



(Preliminary logo)

MADCUBA and SLIM:

A lightweight software package for datacube handling and spectral line analysis

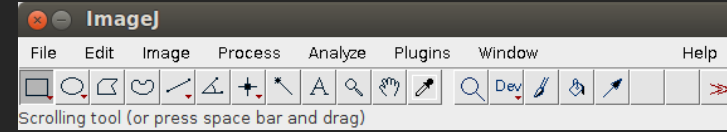
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Why MADCUBA

- MADCUBA is not new
 - Developed for more than a decade now in different forms, it is now ready for massive usage
 - Already used in a number of publications during the last few years
- Two key principles in mind:
 - Efficiency**: Required for handling big datasets
 - Easyness**: Installation and basic usage “mostly” interactive

MADCUBA in a nutshell

- MADCUBA stands for MAdrid Data CUBe Analysis
- Java-based package
- Implemented as a plug-in within the ImageJ framework



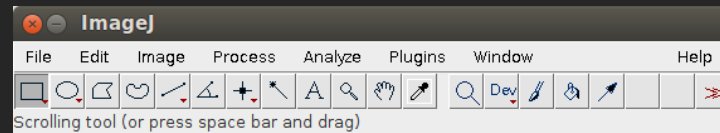
- Easy installation:
 - Requirements: Java 1.6 or 1.8
 - Download MADCUBA (36.6 MB)
 - Unpack
 - `./run.sh`



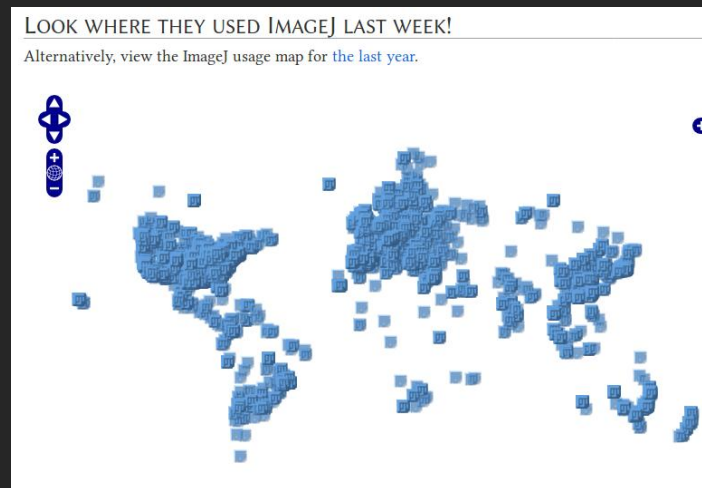
A quick look into ImageJ

- ImageJ is an open source image processing program designed for scientific multidimensional images
- ImageJ is highly extensible, with thousands of plugins and scripts for performing a wide variety of tasks, and a large user community

- Mostly used in life sciences
- Not much attention from astronomical community but for AstrolImageJ (Collins+2017)

