Herschel M33 Key Project

HERM33ES

And

Operational thoughts on two Observatories: Herschel and SOFIA

Steve Lord (IPAC/Caltech)

Part I
HerM33es

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Acknowledgment

Credits: Much of this M33 progress report is borrowed from Guillermo Quintana-Lacaci's (IRAM) Stormy Cosmos Conference Presentation (4 Nov 2010)

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Herschel M33 Open Time Key Project

- PI: Carsten Kramer (IRAM)
- The HERM33S Team: Carsten Kramer, Steve Lord, Daniela Calzetti, Jonathan Braine, Gordon Stacey, Susanne Aalto, Rainer Beck, Frank Bertoldi, Santiago Garcia-Burillo, Francoise Combes, Michael Dumke, Rolf Guesten, Christian Henkel, Frank Israel, Baerbel Koribalski, Andreas Lundgren, Jesus Martin-Pintado, Bhaswati Mookerjea, Karl Schuster, Kartik Sheth, Markus Roellig, Juergen Stutzki, Floris van der Tak, Fatemeh Tabatabaei, Remo Tilanus, Paul van der Werf, Christof Buchbender, Martina Wiedner, Manolis Xilouris, Guillermo Quintana-Lacaci, Manuel Gonzalez, Simon Verley, Erik Rosolowsky, Mederic Boquiem, Albrecht Sievers, Monica Relano, Marcus Albrecht, Thomas Nikola, Christof Buchbender, Pierre Gratier, Sibylle Anderl, Stavros Arkas

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M33 (NGC 598) SA(s)cd

- Local Group galaxy
- Late type, no ring, no bar
- Nearest late-type spiral galaxy: 840kpc, 12" = 50pc
- Low inclination of 56 deg
- Gas rich
- Blue Disk – Active Star Formation
- Several giant HII regions
- Generally unperturbed morphology
- Exists a giant HI bridge connecting M31 and M33
- About half solar metallicity, with large variations

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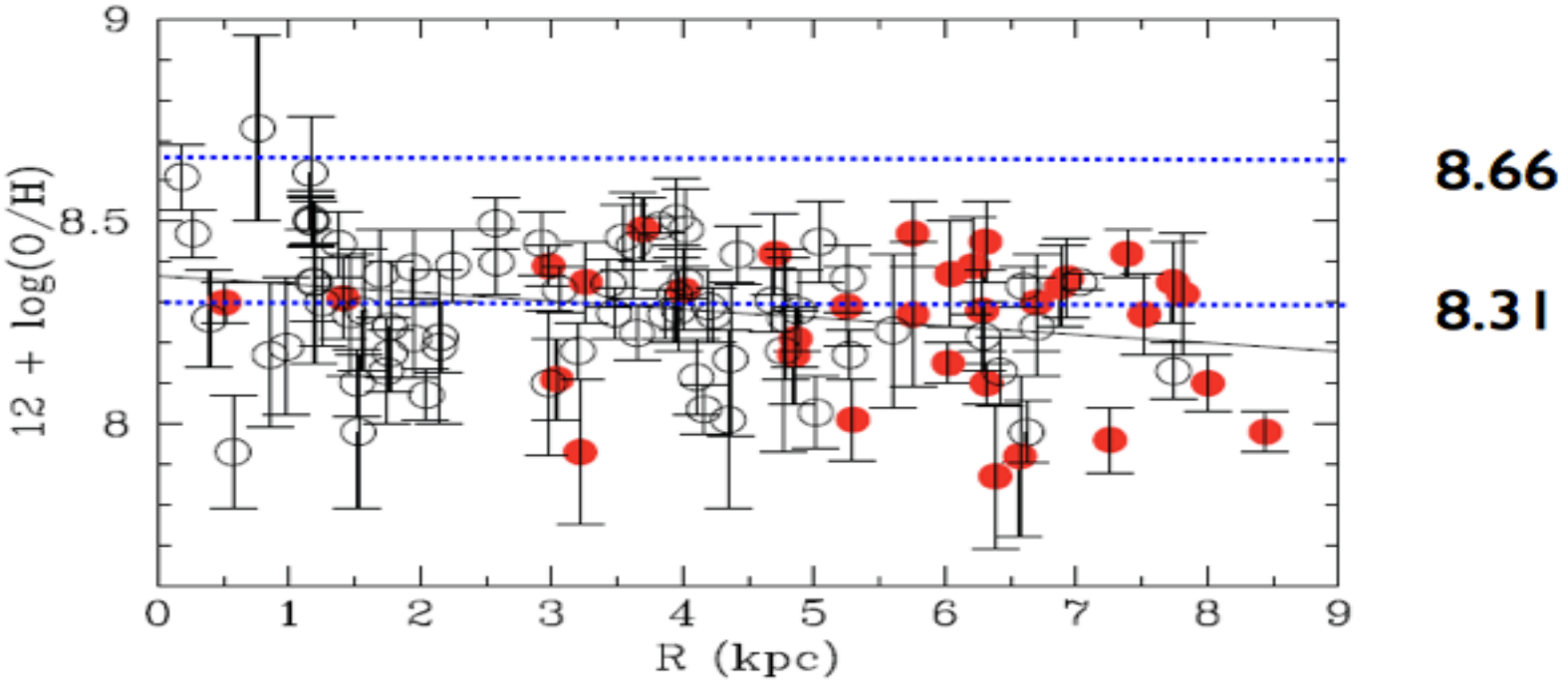
M33 metalicity with radius
Log(O/H)+12 vs. Solar



Magrini et al. 2009

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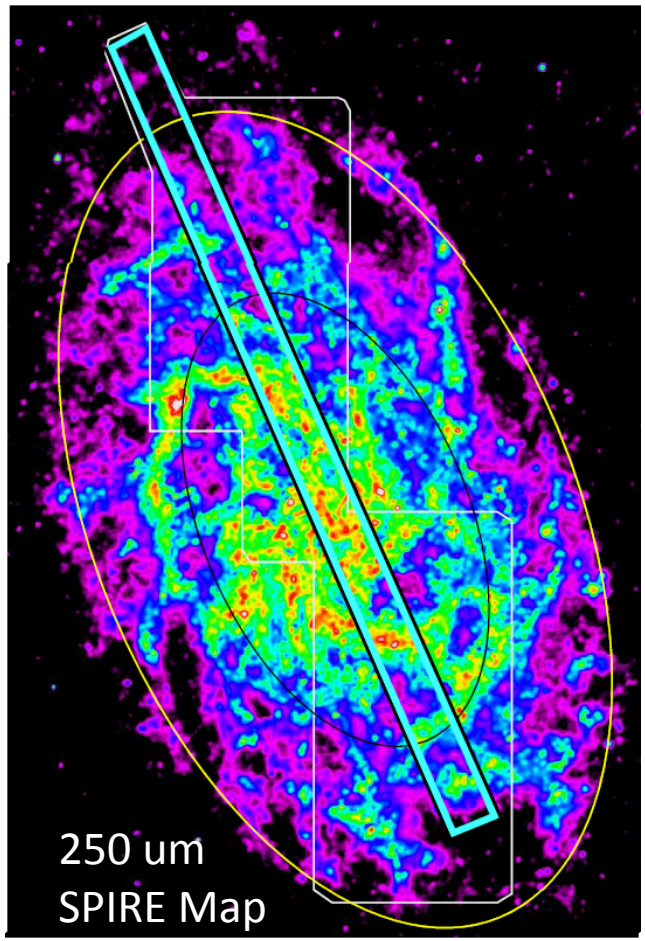
Open Time Key Project Overview



- 191 Hours of Observing time
- Map the entire Galaxy:
  - 6hrs: PACS (75, 100, 170um) & SPIRE (250, 350, 500um) photometry 70'x70' (done)
- Observe Strip along major axis out to 8kpc:
  - PACS spectroscopy, 42 hrs: [CII] 158, [OI] 63,145, [NII] 122,205 (1 hr done)
  - HIFI spectroscopy, 143 hrs: [CII] 158um (1 hr done)

