

## JCMT DR1: HETERODYNE DR

# WORKED EXAMPLES

## THE DATA – INSPECTING THE RAW DATA

www.eaobservatory.org/jcmt/science/reductionanalysis-tutorials/heterodyne-dr-tutorial-1/

AIM (1/2) - By the end of this session you should know:

- How are the raw data arranged?
- What were the typical system and receiver temperatures observed?
- What object/frequency did you look at?
- What was the 225GHz opacity of the observation?

What was the elevation when the observation was taken? https://proposals.eaobservatory.org/jcmt/calculator/heterodyne/time - estimate of the expected rms

## How are the raw data arranged? - ndftrace

	data — -bash — 135×54	
Last login: Fri Jul 22 14:13:29 on ttys003 Harriets-MacBook-Pro-2:~ hparsons\$ cd /Users/hparsons/Doc Harriets-MacBook-Pro-2:RadioSchool2016 hparsons\$ ls JCMT_HETERODYNE_analysis_tutorial_2016 analysing JCMT_HETERODYNE_analysis_tutorial_2016.tar.gz data JCMT_HETERODYNE_tutorial_2016.tar.gz reduced Harriets-MacBook-Pro-2:RadioSchool2016 hparsons\$ stardev Harriets-MacBook-Pro-2:RadioSchool2016 hparsons\$ kappa	uments/EAO/workshops/RadioSchool2016 molecular_data.sh ]	
KAPPA commands are now available (Version 2.3-2) Type kaphelp for help on KAPPA commands. Type 'showme sun95' to browse the hypertext document	ation.	
See the 'Release Notes' section of SUN/95 for detail changes made for this release.	s of the	
Harriets-MacBook-Pro-2:RadioSchool2016 hparsons\$ smurf	]	
SMURF commands are now available (Version 1.6. Type smurfhelp for help on SMURF commands. Type 'showme sun258' to browse the hypertext docu Type 'showme sc21' to view the SCUBA-2 map-making	1) mentation. cookbook.	
Harriets-MacBook-Pro-2:RadioSchool2016 hparsons\$ cd data/ Harriets-MacBook-Pro-2:data hparsons\$ ls a20070705_00034_01_0001.sdf a20110103_00025_01_0001.s a20070705_00038_01_0001.sdf a20110926_00029_01_0001.s a20070705_00039_01_0001.sdf a20110926_00029_02_0001.s Harriets-MacBook-Pro-2:data hparsons\$ ndftrace a20110103_	df a20111025_00007_01_0001.sdf df a20160316_00039_01_0001.sdf df a20160317_00017_01_0001.sdf 00025_01_0001.sdf	

```
0001:
    Label: TA* corrected antenna temperature
    Units: K
 Shape:
    No. of dimensions: 3
    Dimension size(s): 2048 x 15 x 120
    Pixel bounds : 1:2048, 1:15, 1:120
    Total pixels : 3686400
 Data Component:
    Туре
               : _REAL
    Storage form: SIMPLE
    Bad pixels may be present
 World Co-ordinate Systems:
    Number of co-ordinate Frames: 5
    Current co-ordinate Frame (Frame 5):
      Frame title
                       : "3-d compound coordinate system"
                         : DSBSPECTRUM-SPACEINDEX-TIME
      Domain
      First pixel centre : 461.1102, 1, 2011-01-03 10:58:49
         Axis 1:
            Label
                              : Radio velocity (LSB)
            Units
                              : km/s
            Nominal Pixel scale: 0.4444436 km/s
         Axis 2:
            Label
                             : Receptor Number
            Units
                              : pixel
            Nominal Pixel scale: 1 pixel
         Axis 3:
            Label
                              : Date/Time
            Units
                             : d
            Nominal Pixel scale: 0.115891E-04 d
  Extensions:
    JCMTOCS
                     <OCSINFO>
    ACSIS
                     <ACSIS_COMP>
    JCMTSTATE
                     <RTS_ARR>
                     <_CHAR*80>
    FITS
 History Component:
    Created
              : 2011 Jan 03 11:02:46
    No. records: 2
    Last update: 2011 Jan 03 11:02:46 (ACSIS-DA (V0.7-2))
    Update mode: NORMAL
```

## ► How are the raw data arranged? - GAIA

#### [Harriets-MacBook-Pro-2:data hparsons\$ gaia a20110103\_00025\_01\_0001.sdf GAIA\_DIR = /Users/hparsons/software/stardev//bin/gaia Started XML-RPC server for SAMP at http://harriets-macbook-pro-2.local:8030

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What were the typical system and receiver temperatures observed? - hdstrace

hdstrace with: raw-file.MORE.ACSIS.TSYS

Harriets-MacBook-Pro-2:data hparsons\$ hdstrace a20110103\_00025\_01\_0001.MORE.ACSIS.TSYS

A20110103\_00025.MORE.ACSIS.TSYS <\_REAL>

TSYS(15,120) 583.9656,538.9691,517.8671,587.4077,571.4322,517.3729,501.1141,505.8583,523.3659,476.5584,460.4876,484.3578,548.9593,456.7339,493.8378, ... 583.9656,538.9691,517.8671,587.4077,571.4322,517.3729,501.1141,505.8583,523.3659,476.5584,460.4876,484.3578,548.9593,456.7339,493.8378

End of Trace.

hdstrace with: raw-file.MORE.ACSIS.TRX

Harriets-MacBook-Pro-2:data hparsons\$ hdstrace a20110103\_00025\_01\_0001.MORE.ACSIS.TRX

A20110103\_00025.MORE.ACSIS.TRX <\_REAL>

TRX(15,120) 157.7215,144.3339,154.5026,183.3538,173.7708,109.0605,124.4508,99.32336,106.6599,77.00642,89.9705,133.0583,141.1756,92.05746,99.22109, ... 157.7215,144.3339,154.5026,183.3538,173.7708,109.0605,124.4508,99.32336,106.6599,77.00642,89.9705,133.0583,141.1756,92.05746,99.22109

End of Trace.

