



Herschel M33 Key Project

HERM33ES

And

Operational thoughts on two Observatories: Herschel and SOFIA
Steve Lord (IPAC/Caltech)

Part I

HerM33es

1 Dec 2010, SOFIA Telecon

Steve Lord, NASA Herschel Science Center
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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)

Herschel M33 Open Time Key Project

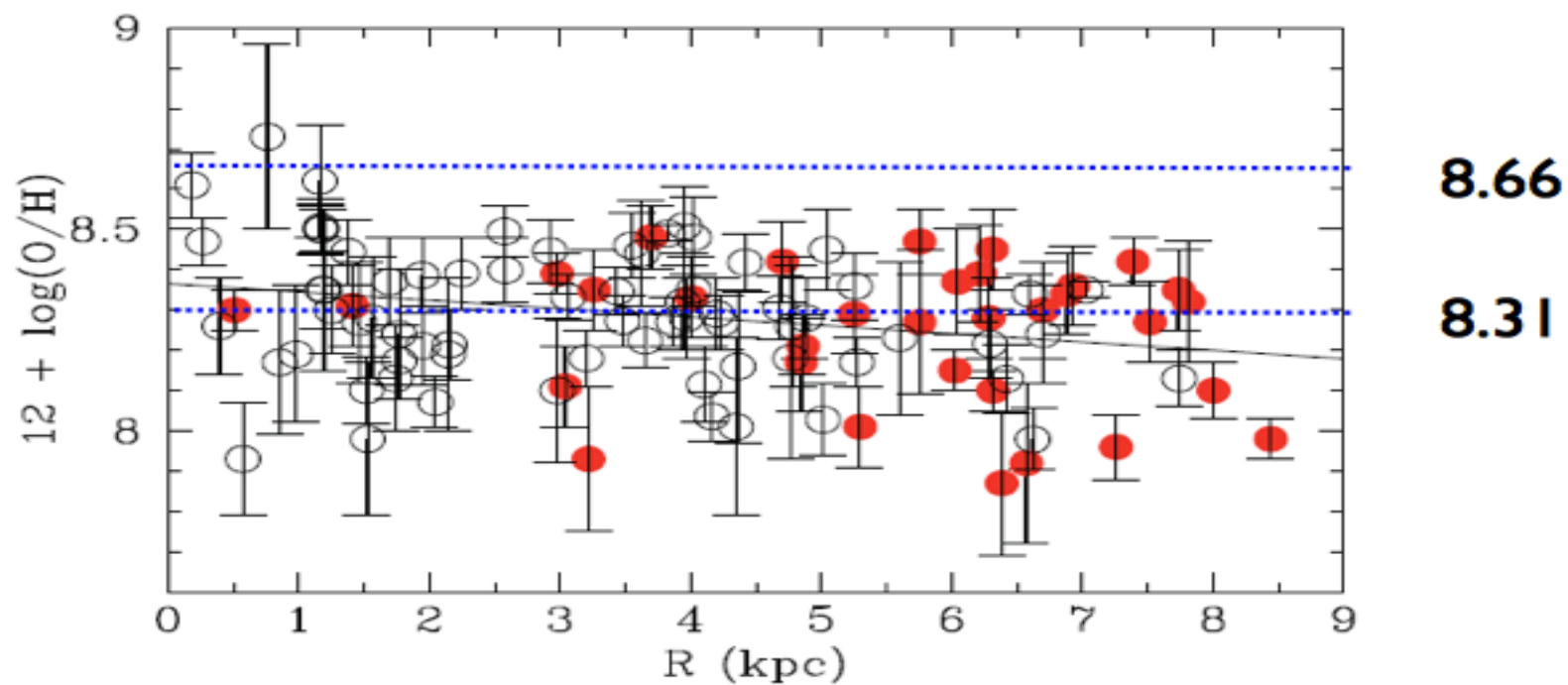
- **PI: Carsten Kramer (IRAM)**
- **The HERM33S Team:** Carsten Kramer, Steve Lord, Daniela Calzetti, Jonathan Braine, Gordon Stacey, Susanne Aalto, Rainer Beck, Frank Bertoldi, Santiago Garcia-Burillo, Francoise Combes, Michael Dumke, Rolf Guesten, Christian Henkel, Frank Israel, Baerbel Koribalski, 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

