LW transient response effect characterization: a summary

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in the absence of a complete correction scheme for LW transient response it is important to try to characterize this effect as much as possible

<u>Three major open questions:</u>

1) **is it possible to estimate the transient response effect from the measurements ?**

2) **is this effect variable with source strength ?**

3) **how much the spectral ratio (derived spectrum over actual spectrum at input port) varies with wavenumber over the actual passband and with source strength ?**

Question 1:

how to estimate the transient response effect from the measurements ?

<u>Main assumptions:</u>

- **the main effect of the pixel transient response is to remove some power from the radiation passband and to inject this removed power at lower or higher frequencies than the actual passband**
- **there is no effective loss of power (the total injected power is maintained)**
- **the transient response effect is an intrinsic property of the pixel**

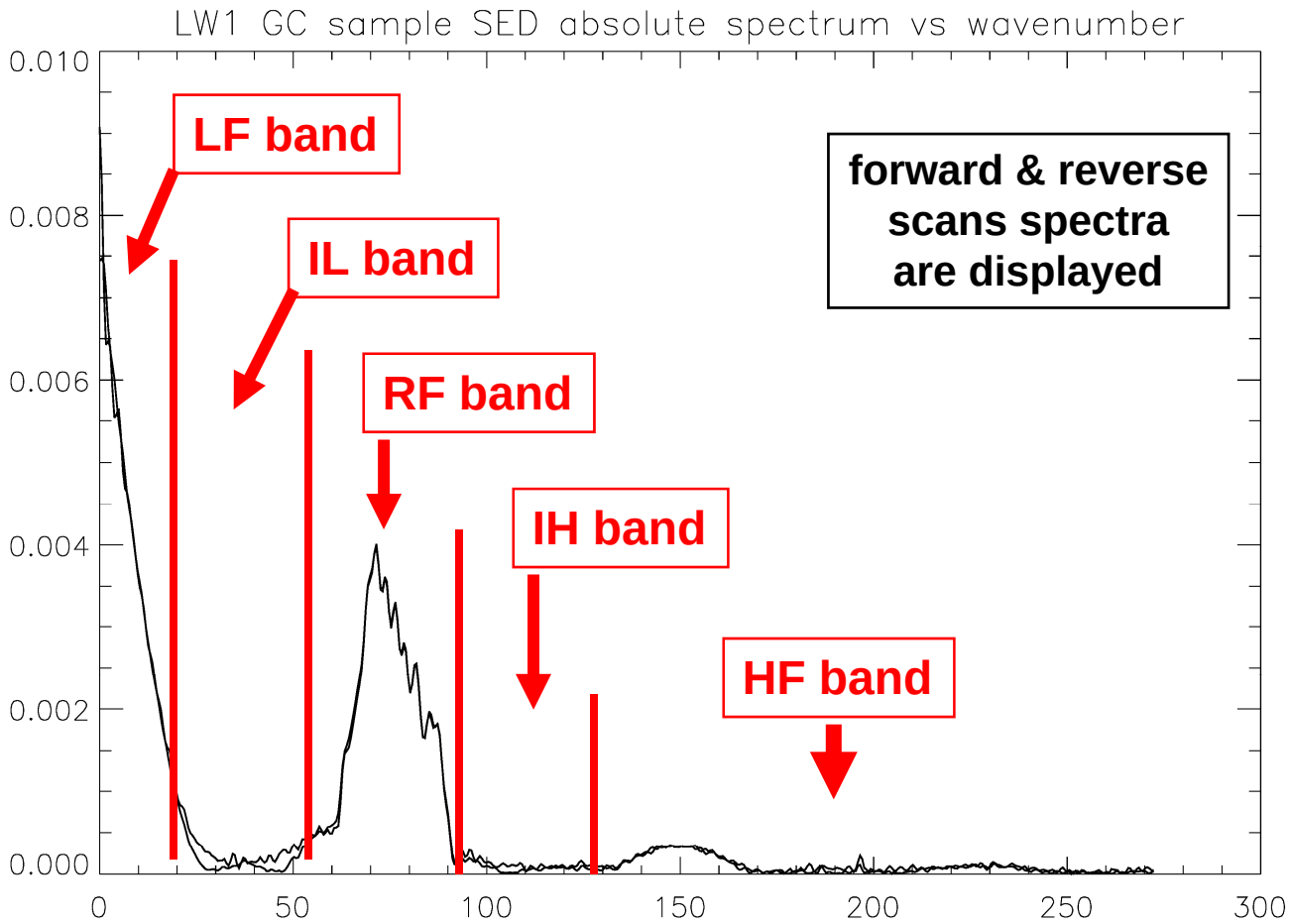
➔ as the primary interest is on the radiation power, the absolute part of the spectrum (derived from the recorded interferogram by FFT; i.e. modulated part of the incoming radiation) is used in this analysis

Data used for this analysis:

- **"calibration" observations**
  - **M17_p1 very bright source (some saturated pixels)**
  - **Gc_p1 bright & very extended source**
- **"OT" observations**
  - **Sh2-104IR _p1 & _p2 generally faint brightness**
  - **RCW79IR _p1 & _p2 quite high brightness**
  - **RCW79IR2_p1 intermediate brightness**
  - **RCW82IR _p1 & _p2 intermediate brightness**

➔ on next page: plot of a typical sample spectrum for LW#1
(LW1 is a pixel known for having a quite strong transient response)

LW#1 sample spectrum (from Gc_p1 observations)



plot of the absolute SED spectrum vs wavenumber (cm-1)

(band limits defined next page)

Band definition and limits:

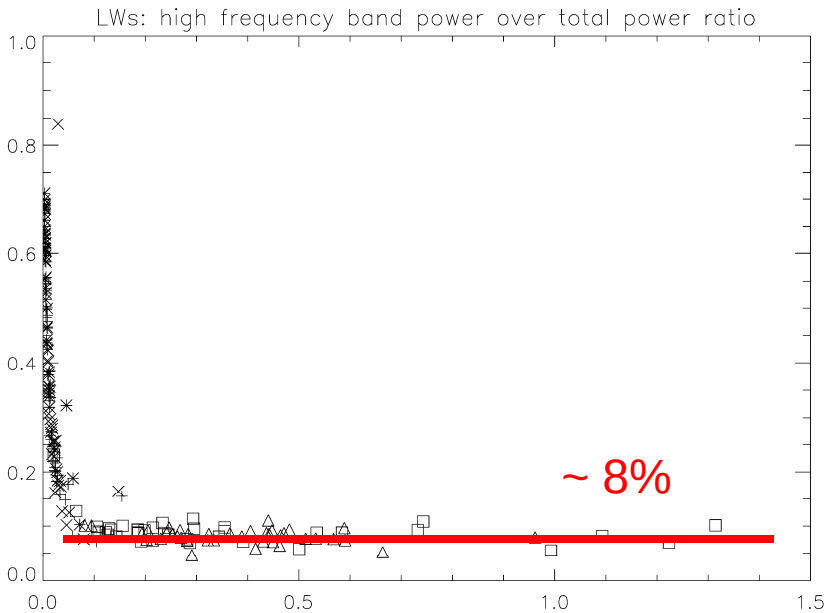
LF	**low frequency band**	**0 - 19 cm-1**
IL	**intermediate low frequency band**	**19 - 55 cm-1**
RF	**radiation frequencies band**	**55 - 91 cm-1**
IH	**intermediate high frequency band**	**91 - 127 cm-1**
HF	**high frequency band**	**127 - 273 cm-1**

