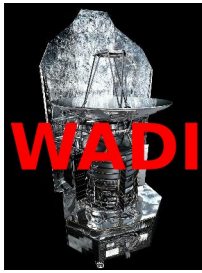




# The Warm and Dense ISM

## Status October 2012

V. Ossenkopf, M. Gerin, R. Güsten, M. Akyilmaz, A.O. Benz, O. Berne, F. Boulanger, J. Le Bourlot, 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



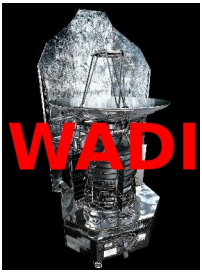
# WADI science goals

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



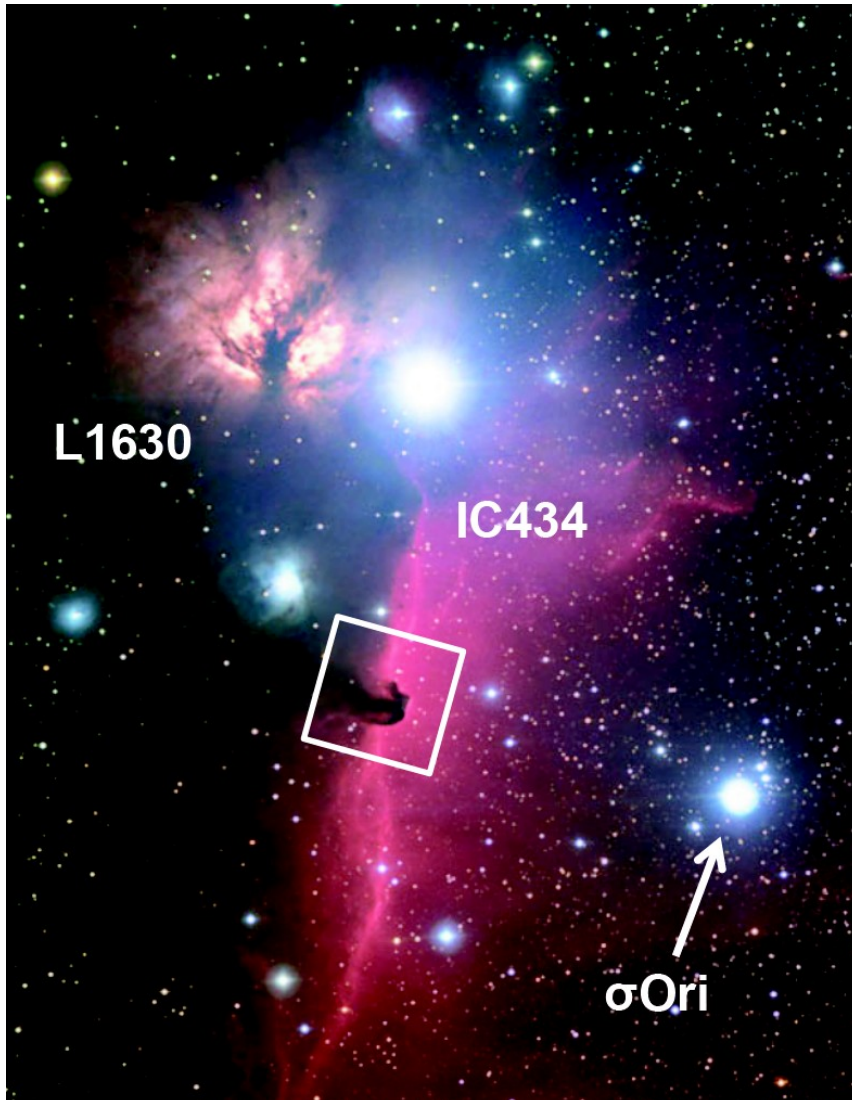
Pillars in Rosette  
(HOBYS team: Motte et al. 2010)