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

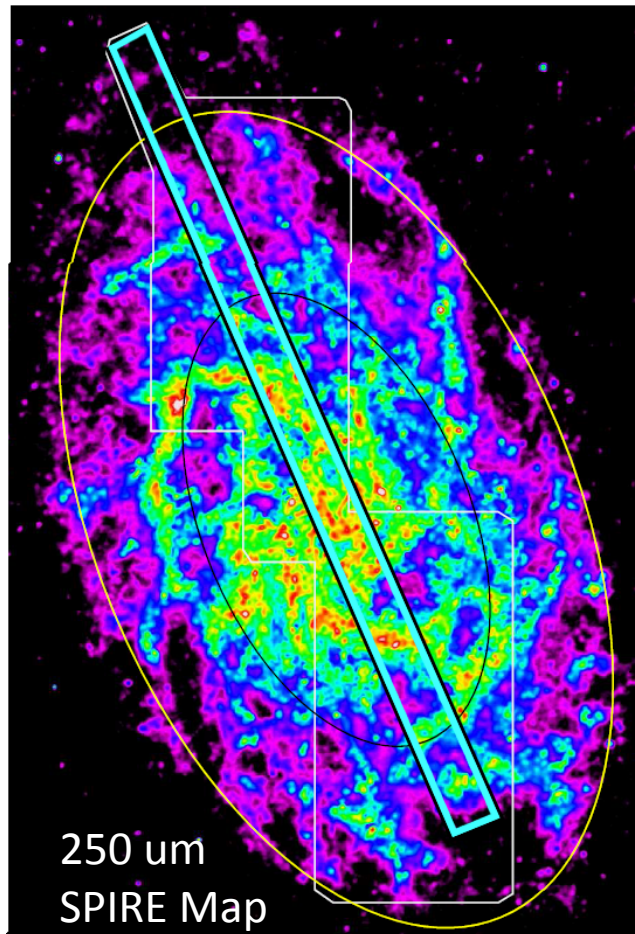


M33 metallicity with radius $\text{Log}(\text{O}/\text{H})+12$ vs. Solar



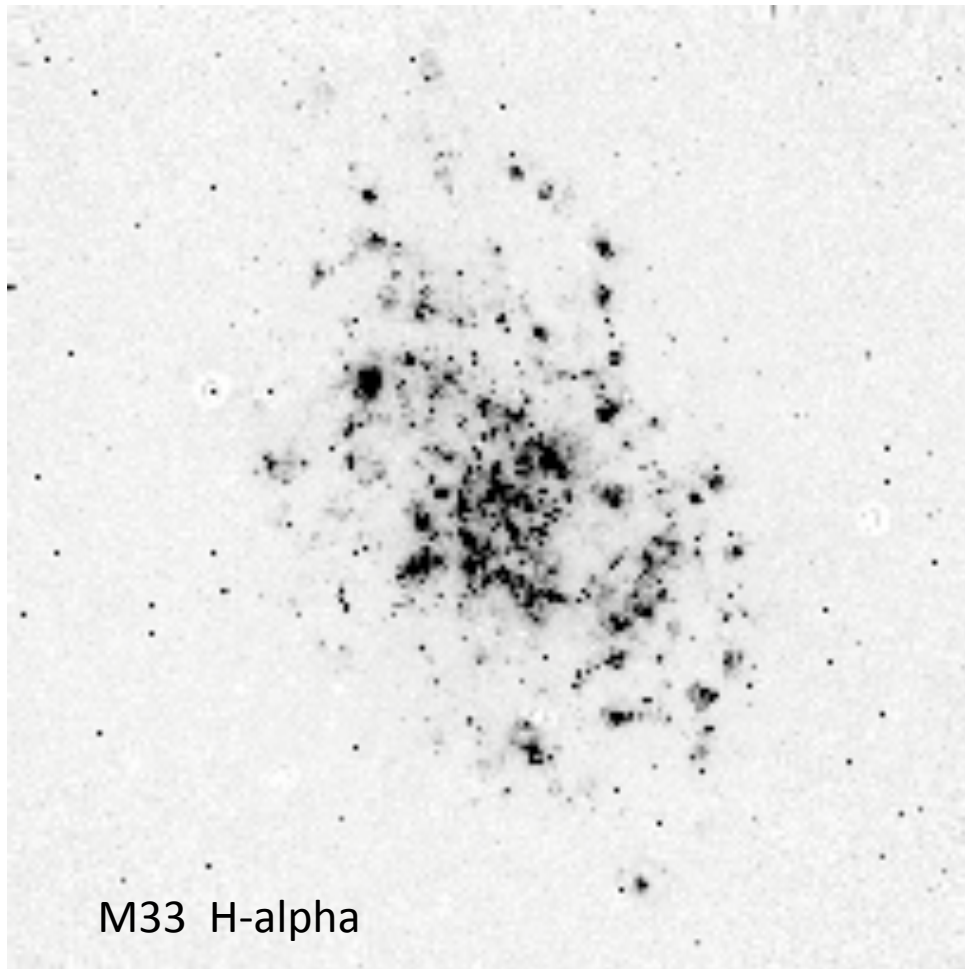
Magrini et al. 2009

Open Time Key Project Overview



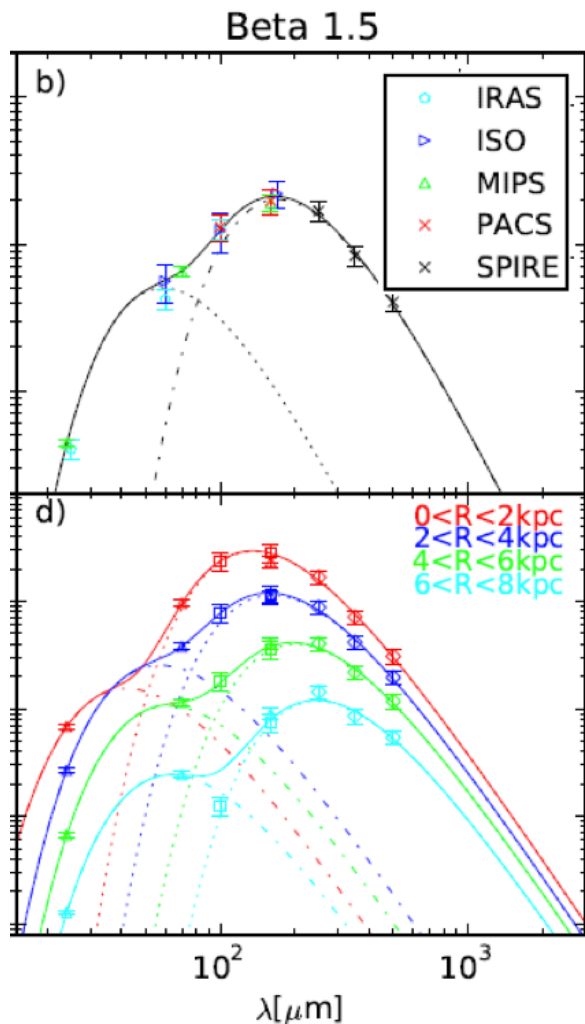
- 191 Hours of Observing time
- Map the entire Galaxy:
 - 6hrs: PACS (75, 100, 170um) & SPIRE (250, 350, 500um) photometry 70'x70' (done)
- Observe Strip along major axis out to 8kpc:
 - PACS spectroscopy, 42 hrs: [CII] 158, [OI] 63,145, [NII] 122,205 (1 hr done)
 - HIFI spectroscopy, 143 hrs: [CII]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

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

Dust Components with Radius



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

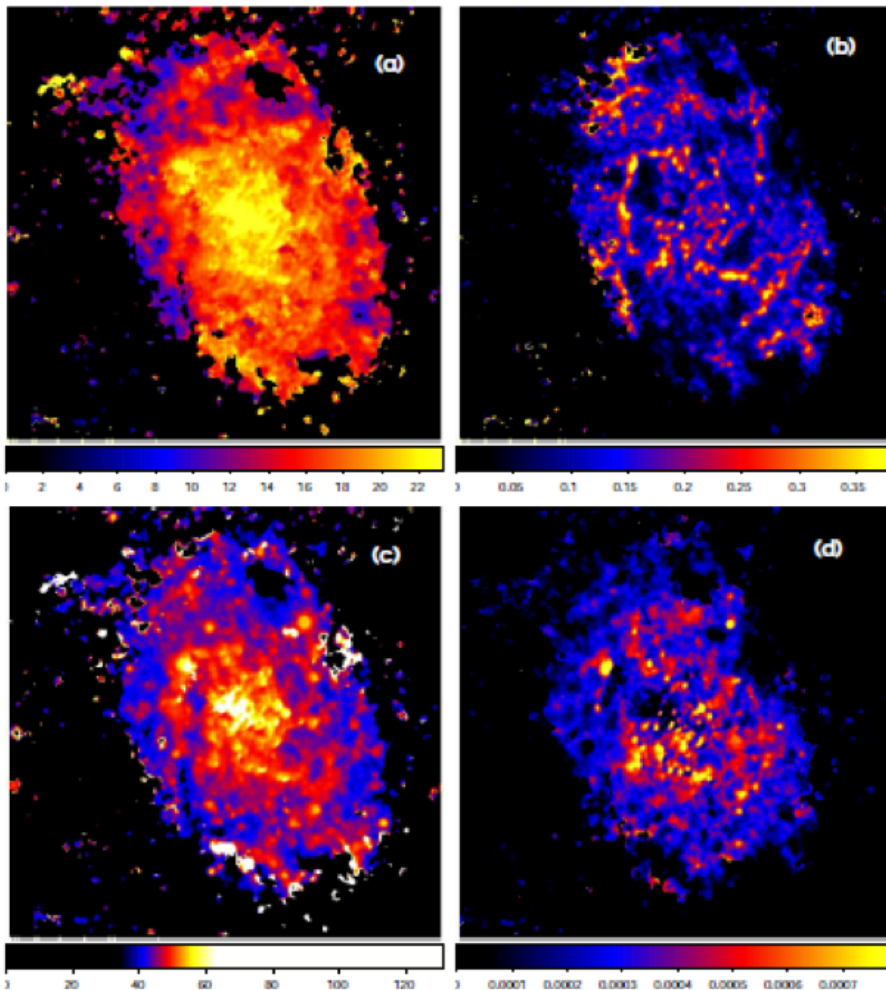
$$\kappa_\nu = 0.04 (\nu / 250 \text{GHz})^\beta \quad (\text{Kruegel \& Siebenmorgen 1994})$$

