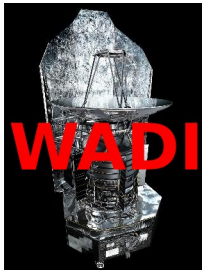




# The Warm and Dense ISM

## Status December 2011

V. Ossenkopf, M. Gerin, R. Güsten, M. Akyilmaz, A.O. Benz, O. Berne, F. Boulanger, J. Le Boulot, S. Bruderer, C. Dedes, K. France, A. Fuente, J.R. Goicoechea, A. Gusdorf, A. Harris, C. Joblin, T. Klein, E. Koumpia, C. Kramer, W. Latter, F. Le Petit, S. Lord, Z. Makai, P.G. Martin, J. Martin-Pintado, B. Mookerjea, D.A. Neufeld, Y. Okada, T. Phillips, P. Pilleri, R. Rizzo, M. Röllig, R. Simon, J. Stutzki, F.S.S. van der Tak, D. Teyssier, H. Yorke

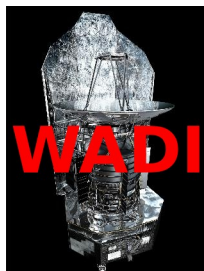


# WADI science goals

- How do winds and radiation from young stars affect the gas in their environment?
  - density
  - temperature
  - velocity field
  - WADI science:
    - chemistry,
    - energy balance,
    - dynamics.
- of the interaction regions:
- PDRs and SNRs



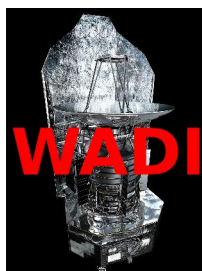
Pillars in Rosette  
(HOBYS team: Motte et al. 2010)



# Matrix of sources and lines

H <sub>3</sub> O <sup>+</sup>	1 <sub>1,1</sub> – 1 <sub>1,0</sub>	1655.814	181.05	0		all PDRs
	0 <sub>0,1</sub> – 1 <sub>0,0</sub>	984.697		7	✓	all PDRs and SNRs
p-H <sub>2</sub> O	1 <sub>1,1</sub> – 0 <sub>0,0</sub>	1113.343		0	✓	all PDRs and SNRs
	2 <sub>0,2</sub> – 1 <sub>1,1</sub>	987.927		53	✓	all PDRs and SNRs
	2 <sub>1,1</sub> – 2 <sub>0,2</sub>	752.033		101		bright PDRs, all SNRs
	2 <sub>2,0</sub> – 1 <sub>1,1</sub>		100.98	53		all PDRs and SNRs
	3 <sub>1,3</sub> – 2 <sub>0,2</sub>		138.53	101		all PDRs and SNRs
	4 <sub>0,4</sub> – 3 <sub>1,3</sub>		125.35	205		all PDRs and SNRs
	5 <sub>1,5</sub> – 4 <sub>0,4</sub>		95.63	319		all PDRs and SNRs
	6 <sub>0,6</sub> – 5 <sub>1,5</sub>		83.28	470		all PDRs and SNRs
o-H <sub>2</sub> O	1 <sub>1,0</sub> – 1 <sub>0,1</sub>	556.936		0	✓	all PDRs and SNRs
	3 <sub>1,2</sub> – 2 <sub>2,1</sub>	1153.127		160	✓	all SNRs
	2 <sub>1,2</sub> – 1 <sub>0,1</sub>		179.53	0		all PDRs and SNRs
	2 <sub>2,1</sub> – 1 <sub>1,0</sub>		108.07	27		all PDRs and SNRs
	3 <sub>0,3</sub> – 2 <sub>1,2</sub>		174.63	80		all PDRs and SNRs
	4 <sub>1,4</sub> – 3 <sub>0,3</sub>		113.54	162		all PDRs and SNRs
	5 <sub>0,5</sub> – 4 <sub>1,4</sub>		99.49	289		all PDRs and SNRs
	6 <sub>1,6</sub> – 5 <sub>0,5</sub>		82.03	434		all PDRs and SNRs
p-H <sub>2</sub> <sup>18</sup> O	1 <sub>1,1</sub> – 0 <sub>0,0</sub>	1101.698		0	✓	all PDRs and SNRs
o-H <sub>2</sub> <sup>18</sup> O	1 <sub>1,0</sub> – 1 <sub>0,1</sub>	547.676		0		all PDRs
HDO	1 <sub>1,1</sub> – 0 <sub>0,0</sub>	893.639		0		bright PDRs

