Absolute Flux Calibration

Melanie Krips
(by Arancha Castro-Carrizo)
Outline

I. Primary/Secondary Flux Calibrators

II. Practical Tips to Calibrate the Fluxes of your Sources
Motivation

**What do we want in a flux calibrator?**

- strong (>1 Jy) emission at mm wavelengths
- compact (≪ 1″) emission at mm wavelengths
- emission should not be variable in time
- preferentially with long LST range (i.e., high declination source)
- no or only little sun-avoidance
- preferentially well known properties (such as SED, size)
Flux Calibrators

1. Quasars
2. Planets
3. Solar Bodies (Satellites, Asteroids, Dwarf Planets)
4. Radio Stars
1. Quasars
2. Planets
3. Solar Bodies (Satellites, Asteroids, Dwarf Planets)
4. Radio Stars
Flux Calibrators: Quasars

Source: 3C484
\[ \mu(\text{GHz}) \quad \text{80-100, 110-230} ; \text{MEAN(RMS)}: 12.37(6.62) 10.41(7.71) 13.15(8.77) 11.23(9.22) \]
\[ F(\nu) - F(\nu/100) \text{**m: } \text{pwv} \#1 \text{mm} < 3.5 \text{ mm} \text{ pwv} \#2 \text{mm} < 7.0 \text{ mm} \]
\[ \begin{align*}
F_0 &- 10.41 \, n = -1.64(\nu/90/100) & F_0 &- 10.41 \, n = 2.45(\nu/100/110) & F_0 &- 12.24 \, n = 0.10(\nu/90/230) \\
F_0 &- 12.78 \, n = 0.31(\nu/90/110) & F_0 &- 10.41 \, n = 0.09(\nu/100/230) & F_0 &- 13.43 \, n = 0.21(\nu/110/230)
\end{align*} \]

Source: 3C484
\[ \mu(\text{GHz}) \quad \text{80-100, 110-230} ; \text{MEAN(RMS)}: 6.42(2.18) 6.20(2.50) 5.33(2.35) 3.96(1.97) \]
\[ F(\nu) - F(\nu/100) \text{**m: } \text{pwv} \#1 \text{mm} < 3.5 \text{ mm} \text{ pwv} \#2 \text{mm} < 7.0 \text{ mm} \]
\[ \begin{align*}
F_0 &- 6.20 \, n = -0.33(\nu/90/100) & F_0 &- 6.20 \, n = -1.57(\nu/100/110) & F_0 &- 6.08 \, n = -0.51(\nu/90/230) \\
F_0 &- 5.82 \, n = -0.92(\nu/90/110) & F_0 &- 6.20 \, n = -0.64(\nu/100/230) & F_0 &- 5.64 \, n = -0.40(\nu/110/230)
\end{align*} \]
Flux Calibrators: Quasars

**Source: 3C484**

- \( \mu(\text{GHz}) \): 90 - 100 - 110 - 230
- MEAN(RMS): 12.37(8.62) 10.41(7.71) 13.15(9.77) 11.23(9.22)
- F(\nu)=F(\nu/100)**n:**
  - pwv @ 1mm < 3.5 mm
  - pwv @ 3mm < 7.0 mm
- F0 = 10.41 n = 1.64(\nu/90/100) F0 = 10.41 n = 2.45(\nu/100/110) F0 = 12.24 n = 0.10(\nu/90/230)
- F0 = 12.78 n = 0.31(\nu/90/110) F0 = 10.41 n = 0.09(\nu/100/230) F0 = 13.43 n = 0.21(\nu/110/230)

**Source: 3C484**

- \( \mu(\text{GHz}) \): 90 - 100 - 110 - 230
- MEAN(RMS): 6.42(2.18) 6.20(2.50) 5.33(2.35) 3.90(1.97)
- F(\nu)=F(\nu/100)**n:**
  - pwv @ 1mm < 3.5 mm
  - pwv @ 3mm < 7.0 mm
- F0 = 6.20 n = 0.33(\nu/90/100) F0 = 6.20 n = 1.57(\nu/100/110) F0 = 6.08 n = 0.51(\nu/90/230)
- F0 = 5.82 n = 0.92(\nu/90/110) F0 = 6.20 n = 0.64(\nu/100/230) F0 = 5.64 n = 0.40(\nu/110/230)

**Source: 3C345**

- \( \mu(\text{GHz}) \): 90 - 100 - 110 - 230
- MEAN(RMS): 4.59(1.31) 4.05(1.05) 4.14(1.00) 2.68(1.00)
- F(\nu)=F(\nu/100)**n:**
  - pwv @ 1mm < 3.5 mm
  - pwv @ 3mm < 7.0 mm
- F0 = 4.05 n = 1.19(\nu/90/100) F0 = 4.05 n = 0.43(\nu/100/110) F0 = 4.38 n = 0.46(\nu/90/230)
- F0 = 4.40 n = 0.42(\nu/90/110) F0 = 4.05 n = 0.37(\nu/100/230) F0 = 4.42 n = 0.47(\nu/110/230)

