

Spectroscopy 2011

January 15-17, 2011 – Victoria BC Canada



Exploring Shock Chemistry in Star Forming Regions with the EVLA

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Atacama Large Millimeter/submillimeter Array
Expanded Very Large Array
Robert C. Byrd Green Bank Telescope
Very Long Baseline Array



Outline

- What is the EVLA?
 - Secondary Title: Doing ALMA Science with the EVLA
- Molecular Spectroscopy primer (thinking 1-50 GHz)
- First results NGC 1333 IRAS 4
 - Tertiary Title: Transformational Science Using Hotel Internet Connections



VLA->EVLA status



Parameter	VLA	EVLA (goal)	Factor	EVLA (now)
Point Source Sensitivity (1σ , 12 hr)	10 μ Jy	1 μ Jy	10	2 μ Jy
Maximum BW in each polarization	0.1 GHz	8 GHz	80	2 GHz
# of frequency channels at max BW	16	16,384	1024	4096
Maximum number of frequency channels	512	4,194,304	8192	12,288
Frequency resolution (coarsest/finest)	50MHz 381 Hz	2 MHz 0.12 Hz	25	2 MHz 0.12 Hz
# of full-polarization spectral windows	2	64	32	16
Frequency Coverage (1 - 50 GHz)	22%	100%	5	94%

- All 28 antennas are converted to EVLA standards (new optics (feeds, towers, etc), new IF electronics, new samplers, new DTS).
- Installation of receivers is ongoing; WIDAR capabilities are expanding
- **Ongoing construction, commissioning, science operations, maintenance.**
 - Observing mode deployment is ongoing: multi-band basic spectral line, continuum; coming: planetary, solar, phased array



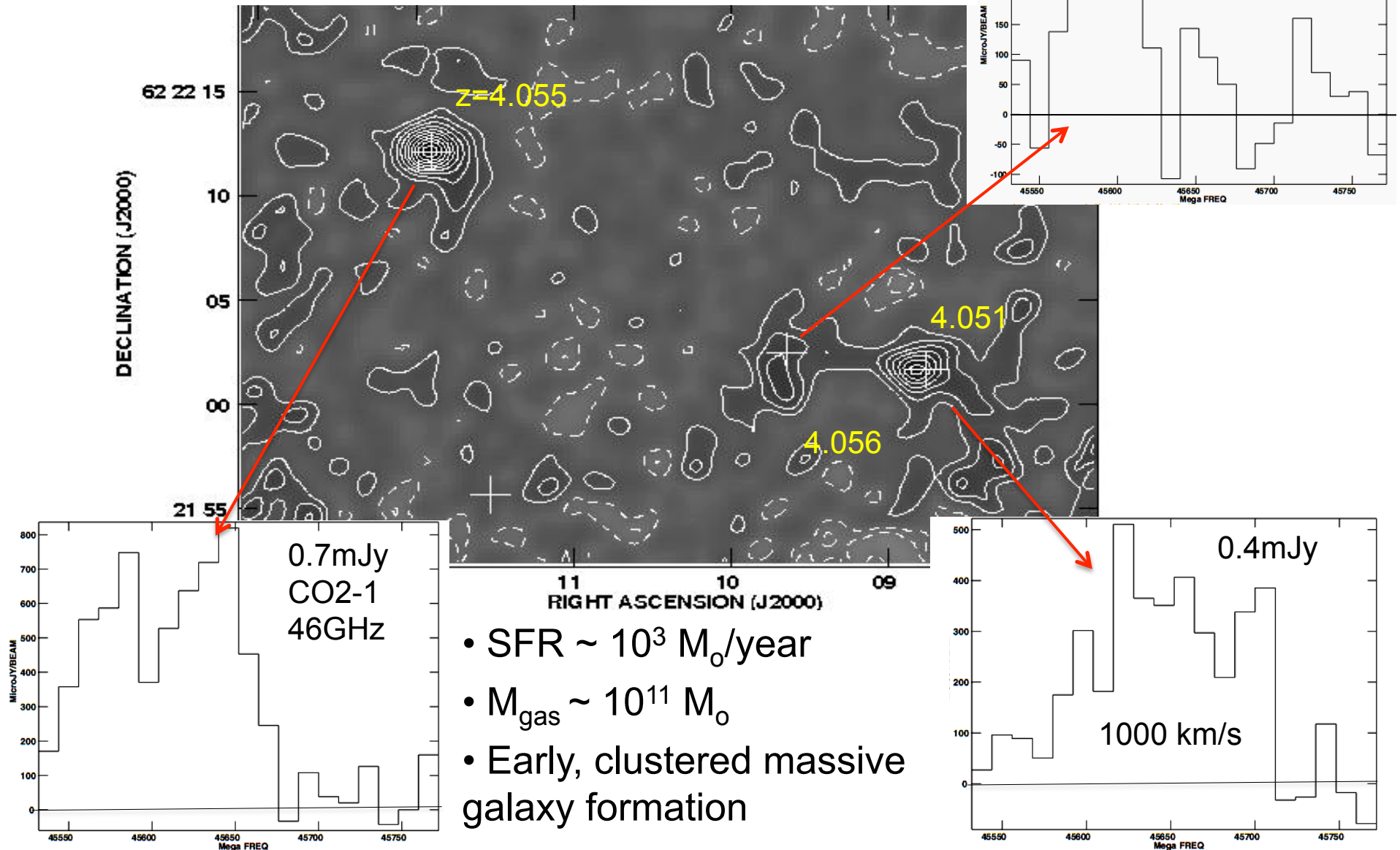
EVLA Early Science

- **E.g., EVLA Special session at the AAS**
 - EVLA Observations of the Largest TNOs
 - Grain Growth and sub-structure in Protoplanetary Disks
 - An EVLA Diagnostic K-Band Survey of Massive Young (Proto)stellar Objects
 - Radio Continuum Emission from Classical Novae: eNova Project Early Results (and Surprises!)
 - EVLA Constraints on the Progenitors of Supernovae Type Ia
 - The Bimodal Luminosity Distribution of QSOs: Starbursts and AGN?
 - Imaging Molecular Gas in Primeval Galaxies with the EVLA



