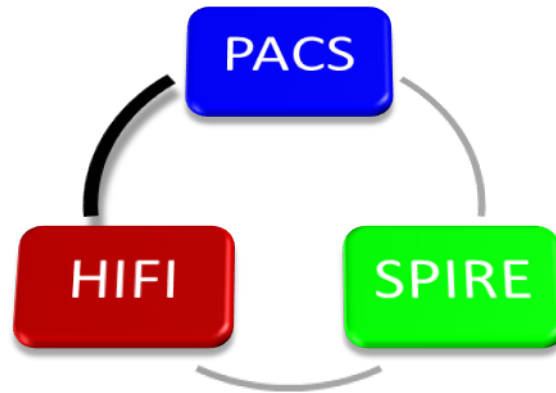


PACS-HIFI Spectral Line Cross Calibration



Elena Puga, David Teyssier and Pierre Royer

Objectives and Assumptions:

- Comparison of line fluxes in the overlap region between PACS & HIFI at their respective native spectral resolution

Assuming:

- We are commanding the telescope to the agreed nominal coordinates of the sources
- All sources are point sources
- No pointing offset considered

Common Calibration Monitoring Programme

Common Calibration Monitoring Sources after Cross-calibration Proposal (Sep 2011):

<i>Name</i>	<i>Alternative names</i>	<i>RA (J2000)</i>	<i>Dec (J2000)</i>	<i>v_{LSR} (km/s)</i>	<i>f₁₆₀ (Jy)</i>
AFGL 2688	V1610 Cyg, Egg nebula	21:02:18.78	+36:41:41.20	-34	488
CRL618	V353 Aur, Westbrook nebula	04:42:53.64	+36:06:53.40	-22	196
NGC7027	HD201272	21:07:01.59	+42:14:10.20	+25	90
NGC6302	HD 155520, Bug nebula	17:13:44.21	-37:06:15.90	-40	400

Other sources belonging to the HIFI Calibration programme.

*Not included in this comparison

<i>Name</i>	<i>Alternative names</i>	<i>RA (J2000)</i>	<i>Dec (J2000)</i>	<i>v_{LSR} (km/s)</i>	<i>f₁₆₀ (Jy)</i>
IRC+10216	CW Leo, Peanut nebula	09:47:57.38	+13:16:43.70	+26	610
VY CMa	HIP 35793, AFGL 1111	07:22:58.33	-25:46:03.20	+21	137
R Dor	HIP 21479	04:36:45.59	-62:04:37.80	+7	32.7
IK Tau	IRC+10050, NML Tau	03:53:28.89	+11:24:21.88	+34	27.6
o Ceti	Mra	02:19:20.79	-02:58:39.50	+46	35.2
EP Aqr	HD 207076, AFGL 2806	21:46:31.85	-02:12:45.90	-34	4.14

Common Calibration Monitoring Programme

Lines included in Cross Calibration Plan

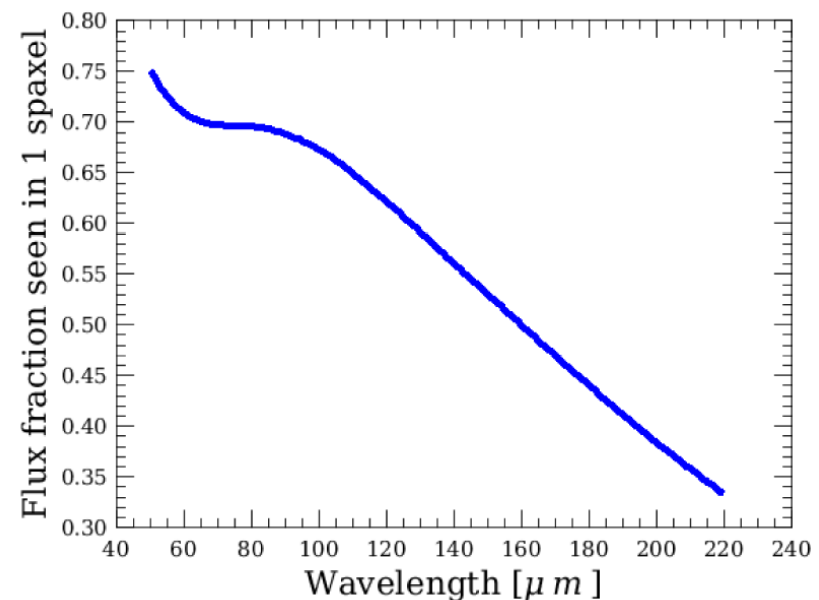
Spectral Line	Frequency (GHz)	Wavelength (μm)	PACS band	HIFI band
CII	1900.53	157.74	R1	7
12CO J=16-15	1841.34	162.81	R1	7
12CO J=13-12	1496.92	200.27	R1	6