**Source: 3C273**

- \( \mu(\text{GHz}) \): 18.18(7.49) 13.50(6.94) 15.37(7.52) 12.68(8.12)
- F(\nu)=F(\nu/100)**n:**
  - pwv @ 1mm < 3.5 mm
  - pwv @ 3mm < 7.0 mm
- F0 = 15.50 n = 1.51(\nu/90/100) F0 = 15.50 n = 0.09(\nu/100/110) F0 = 17.66 n = 0.38(\nu/90/230)
- F0 = 16.54 n = 0.84(\nu/90/110) F0 = 15.50 n = 0.24(\nu/100/230) F0 = 15.75 n = 0.28(\nu/110/230)

*Not suitable!*
Flux Calibrators

1. Quasars
2. Planets
3. Solar Bodies (Satellites, Asteroids, Dwarf Planets)
4. Radio Stars
Flux Calibrators: Planets

• Pro:
  most of the solar planets have strong mm-emission and reasonably well derived flux models

• Contra:
  1.) Fluxes not completely constant
  2.) They start to be resolved (≥3") already at 3mm
  3.) Some of them have broad molecular line absorption (e.g., Mars, Jupiter, Saturn)
  4.) Not always visible, i.e., more constraints due to sun-avoidance, short LST ranges
Flux Calibrators: Planets

- **Pro:**
  most of the solar planets have strong mm-emission and reasonably well derived flux models

- **Contra:**
  1.) Fluxes not completely constant
  2.) They start to be resolved ($\geq 3''$) already at 3mm
  3.) Some of them have broad molecular line absorption (e.g., Mars, Jupiter, Saturn)
  4.) Not always visible, i.e., more constraints due to sun-avoidance, short LST ranges

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![Mars](Mars.png)

![Uranus](Uranus.png)

![Jupiter](Jupiter.png)

![Saturn](Saturn.png)

![Neptune](Neptune.png)
Flux Calibrators: Planets

(e.g., Mars, Jupiter, Saturn)

4.) Not always visible, i.e., more constraints due to sun-avoidance, short LST ranges
Flux Calibrators: Planets

Kramer et al. (2008)

(e.g., Mars, Jupiter, Saturn)

4.) Not always visible, i.e., more constraints due to sun-avoidance, short LST ranges
Flux Calibrators: Planets

Kramer et al. (2008)

(e.g., Mars, Jupiter, Saturn)

The constraints due to sun-earth latitude.
Flux Calibrators: Planets

Kramer et al. (2008)

- **Uranus**: 8.6GHz 90GHz, 6%
- **Neptune**: 8%
- **Uranus**: 10%

(e.g., Mars, Jupiter, Saturn)

The constraints due to sunspot cycles.
Flux Calibrators: Planets

- **Pro:**
  most of the solar planets have strong mm-emission and reasonably well derived flux models

- **Contra:**
  1.) Fluxes not completely constant
  2.) They start to be resolved ($\gtrsim$2") already at 3mm
  3.) Some of them have broad molecular line absorption (e.g., Mars, Jupiter, Saturn)
  4.) Not always visible, i.e., more constraints due to sun-avoidance, short LST ranges

- Mars
- Uranus
- Jupiter
- Saturn
- Neptune
Flux Calibrators: Planets

- Neptune: $< 21.2 \text{ Jy/K} > @ 26.6^\circ$
- Uranus: $< 22.6 \text{ Jy/K} > @ 40.3^\circ$

UV-radius (m)

Temperature (K)
Flux Calibrators: Planets

- Neptune: $< 29.5 \text{ Jy/K} >$ @ 28.4°
- Uranus: $< 27.8 \text{ Jy/K} >$ @ 40.6°
Flux Calibrators: Planets

- Neptune: $\langle 38.8 \text{ Jy/K} \rangle \pm 30.6^\circ$
- Uranus: $\langle 40.9 \text{ Jy/K} \rangle \pm 35^\circ$

Temperature (K) vs. uv-radius (m) at 260GHz
 Flux Calibrators: Planets

- Pro:
  most of the solar planets have strong mm-emission and reasonably well derived flux models

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  2.) They start to be resolved ($\geq 2''$) already at 3mm
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Flux Calibrators: Planets

- Pro:
  most of the time, reasonable

- Contra:
  1.) Fluxes
  2.) They shift
  3.) Some
    (e.g.,
  4.) Not always avoidable
Flux Calibrators: Planets

- PROPs
- Model
- Results
- 1.)
- 2.)
- 3.)
- 4.)