Evolving Universe

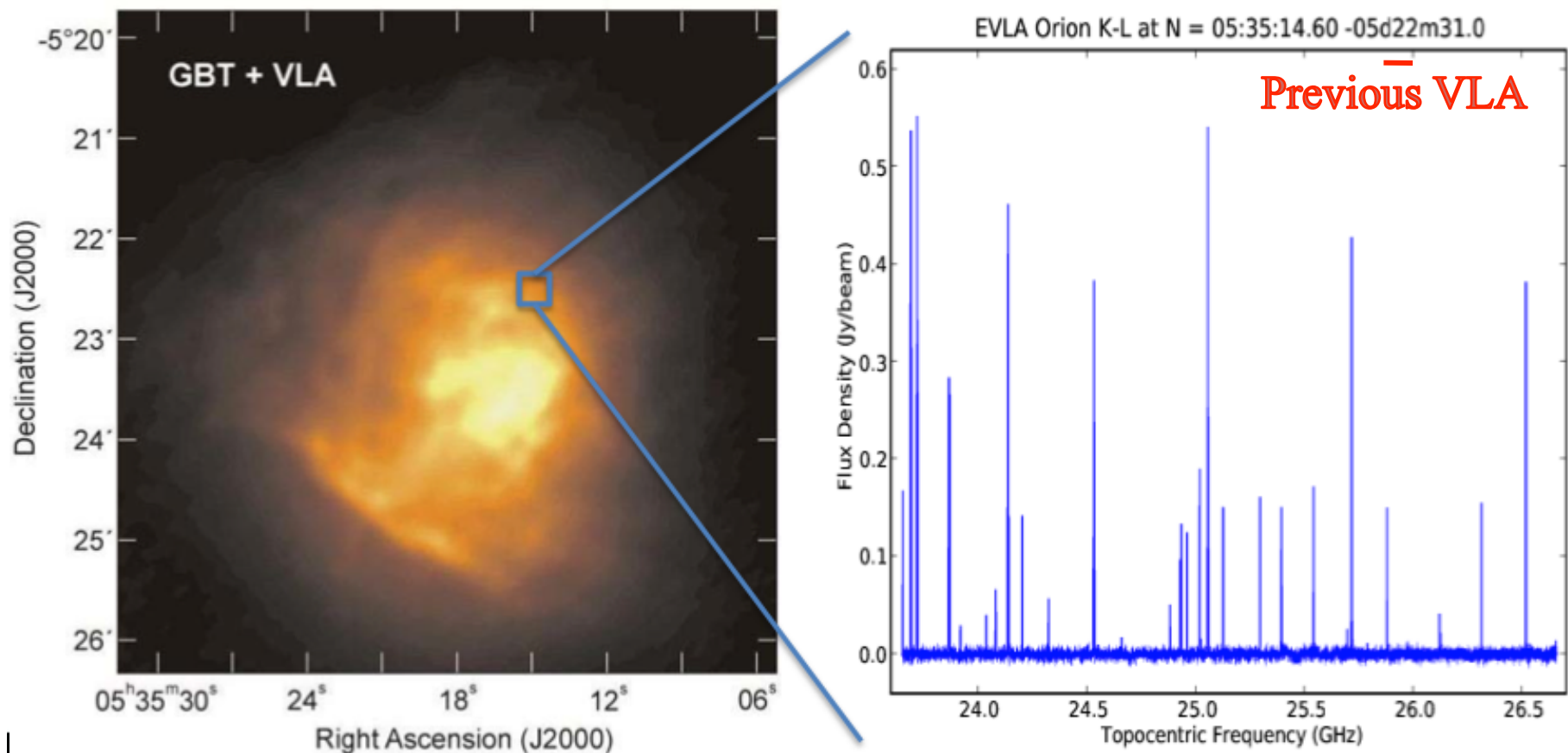
GN20 molecule-rich proto-cluster at $z=4$ (Daddi)
CO 2-1 in 3 submm galaxies, all in 256 MHz band



Obscured Universe

Orion hot molecular core

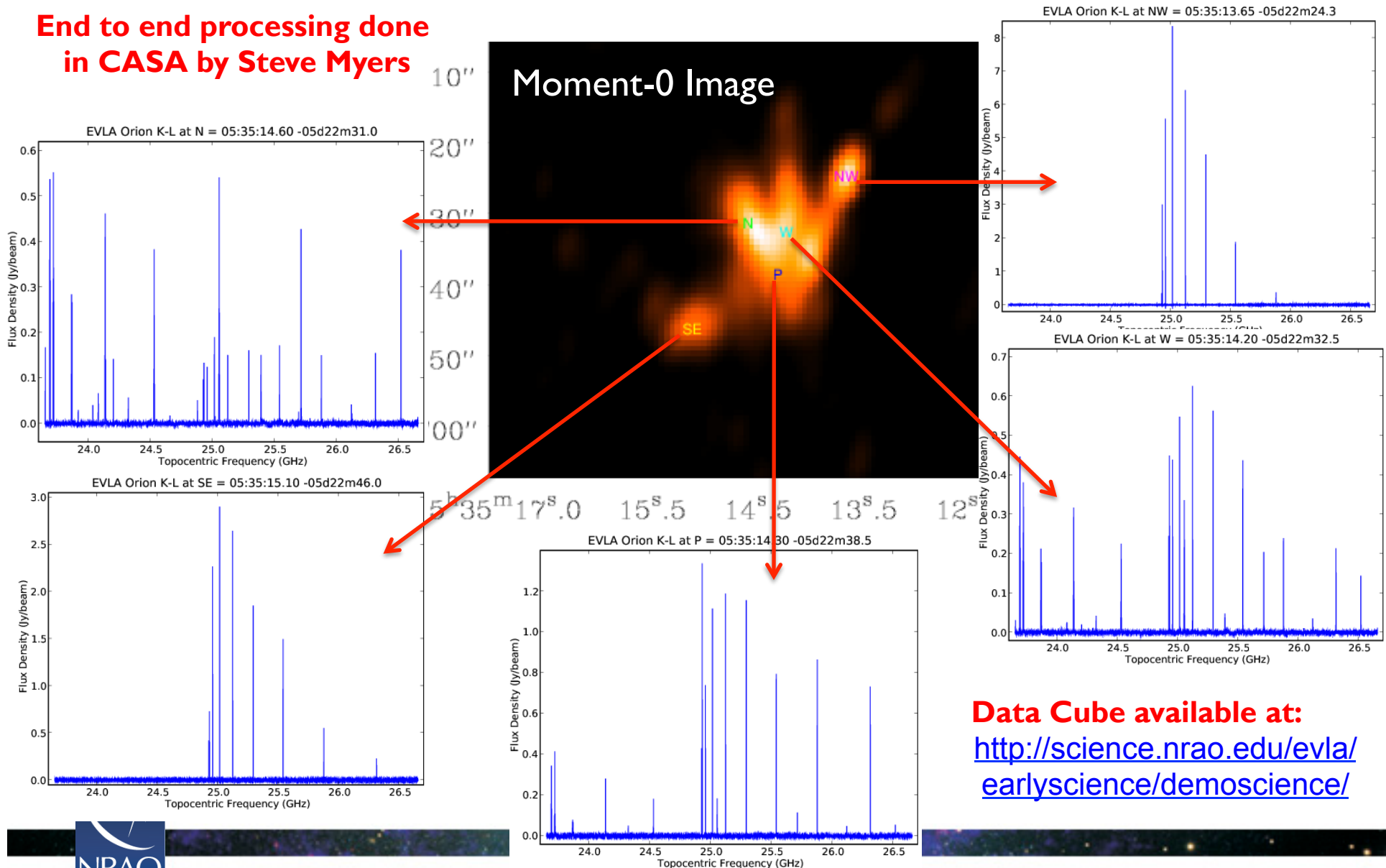
The hot core lies in the molecular cloud behind the nebula. Hot cores are thought to be signposts of the earliest phase of massive star formation; rich chemistry, high densities and temperatures