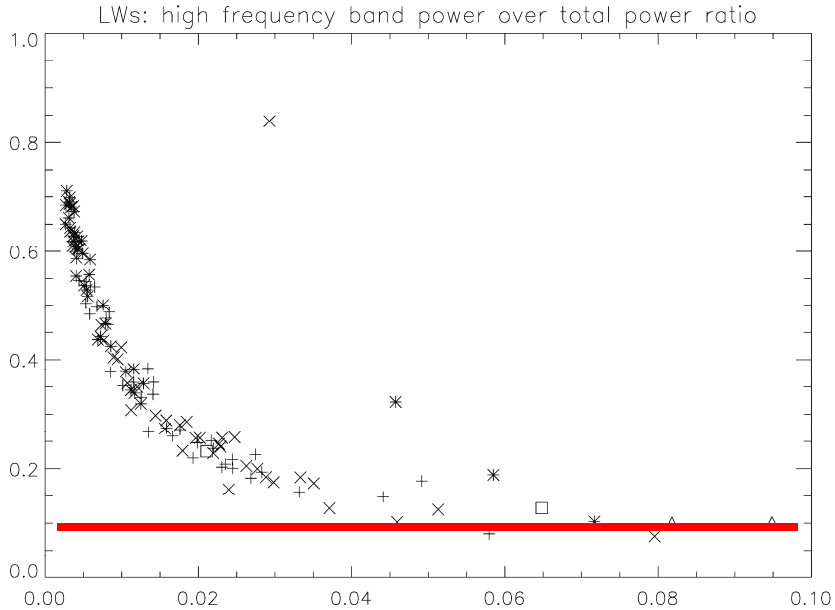
➔ **bands IL, RF & IH have the same extent (in wavenumbers) in order to facilitate the analysis**

➔ **from previous plot:**

- **transient response provides power at almost all frequencies: strong power at low frequencies and power bumps at about 75 cm-1 (seen on both sides of the actual radiation passband), at about 150 cm-1 and also around 230 cm-1**
- **spectral noise appears to be about the same at all frequencies: so the spectral noise contribution may be higher in bands with greater extent since I used the absolute part of the spectrum (this should be the case particularly for the HF band)**

noise contribution in HF band





plot of the power ratio (HF over LF+IL+RF+IH+HF) vs the "total" power for all LW pixels and all observations

M17_p1 squares
Gc_p1 triangles
OT sources other symbols

<u>some explanations for the previous plot:</u>

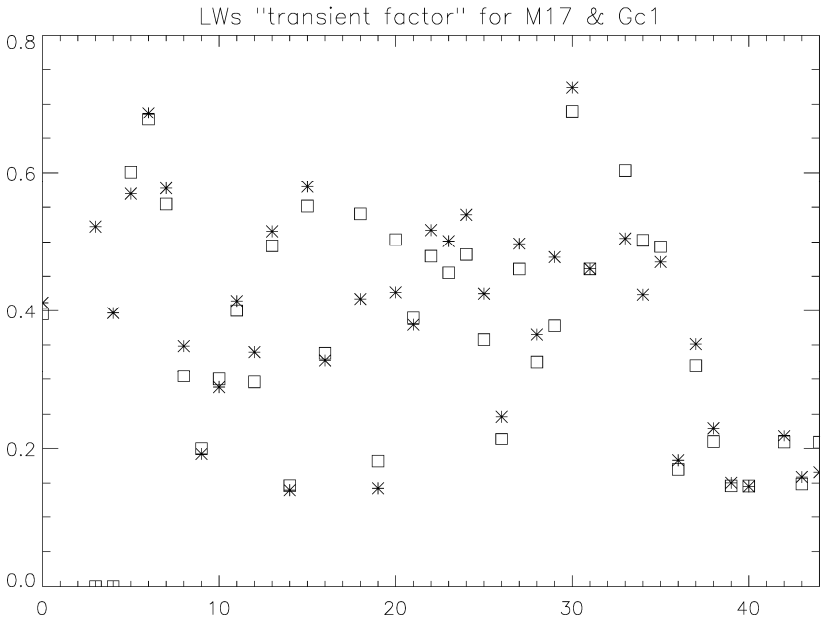
- **for strong sources this power ratio looks approximatively constant (i.e. independently of the pixel and of the source strength) at about a value of 8%**
- **for faint sources (with "total" power less than 0.05) the noise contribution is getting dominant and the power ratio tends to increase as the source strength decreases**
- **as a consequence we can state that the power in the HF band is meaningless for faint sources as this power is dominated by intrinsic measurement noise**
- **I have assumed in the following that the "total" power is now determined by the sum of powers in the bands LF+IL+RF+IH times a factor 1.087 (i.e. 1/0.92) to avoid the HF band too much polluted by noise**

➔ next plot: I use the following definition for what I call the "*transient response factor*" (TRF):

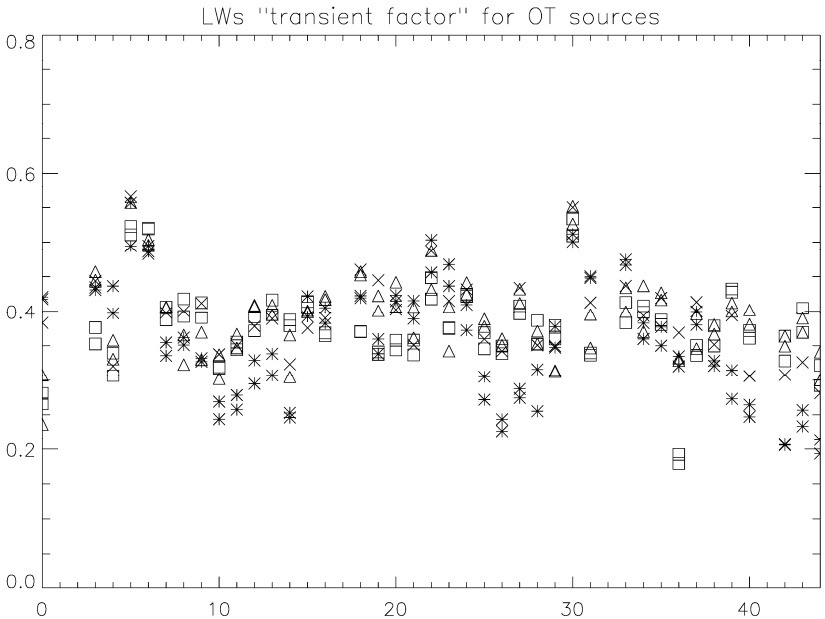
TRF = (power in RF band) / ("total" input power)