**URANUS**

**NEPTUNE**

Brightness Temperature (K)

Frequency (GHz)

Marten et al. (2005)

Cavalie et al. (2009)
Flux Calibrators: Planets

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  most of the solar planets have strong mm-emission and reasonably well derived flux models

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  1.) Fluxes not completely constant
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Flux Calibrators: Planets

- Pro: Flux calibrators are most reliable for continuous observations.

- Cons: Flux calibrators are not always available.
  1. Sun
  2. Mercury
  3. Venus
  4. Mars
  5. Jupiter
  6. Uranus
  7. Neptune

\[ \phi = 16\% \]
\[ m_c = -10.7 \]
Flux Calibrators

1. Quasars
2. Planets
3. Solar Bodies
   (Satellites, Asteroids, Dwarf Planets)
4. Radio Stars
Flux Calibrators: Satellites

- **Pro:**
  - They are quite compact (hence better for extended configurations and/or higher frequencies than planets) and still sufficiently bright (>500mJy@3mm)

- **Already regularly used at the SMA & ALMA:** Titan, Ganymede, Callisto

- **Contra:**
  - Titan also shows broad molecular lines
  - They are not always useable especially when they are too close to their ‘mother’-planet (or each other); one needs at least 3xPB
  - Flux models not as well constrained as for planets
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- flux models not as well constrained as for planets
Flux Calibrators: Asteroids/Dwarf Planets

- **Pro:**
  - bright and relatively small solar bodies

- **Contra:**
  - Still uncertainties in their flux; some of them known to vary quite significantly within a day
  - irregular shapes
Flux Calibrators: Asteroids/Dwarf Planets

• Pro:
  - bright and relatively small solar bodies

• Contra:
  - Still uncertainties in their flux; some of them known to vary quite significantly within a day
  - irregular shapes
Flux Calibrators

1. Quasars
2. Planets
3. Solar Bodies (Satellites, Asteroids, Dwarf Planets)
4. Radio Stars
Radio bright stars:
- MWC349 (binary star)
- CRL618 (PPN)
- W3OH (HII region)
- NGC7072 (young PN)
- NGC7538 (HII region)
- K3-50A (HII-region)
- .....
Flux Calibrators: Radio Stars

Pardo et al. (2009)

CRL618
Flux Calibrators: Radio Stars

Pardo et al. (2009)

CRL618

Too many lines!
Flux Calibrators: Radio Stars

Nakashima et al. (2010)
Flux Calibrators: Radio Stars

NGC7027

CO J=2-1

DEC offset (arcsec)

Too extended!

Nakashima et al. (2010)
Flux Calibrators: Radio Stars

Radio bright stars:
- MWC349
- CRL618
- W3OH
- NGC7072
- NGC7538
- K3-50A
Flux Calibrators: MWC349

**Some facts:**
- binary stellar system: MWC349A (Be) & MWC349B (B0 type III)
- the two stars are separated by $2.4'' \pm 0.1''$ and possibly interact
- MWC349A the brightest radio continuum star
- radio continuum produced by “ionised bipolar flow that photoevaporates from the surface of a neutral Keplerian disk”
- size of flow decreases with frequency
- strong but highly variable hydrogen maser emission (RRLs) from the near-edge-on disk ($\sim 0.065'' = 80\text{AU} @ 1.2\text{kpc}$)
- at declination of $>40\text{deg}$ -> visible for $\sim 13\text{h per day}$
Flux Calibrators: MWC349

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- at declination of >40deg -> visible for ~13h per day
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- size of flow decreases with frequency
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- at declination of >40deg -> visible for ∼13h per day
Flux Calibrators: MWC349

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- binary stellar system: MWC349A (Be) & MWC349B (B0 type III)
- the two stars are separated by 2.4″±0.1″ and possibly interact
- MWC349A the brightest radio continuum star
- radio continuum produced by “ionised bipolar flow that photoevaporates from the surface of a neutral Keplerian disk”
- size of flow decreases with frequency
- strong but highly variable hydrogen maser emission (RRLs) from the near-edge-on disk (≈0.065″=80AU@1.2kpc)
- at declination of >40deg -> visible for ≈13h per day
Flux Calibrators: MWC349

Some facts:
- binary stellar system MWC349A (Be) & MWC349B
- the two stars are separated by a few thousand AU and possibly interact
- MWC349A the brighter star
- radio continuumprésentation of a neutral Keplerian disk - flow that photoevaporates
- size of flow decreases
- strong but highly variable emission (RRLs) from MWC349A
  (≈0.065″=80AU@1AU)
- at declination of >40° the line is not visible for ∼13h/day
Flux Calibrators: MWC349