## What object/frequency did you look at? - fitslist

Harriets-MacBook-Pro-2:data hparsons\$ Harriets-MacBook-Pro-2:data hparsons\$ Harriets-MacBook-Pro-2:data hparsons\$ fitslist a20110103\_00025\_01\_0001.sdf | grep OBJECT OBJECT = 'L1551IRS5' / Object of interest Harriets-MacBook-Pro-2:data hparsons\$ fitsval a20110103\_00025\_01\_0001.sdf OBJECT L1551IRS5 Harriets-MacBook-Pro-2:data hparsons\$ fitslist a20110103\_00025\_01\_0001.sdf | grep Freq 5.0 / [GHz] IF Frequency IFFRE0 = LOFREQS = 334.29206145 / [GHz] LO Frequency at start of obs. LOFREQE = 334.2920544 / [GHz] LO Frequency at end of obs. POL\_FAXS= / Frequency dependency of waveplate offset of pol Harriets-MacBook-Pro-2:data hparsons\$ fitsval a20110103\_00025\_01\_0001.sdf MOLECULE C-18-0 Harriets-MacBook-Pro-2:data hparsons\$ fitsval a20110103\_00025\_01\_0001.sdf TRANSITI 3 - 2 Harriets-MacBook-Pro-2:data hparsons\$

## What was the 225GHz opacity & elevation of the observation? - fitslist

Harriets-MacBook-Pro-2:data hparsons\$ Harriets-MacBook-Pro-2:data hparsons\$ fitslist a20110103\_00025\_01\_0001.sdf | grep Tau TAU225ST= 0.079 / Tau at 225 GHz from CSO at start TAU225EN= 0.059 / Tau at 225 GHz from CSO at end 0.07519523054361 / 186GHz Tau from JCMT WVM at start WVMTAUST= WVMTAUEN= 0.0744467228651 / 186GHz Tau from JCMT WVM at end Harriets-MacBook-Pro-2:data hparsons\$ fitslist a20110103\_00025\_01\_0001.sdf | grep Elevation ELSTART = 49.28808168222 / [deg] Elevation at obs. start - mount sys. 47.6633223084 / [deg] Elevation at obs. end - mount sys. ELEND = Harriets-MacBook-Pro-2:data hparsons\$ Harriets-MacBook-Pro-2:data hparsons\$





## THE DATA – GENERIC REDUCTION

www.eaobservatory.org/jcmt/science/reductionanalysis-tutorials/heterodyne-dr-tutorial-1/

AIM (2/2) - By the end of the session you should:

- Run the raw data through the ORAC-DR pipeline
- Obtained a reduced cube of your chosen object
- Opened up your cube in >> gaia
- Examined a spectrum in >> splat
- Calculated the rms in your spectrum, for a given resolution
- If you have a single line: Estimate the peak temperature, if you have a basket weave produce an integrated intensity map.

- Run the raw data through the ORAC-DR pipeline default
- remember that after oracdr -files you should specify a file that contains the raw file you wish to reduce with the absolute file path. i.e.

>> /Users/hparsons/Documents/EAO/workshops/RadioSchool2016/data/a20070705\_00039\_01\_0001.sdf > g34-bw-subscan39.list

Harriets-MacBook-Pro-2:REDUCE_SCIENCE hparsons\$ oracdr_acsis Can not find data directory in default locations so using current directory
Unable to locate a raw data directory. Please fix ORAC_DATA_IN.
Default output directory (/Users/hparsons/Documents/EAO/workshops/RadioSchool2016/reduced/REDUCE_SCIENCE/reduced/acsis/20160807) does not exist. Assuming cu nt directory.
ORAC Data Reduction Pipeline (ORAC-DR Version 7d287ea07970) Configured for instrument ACSIS
Type "oracdr -man" for usage Type 'showme sun260' to browse the hypertext documentation
Raw data will be read from /Users/hparsons/Documents/EAO/workshops/RadioSchool2016/reduced/REDUCE_SCIENCE/raw/acsis/spectra/20160807 <pre>////////////////////////////////////</pre>
+++++++ For online ACSIS reduction use oracdr -loop flag -skip +++++++++
For comments specific to ACSIS data reduction mail helpdesk@eaobservatory.org For problems with the ORAC-DR system mail oracdr@eaobservatory.org http://www.oracdr.org
Harriets-MacBook-Pro-2:REDUCE_SCIENCE hparsons\$ export ORAC_DATA_IN Harriets-MacBook-Pro-2:REDUCE_SCIENCE hparsons\$ export oracde -files g34-C0-bw-subscan39.list

