

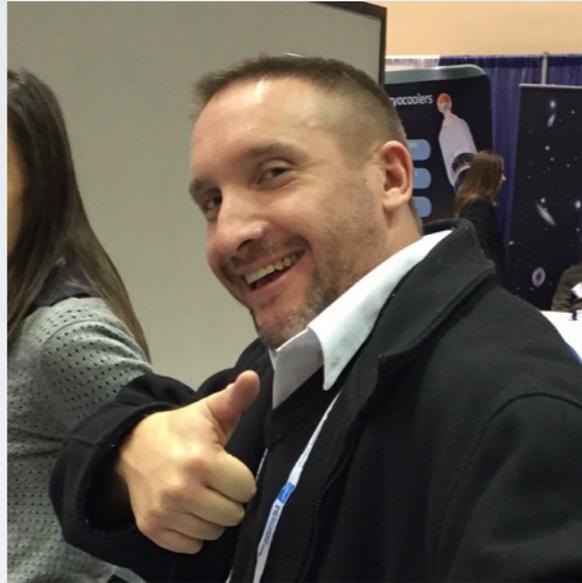
The GBT PRIMOS Project

Probing Our Cosmic Origins



Brett A. McGuire

Jansky Postdoctoral Fellow - NRAO/Harvard-CfA/Caltech



Anthony Remijan

Founders

Mike Hollis
Phil Jewell
Frank Lovas

Current Team

Joanna Corby (UVa)
Andrew Burkhardt (UVa)
Klaus Dollhopf (UVa)
Brandon Carroll (Caltech)

Ryan Loomis (CfA)
Tom Booth (UVa)
Chris Shingledecker (UVa)
You!



Lake Waiau

Brandon Carroll

Kona

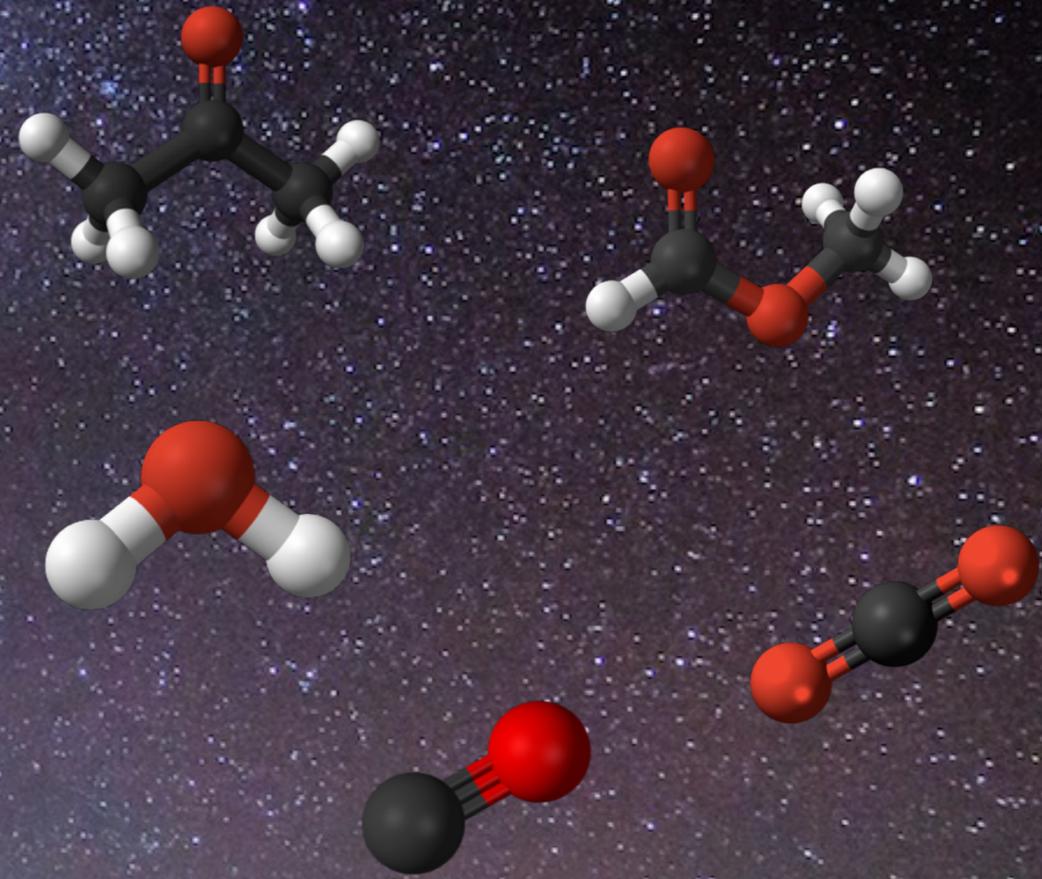
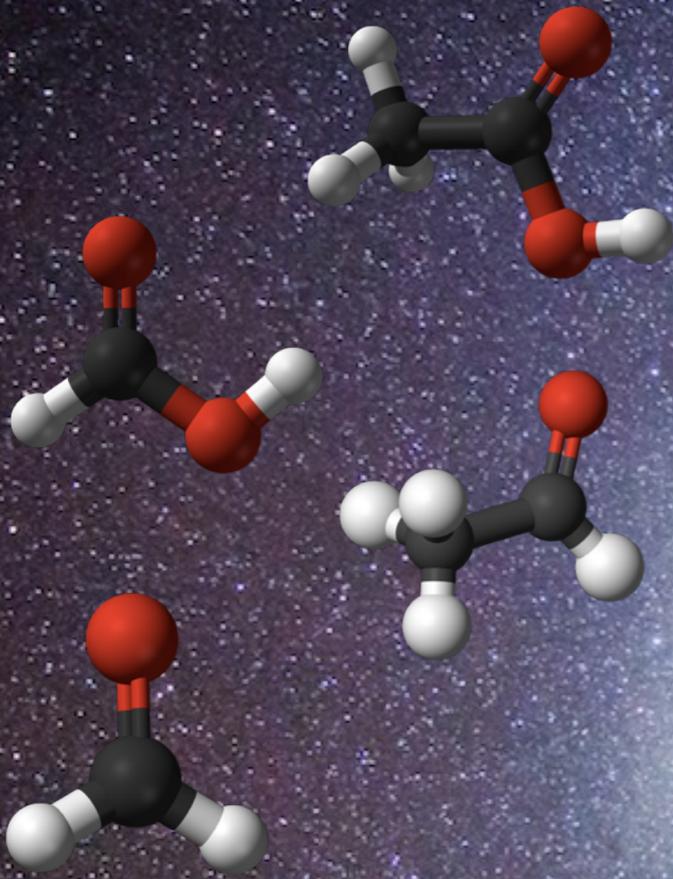
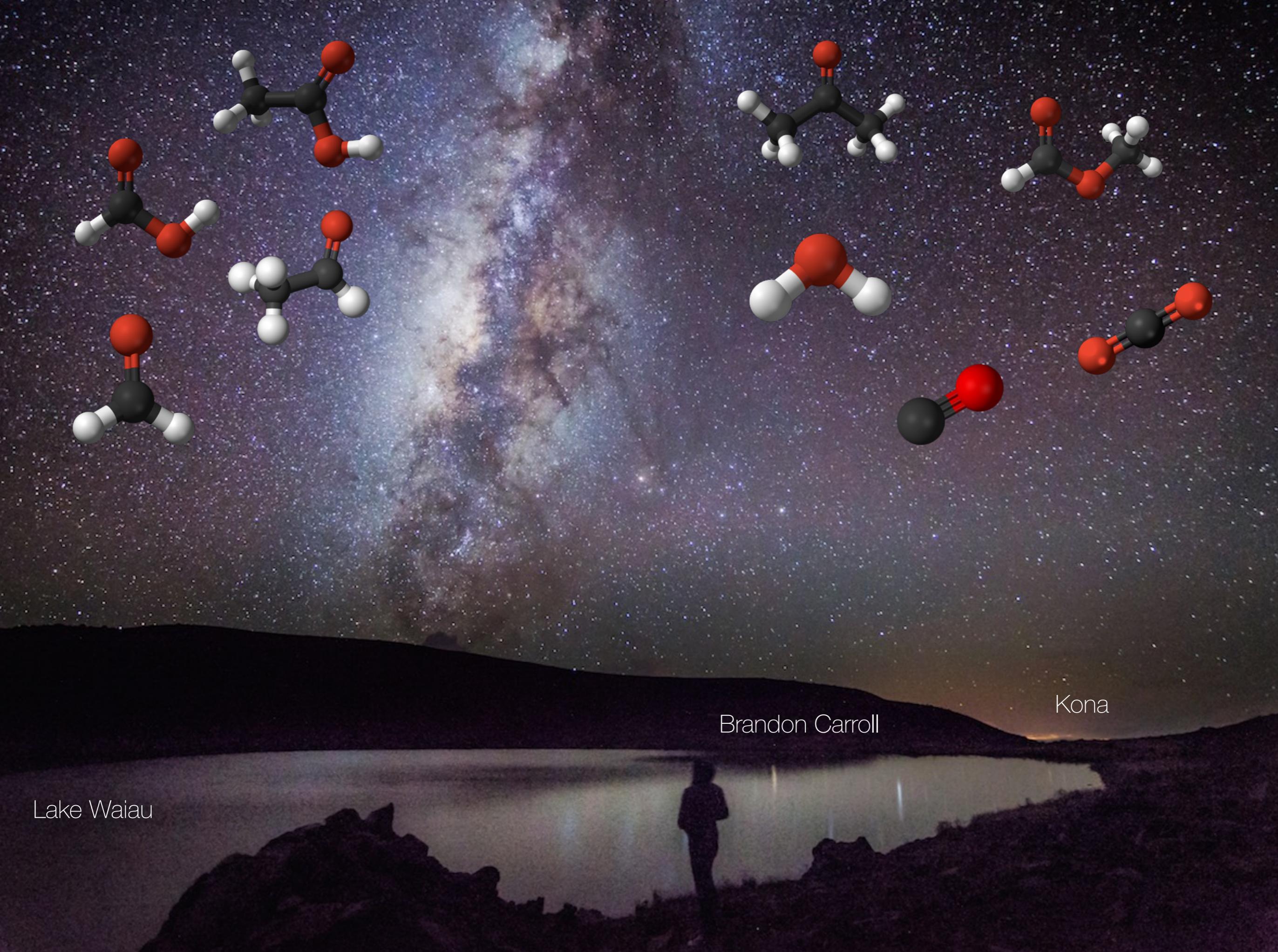
PRebiotic Interstellar MOlecular Survey



Brandon Carroll

Kona

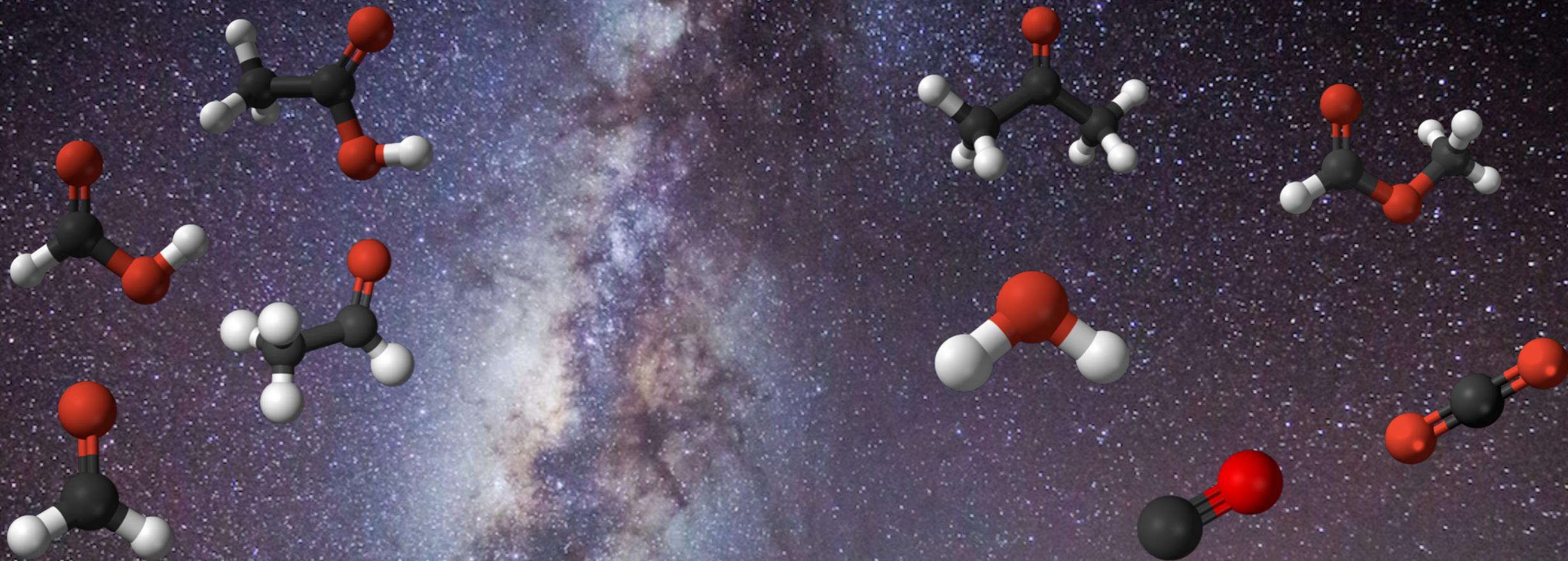
Lake Waiau



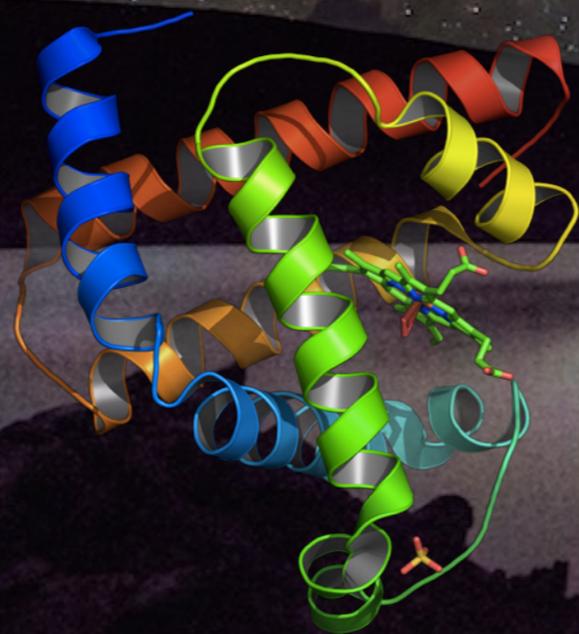
Lake Waiau

Brandon Carroll

Kona

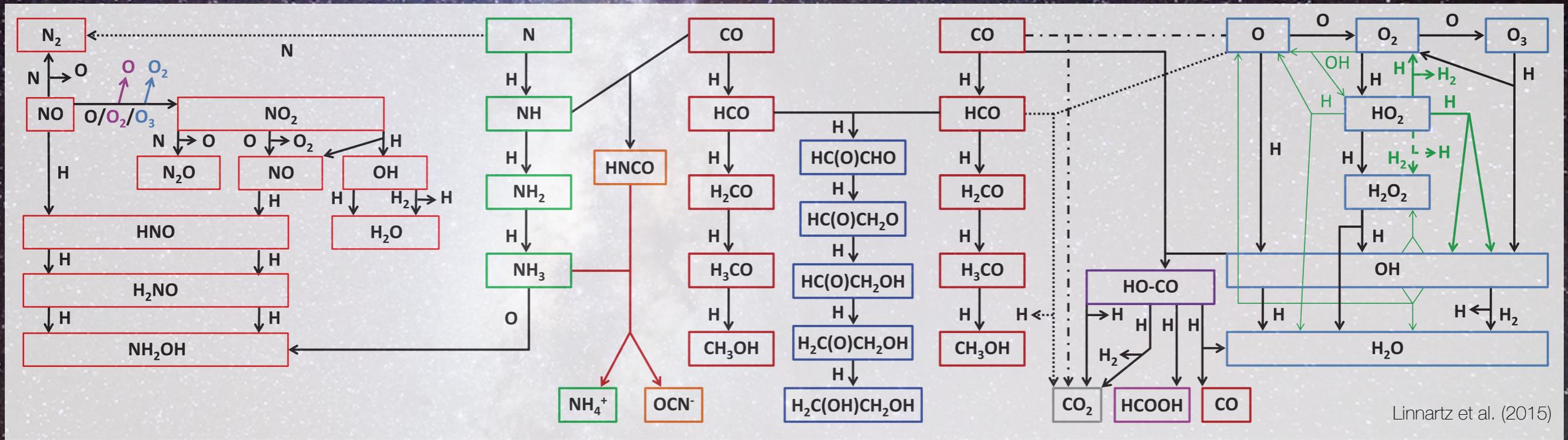


Lake Waiau



Brandon Carroll

Kona



Linnartz et al. (2015)

Brandon Carroll

Kona

Lake Waiau

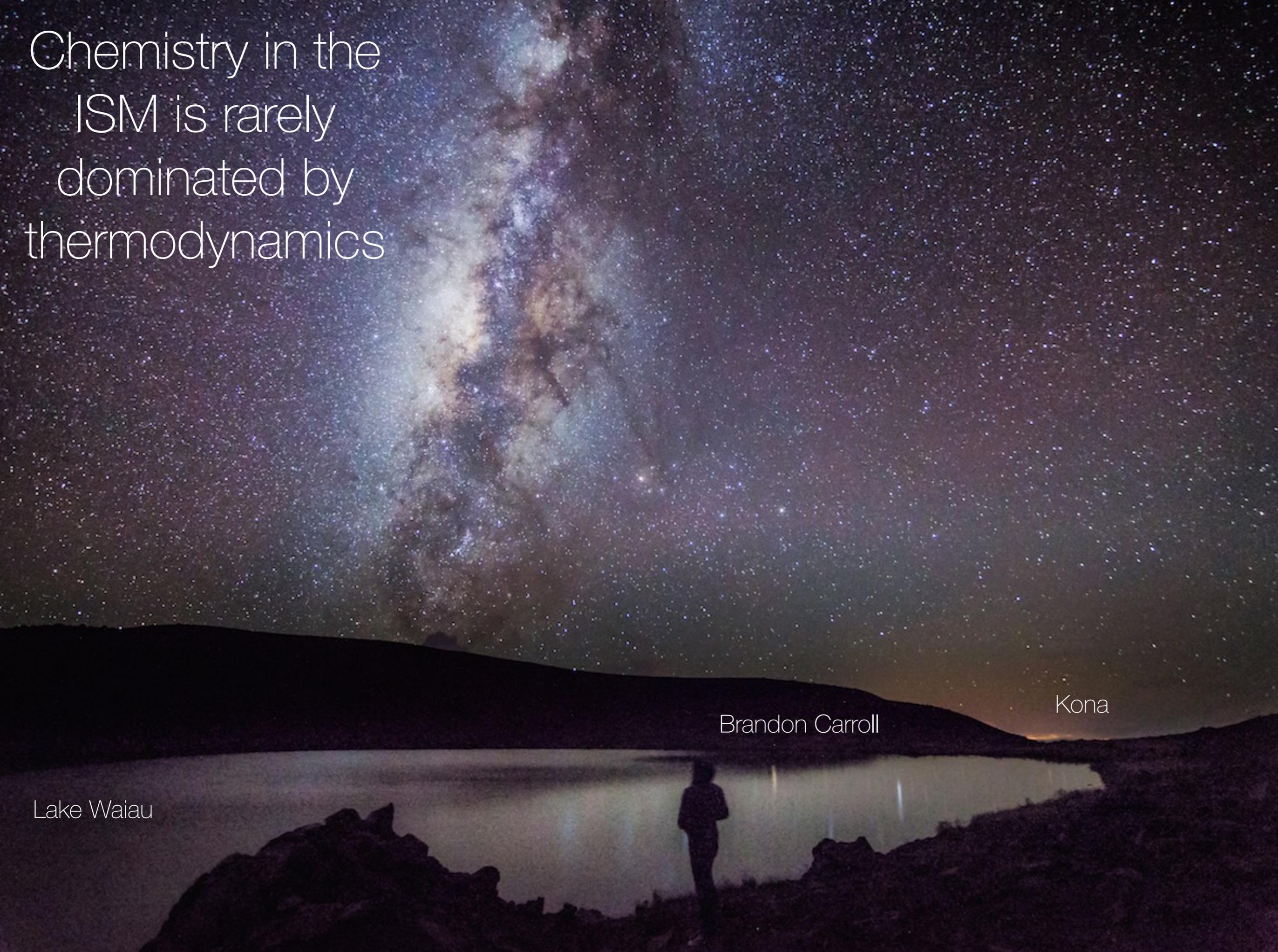


Lake Waiau

Brandon Carroll

Kona

Chemistry in the
ISM is rarely
dominated by
thermodynamics



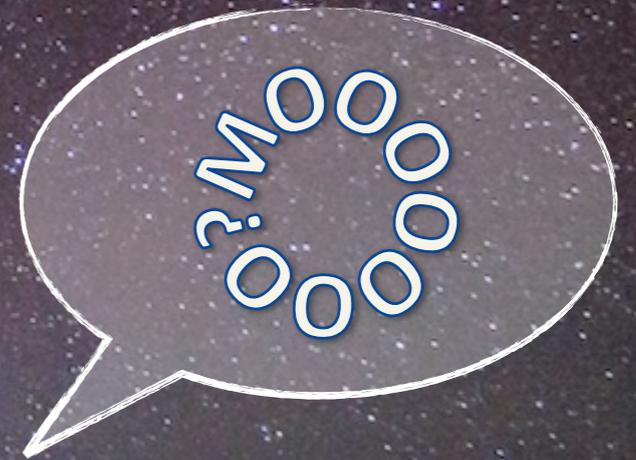
Brandon Carroll

Kona

Lake Waiau

Chemistry in the
ISM is rarely
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thermodynamics

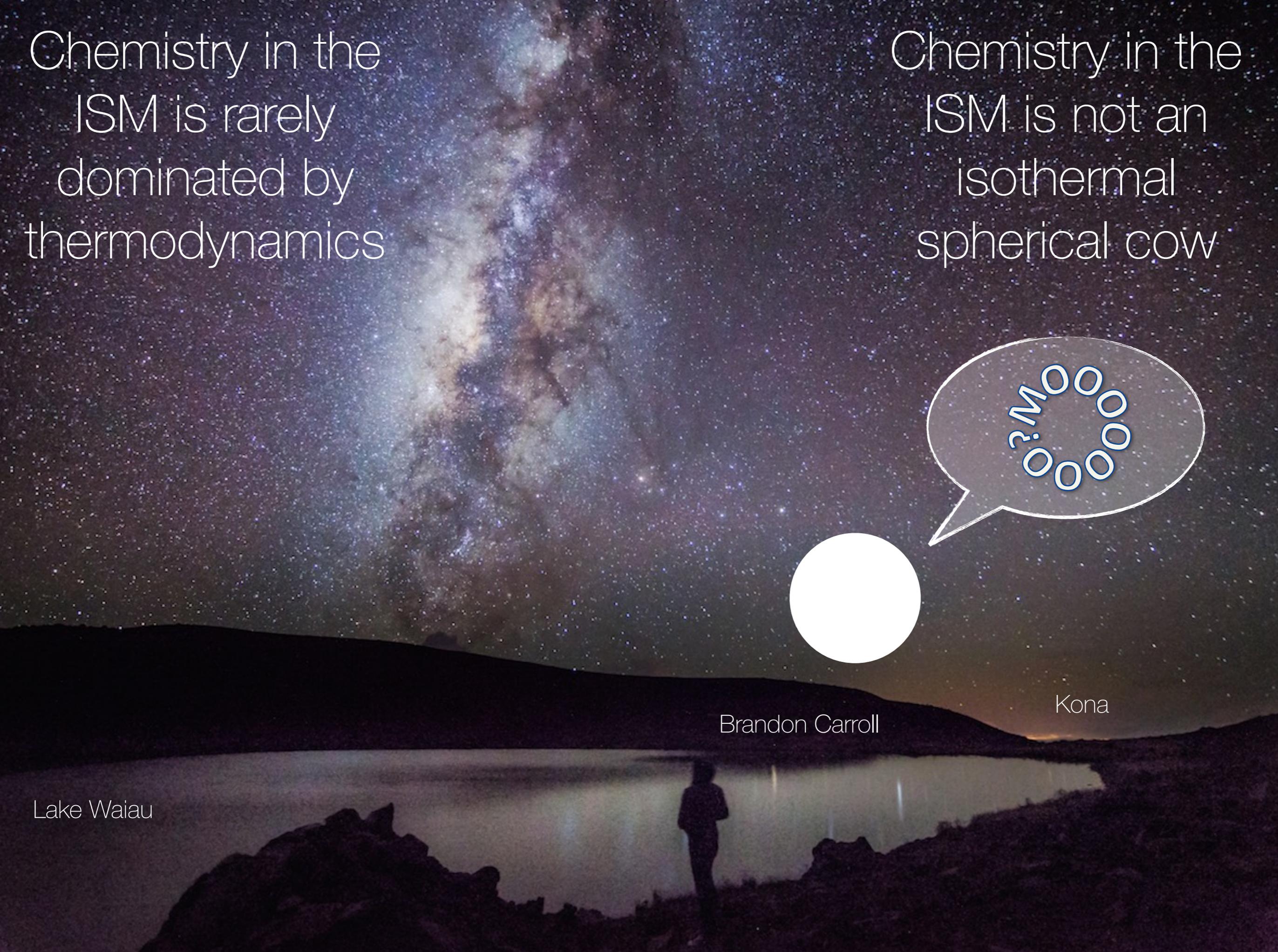
Chemistry in the
ISM is not an
isothermal
spherical cow