	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

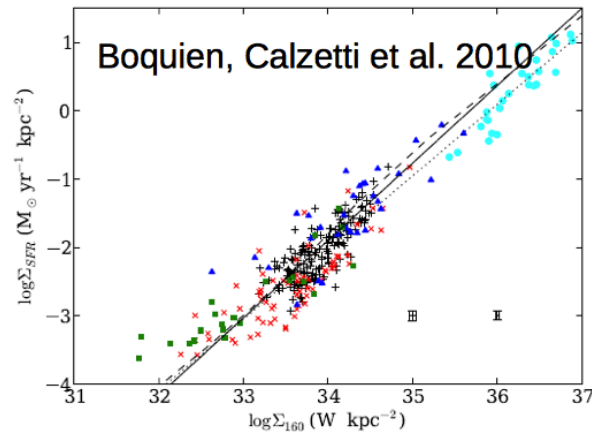
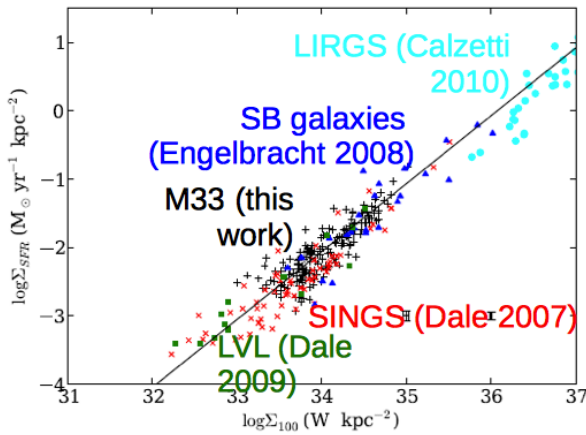
Warm and Cold dust traces SF and Arms, respectively



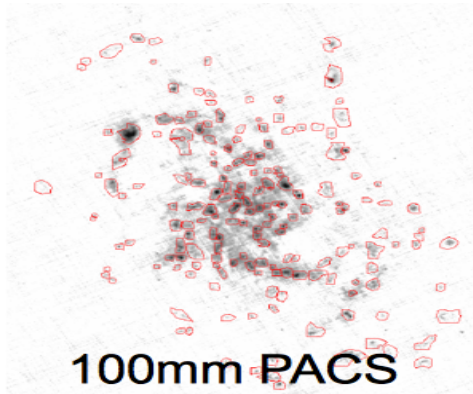
- Two-component grey-body fit to 24, 100, 160, 250, 350, 500um data sets
- Preliminary results:
 - Cold dust traces spiral arms.
 - Warm dust traces bright HII regions.
 - Caveat: due to the degeneracy of fits at individual positions, the warm component is often ill-defined

Xilouris, Tabatabaei et al. 2010
in prep.

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:



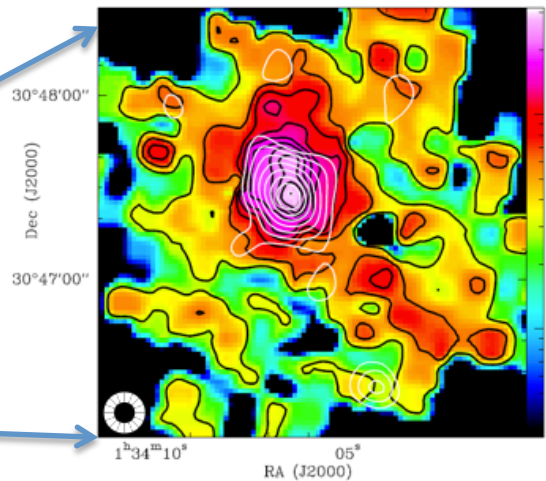
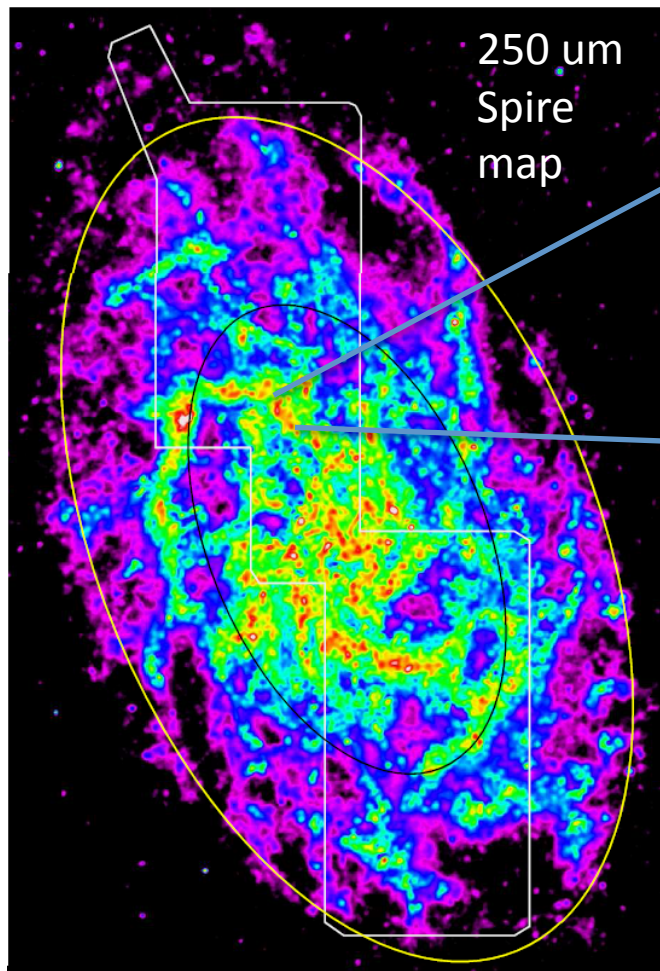
100mm PACS
map with
identified
regions

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

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

- 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.