## Run the raw data through the ORAC-DR pipeline - default

•	ORAC-DR ACSIS	
Ε	it ORAC-DR Pause ORAC-DR ACSIS: ORAC-DR reducing observation 17	
	RAC-DR status log	
	RAC-DR Says: No display will be used RAC-DR Says: Pre-starting mandatory monolithsDone	
	hecking for next data file: /Users/hparsons/Documents/EAO/workshops/RadioSchool2016/data 20160317_00017_01_0001.sdf	ORAC-DR ACSIS
l	larning:Symlink from ORAC_DATA_OUT to /Users/hparsons/Documents/EAO/workshops/RadioSchool 16/data/a20160317_00017_01_0001.sdf already exists. Continuing toring: a20160317_00017_01_0001	Exit ORAC-DR Pause ORAC-DR ACSIS: ORAC-DR reducing observation
	new group 20160317#17#1 has been created	Retrieved calibration information for CRL2688 from database.
	EDUCING: a20160317_00017_01_0001 sing recipe REDUCE_STANDARD provided by the frame	Reference integrated intensity: 299,00K
	bserving Mode: HARP / grid / chop / standard opying a20160317_00017_01_0001 to a20160317_00017_01_raw0001done.	Reference peak flux: 10.70K
	etermining MAKECUBE parameters for GRID.	Calibration information written to log.standard
	etermining parameters for output cubedone. Creating cube from a20160317 00017 01 raw0001done.	Removing temporary files
	1 cube formed: a20160317_00017_01_cube001	Checking a20100317_00017_01_faw0001 Removing Checking a20100317_00017_01_ts001 Removing
	orting time-series data in time order	Checking a20100317_00017_01_thr001 Removing
$\overline{\mathbf{v}}$		Checking a20160317_00017_01_tsmsk001 Removing
	Warnings	Checking a20160317_00017_01_b1001 Removing
$\Delta$	RAC-DR warning messages Jarning:Symlink from ORAC DATA OUT to /Users/hparsons/Documents/EAO/workshops/RadioSchool	Recipe took 16.721 seconds to evaluate and execute.
	16/data/a20160317_00017_01_0001.sdf already exists. Continuing	Pipeline processing complete
ΓZ.	Press	Trocessed one recipe which completed successfully
EX.	RAC-DR error messages	Warnings
Ĩ	NO DA GILOI MARGAGO	<ul> <li>ORAC-DR warning messages</li> <li>Warning:Symlink_from_ORAC_DATA_OUT_to /Users/hparsons/Documents/EAO/workshops/RadioSchool</li> </ul>
Į.		016/data/a20160317_00017_01_0001.sdf already exists. Continuing
	Results	Errors
$\Delta$	RAC-DR results	□ ORAC-DR error messages
		Results
		△ UKAC-DK résults

## Run the raw data through the ORAC-DR pipeline - -log sf

🖲 😑 🔲 REDUCE_SCIENCE — starperl ~/software/stardev/bin/oracdr/src/bin/oracdr -ut 20160713 -batch -files CRL618-CO-stare.list -nodisplay
Harriets-MacBook-Pro-2:REDUCE_SCIENCE hparsons\$ Harriets-MacBook-Pro-2:REDUCE_SCIENCE hparsons\$ Harriets-MacBook-Pro-2:REDUCE_SCIENCE hparsons\$ oracdr -files CRL618-CO-stare.list -nodisplay -log sf I ORAC-DR Says: No display will be used ORAC-DR Says: Pre-starting mandatory monolithsDone Checking for next data file: /Users/hparsons/Documents/EAO/workshops/RadioSchool2016/data/a20160317_00017_01_0001.sdf Warning:Symlink from ORAC_DATA_OUT to /Users/hparsons/Documents/EAO/workshops/RadioSchool2016/data/a20160317_00017_01_0001.sdf already exists. Continuing Storing: a20160317_00017_01_0001 A new group 20160317_00017_01_0001 Using recipe REDUCE_STANDARD provided by the frame Observing Mode: HARP / grid / chop / standard Copying a20160317_00017_01_0001 to a20160317_0017_01_raw0001done.
Determining MAKECUBE parameters for GRID. Determining parameters for output cubedone. Creating cube from a20160317_00017_01_raw0001done. 1 cube formed: a20160317_00017_01_cube001
Sorting time-series data in time order
a20160317_00017_01_raw0001 to a20160317_00017_01_ts001: Sorted time slices in increasing time. Generated variance array based on Tsys values.
Remove frequency ends
a20160317_00017_01_ts001 to a20160317_00017_01_em001: Trimmed 2.75% from lower end of frequency range. Trimmed 2.75% from upper end of frequency range. Trimmed dimensions on axis 1: [226:7967]
a20160317_00017_01_em001 to a20160317_00017_01_thr001: Thresholding between -150 and 150 is not required.
Retrieving Tsys values from a20160317_00017_01_thr001. Tsys for entire array: 229.61 K Tsys values for each receptor: H00 H01 H02 H03 H04 H05 H06 H07 H08 209.584 206.413 189.433 240.375 186.499 193.870 279.435 199.076 249.919 H09 H10 H11 H12 H15 187.894 250.021 273.545 242.295 306.204
Calculating RMS values for a20160317_00017_01_thr001. RMS for entire array: 0.29 K RMS values for each receptor: H00 H01 H02 H03 H04 H05 H06 H07 H08

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## Opened up your reduced data cube in - GAIA



## Examined a reduced spectrum in - splat



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## Calculated the rms in your spectrum, for a given resolution

🛑 😑 🔵 📉 Displ	lay image sections of a cube (1)	Ella.	Maria	Cranhlan	<u></u>		Date Convers	latavaa	
<u>E</u> ile <u>V</u> iew <u>O</u> pt	ions <u>C</u> oords/StdO1Rest <u>G</u> o <u>H</u> elp	Elle	Alew	Graphics	<u>6</u> 0	Image-Analysis	Data-Servers	Interog	B
Input cube: ga2007070	05_38_1_reduced001.sdf Choose file		N						
Axis:	three : spec 🛁		17 24						
Index of plane:	-1 4	E -							
Coordinate of plane:	49.95633								
Coordinate type:	Radio velocity (LSB) (km/s)								
Increment:	1								
Show coordinate label:		Object X	ga20070	0705_38			1000	200 B	Contraction of the local sectors of the local secto
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- Spectrum controls: -		Value	:					1 - C.	
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Show limits on plot:		Equinox	c 🗌			100			
Lower index:	-948	Min	-2.8287	7670612				- <b>-</b>	The second s
Coordinate of plane:	450.8661	Max	9.08890	0342712			1.00		1000
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Fix data range:						XG	AIA: Spectral plot	t (1)	
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	Close		T						
i Send extracted spectrum	to SPLAT-VD and remove existing spectra	14 60.01		1					

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## Calculated the rms in your spectrum, for a given resolution

								Starlin	k SPLAT-VO: <p< th=""><th>olot0&gt;</th><th></th><th></th><th></th><th></th><th></th></p<>	olot0>					
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	Sum =	1.1001403048	86736	032303											
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## Calculated the rms in your spectrum, for a given resolution

[Harriets-MacBook-Pro-2:REDUCE\_SCIENCE hparsons\$ stats ga20070705\_38\_1\_reduced001.sdf comp=error