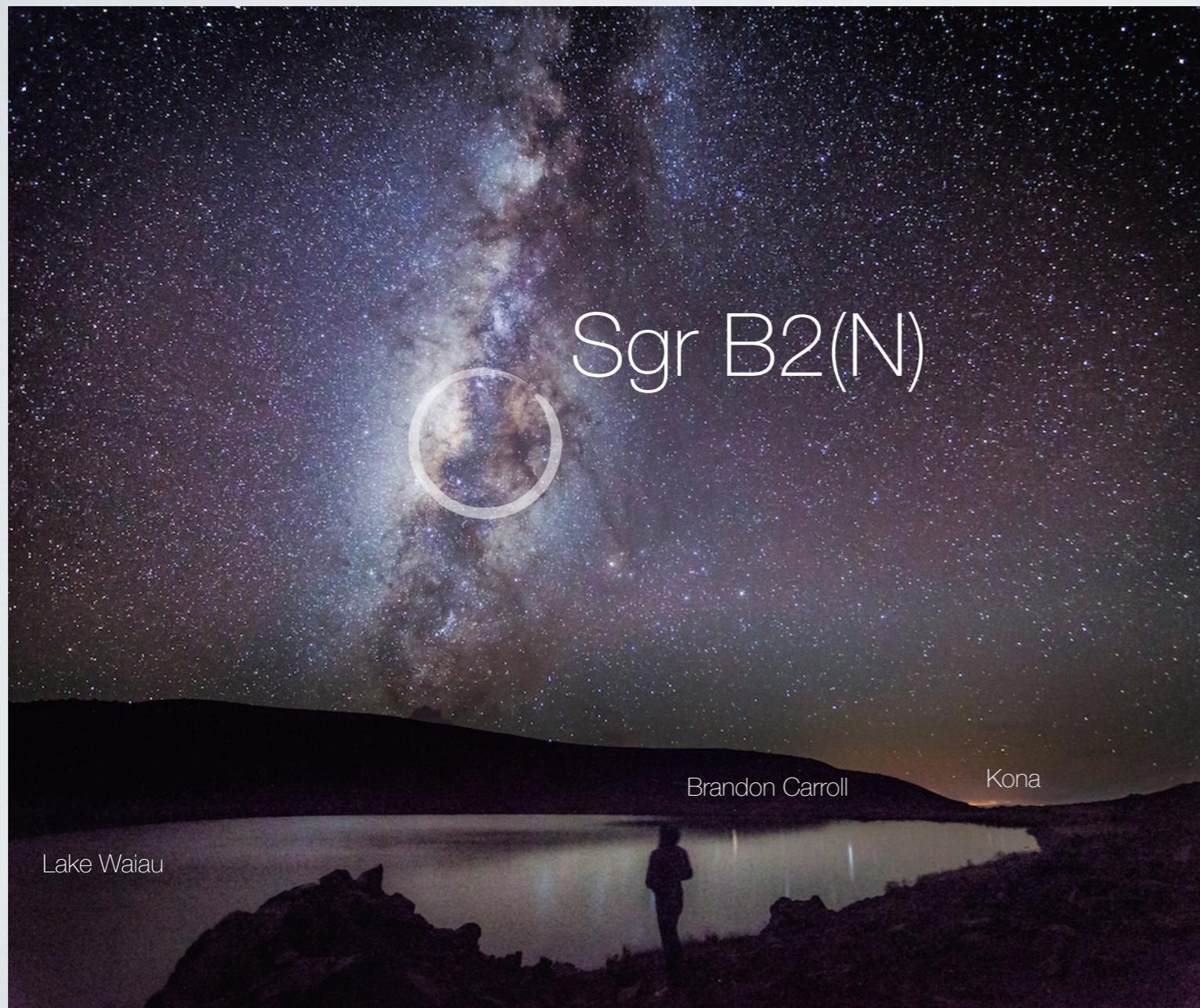
Brandon Carroll

Kona

Lake Waiau



PRebiotic Interstellar MOlecular Survey



Coverage

0.5 - 50 GHz

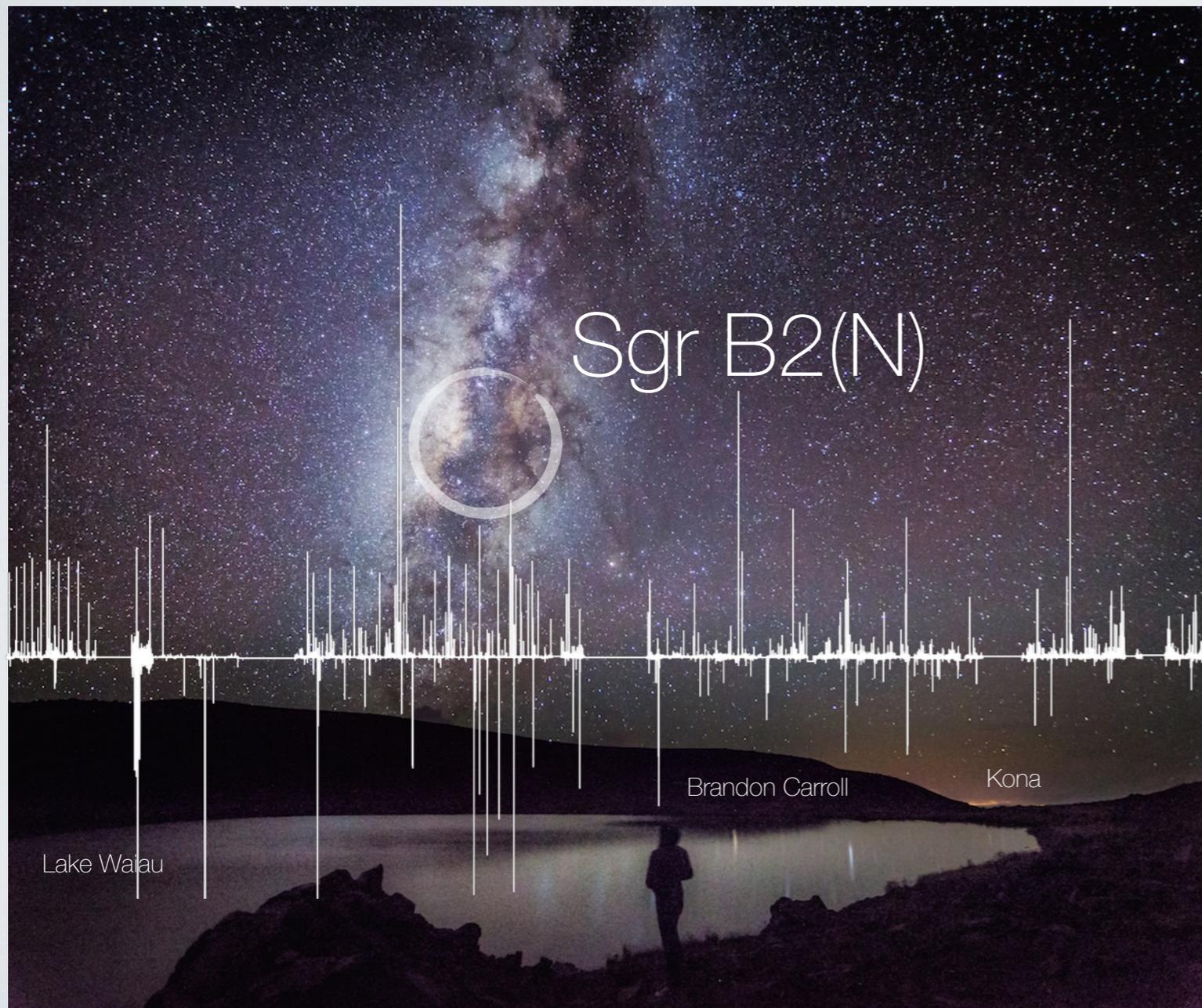
Resolution

24.4 kHz

15 km/s @ 0.5 GHz

0.15 km/s @ 50 GHz

PRebiotic Interstellar MOlecular Survey



Coverage

0.5 - 50 GHz

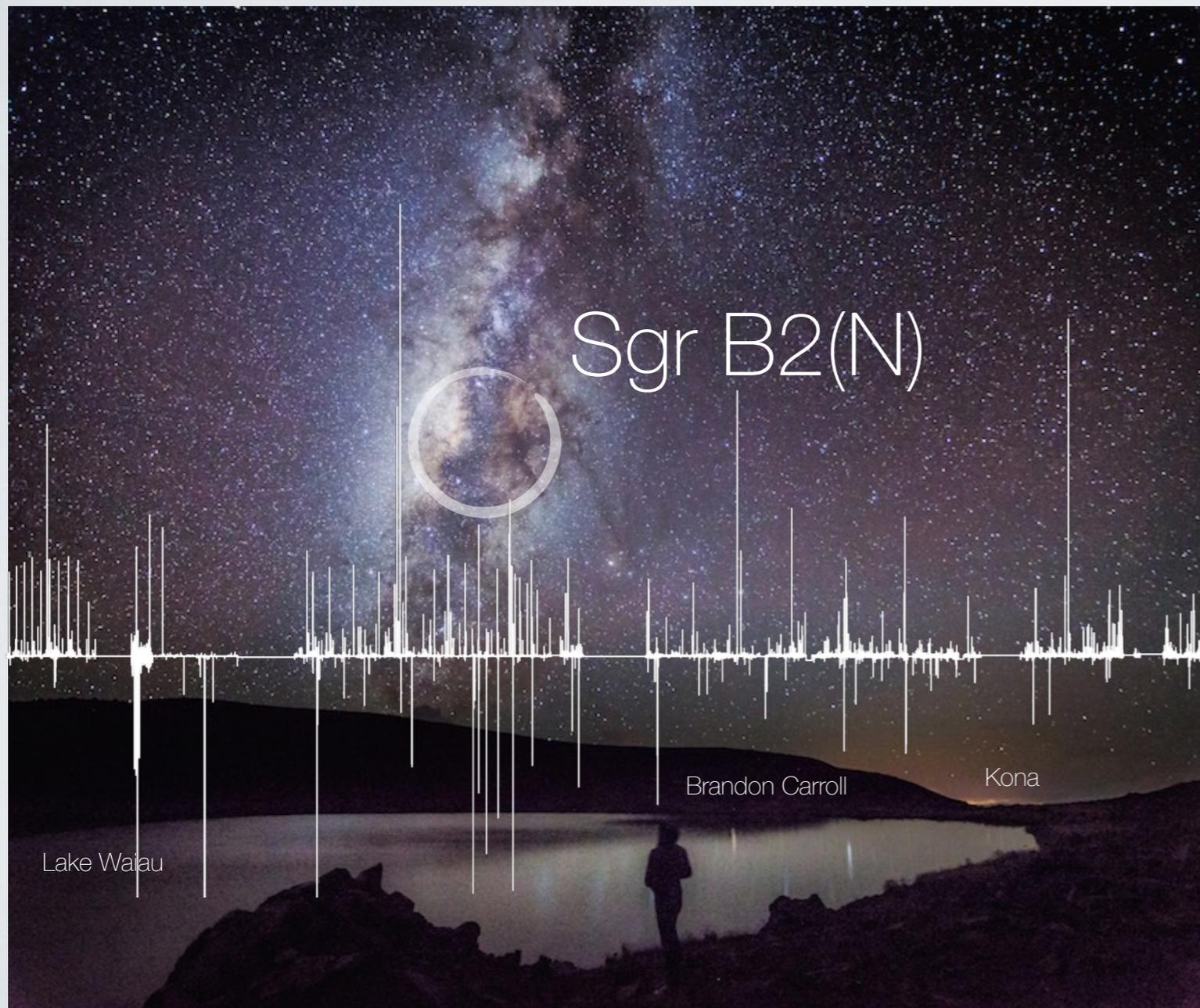
Resolution

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15 km/s @ 0.5 GHz

0.15 km/s @ 50 GHz

PRebiotic Interstellar MOlecular Survey



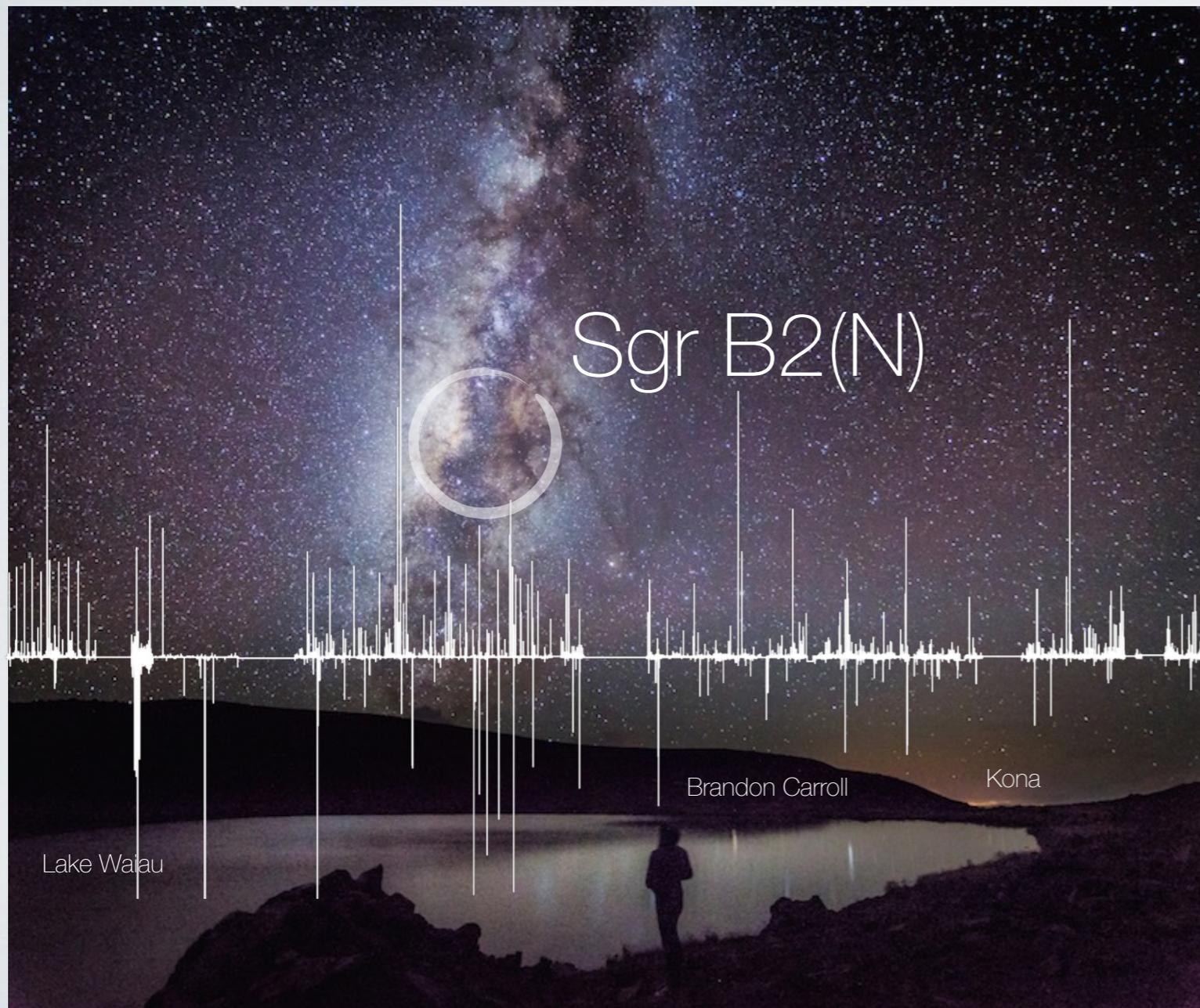
Sensitivity @ 15 GHz

~ 3 mK RMS

Sensitivity @ 50 GHz

~ 10 mK RMS

PRebiotic Interstellar MOlecular Survey



Sensitivity @ 15 GHz

~ 3 mK RMS

19 hrs = 1 mK

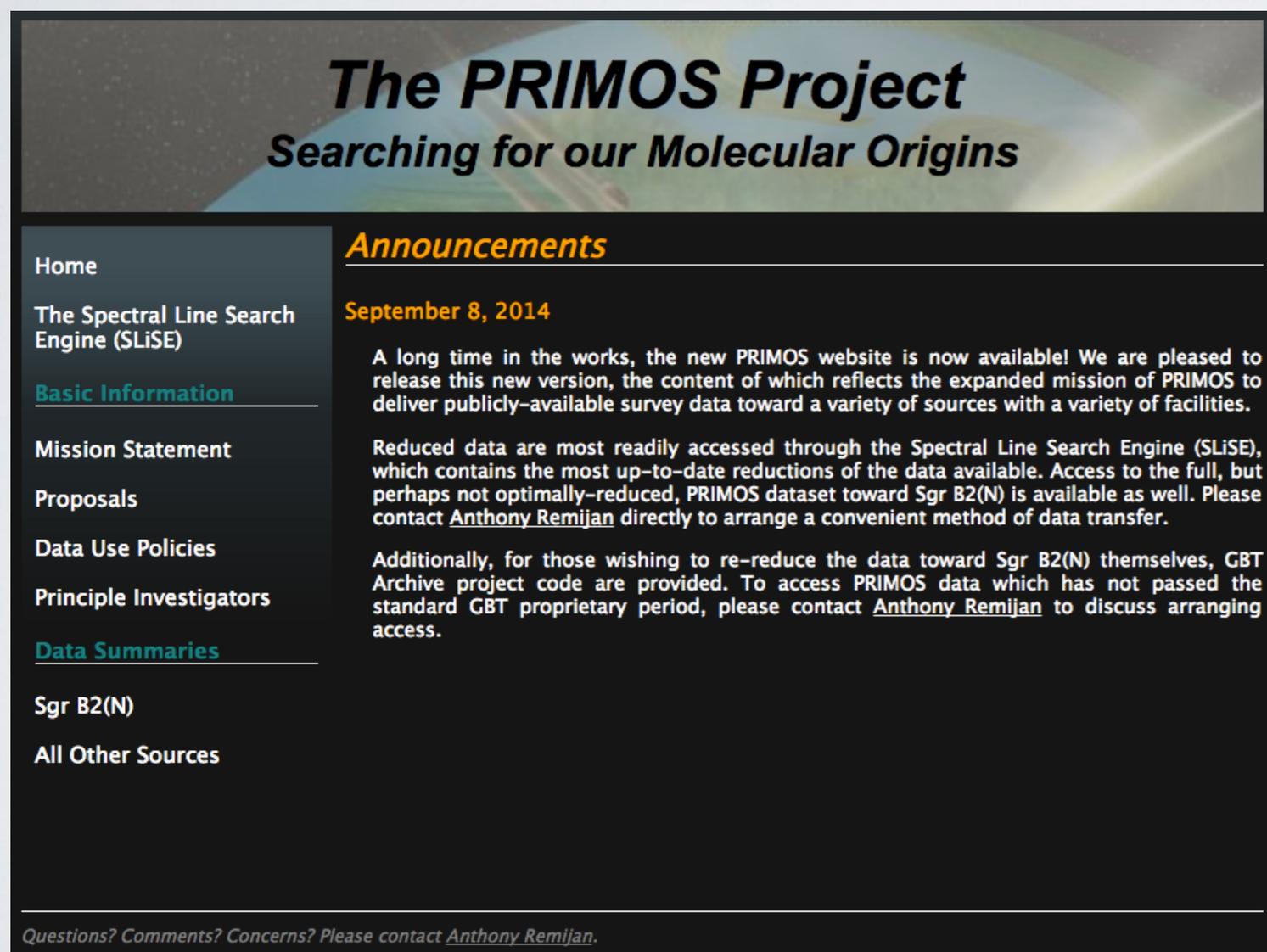
Sensitivity @ 50 GHz

~ 10 mK RMS

38 hrs = 3 mK

PRebiotic Interstellar MOlecular Survey

<http://www.cv.nrao.edu/~aremijan/PRIMOS/>



The PRIMOS Project
Searching for our Molecular Origins

Announcements

September 8, 2014

A long time in the works, the new PRIMOS website is now available! We are pleased to release this new version, the content of which reflects the expanded mission of PRIMOS to deliver publicly-available survey data toward a variety of sources with a variety of facilities.

Reduced data are most readily accessed through the Spectral Line Search Engine (SLiSE), which contains the most up-to-date reductions of the data available. Access to the full, but perhaps not optimally-reduced, PRIMOS dataset toward Sgr B2(N) is available as well. Please contact [Anthony Remijan](#) directly to arrange a convenient method of data transfer.

Additionally, for those wishing to re-reduce the data toward Sgr B2(N) themselves, GBT Archive project code are provided. To access PRIMOS data which has not passed the standard GBT proprietary period, please contact [Anthony Remijan](#) to discuss arranging access.

Home
The Spectral Line Search Engine (SLiSE)
[Basic Information](#)
Mission Statement
Proposals
Data Use Policies
Principle Investigators
[Data Summaries](#)
Sgr B2(N)
All Other Sources

Questions? Comments? Concerns? Please contact [Anthony Remijan](#).

- ✓ Publicly Available
- ✓ Fully reduced
- ✓ Raw data
- ✓ No Proprietary Period

PRebiotic Interstellar MOlecular Survey

<http://www.cv.nrao.edu/~aremijan/PRIMOS/>

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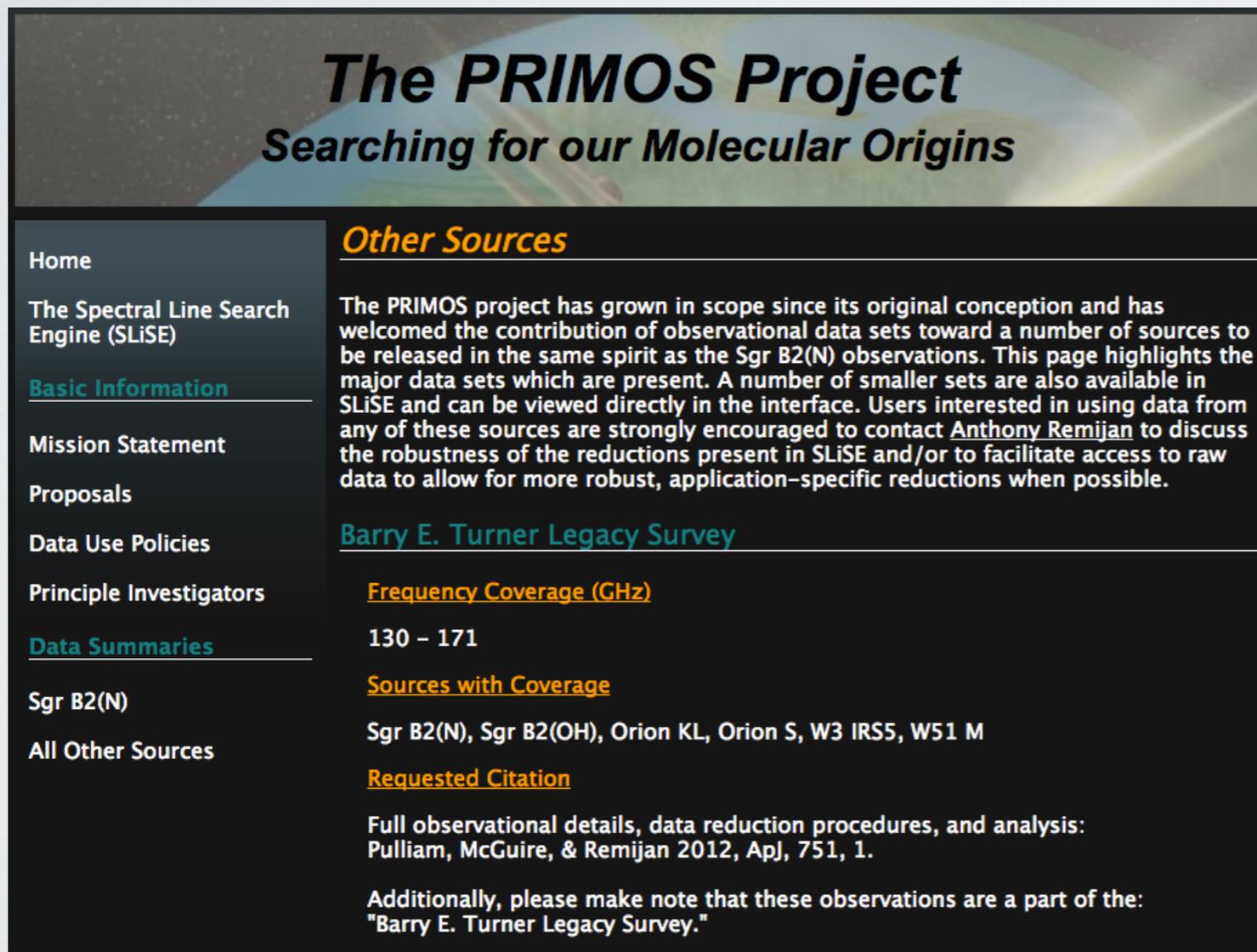
Data made available through the PRIMOS project and the SLiSE interface are available for use by the scientific community with "no strings attached." We request, but do not require, that those using the data kindly consider the following:

- Notifications of use (or intent to use) PRIMOS data by contacting [Anthony Remijan](#) are greatly appreciated.
- Suggested citations and/or attributions for the data reduction strategy and original publication of each observational set are given in their respective data summary pages. We would greatly appreciate the citation of these works and/or individuals in publications and presentations.
- When PRIMOS data are used in publications, we would appreciate a footnote in the observational section to the effect of: "Access to the entire PRIMOS data set, specifics on the observing strategy, and overall frequency coverage information is available at <http://www.cv.nrao.edu/~aremijan/PRIMOS/>."
- When data from SLiSE are used in publications, we would appreciate a footnote in the observation section to the effect of: "These observational data are accessible at <http://www.cv.nrao.edu/~aremijan/SLiSE/>."
- The PRIMOS team of PIs and Co-Is includes staff, postdoctoral scholars, graduate students, and undergraduate students in astronomy, astrochemistry, and experimental chemistry who are always interested in pursuing potential collaborations using PRIMOS data. If you are interested in working with a PRIMOS team member, please contact [Anthony Remijan](#).

Data made available through the PRIMOS project and the SLiSE interface are available for use by the scientific community with 'no strings attached.'

PRebiotic Interstellar MOlecular Survey

<http://www.cv.nrao.edu/~aremijan/PRIMOS/>



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Other Sources

The PRIMOS project has grown in scope since its original conception and has welcomed the contribution of observational data sets toward a number of sources to be released in the same spirit as the Sgr B2(N) observations. This page highlights the major data sets which are present. A number of smaller sets are also available in SLiSE and can be viewed directly in the interface. Users interested in using data from any of these sources are strongly encouraged to contact [Anthony Remijan](#) to discuss the robustness of the reductions present in SLiSE and/or to facilitate access to raw data to allow for more robust, application-specific reductions when possible.

Barry E. Turner Legacy Survey

Frequency Coverage (GHz)
130 - 171

Sources with Coverage
Sgr B2(N), Sgr B2(OH), Orion KL, Orion S, W3 IRS5, W51 M

Requested Citation
Full observational details, data reduction procedures, and analysis:
Pulliam, McGuire, & Remijan 2012, ApJ, 751, 1.

Additionally, please make note that these observations are a part of the:
"Barry E. Turner Legacy Survey."