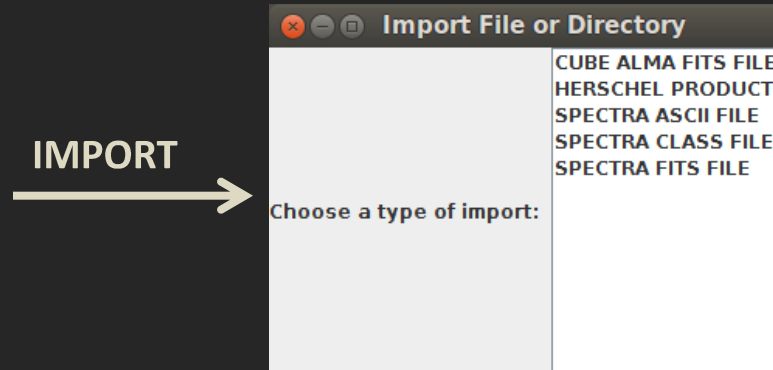
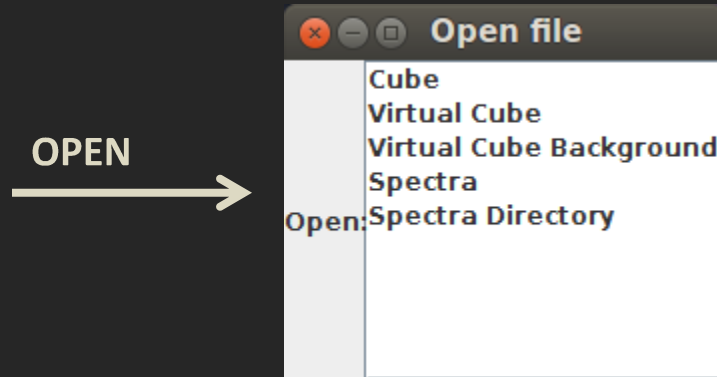
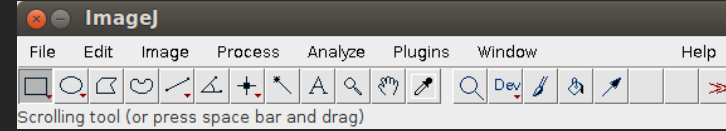


<https://imagej.net/Welcome>



MADCUBA: Open/Import

- MADCUBA uses FITS as native format
- Cube can be opened using the java virtual memory
- Allows importing data from ALMA, Herschel, ASCII formatted spectra and GILDAS files
- Handles/converts a wide range of intensity units
- Ensuring WCS completeness while importing (FITS \neq standard)



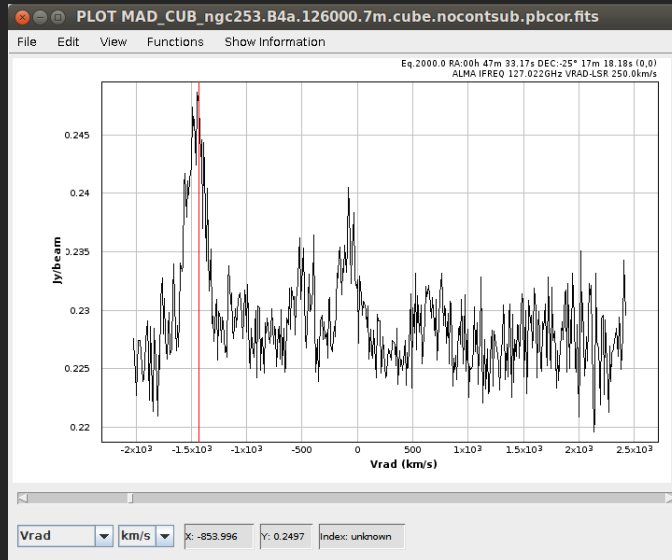
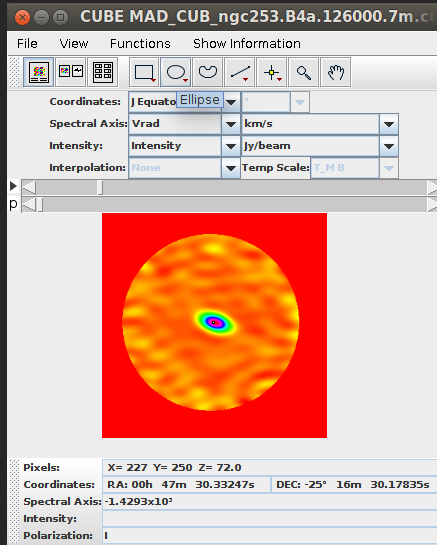
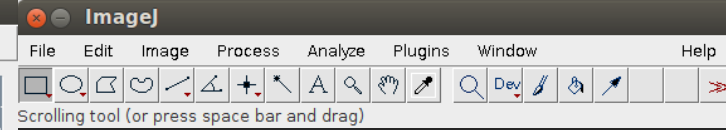
MADCUBA: Datacube handling (Virtual Cube Background + Synchronize Cube)