of the interaction regions: PDRs and SNRs

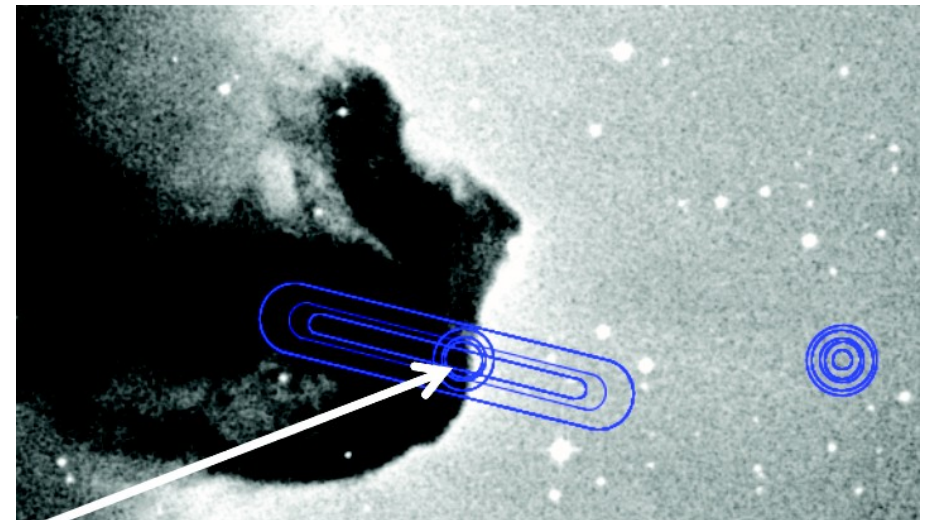


# Strategy

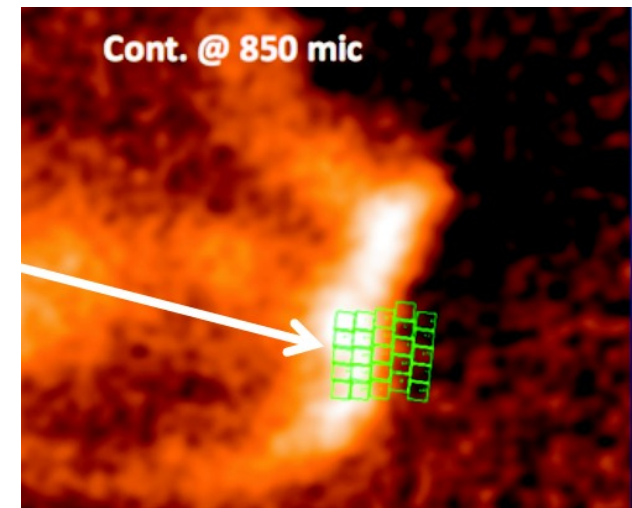
- cuts across the interfaces of PDRs and shock regions



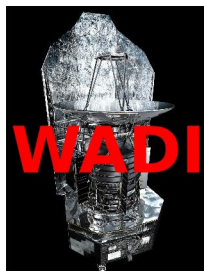
The Horsehead as a typical PDR



- deep integrations at selected positions for rare species



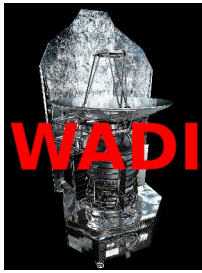




# Matrix of sources and lines

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



# Status

- Reality

- Most of our line estimates were very optimistic
  - Many non-detections (in particular N-bearing species)
  - $\text{H}_2\text{O}$  usually weak

→ Revision of the AORs:

- Only sparse matrix of sources vs. frequencies kept
- IC63/59 completely dropped
- Split of PACS spectral scans into dedicated line observations
- More lines dropped due to expected non-detections

- All released AORs observed:

- Large fraction of data is already public
  - We are still bound to the KP policy rules for data usage



# Summary of HIFI cuts

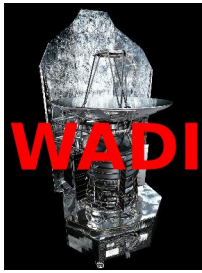
Summary of the HIFI mapping data. Numbers give the peak  $T_A^*$  in Kelvin for the considered stripe and transition.