Beyond Sgr B2(N)

Spectral Line Search Engine

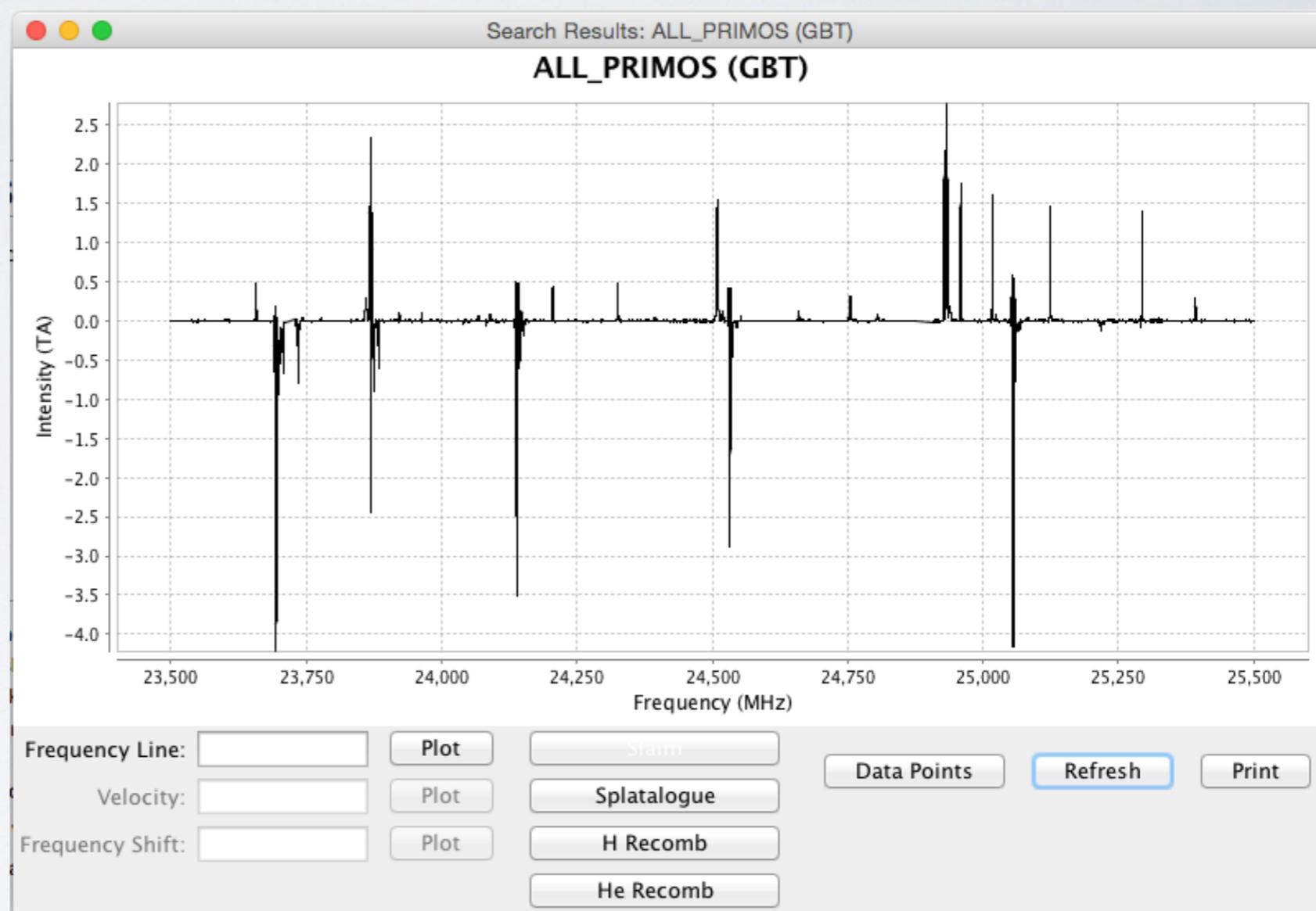
<http://www.cv.nrao.edu/~aremijan/SLiSE/>



Source Name : ALL_PRIMOS

Telescope: Telescope Include In Search
GBT

Frequency (MHz) : min 23500 max 25500
center +/-



Spectral Line Search Engine

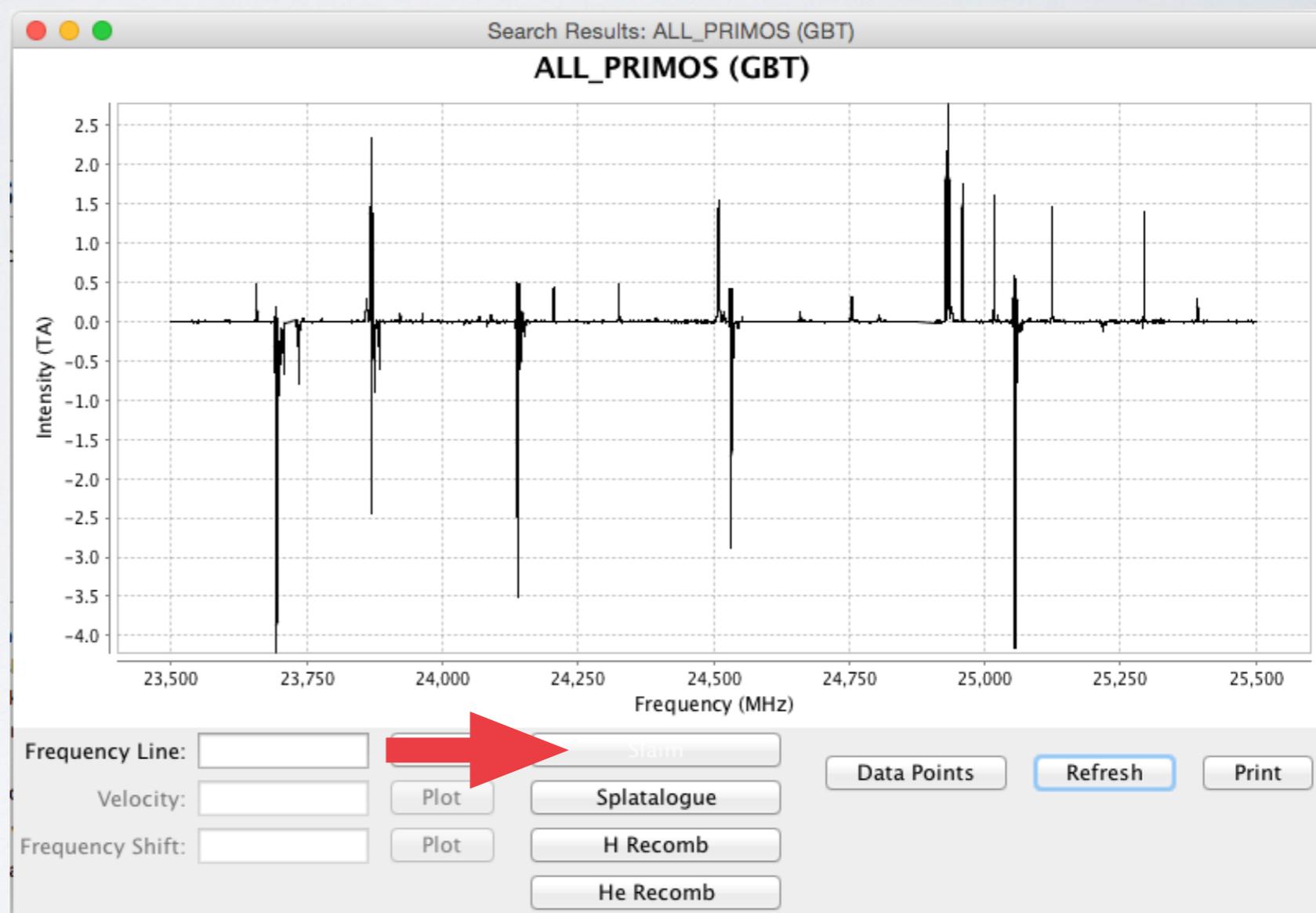
<http://www.cv.nrao.edu/~aremijan/SLiSE/>



Source Name : ALL_PRIMOS

Telescope: Telescope Include In Search

Frequency (MHz) : min max
center +/-



Spectral Line Search Engine

<http://www.cv.nrao.edu/~aremijan/SLiSE/>

Slaim Search: ALL_PRIMOS (GBT)

Line Lists:

Species:

Frequency (MHz): min max
 center +/-

Energy Level: <

Sij: >

J_Up: min max

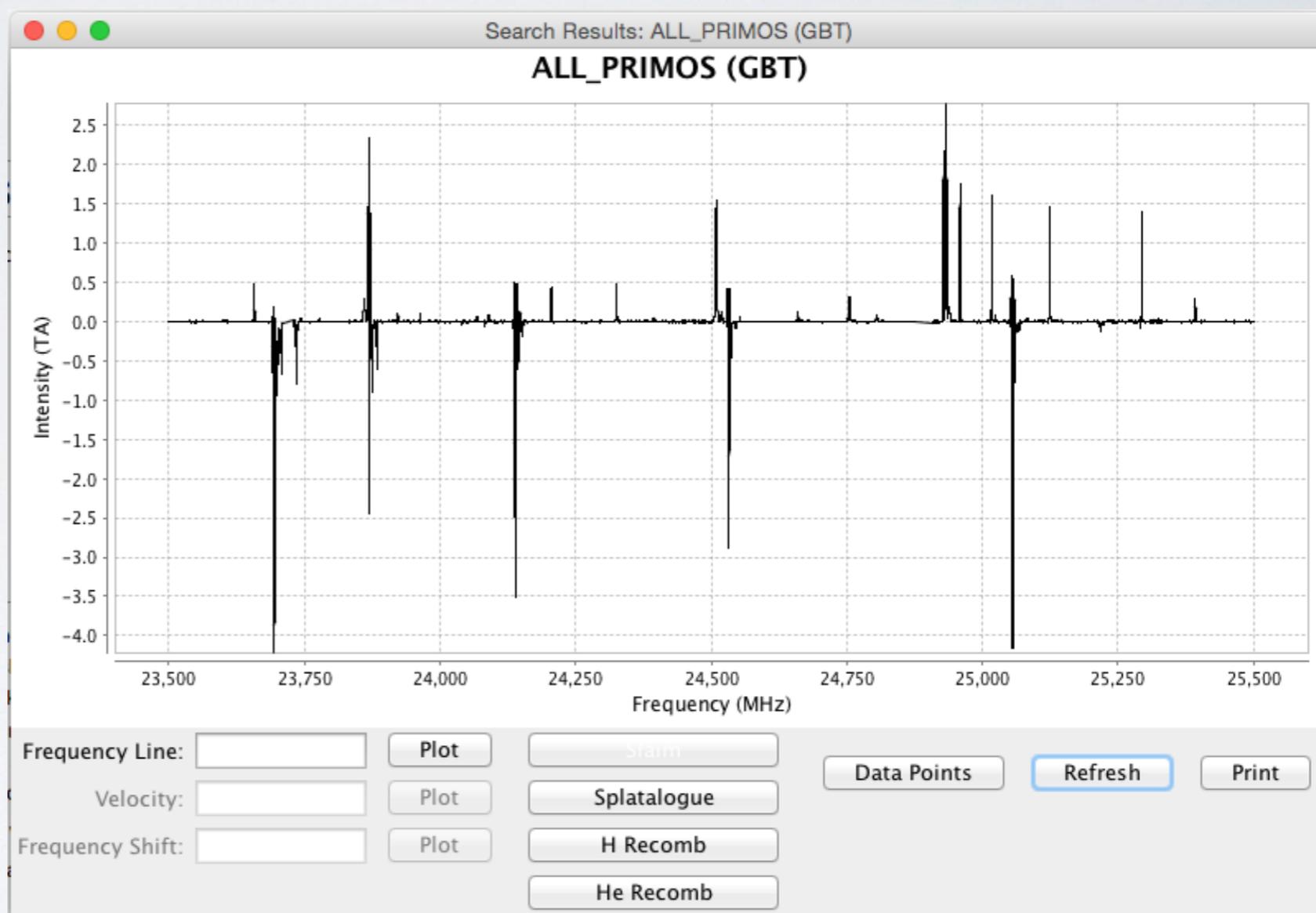
Ka_Up: min max

Kc_Up: min max

J_Lo: min max

Ka_Lo: min max

Kc_Lo: min max



Spectral Line Search Engine

<http://www.cv.nrao.edu/~aremijan/SLiSE/>

Slaim Search: ALL_PRIMOS (GBT)

Line Lists:

Species:

Frequency (MHz): min max
 center +/-

Energy Level: <

Sij: >

J_Up: min max

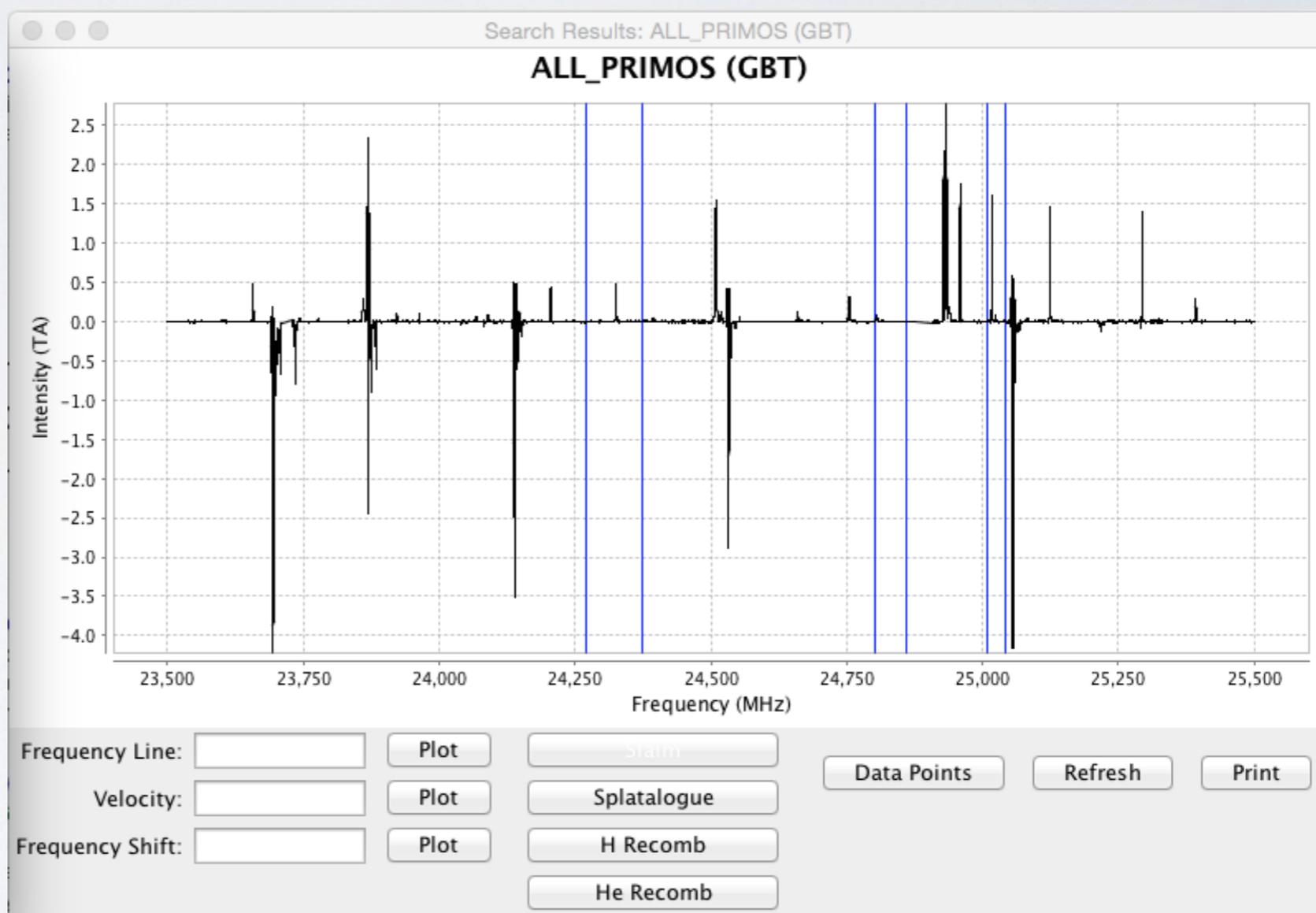
Ka_Up: min max

Kc_Up: min max

J_Lo: min max

Ka_Lo: min max

Kc_Lo: min max



Spectral Line Search Engine

<http://www.cv.nrao.edu/~aremijan/SLiSE/>

Slaim Search: ALL_PRIMOS (GBT)

Line Lists:

Species:

Frequency (MHz): min max
center +/-

Energy Level: <

Sij: >

J_Up: min max

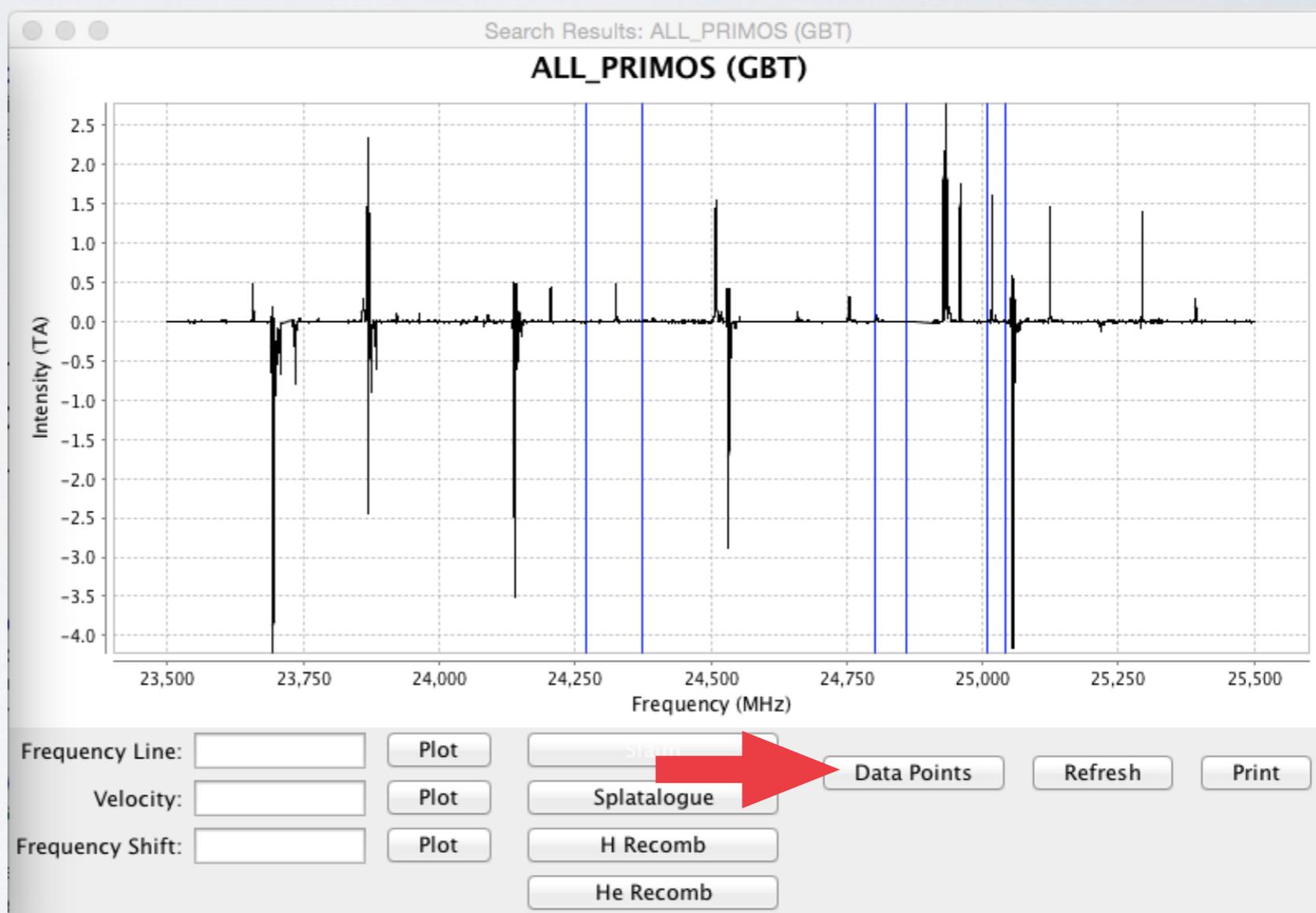
Ka_Up: min max

Kc_Up: min max

J_Lo: min max

Ka_Lo: min max

Kc_Lo: min max



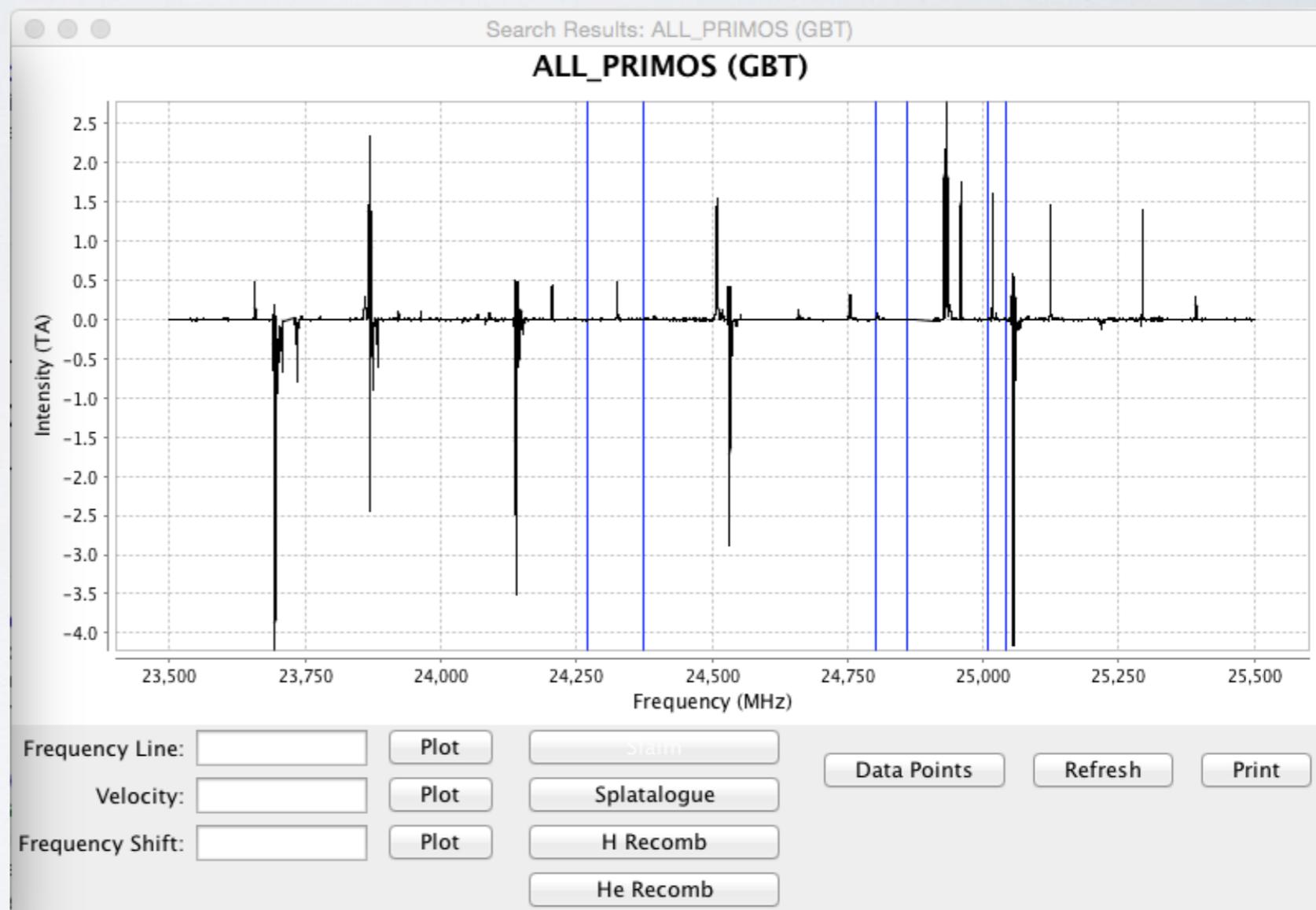
Spectral Line Search Engine

<http://www.cv.nrao.edu/~aremijan/SLiSE/>

Data Points: ALL_PRIMOS (GBT)

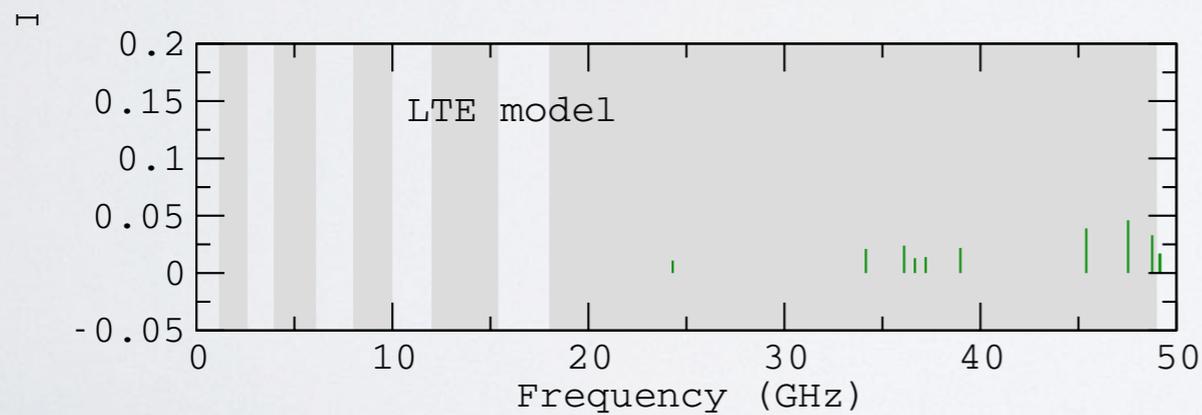
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23500.048	1.0E-4	2009			
23500.072	-0.0028	2009			
23500.096	0.0031	2009			
23500.121	0.0067	2009			
23500.145	0.0029	2009			
23500.17	0.0011	2009			
23500.194	0.0019	2009			
23500.219	0.0026	2009			
23500.243	0.0011	2009			
23500.267	-0.0012	2009			
23500.292	-8.0E-4	2009			
23500.316	-1.0E-4	2009			
23500.341	9.0E-4	2009			
23500.365	0.0027	2009			
23500.389	9.0E-4	2009			
23500.414	1.0E-4	2009			
23500.438	0.0023	2009			
23500.463	0.0015	2009			
23500.487	0.0	2009			
23500.512	-4.0E-4	2009			
23500.536	-5.0E-4	2009			
23500.56	8.0E-4	2009			
23500.585	0.0024	2009			

