THE SIMILARITIES AND DIFFERENCES IN THE FORMATION OF METHANOL MASERS AND OH MASERS ACCORDING TO DATA FROM RADIO ASTRONOMY OBSERVATIONS

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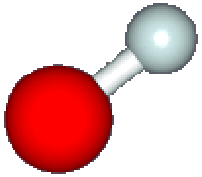
OH MASER

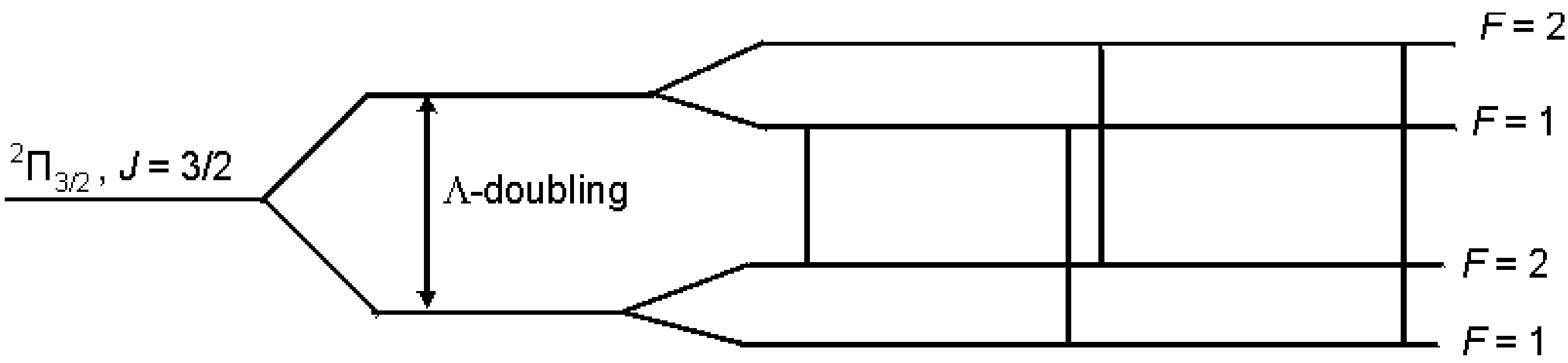


- The OH molecules were first maser discovered in space
- Their research is now a routine process

Methanol

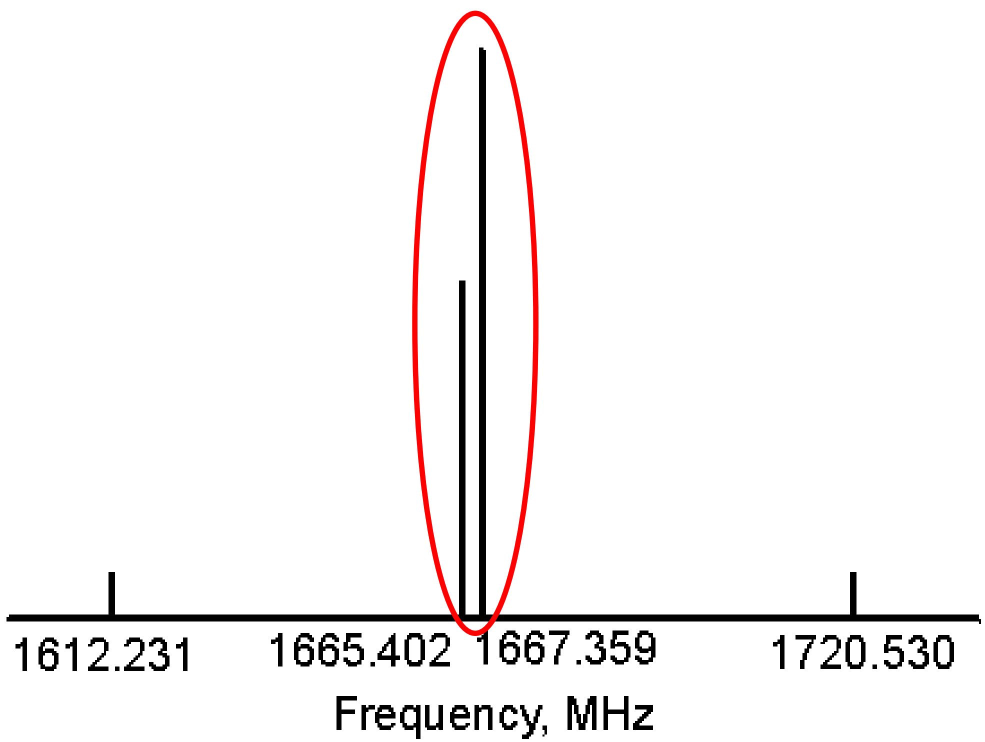
- Methanol the last of ten molecules from which maser emission has been observed in space
- At the present time a methanol is one of the most common and one of the most investigated molecules in space

- What is common between these masers and what are the differences, is strongly dependent on the type of objects in which these masers are formed, and the evolutionary status of the molecular cloud



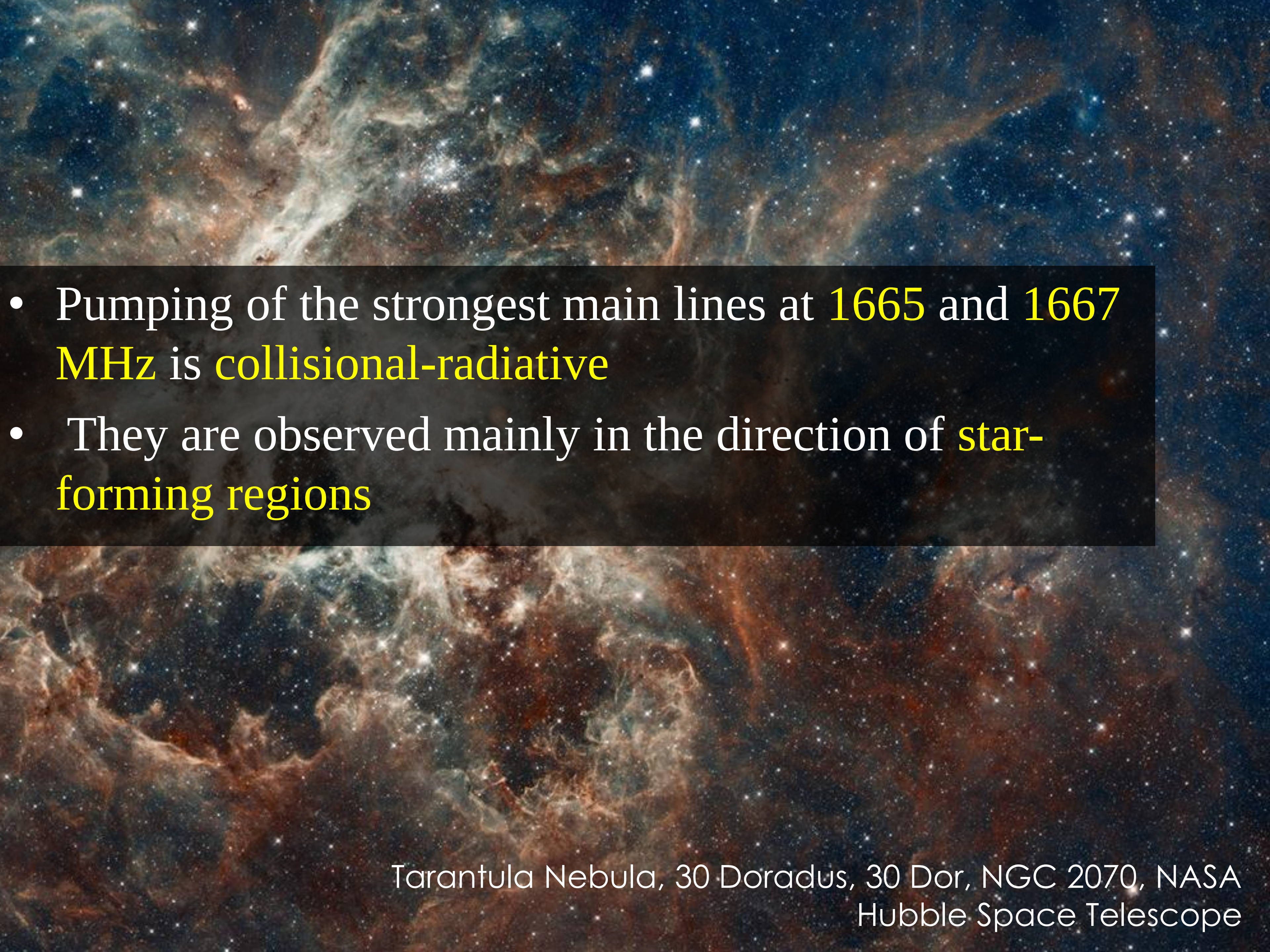
²Π3/2 , J = 3/2
Λ-doubling
F = 2
F = 1
F = 2
F = 1

OH



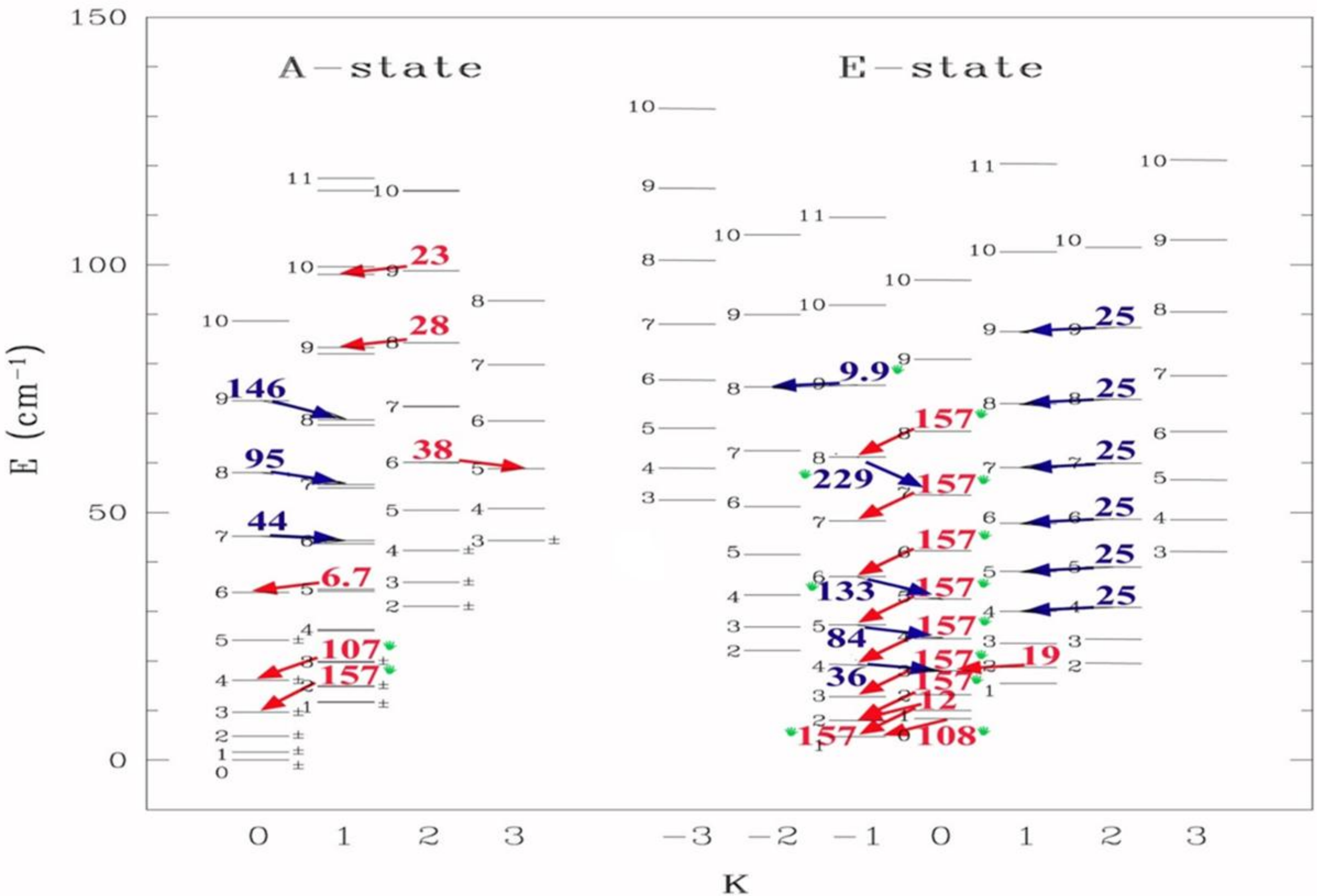
1612.231
1665.402
1667.359
1720.530
Frequency, MHz

- Pumping of the strongest main lines at 1665 and 1667 MHz is collisional-radiative
- They are observed mainly in the direction of star-forming regions



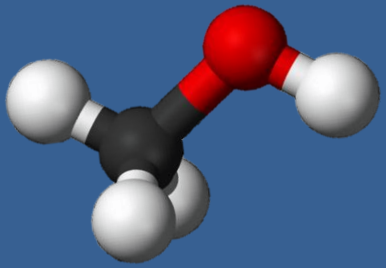
Tarantula Nebula, 30 Doradus, 30 Dor, NGC 2070, NASA Hubble Space Telescope