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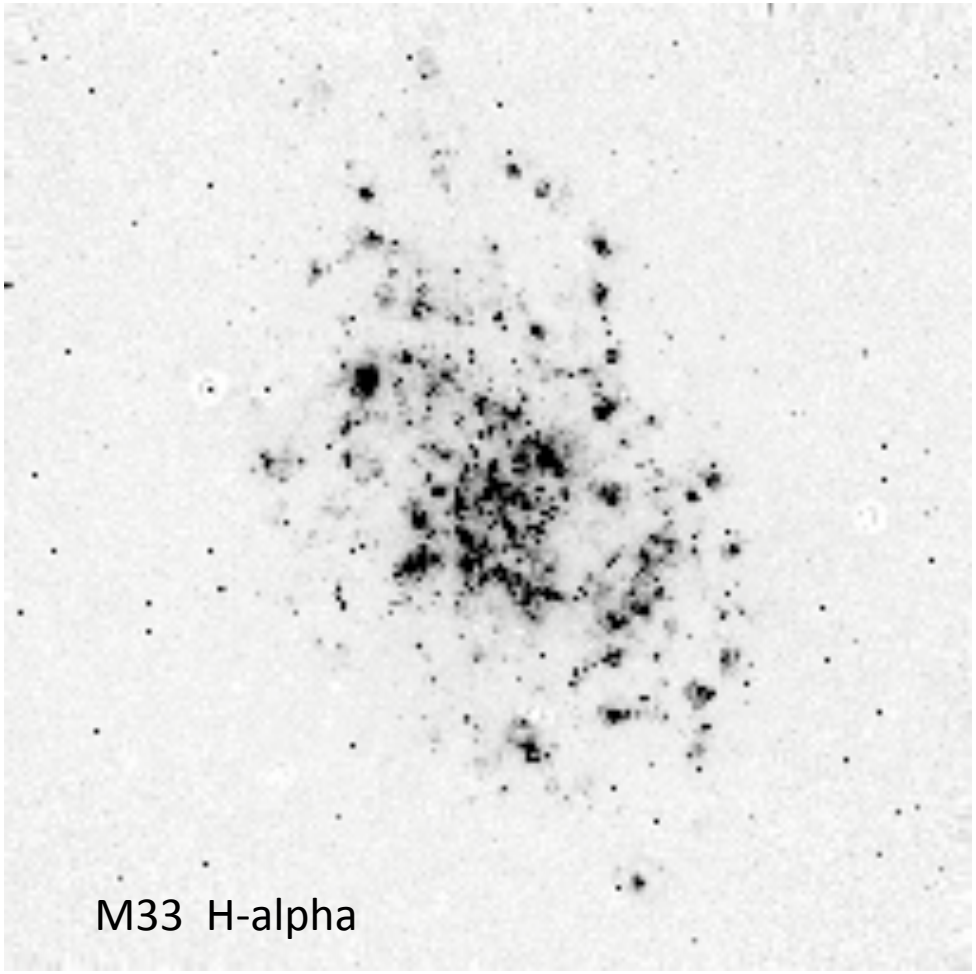
Science Goals



- Study the phases of the ISM: molecular, atomic, ionized
- Energy balance of the ISM: cooling & heating mechanisms
- Use extinction-free tracers of star formation and dust: TIR continuum, [NII], [CII], etc.
- Study Triggering and Formation of molecular clouds: HII, HI, H2, and their interface regions

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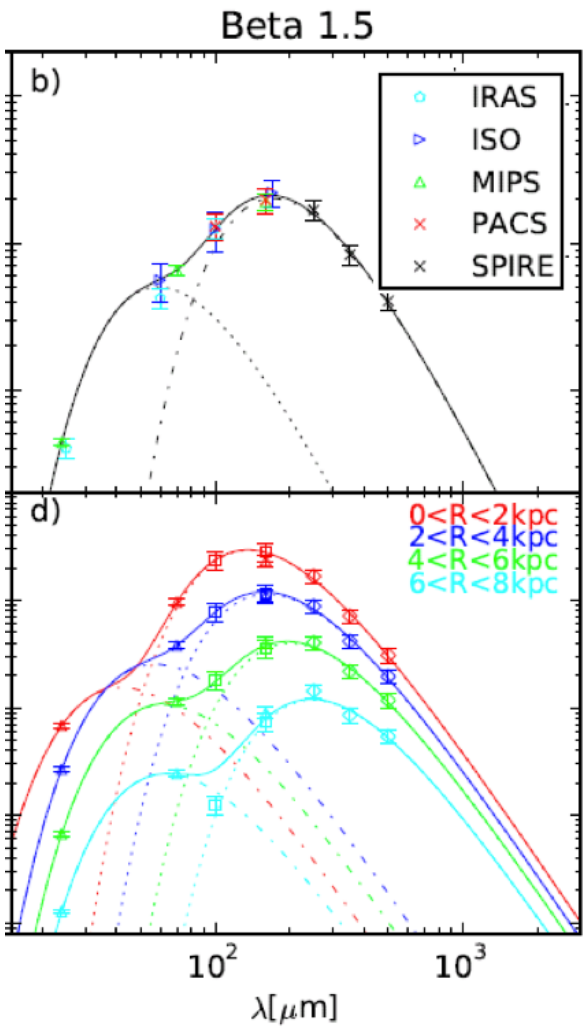
Dust Components with Radius



$$S_\nu = M_c B(\nu, T_c)\kappa_\nu + M_w B(\nu, T_w)\kappa_\nu$$

$$\kappa_\nu = 0.04\,(\nu/250\mathrm{GHz})^\beta$$ (Kruegel &Siebenmorgen 1994)

	Total	(1)	(2)	(3)	(4)
Two-component fits with $\beta = 1.5$					
T_c/[K]	19	24	20	16	13
T_w/[K]	55	77	57	52	51
M_c/[10^6 $M_\odot$]	10	1.2	3.0	4.6	4.9
M_c/M_w	500	3800	480	730	2200
χ^2_{red}	0.14	0.10	0.12	0.20	1.8
M_{gas}/M_c	200	190	150	120	160

- 24mm – 500mm
- two grey-body components needed
- cold component: dust temperatures drop from 24K in inner parts to 13K in the outer regions.
- The warm component is not well constrained
  - 1 < b < 2 provide reasonably well fits

Kramer, Xilouris et al. 2010

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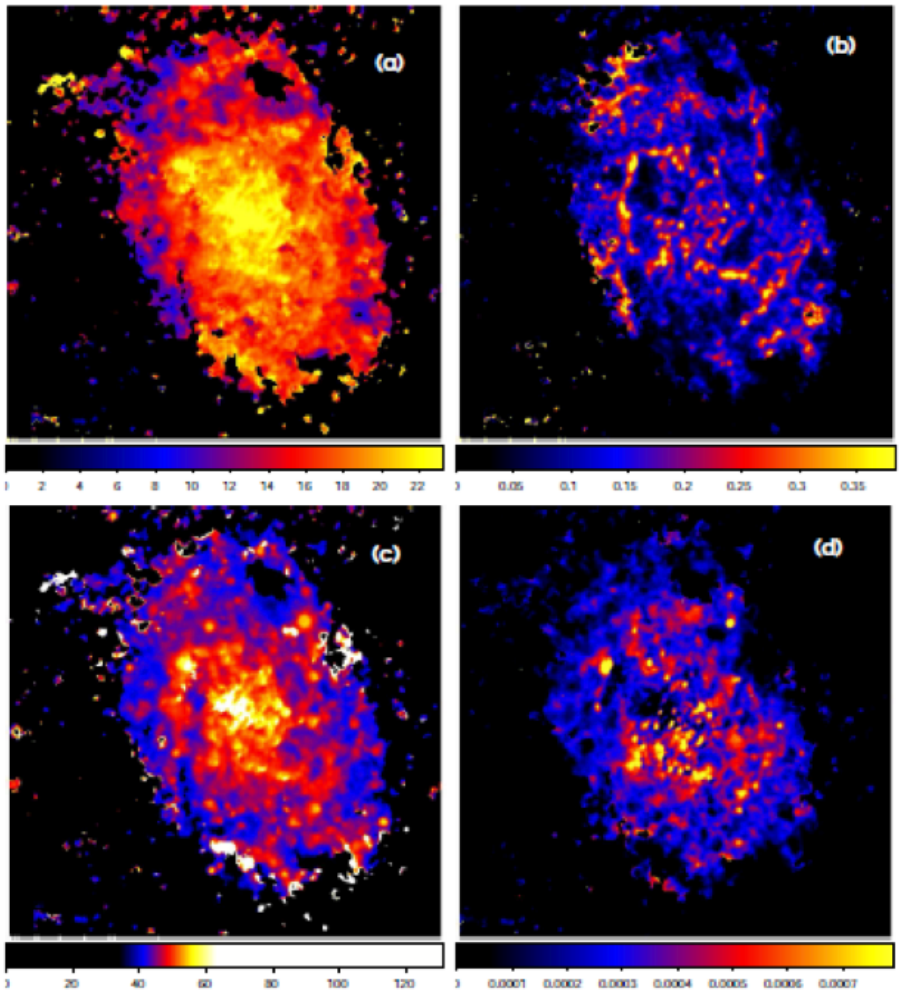
Warm and Cold dust traces SF and Arms, respectively



- Two-component grey-body fit to 24, 100, 160, 250, 350, 500um data sets
- Preliminary results:
  - Cold dust traces spiral arms.
  - Warm dust traces bright HII regions.
  - Caveat: due to the degeneracy of fits at individual positions, the warm component is often ill-defined

Xilouris, Tabatabaei et al. 2010 in prep.

