**Total intensity**

When observing the sky with a radiotelescope, we measure, for a signal of antenna temperature TA, an intensity proportional to the received power

I = C S A = C 2k TA

with a flux density

S = 2k TA / A (if the signal is unpolarized)

A is the effective area, with A Ω = λ2

When observing Jupiter,

TAj = Tj ωj /Ω

Sj = 2k TAj / A = 2k Tj ωj / (Ω A) = 2k Tj ωj / λ2 is independent of the instrument

but

Ij = C Sj A = C 2k (Tj ωj / Ω) depends on the instrument

When observing the Gakaxy

TAg = Tg = 60 λ2.55

Sg = 2k Tg / A depends on the effective area

Ig = C Sg A = C 2k Tg is independent of the effective area

When taking into account the instrument noise Ti (with arbitrary dependence on λ)

the system temperature is

Ts = Tg + Ti

Ss = 2k Ts / A = 2k (Tg + Ti)/ A is the SEFD (by definition, in Jy)

Is = C Ss A = C 2k Ts = C 2k (Tg + Ti) is the background measured in the data, i.e. the robust average determined e.g. with the subroutine BACKGROUND.pro

For a given observation by a given instrument

Ij / Is = Sj / Ss = (Tj ωj / Ω) / (Tg + Ti)

*If we can neglect the instrument noise Ij / Is = Tj ωj / (Ω Tg)*

For 2 observations of the same emission from Jupiter by two different instruments

Ij1 / Ij2 = C1 A1 / (C2 A2)

Comparing the two backgrounds give

Is1 / Is2 = C1 Ss1 A1 / (C2 Ss2 A2) = C1 (Tg1 + Ti1) / (C2 (Tg2 + Ti2))

If observations are at the same frequency, Tg1 = Tg2

*Note that (Ij/Is)1 / (Ij /Is)2 = (Sj /Ss)1 / (Sj /Ss)2*

*= (Ij1/Is1) / (Ij2/Is2) = (Ij1/Ij2) (Is2/Is1)*

*= (A1/A2) (Tg2 + Ti2)/(Tg1 + Ti1)*

*if Ti << Tg = (A1/A2) (Tg2/Tg1)*

*and if at the same frequency = A1 /A2 = Ω2 /Ω1 = G1 /G2*

From an **observation 1** with an instrument in a given frequency band, of Jupiter in beam **1a** and the nearby sky background simultaneously in beam **1b**

and an **observation 2** of the sky background only with possibly another instrument possibly in another frequency band

we want to

**synthesize a signal 3** with the sky background **2** + the Jupiter signal as observed by instrument **2** and attenuated by an arbitrary (small) factor **α**

I3 = Is2 + α Ij2 (1)

with Ij2 as observed by instrument 2 with same flux density as in observation 1a

I3 = Is2 ( 1 + α Ij2 / Is2 ) = Is2 [ 1 + α (Ij2/I j1) (I j1/Is1) (Is1/Is2) ]

= Is2 [ 1 + α (C2A2/(C1A1)) (I j1/Is1) (C1Ss1A1/(C2Ss2A2)) ]

I3 = Is2 [ 1 + α (I j1/Is1) (Ss1/Ss2) ] (2)

where Is2 = I2 as recorded in observation 2

and I j1/Is1  is computed from the data of observation 1

where I1a = Ij1 + Is1 = Ij1 + Is1a = Ij1 + Is1b

Is1a cannot be computed because observation I1a is dominated by emission from Jupiter Is1 = Is1b  is the spectrum computed as the BACKGROUND or 10% quantile of observation I1b and replicated over all time steps of the dynamic spectrum

Thus I j1/Is1 = (I1a /Is1b) - 1

Ss1/Ss2 is the ratio of the SEFD in the 2 observations

This is equation (2) of our paper, but I’m not sure it was derived clearly in the paper, where we mixed flux densities (SEFD) and measured signal (I).

For LOFAR, the SEFD is considered flat and = 40 kJy in the range 30-70 MHz, and increases in λ2 below 30 MHz i.e. = 40 (λ/10)2 kJy

In the general case

Ss = 2k (Tg + Ti)/ A with Tg = 60 λ2.55

we can assume at zero order that Ti = constant

and A = Nant λ2 / 3 and « saturates » toward long wavelengths due to effective area overlap, thus with decreasing λ

Ss should first decrease as Tg or slightly less steeply (when A saturates and Tg >> Ti)

then as λ0.55 (when A does not saturate and Tg >> Ti)

then increase ~ as λ-2 or slightly less steeply (when Tg becomes ~ or ≤ Ti)

This is what is observed for LOFAR & NenuFAR.