Energy-level diagram of methanol



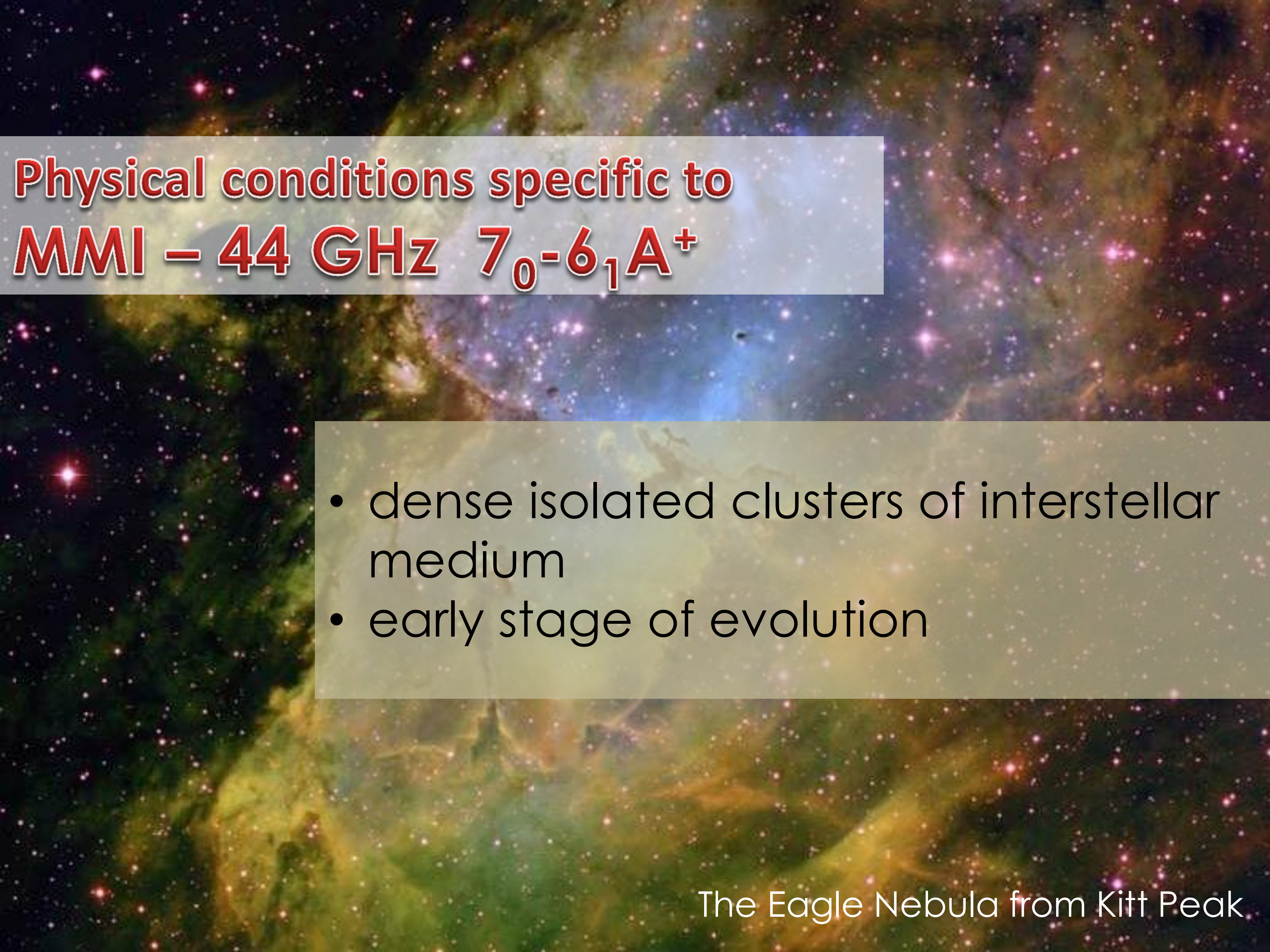
- MMI
- MMII

- The molecule has more than two hundred allowed quantum energy transitions, whose radiation is available for earth observation by radio telescopes



Physical conditions specific to MMI – 44 GHz 7_0-6_1A^+

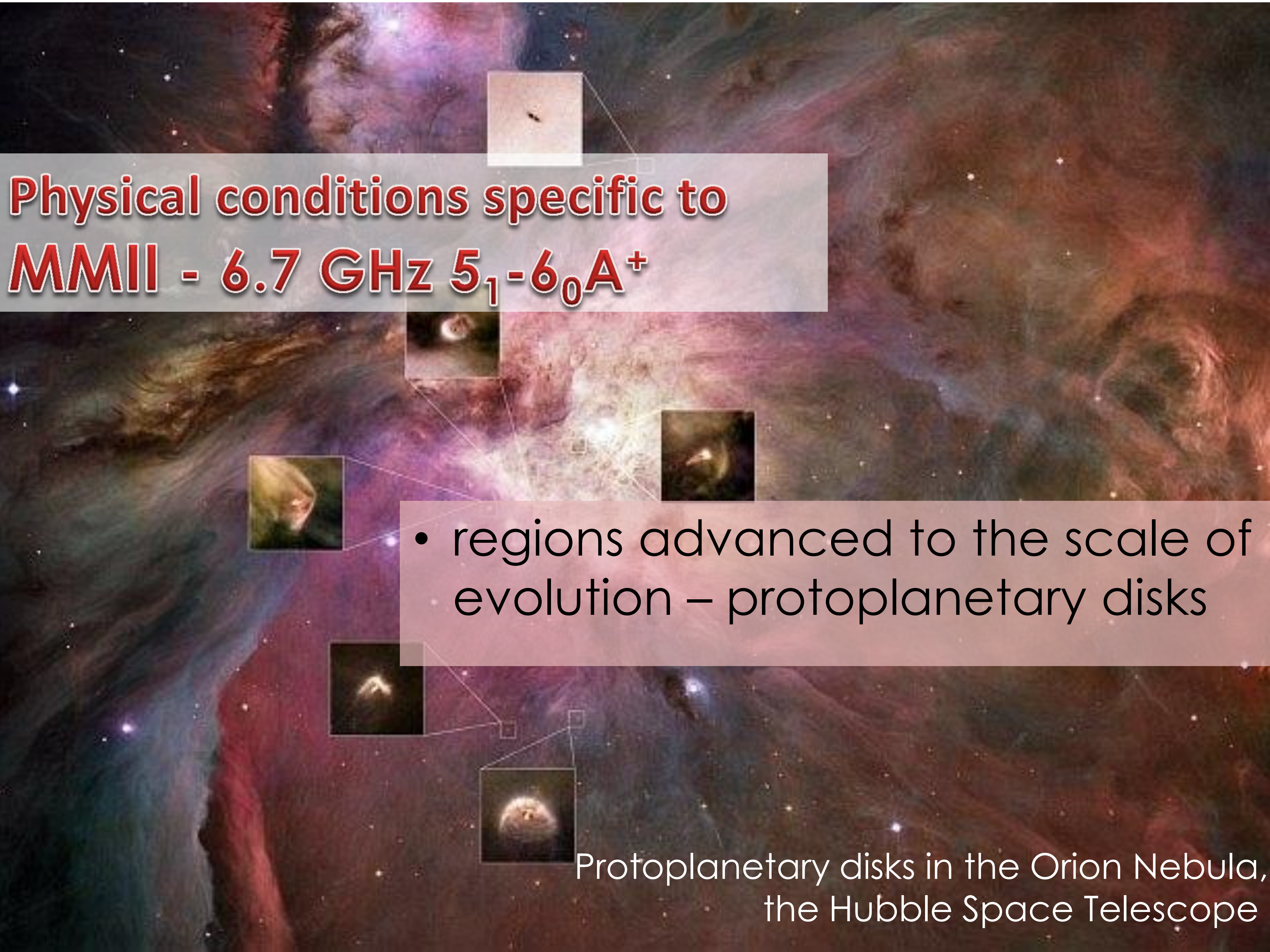
- dense isolated clusters of interstellar medium
- early stage of evolution



The Eagle Nebula from Kitt Peak

Physical conditions specific to MMII - 6.7 GHz 5_1-6_0A^+

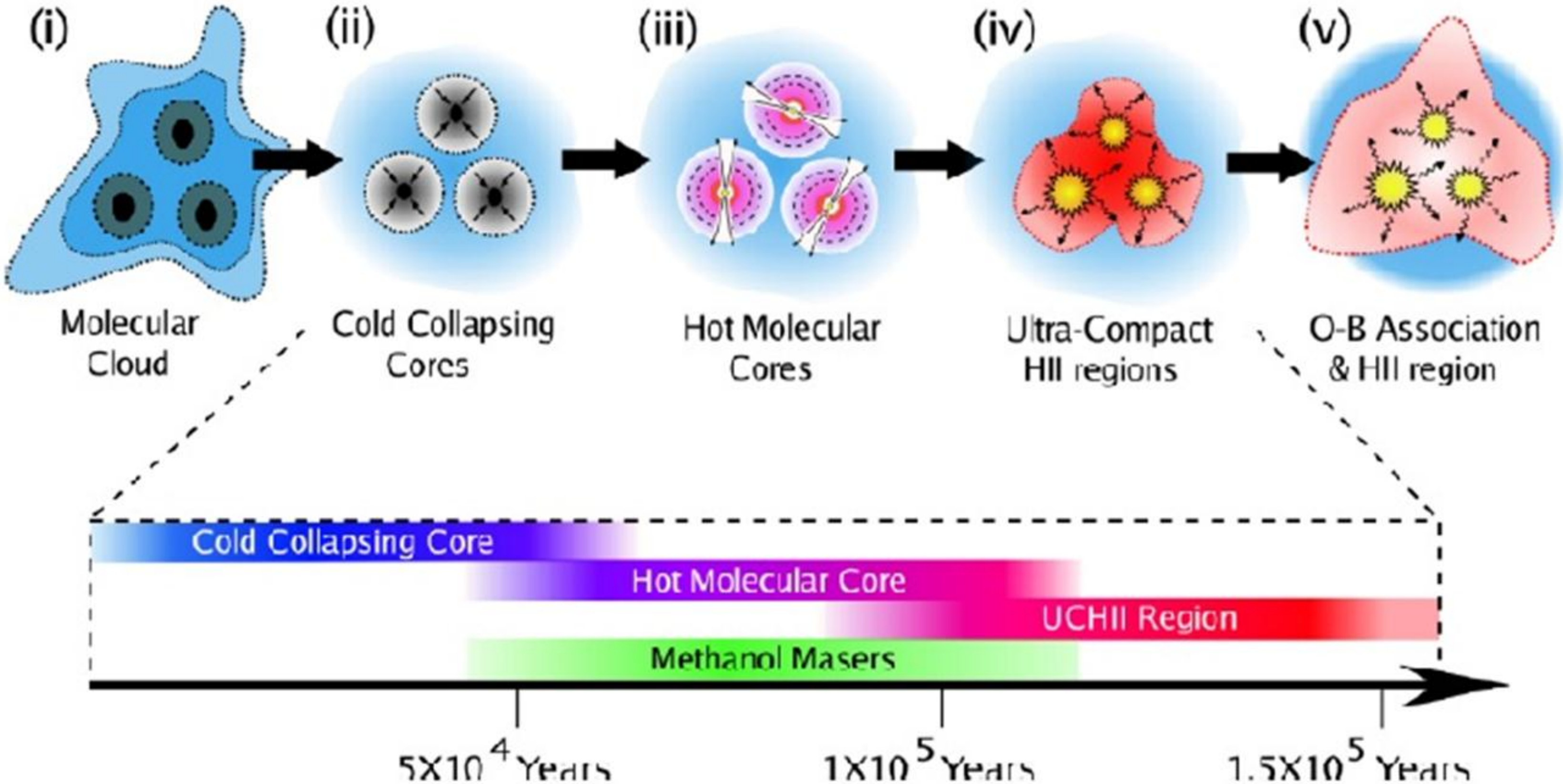
- regions advanced to the scale of evolution – protoplanetary disks