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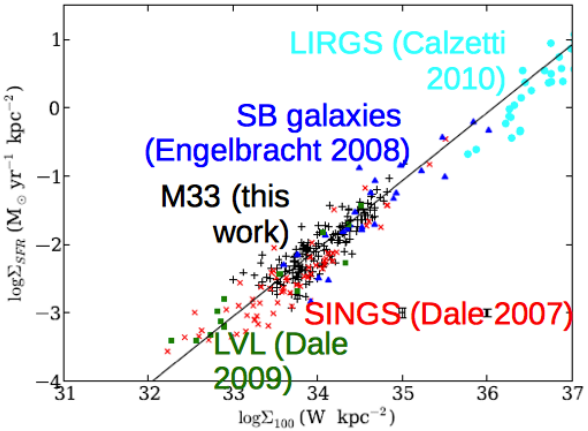
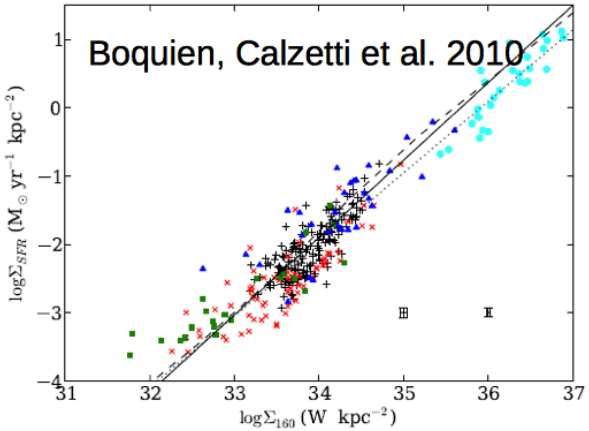
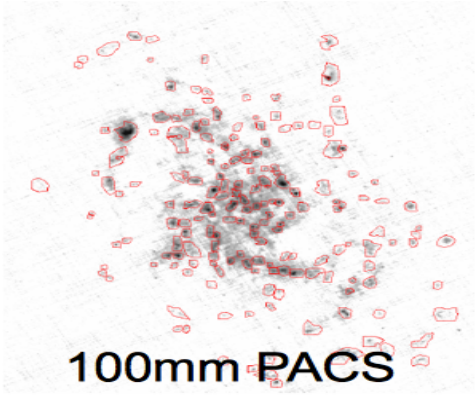
100um and 160um Trace SF well





- H-alpha emission is used to indicate SFR and Identify regions
- The SFR are plotted against corresponding 100, 160 um fluxes
- These are compared with global values for a variety of galaxy types
- Empirical laws derived:



$$\log \Sigma_{SFR} = (0.99 \pm 0.03) \log \Sigma_{100} - (35.84 \pm 0.83)$$
$$\log \Sigma_{SFR} = (1.12 \pm 0.03) \log \Sigma_{160} - (40.42 \pm 0.99)$$

- The Individual M33 SF regions exhibit similar scaling as entire galaxies Including a local volume limited sample (LVL) and Sarbursts (SB).
- 100mm and 160mm fluxes are see as linear estimators of the SFR (Boquien et al. 2010). 250mm fluxes as well (Verley et al. 2010).
- Only 25% of total 160mm flux identified in 179 sources, indicating large-scale diffuse non-ionizing emission.

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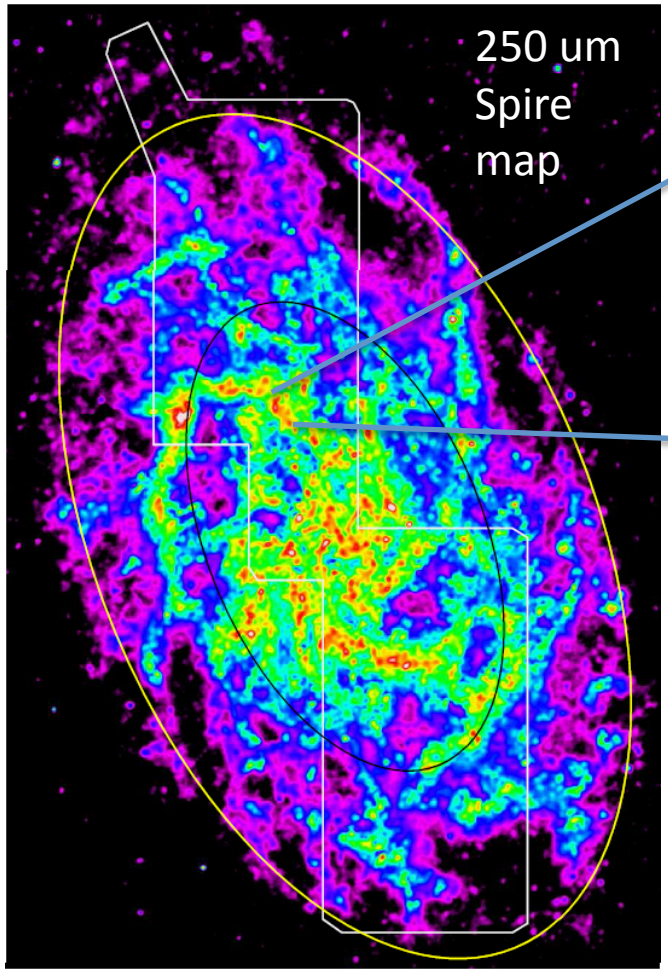
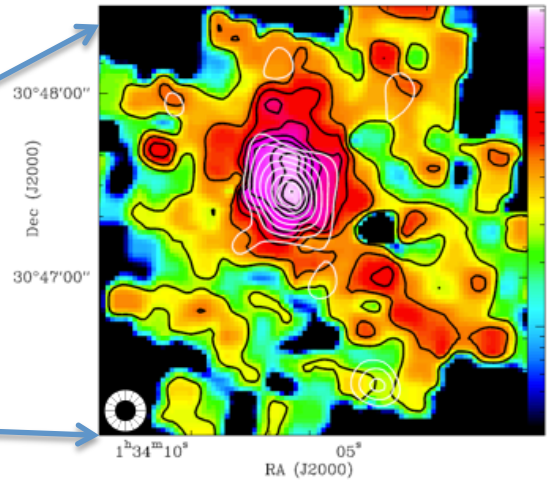
Spectral Analyses on Preliminary Data
(most Herschel Data is coming Jan 2011)





[CII] = Colored contours
[OI] = White contours

- Mapped one HII region in [CII] and [OI]
- 12” and 5” resolution
- 50 pc and 20 pc resolution