Row: 0 - 79641 Column: 1 Save

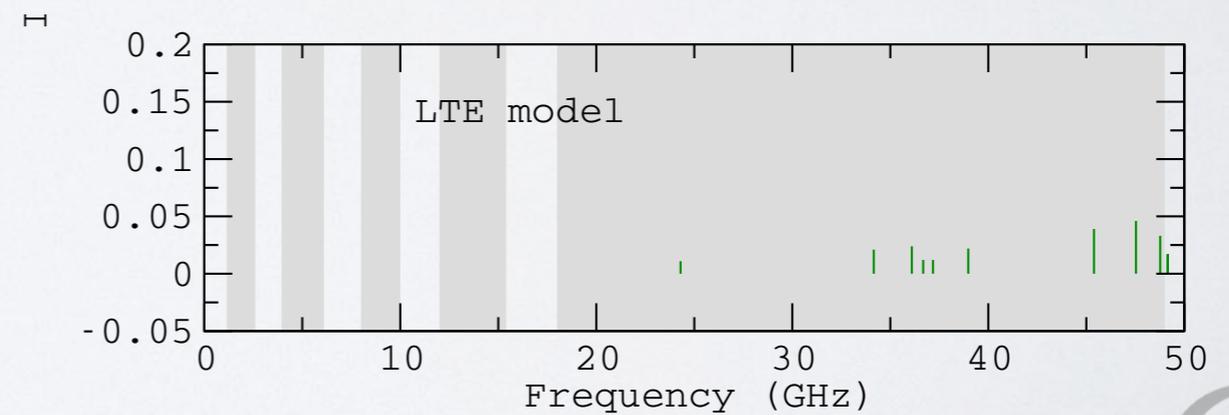


WEAK MASER EMISSION OF METHYL FORMATE TOWARD SAGITTARIUS B2(N) IN THE GREEN BANK TELESCOPE PRIMOS SURVEY

A. FAURE¹, A. J. REMIJAN², K. SZALEWICZ³, AND L. WIESENFELD¹

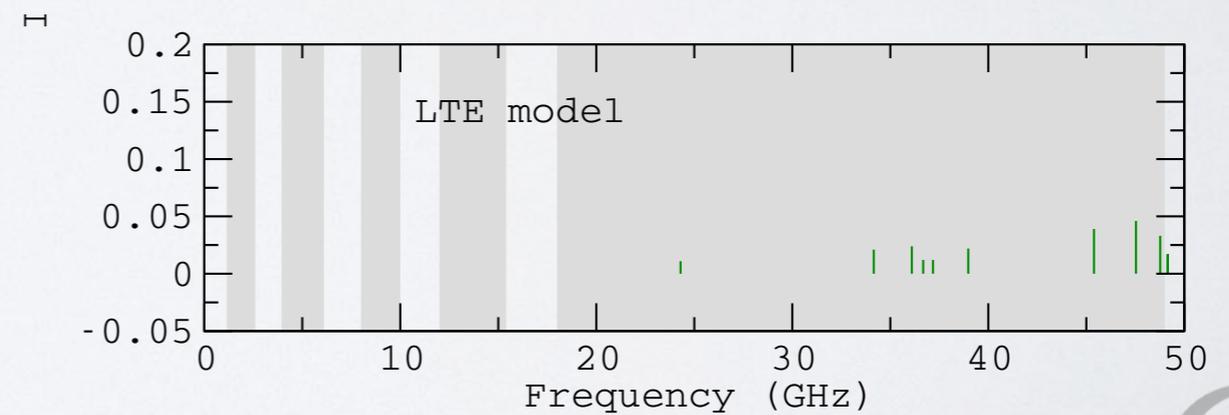
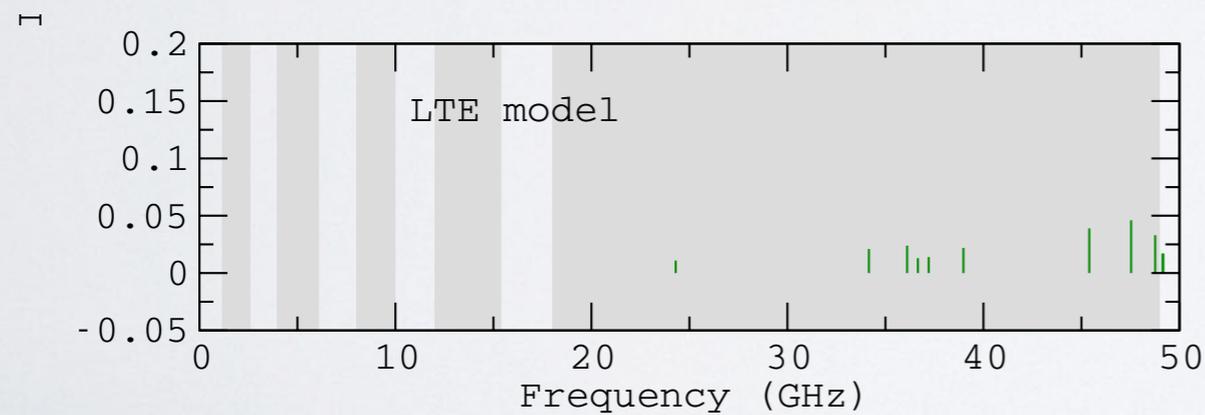
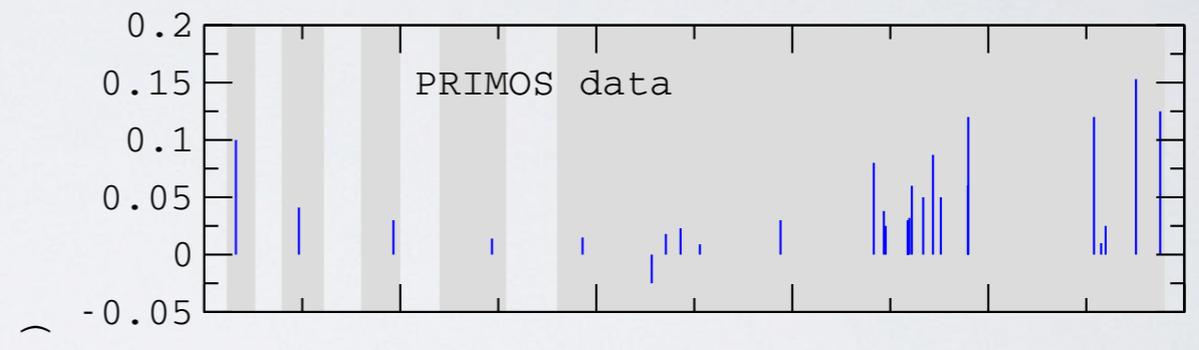
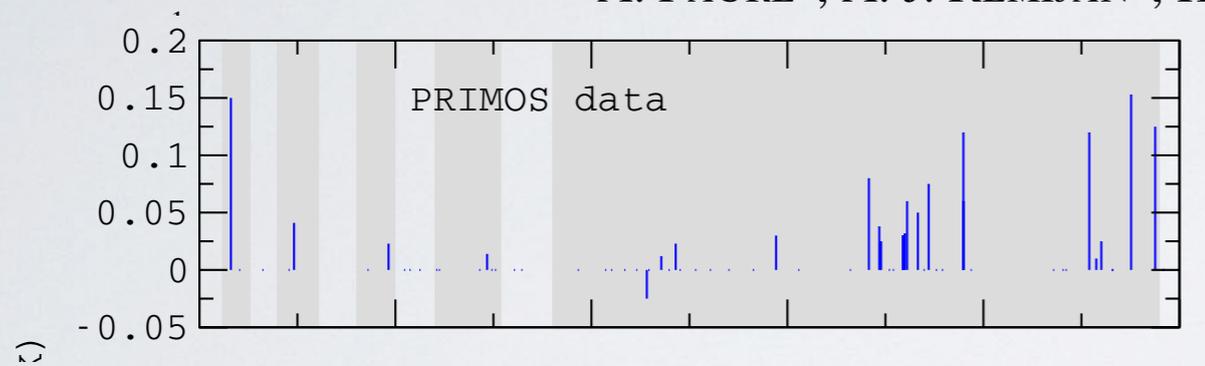


A-methyl formate



E-methyl formate

WEAK MASER EMISSION OF METHYL FORMATE TOWARD SAGITTARIUS B2(N) IN THE GREEN BANK TELESCOPE PRIMOS SURVEY

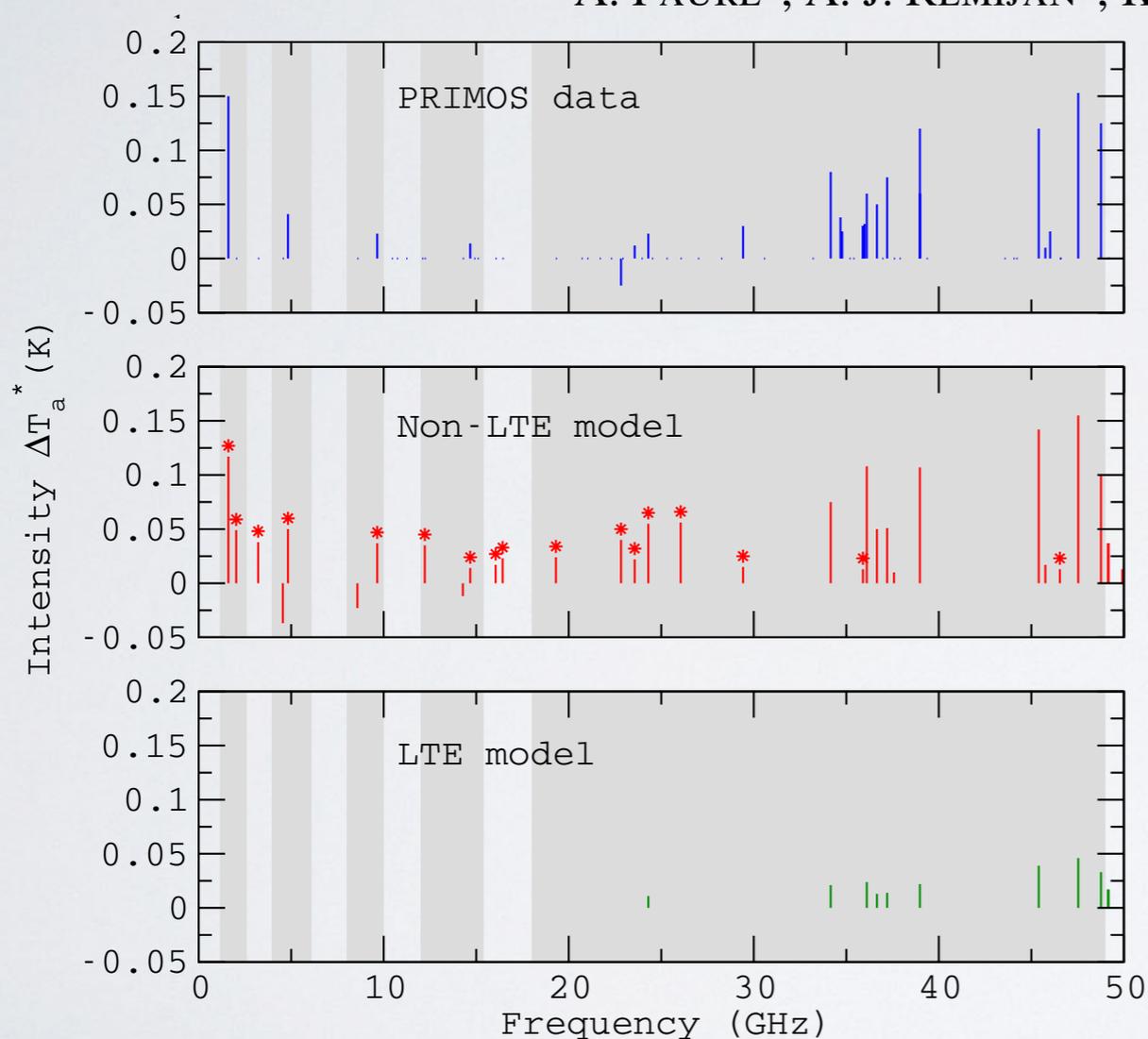
A. FAURE¹, A. J. REMIJAN², K. SZALEWICZ³, AND L. WIESENFELD¹

A-methyl formate

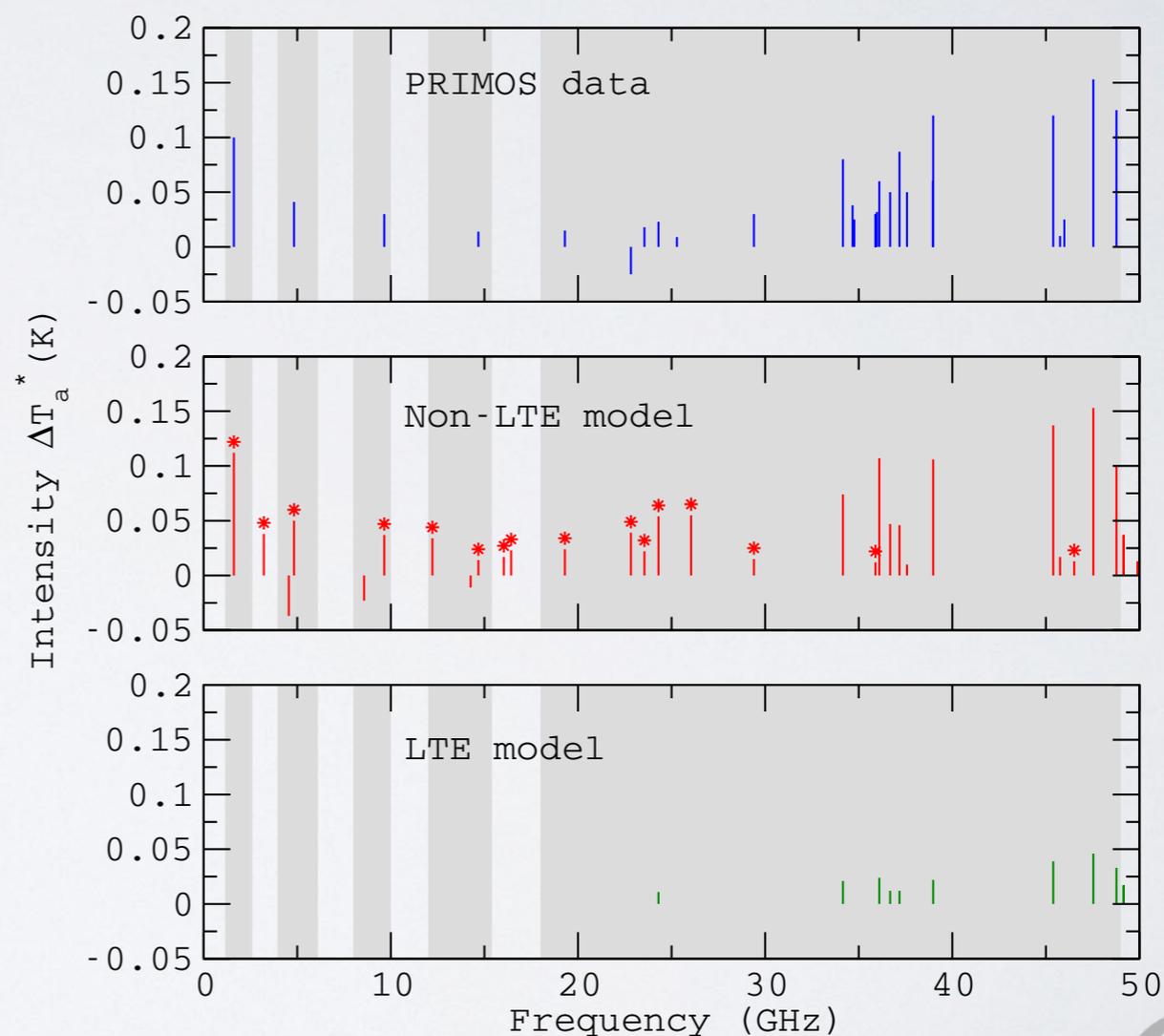
E-methyl formate

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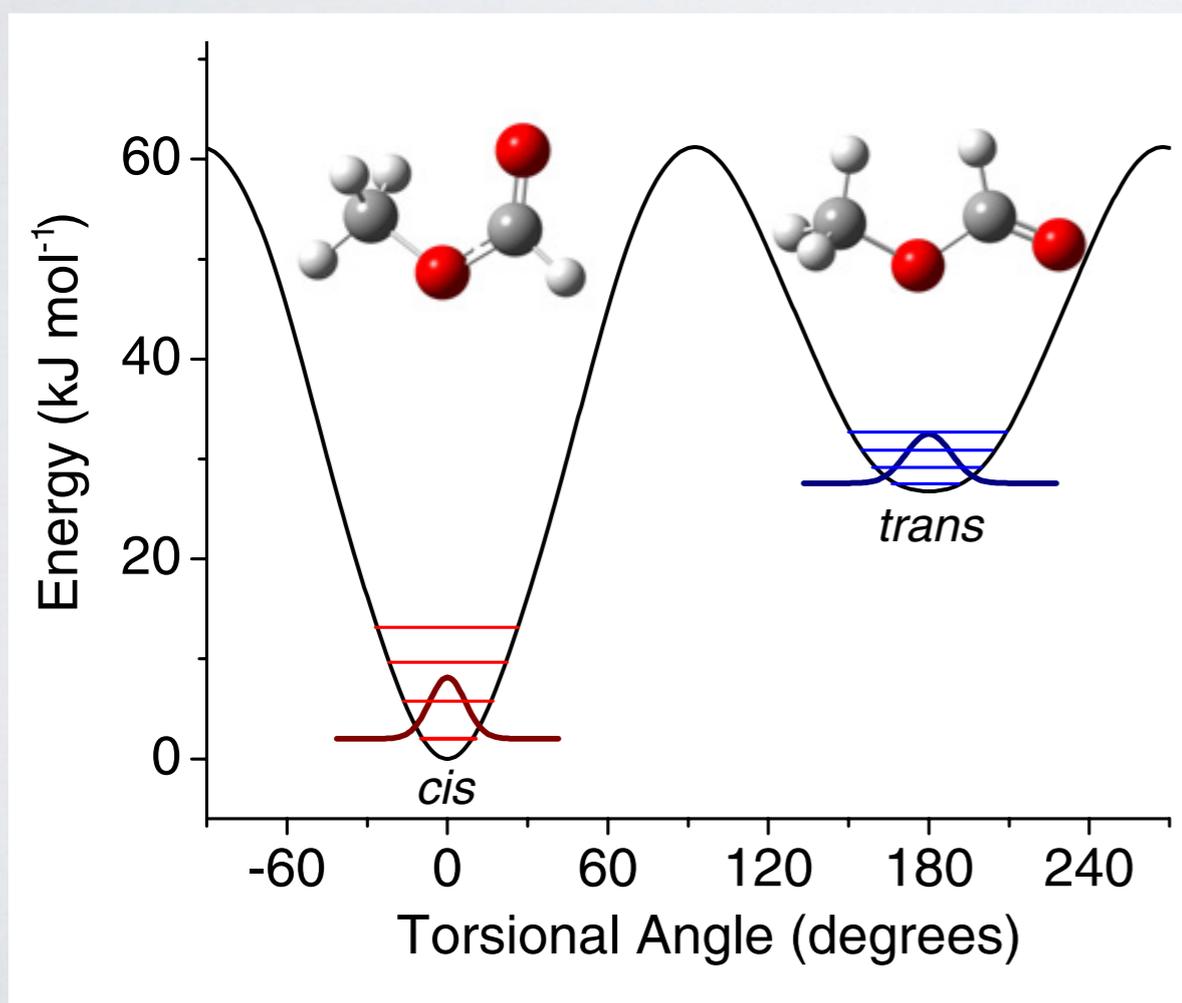
A-methyl formate



E-methyl formate

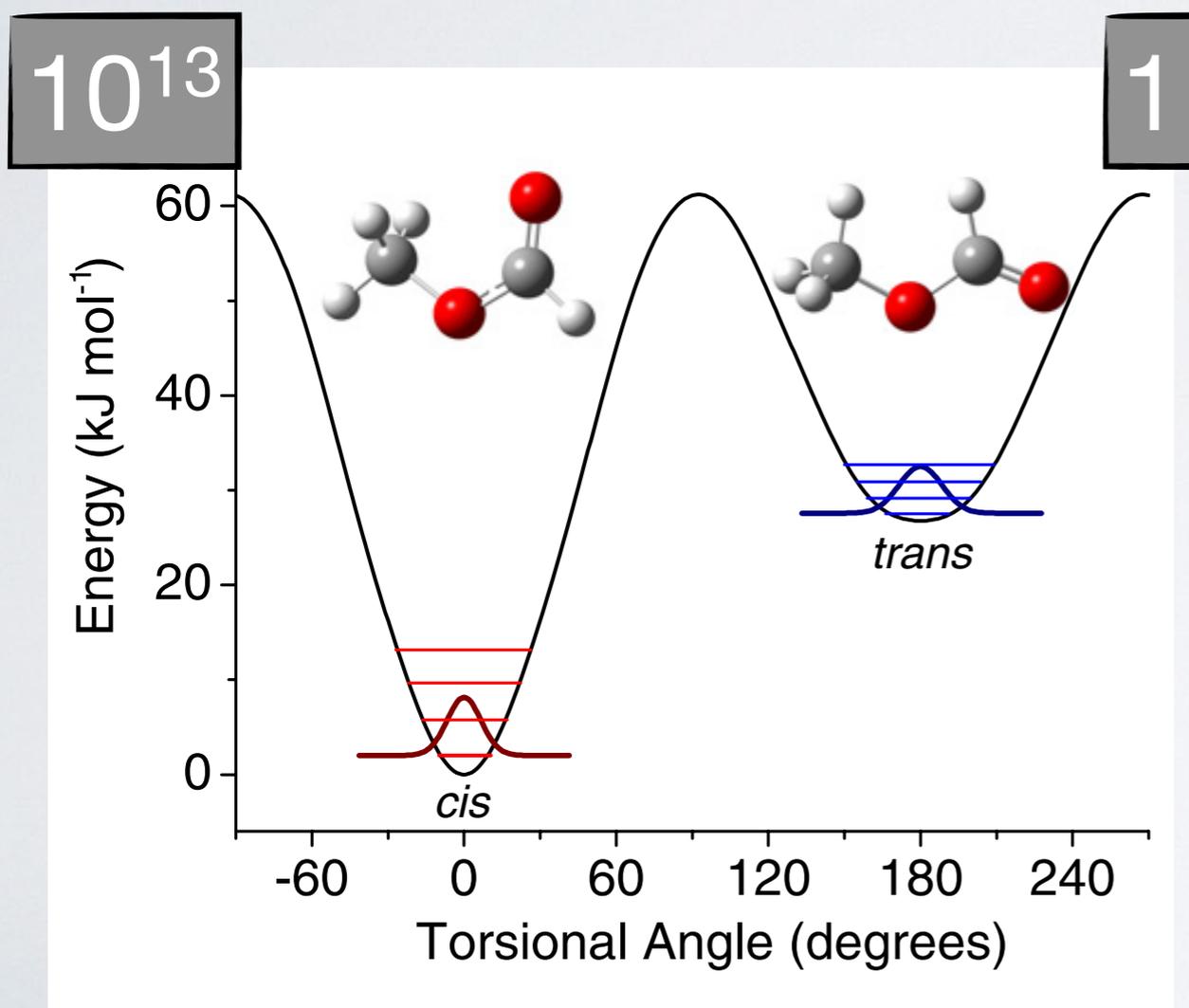
LABORATORY AND TENTATIVE INTERSTELLAR DETECTION OF TRANS-METHYL FORMATE USING THE PUBLICLY AVAILABLE GREEN BANK TELESCOPE PRIMOS SURVEY

JUSTIN L. NEILL^{1,2}, MATT T. MUCKLE¹, DANIEL P. ZALESKI¹, AMANDA L. STEBER¹, BROOKS H. PATE¹, VALERIO LATTANZI^{3,4}, SILVIA SPEZZANO^{3,4}, MICHAEL C. MCCARTHY^{3,4}, AND ANTHONY J. REMIJAN⁵