molecule	transition	frequency [GHz] (HIFI)	wavelength [ $\mu$ m] (PACS)	lower level energy [K]	bonus line	strategy
CII	$^2P_{3/2} - ^2P_{1/2}$	1900.537		0		all PDRs and SNRs
$^{13}\text{CII}$	$^2P_{3/2} - ^2P_{1/2}$	1900.950		0		few PDRs
OI	$^3P_1 - ^3P_2$		63.17	0		all PDRs and SNRs
	$^3P_0 - ^3P_1$		145.53	228		all PDRs and SNRs
NII	$^3P_2 - ^3P_1$		121.91	70		all PDRs and SNRs
	$^3P_1 - ^3P_0$	1462.131	205.18	0		all PDRs and SNRs
NIII	$^2P_{3/2} - ^2P_{1/2}$		57.32	300		all PDRs
OIII	$^3P_2 - ^3P_1$		88.36	0		all PDRs
HD	1-0,R(0)		112.07	0		all PDRs and SNRs
CH	$^2\Pi_{3/2} 1, 2^- - ^2\Pi_{1/2} 1, 1^+$	536.761		0		all PDRs
	$^2\Pi_{5/2} 2, 3^- - ^2\Pi_{3/2} 1, 2^+$	1656.961	180.93	26	✓	all PDRs
CH <sup>+</sup>	1-0	835.07		0		all PDRs
CO	9-8	1036.912		199		all PDRS
CO	10-9	1151.985		249		all SNRs
	>14-13		186.13	504		all PDRs and SNRs
$^{13}\text{CO}$	10-9	1101.350		238		all PDRs and SNRs
NH	$^3\Sigma^- 1, 1/2 - 0, 1/2$	974.479		0		all PDRs
NH <sup>+</sup>	$^2\Pi_{1/2} 3/2 - 1/2$	1012.561		0		bright PDRs
NH <sub>2</sub>	1 <sub>1,0</sub> - 0 <sub>0,0</sub>	952.578		54		few PDRs
NH <sub>3</sub>	1 <sub>0</sub> - 0 <sub>0</sub>	572.498		0.5		all PDRs
OH	$^2\Pi_{3/2} 5/2 - 3/2$		119.44	0		all PDRs and SNRs
	$2\Pi_{1/2} 3/2 - 1/2$		163.40	181		all PDRs and SNRs
	$2\Pi_{1/2} - 2\Pi_{3/2} 1/2 - 3/2$		79.18	0		all PDRs and SNRs
OH <sup>+</sup>	$^3\Sigma^- 1, 2, 5/2 - 0, 1, 3/2$	971.804		0	✓	bright PDRs

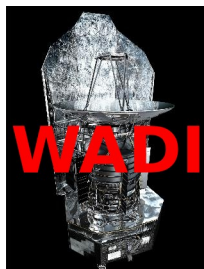


# AORs

PDRs:

		NGC3603	MonR2	Carina	NGC7023	IC63/IC59	Ced201	S140	Rosette	Horsehead	B68
$\Delta v$		0.7 km/s	0.7 km/s	0.7 km/s	0.7 km/s	0.7 km/s	0.7 km/s	0.7 km/s	0.7 km/s	0.3 km/s	0.2 km/s
HIFI – single lines											
[C II]	1901 GHz	2 HIFI cuts (1.4K)	1 HIFI cut (1.0K)	2 HIFI cuts (1.0K)	3 HIFI cuts (1.0K)	3 HIFI cuts (0.75K)	1 HIFI cut (0.5K)	1 HIFI cut (0.7K)	2 HIFI cuts (0.7K)	2 HIFI cuts (1.3K)	1 HIFI cut (0.2K)
[ <sup>13</sup> C II]	1901 GHz	1 HIFI pt. (150mK)	1 HIFI pt. (120mK)	2 HIFI pts. (100mK)							
[N II]	1462 GHz	1 HIFI cut (0.6K)	1 HIFI cut (0.6K)	2 HIFI pts. (0.6K)		2 HIFI pts. (0.25K)			2 HIFI pts. (0.4K)	2 HIFI pts. (0.4K)	
CH	537 GHz	2 HIFI cuts (40mK)	1 HIFI cut (50mK)	2 HIFI cuts (100mK)	3 HIFI cuts (50mK)	3 HIFI cuts (50mK)	1 HIFI cut (30mK)	1 HIFI cut (50mK)	2 HIFI cuts (50mK)	2 HIFI cuts (90mK)	1 HIFI pt. (50mK)
CH <sup>+</sup>	835 GHz	2 HIFI pts. (50mK)	1 HIFI cut (50mK)	2 HIFI pts. (50mK)	1 cut+2 pts. (50mK)	3 HIFI cuts (50mK)	1 HIFI cut (50mK)	3 HIFI pts. (50mK)	3 HIFI pts. (50mK)	2 HIFI cuts (90mK)	1 HIFI pt. (15mK)
NH <sup>+</sup>	1013 GHz	1 HIFI pt. (80mK)		2 HIFI pts. (80mK)	2 HIFI pts. (80mK)			1 HIFI pt. (17mK)	1 HIFI pt. (20mK)		
NH <sub>2</sub>	953 GHz	-		2 HIFI pts. (80mK)	1 HIFI cut (80mK)				1 HIFI pt. (50mK)		
CO 9-8	1036 GHz	2 HIFI cuts (1.0K)	1 HIFI cut (1.0K)	2 HIFI cuts (1.0K)	3 HIFI cuts (1.0K)	3 HIFI cuts (0.2K)	1 HIFI cut (0.15K)	1 HIFI cut (0.1K)	2 HIFI cuts (0.5K)	2 HIFI cuts (0.45K)	
p-H <sub>2</sub> O	752 GHz	2 HIFI cuts (100mK)	1 HIFI cut (100mK)	2 HIFI cuts (100mK)	1 HIFI cut (100mK)	2 HIFI pts. (10mK)		2 HIFI pts. (20mK)	3 HIFI pts. (20mK)	2 HIFI pts. (40mK)	
HDO	894 GHz			2 HIFI pts. (20mK)	1 HIFI pt. (15mK)					3 HIFI pts. (30mK)	
HIFI – multiple line settings											
p-H <sub>3</sub> O <sup>+</sup>	1656 GHz										
CH	1657 GHz	2 HIFI pts. (200mK)	1 HIFI cut (200mK)	2 HIFI pts. (200mK)	2 HIFI pt. (200mK)	2 HIFI pts. (200mK)	1 HIFI pt. (200mK)	2 HIFI pts. (200mK)	3 HIFI pts. (200mK)	2 HIFI pts. (230mK)	

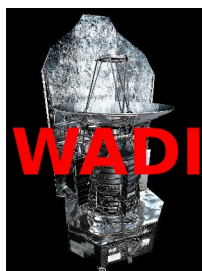




# AORs

PDRs:

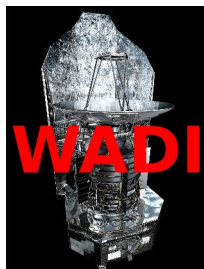
		NGC3603	MonR2	Carina	NGC7023	IC63/IC59	Ced201	S140	Rosette	Horsehead	B68
$\Delta v$		0.7 km/s	0.7 km/s	0.7 km/s	0.7 km/s	0.7 km/s	0.7 km/s	0.7 km/s	0.7 km/s	0.3 km/s	0.2 km/s
$^{13}\text{CO}$ 10-9	1101 GHz										
p-H <sub>2</sub> O	1113 GHz	2 HIFI cuts (100 mK)	1 HIFI cut (100 mK)	2 HIFI cuts (100mK)	2 HIFI cuts (100 mK)	3 HIFI cuts (100mK)	1 HIFI cut (80mK)	1 HIFI cut (200mK)	2 HIFI cuts (200mK)	2 HIFI cuts (220mK)	
p-H <sub>2</sub> <sup>18</sup> O	1102 GHz				+1 HIFI pt. (20mK)	+2 HIFI pt. (30mK)		+2 HIFI pts. (50mK)	+2 HIFI pts. (50mK)	+ 2 HIFI pts. (55mK)	
NH	974 GHz										
o-H <sub>3</sub> O <sup>+</sup>	985 GHz	3 HIFI pts. (50mK)	2 HIFI pt. (50mK)	2 HIFI pts. (60mK)	3 HIFI pts. (60mK)	2 HIFI pts. (30mK)	1 HIFI pt. (60mK)	3 HIFI pts. (30mK)	3 HIFI pts. (70mK)		1 HIFI pt. (20mK)
OH <sup>+</sup>	972 GHz										
NH	974 GHz										
o-H <sub>3</sub> O <sup>+</sup>	985 GHz	3 HIFI pts. (50mK)	1 HIFI cut (100mK)	2 HIFI pts. (60mK)	1 HIFI cut (60mK)	2 HIFI pts. (30mK)	1 HIFI pt. (50mK)	3 HIFI pts. (70mK)	3 HIFI pts. (70mK)	2 HIFI pts. (140mK)	
p-H <sub>2</sub> O	988 GHz										
o-H <sub>2</sub> O	557 GHz										
NH <sub>3</sub>	572 GHz	2 HIFI cuts (200mK)	1 HIFI cut (50mK)	2 HIFI cuts (100mK)	3 HIFI cuts (50mK)	3 HIFI cuts (100mK)	1 HIFI cut (50mK)	1 HIFI cut (50mK)	2 HIFI cuts (100mK)	2 HIFI cuts (140mK)	1 HIFI pt. (10mK)
o-H <sub>2</sub> O	557 GHz										
o-H <sub>2</sub> <sup>18</sup> O	548 GHz	1 HIFI pts. (10mK)	2 HIFI pts. (20mK)	2 HIFI pts. (20mK)	2 HIFI pts. (10mK)	2 HIFI pts. (5mK)		3 HIFI pts. (10mK)	3 HIFI pts. (10mK)	3 HIFI pts. (20mK)	



# AORs

## PDRs:

[illegible]

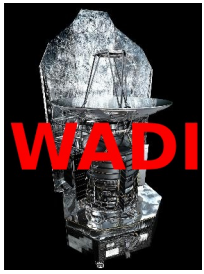


# AORs

SNRs:

		IC443	3C391	W28	W44
$\Delta v$		10.0 km/s	10.0 km/s	10.0 km/s	10.0 km/s
HIFI – single lines					
[C II]	1901 GHz	3 HIFI maps (100mK)	1 HIFI map (100mK)	1 HIFI map (100mK)	1 HIFI map (100mK)
p-H <sub>2</sub> O	752 GHz	3 HIFI maps (30mK)	1 HIFI map (30mK)	1 HIFI map (30mK)	1 HIFI map (30mK)
HIFI – multiple line settings					
CO 10-9	1152 GHz	3 HIFI maps (200mK)	1 HIFI map (200mK)	1 HIFI map (200mK)	1 HIFI map (200mK)
o-H <sub>2</sub> O <sup>+</sup>	1153 GHz				
<sup>13</sup> CO 10-9	1101 GHz	3 HIFI maps (80 mK)	1 HIFI map (80 mK)	1 HIFI map (80mK)	1 HIFI map (80mK)
p-H <sub>2</sub> O	1113 GHz				
p-H <sub>2</sub> <sup>18</sup> O	1102 GHz				
NH	974 GHz	3 HIFI maps (50mK)	1 HIFI map (50mK)	1 HIFI map (50mK)	1 HIFI map (50mK)
o-H <sub>3</sub> O <sup>+</sup>	985 GHz				
p-H <sub>2</sub> O	988 GHz				
o-H <sub>2</sub> O	557 GHz	3 HIFI maps (16mK)	1 HIFI map (16mK)	1 HIFI map (16mK)	1 HIFI map (16mK)
NH <sub>3</sub>	572 GHz				
PACS blue spectroscopy					
[O I]	63 $\mu$ m	3 PACS arr. (1x BS)	1 PACS arr. (1x BS)	1 PACS arr. (1x BS)	1 PACS arr. (1x BS)
PACS red SED scan					
72 –	210 $\mu$ m	3 PACS arr. (6x SED)	1 PACS arr. (6x SED)	2 PACS arr. (6x SED)	4 PACS arr. (6x SED)
Total [h]	HIFI	12.5	3.2	3.2	3.2
	PACS	13.4	3.3	3.3	3.3
Total	[h]	25.9	6.5	6.5	6.5