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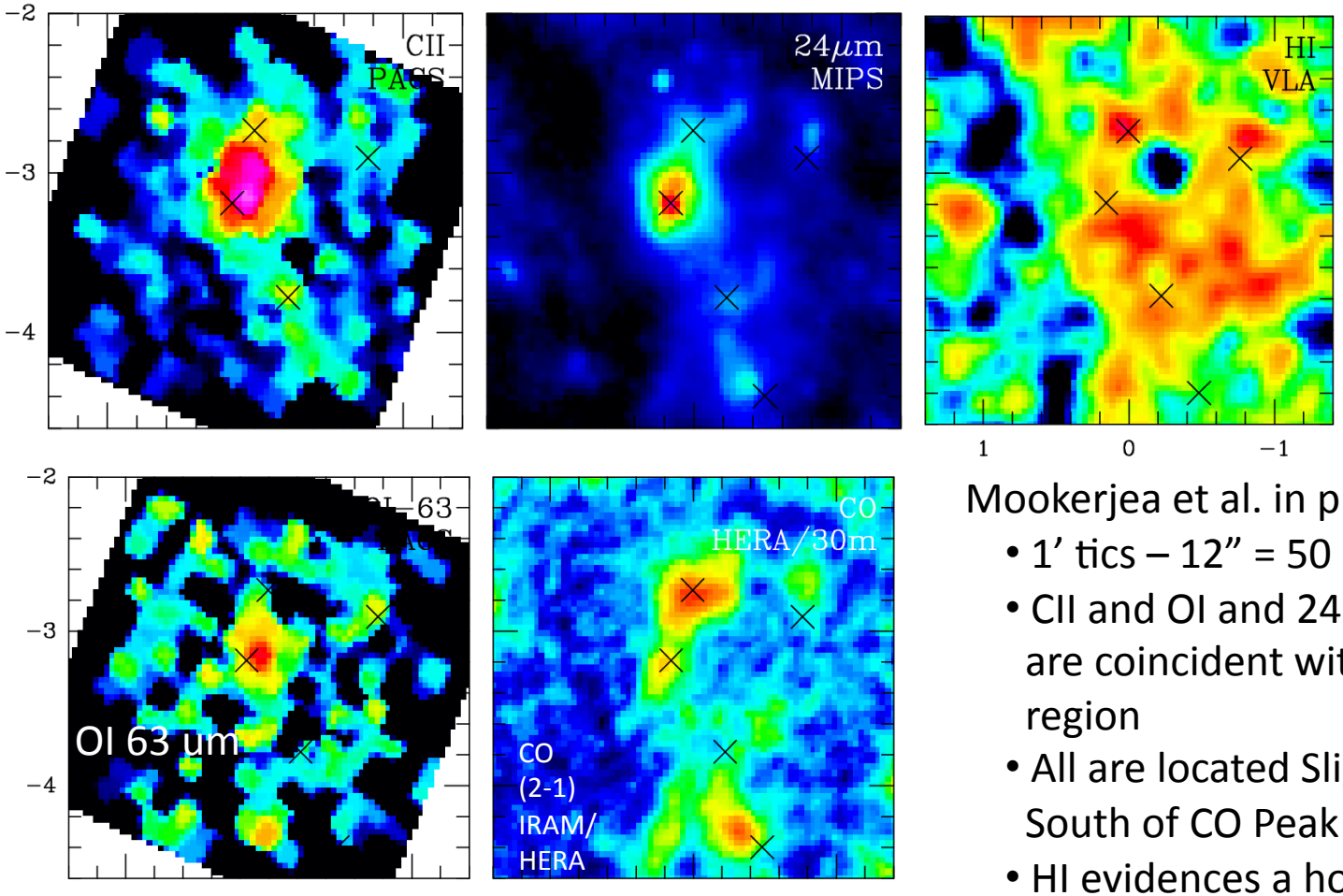
Compare: Fine structure Lines, CO, Mid-IR Continuum and HI



Mookerjea et al. in preparation, 2011.

- 1’ tics – 12” = 50 pc
- CII and OI and 24um are coincident with HII region
- All are located Slightly South of CO Peak
- HI evidences a hole

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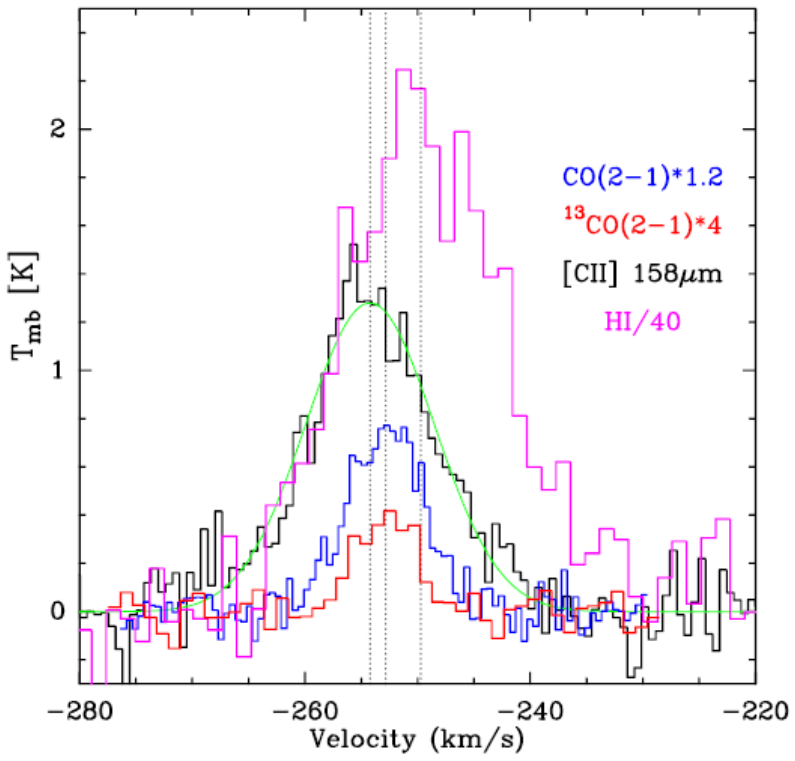
Velocities indicate gas association



- HI evidences a broader origin
- CO is systematically displaced 2 km/s from [CII] 158um
- This velocity displacement is being investigated on a fine spatial scale

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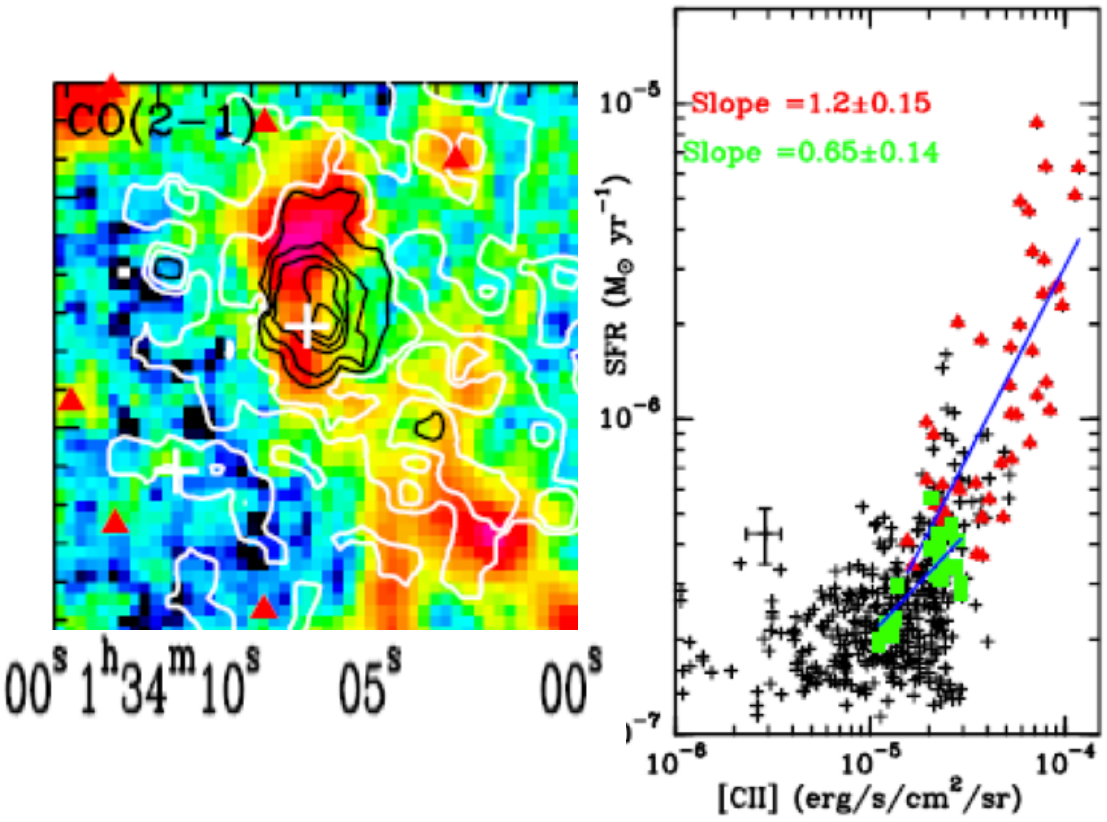
CII and Star formation



Mookerjea et al. in preparation, 2011.