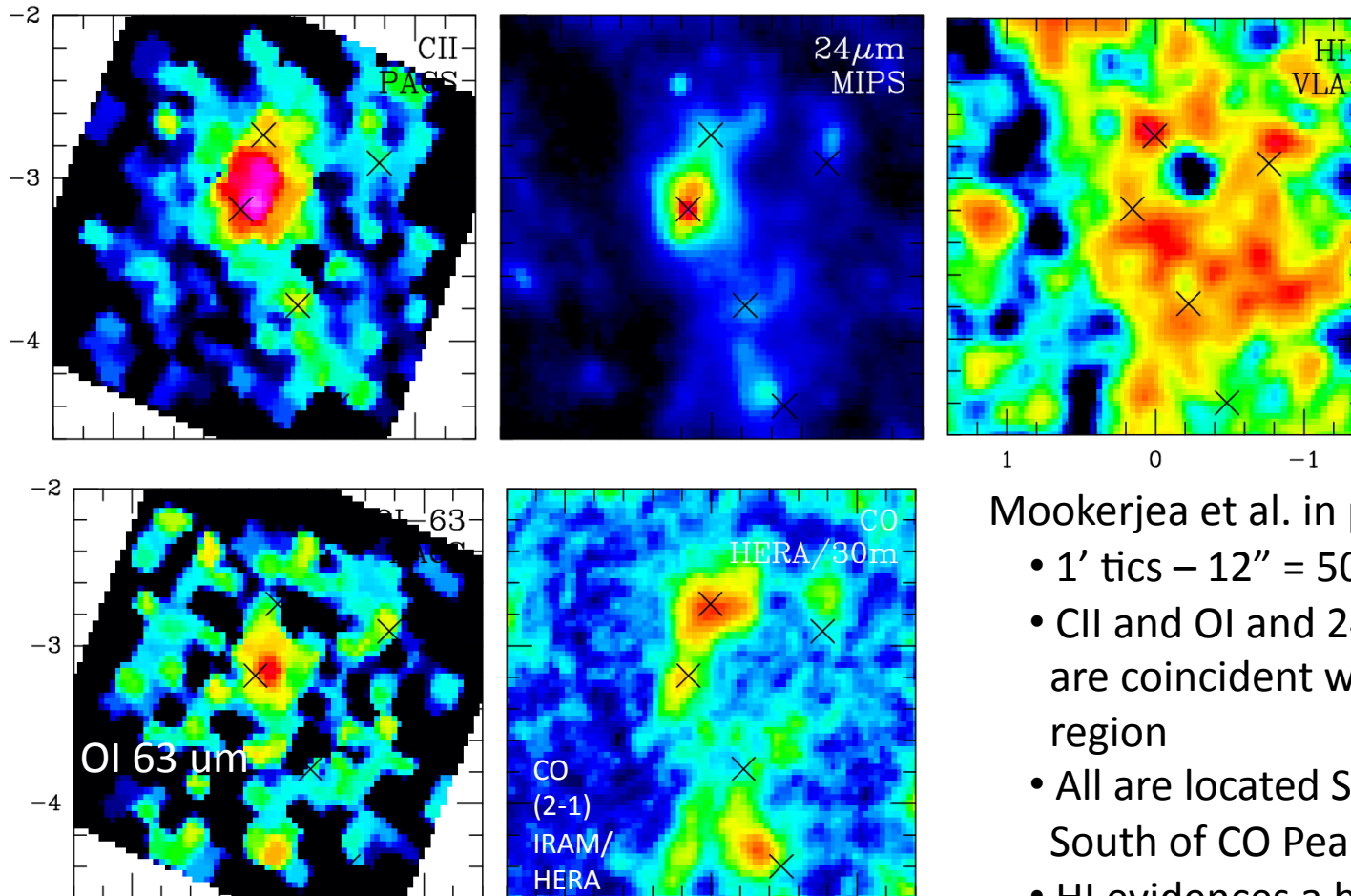
Spectral Analyses on Preliminary Data (most Herschel Data is coming Jan 2011)



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

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

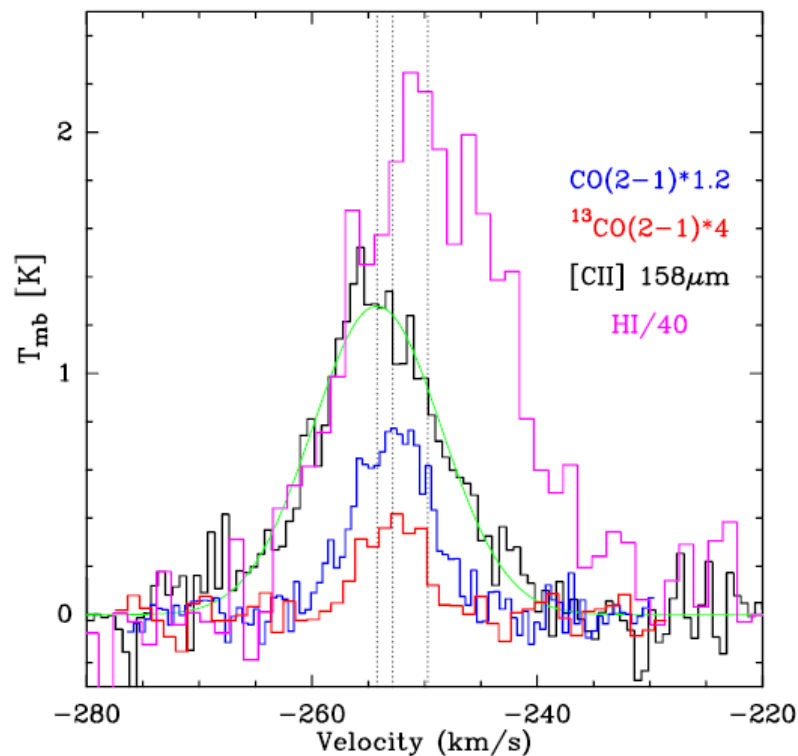
Compare: Fine structure Lines, CO, Mid-IR Continuum and HI



Mookerjea et al. in preparation, 2011.