species	[CII]	CO	<sup>13</sup> CO	HCO <sup>+</sup>	CH	CH <sup>+</sup>	C <sub>2</sub> H	H <sub>2</sub> O	H <sub>2</sub> O
frequency [GHz]	1901	1037	1101	535	537	835	524	1113	557
NGC3603 MM1	40.4	12.8	2.61	0.56	0.48	0.64 <sup>a</sup>	0.39	0.43	0.46
NGC3603 MM2	44.0	11.3	2.69	0.47	0.51	0.60 <sup>a</sup>	0.30	0.39	0.45
MonR2	62.7	32.8	10.4	4.55	1.10	1.31	1.04	1.05	1.04
S140	23.8	25.9	7.71	7.44	0.69	0.39 <sup>a,r</sup>	0.89	2.55	2.54
Carina N	63.6	16.3	3.19	0.89	0.80	<0.1 <sup>a</sup>	0.46	<0.15	0.16 <sup>a</sup>
Carina S	9.82	3.48	<0.1	0.09	<0.05	<0.1 <sup>a</sup>	<0.03	<0.15	<0.02 <sup>a</sup>
NGC7023 N	33.6	19.9	3.46	0.27	0.71	0.37	0.11	<0.15	0.12 <sup>a</sup>
NGC7023 C	33.1	14	-	0.27	0.7	-	0.11	-	0.12 <sup>a</sup>
NGC7023 E	13.8	3.93	<0.1	<0.07	0.09 <sup>m</sup>	<0.03 <sup>a</sup>	<0.05	<0.1	<0.02 <sup>a</sup>
Rosette N	5.92	2.36	<0.3	0.14	0.18	<0.07 <sup>a</sup>	<0.07	<0.3	<0.03 <sup>a</sup>
Rosette S	5.3	<0.5	<0.3	<0.03	<0.1	<0.07 <sup>a</sup>	<0.07	<0.3	0.04 <sup>a</sup>
Horsehead	13.5	2.62	-	0.16	0.26	<0.1 <sup>a</sup>	<0.03	-	0.09 <sup>a</sup>
Ced 201	5.82	<0.15 <sup>a</sup>	<0.03 <sup>a</sup>	<0.03 <sup>a</sup>	<0.03 <sup>a</sup>	<0.15 <sup>a</sup>	<0.03 <sup>a</sup>	<0.03 <sup>a</sup>	0.02 <sup>a,m</sup>
species	H <sub>2</sub> CO	CS	SO	SH <sup>+</sup>	NH <sub>3</sub>	N <sub>2</sub> H <sup>+</sup>			
frequency [GHz]	526	539	560	526	572	559			
NGC3603 MM1	<0.06	0.08	<0.1	<0.07	0.13	<0.07			
NGC3603 MM2	<0.07	0.09 <sup>m</sup>	<0.1	<0.07	0.13	<0.1			
MonR2	0.31	0.38	0.31	<0.03	1.02	1.21			
S140	0.52	0.36	0.42	<0.03	1.75	1.44			
Carina N	0.10	0.08	<0.02 <sup>a</sup>	0.07 <sup>m</sup>	0.08 <sup>a</sup>	<0.02 <sup>a</sup>			
Carina S	<0.03	<0.03	<0.02 <sup>a</sup>	<0.03	<0.02 <sup>a</sup>	<0.02 <sup>a</sup>			
NGC7023 N	<0.03	<0.03	<0.03 <sup>a</sup>	0.08	0.05 <sup>a</sup>	<0.03 <sup>a</sup>			
NGC7023 C	<0.03	<0.03	<0.03 <sup>a</sup>	0.06	0.05 <sup>a</sup>	<0.03 <sup>a</sup>			
NGC7023 E	<0.03	0.05 <sup>m</sup>	<0.02 <sup>a</sup>	<0.05	<0.02 <sup>a</sup>	<0.02 <sup>a</sup>			
Rosette N	<0.07	<0.03	<0.03 <sup>a</sup>	<0.05	<0.03 <sup>a</sup>	<0.03 <sup>a</sup>			
Rosette S	<0.07	<0.07	<0.03 <sup>a</sup>	<0.05	<0.03 <sup>a</sup>	<0.03 <sup>a</sup>			
Horsehead	<0.02	<0.02	<0.01	<0.02	0.02	0.01 <sup>a,m</sup>			
Ced 201	<0.03 <sup>a</sup>	<0.03 <sup>a</sup>	<0.02 <sup>a</sup>	<0.03 <sup>a</sup>	<0.02 <sup>a</sup>	<0.02 <sup>a</sup>			

(<sup>a</sup>) Only single point on stripe observed, no OTF map.