Number of observations used for this comparison

Source	HIFI		PACS	
	CO 16-15	CO 13-12	CO 16-15	CO 13-12
AFGL2688	2	1	2	2
CRL618	3	1	2	4
NGC7027	1	1	2	2
NGC6302	1	1	-	-
IRC+10216	3	2	2	-
VYCMa	1	2	2	-
RDor	2	2	3	-
o Ceti	1	1	1	1

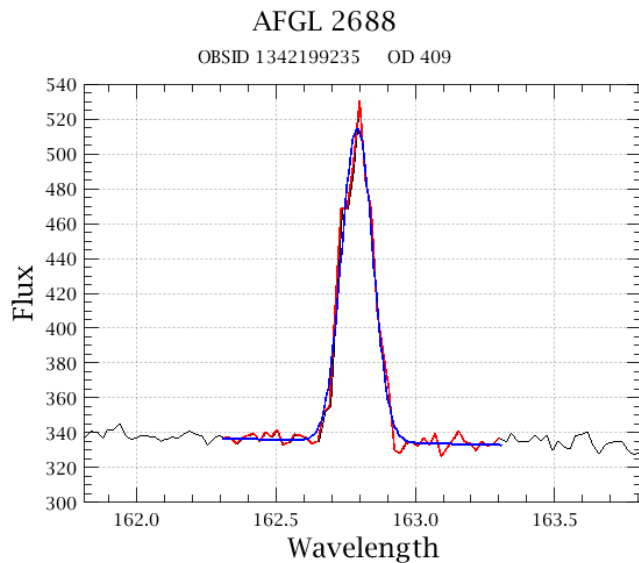
PACS Data Processing

- Used both Science and Calibration data
- Data were reprocessed with correspondent ipipe script HIPE 8.0.2106 -Absolute flux calibration with Calblock, range flatfield
- Extension of data was reprocessed with HIPE 9.0.588 – Absolute flux calibration with Calblock - cal set 35 - ov2 up 3, range flatfield
- Central spaxel spectrum extraction + point source correction (assuming perfect centering of the point source in the central spaxel)

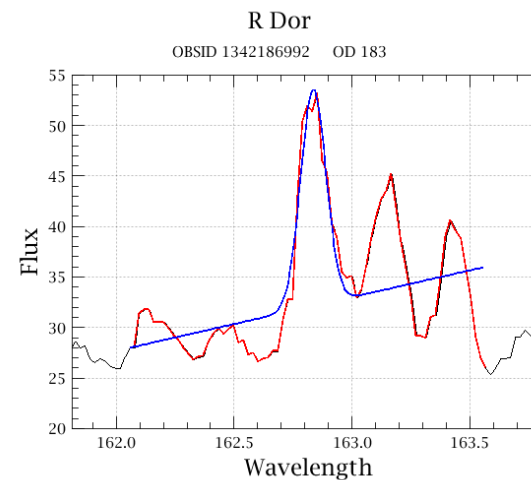


PACS Data Analysis

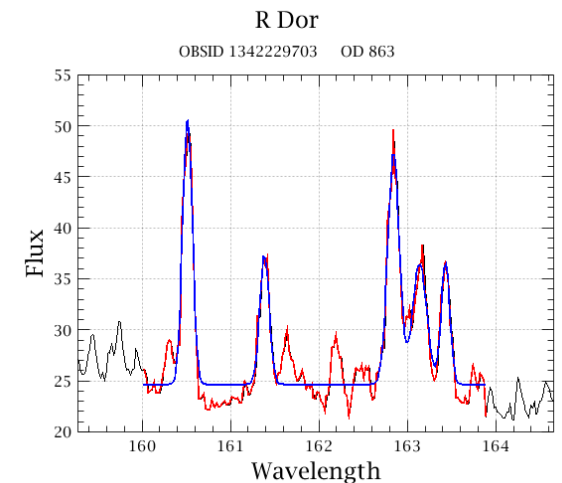
- LineFitter.py by Pierre Royer in different evolutions. Fits a list of individual or cluster of Gaussians with approximated input line centers in a spectral range.
- Line Fluxes are estimated in $W m^{-2}$