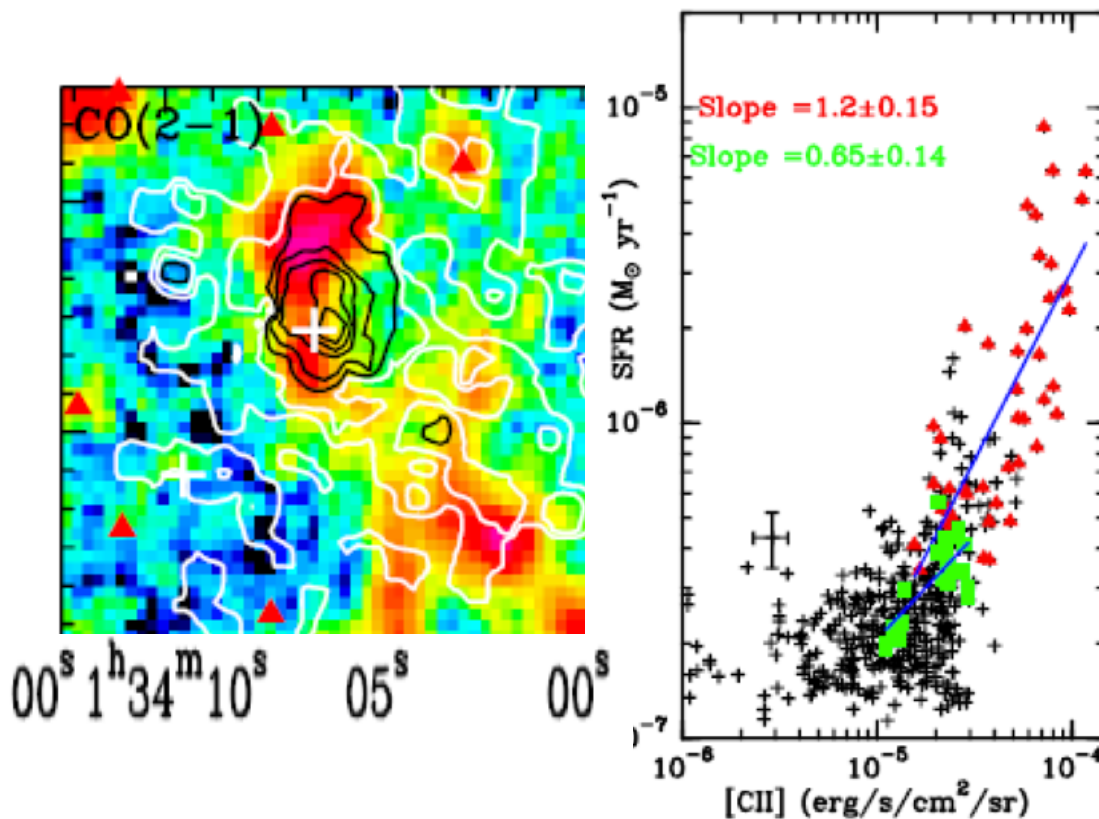
- 1' tics – 12" = 50 pc
- CII and OI and 24 μ m are coincident with HII region
- All are located Slightly South of CO Peak
- HI evidences a hole

Velocities indicate gas association



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

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

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]

Part II

Things that worked for Herschel

Thoughts for SOFIA

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

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

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"!**

[#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&focuser=PRIVATE

Electoral CsdtdSchedul...css < TWiki CsdtdSchedul...css < TWiki Yahoo! Tetris Google Maps News (480) Popular YouTube Netty's BLOG

[#HIFI-3840] Tool needed in HIPE...

Main Browse Project Query Reports New Report Search (E.g. HCSS-1234):

Issue Details (XML | Word | Printable)

Key: [HIFI-3840](#)

Type: SCR

Status: Issued

Priority: Normal

Assignee: [Russ Shipman](#)

Reporter: [Pat Morris](#)

Votes: 0

Watchers: 0

Operations

- [Assign](#) this issue (to me)
- [Attach file](#) to this issue
- [Attach screenshot](#) to this issue
- [Clone](#) this issue
- [Comment](#) on this issue
- Create [sub-task](#)
- [Edit](#) this issue
- [Link](#) this issue to another issue
- [Move](#) this issue
- [Convert](#) to sub-task
- Voting:**
You have not voted for this issue.
[Vote for it](#) if you wish it to be fixed
- Watching:**
You are not watching this issue.
[Watch it](#) to be notified of changes
- Worklog:**
Worked on this issue? [Log work done](#)

HIFI-3840
Tool needed in HIPE to aid spectral line identification
 Created: Yesterday 18:15 Updated: Yesterday 19:50

Component/s: [hifi-ia](#)

Affects Version/s: 5.0.0-RC10

Fix Version/s: None

File Attachments:

- [HIFI3480OneCodeLine.pdf](#) (94 kB)
- [LoomisWoodMethanolSFR.pdf](#) (180 kB)

Issue Links:

These items must go together:

This issue *coupled with*:
[HCSS-11860](#) Tool needed in HIPE to aid spectral line identification

Description Hide

At the consortium meeting in Pasadena it was agreed that a tool which uses analytical expressions to easily generate a simple synthetic spectrum that can be quickly compared to reduced spectra in HIPE is overdue. The sense is a connection in IA back to the observation planning in HSpot which gives the User access to atomic/molecular line databases, so that the User has a quick first-look capability to identify the expected lines and deduce what problems the data may present (e.g., interloping lines, blending or sideband confusion) prior to advancing to more sophisticated tailored modeling. There are many ways to accomplish a basic tool similar to what is available in exo-HCSS environments, such as basic overplotting stick spectra of selected species in ISAP. Some KP teams may use similar basic tools already.

The basic functionality requested here includes:

- Access to the line databases at JPL and Cologne, using essentially the same machinery as in HSpot to query these databases by molecular/atomic species and available transitions.
 - Users should be able to enter their own line parameters as well, again similar to this capability in HSpot observation planning.
 - A default list like HSpot's can be provided with the tool, but the User should have to select from this (not plot it automatically as in HSpot).
- Calculation of a line spectrum in LTE that provides relative intensities for a set of transitions by selected species and frequency/wavelength range. This will yield essentially a so-called Loomis-Wood plot (1928 Phys. Rev. 32, 223). Attached is an example of such a plot, using methanol, and a document (both written by John Pearson) which specifies the basic formula that generates the synthetic spectrum from the queried line physical parameters. About this formula, note:
 - The User's free parameters are the temperature T, and a velocity or redshift. The redshift is not built into the exact formula (must be applied to the synthetic spectrum).
 - The relative intensities I_{ab} will not be applicable for many astrophysical environments (very cold regions, stellar atmospheres, etc). The tool is intended only as a visual aid.
- Put the synthetic [wave,flux] array into a Spectrum1d for (over-)plotting in SpectrumExplorer or TablePlotter, etc.

From these basic requirements there can be other helpful visualization aids, such as making a plot "ladder" of specified transitions by a user-selected molecule like CO that quickly shows the synthetic stick spectrum and observed relative line intensities and profile shapes for related transitions. These extras can be better defined once the basic tool is in place.