(<sup>m</sup>) Marginal/tentative detection.

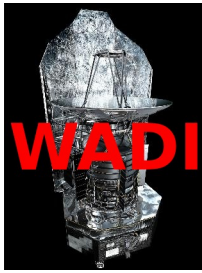
(<sup>r</sup>) Emission above absorption trunk of 0.27 K.



# Results

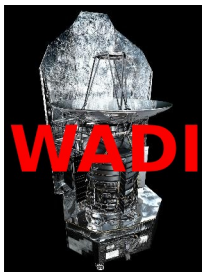
- Analysis of the data in very non-uniform way so far
  - Not all data inspected yet
  - Entries in results matrix very sparse
  - Uniform analysis only for dedicated science subtopics
- More sophisticated models needed
- Modelling/interpretation has only started
- Data delivery to HSA:
  - No formal request yet
  - Informal discussions ongoing





# Results

- Recent papers:
  - $\text{H}_2\text{O}$  and  $\text{NH}_3$  in MonR2 structure - accepted (Paolo)
  - PE heating – submitted (Yoko)
  - [CII] and [ $^{13}\text{CII}$ ] – submitted (Volker)
- Pending (overdue):
  - NGC3603 (Zoltan)
  - Horsehead (David)
  - pv-diagrams (Volker)
  - NGC7023 + Orion Bar (Christine)

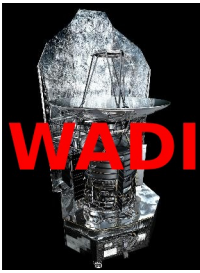


GT2

- Follow-up on WADI sources for  $^{13}\text{C}$  fractionation study
  - Only 2 observations still missing:
    - $^{13}\text{CII}$  in NGC3603 and Carina N