**Some facts:**
- binary stellar system: MWC349A (Be) & MWC349B (B0 type III)
- the two stars are separated by 2.4″±0.1″ and possibly interact
- MWC349A the brightest radio continuum star
- radio continuum produced by “ionised bipolar flow that photoevaporates from the surface of a neutral Keplerian disk”
- size of flow decreases with frequency
- strong but highly variable hydrogen maser emission (RRLs) from the near-edge-on disk (∼0.065″=80AU@1.2kpc)
- at declination of >40deg -> visible for ∼13h per day
Flux Calibrators: MWC349

Some facts:
- binary stellar system

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Weintraub et al. (2008)

![Graph showing velocity vs. RA Offset for MWC349](image)

![Graph showing Jy/Beam vs. VLSR for H38α](image)
Flux Calibrators: MWC349

Some facts:
- binary stellar system: MWC349A (Be) & MWC349B (B0 type III)
- the two stars are separated by $2.4'' \pm 0.1''$ and possibly interact
- MWC349A the brightest radio continuum star
- radio continuum produced by “ionised bipolar flow that photoevaporates from the surface of a neutral Keplerian disk”
- size of flow decreases with frequency
- strong but highly variable hydrogen maser emission (RRLs) from the near-edge-on disk ($\sim 0.065'' = 80\text{AU} @ 1.2\text{kpc}$)
- at declination of $>40^\circ$ => visible for $\sim 13\text{h}$ per day at Bure
Flux Calibrators: MWC349

Some observations:
- bright
- MWC349
- 3C84
- Moon
- Sun
- Mercury
- Venus
- Mars
- Saturn
- Jupiter
- Neptune
- Uranus
- alkappa = 

Day: 04-DEC-2010
0  3  6  9  12  15  18  21

U.T.C.  Obs: 05:54:28.500  44:38:02.000

L.S.T.  20:04

m_e = -10.6
How to calibrate a calibrator?

12-OCT-2008 @ 86.2 GHz (L01REF=1853 MHz)

ANTENNA

<table>
<thead>
<tr>
<th></th>
<th>3c454.3@46°</th>
<th>mwc349@72°</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21.5 Jy/K</td>
<td>21.3 Jy/K</td>
</tr>
<tr>
<td>2</td>
<td>22.3 Jy/K</td>
<td>22.5 Jy/K</td>
</tr>
<tr>
<td>3</td>
<td>21.7 Jy/K</td>
<td>22.1 Jy/K</td>
</tr>
<tr>
<td>4</td>
<td>22.1 Jy/K</td>
<td>22.4 Jy/K</td>
</tr>
<tr>
<td>6</td>
<td>22 Jy/K</td>
<td>21.9 Jy/K</td>
</tr>
</tbody>
</table>

Weighted Av. 21.8 Jy/K 21.9 Jy/K

MWC349 = <1.1 Jy> @ 71.7°; Fitted size: 0''

NEPTUNE = < 21.2 Jy/K > @ 26.6°
MWC349 = < 1.09 Jy > @ 71.7°

URANUS = < 22.6 Jy/K > @ 40.3°
MWC349 = < 1.16 Jy > @ 71.7°

SOURCE FLUX MAJOR MINOR PA
URANUS 7.4 3.64 3.53 255
NEPTUNE 2.7 2.27 2.21 340
3c454.3 26.51 (Neptune)
3c454.3 28.16 (Uranus)

Flagged:
L02 C02 for Line Frequency:86243MHz
L03 C03 for Line Frequency:86243MHz
L06 C06 for Line Frequency:86243MHz
L07 C07 for Line Frequency:86243MHz
How to calibrate a calibrator?

16-NOV-2008 @ 260 GHz (LO1REF=1888 MHz)

ANTENNA
3c454.3 @ 52°
1 39.9 Jy/K
2 34.6 Jy/K
3 41.8 Jy/K
4 51.4 Jy/K
5 34.5 Jy/K
6 39.9 Jy/K

mwc349 @ 75°
1 41.2 Jy/K
2 35.8 Jy/K
3 45.3 Jy/K
4 50.4 Jy/K
5 34.9 Jy/K
6 40.5 Jy/K

Weighted Av. 38 Jy/K 39.3 Jy/K

MWC349 = < 2.3 Jy > @ 75.5°; Fitted size: 0.14''

NEPTUNE = < 38.8 Jy/K > @ 30.6°
MWC349 = < 2.19 Jy > @ 75.5°

URANUS = < 40.9 Jy/K > @ 35°
MWC349 = < 2.04 Jy > @ 75.5°

SOURCE
FLUX  MAJOR  MINOR  PA
URANUS 41.1 3.56 3.45 255
NEPTUNE 15.4 2.23 2.17 340
3c454.3 13.76 (Neptune)
3c454.3 14.5  (Uranus)
Flux of MWC349: SED

\[ f(\nu [\text{GHz}]) = f_{100} \left( \frac{\nu}{100} \right)^{\alpha} \]