Protoplanetary disks in the Orion Nebula, the Hubble Space Telescope

Table shows a comparison of the characteristics of MMI and MMII

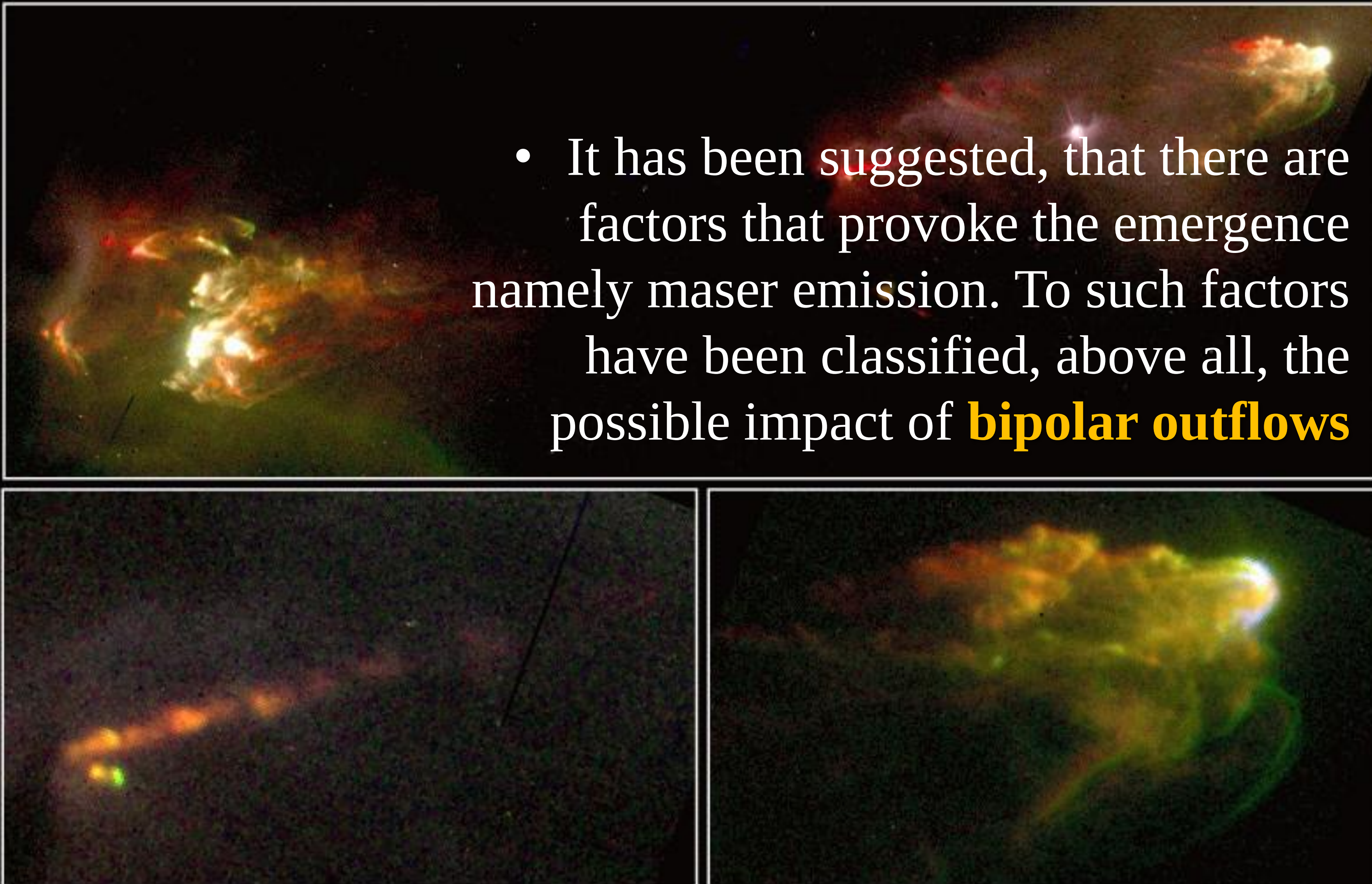
	MMI	MMII
methanol column density	10^{16}–10^{17} cm^{-2}	10^{17} cm^{-2}
density	~10^{5} cm^{-3}	10^{6}-10^{7} cm^{-3}
temperature	~25–100 K	~30-175 K
scale	1000 A.U.	<1000 A.U.
number	~200 objects (not including the objects from work X. Chen, S. P. Ellingsen 2011)	~800 objects



- Nature of MMII well studied and understood - basically, it's protoplanetary disks at the edge of HII regions
  - *A cartoon shows when the methanol maser emission supposedly occurs*

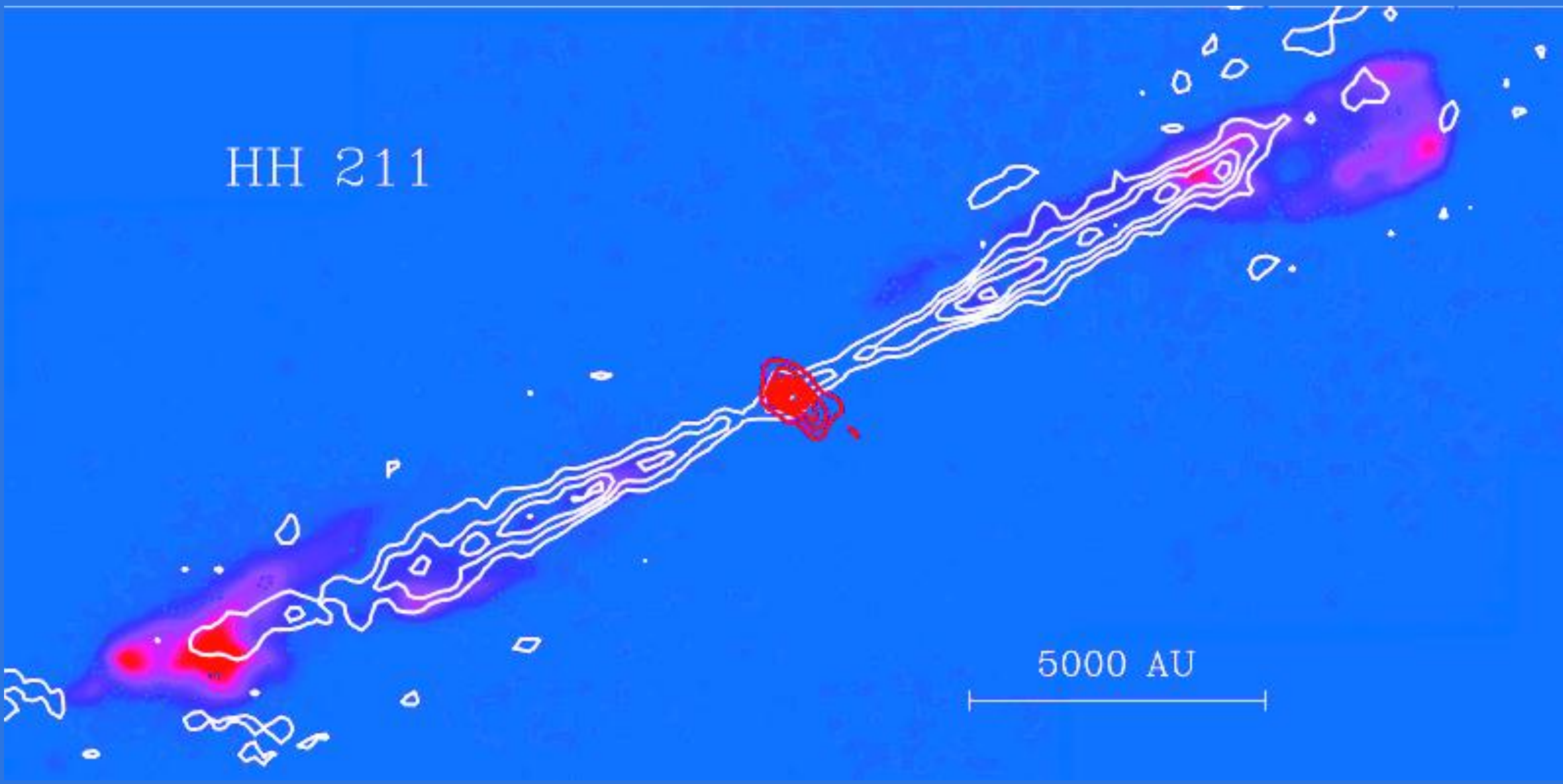
- The nature of MMI is still a mystery
- Although the type of collisional pumping of these masers was obvious since the start of their research and is associated with the specific structure of the quantum levels of a methanol molecule, still not clear the fact why the thermal emission of methanol in the interstellar medium occurs quite often, but maser - much less

- It has been suggested, that there are factors that provoke the emergence namely maser emission. To such factors have been classified, above all, the possible impact of **bipolar outflows**



Jets from Young Stars · HH1/HH2 HST · WFPC2
PRC95-24c · ST ScI OPO · June 6, 1995 · J. Hester (AZ State U.), NASA

bipolar outflows



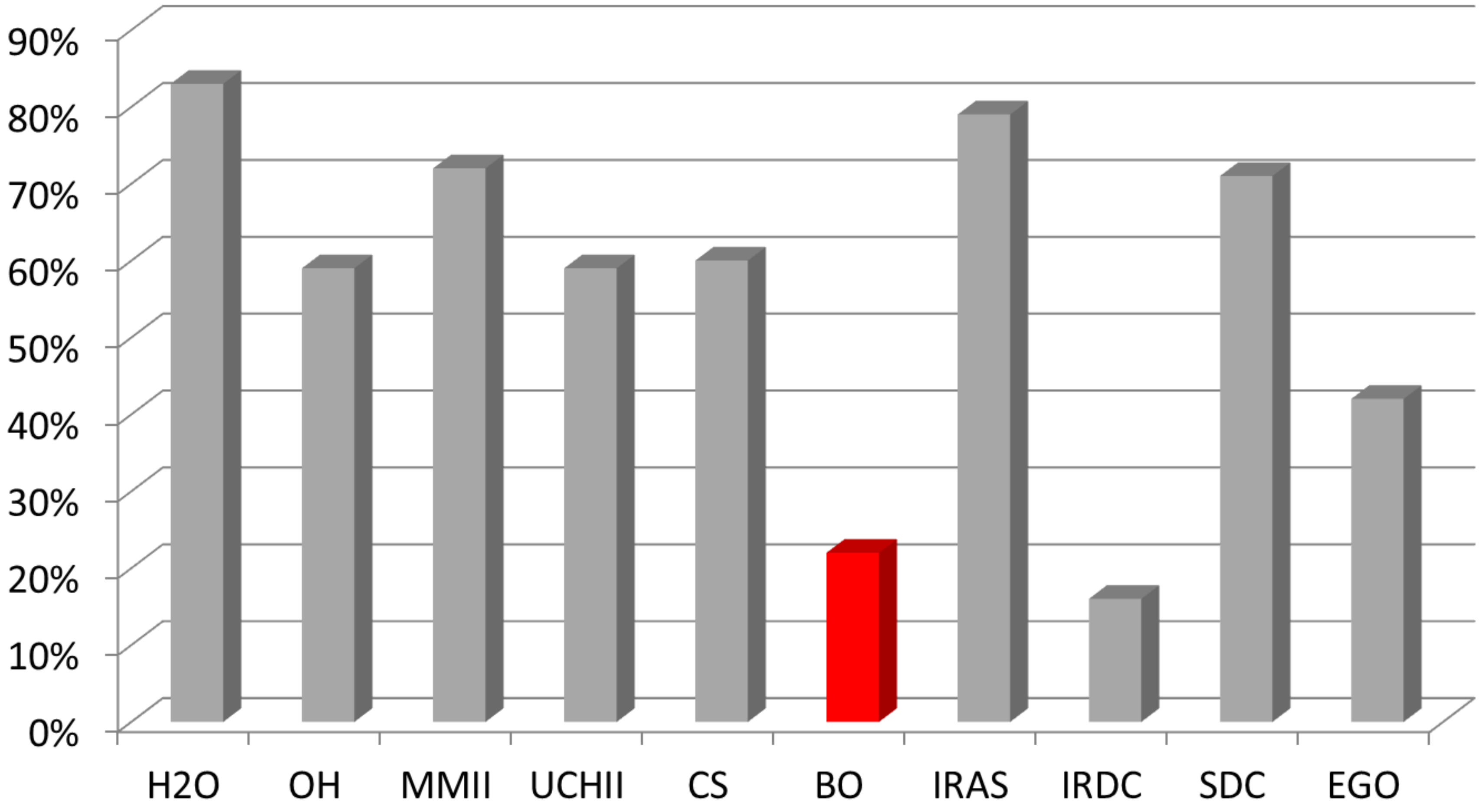
- It is assumed, that bipolar outflows wrap around the condensation can increase density of matter in it, thus accelerating and intensifying the evaporation of methanol molecules from the surface of interstellar grains

Class I methanol maser catalog

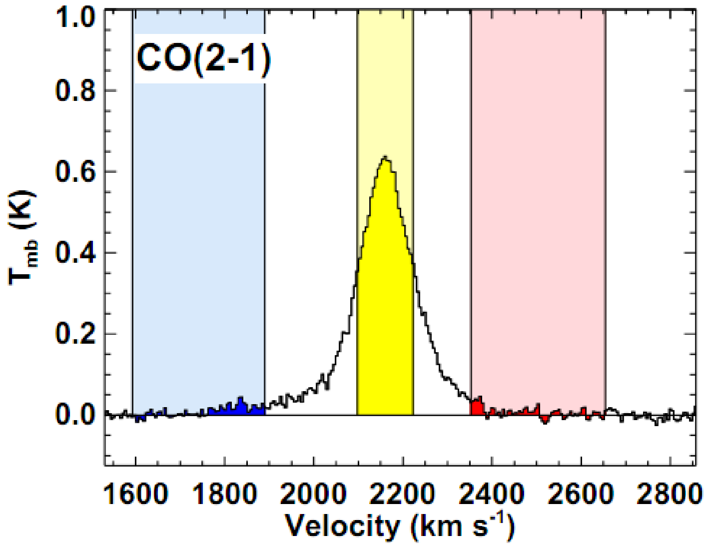
206 Class I methanol masers,
third version - http://www.asc.rssi.ru/MMI