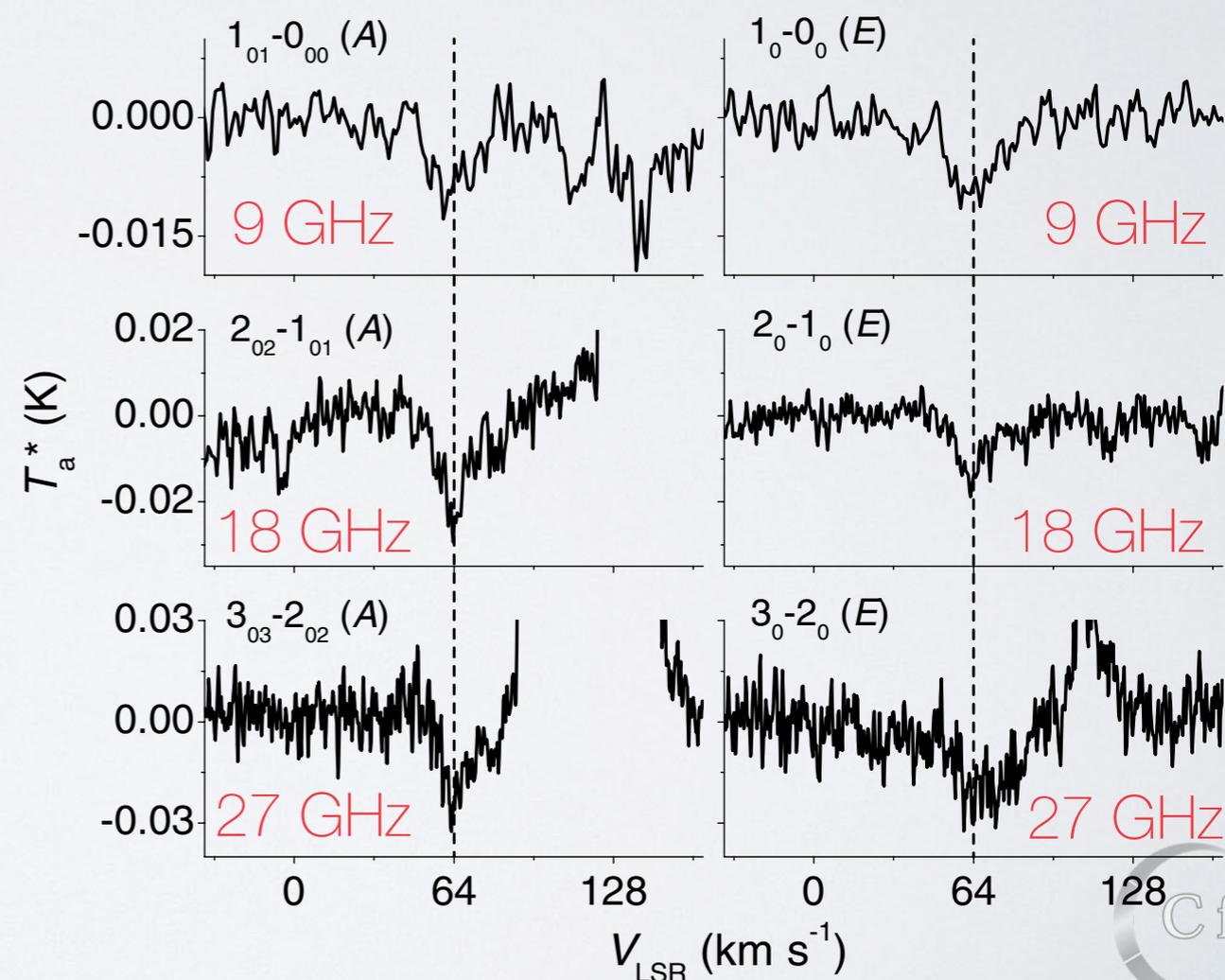
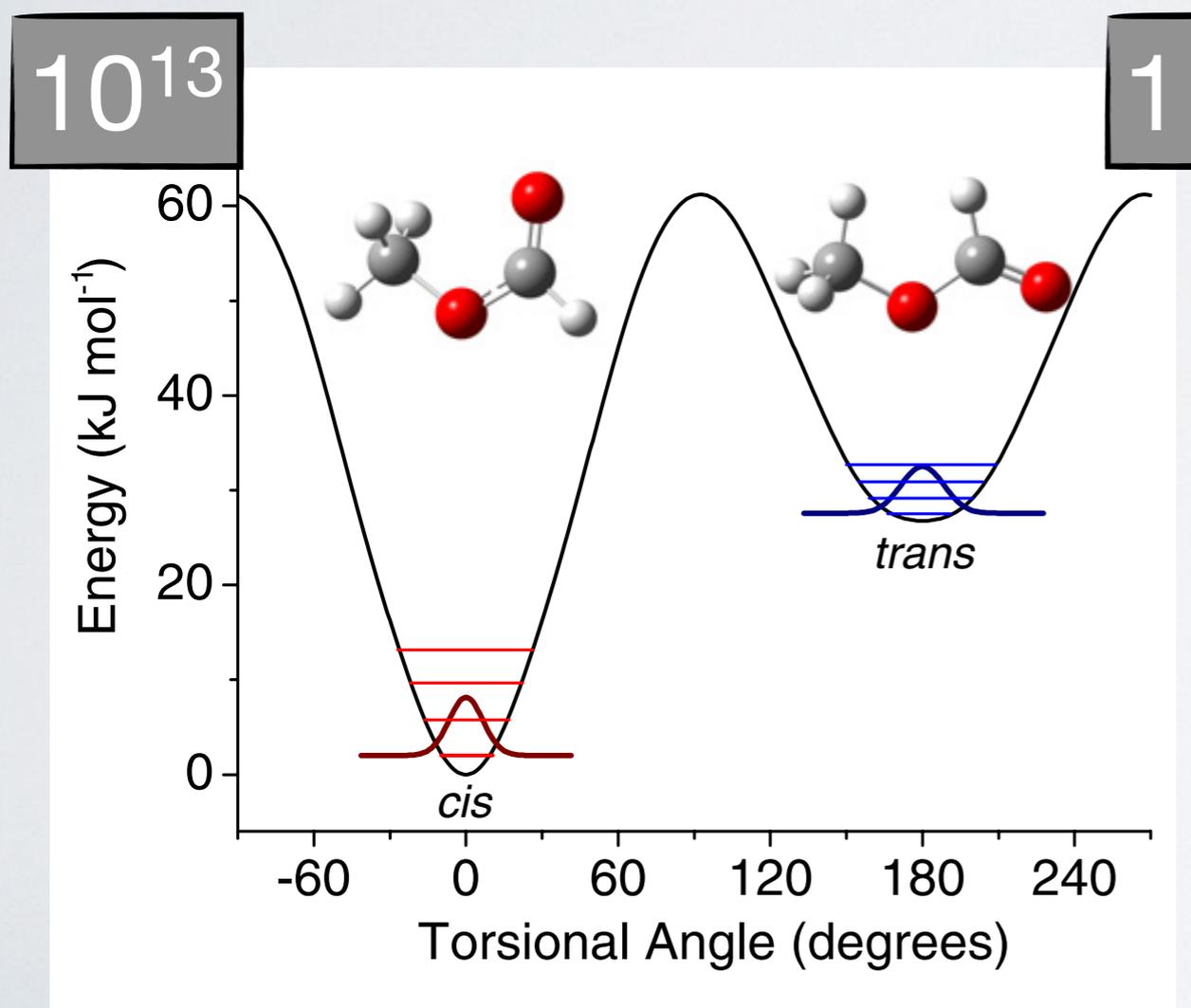
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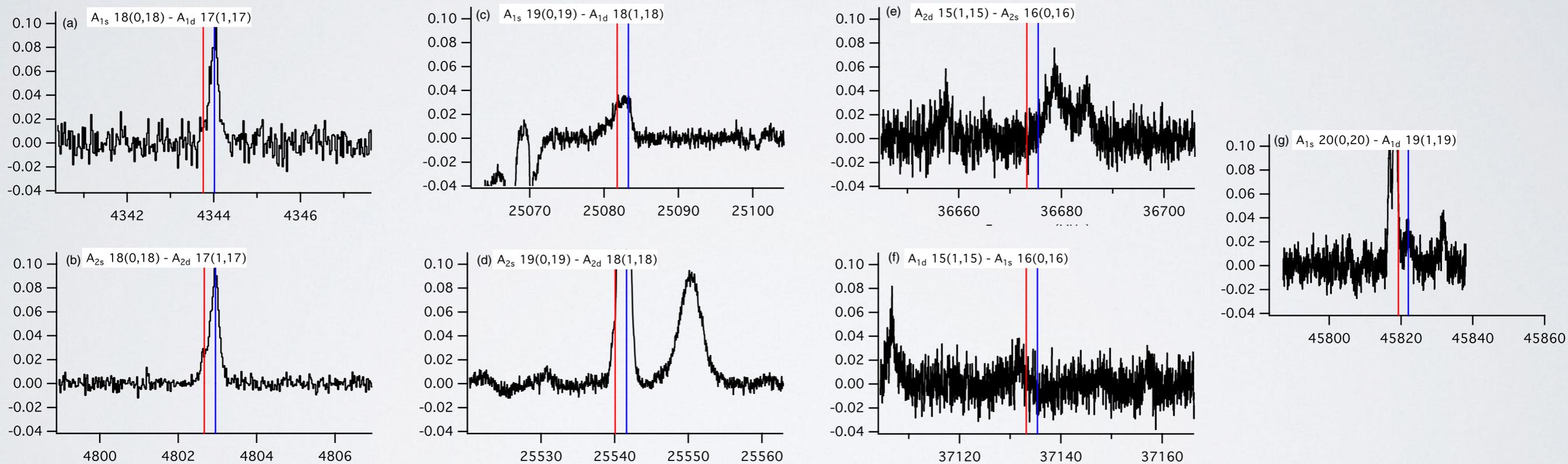
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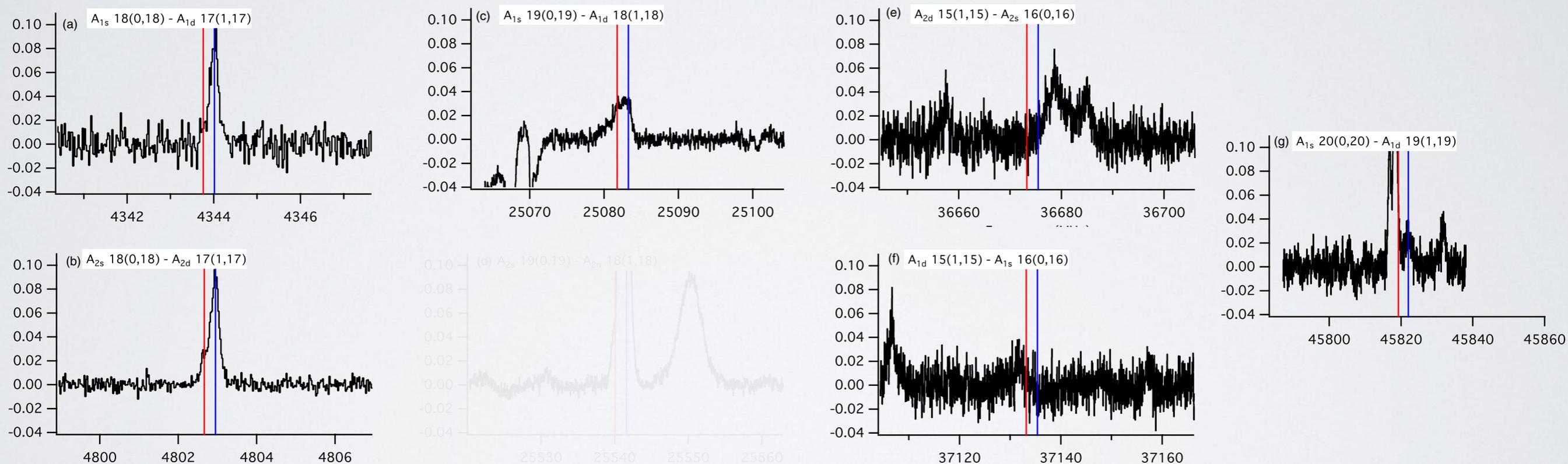
INTERSTELLAR CARBODIIMIDE (HNCNH): A NEW ASTRONOMICAL DETECTION FROM THE GBT PRIMOS SURVEY VIA MASER EMISSION FEATURES

BRETT A. MCGUIRE¹, RYAN A. LOOMIS², CAMERON M. CHARNESSE³, JOANNA F. CORBY³, GEOFFREY A. BLAKE⁴, JAN M. HOLLIS⁵, FRANK J. LOVAS⁶, PHILIP R. JEWELL⁷, AND ANTHONY J. REMIJAN⁷



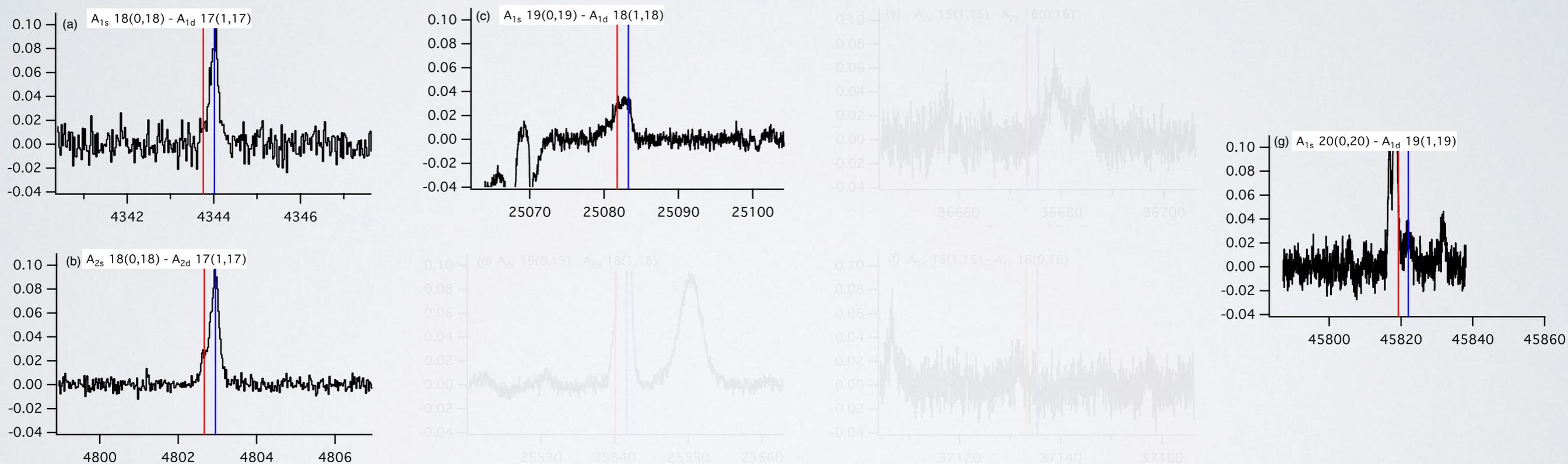
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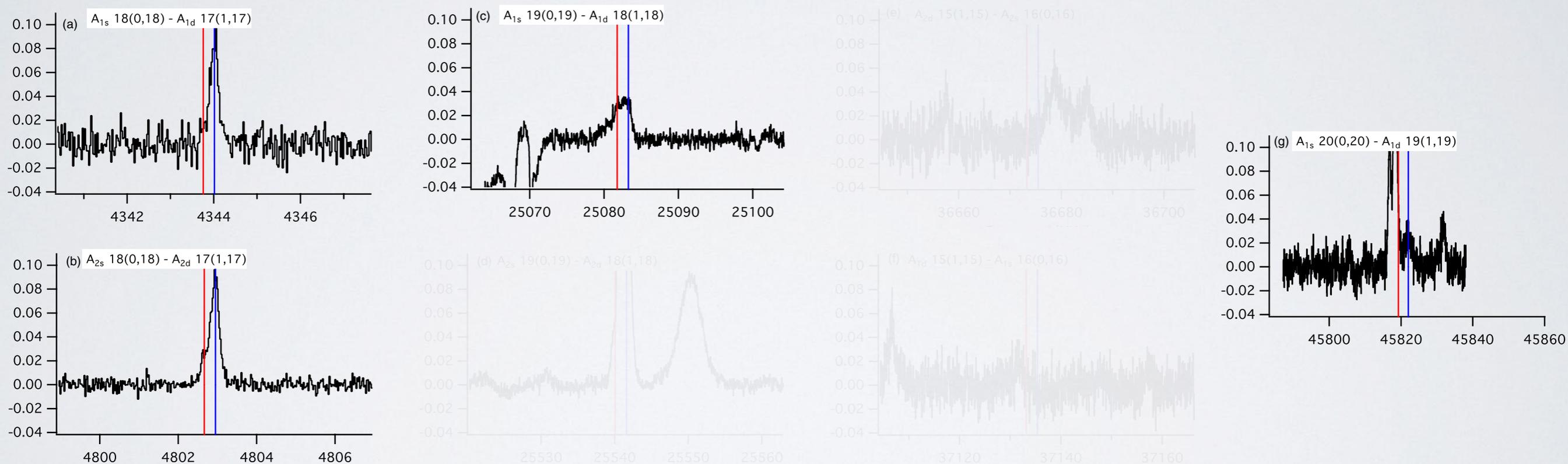
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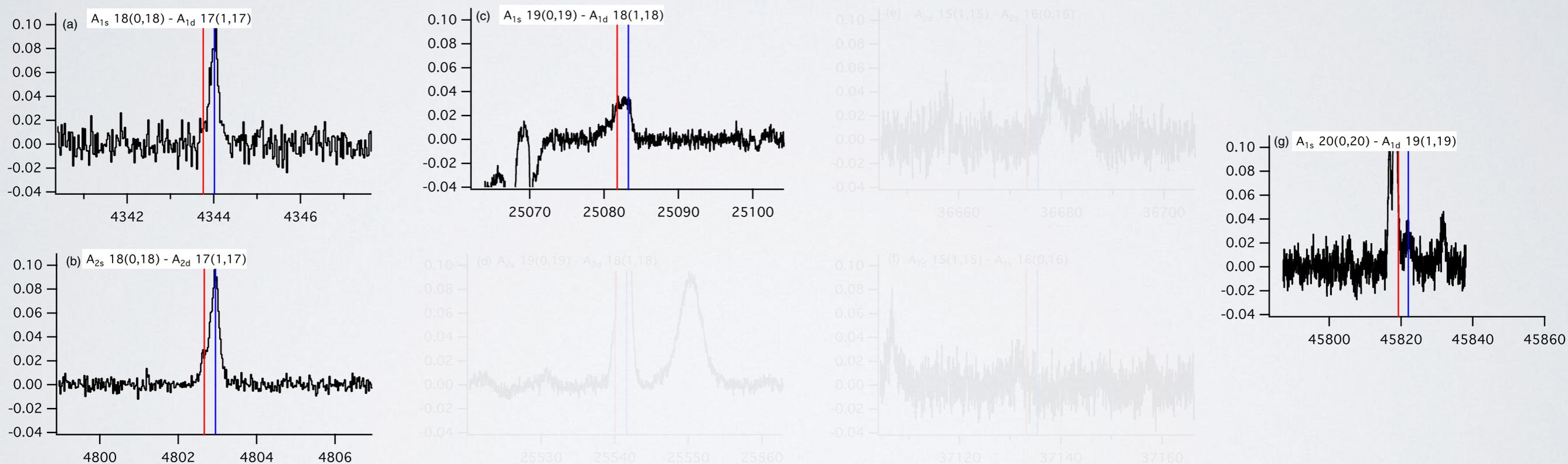
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$$\log(A_{ij}) = -9$$

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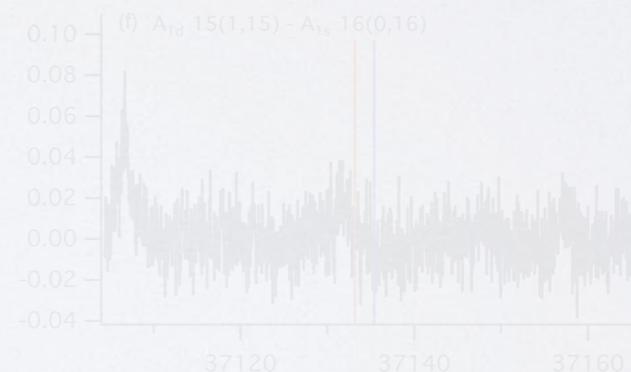
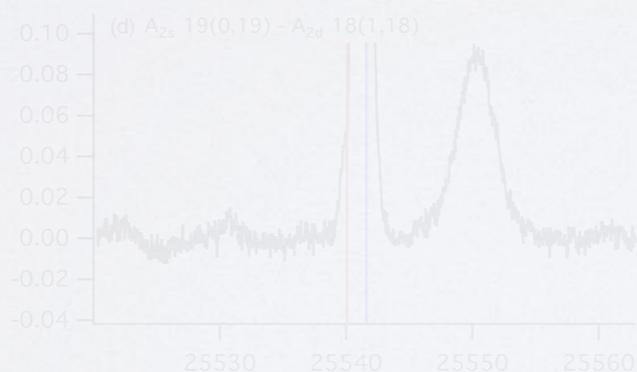
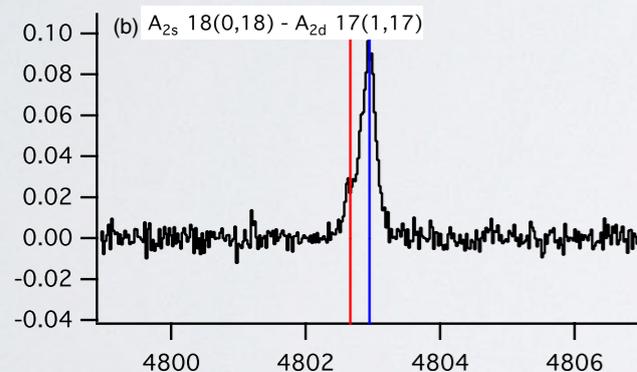
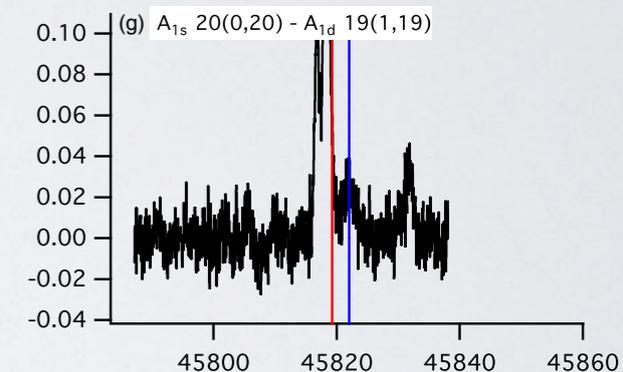
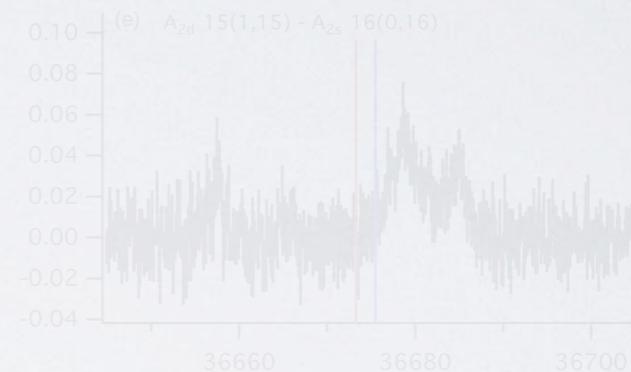
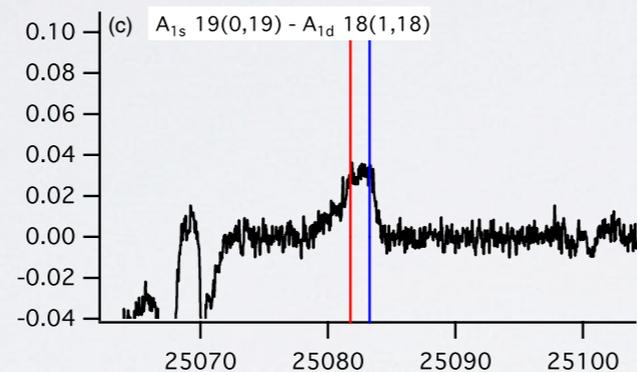
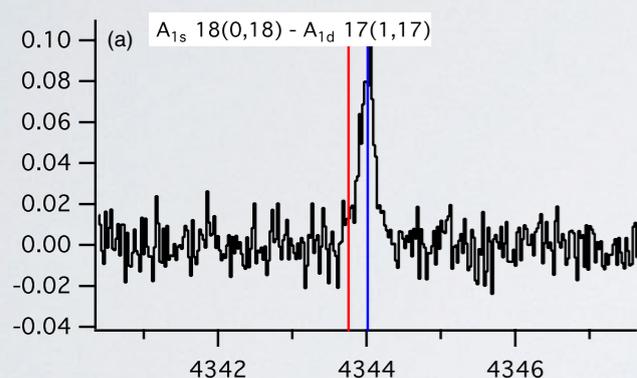


$$\log(A_{ij}) = -9$$

$$\log(A_{ij}) = -7$$

INTERSTELLAR CARBODIIMIDE (HNCNH): A NEW ASTRONOMICAL DETECTION FROM THE GBT PRIMOS SURVEY VIA MASER EMISSION FEATURES

BRETT A. MCGUIRE¹, RYAN A. LOOMIS², CAMERON M. CHARNESSE³, JOANNA F. CORBY³, GEOFFREY A. BLAKE⁴, JAN M. HOLLIS⁵, FRANK J. LOVAS⁶, PHILIP R. JEWELL⁷, AND ANTHONY J. REMIJAN⁷



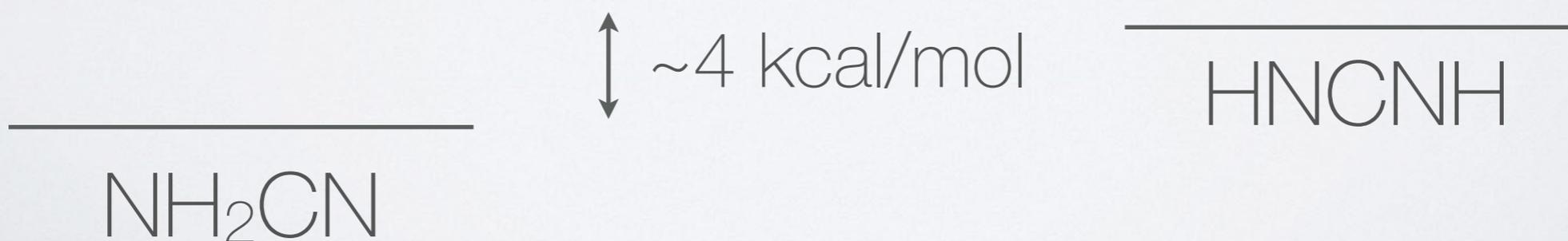
$$\log(A_{ij}) = -6$$

$$\log(A_{ij}) = -9$$

$$\log(A_{ij}) = -7$$

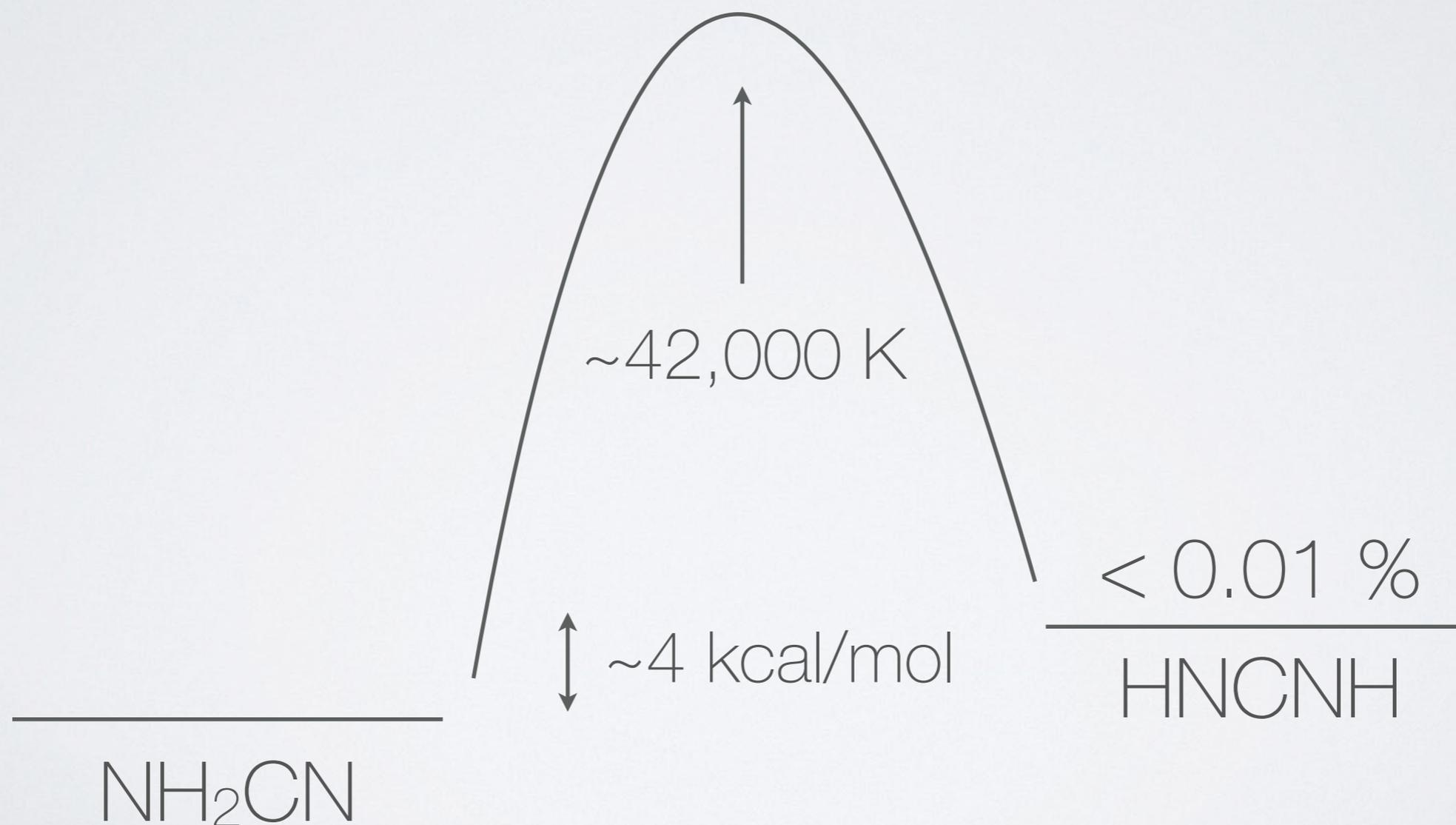
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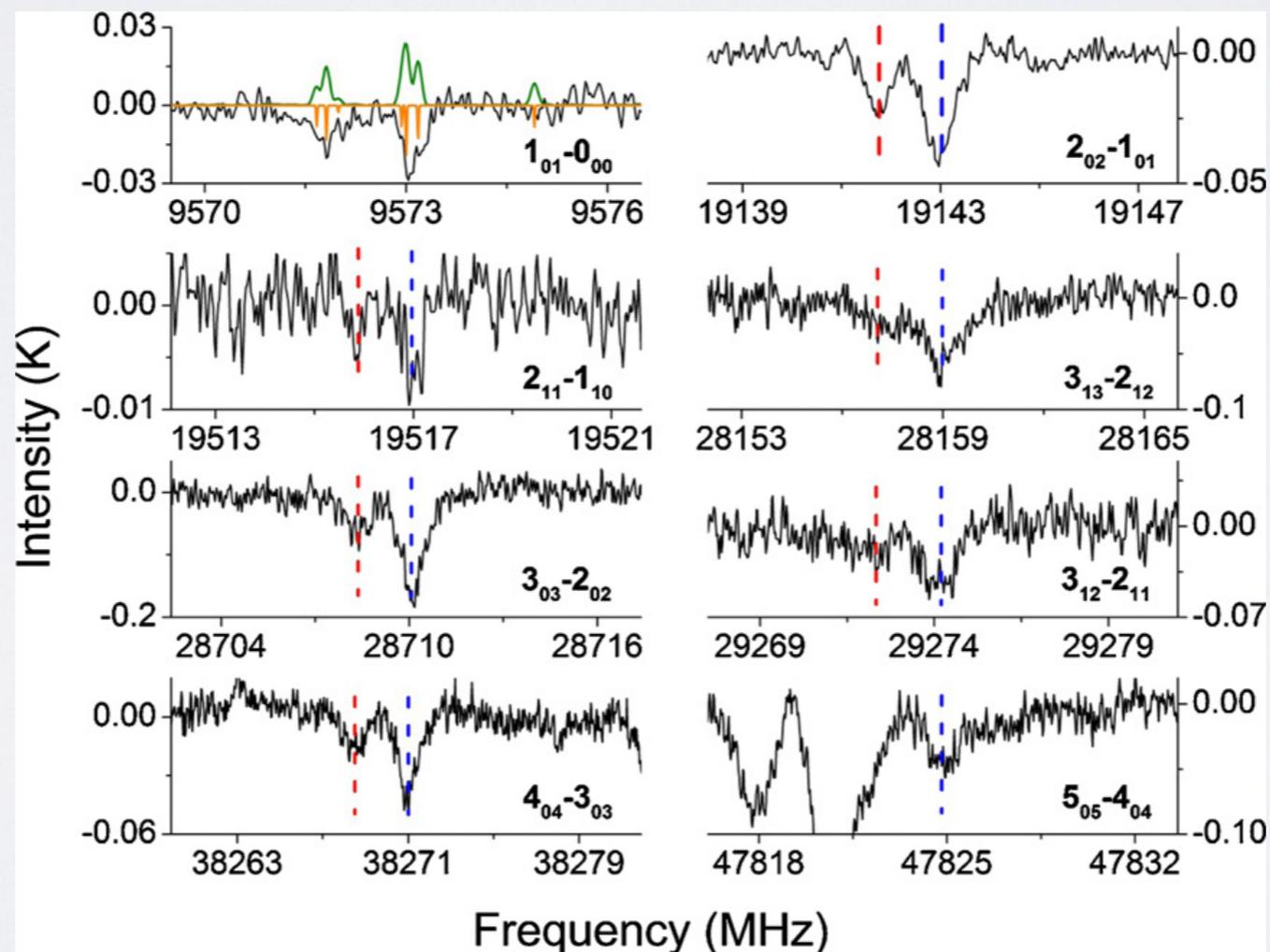
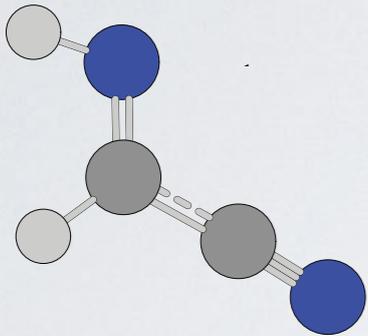
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Self-consistent tracer of both
physical conditions and **processing in ices**