TRF for all LW pixels

M17 & GC1



OT sources



symbols
left: squares (M17_p1), stars (GC_p1)
right: stars (Sh2-104IR), triangles (RCW82IR), squares (RCW79IR1) & "X" (RCW79IR2)

<u>comparison of the two previous plots:</u>

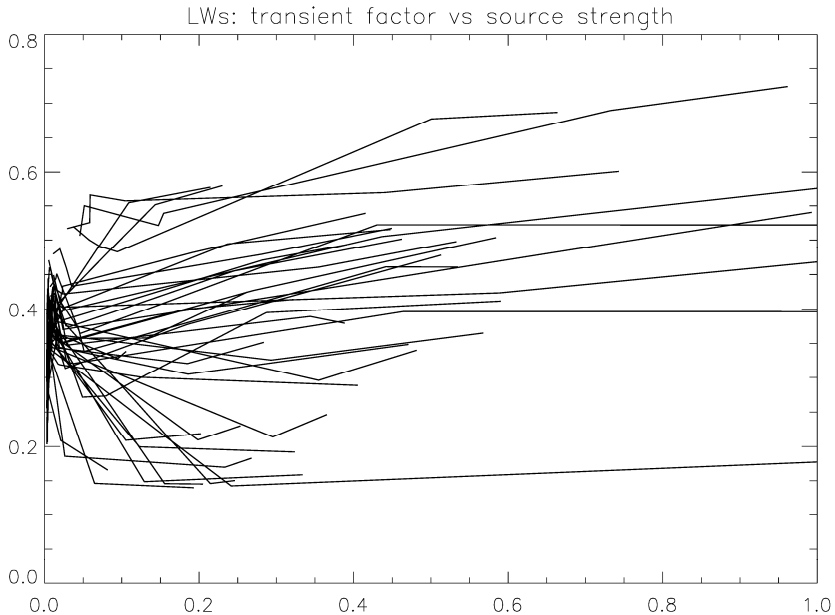
- **first impression: M17 & GC provide a TRF scatter from pixel to pixel more pronounced than the OT sources**
- **the difference between TRFs from M17 & GC on one side, and between TRFs from OT sources on the other side are quite small (from a few % up to a spread of about 30% for the faintest OT sources)**

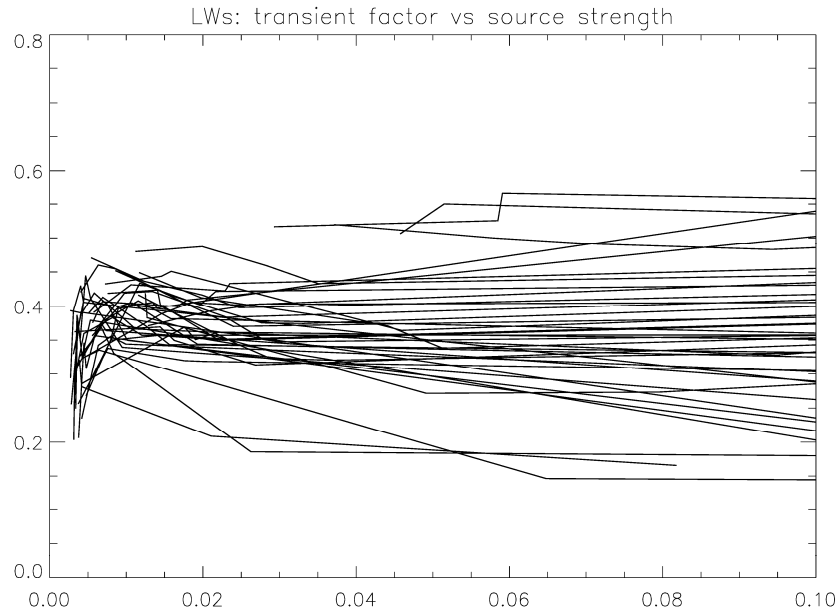
➔ **is there a systematic change of the TRFs from strong sources (M17 & GC) to faint sources (OT) ?**

Question 2:

is the transient response effect variable with source strength ?

plots of the TRFs vs the source strength for each pixel





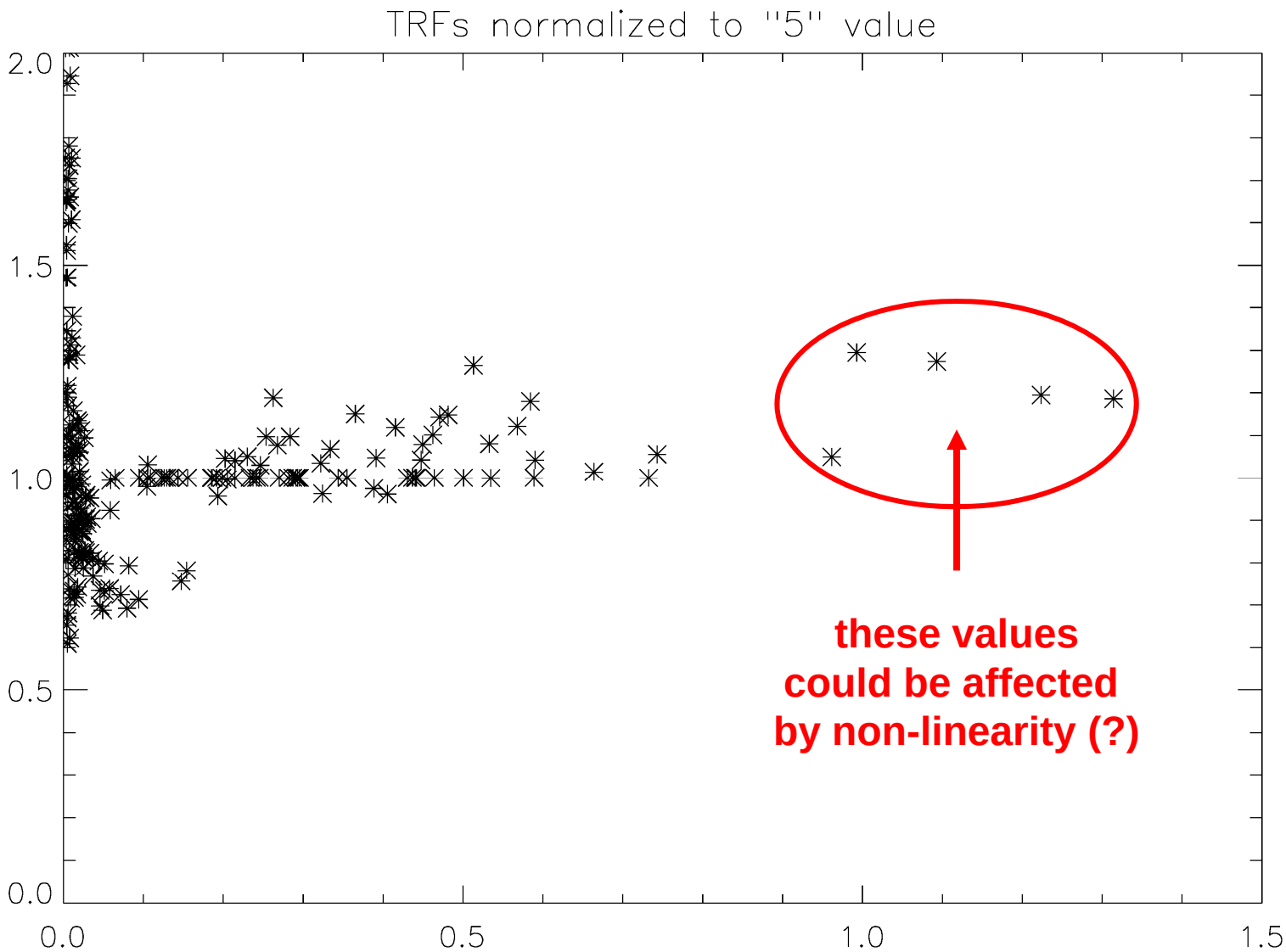
this plot shows the variation of TRF with source strength: each plotted line corresponds to a given pixel and joins the TRF determination from the strongest source to the faintest one (for this pixel)