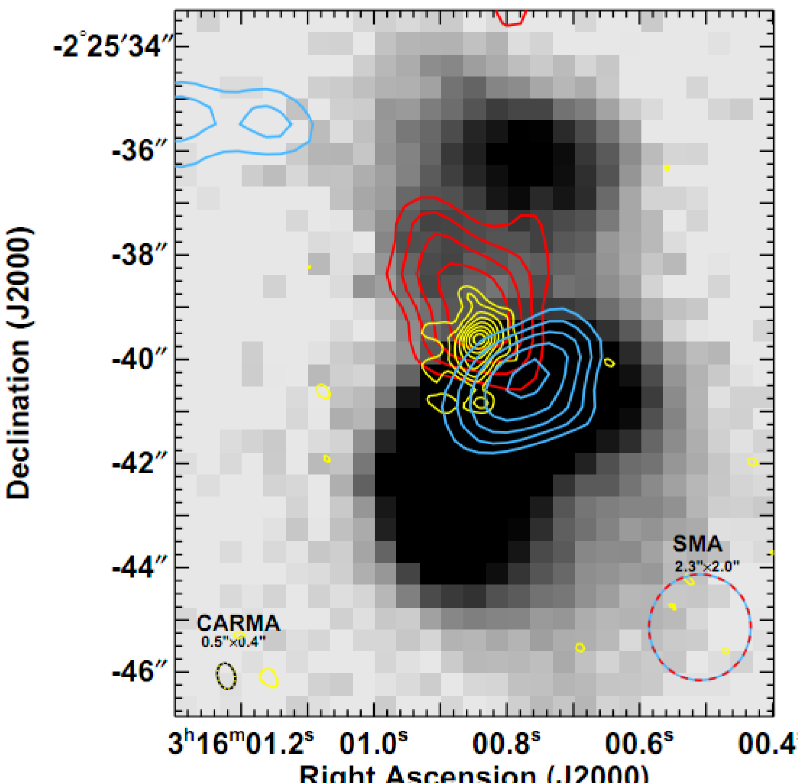
N	Position	Source Name	RA (B1950) / (J2000)	Dec (B1950) / (J2000)	∫Sdv ; V_{LSR} for the strongest detail of the methanol spectra	Maser Identification MMII (Y) OH H_2O	IR identification: /IRAS /IRDC /SDC /EGO(number of table in [CWH])	Identification with UCHII BO	Molecules traced dense gas: CS	Distance
			h m s	° ′ ″	Jy km s^{-1} ; km s^{-1}					kpc
1	2	3	4	5	6	7	8	9	10	11
1	119.779-6.031	CB3 NGC2071 HH7-11 IMYSO [BKY]	00 25 56.98 / 00 28 42.7	56 25 32.1 / 56 42 07	20.64; -33.96 [BKY]	W [BKY]	/00252+5625 / / /	BO [CB]	CS [CB]	2.5 [BKY]
2	121.298+0.659	IMYSO [BKY]	00 33 53.38 / 00 36 47.5	63 12 31.9 / 63 29 02	4.29; -17.54[BKY]	Y [SHK] W[BKY]	/00338+6312 / / /		CS [BNM]	0.85 [BKY]
3	122.015-7.072	Mol 3	00 42 05.46 / 00 44 57.6	55 30 54 / 55 47 18	1.6; -48.8 [FCF]	W [PBC]	/00420+5530 / / /			4.33 [PBC]
4	133.749+1.198	W3(3) LDN1359	02 22 06.1 / 02 25 53.5	61 50 40 / 62 04 10.7	10; -38.40 [BMG]	W [SIM]	*/02226+6150 / / /*	*BO W33IRS5 [H1]*	CS [AEP]	2.4 [AEP]
5	133.949+1.065	W3(OH)	02 23 17.3 / 02 27 4.62	61 38 58 / 61 52 25.6	4.2; -46.49 [HMB]	Y [PMB] OH [SIM] [ARM] W [SIM]	02232+6138 / / /	UCHII [BNM]	CS [BNM]	2.4 [AEP] 1.95 [RMZ1]

- According to our researches a formal association of bipolar flows and MMI - is not obvious



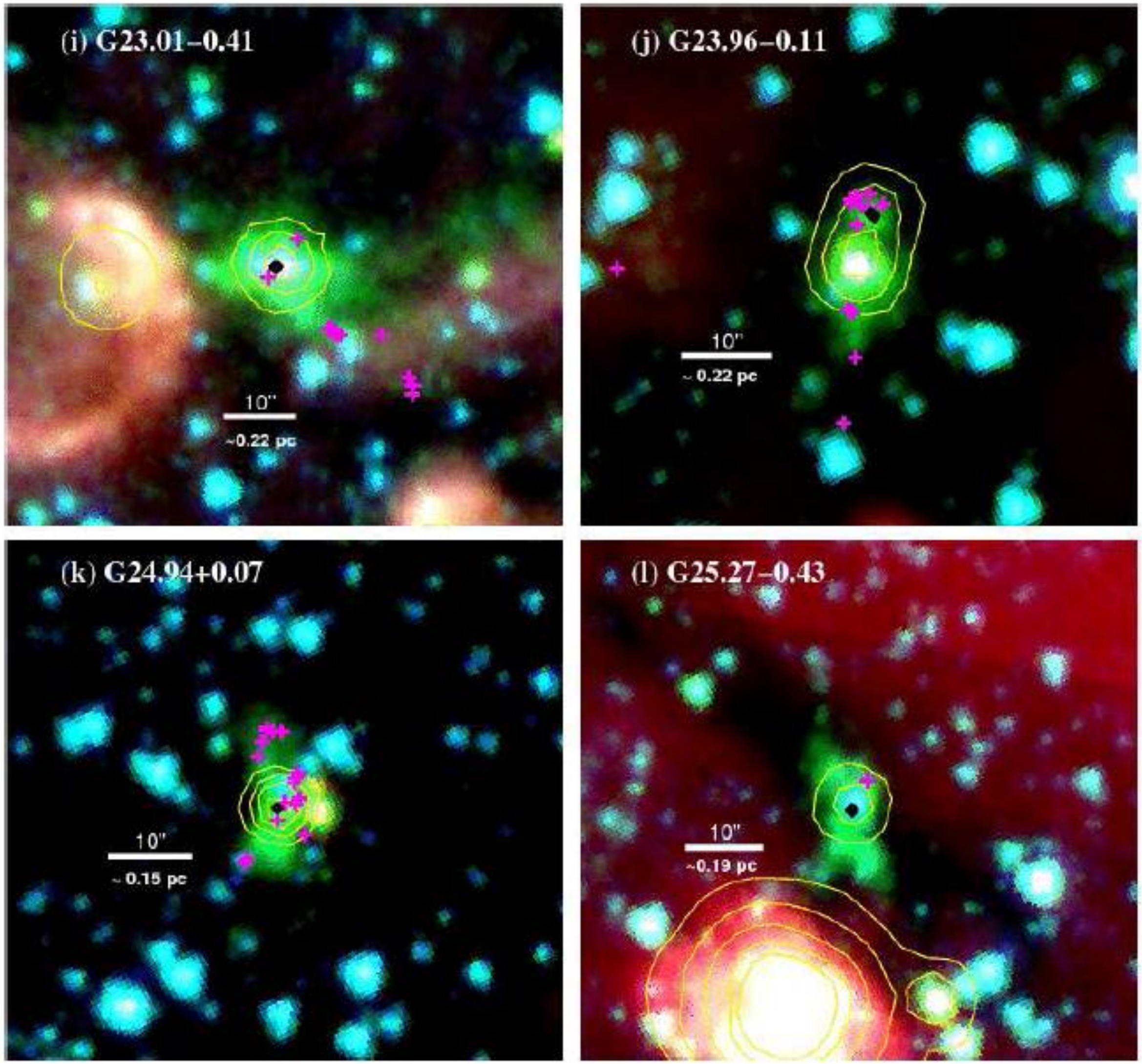
22% (46) of the MMI are associated with bipolar outflows





- These results are based on traditional methods of detection bipolar outflows, mainly on the presence of broad CO line wings
- Observational selection effects are probably important in this case, since bipolar outflows cannot always be revealed using the lines that are usually used to search for them

The line profile of the CO (J = 2 -> 1) transition as observed by the SMA submillimeter array



Three-color GLIMPSE IRAC images showing

8.0 μm

4.5 μm

3.6 μm

A Class I and Class II CH3OH Maser Survey of Extended Green Objects (EGO) from the GLIMPSE Survey
C.J. Cyganowski, C.L. Brogan, T.R. Hunter, E. Churchwell

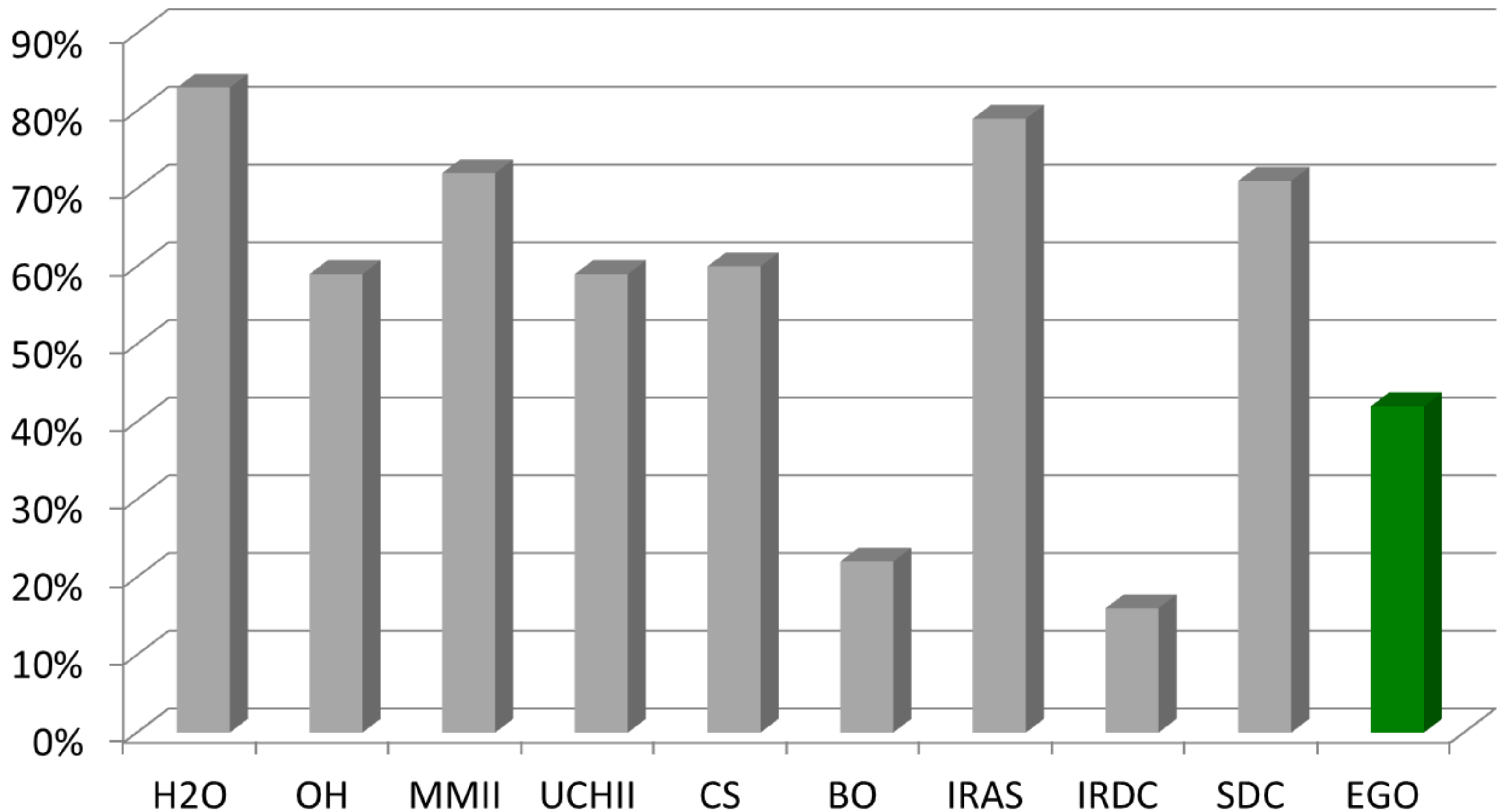
Extended green objects (EGO)

Organization	NASA/ JPL/ Caltech
Launch date	2003-08-25
Mission length	2.5 to 5+ years (8 years, 8 months and 24 days elapsed)
Wavelength	3 to 180 micrometers
Diameter	0.85 m

Spitzer Space Telescope

- is an infrared space observatory launched in 2003

- It is the fourth and final of the NASA Great Observatories program



According to our research

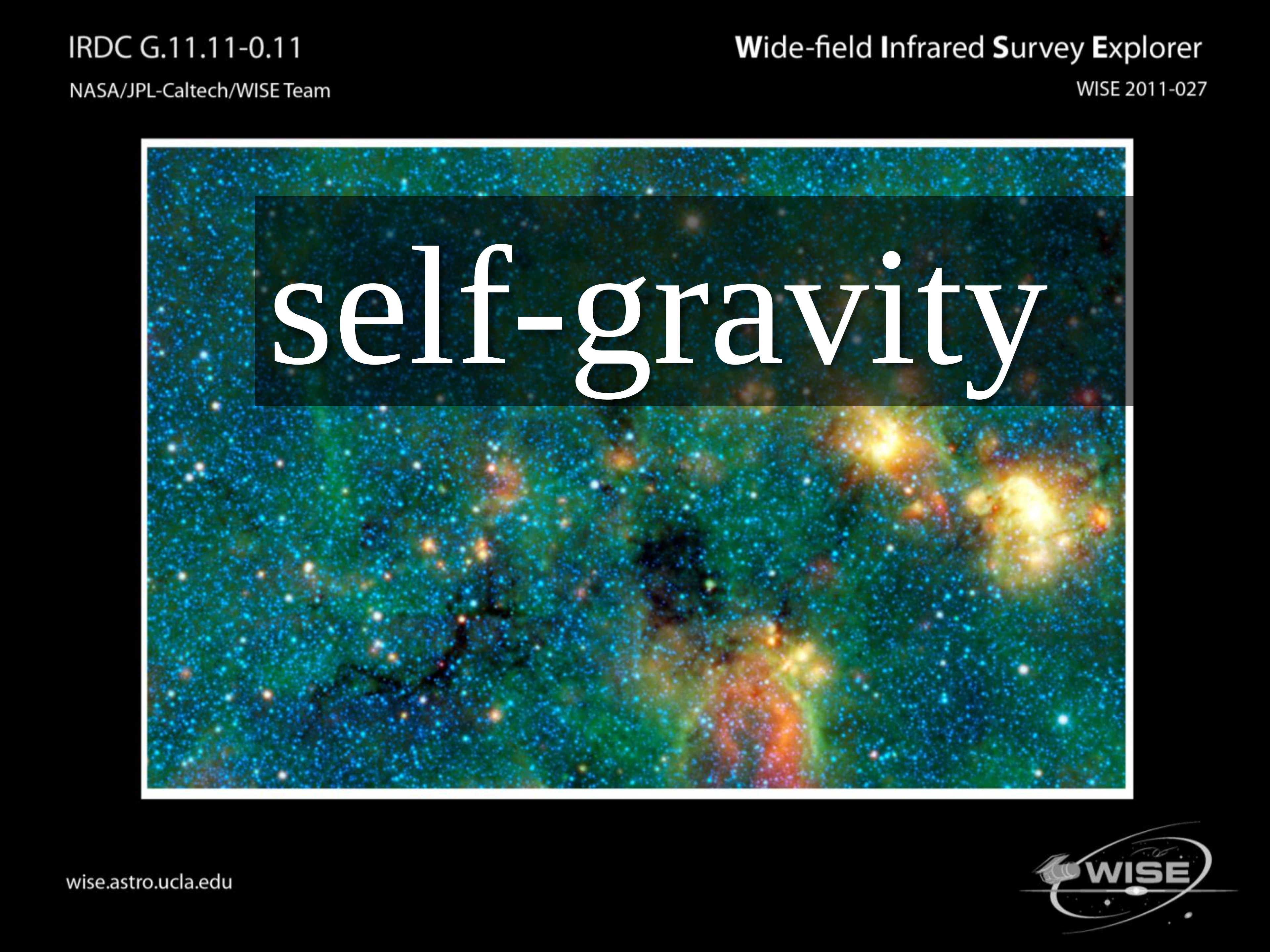
42% (59 of 139*) of the MMI are associated with EGO