\[ \alpha = 0.6 \pm 0.01 \quad f_{100} = 1.17 \pm 0.01 \text{Jy} \quad \text{(PdBI)} \]

\[ f(\nu [\text{GHz}]) = f_{100} \left( \frac{\nu}{100} \right)^{\alpha} \]

\[ \alpha = 0.6 \pm 0.01 \quad f_{100} = 1.16 \pm 0.01 \text{Jy} \quad \text{(PdBI+VLA)} \]
Size of MWC349

\[ \text{MWC349} = \langle 1.2 \text{ Jy} \rangle @ 3\text{mm}; \quad \langle 1.5 \text{ Jy} \rangle @ 2\text{mm}; \quad \langle 1.9 \text{ Jy} \rangle @ 1\text{mm}; \]
Size of MWC349

Fit: $\theta \propto \nu^{-0.62\pm0.03}$ (fitted to cm and mm data)

Fit: $\theta \propto \nu^{-0.72\pm0.03}$ (Tafaya et al. 2004)
Reference radio bright stars:
- MWC349
Flux Calibrators: Radio Stars

Reference radio bright stars:
• MWC349

• Since ~ 2013 we also use LkHa101

• LkHa101 covers the complementary observable LST

• 24h LST coverage with FLUX reference
Flux Calibrators: Radio Stars / our main references

**Flux density (Jy)**

![Graph showing Flux density (Jy) vs Frequency (GHz) for MWC349 and LkHa101.]

MWC349

LkHa101
Primary Flux Calibrators

1. Quasars
2. Planets
3. Solar Bodies (Satellites, Asteroids, Dwarf Planets)
4. Radio Stars
Amplitudes vs time for all calibrators in $T_a^\ast$ (K)
Amplitudes vs time for all calibrators in Ta* (K)
Steps in flux calibration:

1) Fix the flux (Jy) of the reference calibrator
2) Estimate K/Jy factor (antenna efficiency)
3) Derive flux for other calibrators

Final representation = normalized amplitudes = antenna efficiencies (Jy/K or K/Jy)
We derive the FLUX for each source.

Here normalized amplitudes = K/Jy = characteristic of each antenna (or antenna performance).
Visual Output from FLUX calibration

- We derive the FLUX for each source
- Here normalized amplitudes = K/Jy = characteristic of each antenna (or antenna performance)
- If at some moment the performance/data are BAD and not representative – ignore that
We derive the FLUX for each source.

Here normalized amplitudes $= \text{K/Jy} = \text{characteristic of each antenna (or antenna performance)}$

If at some moment the performance/data are BAD and not representative - ignore that.
Practical Tips

Which are the issues to consider?

Checklist:
- Antenna Shadowing
- Pointing/Focus Problems
- Tracking Problems
- Noisy data
- Has Flux Calibrator Lines?
- Is Flux Calibrator Extended?
- Check Elevation of your source
- Check whether source is polarised (only important when using one polarisation)
- Do phases of different spectral windows overlap?
Practical Tips: Shadowing

First Look
Practical Tips: Shadowing
Which are the issues to consider?

Checklist:
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- Has Flux Calibrator Lines?
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Practical Tips: Pointing/Focus

First Look
Practical Tips: Pointing/Focus

First Look

Point change > 30% PrimBeam = 13.8°
Focus change > 30% $\lambda = 0.82$ mm
These scan ranges should be excluded!!!
Which are the issues to consider?

Checklist:
- Antenna Shadowing
- Pointing/Focus Problems
- Tracking Problems
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- Has Flux Calibrator Lines?
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- Check Elevation of your source
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- Do phases of different spectral windows overlap?
Practical Tips: CLIC software tools

Standard calibration package for NGR

**FLUX**

Use previous settings? Yes

File name: /SOG/project/s16bg001/10-oct-2016-s16bg001.hp

First and last scan: 0 10000

**RECEIVER BAND = 1**

ccarrizo@pipeline-pdb:/SOG/project/s16bg001

Selecting calibrators for phase and amplitude calibration...

Sources:
- I-LISTE, [4539] Source # 1: NGC30791, 273 Observations
- Calibrators:
  - I-LISTE, [4974] Source # 1: 0954+556, 27 Observations
  - I-LISTE, [4974] Source # 2: 0954+658, 24 Observations

0954+556 is at 0.7 degrees from NGC30791
0954+658 is at 9.9 degrees from NGC30791

The recommended calibrators are: 0954+556 0954+658
which have been adopted for phase and amplitude calibration

0954+556 is found to be polarized at 70.7xsigma
Averaged polarization mode is selected for the amplitude calibration
You can change it with "let do_avpol no" before the amplitude calibration

0954+658 is found to be polarized at 42.5xsigma
Averaged polarization mode is selected for the amplitude calibration
You can change it with "let do_avpol no" before the amplitude calibration

