Heterodyne Calibration at JCMT

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(with lots of help from EAO Staff)

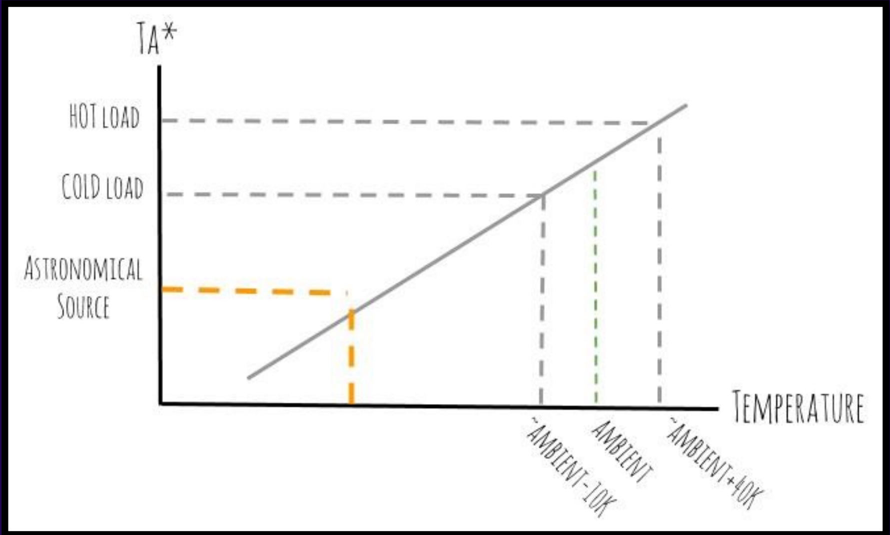
Overview of Heterodyne Calibration

- Two types:
  - Online Calibration
  - Offline Calibration
- Additional instrument specific fixes
- Workflow for HARP and `$\bar{U}$`$\bar{U}$

Online Calibration

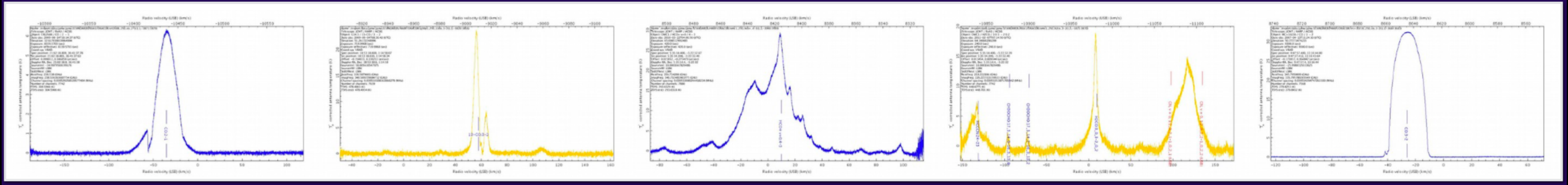
- Already applied to raw data.
- What – Calibrate all ACSIS data into T_A* scale.
- Why – Correct spectra for atmospheric attenuation and instrumental effects.
- How – Combine measurements of hot/cold/ambient loads, with knowledge of sky conditions.

$$T_{noise} = T_R + T_{atm}(1 - e^{-\tau})$$



Chopper Wheel Calibration (Penzias & Burrus 1973)