*only 139 MMI fall in the longitude range explored by Spitzer

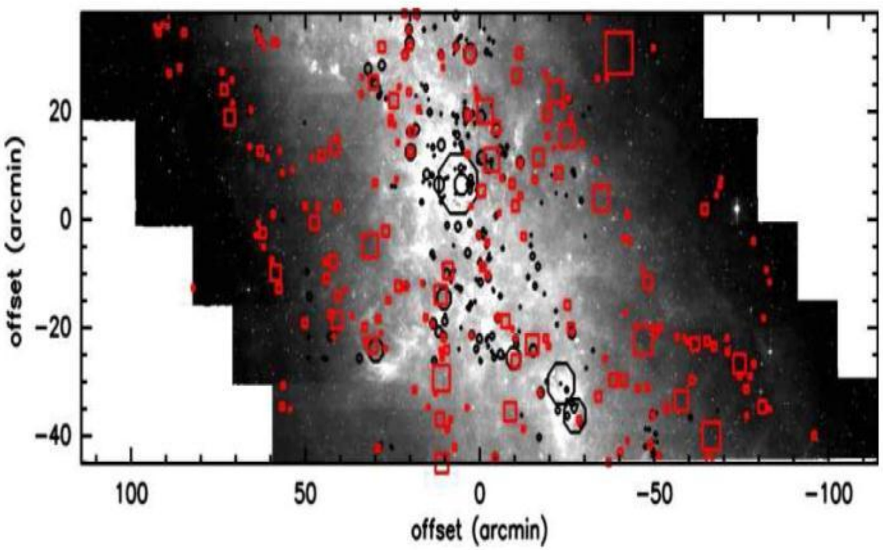
We consider that in addition to bipolar outflows, provocative factors may also be:

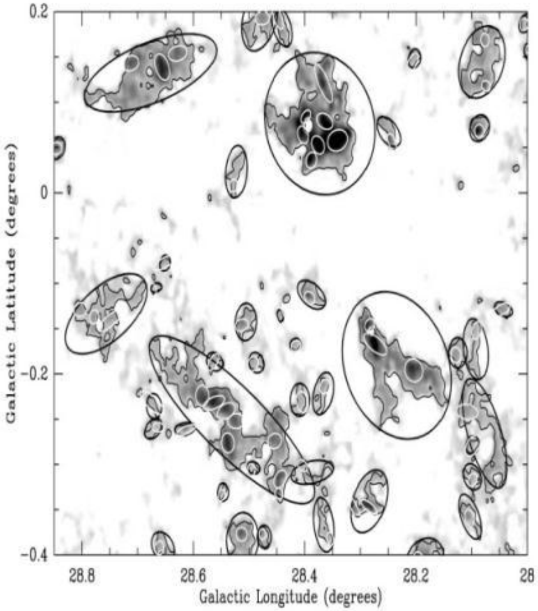
- **self-gravity**
- **shock front of SNR**
- **cloud collisions**
- **and magnetic fields**

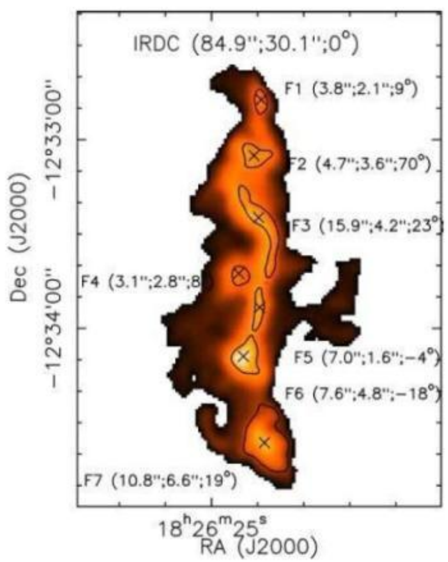
we decided to study these possibilities


IRDC G.11.11-0.11
NASA/JPL-Caltech/WISE Team
Wide-field Infrared Survey Explorer
WISE 2011-027
self-gravity
wise.astro.ucla.edu
WISE

Dark clouds in the Milky Way on the background radiation of polycyclic aromatic hydrocarbons (PAH) to 8 µm

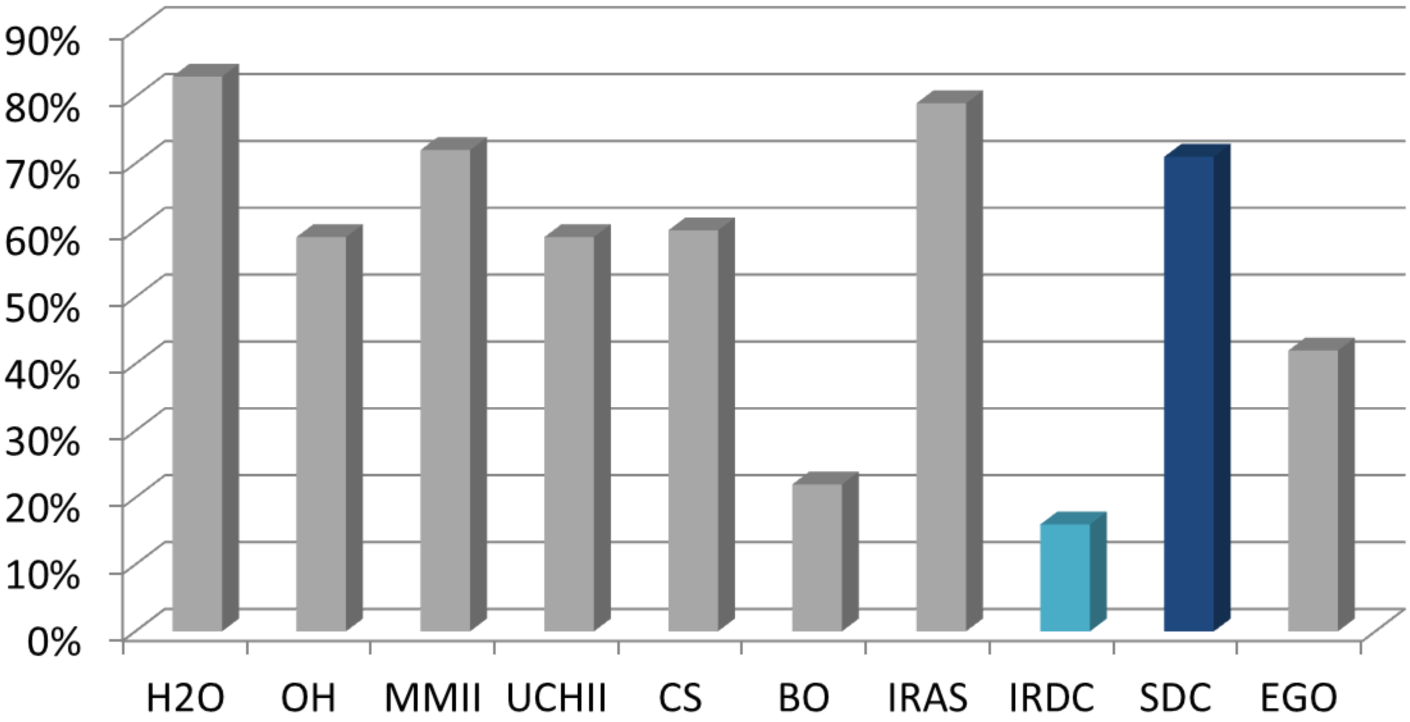




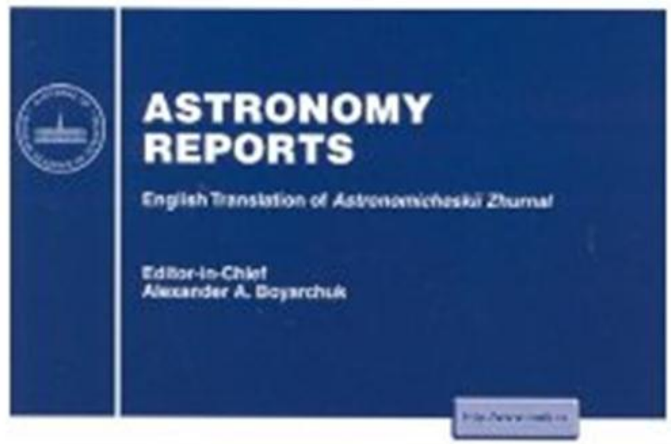


top left: SPITZER map
top right: MSX map
Bottom: map of the typical SPITZER SDC dark cloud

Statistical analysis of the association MMI and IRDC/SDC based on our catalog show:



- **16%** (33) of the MMI are associated with IRDC from the MSX survey
- **71%** (99 of 139) of the MMI are associated with SDC from the Spitzer survey



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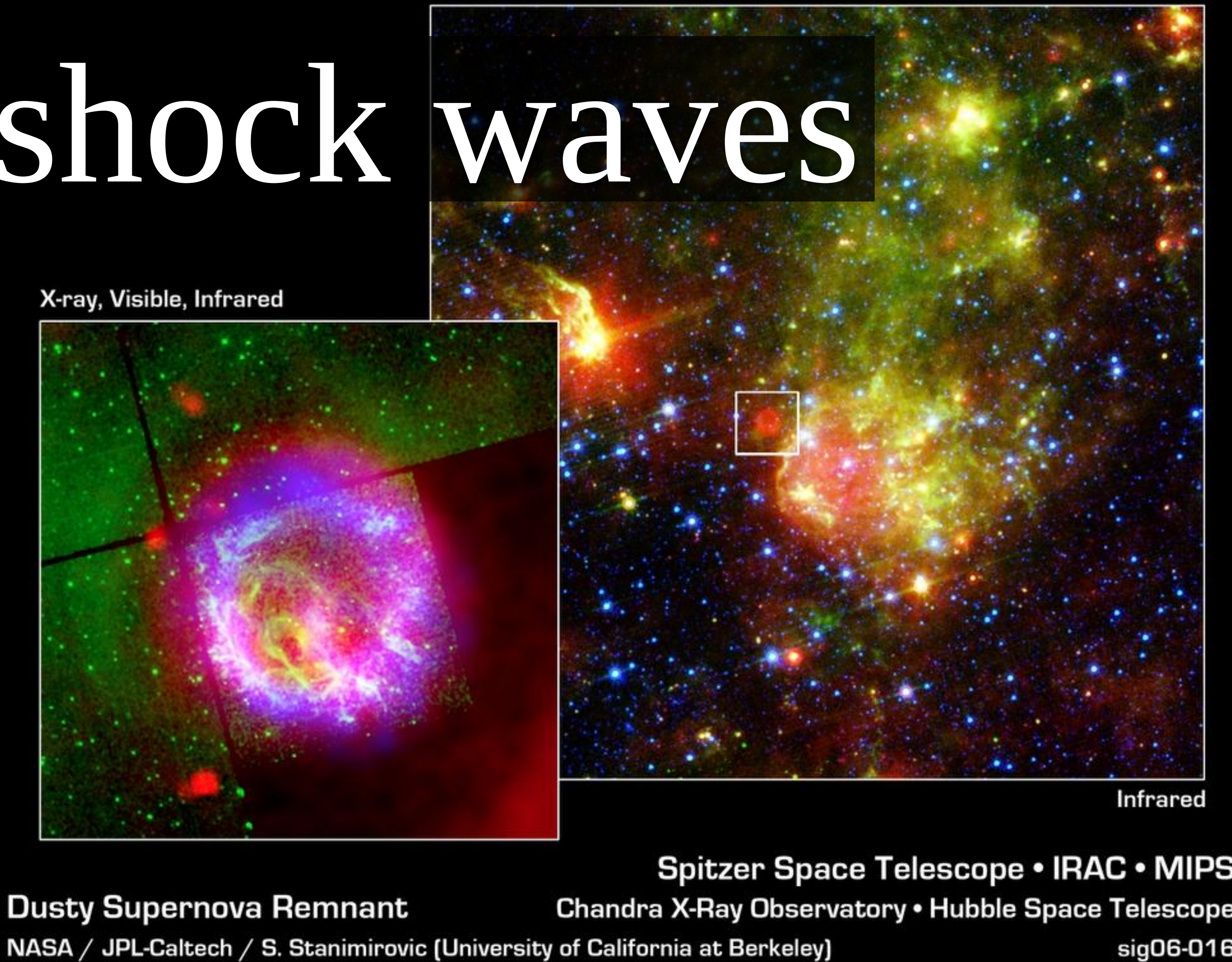
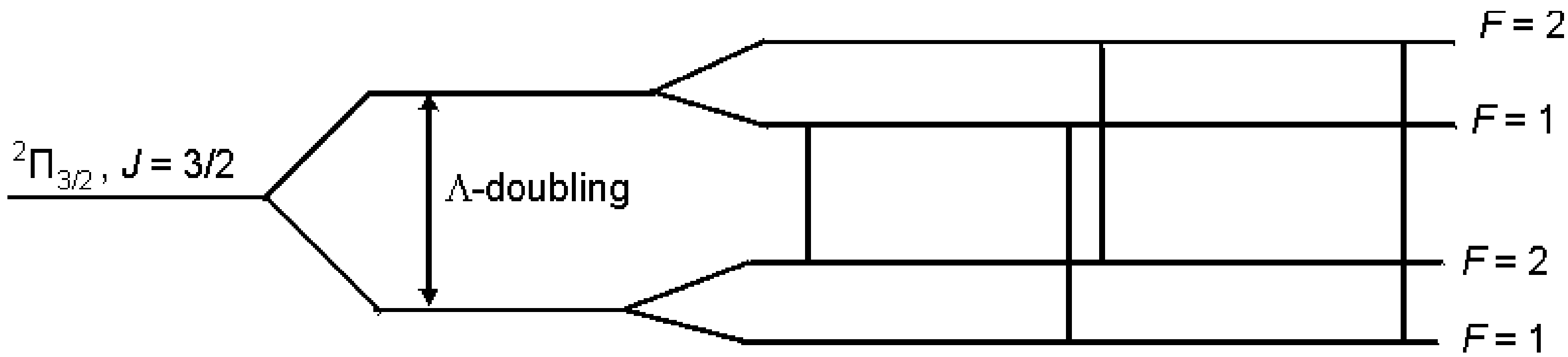
2012, Vol. 56, No. 7, pp. 536–552

