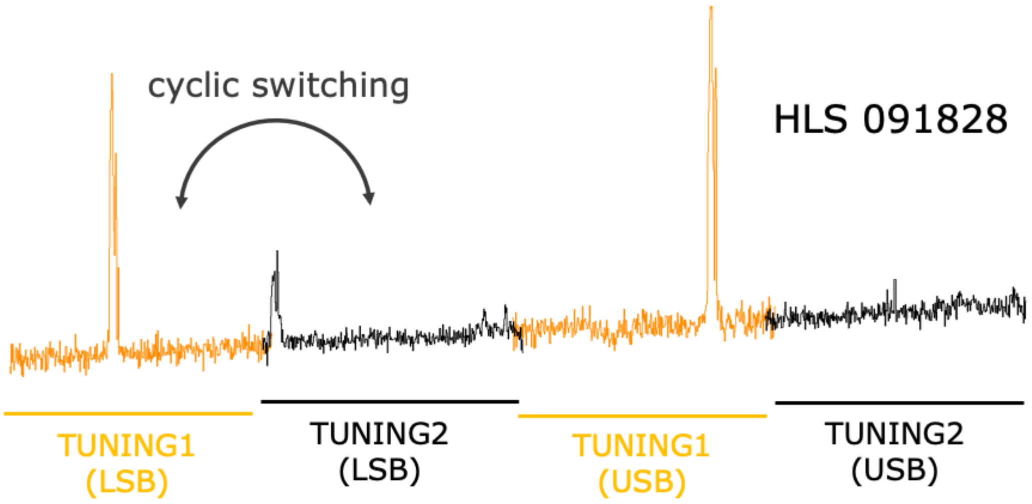
Together with the wealth of information from other wavelengths with similar angular resolution and in particular with optical and NIR data, large samples of high angular resolution millimeter wave observations will allow to study the formation process of galactic bulges and therefore the origin of the stellar bulge black hole mass correlation.

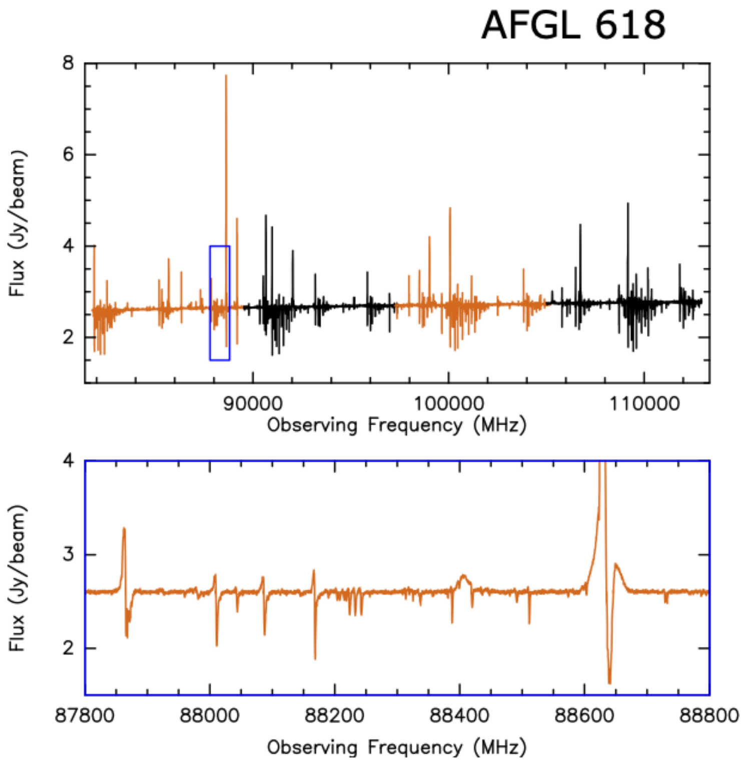
Fig. 8: Spectra of the dust emission from molecular cores at a distance of 10 kpc with temperatures of 10 K and masses as indicated beside each curve. The 3σ sensitivity of NOEMA, ALMA, SMA and the VLA assume an on-source integration time of 5 hrs (adapted from Cesaroni 2008).