- Opening cube

300x300x450

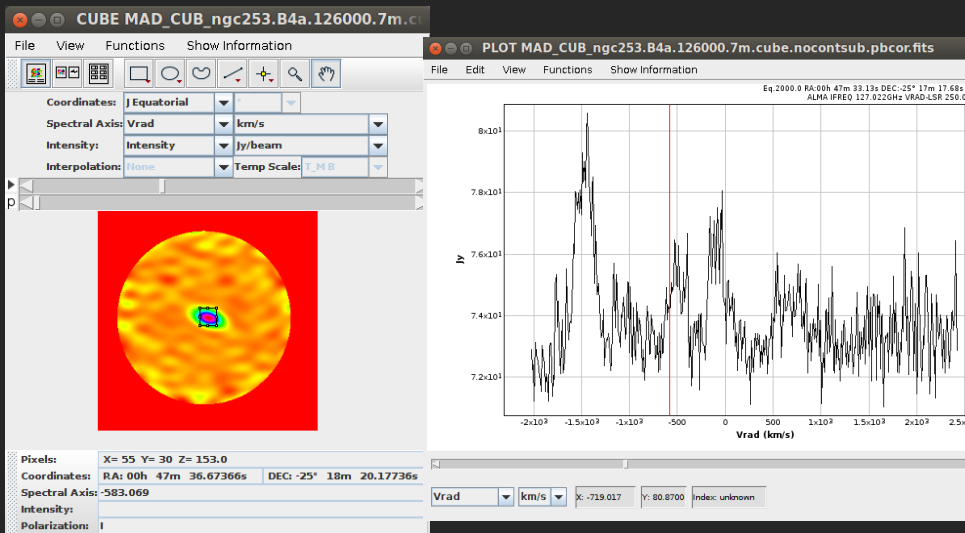
Cube Container

Select	Name	OBJECT	REST.F...	BEAM	VELOC.	ΔV	Display
false	CUBE ...	ngc253	126.10...	0"x0" 0"	-2.171...	10.447...	true



MADCUBA: Scripting

- Most MADCUBA operations on cubes can be automated
- Makes use of ImageJ script record/edit/run functionality
- Scripts can be easily created for massive operations on large datasets



The Recorder window shows a macro script for automating MADCUBA operations. The macro name is "Macro.ijm". The script contains the following code:

```
run("Open Virtual Cube", "writemacro=true  
select=/home/smartin/Trabajos/ALMADATA/Cycle5/ALCHEMI/v2_DATA/ACAdata/ngc253.B4a.126000  
.7m.cube.nocontsub.pbcor.fits");  
selectWindow("CUBE MAD_CUB_ngc253.B4a.126000.7m.cube.nocontsub.pbcor.fits");  
makeRectangle(140, 143, 23, 25);  
run("GET SPECTRUM", "ROI");  
selectWindow("PLOT MAD_CUB_ngc253.B4a.126000.7m.cube.nocontsub.pbcor.fits");  
makeRectangle(140, 143, 23, 25);  
run("Extract Spectra",  
"select=/home/smartin/Trabajos/ALMADATA/Cycle5/ALCHEMI/v2_DATA//testspectra.fits");
```


SLIM: The spectroscopic analysis tool within MADCUBA

- Modeling molecular emission assuming Local Thermodynamic Equilibrium and Gaussian shape line profiles

Peak line intensity $(T_R)_L = (J_\nu(T_{ex}) - J_\nu(T_c) - J_\nu(T_{bg}))(1 - e^{-\tau_\nu})$