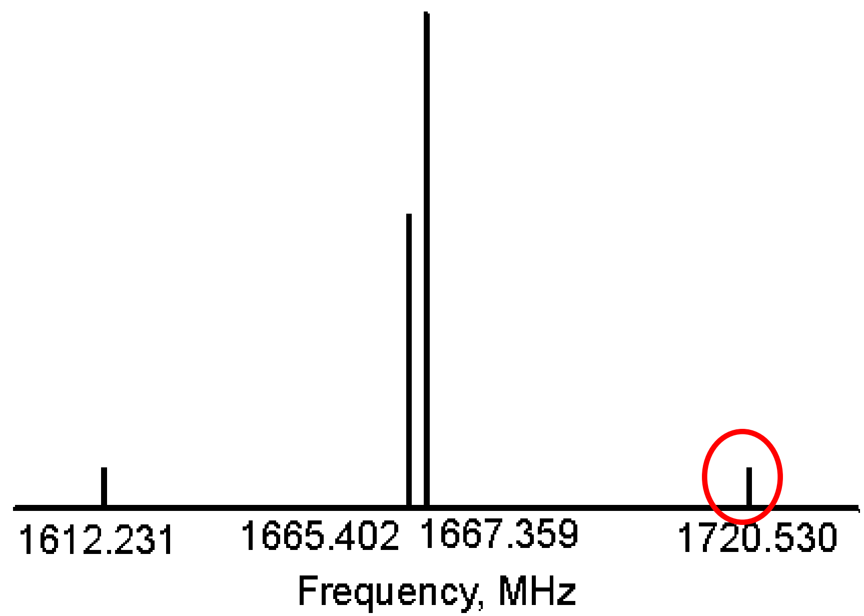
shock waves


X-ray, Visible, Infrared
Infrared
Spitzer Space Telescope • IRAC • MIPS
Dusty Supernova Remnant
Chandra X-Ray Observatory • Hubble Space Telescope
NASA / JPL-Caltech / S. Stanimirovic (University of California at Berkeley)
sig06-016

Let’s go back to OH molecule



OH



- Pumping of one of the satellite line at 1720 MHz is purely collisional
- They are observed mainly in the direction of supernova remnants, ie, are tracers of shock waves

Tarantula Nebula, 30 Doradus, 30 Dor, NGC 2070, NASA
Hubble Space Telescope

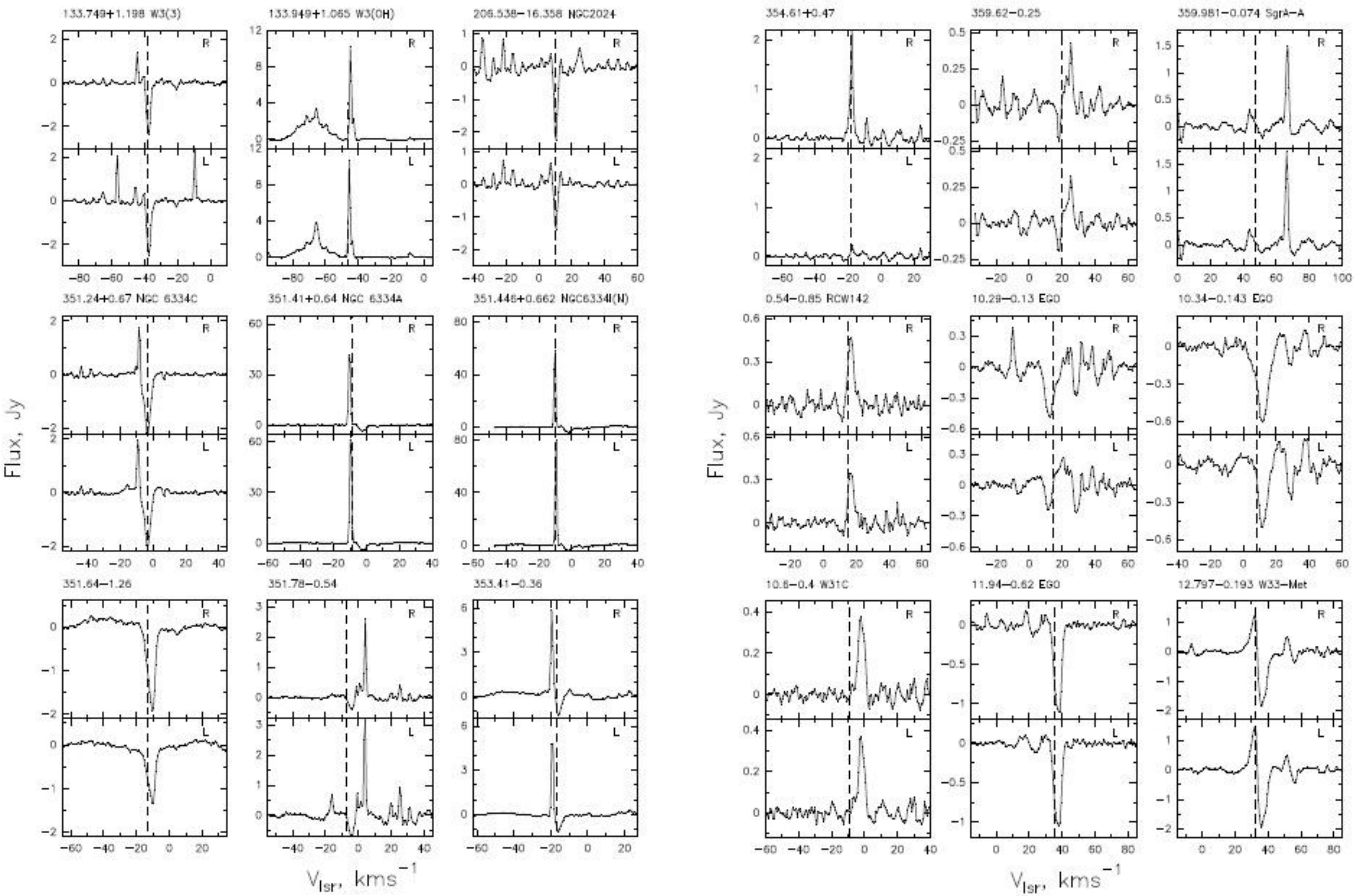
- We have carried out observations in the direction of the MMI at a frequency of 1720, assuming that, if the collisional pumping provides this type of radiation, physical conditions in the condensations MMI and OH(1720) should be similar and in the direction of the MMI should be observed a statistically significant number of OH(1720) maser

RT-70 radio telescope

is a radio telescope and planetary radar at the Center for Deep Space Communications, Yevpatoria, Ukraine.
With its 70m antenna diameter, it is among the largest single dish radio telescopes in the world.

Organization	Center for Deep Space Communications
Frequencies	5–300 GHz
Diameter	70 m
Beamwidth at 1720 MHz	9′
Noise temperature	35 K

The spectra obtained from our observations on the RT-70



Results

- We obtained **72 spectra** without obvious interference
- We have estimated the following mean column densities of OH molecules:

$$N_{\mathrm{OH}} = 1.5 \times 10^{17}\ \mathrm{cm}^{-2}$$

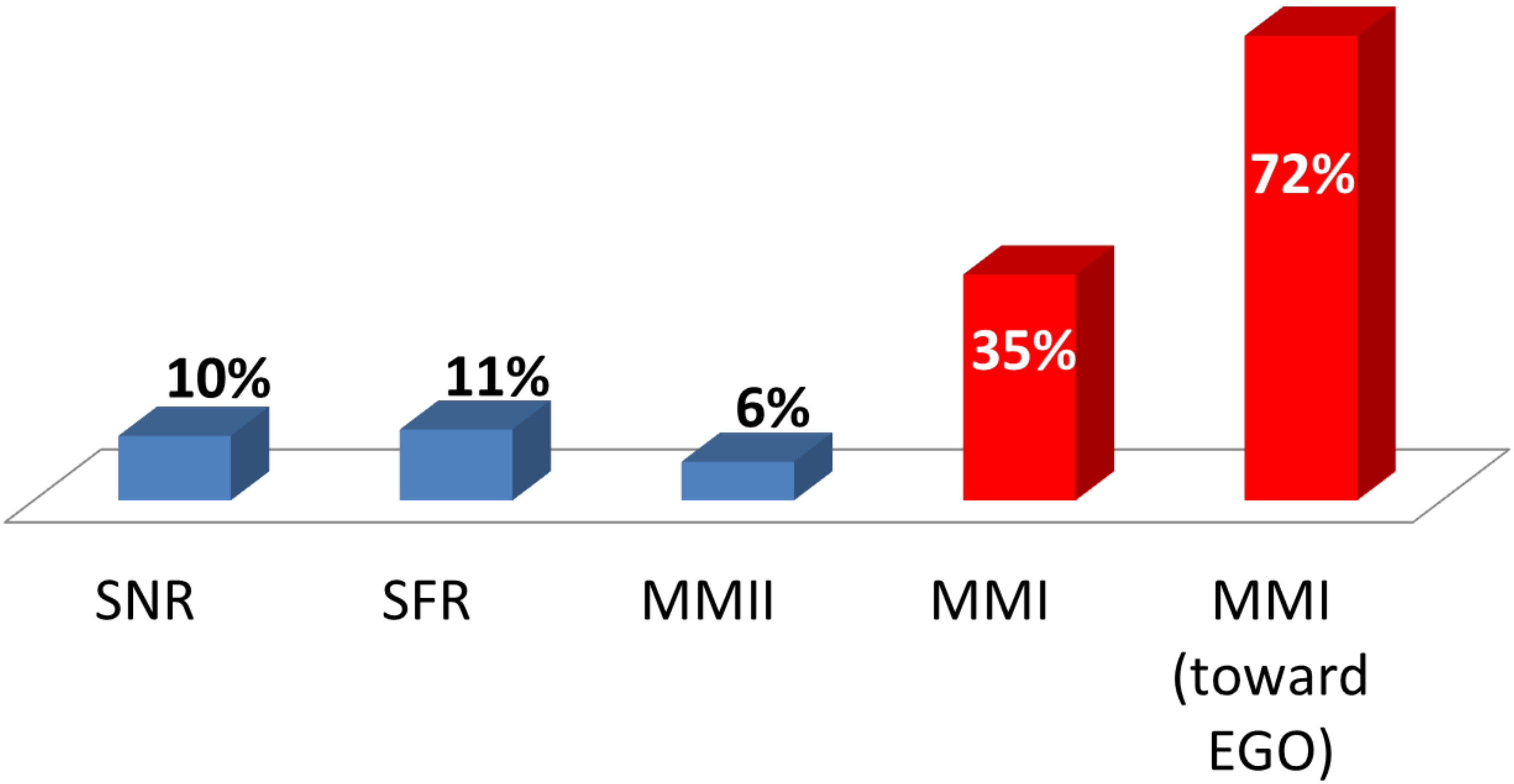
for narrow emission features with linewidths not exceeding 2 km/s

$$N_{\mathrm{OH}} = 3.6 \times 10^{16}\ \mathrm{cm}^{-2}$$

for absorption features

- The flux densities in narrow features are no less than 100 mJy (exceed 500 mJy for a considerable number of lines)