left panel is for the whole extent in source strength (up to power = 1) and right panel is a zoom for the powers less than 0.1

- **the previous plots are not so easy to read**

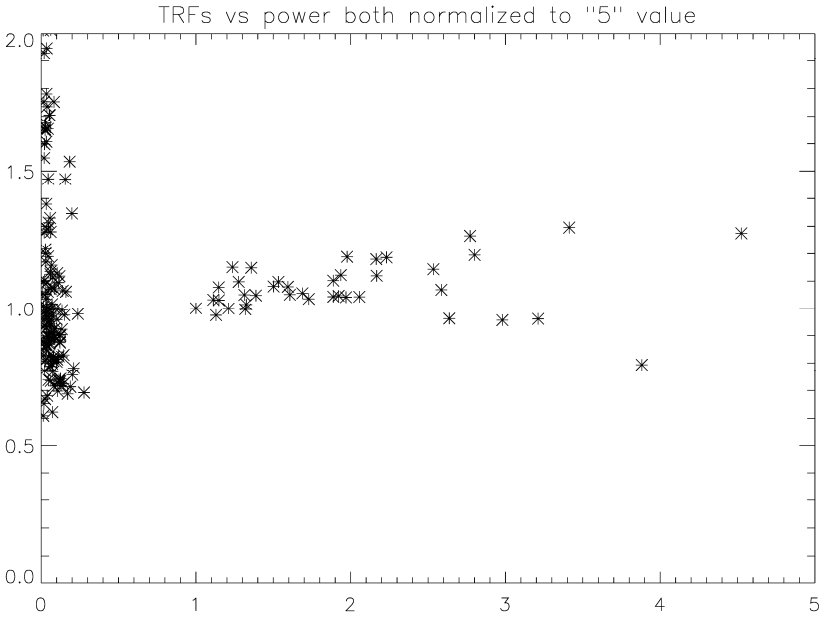
  ➔ so an other way to derive this information is used here
- **presently we have 6 different sources: M17_p1, GC_p1, Sh2-104IR (mean of 2 obs.), RCW82IR (mean of 2 obs.), RCW79IR1 (mean of 2 obs.) & RCW79IR2**
- **for each LW pixel these 6 TRF values are ordered in increasing source strength**
- **I used the "normalized" TRF (i.e. taking the 5th value as "reference" since the 6th one due generally to the brightest source (M17) may be affected by saturation for some pixels)**

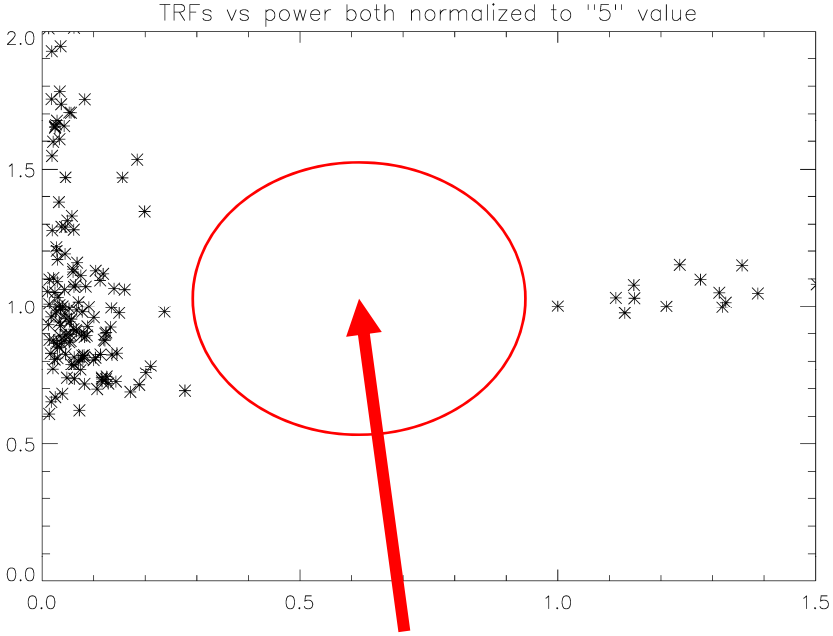
  ➔ see next plots



plot of "normalized" TRFs versus total power for all LW pixels

TRF normalized values vs "normalized" power





missing measurements:
to be populated ?

"normalized" power means using the 5th power value as reference

<u>tentative explanations for previous page plots:</u>

- **if we exclude the very faint sources (powers less than 0.01; for which the noise should be dominating the true signal) we can say that the plots are spread approximately horizontally**

  ➔ i.e. TRF is about constant with input power

- **however we also get the impression that there is some trend to increase TRF as power is increasing**

  ➔ Is this trend real/significant or not ?

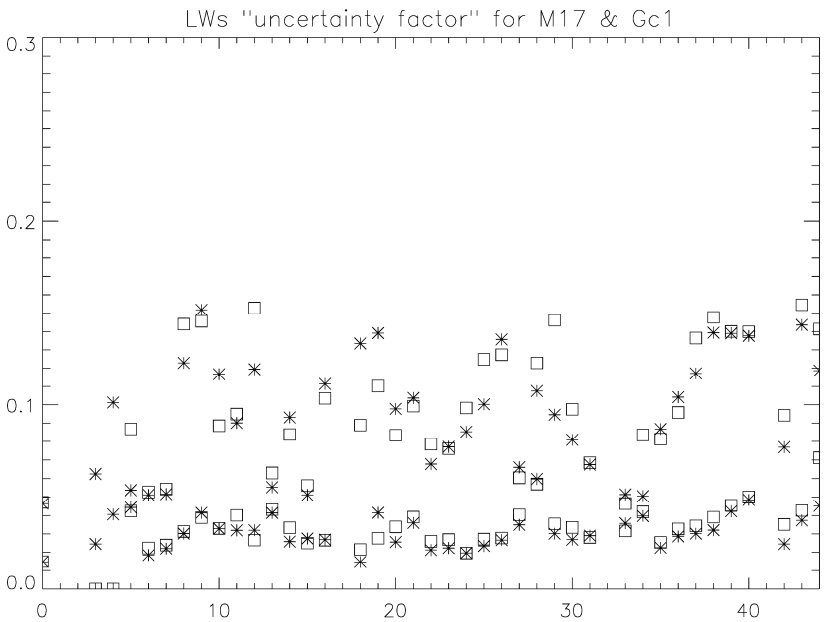
- **to confirm this apparent trend would require to populate the plots with intermediate source strengths than given here (on my side I will not have more observations than these present ones)**