Pixel statistics for the NDF structure /Users/hparsons/Documents/EAO/workshops/RadioSchool2016/reduced/REDUCE\_SCIENCE/ ga20070705\_38\_1\_reduced001

<pre>Pixel sum : 3.15748e+06 Pixel mean : 0.807633 Standard deviation : 0.252796 Skewness : 0.774191 Kurtosis : -2.97661 Minimum pixel value : 0.484856 At pixel : (9, 15, -948) Co-ordinate : (18:53:14.511, 1:16:40.01, 450.8661 Maximum pixel value : 1.34567 At pixel : (9, -21, -948) Co-ordinate : (18:53:14.511, 1:12:18.07, 450.8661 Total number of pixels : 4633824 Number of pixels used : 3909552 (84.4%)</pre>	Title NDF array analysed	:	<undefined> ERROR</undefined>
Pixel mean : 0.807633 Standard deviation : 0.252796 Skewness : 0.774191 Kurtosis : -2.97661 Minimum pixel value : 0.484856 At pixel : (9, 15, -948) Co-ordinate : (18:53:14.511, 1:16:40.01, 450.8661 Maximum pixel value : 1.34567 At pixel : (9, -21, -948) Co-ordinate : (18:53:14.511, 1:12:18.07, 450.8661 Total number of pixels : 4633824 Number of pixels used : 3909552 (84.4%)	Pixel sum		3.15748e+06
Standard deviation       : 0.252796         Skewness       : 0.774191         Kurtosis       : -2.97661         Minimum pixel value       : 0.484856         At pixel       : (9, 15, -948)         Co-ordinate       : (18:53:14.511, 1:16:40.01, 450.8661         Maximum pixel value       : 1.34567         At pixel       : (9, -21, -948)         Co-ordinate       : (18:53:14.511, 1:12:18.07, 450.8661         Total number of pixels       : 4633824         Number of pixels used       : 3909552 (84.4%)	Pixel mean	÷	0.807633
Skewness       : 0.774191         Kurtosis       : -2.97661         Minimum pixel value       : 0.484856         At pixel       : (9, 15, -948)         Co-ordinate       : (18:53:14.511, 1:16:40.01, 450.8661         Maximum pixel value       : 1.34567         At pixel       : (9, -21, -948)         Co-ordinate       : (18:53:14.511, 1:12:18.07, 450.8661         Total number of pixels       : 4633824         Number of pixels used       : 3909552 (84.4%)	Standard deviation	÷	0.252796
Kurtosis : -2.97661 Minimum pixel value : 0.484856 At pixel : (9, 15, -948) Co-ordinate : (18:53:14.511, 1:16:40.01, 450.8661 Maximum pixel value : 1.34567 At pixel : (9, -21, -948) Co-ordinate : (18:53:14.511, 1:12:18.07, 450.8661 Total number of pixels : 4633824 Number of pixels used : 3909552 (84.4%)	Skewness	÷	0.774191
Minimum pixel value : 0.484856 At pixel : (9, 15, -948) Co-ordinate : (18:53:14.511, 1:16:40.01, 450.8661 Maximum pixel value : 1.34567 At pixel : (9, -21, -948) Co-ordinate : (18:53:14.511, 1:12:18.07, 450.8661 Total number of pixels : 4633824 Number of pixels used : 3909552 (84.4%)	Kurtosis	-	-2.97661
At pixel : (9, 15, -948) Co-ordinate : (18:53:14.511, 1:16:40.01, 450.8661 Maximum pixel value : 1.34567 At pixel : (9, -21, -948) Co-ordinate : (18:53:14.511, 1:12:18.07, 450.8661 Total number of pixels : 4633824 Number of pixels used : 3909552 (84.4%)	Minimum pixel value	÷	0.484856
Co-ordinate : (18:53:14.511, 1:16:40.01, 450.8661 Maximum pixel value : 1.34567 At pixel : (9, -21, -948) Co-ordinate : (18:53:14.511, 1:12:18.07, 450.8661 Total number of pixels : 4633824 Number of pixels used : 3909552 (84.4%)	At nixel	-	(9, 15, -948)
Maximum pixel value : 1.34567 At pixel : (9, -21, -948) Co-ordinate : (18:53:14.511, 1:12:18.07, 450.8661 Total number of pixels : 4633824 Number of pixels used : 3909552 (84.4%)	Co-ordinate	-	(18:53:14.511, 1:16:40.01, 450.8661)
At pixel : (9, -21, -948) Co-ordinate : (18:53:14.511, 1:12:18.07, 450.8661 Total number of pixels : 4633824 Number of pixels used : 3909552 (84.4%)	Maximum pixel value	÷	1.34567
Co-ordinate : (18:53:14.511, 1:12:18.07, 450.8661 Total number of pixels : 4633824 Number of pixels used : 3909552 (84.4%)	At nixel	÷	(9, -21, -948)
Total number of pixels : 4633824	Co-ordinate	-	(18:53:14.511, 1:12:18.07, 450.8661)
Number of pixels used : $3009552$ (84.4%)	Total number of nixels	:	4633824
	Number of nixels used	:	3909552 (84.4%)
No. of pixels excluded : $724272$ (15.6%)	No. of pixels excluded	;	724272 (15.6%)

Harriets-MacBook-Pro-2:REDUCE\_SCIENCE hparsons\$

above is higher than previous estimate but the above is based on all the data...

so we could try...