USB tuning for receiver 1

CLIC>
Practical Tips: CLIC software tools

FILE

Pencil ▼ Marker ▼ Hardcopy Draw Clear

ccarrizo@pipeline-pc

Frequency 114.846 GHz
Efficiencies: 0 0 0 0 0 0 0
Scan list? 4492 4993

Calibrator 3C84
Input Flux? 23.4
Fixed flux? No
Solved Flux: 0
Flux in File: 23.4

Source LKHA101, Model Flux 0.29 Jy
Input Flux? 0.27
Fixed flux? No
Solved Flux: 0
Flux in File: 0.27

Calibrator 0954+658
Input Flux? 0.9
Fixed flux? No
Solved Flux: 0
Flux in File: 0.9

Calibrator 0954+556
Input Flux? 0.45
Fixed flux? No
Solved Flux: 0
Flux in File: 0.45

Phase are Degrees Continuous 10
RF Passband Calibration is applied
RF Passband Calibration is frequency dependent
RF Passband Calibration is antenna-based
RF Passband Calibration from input file
W-FIND,[4496] Nothing found
W-FIND,[4496] Nothing found
W-FIND,[4496] Nothing found

Checking if LKHA101 correlations present contaminating H38alpha line at 115.27 GHz in LKHA101,
Polluting H38alpha line at 115.27 GHz in LKHA101,

Phases are Degrees Continuous 10

CLIC>
Practical Tips: CLIC software tools

Checking if LKHA101 correlations present contain:
Polluting H38alpha line at 115.27 GHz in LKHA101,
Polluting H38alpha line at 115.27 GHz in LKHA101,
Practical Tips: CLIC software tools

Checking if LKHA101 correlations present containning Polluting H38alpha line at 115.27 GHz in LKHA101,
1.) Choice of flux calibrator!!

Default references:
MWC349 & LKHa101
1.) Choice of flux calibrator!!

Default references: MWC349 & LKHa101
2.) Exclude bad data!!

Dotted colored lines show the thresholds below which data is ignored for flux calibration. Calibration results can be plotted after flux setup.

Source LKHA101, Model Flux 0.29 Jy
- Input Flux: 0.29
- Fixed flux: Yes
- Solved Flux: 0.29
- Flux in File: 0.27

Calibration results can be plotted after flux setup.

SOLVE:
- Frequency: 114.846 GHz
- Efficiencies: 23.46, 23.74, 22.07, 23.18, 23.96, 24.2, 22.14, 22.32
- Scan list: 4492, 4993
- Calibrator 3C84
- Input Flux: 23.4
- Fixed flux: No
- Solved Flux: 23.545
- Flux in File: 23.4
Practical Tips: CLIC software tools

3C84 may be considered for flux calibration
LKHA101 may be considered for flux calibration
0954+658 may be considered for flux calibration
0954+556 may be considered for flux calibration

CALIB FLAGGED is a logical Array of dimensions 5
F F F F F
CAL_SOURCE is a character* 20 Array of dimensions 5
3C84
0954+658
0954+556
0745+241
Source LKHA101, Model Flux 0.29 Jy
Phases are Degrees Continuous 10

Always interesting information in prompt
3.) Check Antenna efficiencies and found source fluxes !!!

Flux Receiver 1

Frequency 114.846 GHz

Efficiencies: 23.46 23.74 22.07 23.18 23.96 24.2 22.14 22.32

Scan list? 4492 4993

Calibrator 3C84

Input Flux? 23.4

Fixed flux? No

Solved Flux: 23.545

Flux in File: 23.4

Source LKHA101, Model Flux 0.29 Jy

Input Flux? 0.29

Flux and efficiency result for receiver 1 at 114.8 GHz:

<table>
<thead>
<tr>
<th>in file</th>
<th>solve flux</th>
</tr>
</thead>
<tbody>
<tr>
<td>3C84</td>
<td>23.40 Jy</td>
</tr>
<tr>
<td>LKHA101</td>
<td>0.27 Jy</td>
</tr>
<tr>
<td>0954+658</td>
<td>0.90 Jy</td>
</tr>
<tr>
<td>0954+556</td>
<td>0.45 Jy</td>
</tr>
<tr>
<td>0745+241</td>
<td>0.70 Jy</td>
</tr>
</tbody>
</table>

Antenna 1 (A1) 23.5 Jy/K (1.01)
Antenna 2 (A2) 23.7 Jy/K (1.00)
Antenna 3 (A3) 22.1 Jy/K (1.07)
Antenna 4 (A4) 23.2 Jy/K (1.02)
Antenna 5 (A5) 24.0 Jy/K (1.87)
Antenna 6 (A6) 24.2 Jy/K (0.98)
Antenna 7 (A7) 22.1 Jy/K (1.07)
Antenna 8 (A8) 22.3 Jy/K (1.06)