Spectra from the 128 x 128 x 24012 data cube

End to end processing done
in CASA by Steve Myers

Moment-0 Image



Data Cube available at:
<http://science.nrao.edu/evla/earlyscience/demoscience/>

Demo Science

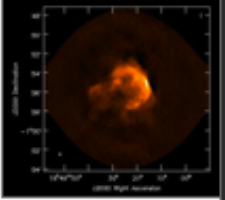
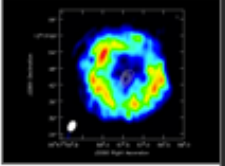
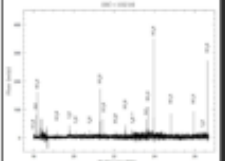
EVLA Demonstration Science

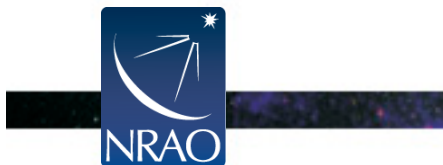
A number of observations demonstrating new EVLA and WIDAR capabilities are being undertaken, and are described in the table below. Both raw and calibrated demonstration science data will be public. Raw data can be downloaded through the archive by selecting the project code listed. Processed data will be provided through links from this page, as they become available.

Data and reduction examples
available to everyone.

[http://science.nrao.edu/
evla/earlyscience/
demoscience/](http://science.nrao.edu/evla/earlyscience/demoscience/)

EVLA Demonstration Science Observations

Project Code	Overview	Observations	Notes/status
TDEM0001	5 GHz continuum polarimetry mosaic of the SNR 3C391 for the synthesis imaging summer school data reduction tutorials	7 pointings in D-configuration, two widely separated 128 MHz sub-bands using the 4-8 GHz EVLA receivers	Data and casa reduction scripts are available at the casaguides web page 
TDEM0002	36 GHz imaging of SiS and HC3N line emission from the AGB star IRC+10216 for the synthesis imaging summer school data reduction tutorials	Single pointing with two 8 MHz sub-bands in D-configuration, full polarization, each centered on one of the spectral lines	Data and casa reduction scripts are available at the casaguides web page 
TDEM0003	Spectral sweep of the AGB star IRC+10216 from 18 to 26.5 GHz with coarse spectral resolution, plus targetted imaging of several lines between 18 and 40 GHz with higher spectral resolution	Single pointing in D and DnC-configurations, 128 MHz sub-bands (2 MHz channels) for spectral sweep, 8 MHz sub-bands (125 kHz channels) for detailed imaging	Data will be posted here when reduction is complete 



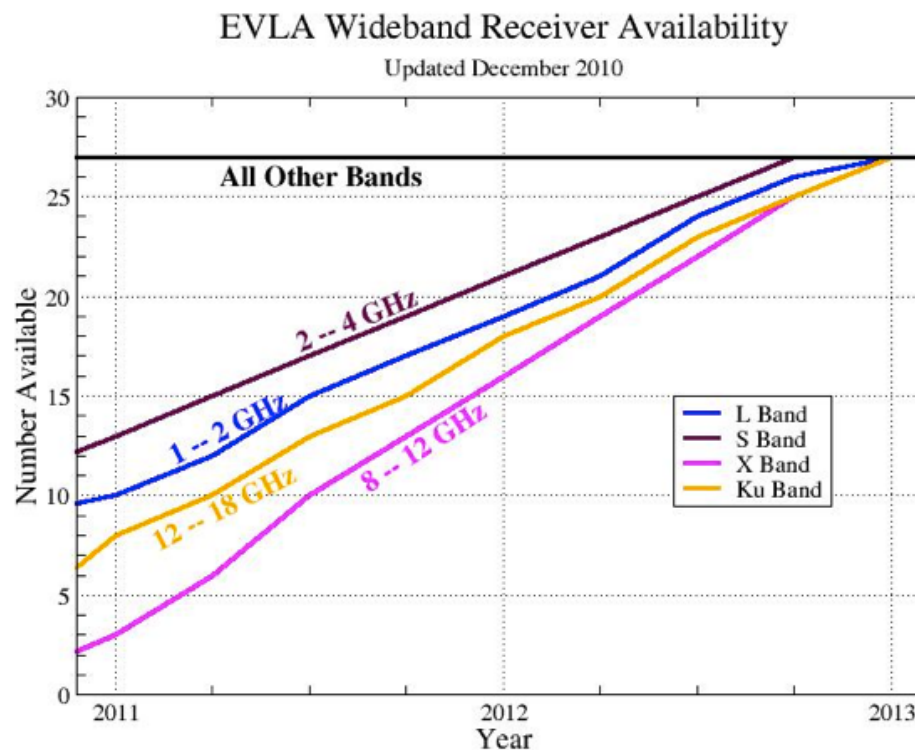
Early Science Observing Programs

- OSRO = 'Open Shared Risk Observing'
 - Standard observing protocol (proposal submission->grading->dynamic scheduling)
 - Have access to initial WIDAR capabilities
 - First set of configurations, these are based on the VLA capabilities.
 - Next D configuration (Sep 2011), these increase dramatically (to those vetted and used by the RSRO program).
 - <http://science.nrao.edu/evla/earlyscience/osro.shtml>
- RSRO = 'Resident Shared Risk Observing'
 - For those willing to spend significant time in Socorro (~3 months) and have skills and interest in assisting in implementing advanced correlator modes or calibration methodologies.
 - Participants will have much more extensive observing capabilities made available to them.
 - <http://science.nrao.edu/evla/earlyscience/rsro.shtml>



EVLA Projected Completion

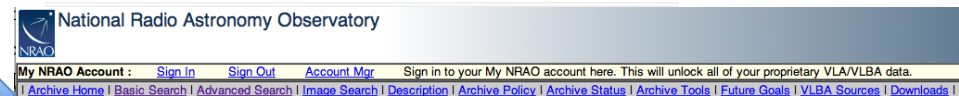
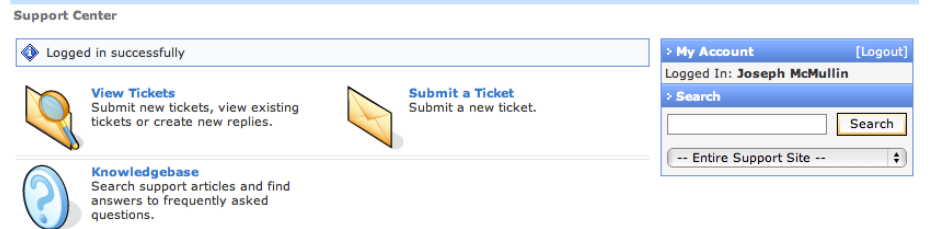
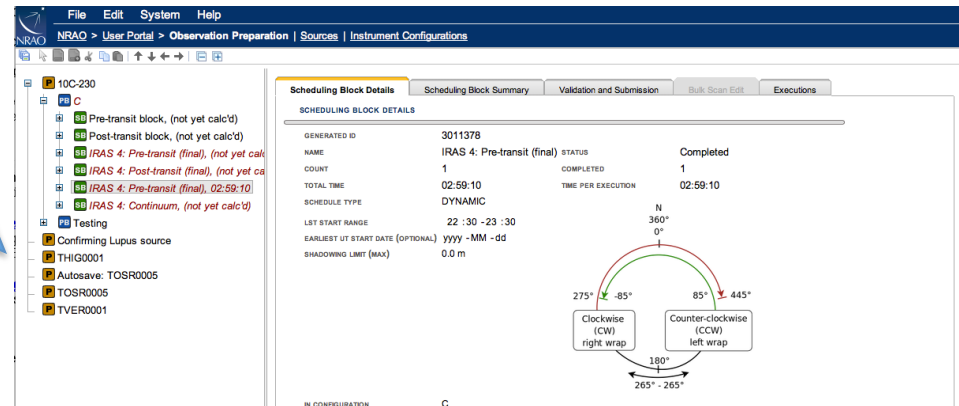
(Rx & WIDAR)