Gaussian optical
depth profile

$$\tau_\nu = \tau_\circ e^{-4 \ln 2 (v - v_\circ)^2 / \Delta v^2}$$

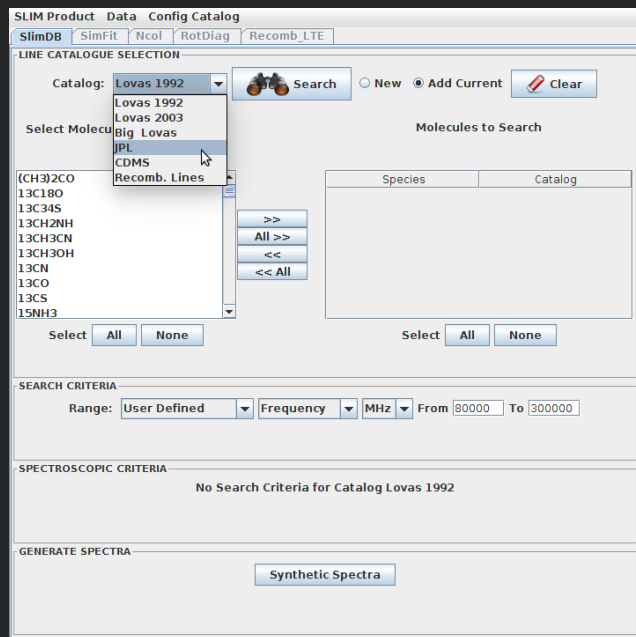
$$\tau_\circ = \frac{c^3}{8.515736 \pi \nu_{ul}^3 \Delta v} A_{ul} \frac{N}{Q(T_{ex})} g_u (e^{-E_l/kT_{ex}} - e^{-E_u/kT_{ex}})$$

Molecular spectroscopic parameters are required for modeling the emission

SLIM: The spectroscopic analysis tool within MADCUBA

SEARCHING

- Spectroscopic information is available offline within SLIM standalone database in HSQLDB (HyperSQL Database <http://hsqldb.org/> is 100% Java)



- CATALOGS: (1 GB extra download)

- SLAIM
- NIST
- JPL
- CDMS
- List of Atomic Recombination lines
- User created catalogs

SLIM: The spectroscopic analysis tool within MADCUBA

MODELING

- Modeled spectra and automatic fitting done through the parameters of N , T_{ex} , V , Δv , and Source Size
- Non-linear least-squares fitting of the molecular emission/absorption using the Levenberg-Marquardt algorithm

SLIM Product Data Config Catalog

SlimDB SimFit Ncol RotDiag Recomb_LTE

CONTINUUM

Expand Display Mode: w/o continuum Model: Load Save

DISPLAY

Sorted Intensity Lines Sel. Range(km/s) 26.072 Components ALL

FILTER SELECTED

Molecules: Threshold Intensity 1.0E-4 Purge

Only Checked All Species Units: JPLOrig Select Tab

Spectra Table Simulate Auto Fit Residual: Show Apply

MOLECULAR PARAMETERS

formula	Comp.	log ₁₀ M	f	T _{ex}	f	V _{LSR}	f	FWHM	f	S.Size	f	C...	Purge	Filter	Noise
C-13-CH	1	13.0...	15.0	187...	106...	6.0	0.0	1.0E-4	0.0						
C-13-H3CC	1	13.3...	43.0...	196...	118...	6.0	0.0	1.0E-4	0.0						
C-13-H3OH...	1	12.96	28.5...	175...	76.2...	6.0	0.0	1.0E-4	0.0						
C-13-O	1	17.2...	12.0...	180.0	87.0...	6.0	0.0	1.0E-4	0.0						
C-13-S	1	13.2...	15.4...	189...	103...	6.0	0.0	1.0E-4	0.0						
CC-13-H	1	13.0...	15.0	187...	106...	6.0	0.0	1.0E-4	0.0						
CCH	1	15.0...	15.0	187...	106...	6.0	0.0	1.0E-4	0.0						
CCS	1	14.0	11.3...	180.0	91.9...	6.0	0.0	1.0E-4	0.0						
CH2NH	1	13.6...	30.0	186...	88.3...	6.0	0.0	1.0E-4	0.0						
CH3C-13-CH	1	13.3	43.0...	196...	118...	6.0	0.0	1.0E-4	0.0						
CH3CC-13-H	1	13.3...	43.0...	196...	118...	6.0	0.0	1.0E-4	0.0						
CH3CCCH	1	15.0...	43.0...	196...	118...	6.0	0.0	1.0E-4	0.0						
CH3CN	1	13.0...	56.6...	206...	90.0	6.0	0.0	1.0E-4	0.0						
CH3OH	1	14.7...	28.5...	175...	76.2...	6.0	0.0	1.0E-4	0.0						
CO	1	17.8...	15.0	176...	97.5...	6.0	0.0	1.0E-4	0.0						
CO-17	1	15.7...	15.0	181...	94.2...	6.0	0.0	1.0E-4	0.0						
CO-18	1	16.6...	14.0...	179...	79.6...	6.0	0.0	1.0E-4	0.0						
C	0	0	0	0	0	0	0	0	0						