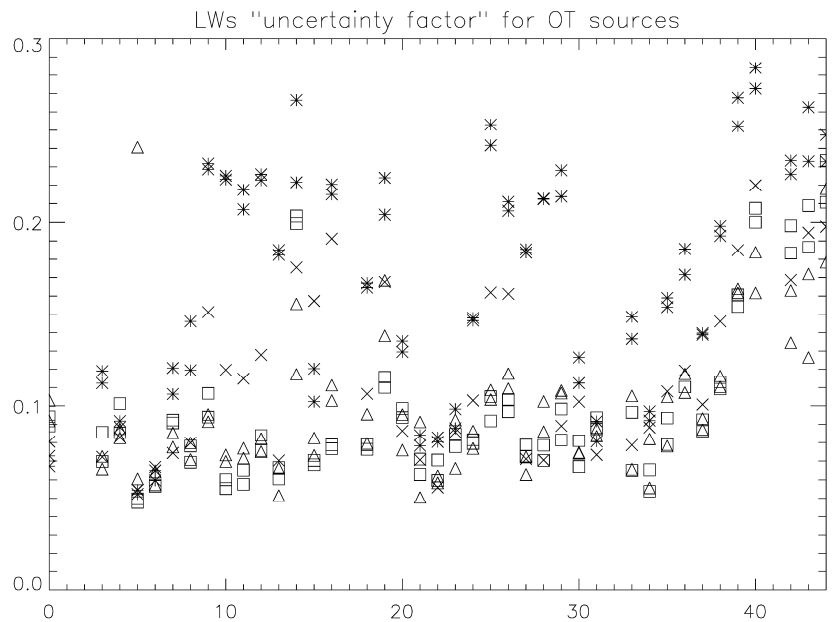
<u>what about uncertainties in TRFs determinations ?</u>

- **when looking at the first plot (p. 6) we clearly see broad features due to transient response on both sides of the true radiation passband (RF band here): we should anticipate that some power is removed from the radiation passband at certain frequencies and potentially re-injected within the radiation passband itself, but at slightly different frequencies**
- **it's difficult to have a good assessment of this phenomenon but, at least, we can have some insight on the amount of power that could be polluting the true radiation passband (i.e. input power redistributed within the RF band but at different frequencies than the original ones)**

➔ the next plots give the power injected on the two adjacent bands (IL & IH) normalized to the "total" power as defined previously

power ratios in the two sidebands





plots of normalized IL & IH powers from M17 & Gc1 observations

➔ **IL powers are systematically higher than IH powers**

plots of the averaged normalized (IL+IH)/2 powers for OT sources (for better lisibility)

same symbols as for plots p.10

<u>explanations for previous plots:</u>

- **the averaged normalized (IL+IH)/2 powers for OT sources are coherent with the determinations from M17 & GC1 observations (I suspect the high values found for some pixels are only due to the high noise levels)**

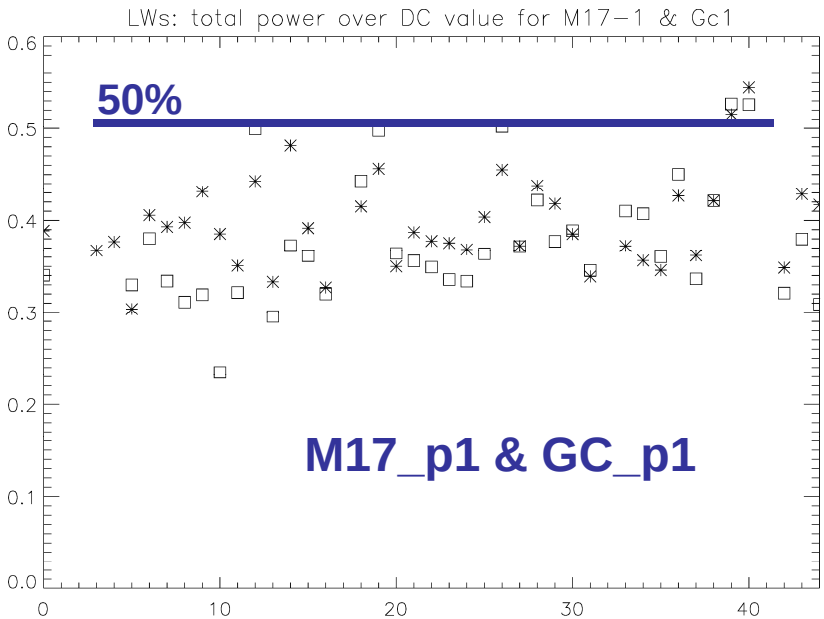
<u>conclusions from previous plots:</u>

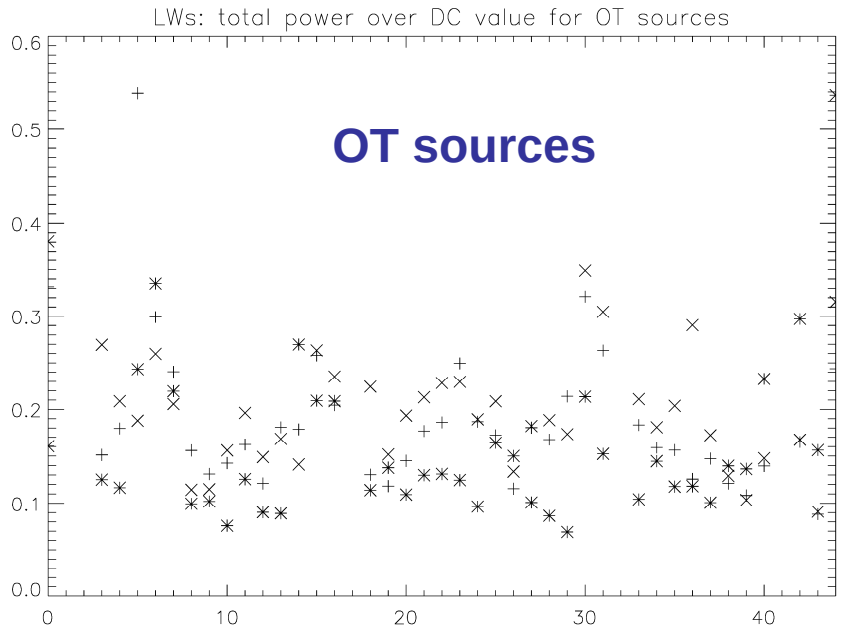
- **the measured power in the IL and IH bands (removed from the original radiation band) is between 3 and 10% depending on the pixel and on the band considered**
- **these figures may provide some indication of the potential degree of uncertainty in the TRF determination when using the procedure described here**

extra Question:

is the total spectral power representative of the source input (as measured by the DC value) ?