12CO 16-15



V 1.0



V 2.0

It is not same OBSID

Data processing HIFI

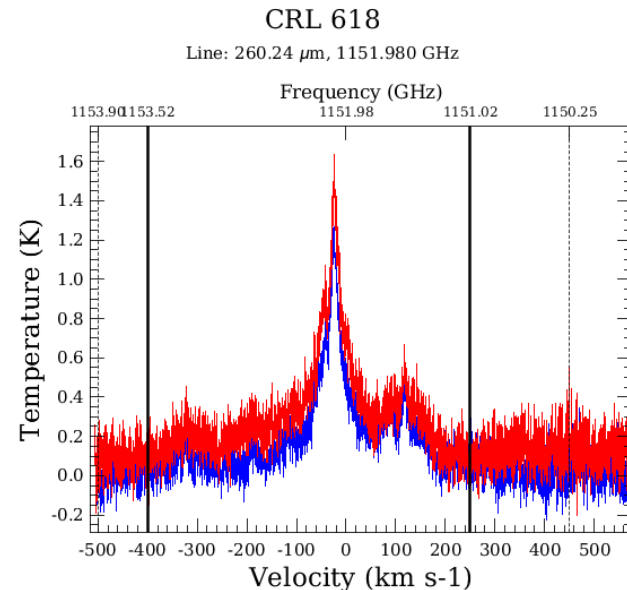
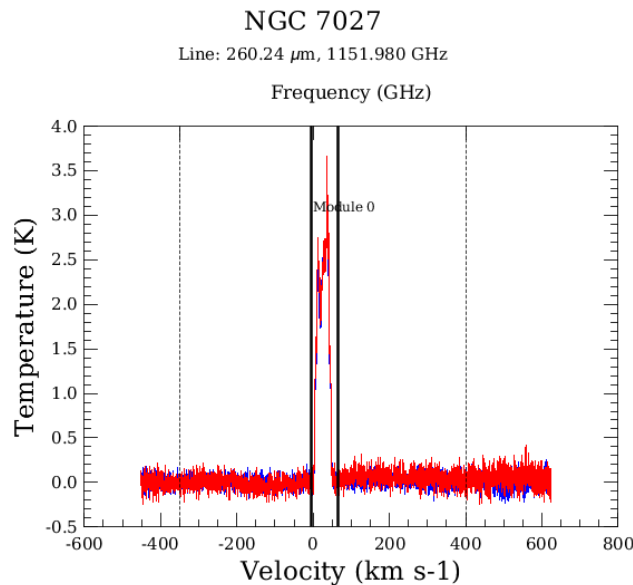
- Used both Science and Calibration data
- Data processed with SPG 6.1.0
- Extraction of level2 spectra from Wide-band Spectrometer (WBS) in the H- and V-polarization orientations.
- Conversion from frequency to velocity scale.
- Stitching of spectrum sub-bands

Data Analysis HIFI

- Integration of the profile in a velocity (frequency) range $[l_0, l_1]$, after baseline removal (order 1).
- Baseline ranges adjacent to line ranges $[b_0, l_0]$ and $[l_1, b_1]$
- Error Flux = Baseline range RMS * SQRT(number of channels in line range)
- Conversion of the line flux from $K \text{ km s}^{-1}$ following the expression:

$$F \left[\frac{W}{m^2} \right] = \frac{3 \cdot 10^{-12} \cdot 2 \cdot 1.3806488 \cdot 10^{-16}}{8.45 \cdot 10^{-19} \cdot (2.99 \times 10^5)^2} \cdot \frac{1}{\eta_A} \cdot f [GHz] \cdot \eta_l \cdot T_A \cdot \Delta v [K \cdot km \cdot s^{-1}]$$