PARAMETER SLIDERS

log₁₀ N: 12 12.8 13.6 14.4 15.2 16

T_{ex}: 1 11 21 31 41 51

V_{LSR}: 162 172 182 193 203 213

FWHM: 81 91 101 112 122 132

Cont. Size: 0 4 8 12 16 20

Source Size: 0 4 8 12 16 20

T_c: 0 2.2 4.4 6.6 8.8 11

SLIM Table: 'ngc253_ALCHEMI.mad.zip'

Lines Table View Preferences Table Filtering

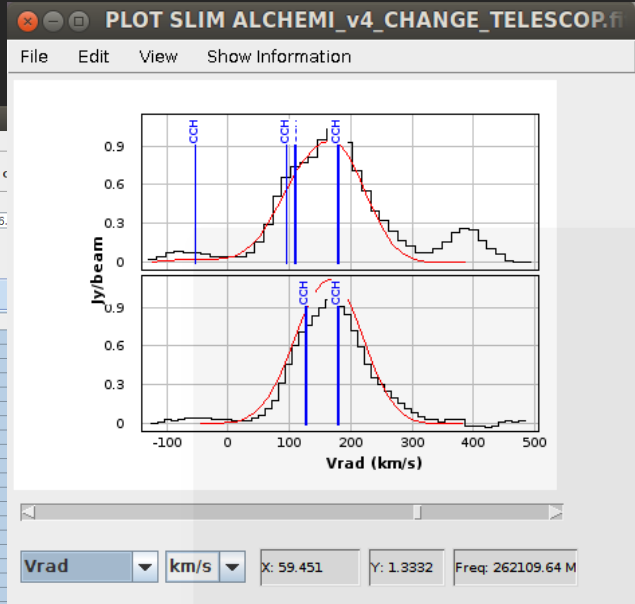
Sel. Spectral Fit Phys. formula CCH

Table/Cube: ALCHEMI_v4_CHANGE_TELESCOP.fits/Orig. Width Velocity (km/s): 426.