- CII to SF correlation changes from inner (red points) HII region to outer (green points) to background (black points)
- Good correlation obtains with significant flux within 50 pc regions

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Summary for M33

- With preliminary data we have launched
- Dust investigations
  - Warm, cold and
  - very very cold (not presented here - Quintana-Lacaci's (in prep.)
- SFR Studies
  - HII heating molecular vs. atomic cooling, HI environment studies
  - Dust cross section study (not presented here - Braine et al. in prep)

  We have shown the value of these maps and now we prepare to do the whole strip with PACs [CII] and [OI]

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Part II
Things that worked for Herschel

Thoughts for SOFIA

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Herschel Things That worked

- A Science Center that sent its instrument "Liaisons" to spend time with the instrument development teams
  - Months working with the instrument teams on specific tasks
  - Got to know the personnel
  - Produced good communications to help solve problems quickly

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Herschel Things That worked

- Once calls for substantial observing time were issued – relentless workshops on observation planning were held
  - A proactive community outreach staff (newsletters, mailings)
  - A help desk with fast turnaround linked to one in Europe
- Once results were expected for substantial data return – relentless workshops on data reduction were held
  - The same two sub-bullets as above

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Development Cycle Controlled by JIRA

- JIRA is a development system that has allowed about 200 Herschel scientists and developers to work together in a distributed manner to track problems and fixes and needs and solutions in the Herschel System. It has organized and made visible work problems and progress
- It would also be appropriate to any size projects
- JIRA organizes problems and solution by types, and groups, by reporter and assignee, and allows for conversation, attachment and time tracking.
- JIRA works very very well
- See screen shots attached

- **JIRA's name derives from Gojira is Japanese and roughly translated as "gorilla the size of a whale"!**

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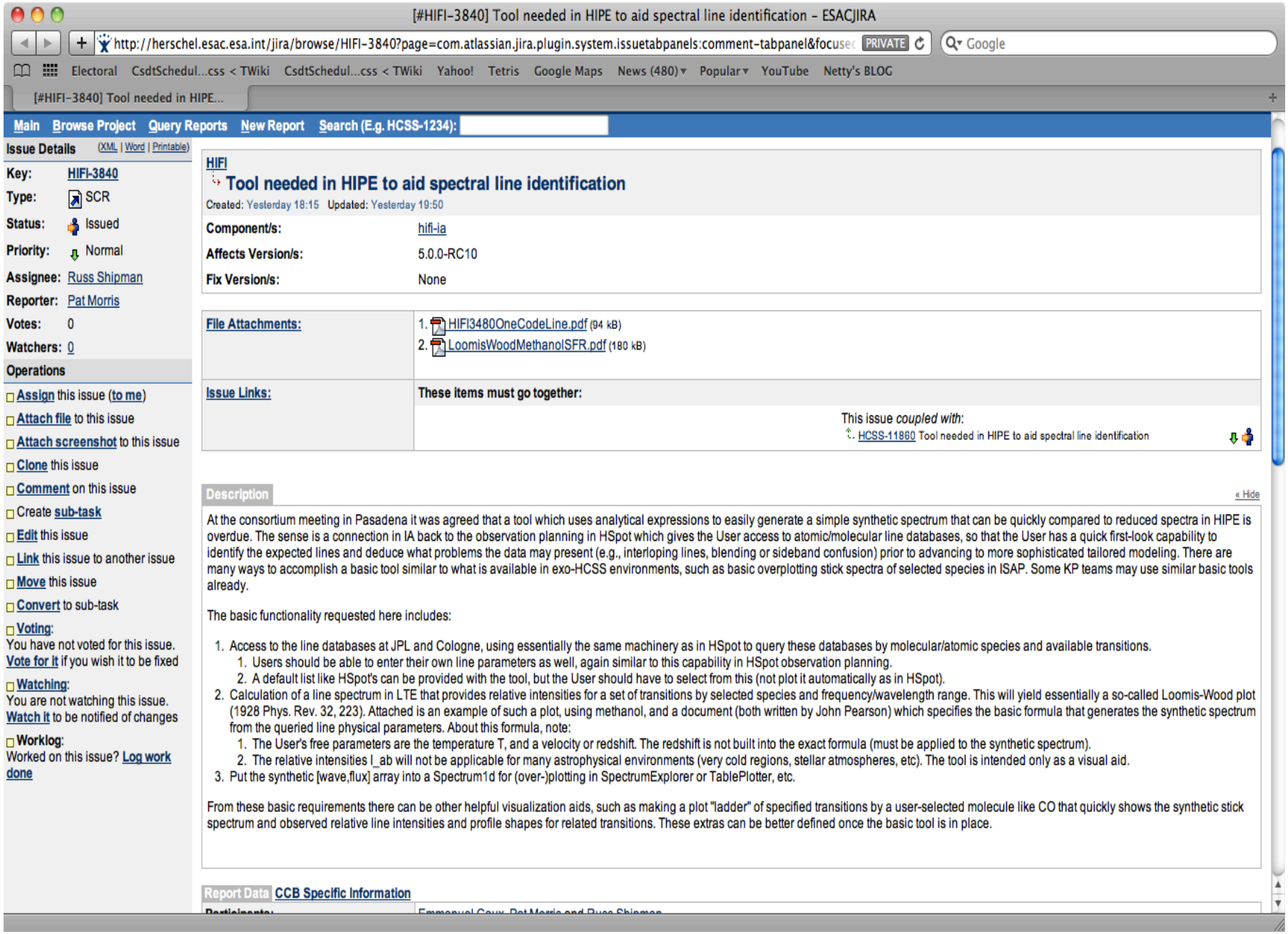

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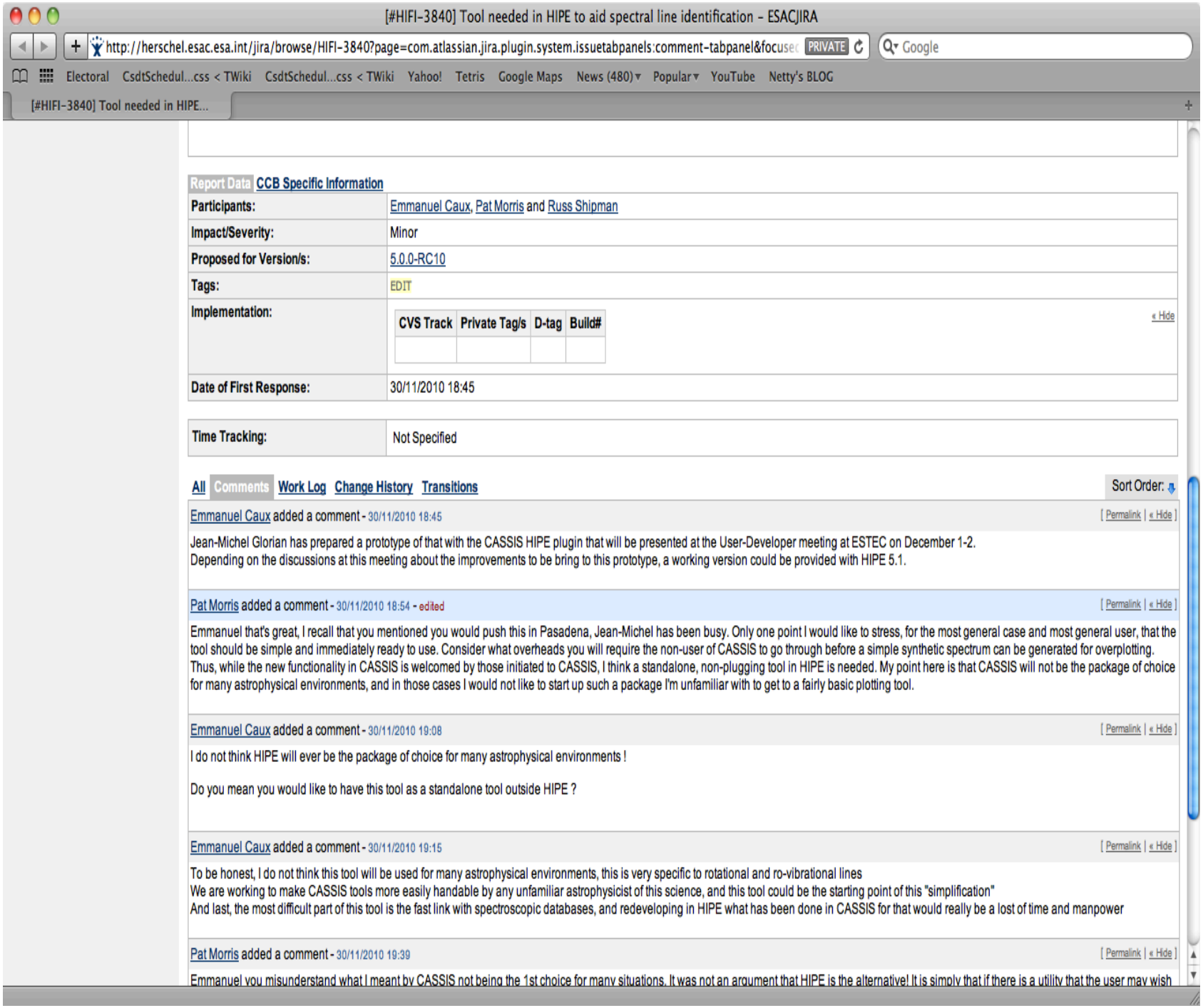
[#HIFI-3840] Tool needed in HIPE to aid spectral line identification - ESACJIRA
http://herschel.esac.esa.int/jira/browse/HIFI-3840?page=com.atlassian.jira.plugin.system.issuetabpanels:comment-tabpanel&focuse
PRIVATE
Google
Electoral
CsdtSchedul...css < TWiki
CsdtSchedul...css < TWiki
Yahoo!
Tetris
Google Maps
News (480)
Popular
YouTube
Netty's BLOG
[#HIFI-3840] Tool needed in HIPE...
Report Data
CCB Specific Information
Participants:
Emmanuel Caux, Pat Morris and Russ Shipman
Impact/Severity:
Minor
Proposed for Version/s:
5.0.0-RC10
Tags:
EDIT
Implementation:
CVS Track
Private Tag/s
D-tag
Build#
« Hide
Date of First Response:
30/11/2010 18:45
Time Tracking:
Not Specified
All
Comments
Work Log
Change History
Transitions
Sort Order:
Emmanuel Caux added a comment - 30/11/2010 18:45
[Permalink | « Hide]
Jean-Michel Glorian has prepared a prototype of that with the CASSIS HIPE plugin that will be presented at the User-Developer meeting at ESTEC on December 1-2.
Depending on the discussions at this meeting about the improvements to be bring to this prototype, a working version could be provided with HIPE 5.1.
Pat Morris added a comment - 30/11/2010 18:54 - edited
[Permalink | « Hide]
Emmanuel that's great, I recall that you mentioned you would push this in Pasadena, Jean-Michel has been busy. Only one point I would like to stress, for the most general case and most general user, that the tool should be simple and immediately ready to use. Consider what overheads you will require the non-user of CASSIS to go through before a simple synthetic spectrum can be generated for overplotting.
Thus, while the new functionality in CASSIS is welcomed by those initiated to CASSIS, I think a standalone, non-plugging tool in HIPE is needed. My point here is that CASSIS will not be the package of choice for many astrophysical environments, and in those cases I would not like to start up such a package I'm unfamiliar with to get to a fairly basic plotting tool.
Emmanuel Caux added a comment - 30/11/2010 19:08
[Permalink | « Hide]
I do not think HIPE will ever be the package of choice for many astrophysical environments !
Do you mean you would like to have this tool as a standalone tool outside HIPE ?
Emmanuel Caux added a comment - 30/11/2010 19:15
[Permalink | « Hide]
To be honest, I do not think this tool will be used for many astrophysical environments, this is very specific to rotational and ro-vibrational lines
We are working to make CASSIS tools more easily handable by any unfamiliar astrophysicist of this science, and this tool could be the starting point of this "simplification"
And last, the most difficult part of this tool is the fast link with spectroscopic databases, and redeveloping in HIPE what has been done in CASSIS for that would really be a lost of time and manpower
Pat Morris added a comment - 30/11/2010 19:39
[Permalink | « Hide]
Emmanuel you misunderstand what I meant by CASSIS not being the 1st choice for many situations. It was not an argument that HIPE is the alternative! It is simply that if there is a utility that the user may wish