total spectral power compared to DC value





plots of total power over DC value ratio for LW pixels

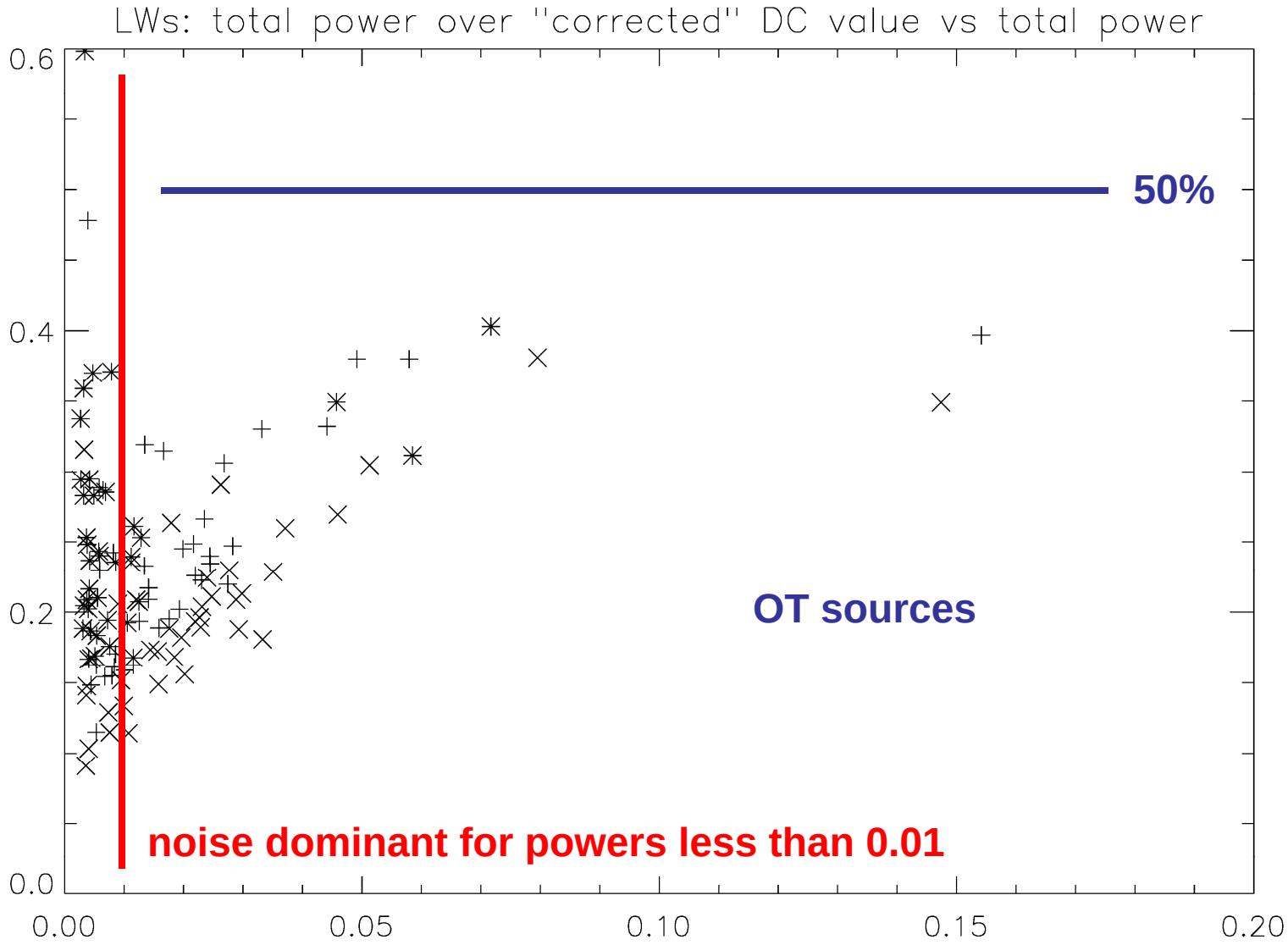
symbols
left: squares (M17_p1), stars (GC_p1)
right: stars (Sh2-104IR), "+" (RCW82IR) & "X" (RCW79IR1)

- **DC level may include some "unmodulated" power that is not producing power in the spectra**
- **total power over DC value ratio for M17 & GC are within 30% and 50%**

  [note: a perfect FTS would give 50%]
- **the ratios are significantly less for OT sources**
- **is there, also for this ratio, a change with source strength ?**

- **DC values in the previous plots were not corrected from Dark**

  ➔ next plots give the results after Dark correction of DC values

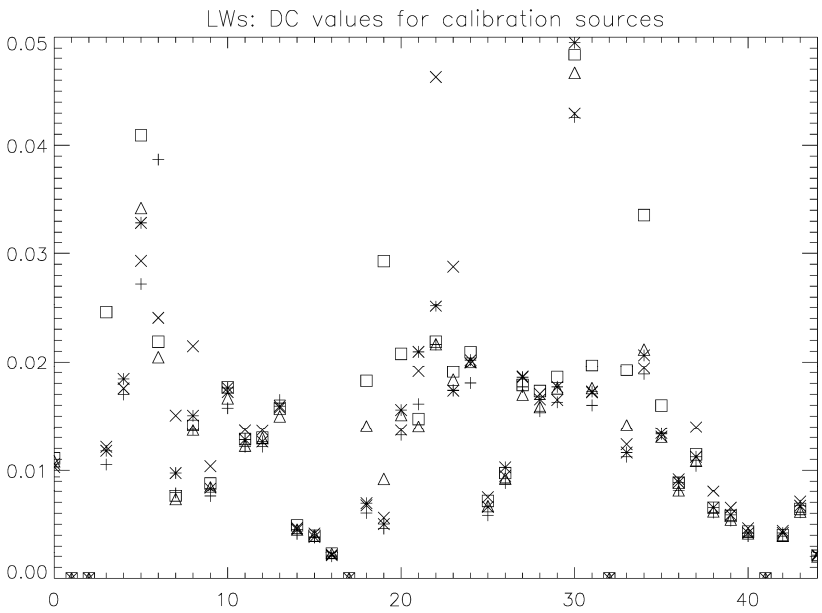


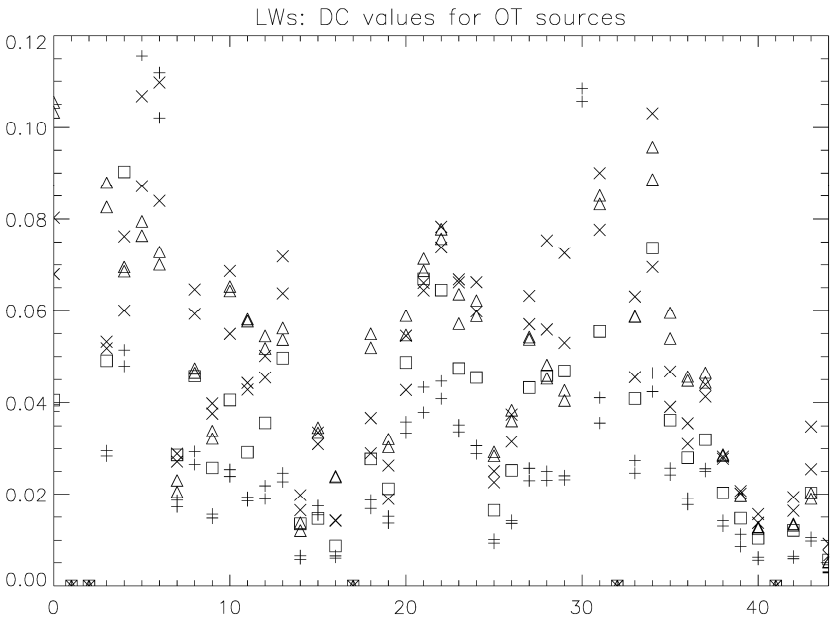
plot of total power over "corrected" DC value vs total power