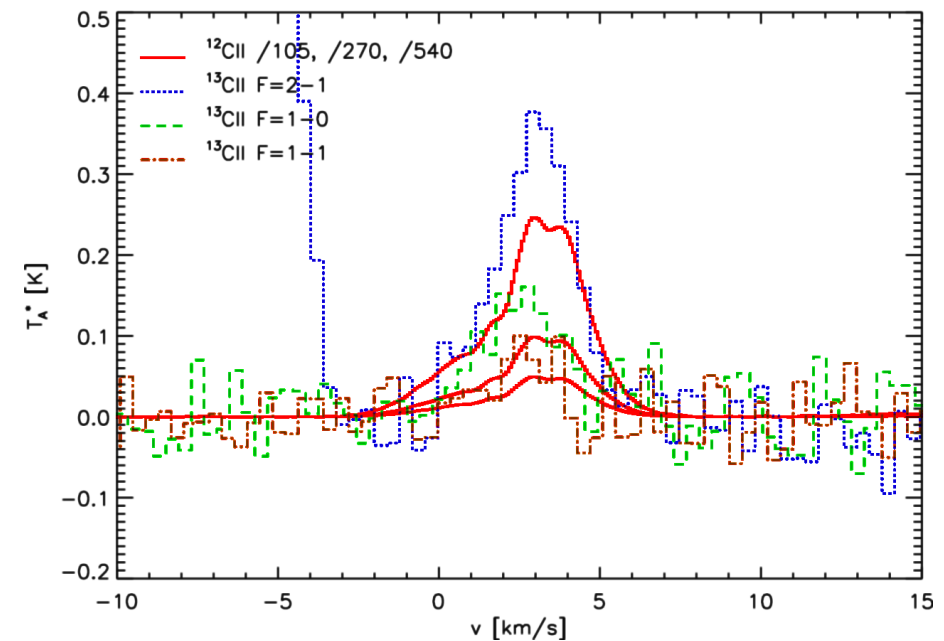
OD	Target	RA	DEC	AOT	Duration	Start time	Obs. Id	AOR Label
1233	MonR2	6h07m46.200s	-6d23m08.00s	HifiPoint	3314	2012-09-28T16:46:40Z	1342251588	13C+_MonR2
1233	MonR2-C+peak	6h07m45.600s	-6d23m16.80s	HifiPoint	3314	2012-09-28T15:49:27Z	1342251587	13C+_MonR2-C+peak
1072	MonR2-C+peak	6h07m45.600s	-6d23m16.80s	HifiPoint	1387	2012-04-20T19:51:04Z	1342244634	13C_MonR2-C+peak
1072	MonR2	6h07m46.200s	-6d23m08.00s	HifiPoint	1387	2012-04-20T19:26:04Z	1342244633	13C_MonR2
1218	Orion Bar front-veil	5h35m19.000s	-5d24m46.80s	HifiPoint	176	2012-09-13T05:58:18Z	1342251023	13C_OrionBar
1203	Orion Bar front-veil	5h35m19.000s	-5d24m46.80s	HifiPoint	399	2012-08-29T07:12:25Z	1342250416	13C+_OrionBar
1106	N7023-H2peak	21h01m32.400s	+68d10m25.00s	HifiPoint	1387	2012-05-23T19:33:28Z	1342246033	13C_NGC7023
1105	N7023-H2peak	21h01m32.400s	+68d10m25.00s	HifiPoint	3384	2012-05-23T17:19:03Z	1342246026	13C+_NGC7023
1134	NGC3603-MM2-pillar	11h15m10.890s	-61d16m15.20s	HifiPoint	1333	2012-06-21T03:21:45Z	1342247185	13C_NGC3603MM2
1134	CarinaN-point-IF	10h43m35.140s	-59d34m04.30s	HifiPoint	1407	2012-06-21T02:35:41Z	1342247183	13C_CarinaN

- Additional  $^{13}\text{CI}$  Orion Bar data from Olivier can be used



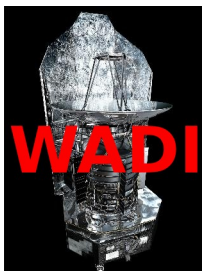
- First glance, preliminary results:

- [CI] also shows only the blue component in MonR2 like [ $^{13}\text{CII}$ ]
- NGC7023 [ $^{13}\text{CII}$ ] results already included in submitted paper
  - Slightly optically thick
  - Possibly fractionated in blue wing



- [CI]/[ $^{13}\text{CI}$ ] ratio in Orion Bar matching isotopic abundance ratio
- [CII]/[ $^{13}\text{CII}$ ] ratio in veil seems to show fractionation
- [CI]/[ $^{13}\text{CI}$ ] in veil not significant

→ Problem: no systematic analysis yet

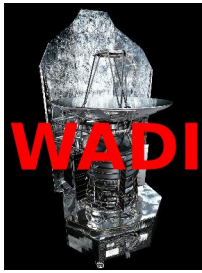


# OT1

WADI follow-up or related:

- DR21 and Mon R2  $\text{H}_2\text{O}^+$ :
  - Only one obsid still missing (972GHz DR21)
  - Analysis coordinated by Ed Chambers
  - Ground state lines of  $\text{OH}^+$  and  $\text{H}_2\text{O}^+$  very similar
  - Excited lines with different profile
  - No  $\text{H}_3\text{O}^+$
  - $\text{H}_2\text{O}^+$  MonR2 non-detections