Dates	Total BW/pol	# SB pairs	Chans/SB pairs (full pol)	Capabilities*
Now	128 MHz (OSRO) 2 GHz (RSRO)	2 (OSRO) 16 (RSRO)	64	
2011Q1	2 GHz (RSRO)	64 (RSRO)	64	Trade SBs for channels
2011Q3	2 GHz (RSRO)	64 (RSRO)	Up to 16,384	Recirculation Relaxed SB tuning
2011Q4	2 GHz (OSRO) 2 GHz (RSRO)	16 (OSRO) 64 (RSRO)	64 (OSRO) Up to 16,384 (RSRO)	Adjacent SBs (OSRO) SBs indep. Tuned; SBs indep BW/chan
2012Q1	8 GHz (RSRO)	64 (RSRO)	Up to 16,384	Basebands have 1 or 4 GHz BW

EVLA Services

- my.nrao.edu integrates:
 - Proposal submission (PST)
 - Observing preparation (OPT)
 - Helpdesk
 - Interact with staff
 - Questions
 - Knowledgebase articles
- Archive
 - Data access and retrieval
- Other resources
 - Post-processing guides
 - Splatalogue



NRAO Science Data Archive : Basic Search Tool

EVLA, VLA and VLBA Data Products

Instructions on how to download your data : [click here](#)

Project (Proposal) Code : 108-126

Observer :

Telescope : ALL

Observe Start Date : 2010-NOV-01

Observe Stop Date :

Format : yyyy-MM-dd or yyyy-MM-dd hh:mm:ss

Format : yyyy-MM-dd or yyyy-MM-dd hh:mm:ss

Query Control Parameters :

Enter Locked Project Access Key :

Query Returns : Download Archive Files

Submit Query **Clear Form**

Please direct feedback and/or questions concerning this page and its associated search engine to [NRAO DAS contact](#).

Version 5.7.0

Project (Proposal) Code	Observer	Telescope	Observe Start Date	Observe Stop Date	Format	Format	Query Returns	Submit Query	Clear Form
108-126	108-126	ALL	2010-NOV-01		yyyy-MM-dd or yyyy-MM-dd hh:mm:ss	yyyy-MM-dd or yyyy-MM-dd hh:mm:ss	Download Archive Files	Submit Query	Clear Form



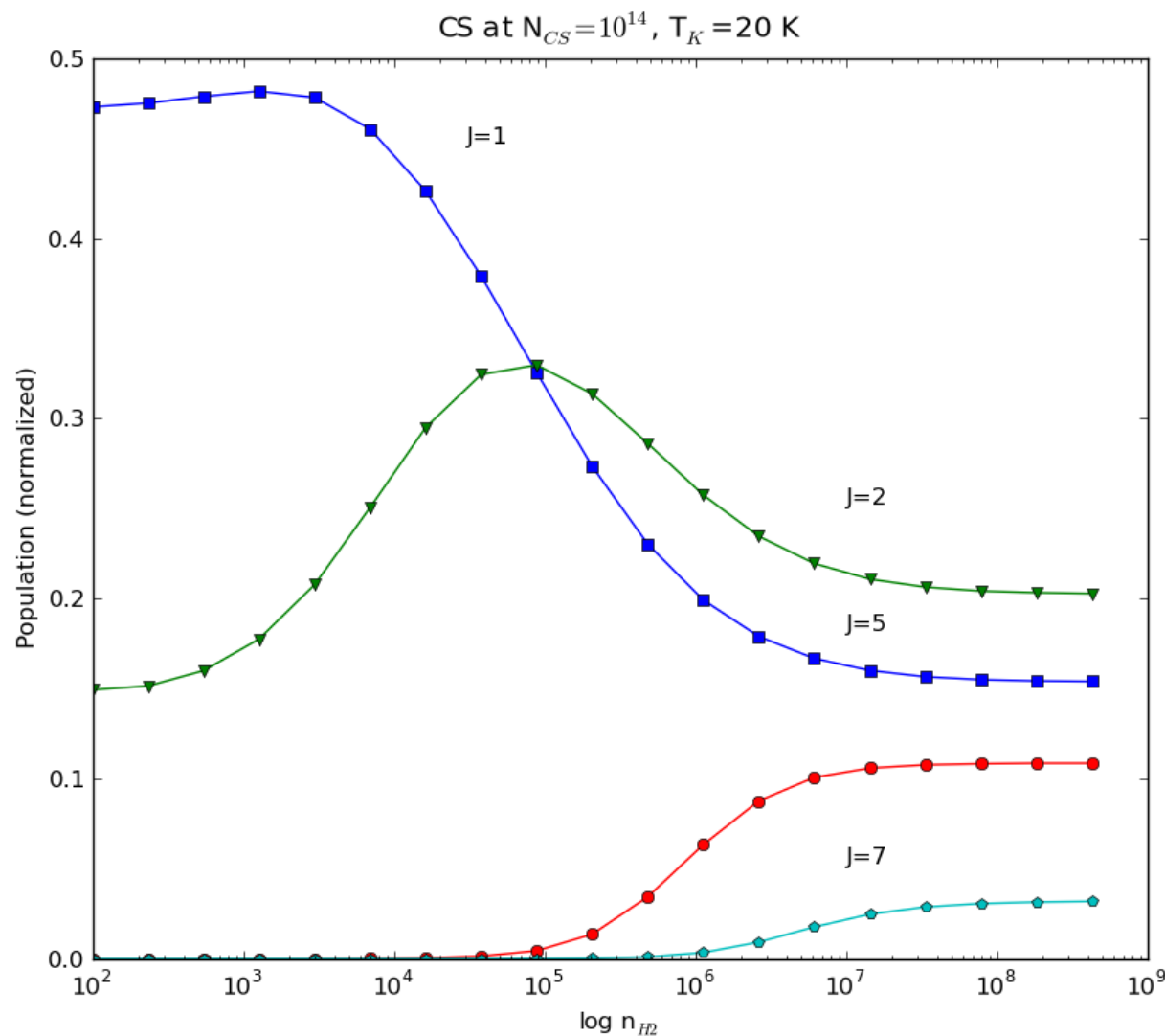
Summary

- EVLA is operating now with expanding capabilities through the end of 2012.
 - Combined construction, commissioning and science operations has been and will remain costly but it has enabled nearly uninterrupted access to the array throughout the conversion. Engagement by the community remains essential (via the RSRO+ programs) for completing the project on time.
- Key Links:
 - Main Page (with all required links): <http://science.nrao.edu/evla>
 - Observational Status Summary:
 - http://evlaguides.nrao.edu/index.php?title=Observational_Status_Summary
- **Call for proposals: 1 February!!!**