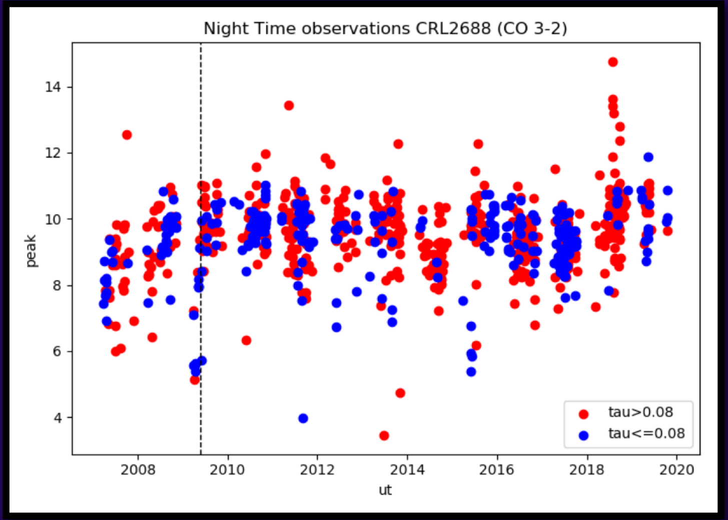
Observing Standards

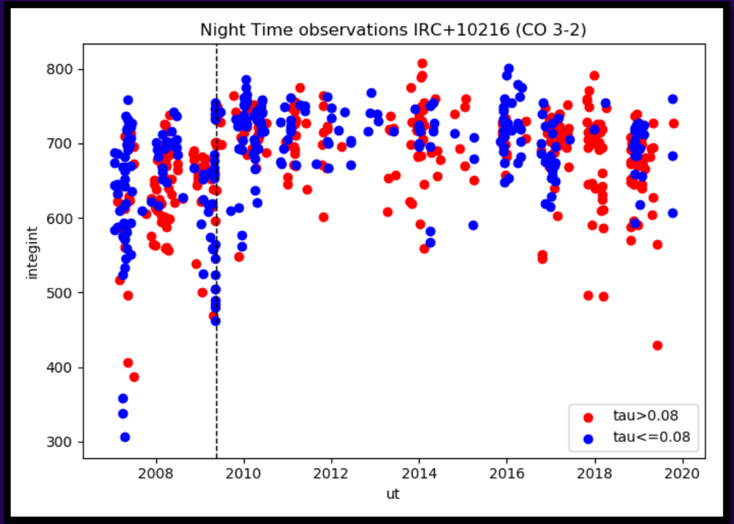


- Observe calibration sources at standard frequencies and bandwidths to match science observations every night.
- TSS checks if standards are within a nominal range (e.g., peak flux).

Instrument	Source	Type	mean	std	% error
HARP	CRL2688	PEAK	9.4	1.1	12.1
HARP	CRL2688	INTEGINT	237.2	28.3	11.9
HARP	CRL618	PEAK	4.4	0.5	11.9
HARP	CRL618	INTEGINT	139.8	19.3	13.8
HARP	IRC+10216	PEAK	31.2	3.2	10.2
HARP	IRC+10216	INTEGINT	672.0	70.4	10.5

Observing Standards





- Monitor performance of telescope and checking the temperature scale.

Offline Calibration - Temperature

- To be applied by user after observation.
- What – Convert TA* into physical units.
- Why – To get data in scientific units.
- How – Use efficiency measurements.

Main beam temperature – point sources

$$T_{mb} = {T_A}^* / \eta_{mb}$$

$$\eta_{mb} = 0.64$$

Radiation temperature – large sources filling beam

$${T_R}^* = {T_A}^* / \eta_{fss}$$

$$\eta_{fss} = 0.75$$

Offline Calibration – Flux Density

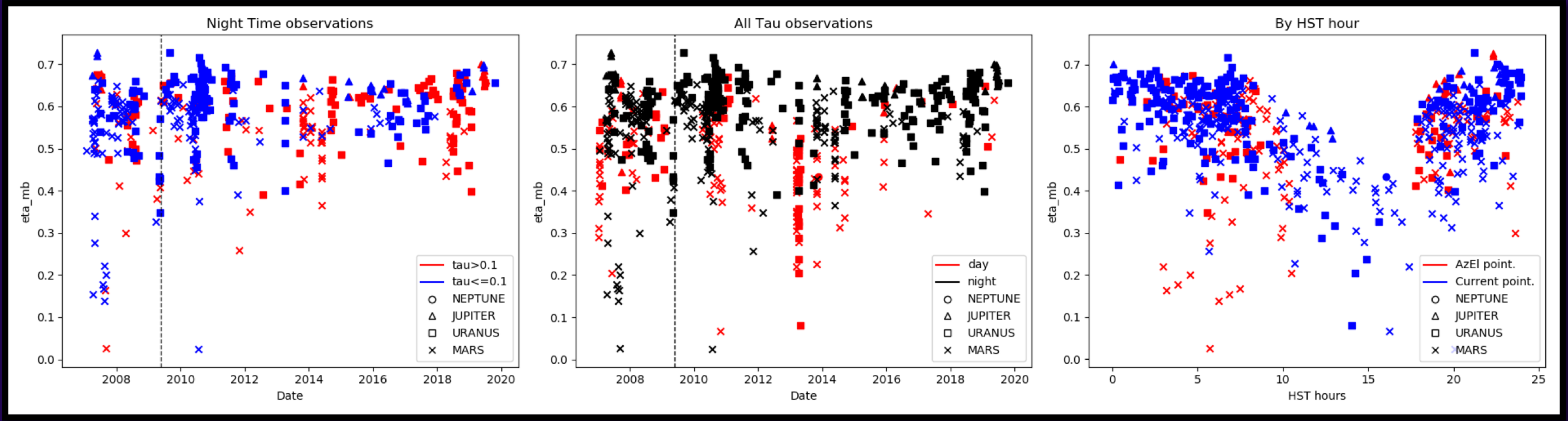
- To get flux density use the aperture efficiency.
- Calculated in same way as η_{fss}.