Report Data [CCB Specific Information](#)

Participants: [Emmanuel Couv](#), [Pat Morris](#) and [Russ Shipman](#)

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:	<table border="1"> <thead> <tr> <th>CVS Track</th> <th>Private Tags</th> <th>D-tag</th> <th>Build#</th> </tr> </thead> <tbody> <tr> <td></td> <td></td> <td></td> <td></td> </tr> </tbody> </table>			CVS Track	Private Tags	D-tag	Build#					Hide
CVS Track	Private Tags	D-tag	Build#									
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 aroument 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:

AORs for a Proposal

Herschel Observation Planning Tool - OT1 Call Phase 2 version

Observations

Astronomical Observation Requests (AORs)

Label	Target	Position	Type	T	G	F	Instrument	Mode Information	Duration	Stat	On
Antennae_over...	NGC4038/9-1	12h01m5...	Fixed Single	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	PACS Line S...	pointed with chopping/nodding	1390	new	<input checked="" type="checkbox"/>
Antennae_over...	NGC4038/9-1	12h01m5...	Fixed Single	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	PACS Line S...	pointed with chopping/nodding	3874	new	<input checked="" type="checkbox"/>
Antennae_over...	NGC4038/9-1	12h01m5...	Fixed Single	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	PACS Line S...	pointed with chopping/nodding	3875	new	<input checked="" type="checkbox"/>
Antennae_N40...	NGC4039-1	12h01m5...	Fixed Single	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	PACS Line S...	pointed with chopping/nodding	1390	new	<input checked="" type="checkbox"/>
Antennae_N40...	NGC4039-1	12h01m5...	Fixed Single	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	PACS Line S...	pointed with chopping/nodding	3874	new	<input checked="" type="checkbox"/>
Antennae_N40...	NGC4039-1	12h01m5...	Fixed Single	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	PACS Line S...	pointed with chopping/nodding	3875	new	<input checked="" type="checkbox"/>
Antennae_N40...	NGC4038-1	12h01m5...	Fixed Single	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	HIFI Mapping	Mode:raster Band:3a LOF:810.8...	1049	new	<input checked="" type="checkbox"/>
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Antennae_over...	NGC4038/9-2	12h01m5...	Fixed Single	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	HIFI Single P...	Mode:dbb Band:1a LOF:492.672...	1310	new	<input checked="" type="checkbox"/>
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Antennae_over...	NGC4038/9-4	12h01m5...	Fixed Single	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	HIFI Mapping	Mode:raster Band:7b LOF:1887....	7260	new	<input checked="" type="checkbox"/>
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Antennae_over...	NGC4038/9-...	12h01m5...	Fixed Single	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	HIFI Mapping	Mode:raster Band:3a LOF:810.8...	5125	new	<input checked="" type="checkbox"/>
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Arp220-case_s...	Arp220	15h34m5...	Fixed Single	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	HIFI Single P...	Mode:dbb Band:3b LOF:929,036...	2765	new	<input checked="" type="checkbox"/>
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Arp220-case_s...	Arp220	15h34m5...	Fixed Single	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	HIFI Single P...	Mode:dbb Band:1b LOF:568,083...	762	new	<input checked="" type="checkbox"/>

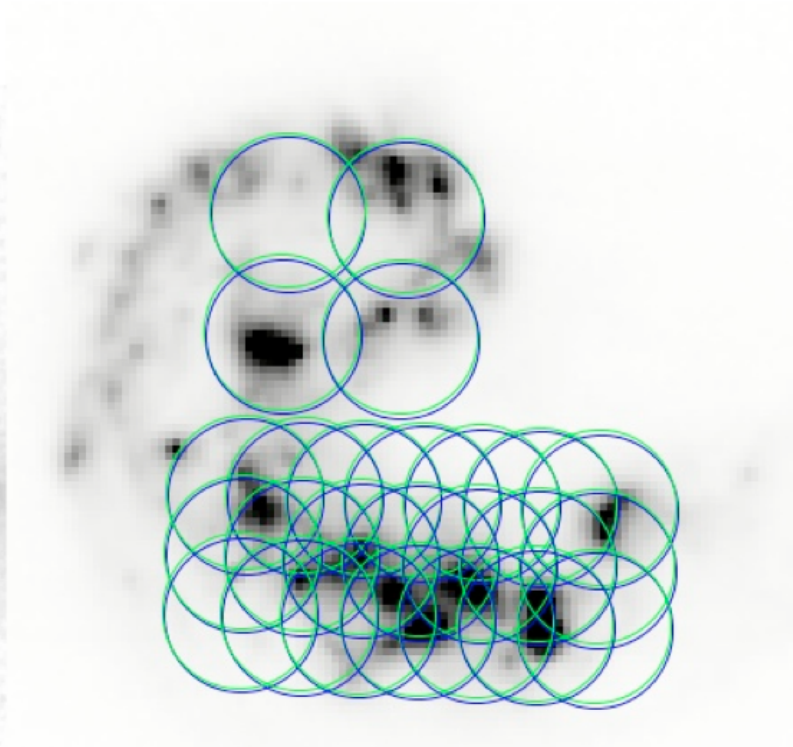
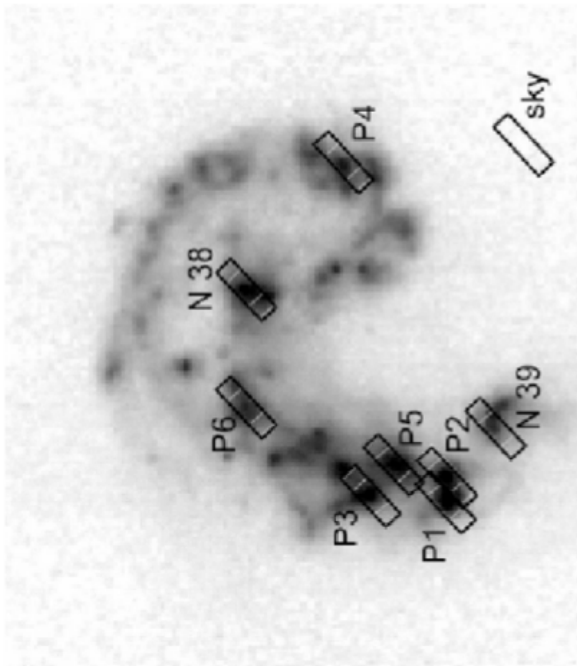
Observations

Target: NGC4038/9-1 Type: Fixed Single Total Duration (hrs): 130.9

Proposal - File Name: rquesten_HexGal_16052010b RELEASED.aor Net Up Total AORs: 229 / Active: 229