HSPOT

- HSPOT is the only way to plan observations for Herschel. It serves to unite many aspects of the project
  - AOT definitions and usage
  - AOR definition, limits, visualization
  - AOR instantiation to command code
  - AOR time estimates (instrument sensitivities)
  - Normal and unusual schedule requirements
  - See screen shot:

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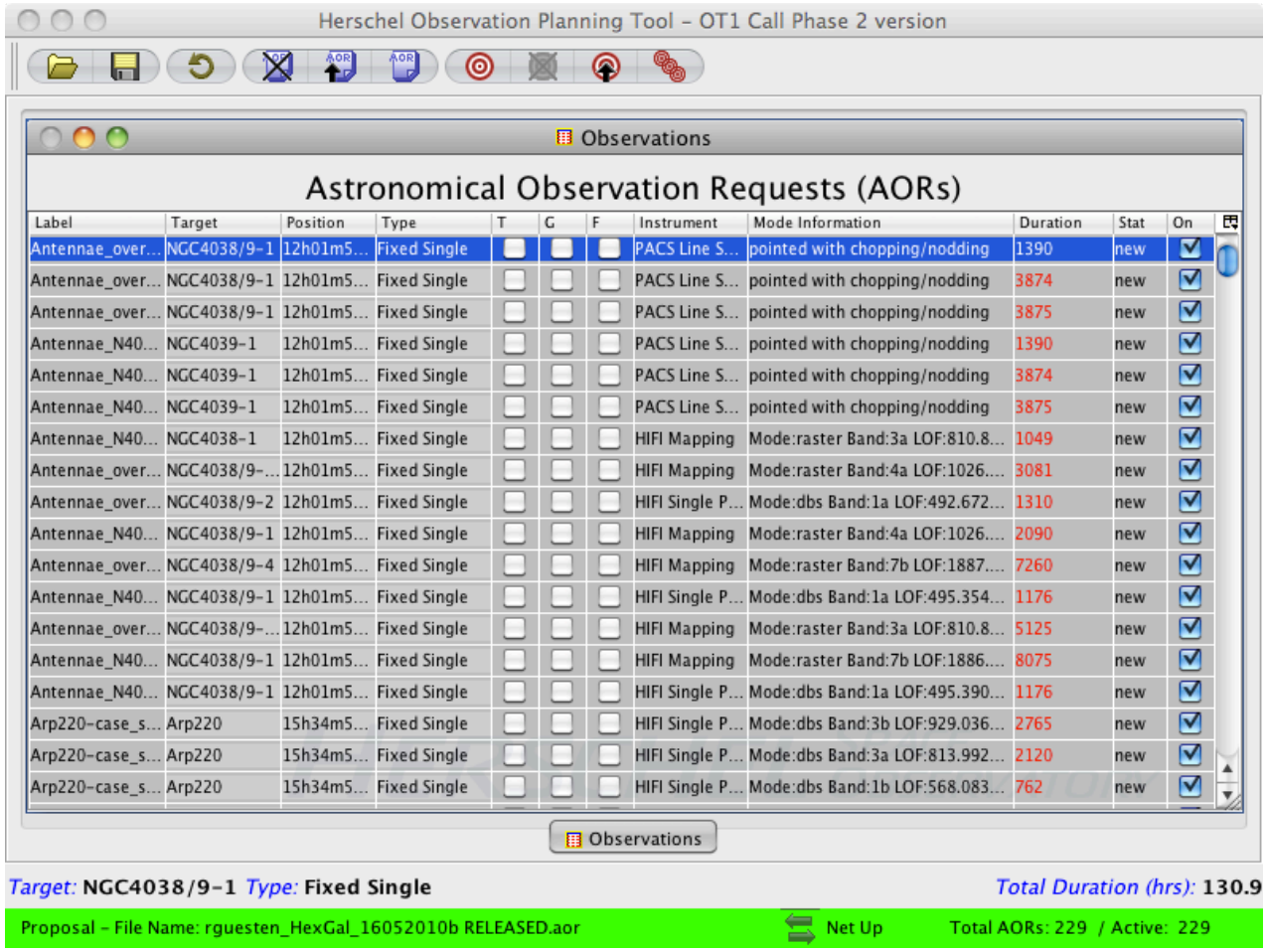
AORs for a Proposal