$$S_{Jy} = 15.6\, T_A{}^* / \eta_A$$

$$\frac{\eta_A}{\eta_{mb}} = 0.8$$

Monitoring Efficiency Measurements

- We regularly measure η_{mb} and η_A.
- There are still sources of uncertainty: natural variation in the beam, systematic issue, brightness of standards.



How to apply?

- Divide data by efficiency value using cdiv task.
- Update file attributes:
  - setlabel
  - setunits (if changed to flux density)
- Example:

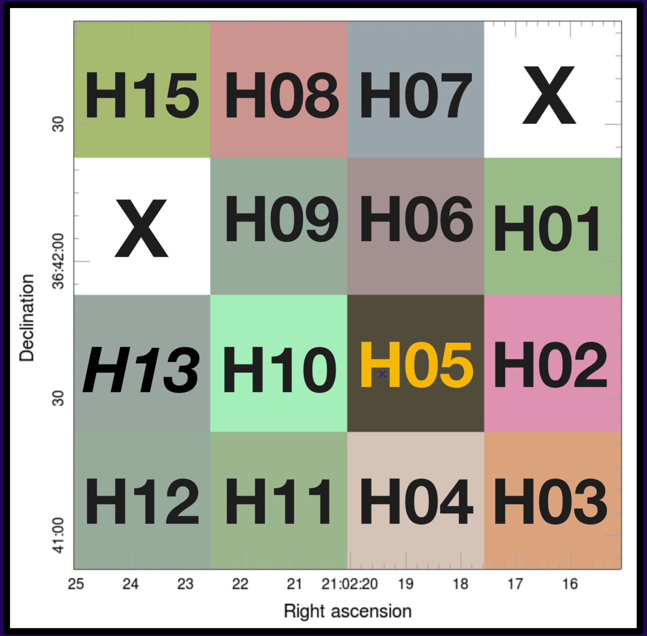
```
cdiv in=harp_reduced.sdf scalar=0.64 out=harp_tmb.sdf
setlabel ndf=harp_tmb.sdf label=`T_mb'
```

Additional Considerations

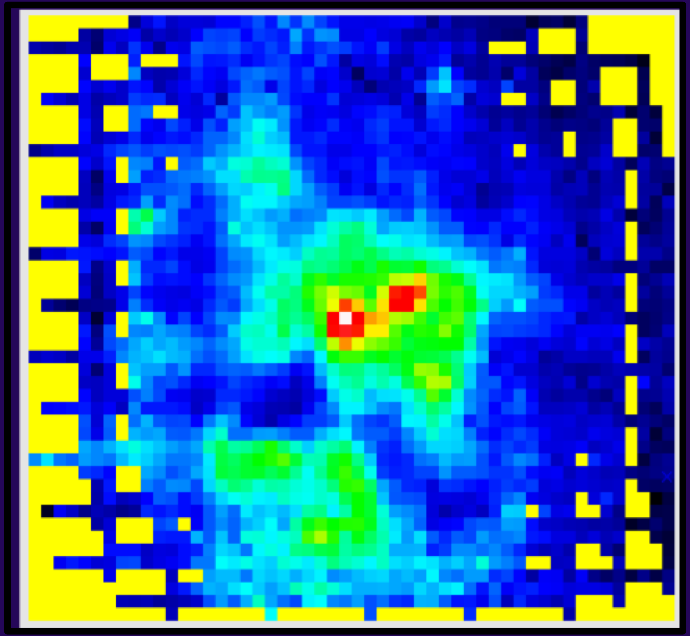
- To be applied by user if needed.
- May need to correct for specific instrument problems.
- Examples:
  - HARP receptor to receptor power variation
  - RxA side-band correction

HARP Reminders

- 16 receptors in the array.
- Raster map: scan across the target source field.