- **apparent clear indication of total power over corrected DC value ratio decreasing with decreasing source strength**

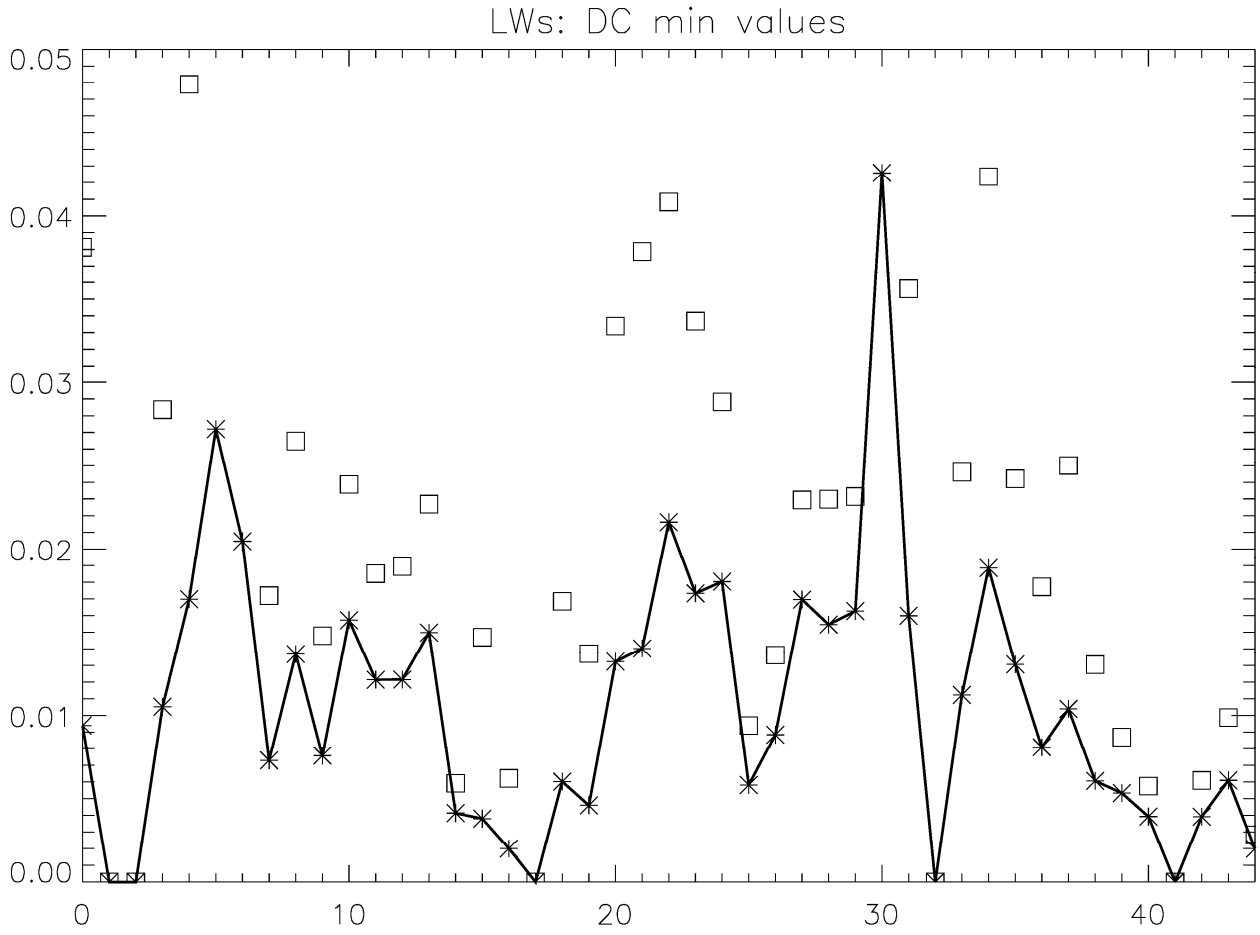
  ➔ is it due to some "background" power input not taken into account when shutter is open ?

- **in order to investigate this point I looked at the DC values recorded in the FIS03 observations from faint sources**
- **"calibration" sources observations (as provided by Yoko-san) are also used for this purpose: i.e. Ceres_p3, Neptune_p3, Neptune_p4, Uranus_p1 & Uranus_p2**