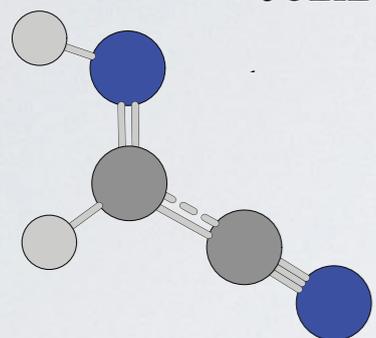
DETECTION OF E-CYANOMETHANIMINE TOWARD SAGITTARIUS B2(N) IN THE GREEN BANK TELESCOPE PRIMOS SURVEY

DANIEL P. ZALESKI¹, NATHAN A. SEIFERT¹, AMANDA L. STEBER¹, MATT T. MUCKLE¹, RYAN A. LOOMIS¹, JOANNA F. CORBY², OSCAR MARTINEZ, JR.^{3,4}, KYLE N. CRABTREE^{3,4}, PHILIP R. JEWELL⁵, JAN M. HOLLIS⁶, FRANK J. LOVAS⁷, DAVID VASQUEZ¹, JOLIE NYIRAMAHIRWE¹, NICOLE SCIORTINO¹, KENNEDY JOHNSON¹, MICHAEL C. MCCARTHY^{3,4}, ANTHONY J. REMIJAN⁵, AND BROOKS H. PATE¹

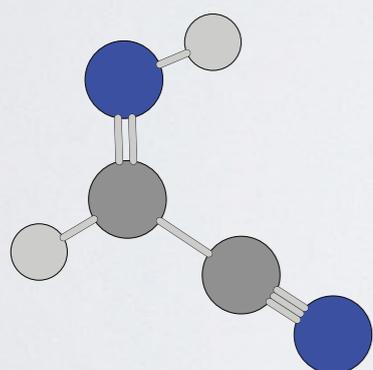


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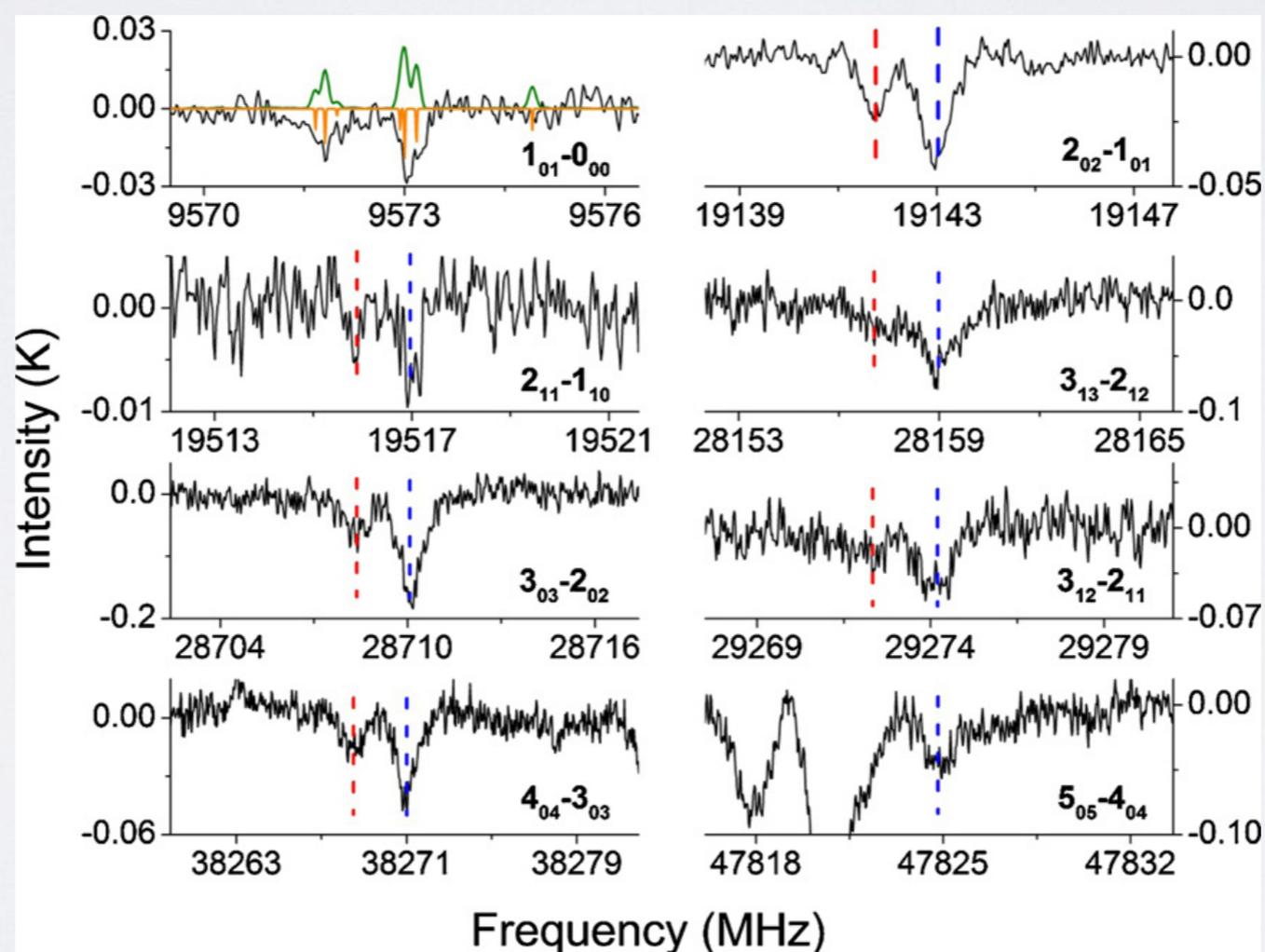
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E-Cyanomethanimine $E = 370$ K

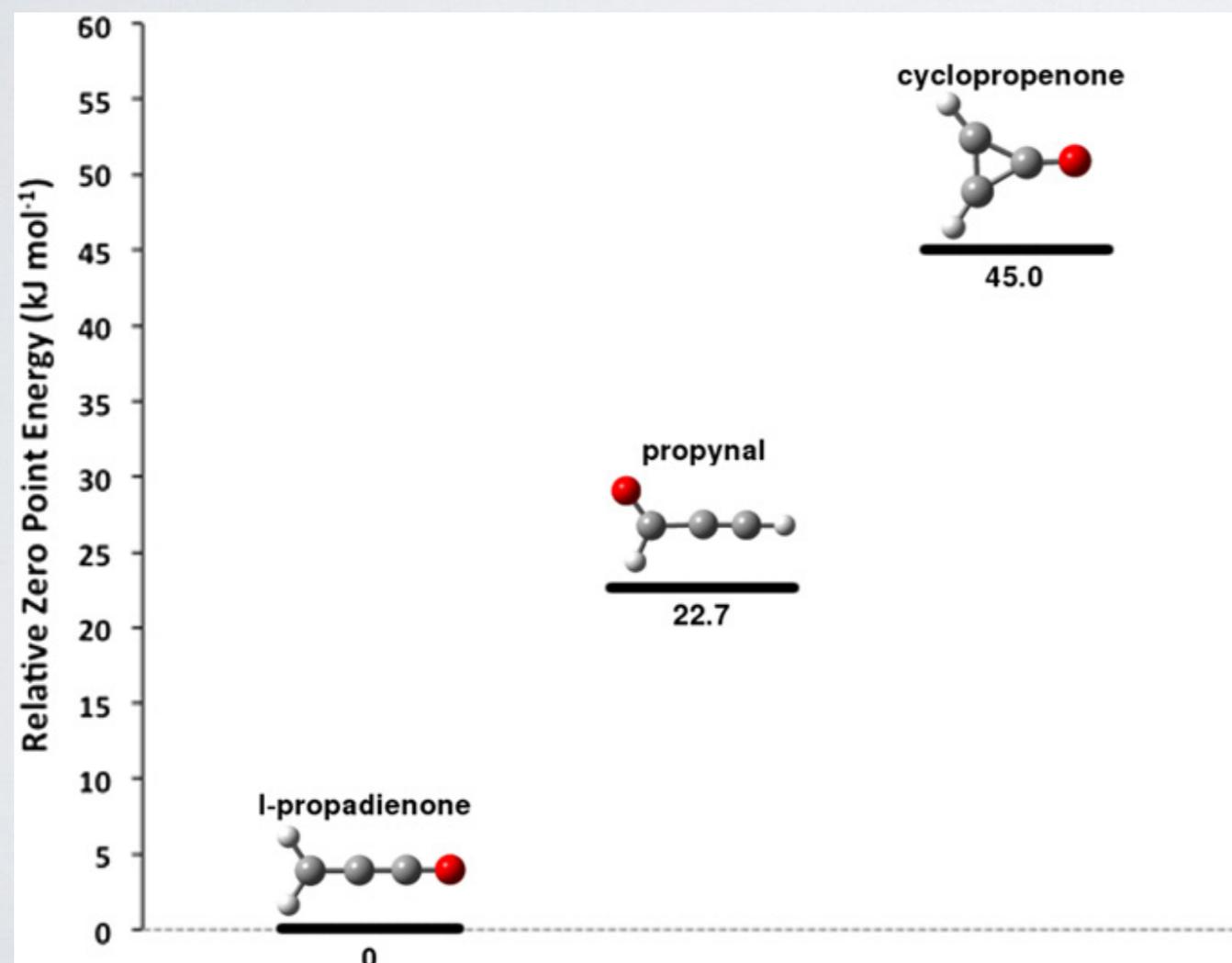


Z-Cyanomethanimine $E = 0$ K



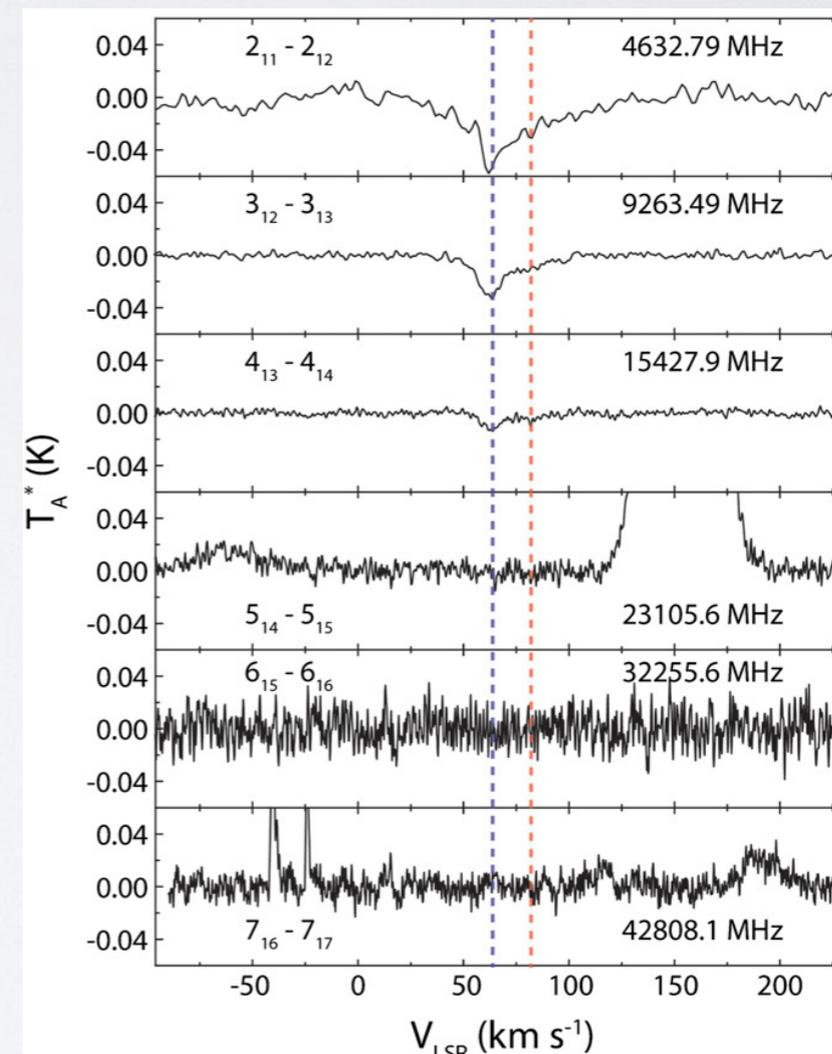
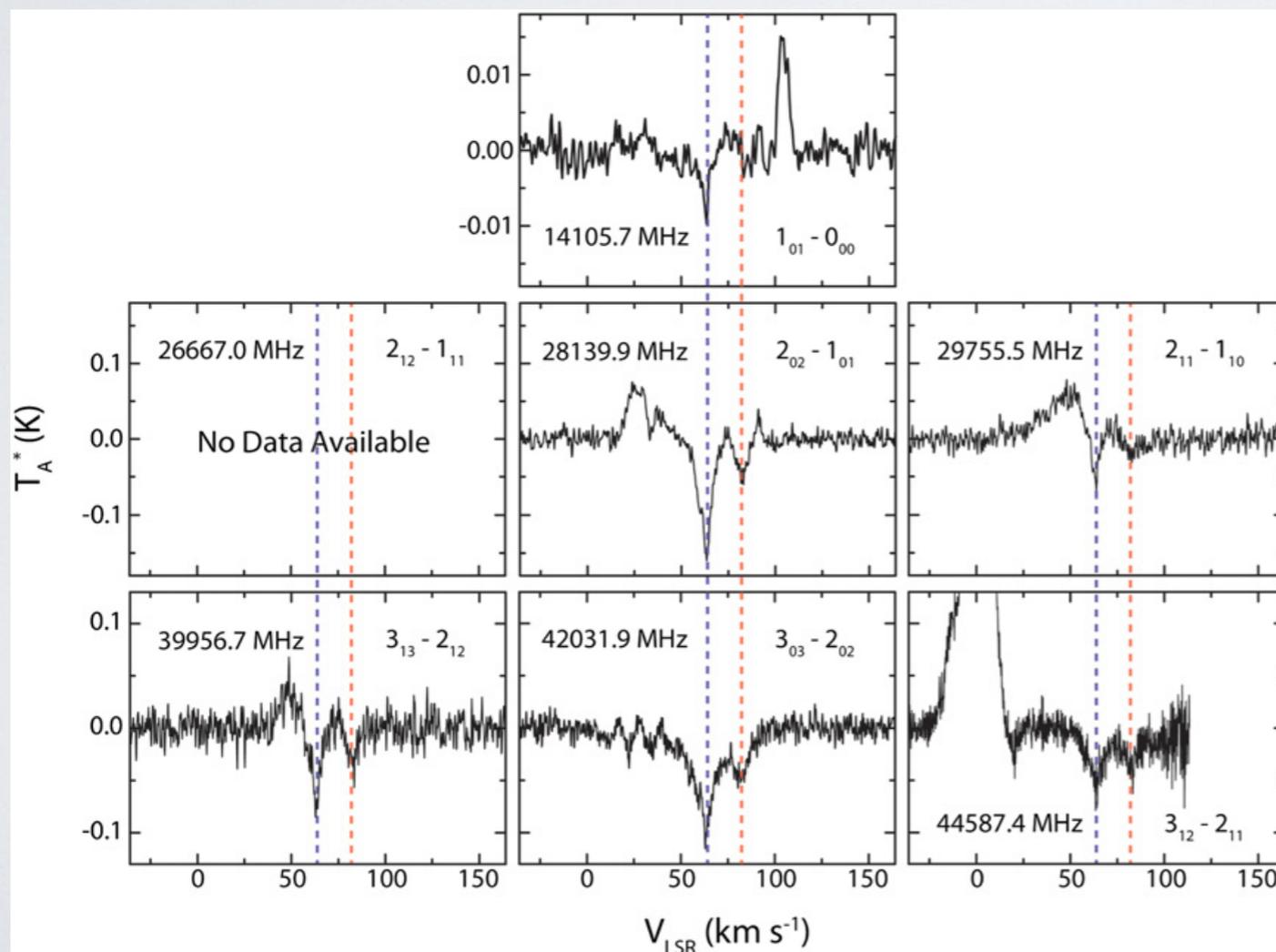
INVESTIGATING THE MINIMUM ENERGY PRINCIPLE IN SEARCHES FOR NEW MOLECULAR SPECIES—THE CASE OF H_2C_3O ISOMERS

RYAN A. LOOMIS^{1,8}, BRETT A. MCGUIRE^{2,3,9}, CHRISTOPHER SHINGLEDECKER⁴, CHELEN H. JOHNSON^{5,10}, SAMANTHA BLAIR⁶, AMY ROBERTSON^{7,11}, AND ANTHONY J. REMIJAN²