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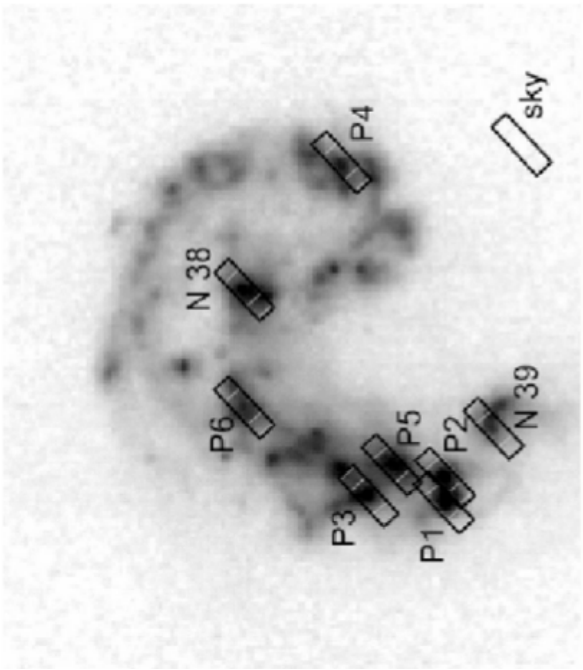
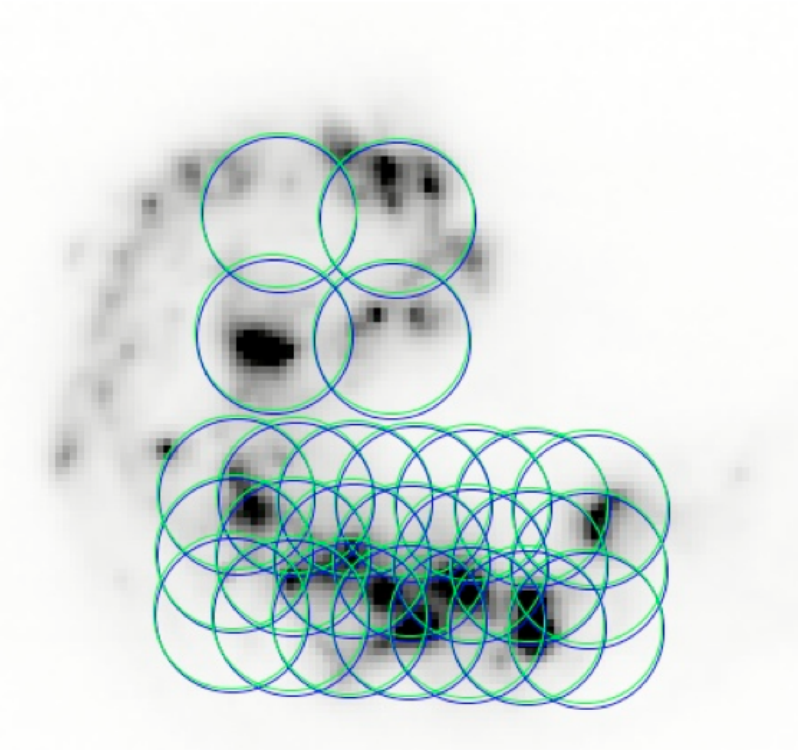
Visualizing for a program

HEXGAL [CI] 810 GHz (0.47, 3.8h)





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Aside – my major contribution to Herschel

- The production of a simple single sideband spectrum of all HIFI spectroscopic surveys is done through iterative deconvolution.
- At IPAC we took the existing method (developed by Schilke and Comito) and put it into the Herschel Data deduction environment (JAVA) – that is – we made it a normal Herschel Tool
- The next slide shows an example

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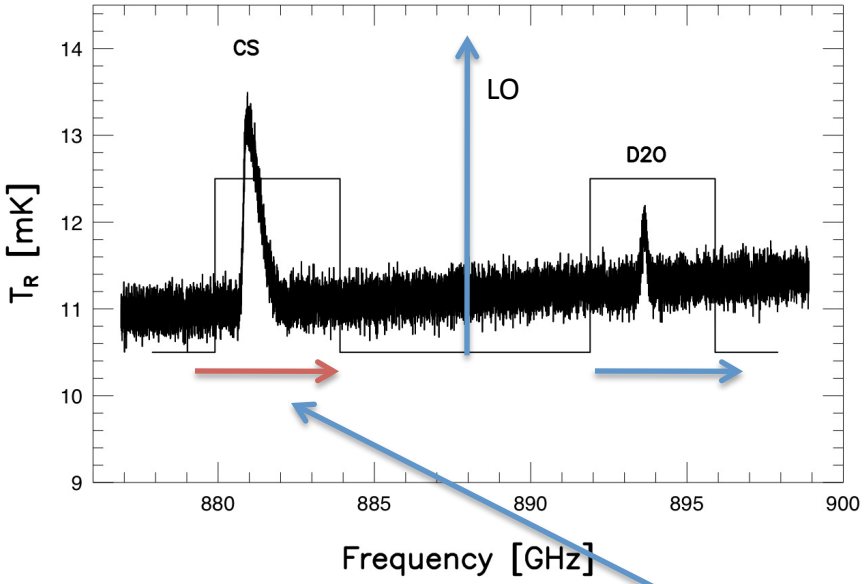
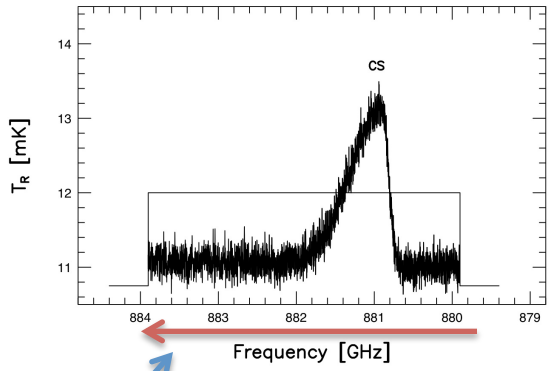
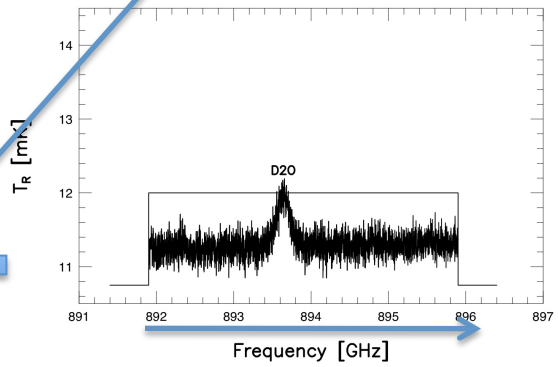
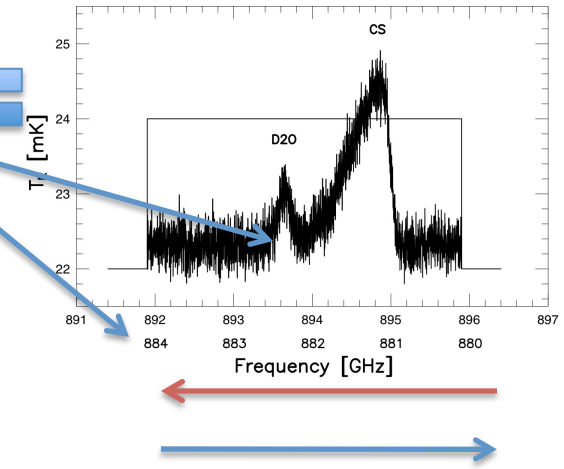
LSB + USB = DSB







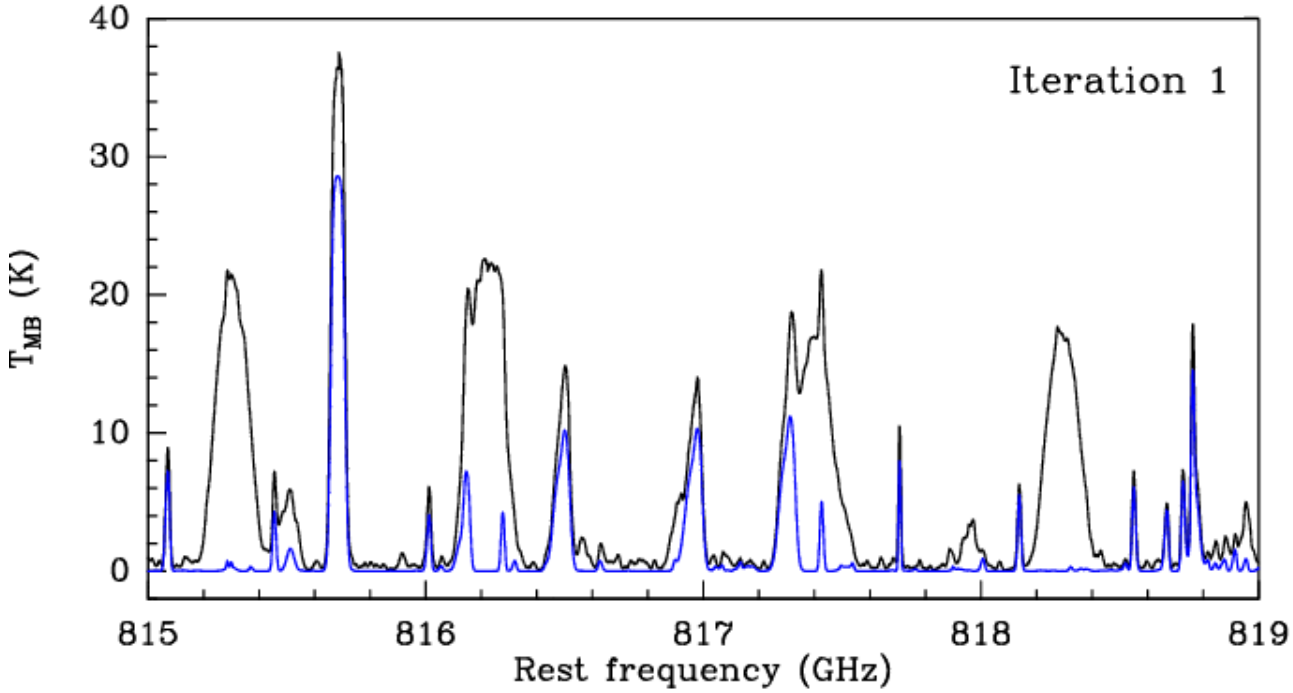


- Lower sideband spectrum is reversed and added
- Two frequency scales result in the DSB result
- The lines may blend but they can be recovered (deconvolved)
- The continuum levels add (double) in the DSB
- The continuum slope is flattened but may be recovered (deconvolved)
- The noise adds in quadrature , increasing as sqrt(2)