Although many aspects of star formation have been revealed during the last years the basic question about which conditions have to be fulfilled in a specific case in order to start the individual star forming event remains open. As a result another key question, that of how the cloud conditions transform into a stellar IMF remains also without answer even if some investigations suggest similar mass spectrum of clouds and stars.
The very cold cores which precede star formation are very particular objects were many molecular species are frozen out onto dust grains. This effect drastically changes the observable line spectra but also the dust emission coefficient. High angular resolution, high sensitivity millimeter wave observations are required to observe the faint emission of these pre-stellar cores (Fig. 8). Interferometry with NOEMA will allow distinguishing different chemical and dynamical zones of the cores on distances out to several kiloparsecs and therefore will be able to include high mass star forming regions. Interferometry will also be essential to investigate

NOEMA’s implementation of frequency cycling

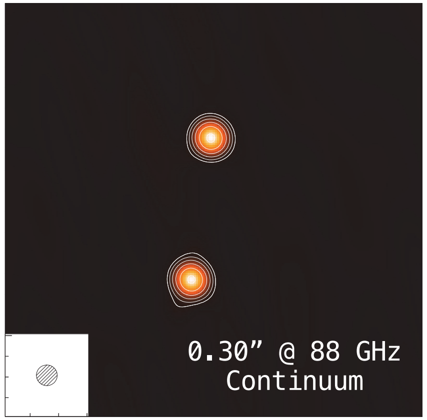
- Frequency cycling mode for perfect side-band interleaving
  - IRAS 20126+4104 from targeted multi-line studies to full spectral surveys
  - From a dynamical to a chemistry-driven view of IRAS 20126+4104