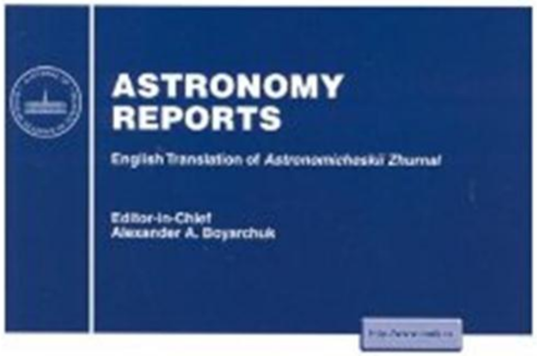
OH (1720) maser emission is observed toward:



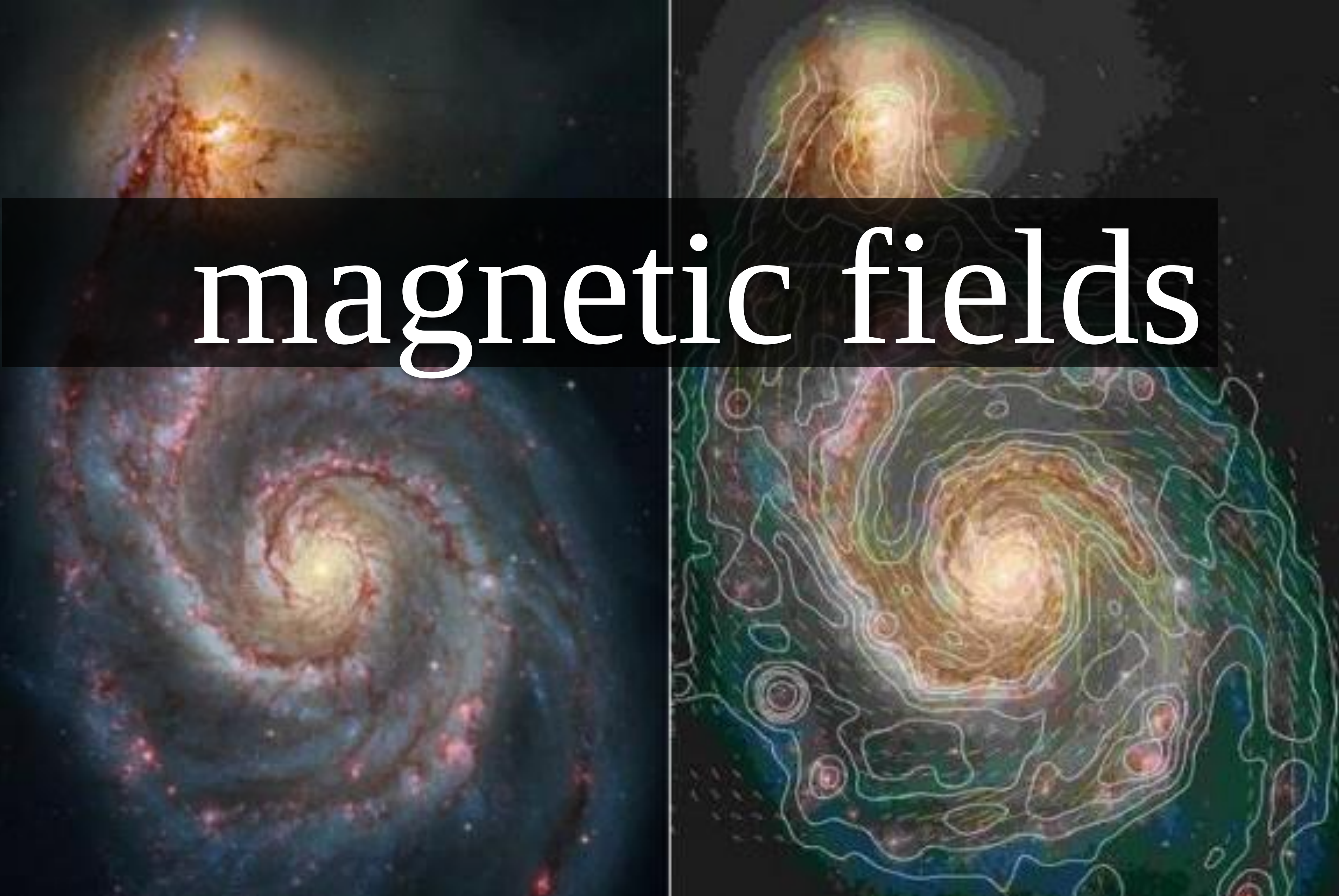
Results

- The main result of this study is the detection of numerous OH (1720) emission lines, many of which could be maser lines, observed in larger numbers toward MMI than toward SNRs, SFRs, and MMIIs, as well as numerous OH (1720) absorption lines, which form narrow asymmetric spectra
- The presence of OH (1720) emission lines can be considered direct evidence for the presence of shocks in the observed regions

The article has been published in *Astronomy Reports, 2012, Vol. 56, No. 7, pp. 536–552*

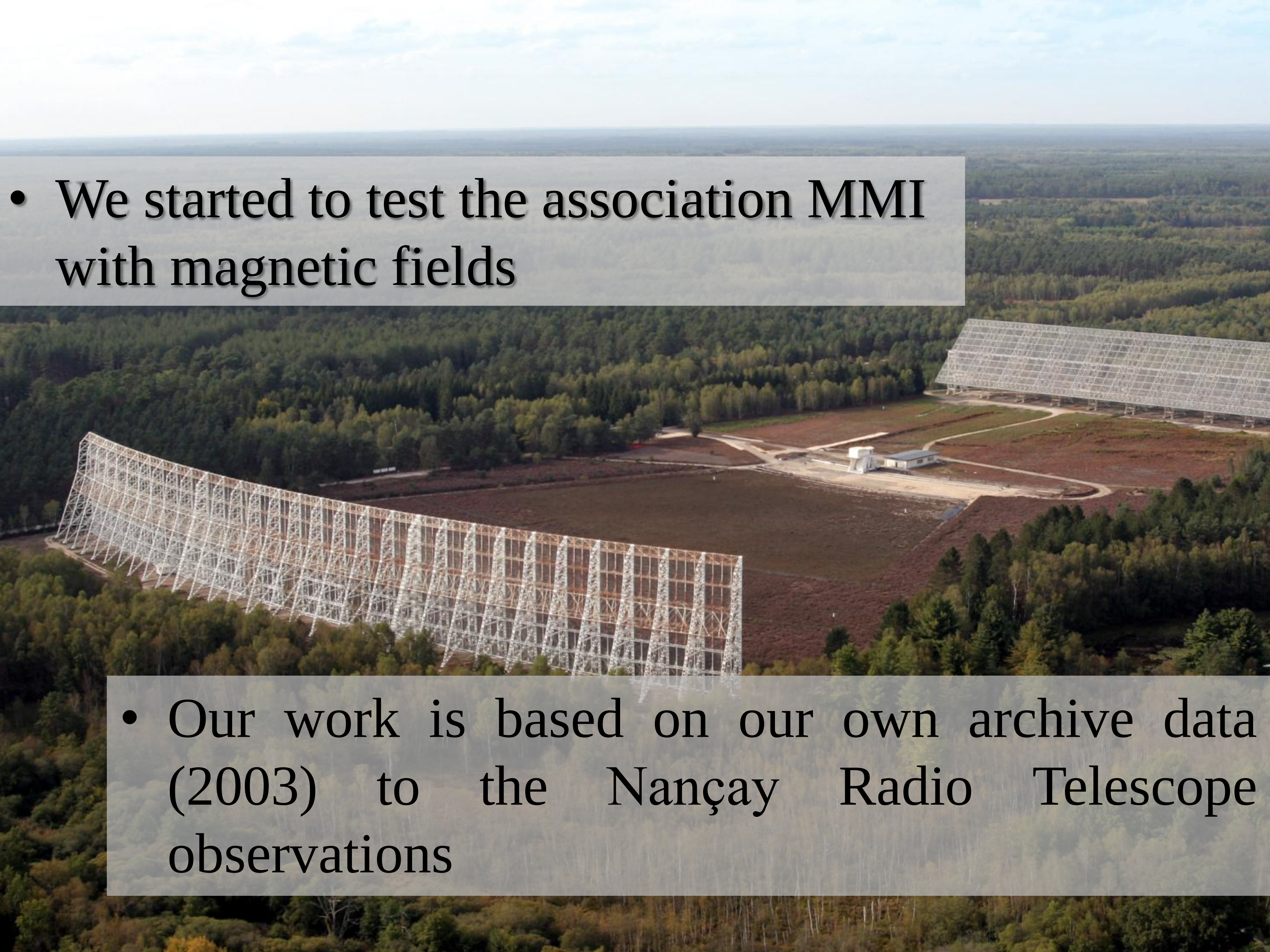


magnetic fields



Magnetic field data from the Whirlpool Galaxy,
M51. Credit: MPIfR Bonn.

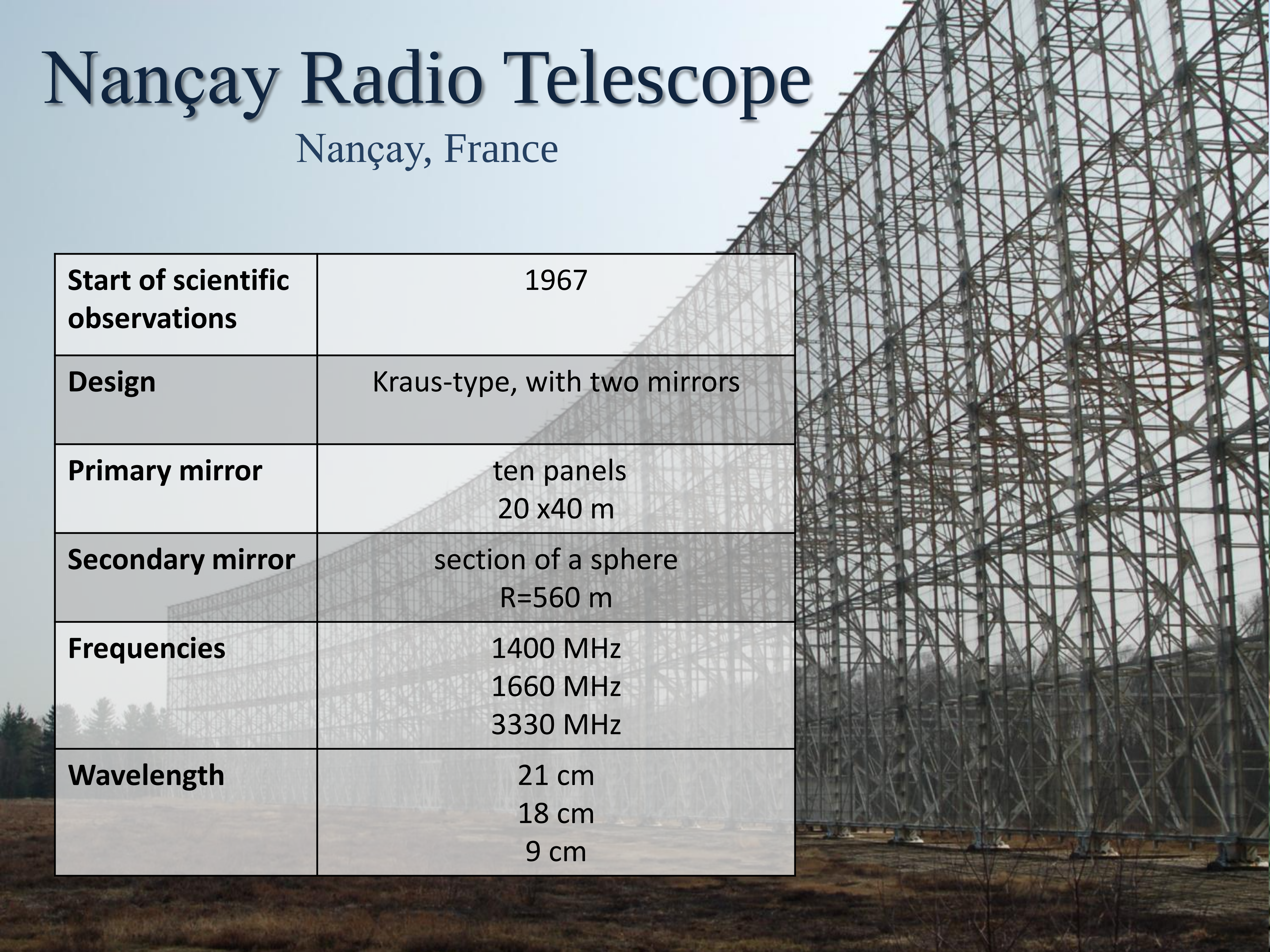
- We started to test the association MMI with magnetic fields



- Our work is based on our own archive data (2003) to the Nançay Radio Telescope observations