Visualizing for a program

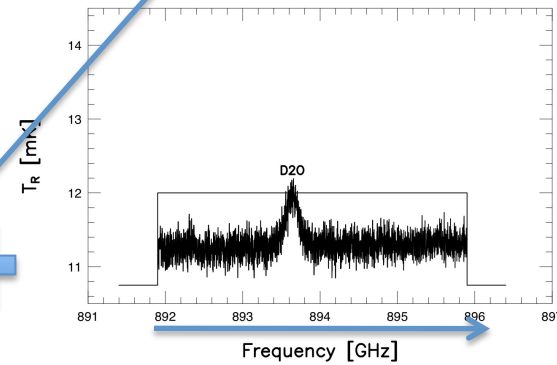
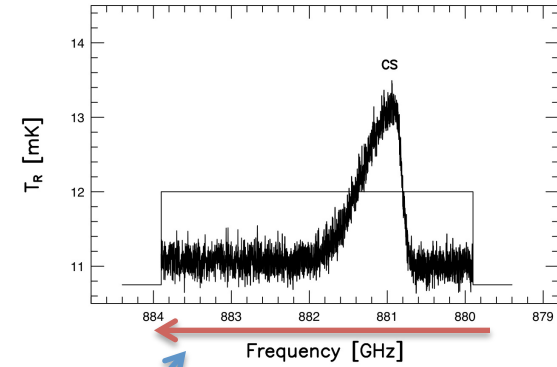
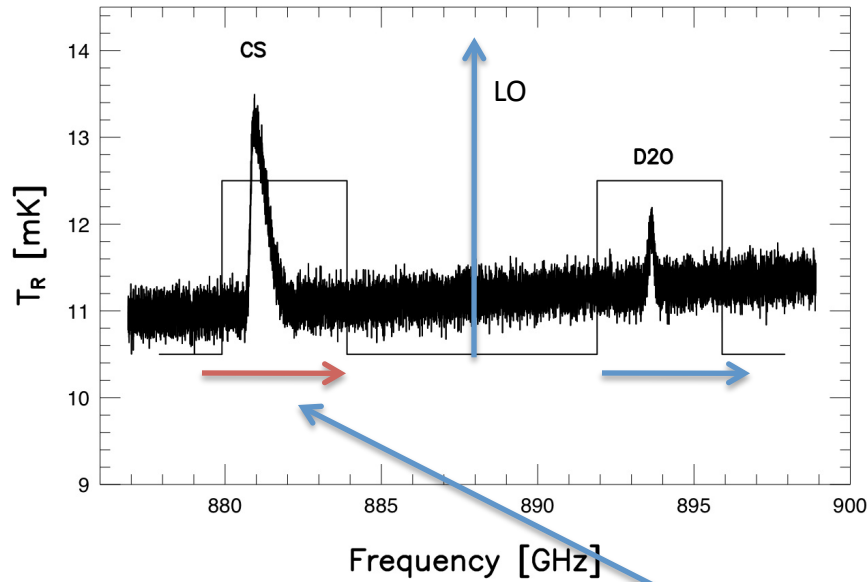
HEXGAL [CI] 810 GHz (0.47, 3.8h)



Aside – my major contribution to Herschel

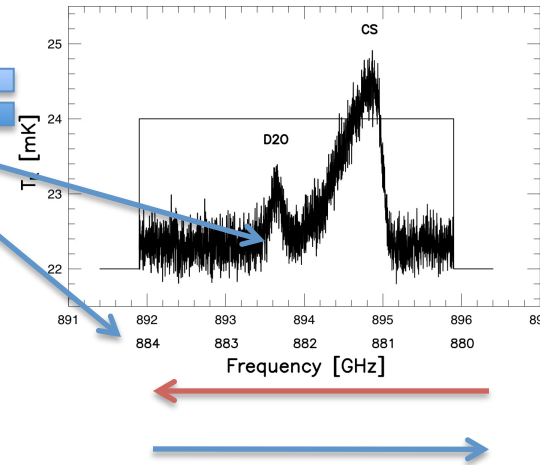
- The production of a simple single sideband spectrum of all HIFI spectroscopic surveys is done through iterative deconvolution.
- At IPAC we took the existing method (developed by Schilke and Comito) and put it into the Herschel Data deduction environment (JAVA) – that is – we made it a normal Herschel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

LSB + USB = DSB



+

=

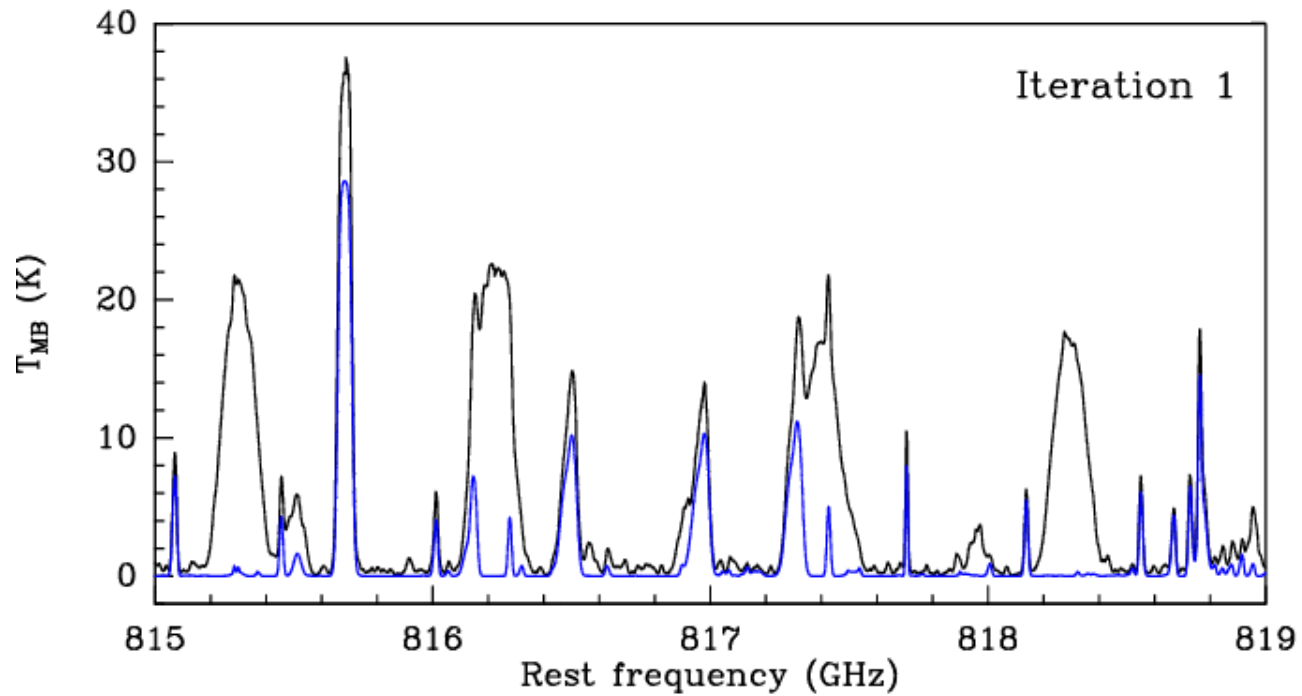


- Lower sideband spectrum is reversed and added
- Two frequency scales result in the DSB result
- The lines may blend but they can be recovered (deconvolved)
- The continuum levels add (double) in the DSB
- The continuum slope is flattened but may be recovered (deconvolved)
- The noise adds in quadrature,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