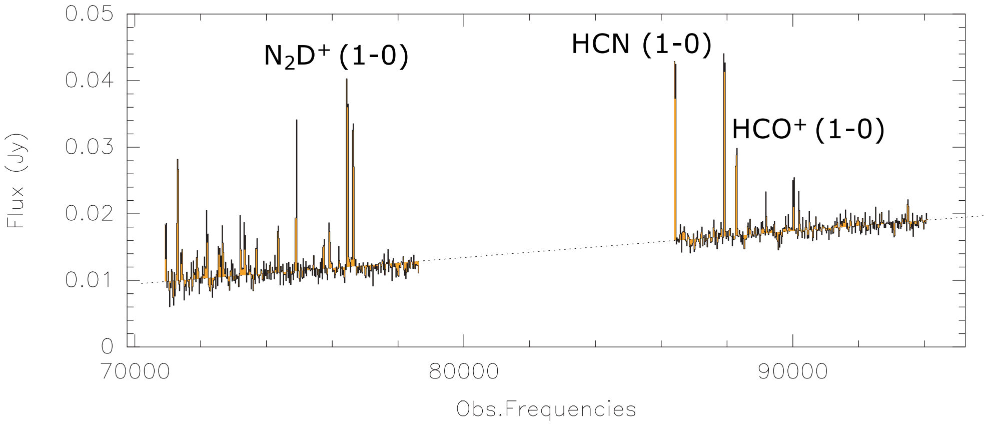




NOEMA’s implementation of Dual-Band observations

A - CONFIGURATION





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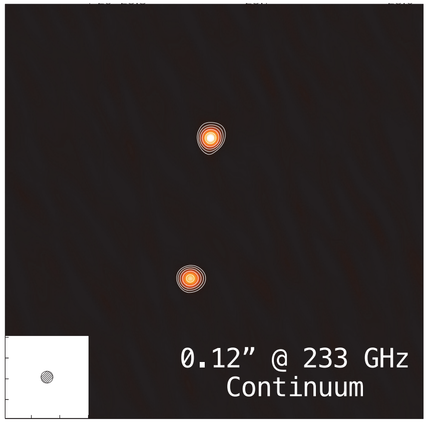
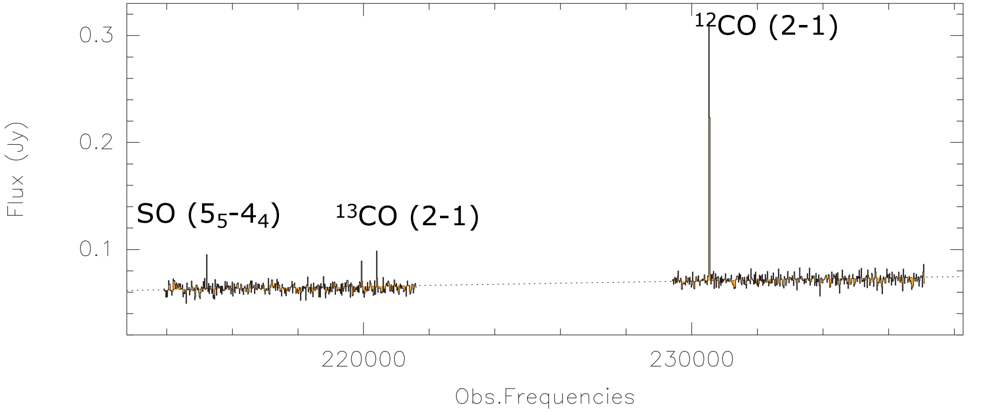
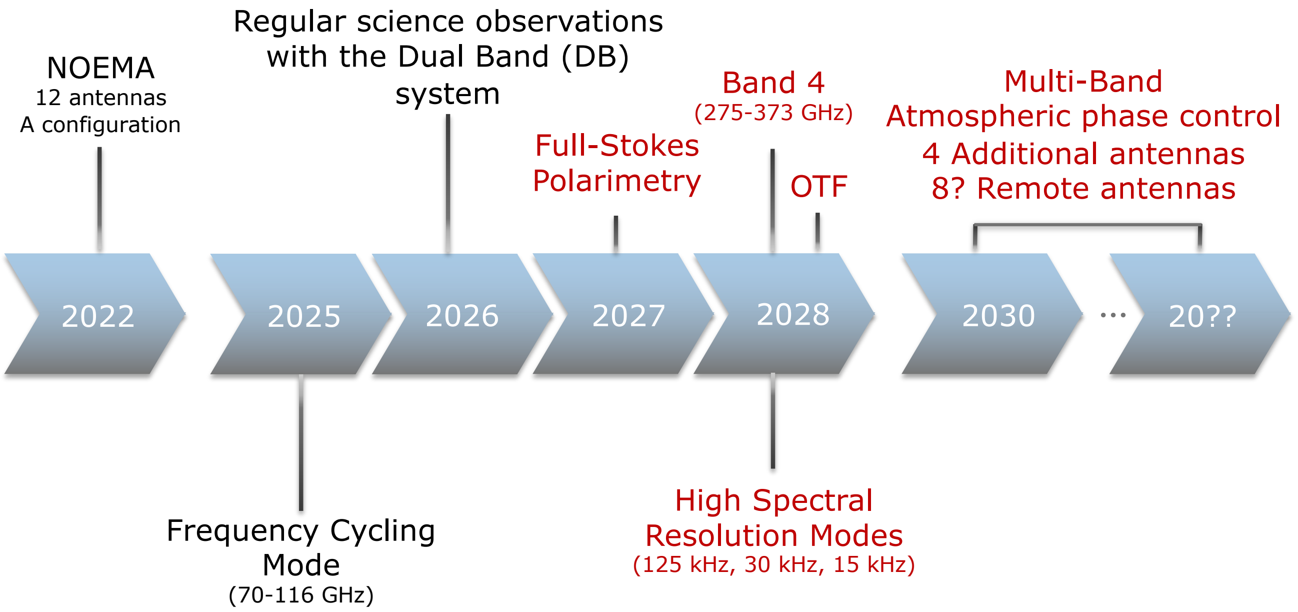




NOEMA roadmap to new capabilities



2022

NOEMA
12 antennas
A configuration

2025

Frequency Cycling Mode
(70-116 GHz)

2026

Regular science observations with the Dual Band (DB) system

2027

Full-Stokes Polarimetry

2028

Band 4
(275-373 GHz)