**Circularly polarized intensity**

Assuming first that V is Ok as measured (i.e. has 0 average) and noting v = V/I

Translating what JMaG wrote with the above notations

V3 = Vs2 + α Vj2 = Vs2 + α vj Ij2 = Vs2 + α vj Ij1 (Ij2/ Ij1) = Vs2 + α Vj1 (Ij2/ Ij1)

assuming that vj is independent on the frequency

hence

V3 = Vs2 + α Vj1 C2A2 / (C1A1) → not obvious to compute in practice

Alternate possibility from equations (1) & (2)

V3 = Vs2 + α Vj2 = vs Is2 + α vj Ij2

= Is2 (vs + α vj Ij2 / Is2 ) = Is2 [ vs + α vj (Ij1/Is1) (Ss1/Ss2) ]

V3 = Vs2 + α Vj1 (Is2/Is1) (Ss1/Ss2) (3)

This is the same equation as JMaG, as (Is2/Is1) (Ss1/Ss2) = C2A2 / (C1A1)

but now it is easy to compute from the data

In (3)

Vs2 = V2 as recorded in observation 2

Vj1 is either directly measured (neglecting Vs1) or

Vj1 = V1 – Vs1 (this is a way to correct for instrumental polarization, see below)

Is1 and Is2 are the backgrounds in intensity

and Ss1/Ss2 is the ratio of the SEFD in the 2 observations

Considering now that V does not have 0 average as a function of frequency

v = V/I

v’(f) = v(f) - < v(f) >t

v’(f) should not be divided by stddev(v(f)) because this would artificially increase it (normally, -1 < v(f) < +1 and -1 < v’(f) < +1)

< v(f) >t is computed as the algebraic BACKGROUND at each frequency

V’ = v’ I

Note that V’ = (v(f) - < v(f) >t) I = V - < V(f)/ I > I ≠ V(f) - < V(f) >

thus I don’t quite agree with JMaG’s equation (3.6)

We should rather compute

V’3 = V’s2 + α V’j1 (Is2/Is1) (Ss1/Ss2) (4)

with V’s2 = v’2 Is2 = (v2(f) - < v2(f) >t) I2

and V’j1 = v’1 Ij1 = (v1a(f) - < v1b(f) >t) (I1a – Is1b)

the backgrounds < v1b(f) >t and Is1b being again computed from observation 1b

I s2/Is1  is the ratio between the backgrounds (or 10% quantiles) computed from the data of observations 2 and 1b

and Ss1/Ss2 is the ratio of the SEFD in the 2 observations

**Linearly polarized intensity**

Linear polarization L = (U2 + Q2)1/2 can be processed as V, i.e. computing

U’3 = U’s2 + α U’j1 (Is2/Is1) (Ss1/Ss2)

Q’3 = Q’s2 + α Q’j1 (Is2/Is1) (Ss1/Ss2) (5)

as V’3 above, and then

L’3 = (U’32 + Q’32)1/2 (6)

It is probably better to correct U and Q → U’, Q’ before computing L’, because they should be ~0 for the sky background, whereas L only takes positive values thus it is difficult to separate its statistical noise from instrumental bias

**Processing**

Processing I data :

• compute I3

• compute RFI mask m

• compute + apply t-f correction → Icor

• Integrate (m Icor) in δt,δf bins → W

• Post-processing : further integration + Qn on W

Processing V data :

• compute I3 and V’3

• compute RFI mask m on I3 (normalized by the 10% quantile on I3) and on V’3

and merge the 2 masks (product)

• compute t-f correction on I3 + apply it to V’3 → Icor, V’cor

• Integrate (m V’cor) in δt,δf bins → W

• Post-processing : further integration + Qn on W (for reference), |W|, W2, W+, W-

with W+ = W >0 and W- = (-W) >0

I think we should not compute the t-f correction on V’3 or |V’3|, because if V’3 is ~0 for the sky and variable for Jupiter, I don’t think that we will fit a meaningful t-f surface.

Jake proposes to use the average instead of the 10% quantile to compute the RFI mask on V’3, and to compare and combine this mask with the one computed from I3. This makes sense.

Processing L data :

• compute I3 and L’3

• compute RFI mask m on I3 and on L’3 and merge the 2 masks (product)

• compute t-f correction on I3 + apply it to L’3 → Icor, L’cor

• Integrate (m L’cor) in δt,δf bins → W

• Post-processing : further integration + Qn on W