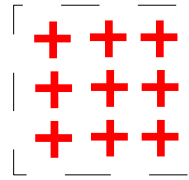
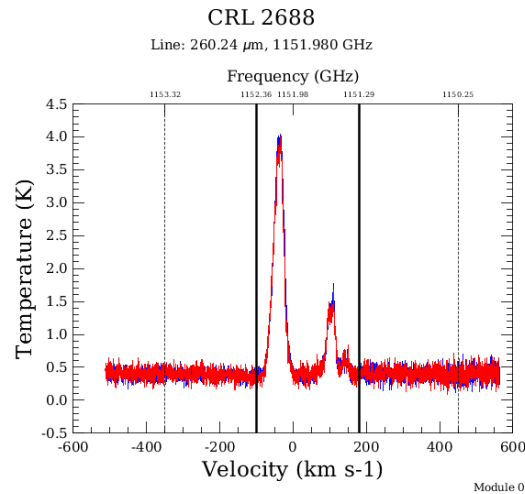
12CO 10-9
 V and H polarizations



Data Analysis HIFI

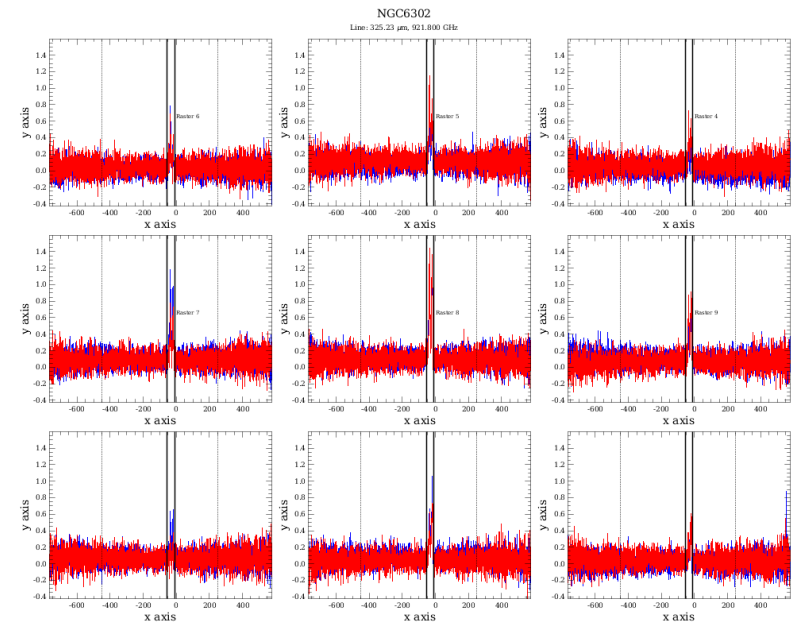
- Average line flux in H- and V-polarization orientations $\Delta F = \frac{\sqrt{\Delta F_V^2 + \Delta F_H^2}}{\sqrt{2}}$