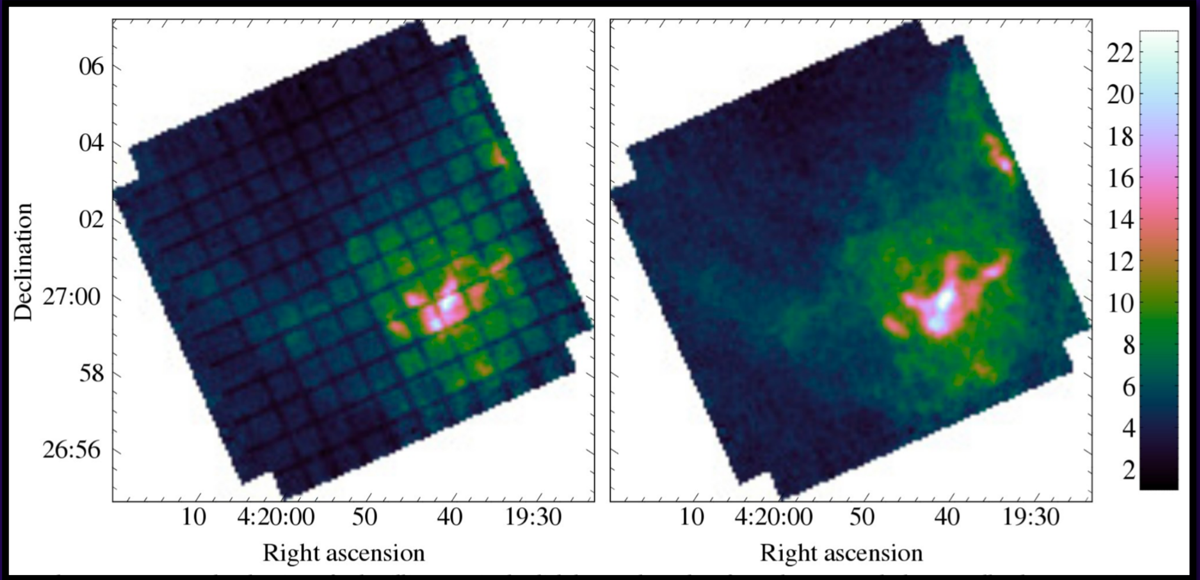


Example HARP Raster Map



Additional Considerations - HARP

- Variation in total power response per receptor causes gridlines in raster maps.
- Can be fixed (sometimes).



Additional Considerations - HARP

1. Calculate relative power across whole map for each receptor & derive normalization constant relative to reference receptor.
2. Apply normalization constant to un-gridded files for each receptor.
3. Re-grid/re-reduce corrected raw files.

- Add `FLATFIELD=1` to your recipe parameters (recpars) file to turn this on in heterodyne recipes.
- WARNING: Assumes each detector sees the same emission in map. Not valid for point sources!
- See Jenness et al., 2015 for details.

Summary of Workflow - HARP

1. Download data.
2. Reduce with ORAC-DR.

```
ORAC_DATA_IN=/User/HARP/raw
ORAC_DATA_OUT=/User/HARP/reduced
ls ORAC_DATA_IN/*.sdf >> data_files.lis
oracdr -files data_files.lis -loop file -batch -log sf -calib qaparams=myqa.ini
bad_receptors=index -recpars mypar.ini -nodisplay
```

3. Check data quality (do you have the HARP raster problem?).
4. Review logs and check standards for the night are in nominal range.
5. Select temperature/flux scale and apply related efficiency value.