Harriets-MacBook-Pro-2:REDUCE\_SCIENCE hparsons\$ ndfcopy ga20070705\_38\_1\_reduced001.sdf out=ga20070705\_38\_1\_reduced001\_error comp=error Harriets-MacBook-Pro-2:REDUCE\_SCIENCE hparsons\$ gaiadisp ga20070705\_38\_1\_reduced001\_error Displayed image: ga20070705\_38\_1\_reduced001\_error Harriets-MacBook-Pro-2:REDUCE\_SCIENCE hparsons\$

## Calculated the rms in your spectrum, for a given resolution



#### JCMT DR1 - TIARA RADIO ASTRONOMY SUMMER SCHOOL

## If you have a single line: Estimate the peak temperature

			Starlink SPLAT-VO: <plo< th=""><th>ot0&gt;</th><th></th><th></th><th></th><th></th></plo<>	ot0>				
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				-	Radio v	elocity (LSB) (	(km/s)	

## If you have a single line: Estimate the peak temperature



## if you have a basket weave produce an integrated intensity map

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## if you have a basket weave produce an integrated intensity map



## if you have a basket weave produce an integrated intensity map

Harriets-MacBook-Pro-2:REDUCE\_SCIENCE hparsons\$ collapse in=ga20070705\_38\_1\_reduced001.sdf out=ga20070705\_38\_1\_reduced001\_integ axis=3 estimator=integ Collapsing pixel axis 3 from pixel -948 to pixel 947 inclusive...

WARNING: 0.156 of the output pixels (382 of 2444) are set bad due to an excessive number of bad values along the collapse axis. If this is undesired, decrease the fraction of good values required with Parameter WLIM (currently 0.300).

Harriets-MacBook-Pro-2:REDUCE\_SCIENCE h;



www.eaobservatory.org/jcmt/science/reductionanalysis-tutorials/heterodyne-dr-tutorial-1/

If you need to catch up please let me know, if you are ahead feel free to look at the heterodyne cookbook, find your own favorite object in the JCMT archive:

Heterodyne Cookbook:

http://starlink.eao.hawaii.edu/devdocs/sc20.htx/sc20.html

If you want to look for your own data:

http://www.cadc-ccda.hia-iha.nrc-cnrc.gc.ca/en/jcmt/



## JCMT DR2: HETERODYNE DR

# WORKED EXAMPLES

## THE DATA – ADVANCED REDUCTION

www.eaobservatory.org/jcmt/science/reductionanalysis-tutorials/heterodyne-dr-tutorial-2/

AIM (1/2) - By the end of this session you should know:

- How to run with a reduction of your choosing or a different reduction to the one specified
  - beware unless reduced in new directory files will be overwritten
- Choose a specific recipe, specify the binning/pixels
- Apply an efficiency factor to your data

Harriets-MacBook-Pro-2:reduced hparsons\$ cd REDUCE\_SCIENCE Harriets-MacBook-Pro-2:REDUCE\_SCIENCE hparsons\$ export ORAC\_DATA\_OUT=. Harriets-MacBook-Pro-2:REDUCE\_SCIENCE hparsons\$ oracdr -files g34-CO-bw.list -nodisplay -log sf ORAC-DR Says: No display will be used ORAC-DR Says: Pre-starting mandatory monoliths...Done Checking for next data file: /Users/hparsons/Documents/EAO/workshops/RadioSchool2016/data/a20070705\_00038\_01\_0001.sdf Checking for next data file: /Users/hparsons/Documents/EAO/workshops/RadioSchool2016/data/a20070705\_00039\_01\_0001.sdf Warning:Symlink from ORAC DATA OUT to /Users/hparsons/Documents/EAO/workshops/RadioSchool2016/data/a20070705 00038 01 0001.sdf already exists. Continuing... Warning:Symlink from ORAC\_DATA\_OUT to /Users/hparsons/Documents/EAO/workshops/RadioSchool2016/data/a20070705\_00039\_01\_0001.sdf already exists. Continuing... Storing: a20070705\_00038\_01\_0001 A new group 20070705#38#1 has been created Storing: a20070705\_00039\_01\_0001 This observation is part of group 20070705#38#1 Sorting Groups REDUCING: a200 Using Recipe REDUCE\_SCIENCE\_GRADIENT provided by the frame Standar not defined in file Union Tor #38 Warning. rom JCMTSTATE structure. Setting BASEC1 to 283.3275 #38 Warning: BASEC2 header not defined in file. Using TCS\_TR\_BC2 from JCMTSTATE structure. Setting BASEC2 to 1.2495277777778 #38 Warning: TRACKSYS header not defined in file. Using TCS\_TR\_SYS from JCMTSTATE structure. Setting TRACKSYS to J2000 Observing Mode: HARP / scan / pssw Determining MAKECUBE parameters for RASTER. Creating cube from a20070705\_00038\_01\_raw0001...done. 1 cube formed: a20070705\_00038\_01\_cube001

Sorting time-series data in time order...

a20070705\_00038\_01\_raw0001 to a20070705\_00038\_01\_ts001: Sorted time slices in increasing time. Masked detectors H03,H15. Generated variance array based on Tsys values.

Check for bad receptors

Receptors disabled by the calibration system: H15 Check that receptors have non-bad data.

Receptor H00 is valid. Receptor H01 is valid. Receptor H02 is valid. Receptor H04 is valid. Receptor H05 is valid. Receptor H06 is valid. Receptor H07 is valid. Receptor H08 is valid. Receptor H09 is valid. Receptor H10 is valid.