Always interesting information in prompt
Practical Tips: CLIC software tools

** Flux Receiver 1 **

- **Frequency**: 114.846 GHz
- **Efficiencies**: 23.46, 23.74, 22.07, 23.18, 23.96, 24.2, 22.14, 22.32
- **Calibrator 3C84**: Input Flux = 23.545
- **Solved Flux**: 23.545
- **Flux in File**: 23.4
- **Source LKHA101, Model Flux 0.29 Jy**: Input Flux = 0.29, Fixed flux = Yes, Solved Flux = 0.29, Flux in File = 0.27
- **Calibrator 0954+658**: Input Flux = 0.905, Fixed flux = No, Solved Flux = 0.905, Flux in File = 0.9
- **Calibrator 0954+556**: Input Flux = 0.46, Fixed flux = No

Dotted colored lines show the thresholds below which flux is ignored. Calibration results can be plotted after flux steps.
Practical Tips: CLIC software tools

Flux Receiver 1

- Frequency: 114.846 GHz
- Efficiencies: 23.46 23.74 22.07 23.18 23.96 24.2 22.14 22.32
- Scan list: 4492 4993
- Calibrator 3C84
  - Input Flux: 23.545
  - Fixed flux: No
  - Solved Flux: 23.545
  - Flux in File: 23.545
- Source LKHA101, Model Flux 0.29 Jy
  - Input Flux: 0.29
  - Fixed flux: Yes
  - Solved Flux: 0.29
  - Flux in File: 0.29
- Calibrator 0954+658
  - Input Flux: 0.905
  - Fixed flux: No
  - Solved Flux: 0.905
  - Flux in File: 0.905
- Calibrator 0954+556
  - Input Flux: 0.46
  - Fixed flux: No
  - Solved Flux: 0.905
  - Flux in File: 0.905

Rebuilding the Flux list for Receiver 1...

I-FIND,[4496] New generation receivers data
I-FIND,[4496] 7 observations found
Source 1 3C84 Flux 23.55 Jy at 114.8 GHz
I-FIND,[4496] New generation receivers data
I-FIND,[4496] 6 observations found
Source 2 LKHA101 Flux 0.29 Jy at 114.8 GHz
I-FIND,[4496] New generation receivers data
I-FIND,[4496] 32 observations found
Source 3 0954+658 Flux 0.91 Jy at 114.8 GHz
I-FIND,[4519] New generation receivers data
I-FIND,[4519] 35 observations found
Source 4 0954+556 Flux 0.46 Jy at 114.8 GHz
I-FIND,[4525] New generation receivers data
I-FIND,[4525] 3 observations found
Source 5 0745+241 Flux 0.70 Jy at 114.8 GHz
Practical Tips: CLIC software tools

[Screenshot of the CLIC software interface showing various elements such as graphs, data, and options for solving, get result, store, plot, etc.]

- Frequency: 114.846 GHz
- Efficiencies: 23.46 23.74 22.07 23.18 23.96 24.2 22.14 22.32
- Scan list: 4492 4993
- Calibrator 3C84
  - Input Flux: 23.545
  - Fixed flux: No
  - Solved Flux: 23.545
  - Flux in File: 23.545
- Source LKHA101, Model Flux 0.29 Jy
  - Input Flux: 0.29
  - Fixed flux: Yes
  - Solved Flux: 0.29
  - Flux in File: 0.29
- Calibrator 0954+658
  - Input Flux: 0.905
  - Fixed flux: No
  - Solved Flux: 0.905
  - Flux in File: 0.905
- Calibrator 0954+556
  - Input Flux: 0.46
  - Fixed flux: No

[Additional text and options for file, edit, view, search, terminal, help, etc.]
3.) Check Antenna efficiencies and found source fluxes !!!

You can change it with "let do_avpol no" before the amplitude calibration

0954+658 is found to be polarized at 42.5xsigma
Averaged polarization mode is selected for the amplitude calibration
You can change it with "let do_avpol no" before the amplitude calibration

USB tuning for receiver 1

CLIC>
If we adopt wrong fluxes
If we adopt wrong fluxes
If we adopt wrong fluxes

The user choice (via widget) differs from that of pipeline
Adopting user criteria ...

User  0954+658flux= 2.000Jy, fixed=YES
Pipeline 0954+658flux= 2.009Jy, fixed=NO

The user choice (via widget) differs from that of pipeline
Adopting user criteria ...