Summary of Workflow - `Ū`Ū

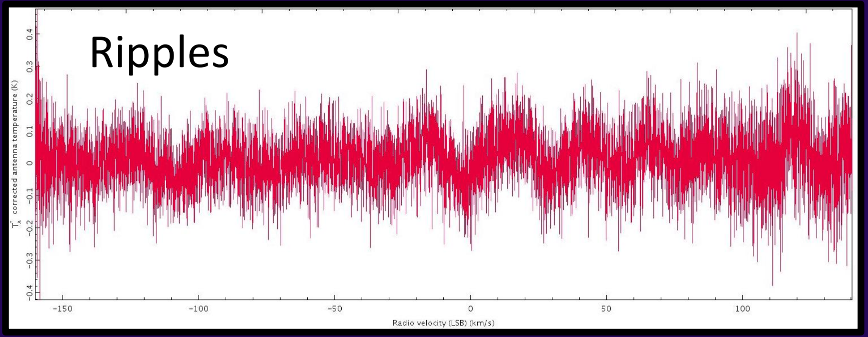
Commissioning in Progress…

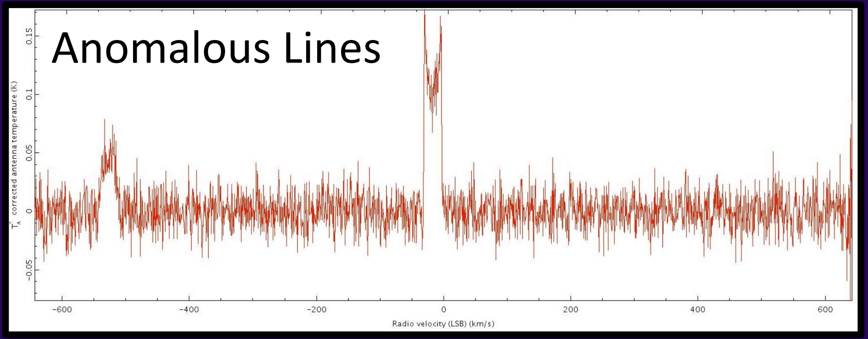
1. Download data.
2. Reduce with ORAC-DR, keeping different polarizations separate.

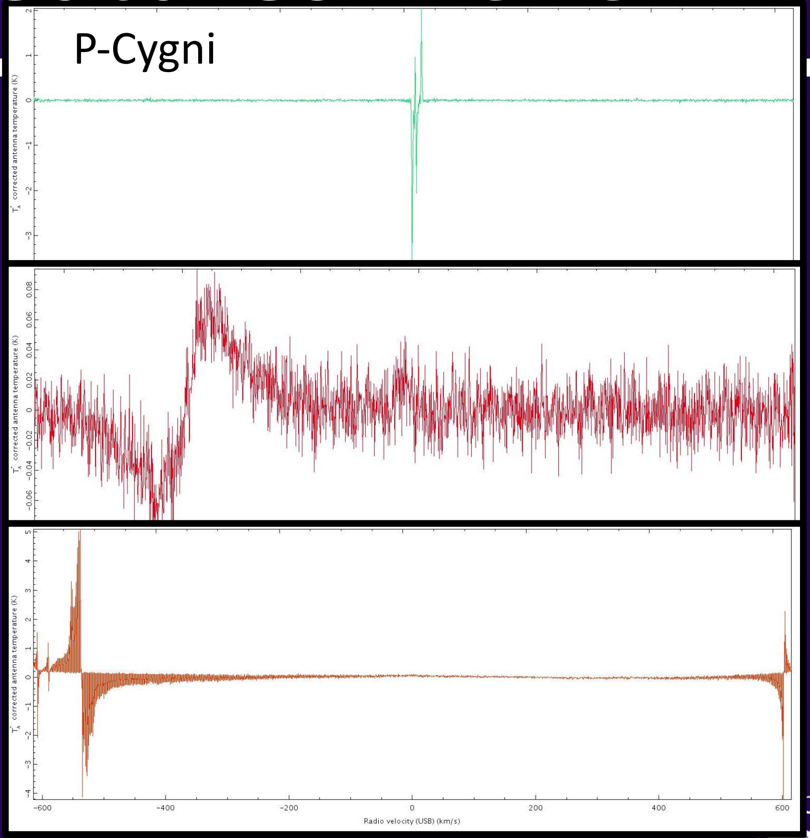
```
ORAC_DATA_IN=/User/UU/raw
ORAC_DATA_OUT=/User/UU/reduced/p0
ls ORAC_DATA_IN/*.sdf >> data_files.lis
echo "NU1L NU1U" > $ORAC_DATA_OUT/bad_receptors.lis
oracdr -loop file -batch -file $ORAC_DATA_IN/filelist.lis -nodisplay -log sf -verbose -calib bad_receptors=$ORAC_DATA_OUT/bad_receptors.lis
```

3. Check data quality: compare p0/p1, compare LSB/USB, check for weird features.
4. Review logs and check standards for the night are in nominal range.
5. Select temperature/flux scale and apply related efficiency value.

Weird Spectral Features - `Ū`Ū







Helpful Links and Info

- Heterodyne calibration webpages:
  - http://www.eaobservatory.org/jcmt/instrumentation/heterodyne/calibration
- HARP Spectral Standard Average Spectra:
  - http://www.eaobservatory.org/jcmt/instrumentation/heterodyne/calibration/harpstandards
- PI/CoIs of projects: see OMP project pages for access to observing logs, especially TSS comments on heterodyne calibration observations.
- If required, e-mail either your FoP or Observatory directly,
  - helpdesk@eaobservatory.org