OD	Target	RA	DEC	AOT	Duration	Start time	Obs. Id	AOR Label
924	DR21	20h39m01.100s	+42d19m43.00s	<a href="#">HifiPoint</a>	843	2011-11-24T05:34:21Z	1342232818	DR21-H2Oplus-1115
1105	DR21	20h39m01.100s	+42d19m43.00s	<a href="#">HifiPoint</a>	7493	2012-05-23T14:27:51Z	1342246023	DR21-H2Oplus-1816
923	DR21	20h39m01.100s	+42d19m43.00s	<a href="#">HifiPoint</a>	286	2011-11-23T14:16:10Z	1342232699	DR21-H2Oplus-607
939	DR21	20h39m01.100s	+42d19m43.00s	<a href="#">HifiPoint</a>	230	2011-12-08T14:35:31Z	1342233886	DR21-H2Oplus-722
1106	DR21	20h39m01.100s	+42d19m43.00s	<a href="#">HifiPoint</a>	7782	2012-05-24T06:52:51Z	1342246057	DR21-H3Oplus-1656
932	DR21	20h39m01.100s	+42d19m43.00s	<a href="#">PacsLineSpec</a>	7111	2011-12-02T09:28:35Z	1342233448	DR21-H3Oplus-2972
929	DR21	20h39m01.100s	+42d19m43.00s	<a href="#">HifiPoint</a>	345	2011-11-29T14:22:28Z	1342233298	DR21-OH-1835
932	DR21	20h39m01.100s	+42d19m43.00s	<a href="#">PacsLineSpec</a>	406	2011-12-02T11:29:16Z	1342233449	DR21-OH-2509
1061	DR21	20h39m01.100s	+42d19m43.00s	<a href="#">HifiPoint</a>	345	2012-04-09T09:48:53Z	1342244093	DR21-OHplus-1892
895	DR21	20h39m01.100s	+42d19m43.00s	<a href="#">HifiPoint</a>	246	2011-10-25T18:09:35Z	1342231441	DR21-OHplus-909
708	MonR2	6h07m46.200s	-6d23m08.00s	<a href="#">HifiPoint</a>	795	2011-04-22T08:47:15Z	1342219303	MonR2-H2Oplus-1115
1066	MonR2	6h07m46.200s	-6d23m08.00s	<a href="#">HifiPoint</a>	7493	2012-04-14T09:45:46Z	1342244392	MonR2-H2Oplus-1816
1062	MonR2	6h07m46.200s	-6d23m08.00s	<a href="#">HifiPoint</a>	286	2012-04-10T06:44:27Z	1342244040	MonR2-H2Oplus-607
1065	MonR2	6h07m46.200s	-6d23m08.00s	<a href="#">HifiPoint</a>	230	2012-04-13T12:10:14Z	1342244297	MonR2-H2Oplus-722
1069	MonR2	6h07m46.200s	-6d23m08.00s	<a href="#">HifiPoint</a>	7782	2012-04-17T12:56:48Z	1342244490	MonR2-H3Oplus-1656
881	MonR2	6h07m46.200s	-6d23m08.00s	<a href="#">PacsLineSpec</a>	7111	2011-10-11T21:37:09Z	1342230893	MonR2-H3Oplus-2972
1061	MonR2	6h07m46.200s	-6d23m08.00s	<a href="#">HifiPoint</a>	345	2012-04-09T08:24:35Z	1342244089	MonR2-OH-1835
881	MonR2	6h07m46.200s	-6d23m08.00s	<a href="#">PacsLineSpec</a>	406	2011-10-11T23:37:50Z	1342230894	MonR2-OH-2509
1061	MonR2	6h07m46.200s	-6d23m08.00s	<a href="#">HifiPoint</a>	345	2012-04-09T08:16:52Z	1342244088	MonR2-OHplus-1892
1066	MonR2	6h07m46.200s	-6d23m08.00s	<a href="#">HifiPoint</a>	246	2012-04-14T03:13:47Z	1342244385	MonR2-OHplus-909



## WADI follow-up or related:

- [CII] and CO 8-7 in Horsehead and NGC7023 (C. Joblin):
  - All observations taken
- HF, HCl, SH<sup>+</sup> in Mon R2 (M. Gonzalez):
  - Only 4 obsids so far: HCl, HCl<sup>+</sup>, SH<sup>+</sup>
- Rosette pillars- [CII] and PACS spectro. (N. Schneider):
  - Finished, analysis ongoing
- Orion large scale mapping (J. Goicoechea):
  - Many data arrived in September including Horsehead
- CO ladder in DR21 (M. Röllig):
  - Only <sup>13</sup>CO 5-4 map obtained so far
- Anything overlooked?