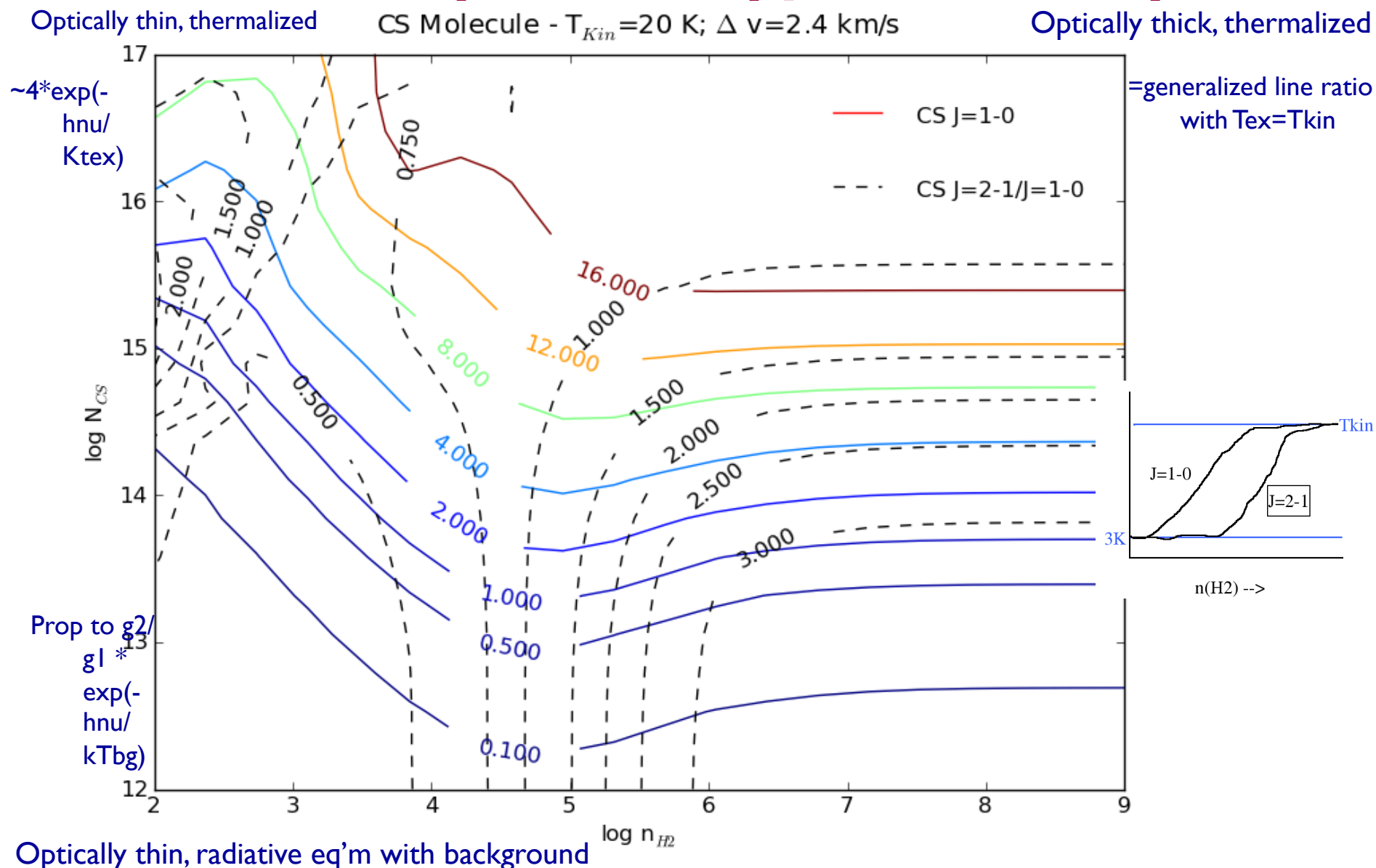


Molecular Spectroscopy – thinking 1-50 GHz

- Splatalogue says: 33K lines from 1-50 GHz, E_u ranging from 0-100K



Molecular Spectroscopy - CS Example

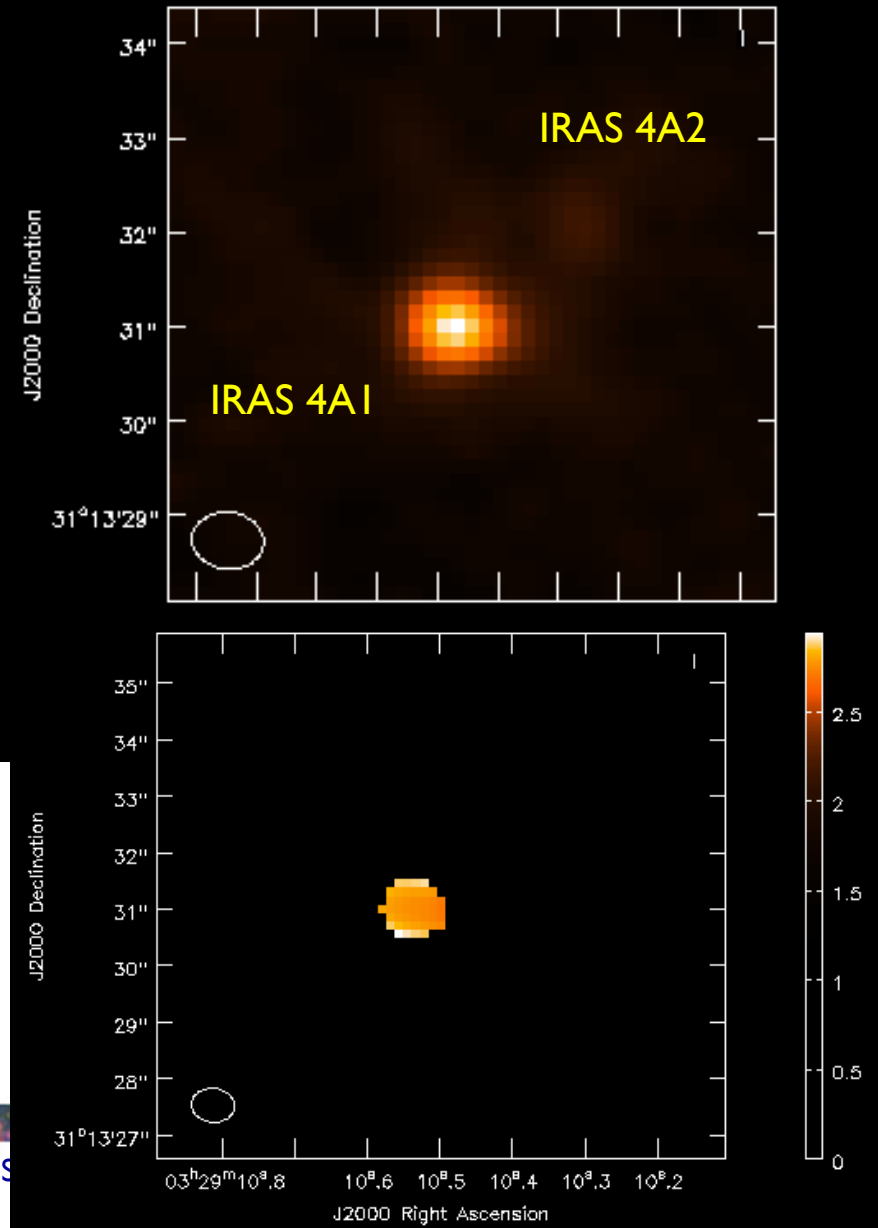
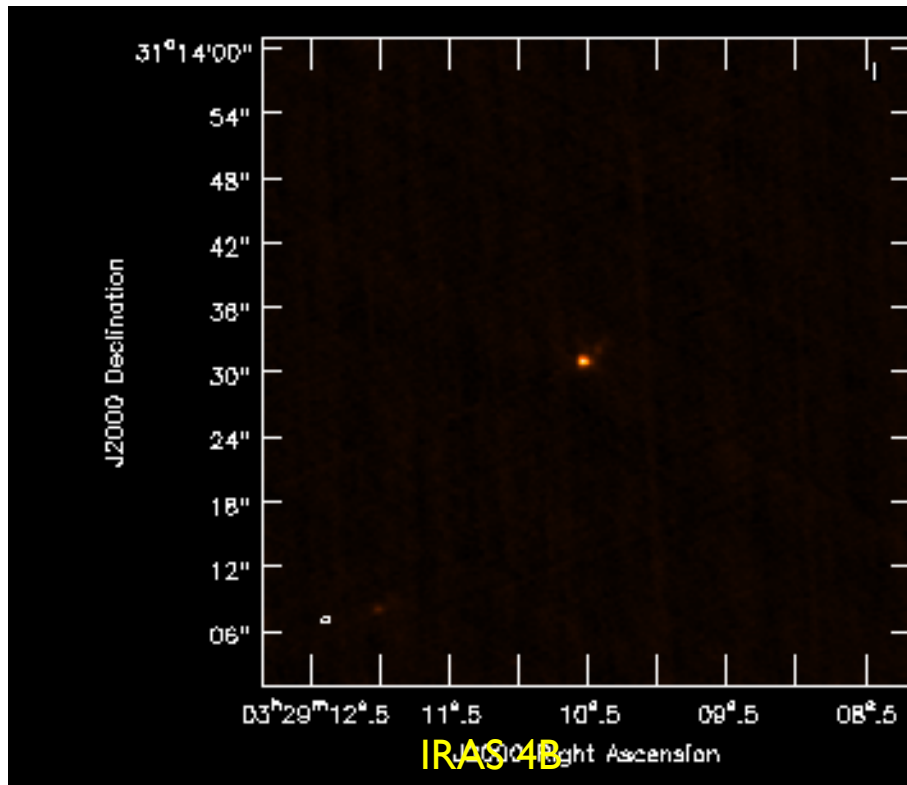


NGC 1333 IRAS 4

- Background:
 - Nearby star forming region (220-320 pc) with large number of low-mass pre-main sequence stars and protostars.
 - IRAS 4 is a multiple system of Class 0 protostars
- Project
 - Exploratory proposal
 - Continuum/Key shock tracers