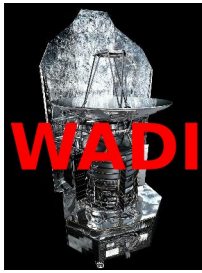
# Matrix of sources and lines

## Reality:

- Early observations showed that most of our line estimates were at the very optimistic limit
  - Many non-detections
  - Non-detections of most N-bearing species,
  - $\text{H}_2\text{O}$  usually weak

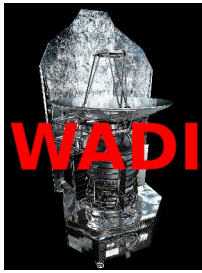
## → Revision of the AORs:

- Sparse/incomplete matrix kept
- IC63/59 completely dropped
- Single integrations instead of 1-D OTF stripes
- Split of PACS spectral scans into dedicated line observations
- More lines dropped due to expected non-detections



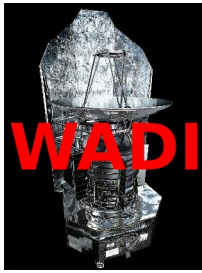
# Status

- All released AORs observed:
  - 294 in total covering 125.4h
  - 3 AORs currently rejected
    - 530GHz setting in NGC7023E, RosetteS, Carina S
    - See HIFIMC-236 discussion later
    - Will be re-observed
  - 9 AORs permanently blocked
    - Non-detections expected for 752GHz water line in NGC3603 and Carina,  $^{13}\text{CO}$  10-9 and 1113 GHz water line in Rosette and Horsehead, 988 GHz water line in Carina
  - Many AORs observed multiple times due to failures/problems
    - 972/974GHz FSW, CO 10-9 in SNRs



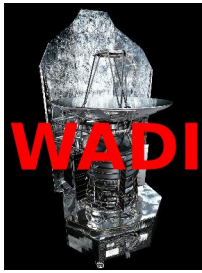
# Status

- All released AORs observed:
  - 294 in total covering 125.4h
    - More efficient than in original plan
    - Formally some GT remaining, but no new observations can be scheduled
      - No good argument for desired Mon R2 H<sub>2</sub><sup>18</sup>O
    - It may be possible to ask for a few re-observations
  - Large fraction of data is already public
    - We are still bound to the KP policy rules for data usage



# Results

- Analysis of the data in very non-uniform way so far
  - Not all data inspected yet
  - Entries in results matrix very sparse
  - Uniform analysis only for dedicated science subtopics
- Paper submissions:
  - Special A&A issues: 6 papers
  - Recent resubmissions:
    - PE heating in Carina (Yoko)
    - H<sub>2</sub>O in MonR2 structure (Paolo)
  - 5 more papers in preparation



# Follow-up projects

OT1, GT2, and OT2:

- DR21 CO: 11.6h (OT1p2 no OT2)
- DR21 H<sub>2</sub>O<sup>+</sup>: 18.1h (OT1p1)
- H<sub>2</sub>O in Mon R2: 3.4h (OT1p2 - OT2p2)
- Rosette pillars: 31.0h (OT1p1)
- Horsehead (in OMC1): 27.7h (OT1p1)
- Water in Horsehead: (OT2p1)
- [<sup>13</sup>CII] in MonR2: (GT2)