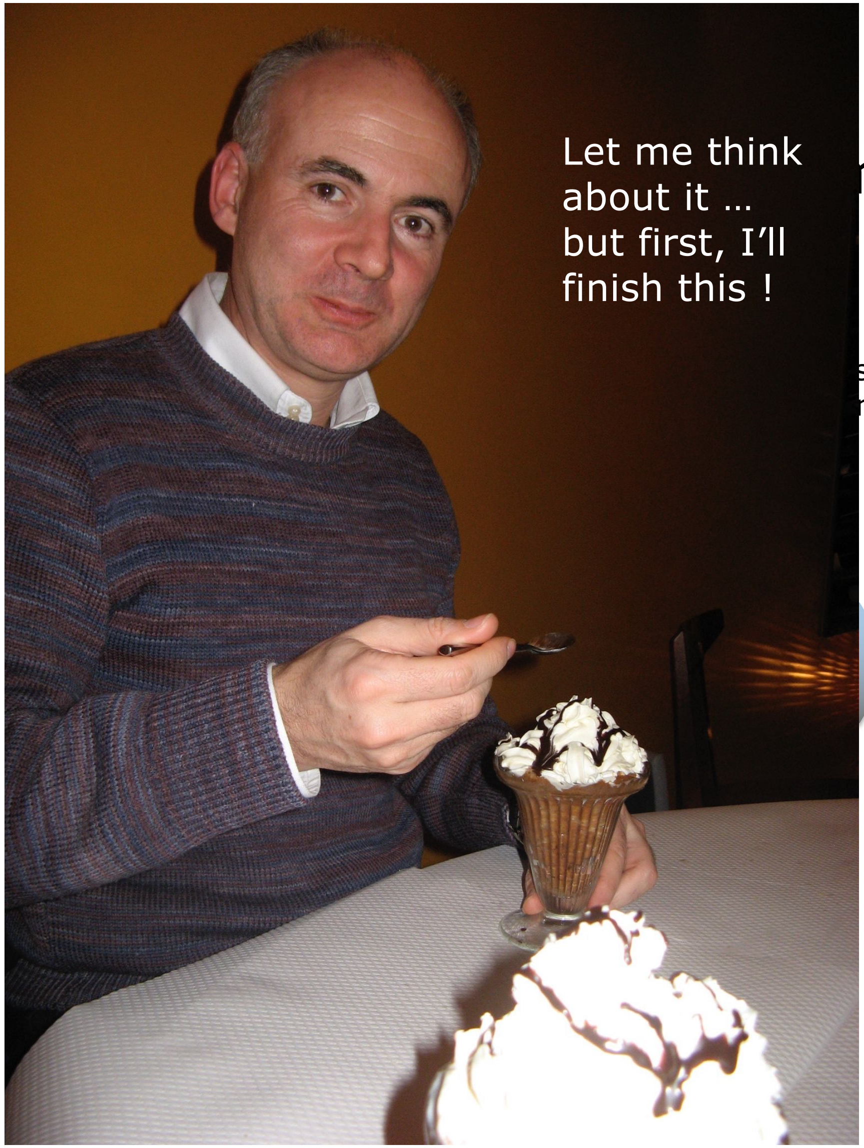
OTF

High Spectral Resolution Modes
(125 kHz, 30 kHz, 15 kHz)

2030 … 20??

Multi-Band
Atmospheric phase control
4 Additional antennas
8? Remote antennas

nap to new capabilities



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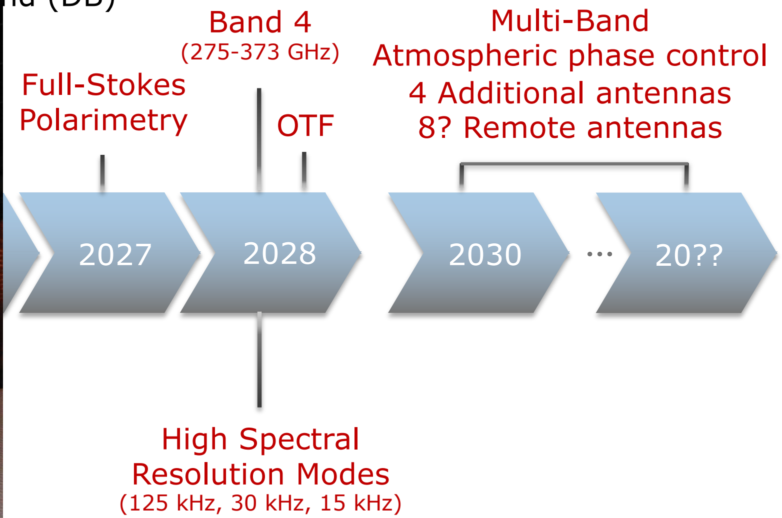

Band 4
(275-373 GHz)

Full-Stokes
Polarimetry

OTF

Multi-Band
Atmospheric phase control
4 Additional antennas
8? Remote antennas

2027 2028 2030 … 20??

High Spectral
Resolution Modes
(125 kHz, 30 kHz, 15 kHz)