Nançay Radio Telescope

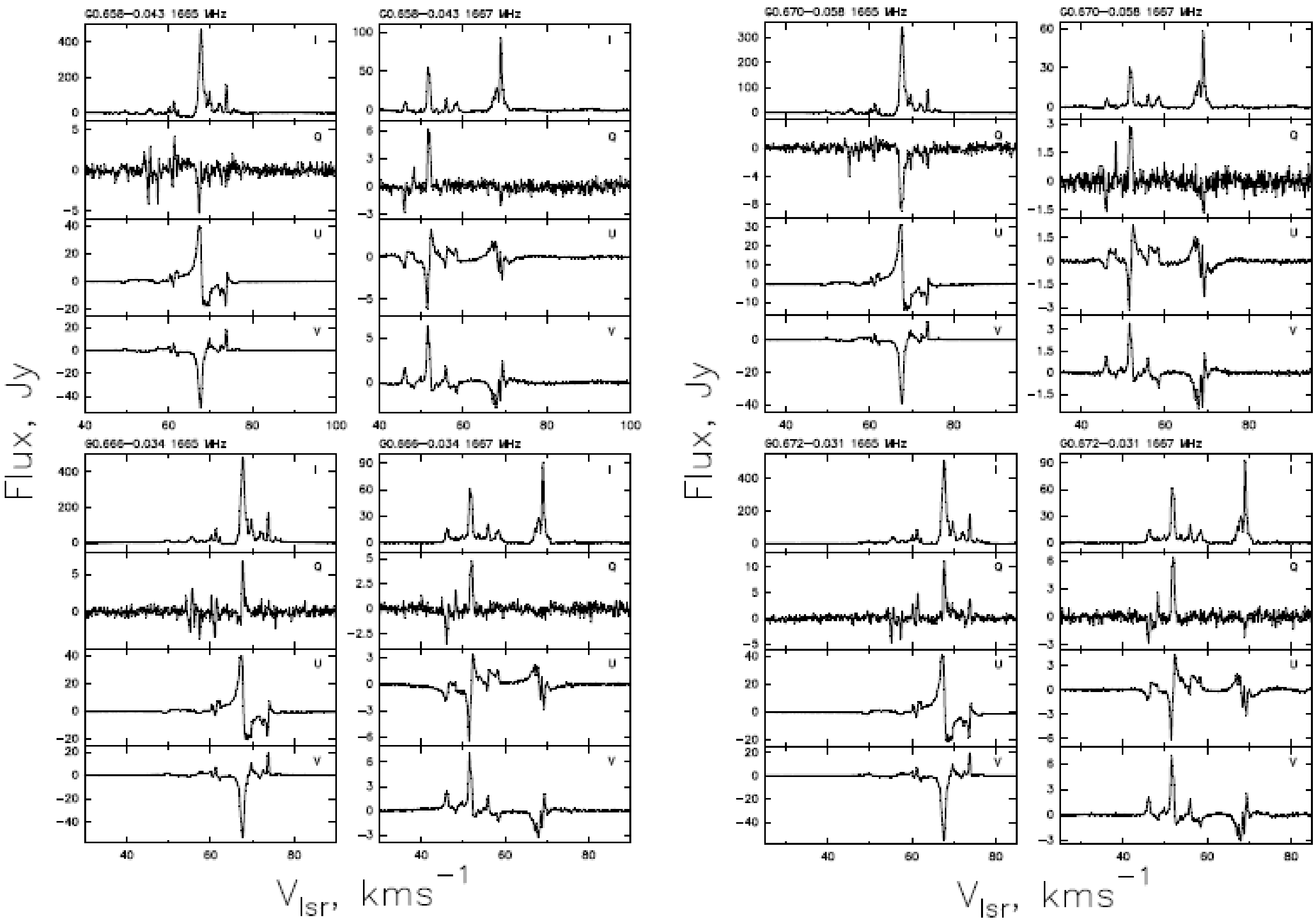
Nançay, France



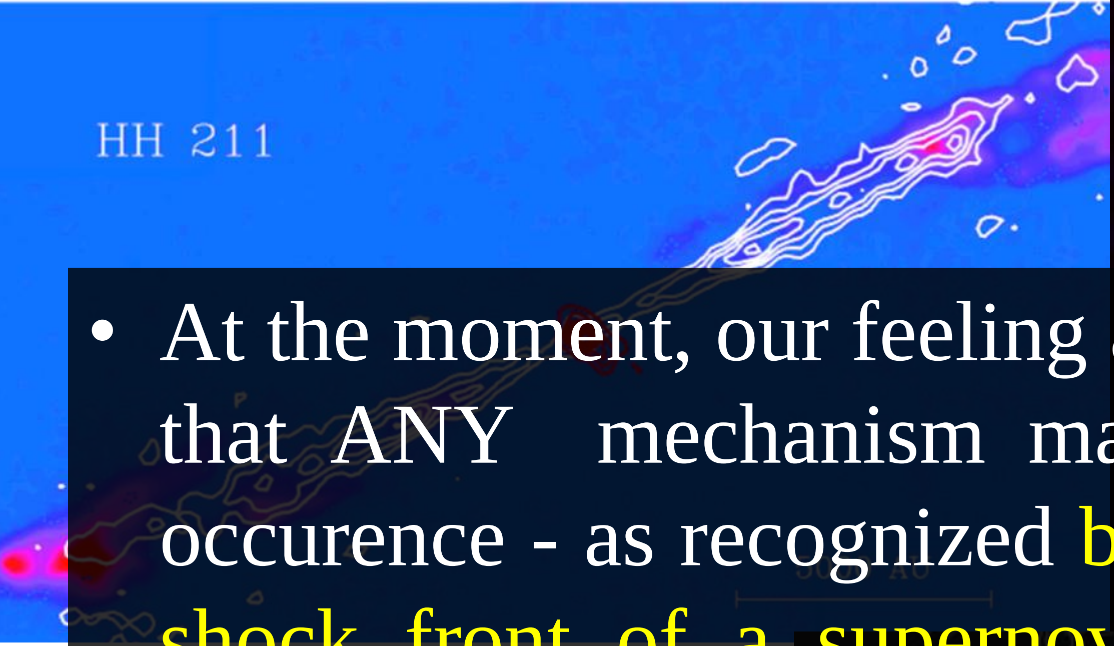
Start of scientific observations	1967
Design	Kraus-type, with two mirrors
Primary mirror	ten panels 20 x40 m
Secondary mirror	section of a sphere R=560 m
Frequencies	1400 MHz 1660 MHz 3330 MHz
Wavelength	21 cm 18 cm 9 cm

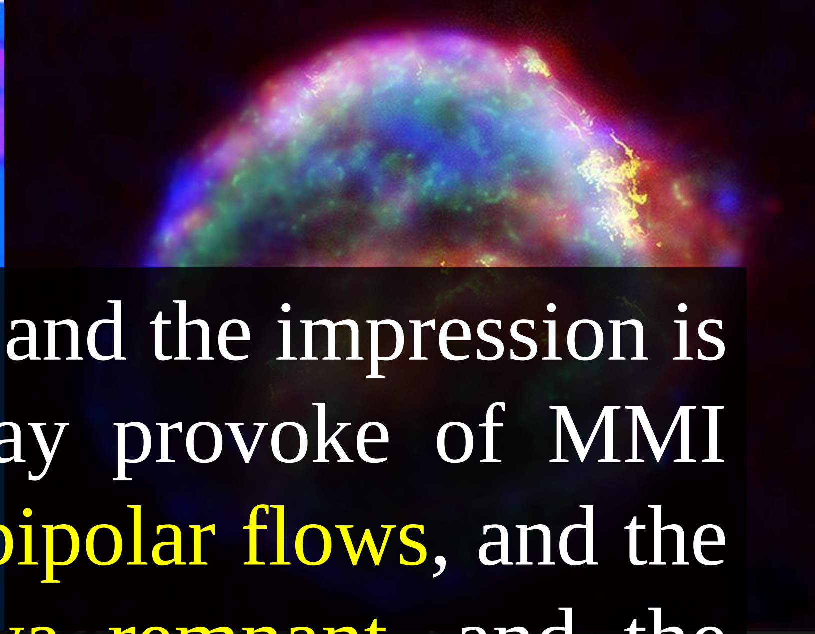
- In this project we have conducted a survey of OH masers in all four Stokes parameters in order to measured their full polarization properties and found new highly linear polarized masers. This was the first such survey. Usually only LCP and RCP spectra have been measured, and only several OH masers have their Stokes parameters determined. In our list there were all known OH masers accessible from Nancay with flux density above 1 Jy.

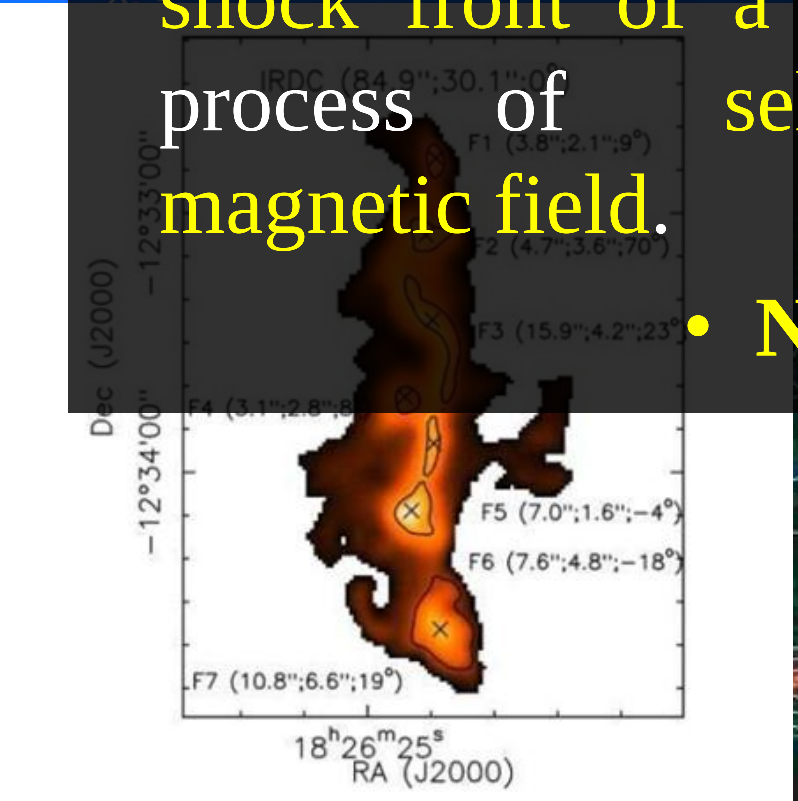
PROSPECTS

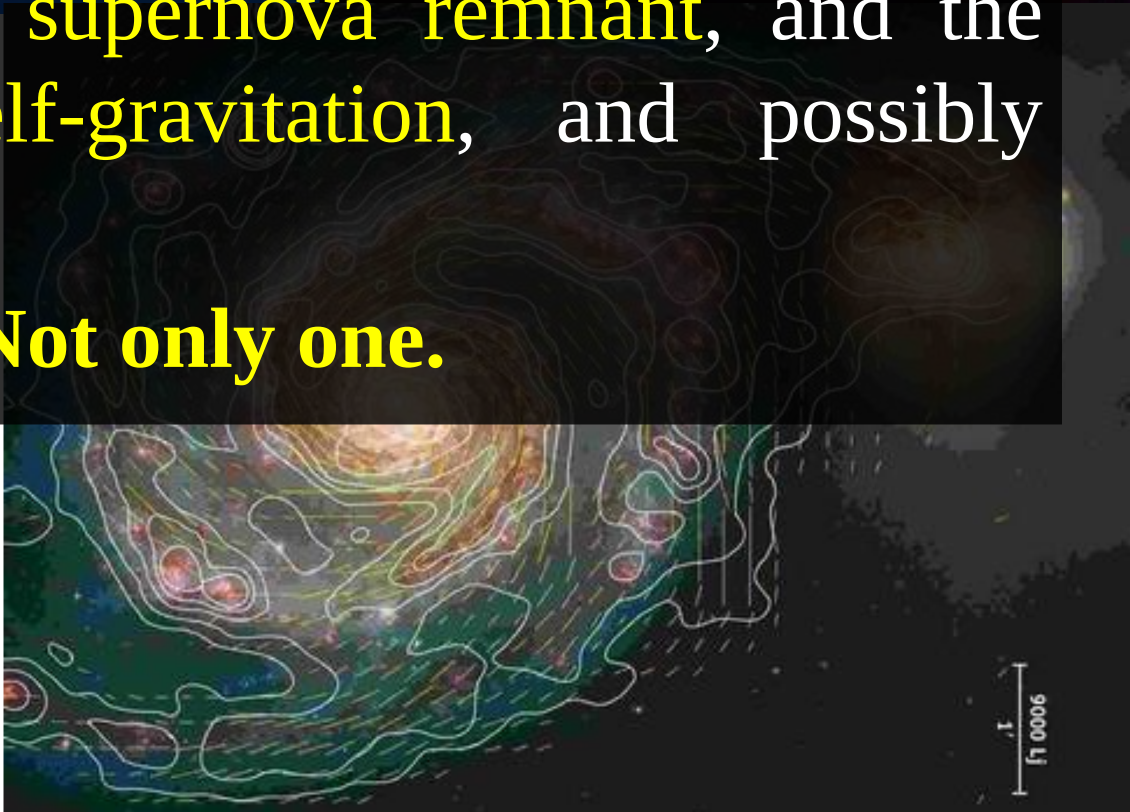

G0.658−0.043 1665 MHz
G0.658−0.043 1667 MHz
G0.670−0.058 1665 MHz
G0.670−0.058 1667 MHz
G0.666−0.034 1665 MHz
G0.666−0.034 1667 MHz
G0.672−0.031 1665 MHz
G0.672−0.031 1667 MHz
I
Q
U
V
Flux, Jy
V_{lsr}, kms^{-1}

- At present processed all the sources (92) of this survey
- We propose to estimate the magnetic fields and to make conclusions









- At the moment, our feeling and the impression is that ANY mechanism may provoke of MMI occurence - as recognized bipolar flows, and the shock front of a supernova remnant, and the process of self-gravitation, and possibly magnetic field.

- **Not only one.**

- We continue this work and hope to get **reliable arguments in favor of one factor** that provoke the most enigmatic of masers – MMI.


Thank you for your attention!