Single Pointing



Nyquist sampled map

Raster Map



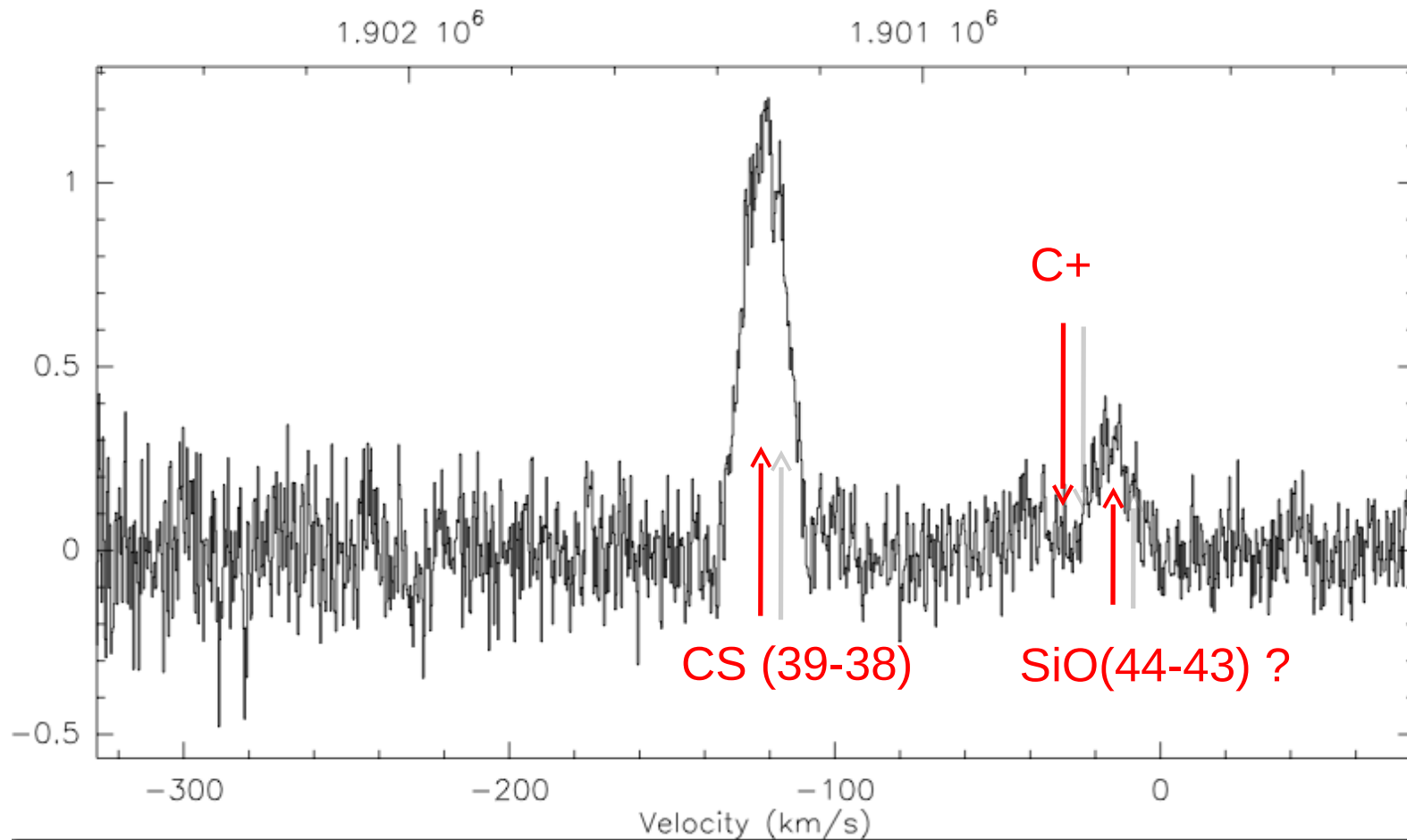
Maximum line flux among n raster positions (not necessarily at center)