The Solution of the Problem

- Start with a guess of the answer – a model with no assumptions for the SSB spectrum – flat
- "Observe it" – using knowledge of the instrument
- compare the observations of the model with the real observations
- compute a chi square and a delta (differential) chi-square)
- each model "spectral channel" was in part responsible for some of the chi square change
- follow the slope of the chi square downward
- always move at right angles – thus Conjugate Gradient Method
- Stop when asymptote is reached

An example with simulated data



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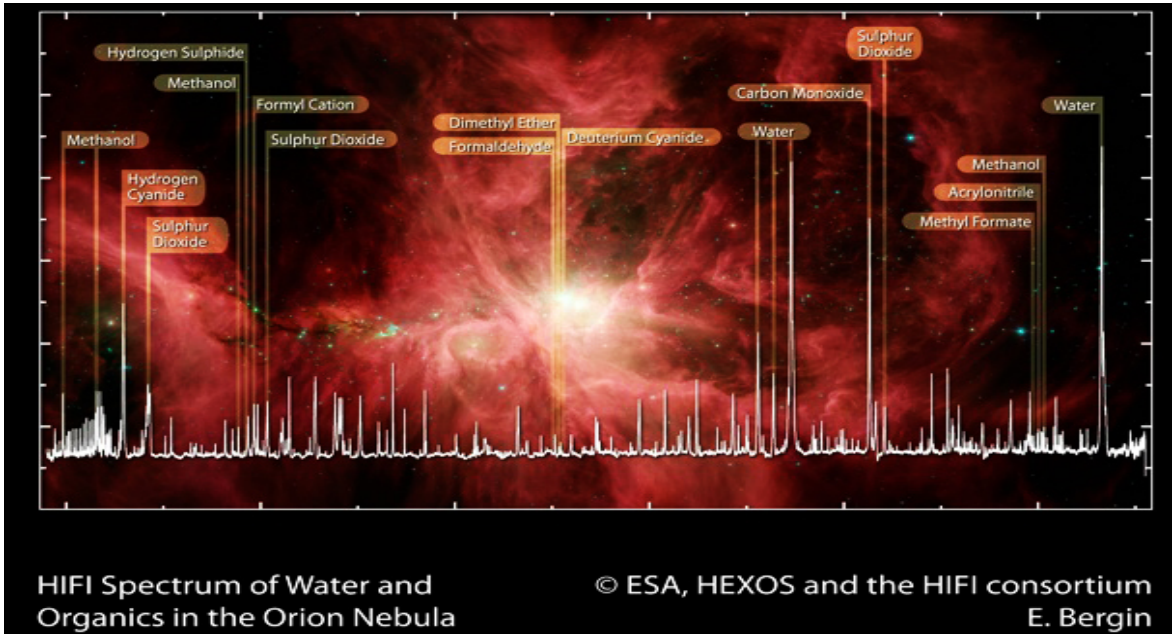
The Molecule Factory of the Orion Bar was deconvolved with this software

- Press release - Bergin et al. 2010



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Other Herschel Project Efforts

- HIPE – Herschel Interactive Processing environment
  - Distributed
  - JAVA / Jython environment
  - Used in the piplines and to some extent beyond (Level 2) in reducing/Analyzing data
  - Is cumbersome but gets the job done.
  - I don't imagine another observatory will use it

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For SOFIA - ATRAN

- I developed ATRAN in 1991. It has been improved and is in wide use
- Since SOFIA is getting SPOT, I have been asked to install an ATRAN server for this effort which I will do.
- ATRAN:
  - Models the Earth Atmosphere Transmittance from 0.8 um to 1 mm
  - It uses approximately 400,000 transition from 7 different molecular species (a subset of the HITRAN database)
  - Allows for "Tank" measurement or differing Atmosphere distribution (O3, H2O, etc.)
  - Compute the transmittance spectrum rapidly using knowledge of "line density per wave number" and whne to stop looking at faint lines or wings.
  - It is working at about 100 installations.

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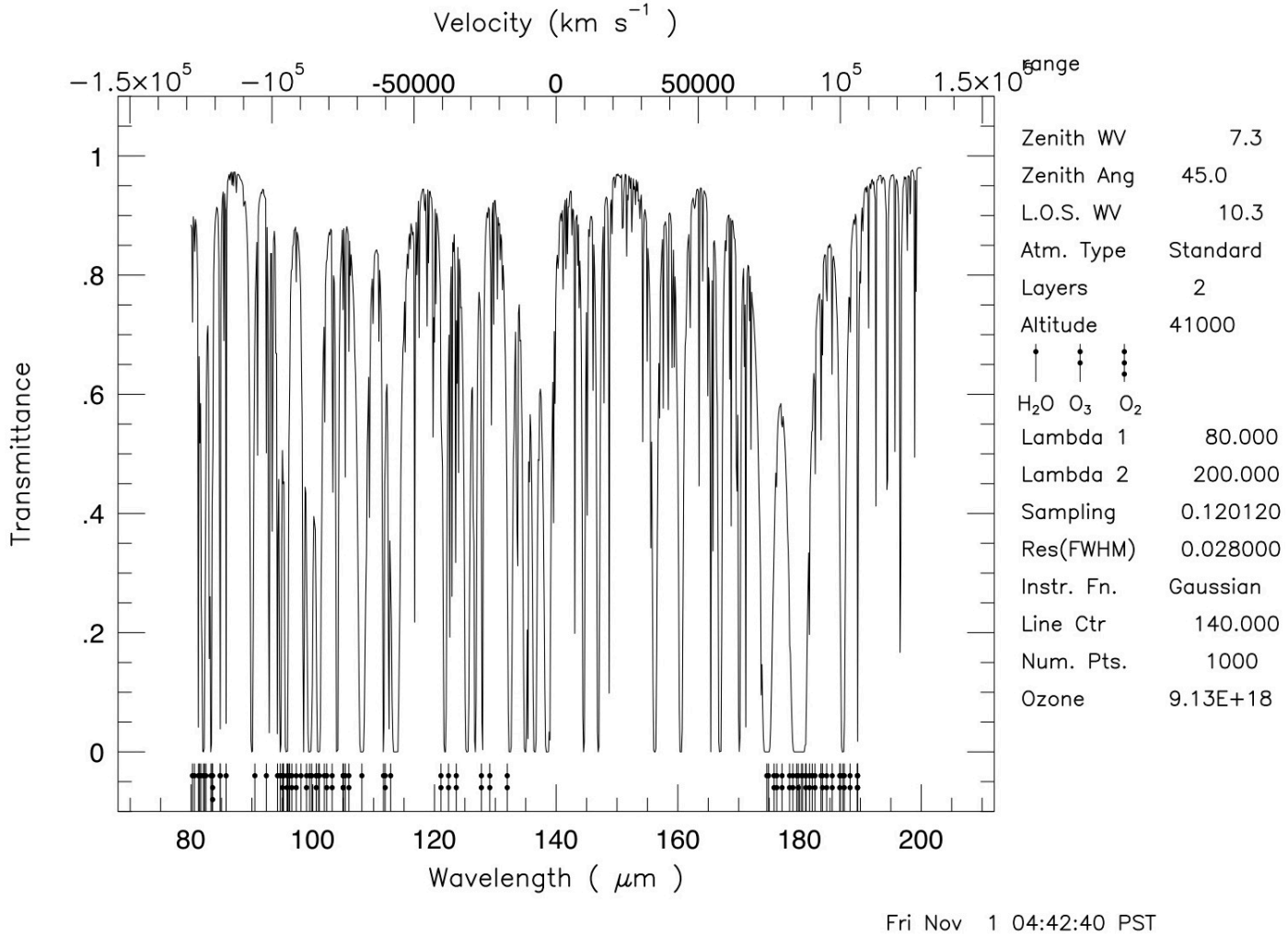
Example ATRAN output



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Possible Improvement to ATRAN

- Updated Line List
- Include more species
- Double Precession
- Modern Language
- Line Width improvements? Possible?
- So-called “dry continuum” improvements? Possible?
- More (expect lists from SOFIA Ames and DSI)

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