Harriets-MacBook-Pro-2:REDUCE\_SCIENCE\_NARROWLINE hparsons\$ export ORAC\_DATA\_OUT=. Harriets-MacBook-Pro-2:REDUCE\_SCIENCE\_NARROWLINE hparsons\$ Harriets-MacBook-Pro-2:REDUCE\_SCIENCE\_NARROWLINE hparsons\$ oracdr -files g34-C0-bw.list -nodisplay -log sf REDUCE\_SCIENCE\_NARROWLINE ORAC-DR Says: No display will be used ORAC-DR Says: Pre-starting mandatory monoliths...Done Checking for next data file: /Users/hparsons/Documents/EAO/workshops/RadioSchool2016/data/a20070705\_00038\_01\_0001.sdf Checking for next data file: /Users/hparsons/Documents/EAO/workshops/RadioSchool2016/data/a20070705\_00039\_01\_0001.sdf Warning:Symlink from ORAC\_DATA\_OUT to /Users/hparsons/Documents/EAO/workshops/RadioSchool2016/data/a20070705\_00038\_01\_0001.sdf already exists. Continuing... Varning:Symlink from ORAC DATA\_OUT to /Users/hparsons/Documents/EAO/workshops/RadioSchool2016/data/a20070705\_00039\_01\_0001.sdf already exists. Continuing... Storing: a20070705\_00038\_01\_0001 A new group 20070705#38#1 has been created Storing: a20070705\_00039\_01\_0001 This observation is part of group 20070705#38#1 Sorting Groups REDUCING: 020070705\_00038\_01\_0001 Using recipe REDUCE\_SCIENCE\_NARROWLINE specified on command-line #38 Warning: BASECT neader not berined in file. Using TCS\_TR\_BC1 from JCMTSTATE structure. Setting BASEC1 to 283.3275 #38 Warning: BASEC2 header not defined in file. Using TCS\_TR\_BC2 from JCMTSTATE structure. Setting BASEC2 to 1.2495277777778 #38 Warning: TRACKSYS header not defined in file. Using TCS\_TR\_SYS from JCMTSTATE structure. Setting TRACKSYS to J2000 Observing Mode: HARP / scan / pssw Determining MAKECUBE parameters for RASTER. Creating cube from a20070705\_00038\_01\_raw0001...done. 1 cube formed: a20070705\_00038\_01\_cube001

Sorting time-series data in time order...

a20070705\_00038\_01\_raw0001 to a20070705\_00038\_01\_ts001: Sorted time slices in increasing time. Masked detectors H03,H15. Generated variance array based on Tsys values.

Check for bad receptors

Receptors disabled by the calibration system: H15 Check that receptors have non-bad data. Receptor H00 is valid. Receptor H01 is valid. Receptor H02 is valid. Receptor H04 is valid. Receptor H05 is valid. Receptor H06 is valid. Receptor H06 is valid. Receptor H07 is valid. Receptor H08 is valid. Receptor H08 is valid.



Retrieving Tsys values from a20070705\_00038\_01\_thr001.

#### JCMT DR2 - TIARA RADIO ASTRONOMY SUMMER SCHOOL

## How to run with a reduction of your choosing (or a different reduction to the one specified)



It pays to check what reduction is being run and compare!



#### JCMT DR2 - TIARA RADIO ASTRONOMY SUMMER SCHOOL

## Choose a specific recipe, specify the binning

Harriets-MacBook-Pro-2:modified hparsons\$ export ORAC\_DATA\_OUT=. Harriets-MacBook-Pro-2:modified hparsons\$ oracdr -files g34-C0-bw.list -nodisplay -log sf -recpars myprams.ini ORAC-DR Says: No display will be used ORAC-DR Says: Pre-starting mandatory monoliths...Done Checking for next data file: /Users/hparsons/Documents/EAO/workshops/RadioSchool2016/data/a20070705\_00038\_01\_0001.sdf Checking for next data file: /Users/hparsons/Documents/EAO/workshops/RadioSchool2016/data/a20070705\_00039\_01\_0001.sdf Storing: a20070705\_00038\_01\_0001 A new group 20070705#38#1 has been created Storing: a20070705\_00039\_01\_0001 This observation is part of group 20070705#38#1 Sorting Groups REDUCIN Using recipe REDUCE\_SCIENCE\_GRADIENT provided by the frame #38 Warnage: RASEC1 header not defined on file. Using TCS\_TR\_BC1 from JCMTSTATE structure. Setting BASEC1 to 283.3275 #38 Warning: BASEC2 header not defined in file. Using TCS\_TR\_BC2 from JCMTSTATE structure. Setting BASEC2 to 1.2495277777778 #38 Warning: TBACKSYS bundles and defined in file. Using TCS\_TR\_SYS from JCMTSTATE structure. Setting TRACKSYS to J2000 Observing Mode: HARP / scan / pssw Recipe parameter overrides: Setting pixel scale to 4 arcseconds per pixel. Will rebin final cubes to 10 km/s resolution. a20070705\_00038\_01\_0001 to a20070705\_00038\_01\_raw0001...done. Determining MAKECUBE parameters for RASTER. Creating cube from a20070705\_00038\_01\_raw0001...done. [REDUCE\_SCIENCE\_GRADIENT] 1 cube formed: a20070705\_00038\_01\_cube001  $PIXEL_SCALE = 4$ Sorting time-series data in time order... rebin=10 a20070705\_00038\_01\_raw0001 to a20070705\_00038\_01\_ts001: Sorted time slices in increasing time. Masked detectors H03. Generated variance array based on Tsys values.

Check for bad receptors

Receptors disabled by the calibration system: Check that receptors have non-bad data. Receptor H00 is valid. Receptor H01 is valid. Receptor H02 is valid. Receptor H04 is valid. Receptor H05 is valid. Receptor H06 is valid. Receptor H07 is valid. Receptor H08 is valid.

## Apply an efficiency factor to your data

Harriets-MacBook-Pro-2:REDUCE\_SCIENCE hparsons\$
[Harriets-MacBook-Pro-2:REDUCE\_SCIENCE hparsons\$ cdiv in=ga20070705\_38\_1\_reduced001.sdf scalar=0.63 out=ga20070705\_38\_1\_reduced001\_Tmb
Harriets-MacBook-Pro-2:REDUCE\_SCIENCE hparsons\$

## THE DATA – EXTRACTING SCIENCE

www.eaobservatory.org/jcmt/science/reductionanalysis-tutorials/heterodyne-dr-tutorial-2/ AIM (2/2) - By the end of this session you should know:

- How to produce channel maps (cube)
- How to produce position-velocity diagrams (cubes)
- How to find clumps
- How to produce a grid of spectra

if time:

Investigate GAIA's tools - catalogs, GAIA3D, contouring...