User  0954+556flux= 0.700Jy, fixed=YES
Pipeline 0954+556flux= 0.700Jy, fixed=NO

Always interesting information in prompt
To ignore data for FLUX calibration

Ant. 8
L01 L02 L03 L04 L05 L06 L07 L08 L09 L10 L11 L12 USB
X: Time = -14.4794508
Y: Amplitude (K/Jy) = 2.205424703E-02
Scan: 4978 Obs: 605 Rec: 1 Weight = 52.3030319
CLIC> curs
I-CLIC_CURSOR,[4496] Use closest point in X
To ignore data for FLUX calibration

Efficiencies: 23.46 23.74 22.07 23.18 23.96 24.2 22.14 22.32

Scan list: 4492 4888 4979 4993

Calibrator 3C84

Input Flux? 23.545
Fixed flux? No
Solved Flux: 23.545
Flux in File: 23.545

Source LKHA101, Model Flux 0.29 Jy

Input Flux? 0.29
Fixed flux? Yes
Solved Flux: 0.29
Flux in File: 0.29

Calibrator 0954+658

Input Flux? 0.905
Fixed flux? No
Solved Flux: 0.905
Flux in File: 0.905

Calibrator 0954+556

Input Flux? 0.46
Fixed flux? No

Help  Go  Close
To ignore data for FLUX calibration

Ignored range is plotted

Calibration results can be plotted after flux storage
Special case: FLUX reference not used

BC345 is not considered for flux calibration, since phases are too unstable.

MWC349 is not considered for flux calibration, since phases are too unstable.

CALIB_FLAGGED is a logical Array of dimensions 5

F T T F F

CAL_SOURCE is a character* 20 Array of dimensions 5

J1310+323

BC345

MWC349

1538+149

1611+343

Source MWC349, Model Flux 1.13 Jy

No calibrator is considered for flux calibration ..., fixing the strongest.

The flux of 1611+343 is fixed to 2.185 Jy.

Phases are Degrees Continuous 10.

Here the reference is not used —---> a more complex case.
### Special case: FLUX reference not used

3.) Check Antenna efficiencies and found source fluxes !!!

<table>
<thead>
<tr>
<th>Antenna</th>
<th>in file</th>
<th>solve flux</th>
</tr>
</thead>
<tbody>
<tr>
<td>J1310+323</td>
<td>1.07 Jy</td>
<td>1.07 Jy</td>
</tr>
<tr>
<td>3C345</td>
<td>3.17 Jy</td>
<td>3.17 Jy</td>
</tr>
<tr>
<td>MWC349</td>
<td>0.91 Jy</td>
<td>0.88 Jy (model: 1.13 Jy)</td>
</tr>
<tr>
<td>1538+149</td>
<td>0.69 Jy</td>
<td>0.69 Jy</td>
</tr>
<tr>
<td>1611+343</td>
<td>2.19 Jy</td>
<td>2.19 Jy</td>
</tr>
</tbody>
</table>

- Be critical, to understand why MWC349 is not used: e.g. briefly degraded conditions, perhaps due to source elevation or changing weather, which is not representative of the track.

- If the conditions are representative of the track, MWC349 should be used.

- Other sources can be used otherwise as reference: in this case flux monitorings, plus information coming from additional tracks should be considered.

- Our knowledge about antenna efficiencies should also be used (SOG will support you)
It automatically considers extension of MWC349!
Practical Tips: CLIC software tools

**It only takes the 3 best Antennas!**

I-LISTE,[8620] Source # 1  J1310+323  1 Observations
I-LISTE,[8620] Source # 2  3C345  4 Observations
I-LISTE,[8620] Source # 3  MWC349  3 Observations
I-LISTE,[8620] Source # 4  1538+149  36 Observations
I-LISTE,[8620] Source # 5  1611+343  36 Observations

I-SOLVE_FLUX,[8620] Average fluxes will use the best 3 antennas

Amplitudes are absolute
Amplitude Calibration is antenna-based
Amplitudes are divided by assumed calibrator flux
Amplitudes are expressed in kelvins
I-SCALING,[8637] MWC349 has known structure
I-SCALING,[8638] MWC349 has known structure
I-SOLVE_FLUX,[9161] Reference sources:
I-SOLVE_FLUX,[9161] 1611+343  Flux = 2.1850 Jy
I-SOLVE_FLUX,[9161] Average efficiencies:
I-SOLVE_FLUX,[9161] Ant. 1  22.165 ± 0.003 Jy/K (0.99)
I-SOLVE_FLUX,[9161] Ant. 2  23.452 ± 0.003 Jy/K (0.93)
I-SOLVE_FLUX,[9161] Ant. 3  21.911 ± 0.003 Jy/K (1.00)
I-SOLVE_FLUX,[9161] Ant. 4  20.588 ± 0.002 Jy/K (1.06)
I-SOLVE_FLUX,[9161] Ant. 5  21.419 ± 0.003 Jy/K (1.02)
I-SOLVE_FLUX,[9161] Ant. 6  21.648 ± 0.003 Jy/K (1.01)
I-SOLVE_FLUX,[9161] Sources, Fluxes and errors:
I-SOLVE_FLUX,[9161] J1310+323 Ant 1  1.3902 ± 0.0016
Questions?