 - single correlator setup 43.5/48.5 GHz; $\sim 0.6''$ beam
 - Continuum: dust, $n(\text{H}_2)$ tracer
 - SiO – J-type shock interactions
 - SO₂, OCS – Sulfur chemistry
 - CH₃OH, CH₃OCHO – C-type shock interactions
 - CS, H₂CO – dense gas tracers
 - → 2 field mosaic, many spectral lines = sounds like ALMA!



NGC 1333 IRAS 4 Continuum



$$M_{\text{IRAS 4A1}} = 2.4 M_{\text{sol}} (T_d = 50 \text{ K})$$

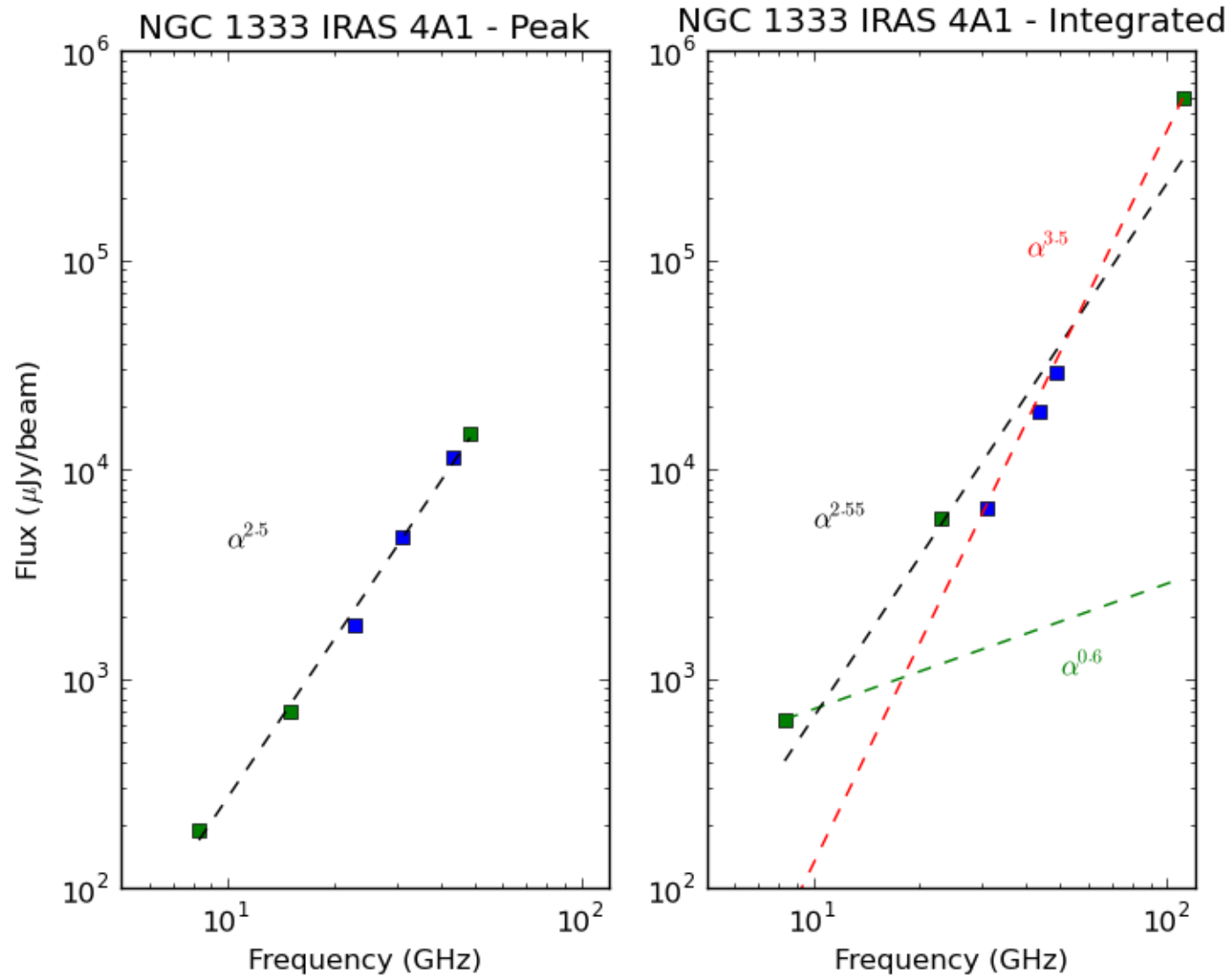
$$M_{\text{IRAS 4A2}} = 0.3 M_{\text{sol}} (T_d = 40 \text{ K})$$