## How to produce channel maps (cube)

#### [Harriets-MacBook-Pro-2:REDUCE\_SCIENCE hparsons\$ gaiadisp ga20070705\_38\_1\_reduced001.sdf Displayed image: ga20070705\_38\_1\_reduced001.sdf

Harriets-MacBook-Pro-2:REDUCE SCIENCE hparsonss



## How to produce channel maps (cube)

	lay image sections of a cube (		•			X Starlink GAIA::	Skycat: GaiaTemp	Chanmap2.sdf (1)	)	
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Axis:	three : spec									
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## How to produce position-velocity diagrams (cubes)

Harriets-MacBook-Pro-2:REDUCE\_SCIENCE hparsons\$ collapse in=ga20070705\_38\_1\_reduced001.sdf axis=skylat estimator=sum out=ga20070705\_38\_1\_reduced001\_pv1 Collapsing pixel axis 2 from pixel -22 to pixel 24 inclusive...

WARNING: 0.09615 of the output pixels (9480 of 98592) are set bad due to an excessive number of bad values along the collapse axis. If this is undesired, decrease the fraction of good values required with Parameter WLIM (currently 0.30000).

Harriets-MacBook-Pro-2:REDUCE\_SCIENCE hparsons\$ collapse in=ga20070705\_38\_1\_reduced001.sdf axis=skylon estimator=sum out=ga20070705\_38\_1\_reduced001\_pv2 Collapsing pixel axis 1 from pixel -25 to pixel 26 inclusive...

WARNING: 0.02128 of the output pixels (1896 of 89112) are set bad due to an excessive number of bad values along the collapse axis. If this is undesired, decrease the fraction of good values required with Parameter WLIM (currently 0.30000). Harriets-MacBook-Pro-2:REDUCE\_SCIENCE hparsons\$ gaiadisp ga20070705\_38\_1\_reduced001\_pv1 Displayed image: ga20070705\_38\_1\_reduced001\_pv1 Harriets-MacBook-Pro-2:REDUCE\_SCIENCE hparsons\$ gaiadisp ga20070705\_38\_1\_reduced001\_pv2 Displayed image: ga20070705\_38\_1\_reduced001\_pv2 Harriets-MacBook-Pro-2:REDUCE\_SCIENCE hparsons\$ gaiadisp ga20070705\_38\_1\_reduced001\_pv2

## How to produce position-velocity diagrams (cubes)

[	Harriets-MacBook-Pro-2:REDUCE_SCIENCE hparsons\$ collapse in=ga20070705_38_1_reduced001.sdf axis=skylat estimator=sum out=ga20070705_38_1_reduced001_pv1 Collapsing pixel axis 2 from pixel -22 to pixel 24 inclusive																
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Harriets-MacBook-Pro-2:REDUCE\_SCIENCE hparsons\$ collapse in=\"ga20070705\_38\_1\_reduced001.sdf\(:,:,-72:46\)\" ut=ga20070705\_38\_1\_reduced001\_collapse1 axis=1 estimator=integ Collapsing pixel axis 1 from pixel -25 to pixel 26 inclusive...

WARNING: 0.0426 of the output pixels (238 of 5593) are set bad due to an excessive number of bad values along the collapse axis. If this is undesired, decrease the fraction of good values required with Parameter WLIM (currently 0.3000).

Harriets-MacBook-Pro-2:REDUCE\_SCIENCE hparsons\$

Harriets-MacBook-Pro-2:REDUCE\_SCIENCE hparsons\$

Harriets-MacBook-Pro-2:REDUCE\_SCIENCE hparsons\$ collapse in=\"ga20070705\_38\_1\_reduced001.sdf\(:,:,-72:46\)\" out=ga20070705\_38\_1\_reduced001\_collapse2 axis=2 estimator=integ Collapsing pixel axis 2 from pixel -22 to pixel 24 inclusive...

WARNING: 0.1923 of the output pixels (1190 of 6188) are set bad due to an



How to find clumps

Harriets-MacBook-Pro-2:clumpfind hparsons\$ findclumps in=ga20070705\_38\_1\_reduced001.sdf out=ga20070705\_38\_1\_reduced\_clumps outcat=ga20070705\_38\_1\_reduced\_clumps

RMS - RMS noise level /0.84616207415676/ >

ClumpFind:

4504 clumps rejected because they contain fewer than MinPix (16) pixels. 231 clumps rejected because they touch an edge of the data array. 1 clump rejected because it spans only a single pixel along one or more axes. 66 further clumps rejected because they are smaller than the spatial beam width. 11 further clumps rejected because they are smaller than the spectral resolution (some of these may also be smaller than the spatial beam width). 234 further clumps rejected because they include too many bad pixels. 179 usable clumps found.

Configuration parameters: CLUMPFIND.ALLOWEDGE=0 CLUMPFIND.DELTAT=1.69232414831352 CLUMPFIND.FWHMBEAM=2 CLUMPFIND.IDLALG=0 CLUMPFIND.MAXBAD=0.05 CLUMPFIND.MINPIX=16 CLUMPFIND.NAXIS=3 CLUMPFIND.RMS=0.84616207415676 CLUMPFIND.TLOW=1.69232414831352 CLUMPFIND.VELORES=2

http://www.starlink.ac.uk/docs/sun255.htx/sun255.html



ClumpFind.AllowEdge = 0 CLUMPFIND.TLOW=5\*RMS ClumpFind.MinPix=10 ClumpFind.VeloRes=2 CLUMPFIND.DELTAT=5\*RMS

Harriets-MacBook-Pro-2:clumpfind hparsons\$ pico config.lis

Harriets-MacBook-Pro-2: clumpfind hparsons\$ findclumps in=ga20070705\_38\_1\_reduced001.sdf out=ga20070705\_38\_1\_reduced\_clumps outcat=ga20070705\_38\_1\_reduced\_clumps config=^config.lis

RMS - RMS noise level /0.84616207415676/ >

ClumpFind:

17 clumps rejected because they contain fewer than MinPix (10) pixels.