- Weighted mean of Science and Calibration observations per source and line and error in the weighted mean

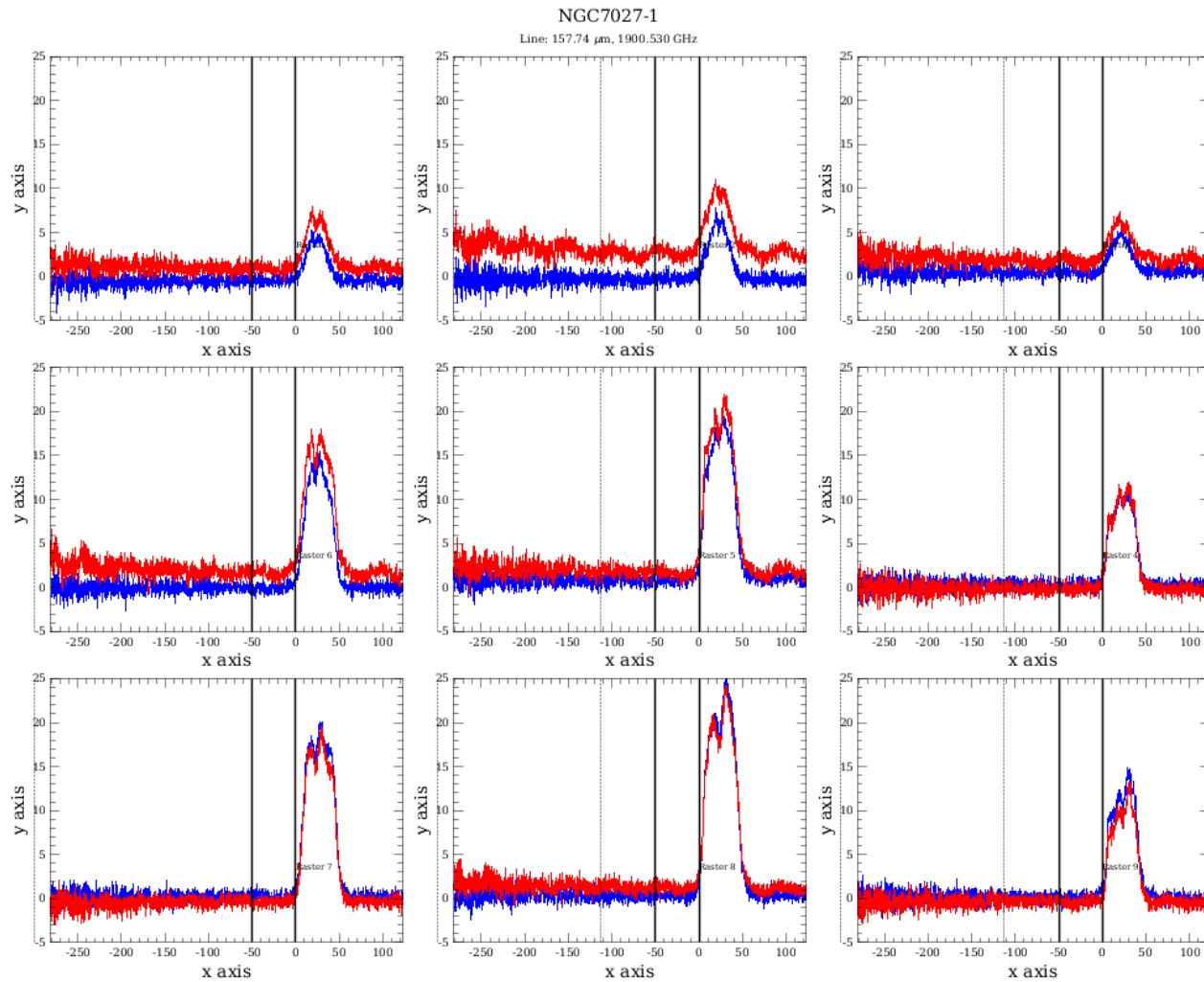
Comparing lines at different spectral resolutions