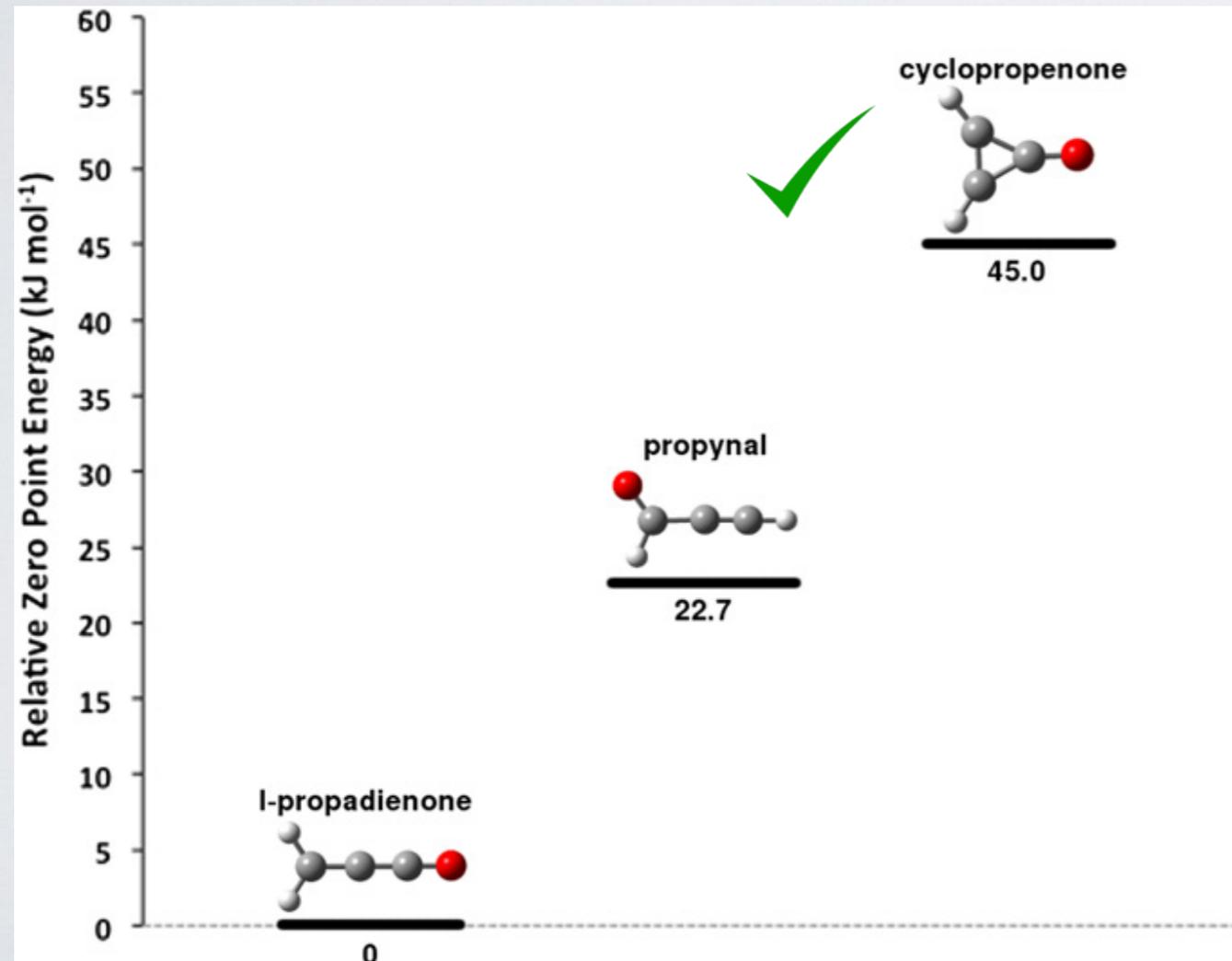
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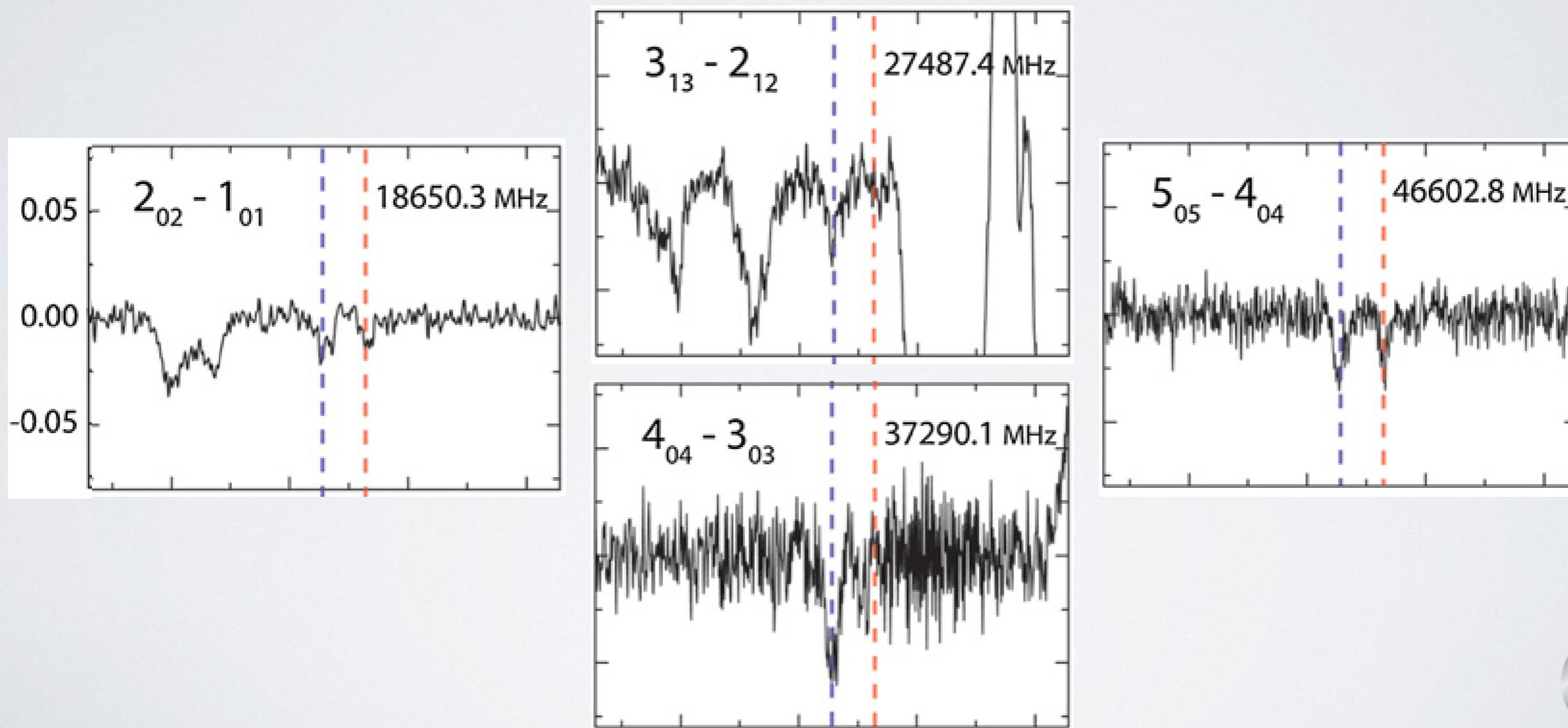
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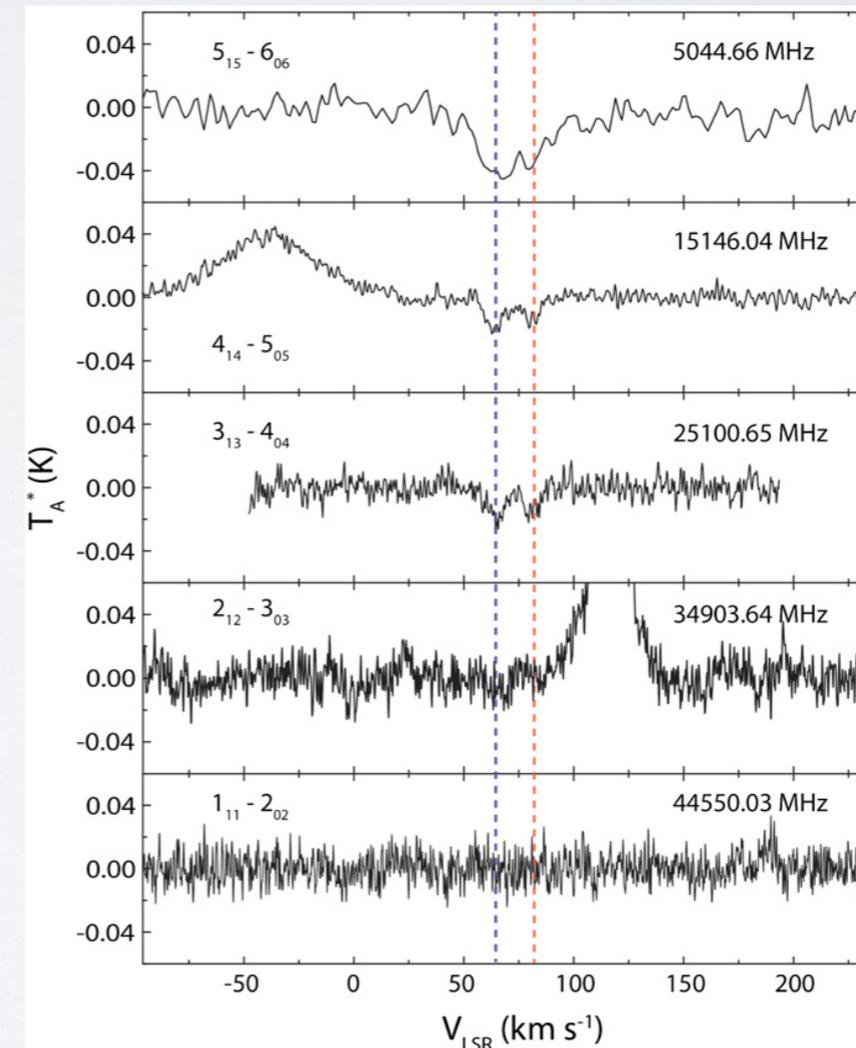
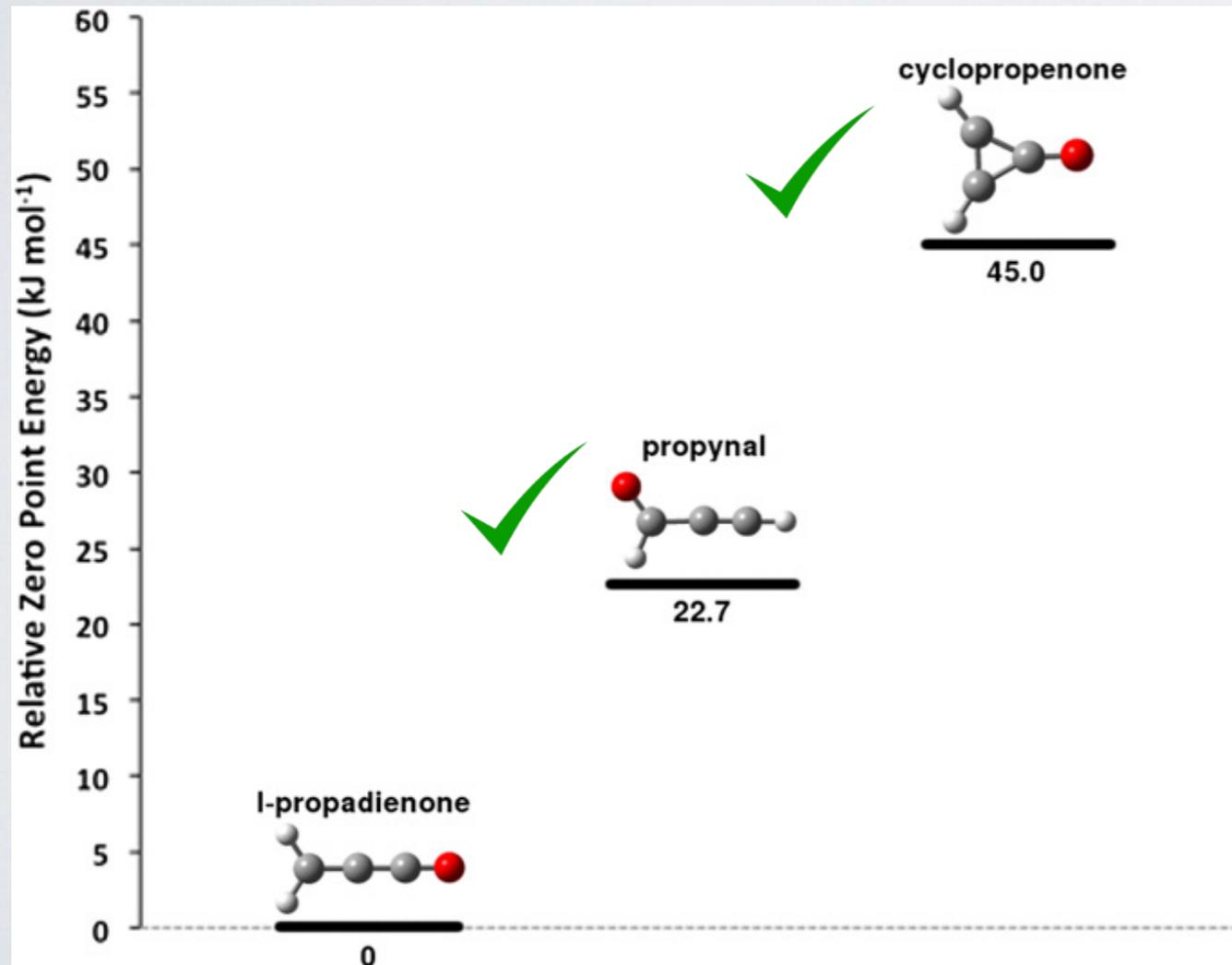
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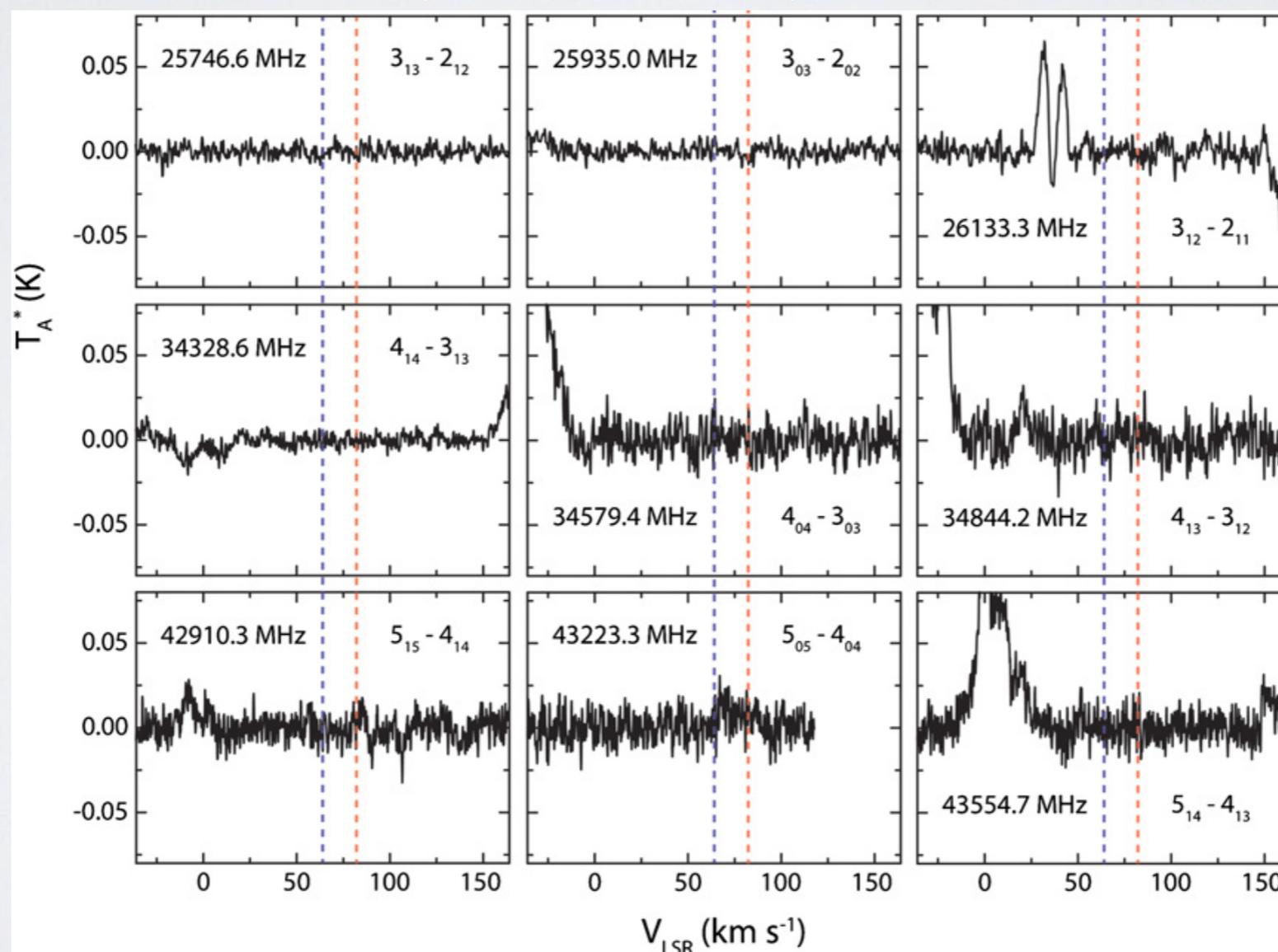
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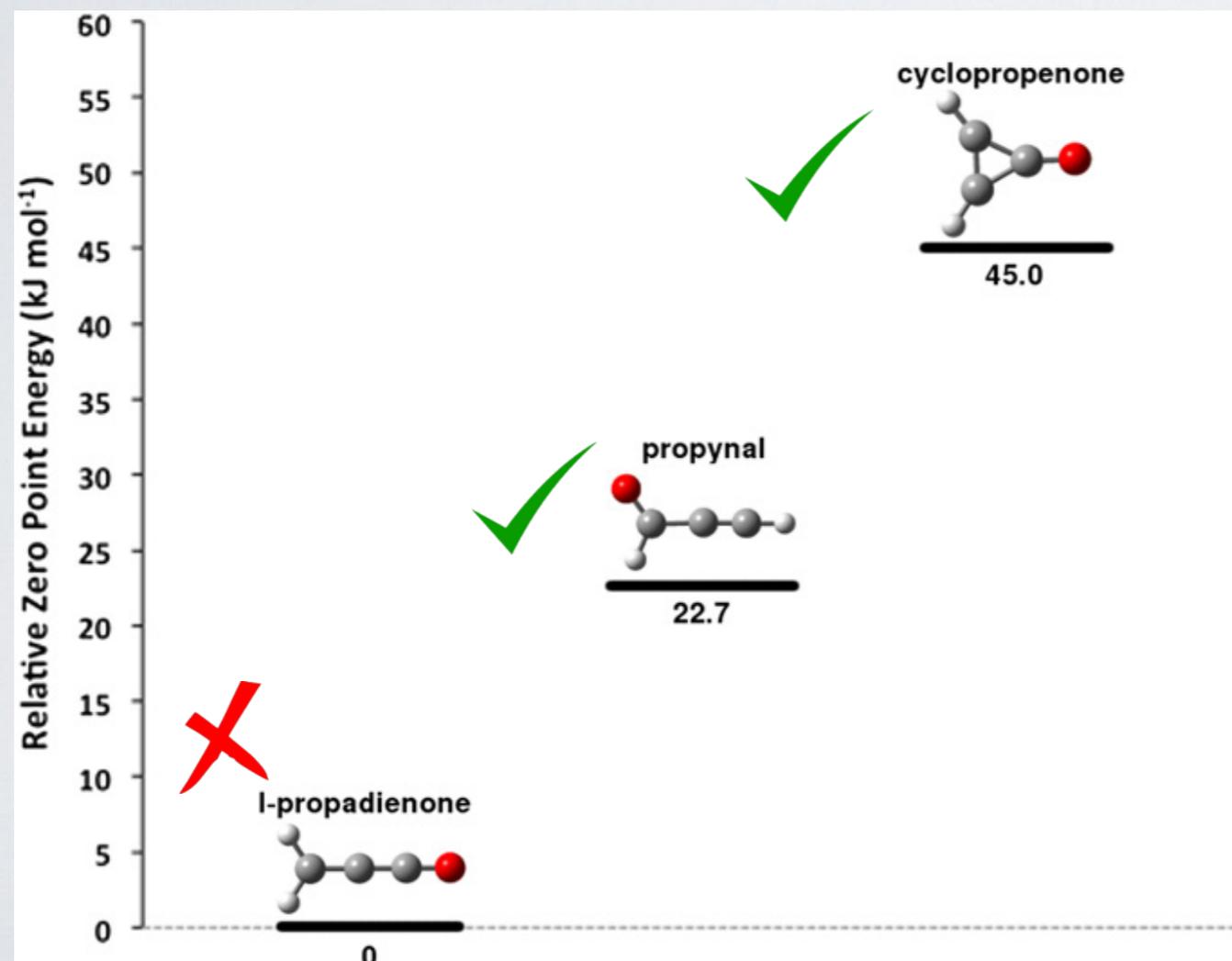
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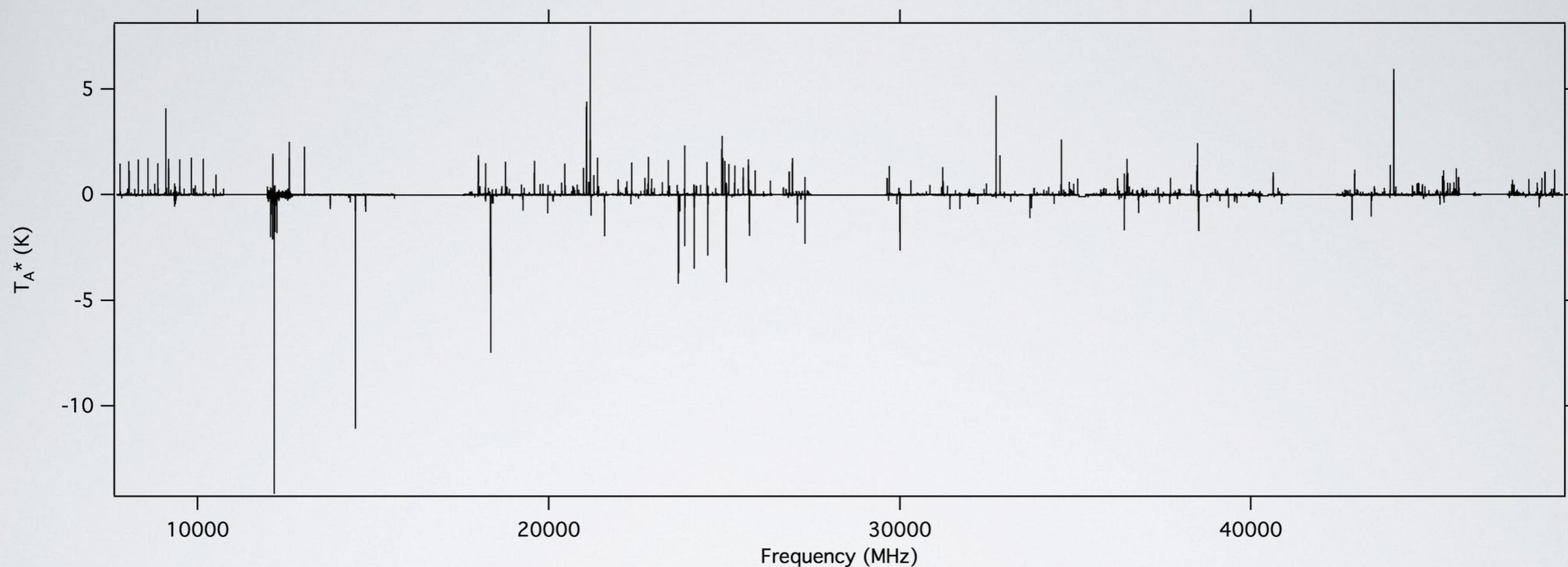
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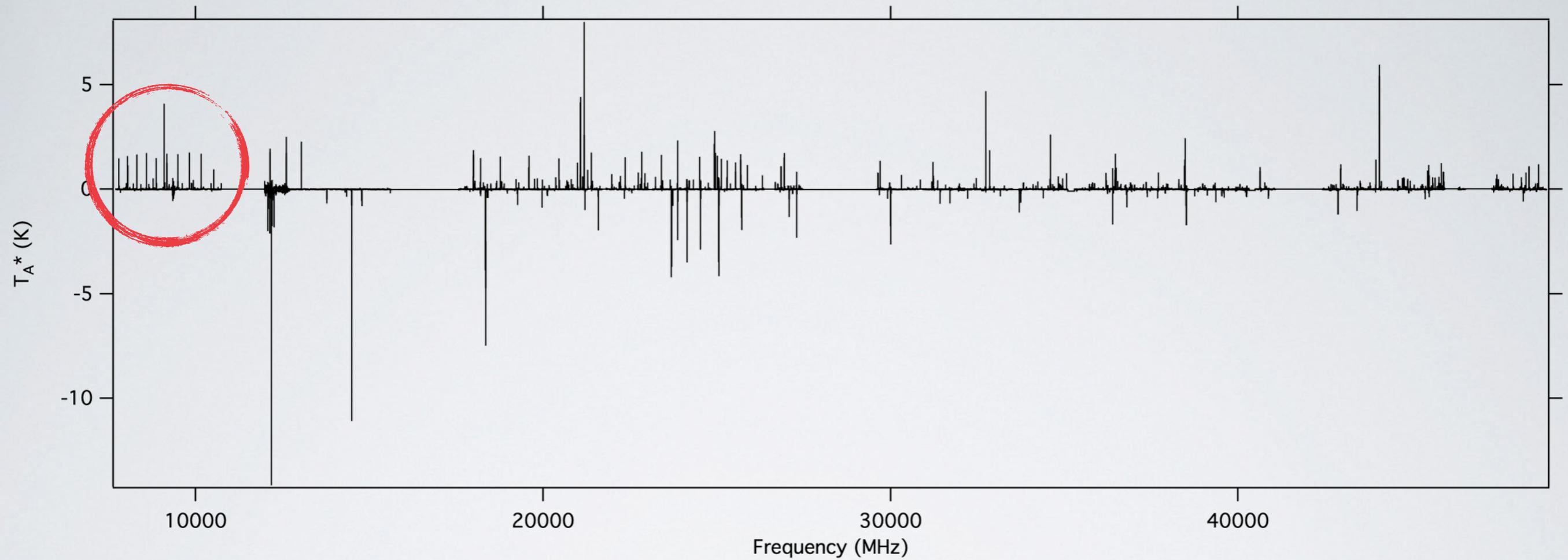


Fill in the Gaps

Shore up RMS > 20 GHz

Expand Ka / Q / W

More Sources



Fill in the Gaps

Shore up RMS > 20 GHz

TABLE 4

UNIDENTIFIED FEATURES IN THE SGR B2(N), W49, AND ORION KL DATA.

Frequency (MHz)	Sgr B2(N)	W49	Orion KL	VY CMa	NGC 2023	IRC+10216	GGD 27
7724.8	E	...	...	...	...	...	...
7761.7	A	...	...	...	...	...	...
7762.1	A	...	...	...	...	...	...
7820.1	A	...	...	...	...	...	...
7925.6	A	...	...	...	...	...	...
7949.1	A	...	...	...	...	...	...
8009.0	-	E	...	-	-	-	-
8136.1	A	E*	...	-	-	-	-
8189.7	A	-	...	-	-	-	-
8237.4	-	E	...	-	-	-	-
8523.0	-	E*	E	-	-	-	-
8601.1	A	-	-	-	-	-	-
8635.2	-	E*	E	-	-	-	-
8752.5	E	E*	...	-	-	-	-
8975.3	-	E	...	-	-	-	-
9029.7	-	E	E	-	-	-	-
9050.7	A	-	-	-	-	-	-
9110.0	A	-	-	-	-	-	-
9133.7	-	E	E	-	-	-	-
9153.3	E	-	-	-	-	-	-
9181.8	E	E	E	-	-	-	-
9207.5	A	-	...	-	-	-	-
9381.5	-	-	-	A	-	-	-
9383.1	-	-	-	A	-	-	-
9383.8	-	-	-	A	-	-	-
9423.4	A	-	...	-	-	-	-
9516.8	A	-	...	-	-	-	-
9578.7	A	-	...	-	-	-	-
9611.1	A	E*	...	-	-	-	-
9630.2	-	E	...	-	-	-	-
9697.1	E	E	...	-	-	-	-
9754.9	E	-	...	-	-	-	-
9852.0	A	-	...	-	-	-	-
9907.7	A	-	E*	-	-	-	-
9910.9	-	E	E	-	-	-	-
9997.0	-	E*	E	-	-	-	-
9999.1	E	-	-	-	-	-	-
10082.0	A
10278.2	E
10339.4	E
10462.3	A
10688.0	A

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8237.4	-	E	...	-	-	-	-
8523.0	-	E*	E	-	-	-	-
8601.1	A	-	-	-	-	-	-
8635.2	-	E*	E	-	-	-	-
8752.5	E	E*	...	-	-	-	-
8975.3	-	E	...	-	-	-	-
9029.7	-	E	E	-	-	-	-
9050.7	A	-	-	-	-	-	-
9110.0	A	-	-	-	-	-	-
9133.7	-	E	E	-	-	-	-
9153.3	E	-	-	-	-	-	-
9181.8	E	E	E	-	-	-	-
9207.5	A	-	...	-	-	-	-
9381.5	-	-	-	A	-	-	-
9383.1	-	-	-	A	-	-	-
9383.8	-	-	-	A	-	-	-
9423.4	A	-	...	-	-	-	-
9516.8	A	-	...	-	-	-	-
9578.7	A	-	...	-	-	-	-
9611.1	A	E*	...	-	-	-	-
9630.2	-	E	...	-	-	-	-
9697.1	E	E	...	-	-	-	-
9754.9	E	-	...	-	-	-	-
9852.0	A	-	...	-	-	-	-
9907.7	A	-	E*	-	-	-	-
9910.9	-	E	E	-	-	-	-
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But, Brett, modern identifications of complex molecules require dozens of clean lines to be secure!