17 clumps rejected because they touch an edge of the data array.

1 further clump rejected because it is smaller than the spatial beam width.

2 further clumps rejected because they are smaller than the spectral

resolution (some of these may also be smaller than the spatial beam width).

6 further clumps rejected because they include too many bad pixels.

16 usable clumps found.

Configuration parameters: CLUMPFIND.ALLOWEDGE=0 CLUMPFIND.DELTAT=4.2308103707838 CLUMPFIND.FWHMBEAM=2 CLUMPFIND.IDLALG=0 CLUMPFIND.MAXBAD=0.05 CLUMPFIND.MINPIX=10 CLUMPFIND.NAXIS=3 CLUMPFIND.RMS=0.84616207415676 CLUMPFIND.TLOW=4.2308103707838 CLUMPFIND.VELORES=2

[Harriets-MacBook-Pro-2:clumpfind hparsons\$ gaiadisp ga20070705\_38\_1\_reduced\_clumps Displayed image: ga20070705\_38\_1\_reduced\_clumps Harriets-MacBook-Pro-2:clumpfind hparsons\$



#### [Harriets-MacBook-Pro-2:clumpfind hparsons\$ topcat -f fits ga20070705\_38\_1\_reduced\_clumps.FIT

۲		TOPCAT	IT — 186×52
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		Location: ga20070705_38_1_reduced_clumps.FIT Name: ga20070705_38_1_reduced_clumps	
_		Rows: 16	
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#### Table Browser for 1: ga20070705\_38\_1\_reduced\_clumps.FIT

2 X

	PIDENT	Peak1	Peak2	Peak3	Cen1	Cen2	Cen3	Size1	Size2	Size3	Sum	Peak	Volume
1	1	283.32866	1.24544	55.0365	283.3229	1.25049	55.02705	25.33113	26.17924	0.78577	13150.89842	33.05497	27590.02051
2	2	283.33674	1.22725	55.0365	283.34258	1.2248	54.59953	18.84148	17.11961	0.31403	4652.65858	37.6769	10914.97732
3	3	283.33472	1.2515	56.72988	283.33419	1.25772	56.35532	24.16079	23.88616	0.84042	9215.3729	25.15452	24474.6563
4	4	283.32866	1.22725	54.61315	283.32484	1.22557	54.38156	15.18904	12.70467	0.36922	2467.17297	34.22217	5827.29806
5	5	283.3145	1.23938	55.0365	283.31099	1.23834	54.8338	18.68781	21.06238	0.62811	7607.94508	23.03697	18333.57752
6	6	283.32866	1.22321	55.88319	283.32361	1.21777	55.75129	15.06296	18.13465	0.7448	4526.43676	21.72127	12058.02355
7	7	283.3145	1.24544	64.35013	283.31321	1.24892	64.70157	15.40112	17.2727	0.8644	3479.28417	16.04313	11901.1369
8	8	283.3327	1.21917	56.30654	283.33068	1.21795	56.50477	6.22722	7.79277	0.53299	643.75302	27.72717	1815.4271
9	9	283.3145	1.23331	63.08009	283.3125	1.2355	62.80368	6.06732	9.49459	0.17448	540.272	39.20407	2174.03046
10	10	283.30035	1.26767	55.45984	283.30002	1.27049	55.17344	17.58317	11.01896	0.28957	427.68682	17.77885	1882.66488
11	11	283.3145	1.20906	57.15323	283.31194	1.21068	56.88509	6.11534	4.56645	0.49286	465.41209	27.01974	1658.53766
12	12	283.31046	1.24746	49.95633	283.31917	1.24934	49.87489	20.52584	5.09756	0.13846	678.72701	41.50911	2779.17302
13	13	283.32259	1.21917	62.65674	283.32306	1.21924	62.68033	14.33216	7.32079	0.59577	663.37777	14.59879	2868.82304
14	14	283.3044	1.20906	57.15323	283.30251	1.20951	56.78007	8.4087	6.30755	0.08763	286.05474	63.6299	1143.04603
15	15	283.31046	1.2131	62.2334	283.30709	1.2148	62.24816	12.39604	4.98815	0.51766	907.77857	18.47295	3563.61497
16	16	283.30237	1.24948	63.92679	283.30174	1.25082	63.6704	10.47686	9.6744	0.52766	784.42086	14.18026	3025.71213

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- Peak1: The position of the clump peak value on axis 1.
- Peak2: The position of the clump peak value on axis 2.
- Peak3: The position of the clump peak value on axis 3.
- Cen1: The position of the clump centroid on axis 1.
- Cen2: The position of the clump centroid on axis 2.
- Cen3: The position of the clump centroid on axis 3.
- Size1: The size of the clump along pixel axis 1.
- Size2: The size of the clump along pixel axis 2.
- Size3: The size of the clump along pixel axis 3.
- Sum: The total data sum in the clump.
- Peak: The peak value in the clump.
- Volume: The total number of pixels falling within the clump.

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7322	Sum 13150.89842 4652.65858 9215.3729 2467.17297 7607.94508 4526.43676	Peak 33.05497 37.6769 25.15452 34.22217 23.03697 21.72127	Volume 27590.02051 10914.97732 24474.6563 5827.29806 18333.57752 12058.02355
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## Clumpfind



## fellwalker

## How to produce a grid of spectra

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## How to produce a grid of spectra

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www.eaobservatory.org/jcmt/science/reductionanalysis-tutorials/heterodyne-dr-tutorial-1/

If you need to catch up please let me know, if you are ahead feel free to look at the heterodyne cookbook, find your own favorite object in the JCMT archive:

Heterodyne Cookbook:

http://starlink.eao.hawaii.edu/devdocs/sc20.htx/sc20.html

If you want to look for your own data:

http://www.cadc-ccda.hia-iha.nrc-cnrc.gc.ca/en/jcmt/

### GAIA: Contouring



## GAIA: Plot known objects



## GAIA: Plot known objects





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