$$N(\text{H} + \text{H}_2)_{\text{IRAS 4A}} = 8 \times 10^{24} \text{ cm}^{-2}$$

$$N(\text{H} + \text{H}_2)_{\text{IRAS 4A}'} = 2.0 \times 10^{24} \text{ cm}^{-2}$$



NGC 1333 IRAS 4 Continuum



Molecular Emission

-- SiO

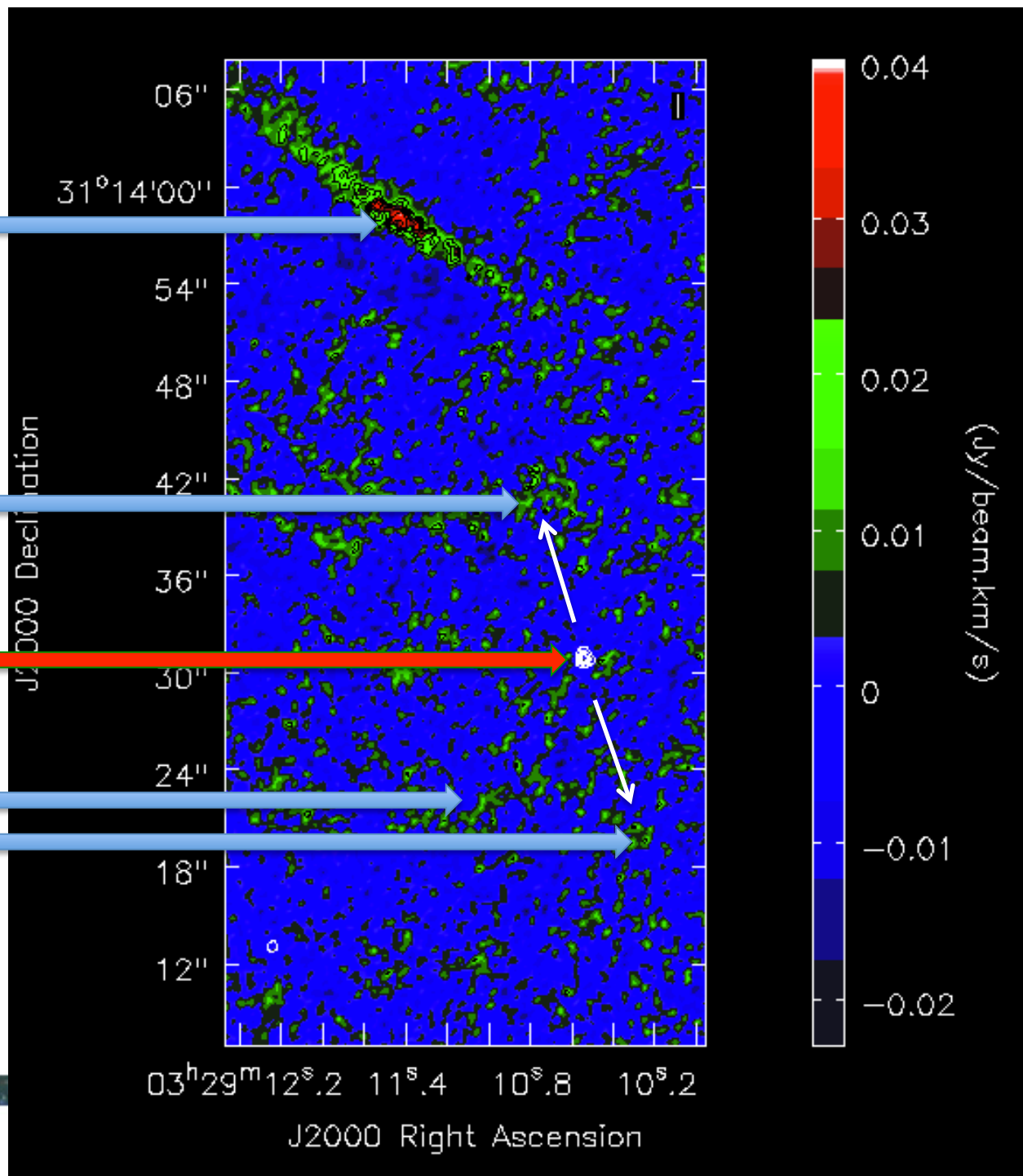
Choi 2005

Clumps 1-3

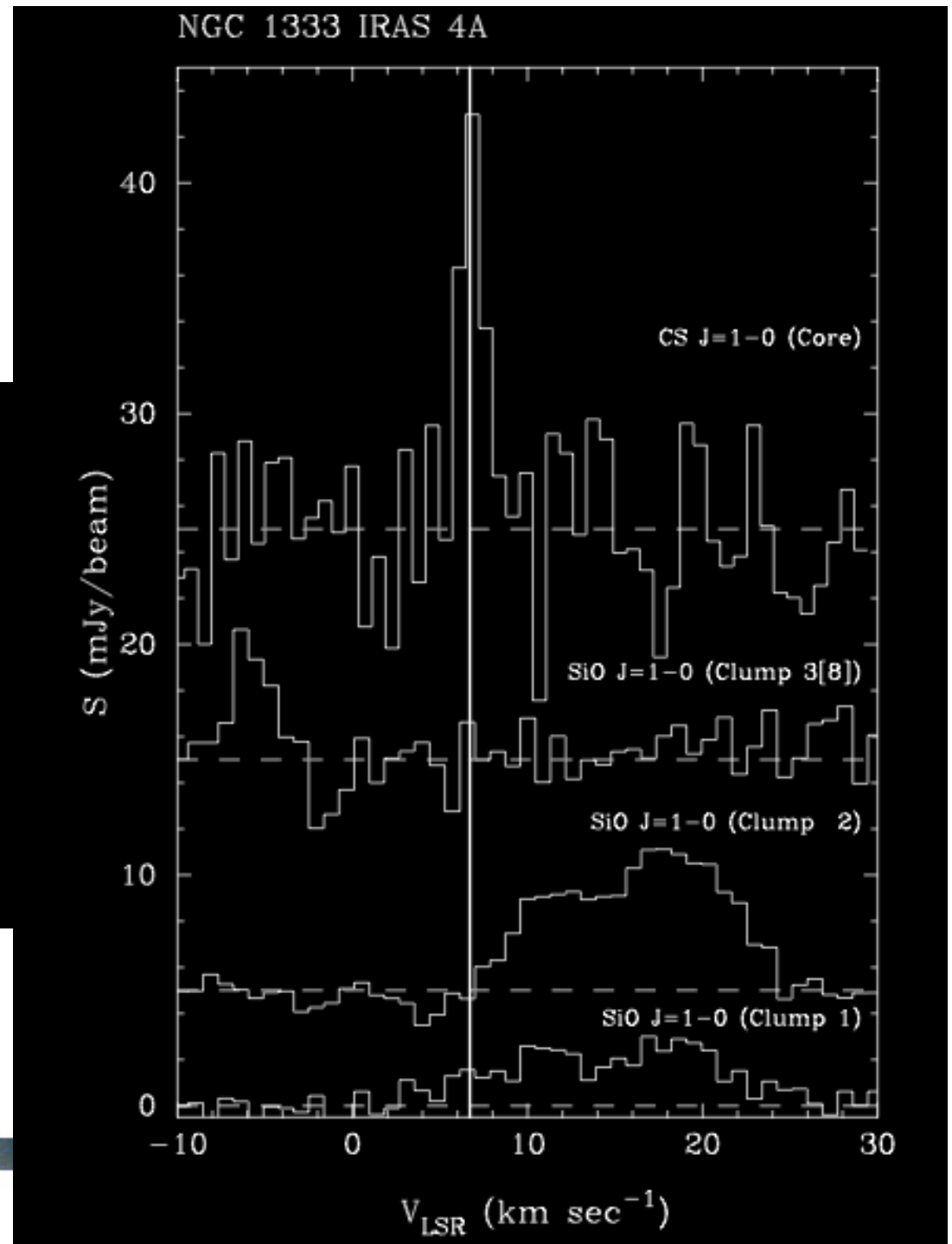
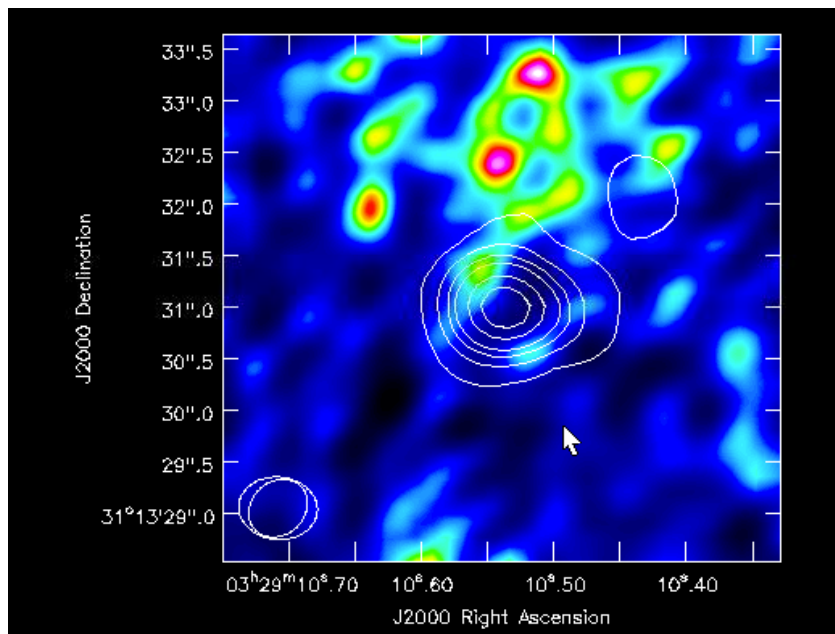
Clumps 4-6

Continuum

Clumps 14-16
Clumps 7-9



Molecular Emission – CS



Molecular Emission - other

- Other lines detected (H_2CO , CH_3OH)
- Combine with other spatial frequencies for more complete sampling of the emission.
- Lots more to do.

Summary

- EVLA
 - Ready and getting better for a broad range of science
 - Spectrally, hemispherically complementary to ALMA
 - Proposals due February 1, 2011
- Molecular Spectroscopy
 - Also ready but lots more interplay between observation and modelling
- NGC 1333 IRAS 4 Exploratory
 - Sub-arcsec resolution emission distributions of several lines
 - First detection of CS $J=1-0$ in IRAS 4A(?)