C+ comparison in IRC+10216

- high-resolution HIFI observation actually shows no C+ - rather, the flux is dominated by CS (39-38), with small contribution from another line (identification TBC)
- total HIFI flux (7.4×10^{-16} W/m²) comparable to that measured by PACS (8.1×10^{-16} W/m²), but beware of line assignment !



Comparing lines at different spectral resolutions



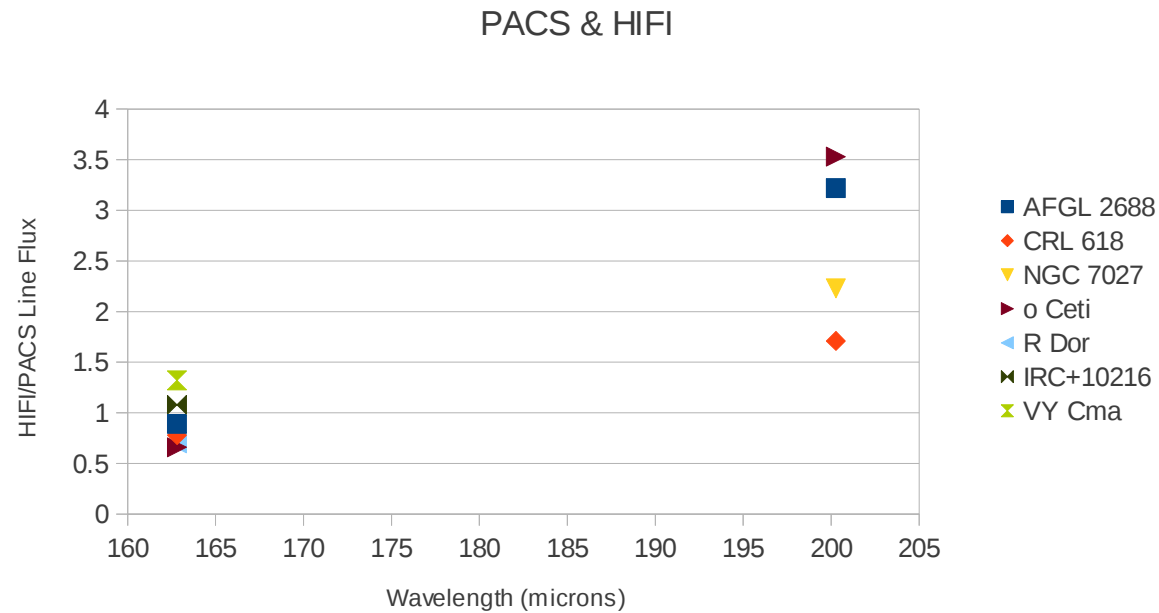
CO 16-15 @162.81 μm 1841.34 GHz

Source	PACS Flux (W m-2)	PACS Flux error (W m-2)	HIFI Flux (W m-2)	HIFI Flux error (W m-2)	(HIFI/PACS)	error (HIFI/PACS)	_
AFGL 2688	2.88E-015	8.20E-017	2.56E-015	1.13E-016	0.89	0.05	
CRL 618	4.21E-015	5.95E-017	3.30E-015	1.31E-016	0.78	0.03	
NGC 7027	1.21E-015	2.65E-017	1.08E-015	1.19E-016	0.89	0.10	
NML Tau	2.68E-016	2.69E-017					
o Ceti	2.71E-016	2.07E-017	1.79E-016	3.47E-017	0.66	0.14	
R Dor	3.14E-016	3.01E-017	2.21E-016	3.05E-017	0.70	0.12	
IRC+10216	6.57E-015	2.30E-016	7.11E-015	7.09E-017	1.08	0.04	
VY Cma	9.79E-016	4.70E-017	1.29E-015	9.28E-017	1.32	0.11	
NGC 6302			4.87E-016	5.84E-017			
W Hya			1.44E-016	3.16E-017			
				MEAN:	0.90	0.25	:TOTERROR
				WMEAN:	0.90	0.02	:WERROR
				STD:	0.23		
				SEM:	0.09		

CO 13-12 @200.27 μm 1496.92 GHz

Source	PACS Flux (W m ⁻²)	PACS Flux error (W m ⁻²)	HIFI Flux (W m ⁻²)	HIFI Flux error (W m ⁻²)	(HIFI/PACS)	Error(HIFI/PACS)	
AFGL 2688	9.65E-016	5.22E-017	3.11E-015	4.13E-016	3.22	0.46	
CRL 618	1.22E-015	2.56E-017	2.09E-015	4.88E-016	1.71	0.40	
NGC 7027	7.41E-016	2.66E-017	1.65E-015	2.82E-016	2.23	0.39	
NML Tau							
o Ceti	1.07E-016	3.52E-017	3.79E-016	1.77E-016	3.53	2.02	
R Dor			2.13E-016	4.01E-017			
IRC+10216			5.94E-015	2.15E-016			
VY Cma			1.03E-015	2.20E-016			
NGC 6302			6.23E-016	2.07E-016			
W Hya							
AFGL 3068	8.16E-017	1.87E-017					
AFGL 4106	6.26E-017	5.19E-018					
alpha Ori	7.57E-017	1.26E-017					
				MEAN:	2.67	2.14	:TOTERR
				WMEAN:	2.33	0.24	:WERROR
				SD:	0.85		
				SEM:	0.43		