The Solution of the Problem

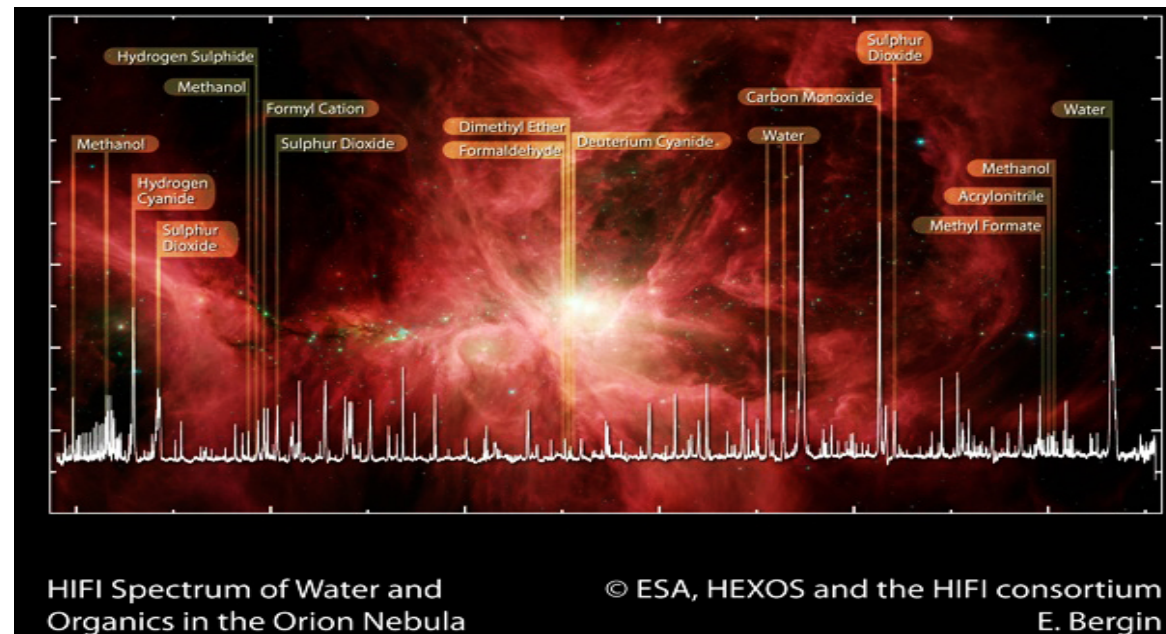
- Start with a guess of the answer – a model with no assumptions for the SSB spectrum – flat
- "Observe it" – using knowledge of the instrument
- compare the observations of the model with the real observations
- compute a chi square and a delta (differential) chi-square)
- each model "spectral channel" 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



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

- Press release - Bergin et al. 2010



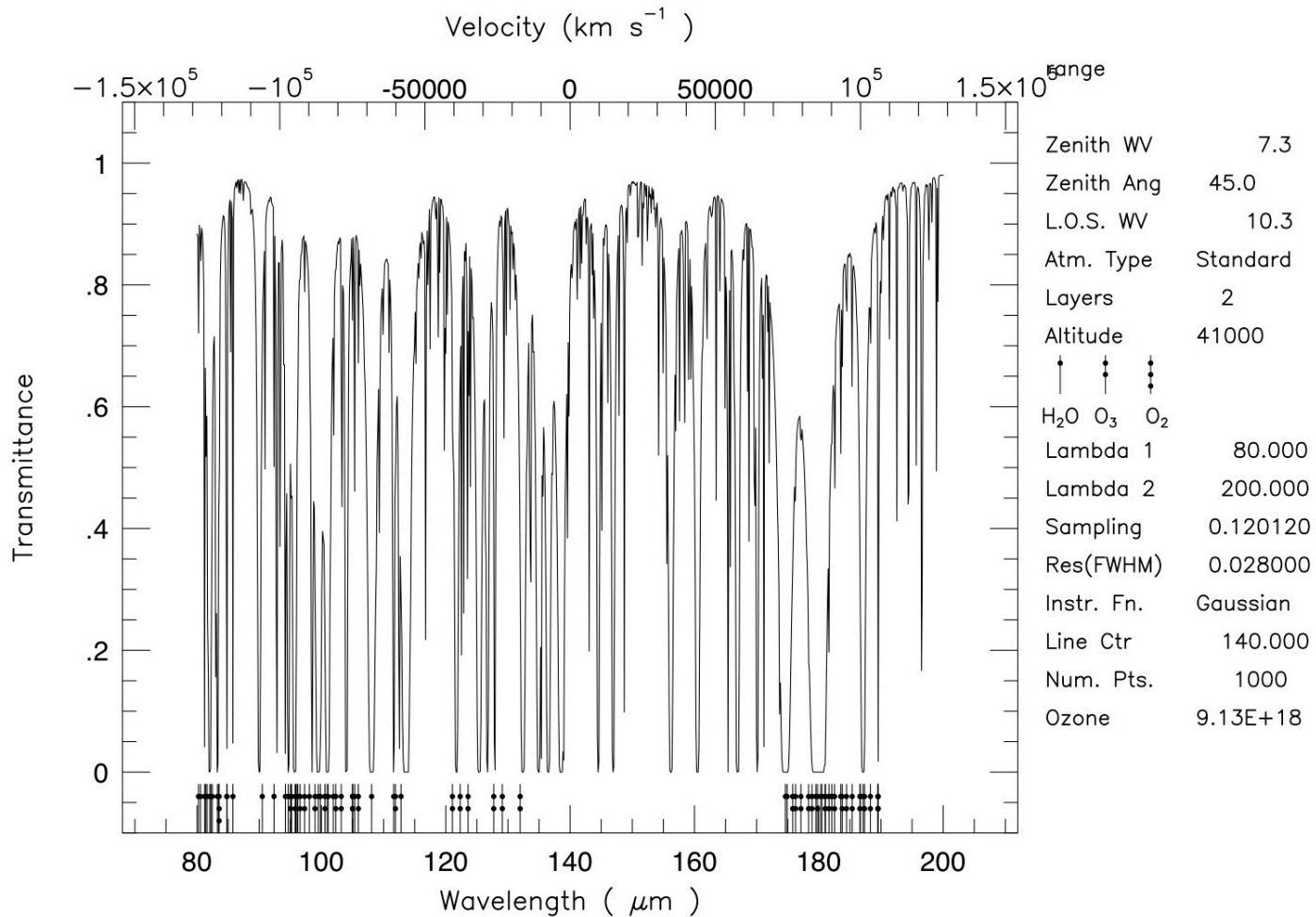
Other Herschel Project Efforts

- HIPE – Herschel Interactive Processing environment
 - Distributed
 - JAVA / Jython environment
 - Used in the pipelines 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

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 μm 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 when to stop looking at faint lines or wings.
 - It is working at about 100 installations.

Example ATRAN output



Fri Nov 1 04:42:40 PST

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)