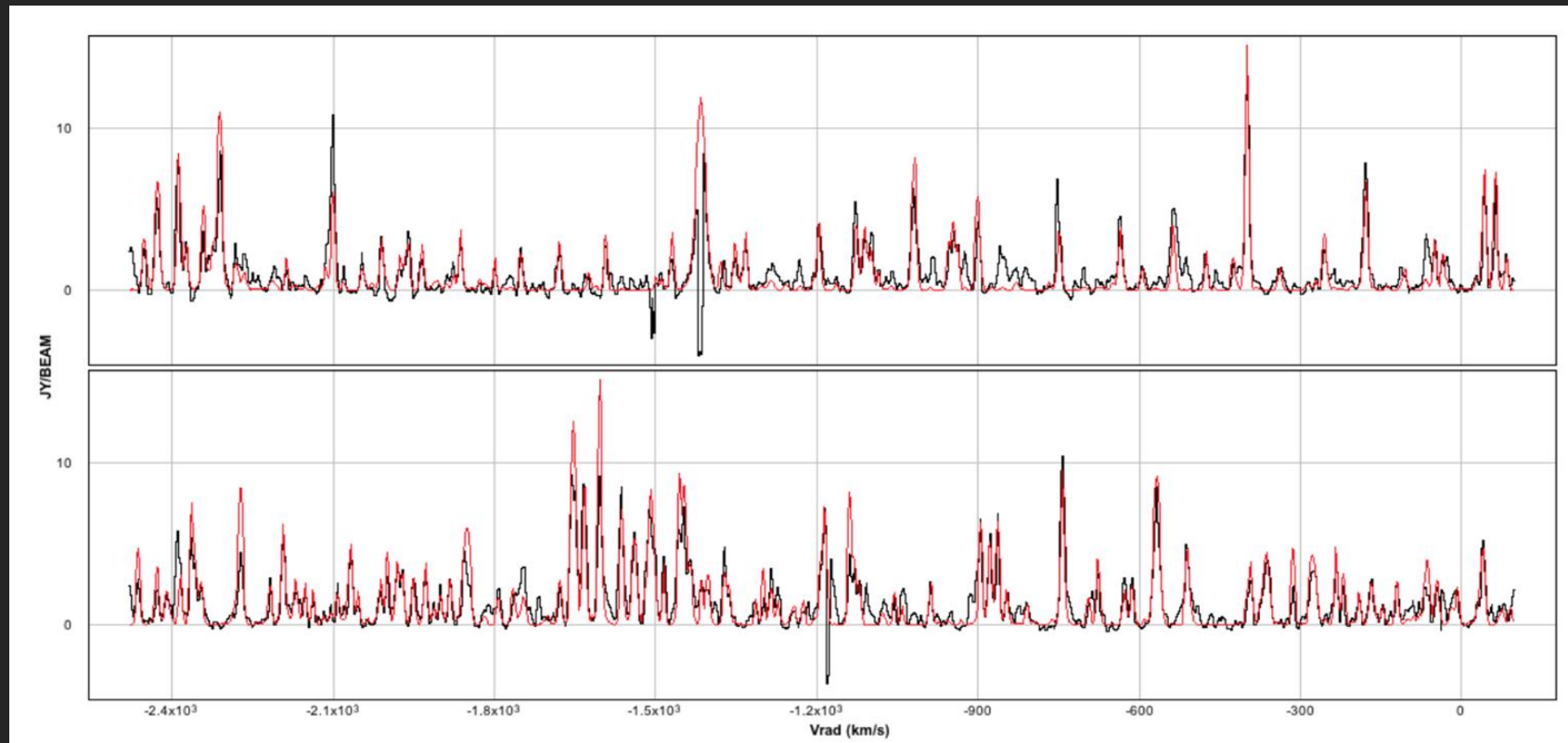
JPL X

Orig X SIMULATE X

Index	Frequency	Formula
546	262,004.227	CCH
552	349,337.456	CCH
553	349,338.728	CCH
554	349,398.906	CCH
547	262,006.403	CCH
548	262,064.843	CCH
555	349,400.292	CCH
540	174,663.222	CCH
549	262,067.331	CCH
541	174,667.685	CCH
542	174,721.777	CCH
543	174,728.1	CCH
544	174,733.195	CCH
545	174,806.827	CCH
550	262,078.776	CCH
551	262,208.439	CCH
534	87,284.156	CCH
535	87,316.925	CCH
536	87,328.624	CCH
537	87,402.004	CCH
538	87,407.165	CCH
539	87,446.512	CCH



Sample usage: Searching complex molecules in complex emitters with SLIM



Galactic hot molecular core G31.41+0.31 (Rivilla et al. 2017)



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- For information and download <http://cab.inta-csic.es/madcuba/Portada.html>
(or just google MADCUBA ...no it is not that restaurant in Madeira)
- Publication currently in preparation (Martin et al.)