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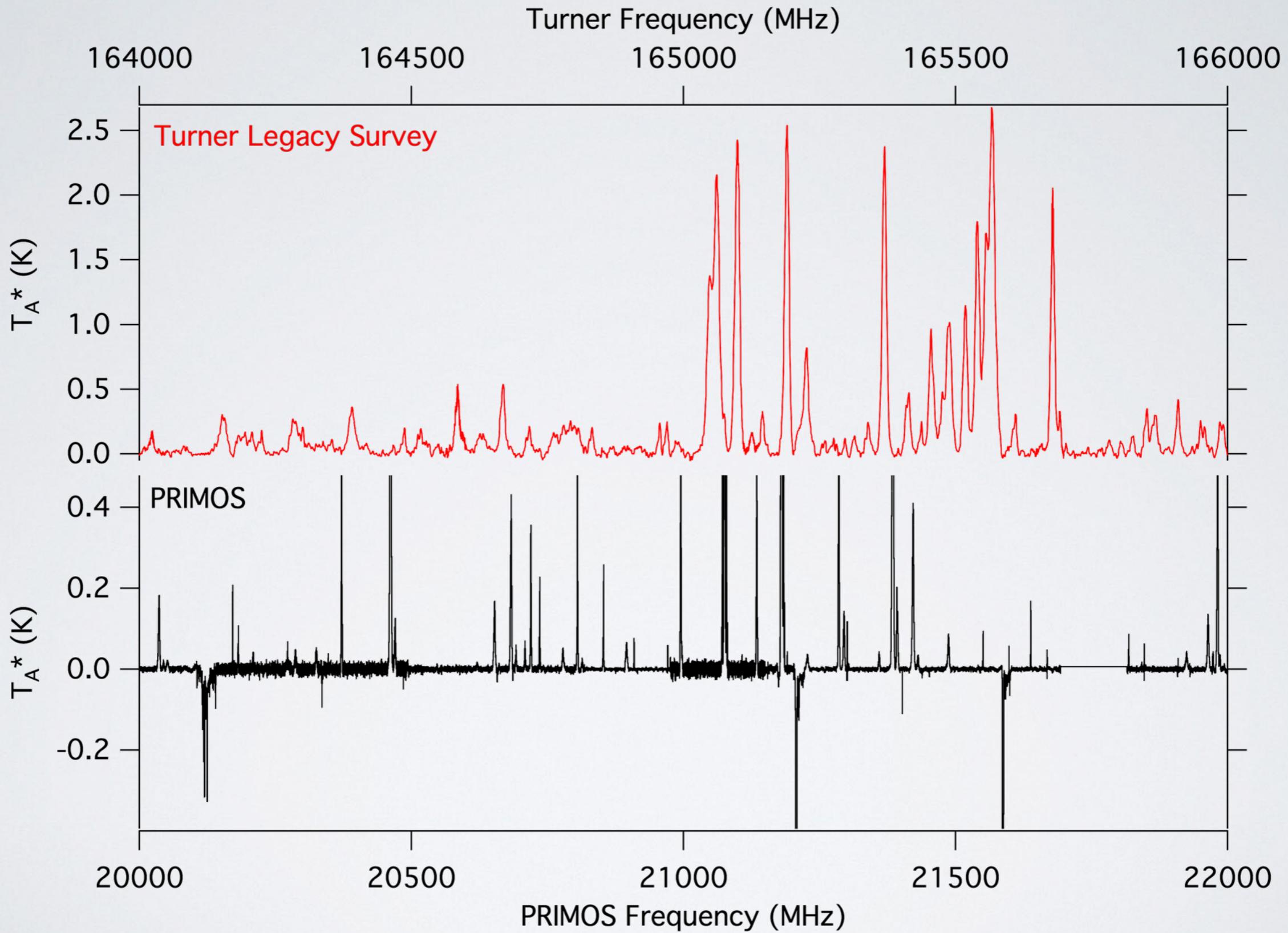
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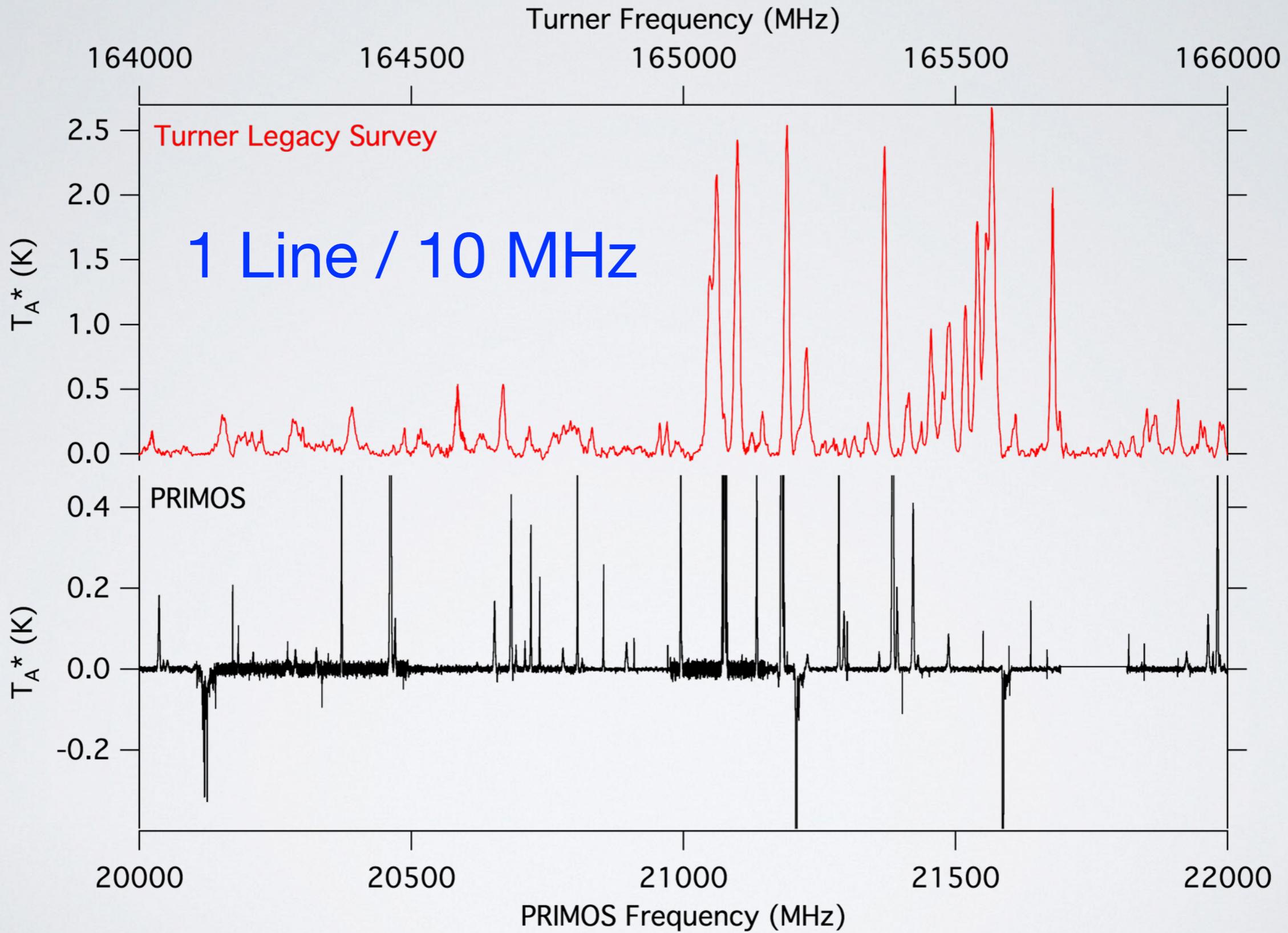
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8237.4	-	E	...	-	-	-	-
8523.0	-	E*	E	-	-	-	-
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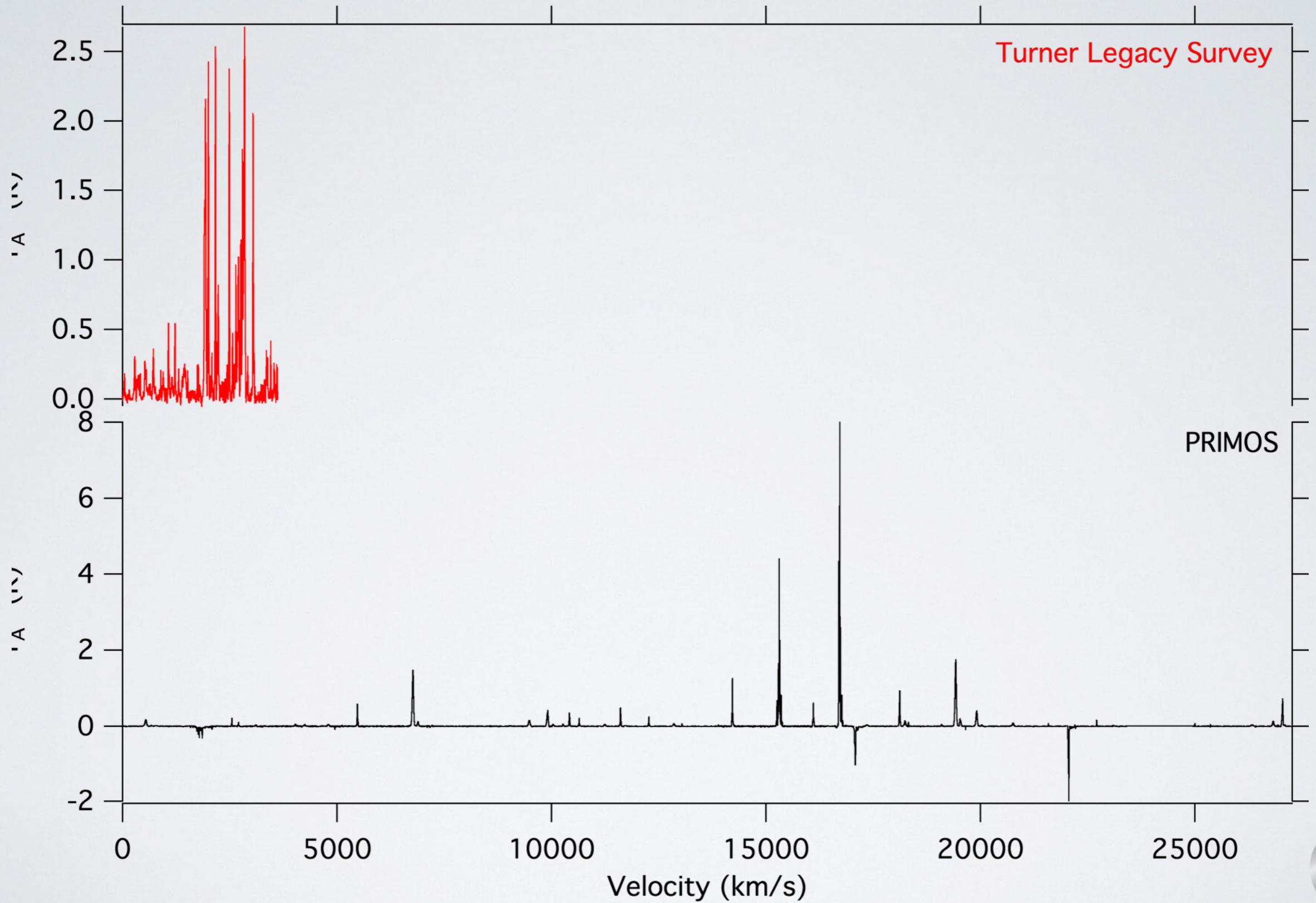
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And here's why...







Barry E. Turner Legacy Survey (150 GHz)

FWHM
10 - 25 km/s

RMS

14 mK

3 σ Line Density

1 Line / 10 MHz

1 Line / 20 km/s

Barry E. Turner Legacy Survey (150 GHz)

EVMH
10 - 25 km/s

RMS

14 mK

3 σ Line Density

1 Line / 10 MHz

1 Line / 20 km/s

PRIMOS (15 GHz)

RMS

3 - 10 mK

3 σ Line Density

1 Line / 10 MHz

1 Line / 230 km/s

Barry E. Turner Legacy Survey (150 GHz)

FWHM
 10 - 25 km/s

RMS

14 mK

3 σ Line Density

1 Line / 10 MHz

1 Line / 20 km/s

PRIMOS (15 GHz)

RMS

3 - 10 mK

3 σ Line Density

1 Line / 10 MHz

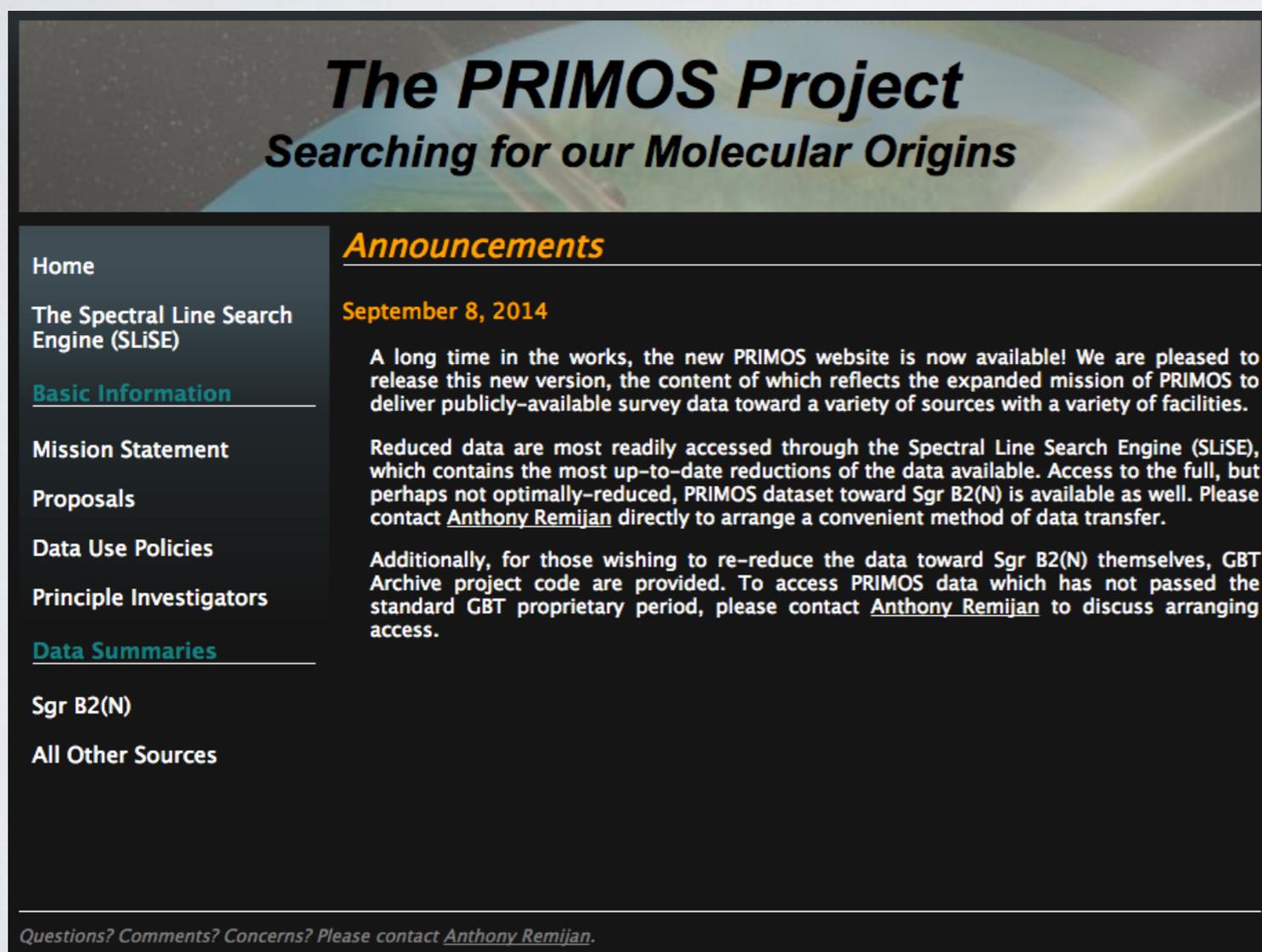
1 Line / 230 km/s

Chance of 3 lines
 coincidentally falling
 within 2x FWHM

5×10^{-6}

PRebiotic Interstellar MOlecular Survey

<http://www.cv.nrao.edu/~aremijan/PRIMOS/>



The PRIMOS Project
Searching for our Molecular Origins

Announcements

September 8, 2014

A long time in the works, the new PRIMOS website is now available! We are pleased to release this new version, the content of which reflects the expanded mission of PRIMOS to deliver publicly-available survey data toward a variety of sources with a variety of facilities.

Reduced data are most readily accessed through the Spectral Line Search Engine (SLiSE), which contains the most up-to-date reductions of the data available. Access to the full, but perhaps not optimally-reduced, PRIMOS dataset toward Sgr B2(N) is available as well. Please contact [Anthony Remijan](#) directly to arrange a convenient method of data transfer.

Additionally, for those wishing to re-reduce the data toward Sgr B2(N) themselves, GBT Archive project code are provided. To access PRIMOS data which has not passed the standard GBT proprietary period, please contact [Anthony Remijan](#) to discuss arranging access.

Home

The Spectral Line Search Engine (SLiSE)

[Basic Information](#)

Mission Statement

Proposals

Data Use Policies

Principle Investigators

[Data Summaries](#)

Sgr B2(N)

All Other Sources

Questions? Comments? Concerns? Please contact [Anthony Remijan](#).

We love to collaborate!

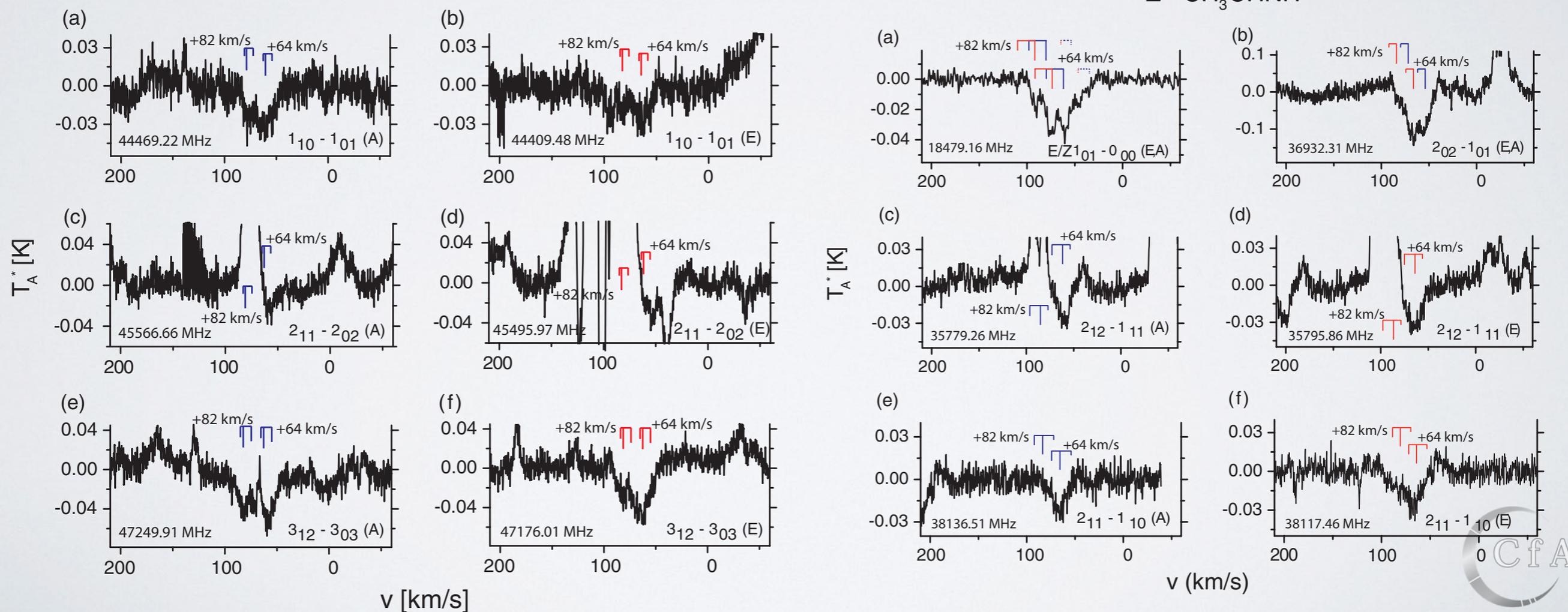
bmcguire@nrao.edu

THE DETECTION OF INTERSTELLAR ETHANIMINE (CH_3CHNH) FROM OBSERVATIONS TAKEN DURING THE GBT PRIMOS SURVEY

RYAN A. LOOMIS¹, DANIEL P. ZALESKI¹, AMANDA L. STEBER¹, JUSTIN L. NEILL¹, MATTHEW T. MUCKLE¹, BRENT J. HARRIS¹, JAN M. HOLLIS², PHILIP R. JEWELL³, VALERIO LATTANZI^{4,5}, FRANK J. LOVAS⁶, OSCAR MARTINEZ, JR.^{4,5}, MICHAEL C. MCCARTHY^{4,5}, ANTHONY J. REMIJAN³, BROOKS H. PATE¹, AND JOANNA F. CORBY⁷

E - CH_3CHNH

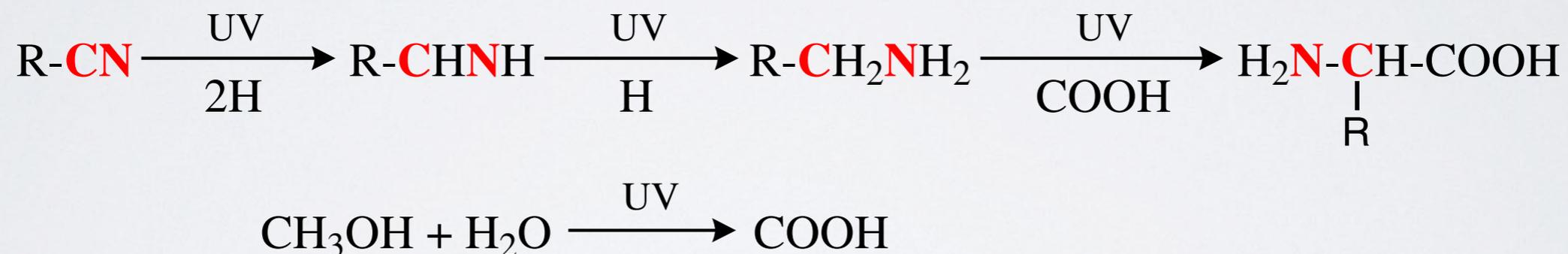
Z - CH_3CHNH



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Woon Radical-Radical:

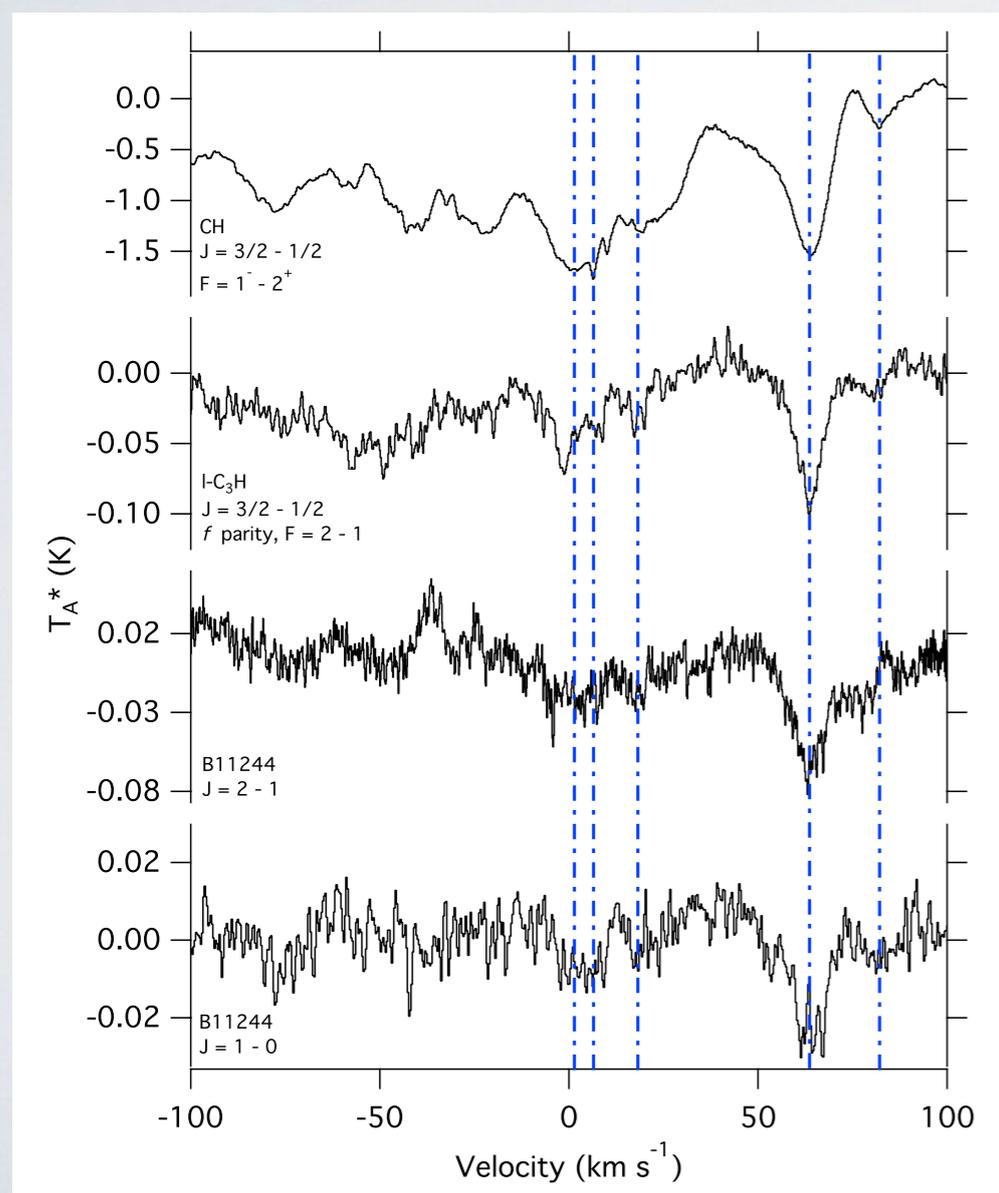


Elsila Modified Nitrile:



AN OBSERVATIONAL INVESTIGATION OF THE IDENTITY OF B11244 ($l\text{-C}_3\text{H}^+/\text{C}_3\text{H}^-$)

BRETT A. MCGUIRE¹, P. BRANDON CARROLL¹, PIERRE GRATIER^{2,3}, VIVIANA GUZMÁN², JEROME PETY^{2,3},
 EVELYNE ROUEFF^{4,5}, MARYVONNE GERIN³, GEOFFREY A. BLAKE⁶, AND ANTHONY J. REMIJAN⁷

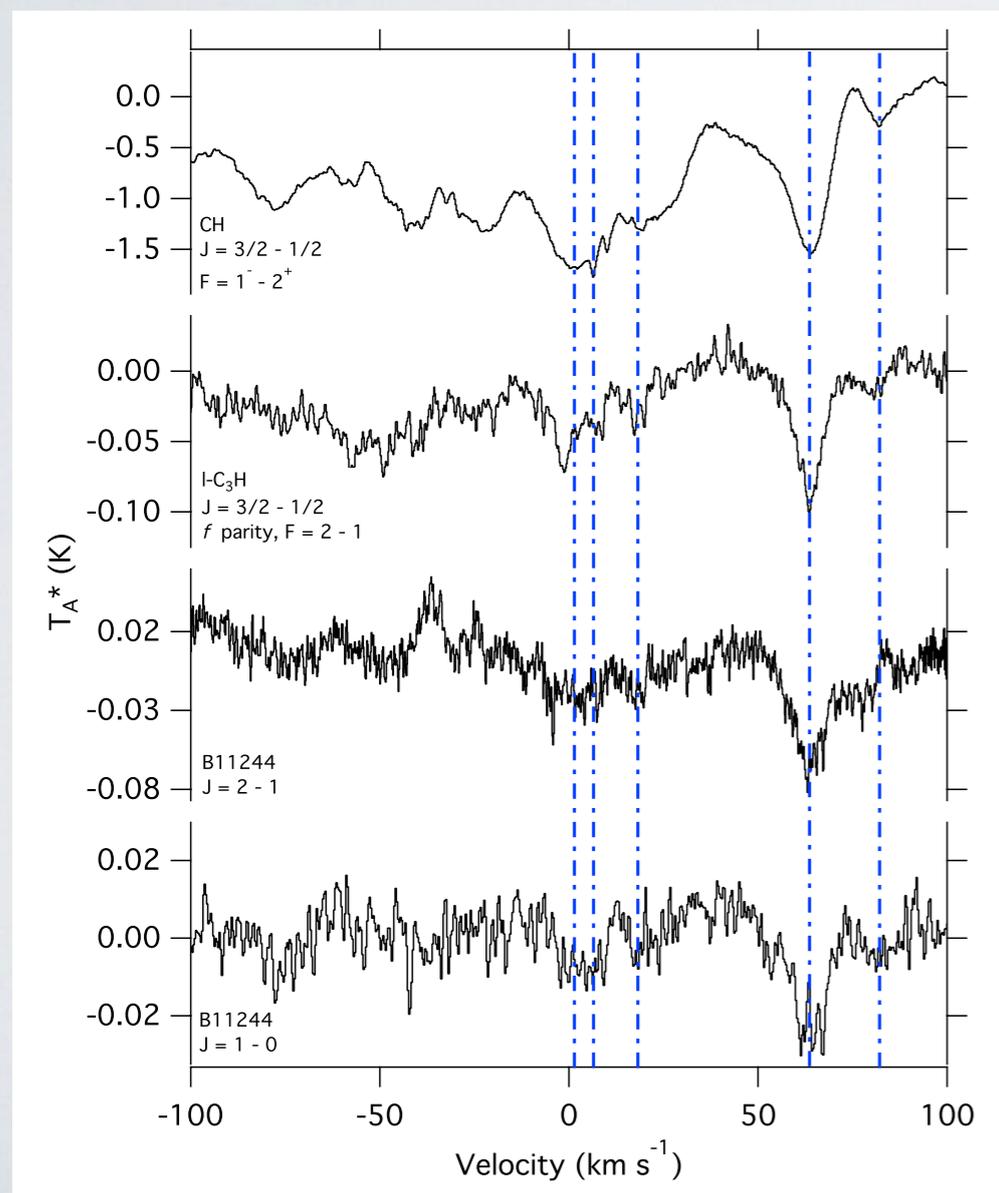


45 GHz

22 GHz

AN OBSERVATIONAL INVESTIGATION OF THE IDENTITY OF B11244 (l -C₃H⁺/C₃H⁻)

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45 GHz

22 GHz



Confirmed
Identification



PDR Environments
in Sgr B2(N)



LOS Cloud
Complexity