 - Able to disentangle properties of close binary system
 - Refine reduction/analysis
 - Look at IRAS 4B system



Backup from OSS

http://evlaguides.nrao.edu/index.php?title=Observational_Status_Summary

Table 5: Configuration Properties

Configuration	A	B	C	D
$B_{\max}$ (km ¹)	36.4	11.1	3.4	1.03
$B_{\min}$ (km ¹)	0.68	0.21	0.035 ⁵	0.035
	Synthesized Beamwidth $\theta_{\text{HPBW}}(\text{arcsec})^{1,2,3}$			
74 MHz (4 band)	24	80	260	850
1.5 GHz (L)	1.3	4.3	14	46
3.0 GHz (S) ⁶	0.65	2.1	7.0	23
6.0 GHz (C)	0.33	1.0	3.5	12
8.5 GHz (X) ⁷	0.23	0.73	2.5	8.1
15 GHz (Ku) ⁶	0.13	0.42	1.4	4.6
22 GHz (K)	0.089	0.28	0.95	3.1
33 GHz (Ka)	0.059	0.19	0.63	2.1
45 GHz (Q)	0.043	0.14	0.47	1.5
	Largest Angular Scale $\theta_{\text{LAS}}(\text{arcsec})^{1,4}$			
74 MHz (4 band)	800	2200	20000	20000
1.5 GHz (L)	36	120	970	970
3.0 GHz (S) ⁶	18	58	490	490
6.0 GHz (C)	8.9	29	240	240
8.5 GHz (X) ⁷	6.3	20	170	170
15 GHz (Ku) ⁶	3.6	12	97	97
22 GHz (K)	2.4	7.9	66	66
33 GHz (Ka)	1.6	5.3	44	44
45 GHz (Q)	1.2	3.9	32	32