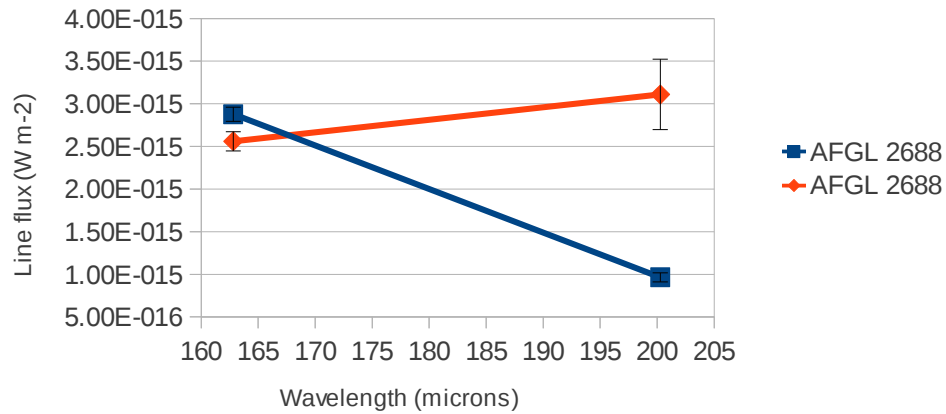
Cross Comparison PACS & HIFI



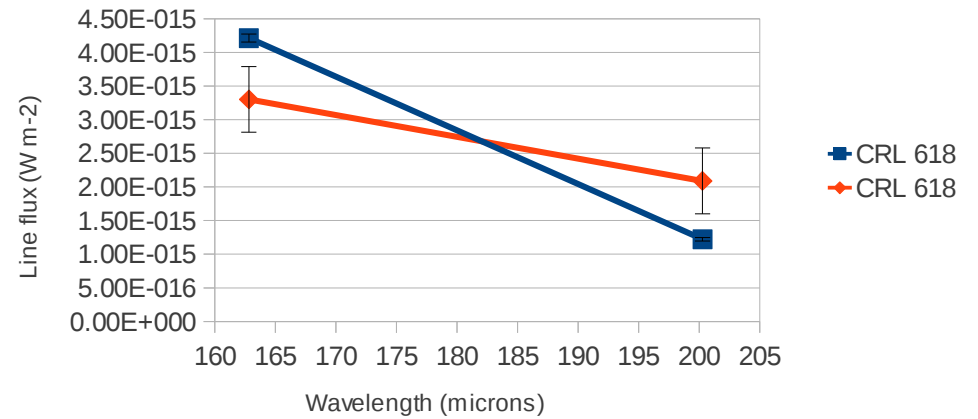
PACS Red Leak Region

CO 16-15 & CO 13-12

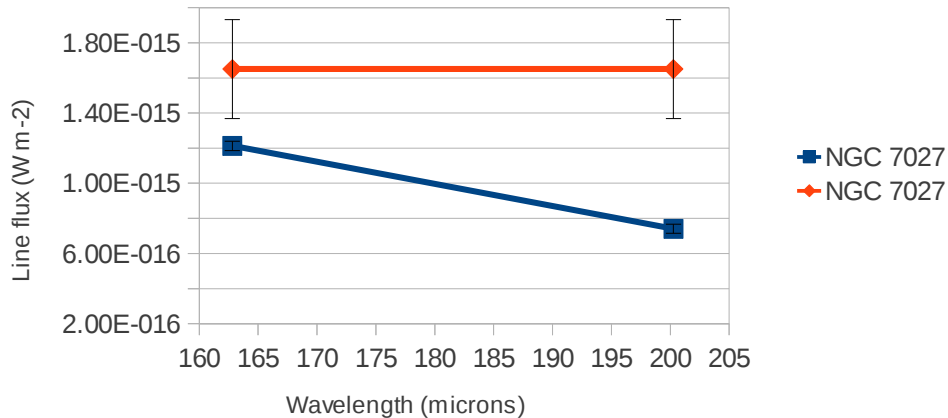
PACS & HIFI



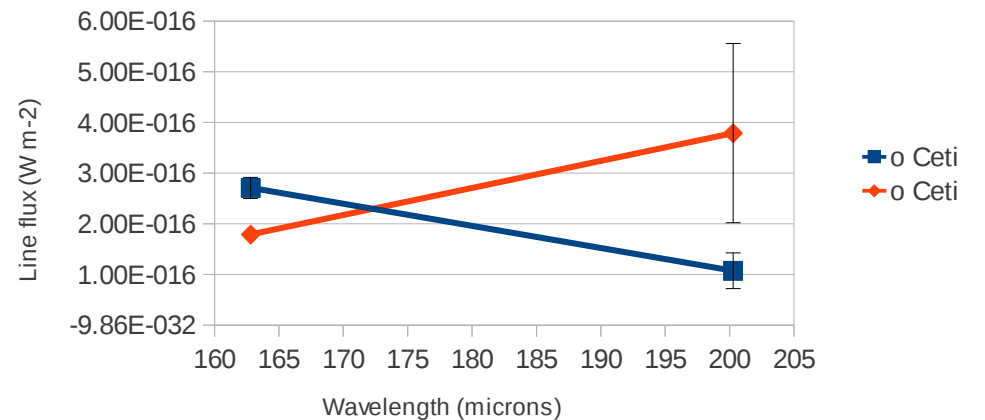
PACS & HIFI



PACS & HIFI



PACS & HIFI



Conclusions

- Care must be taken to compare correspondent lines
- Outside PACS red leak region, the only line compared shows good average agreement 10% with maximum differences of 35%
- Inside PACS red leak, PACS line fluxes are off by a factor ~ 2.3