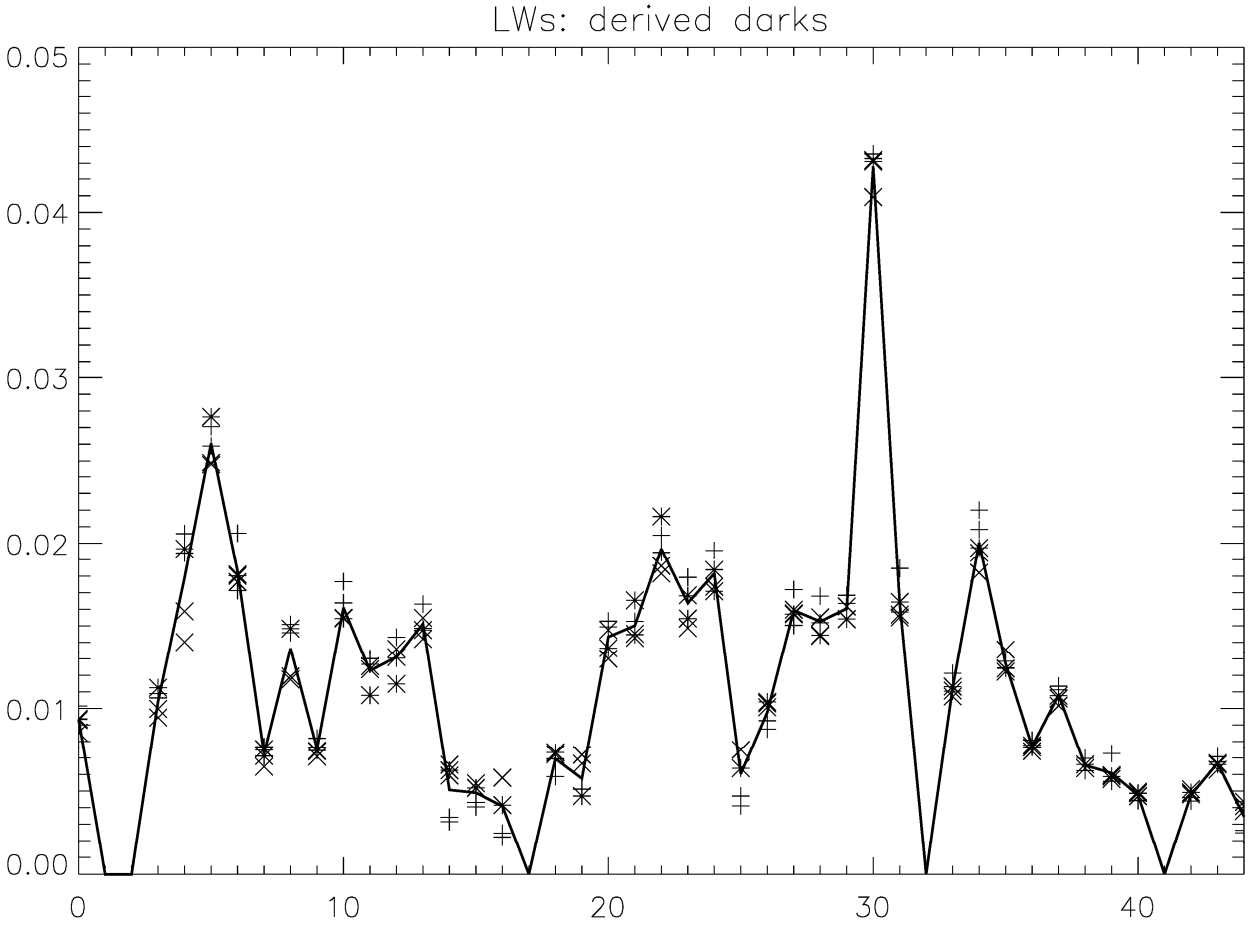




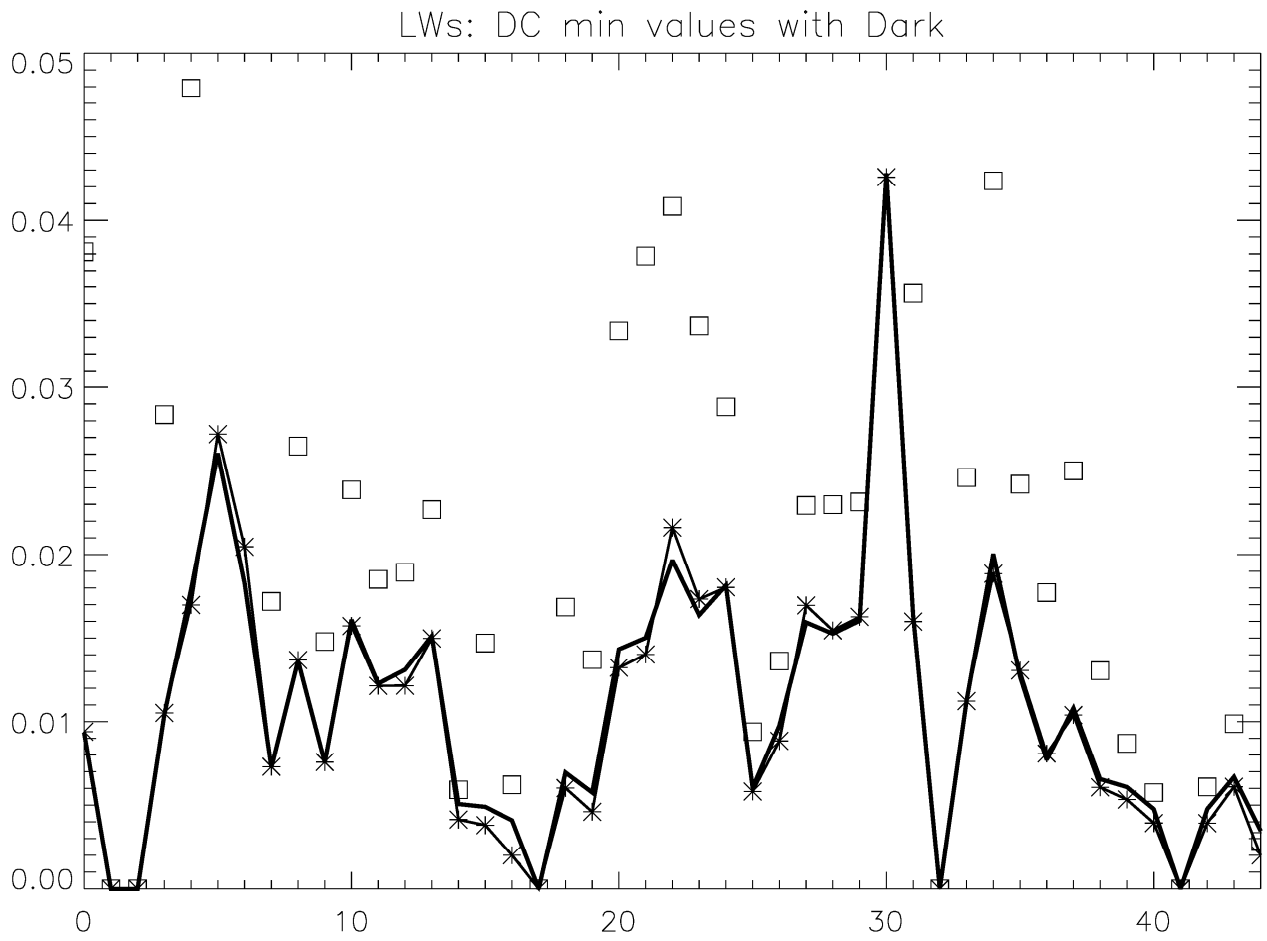
plots of the Dark corrected DC values for each LW pixel from "calibration" sources (left) and from OT sources (right)



plot of the minimum DC value for each LW pixel from "calibration" sources (stars) & from OT sources (squares)



plots of the measured Darks for each LW pixel
from original OT sources fits files (3 determinations per observation)
thick line = averaged value



plots of minimum DC values for each LW pixel with Dark value (thick line)

- **no significant differences between minimum DC values from "calibration" sources and "Dark" determination**

  ➔ therefore no significant extra "background" is seen when shutter is open

- **so, the trend seen in the plot p. 24 cannot be explained by an hypothetical "background"**

  ➔ therefore the decrease of the total power over corrected DC value ratio with decreasing source strength could be due to a real change of the pixel TRF

preliminary conclusions:

- **the analysis described here was intended to try to answer the two first original questions...**

- **I hope I have provided a comprehensive characterization of the transient response effect leading to a "transient response factor" with a quite acceptable estimate of the uncertainties in deriving these correction factors**
- **I provide also some indication that the correcting factor is source strength dependent with some estimate of the factor change function**

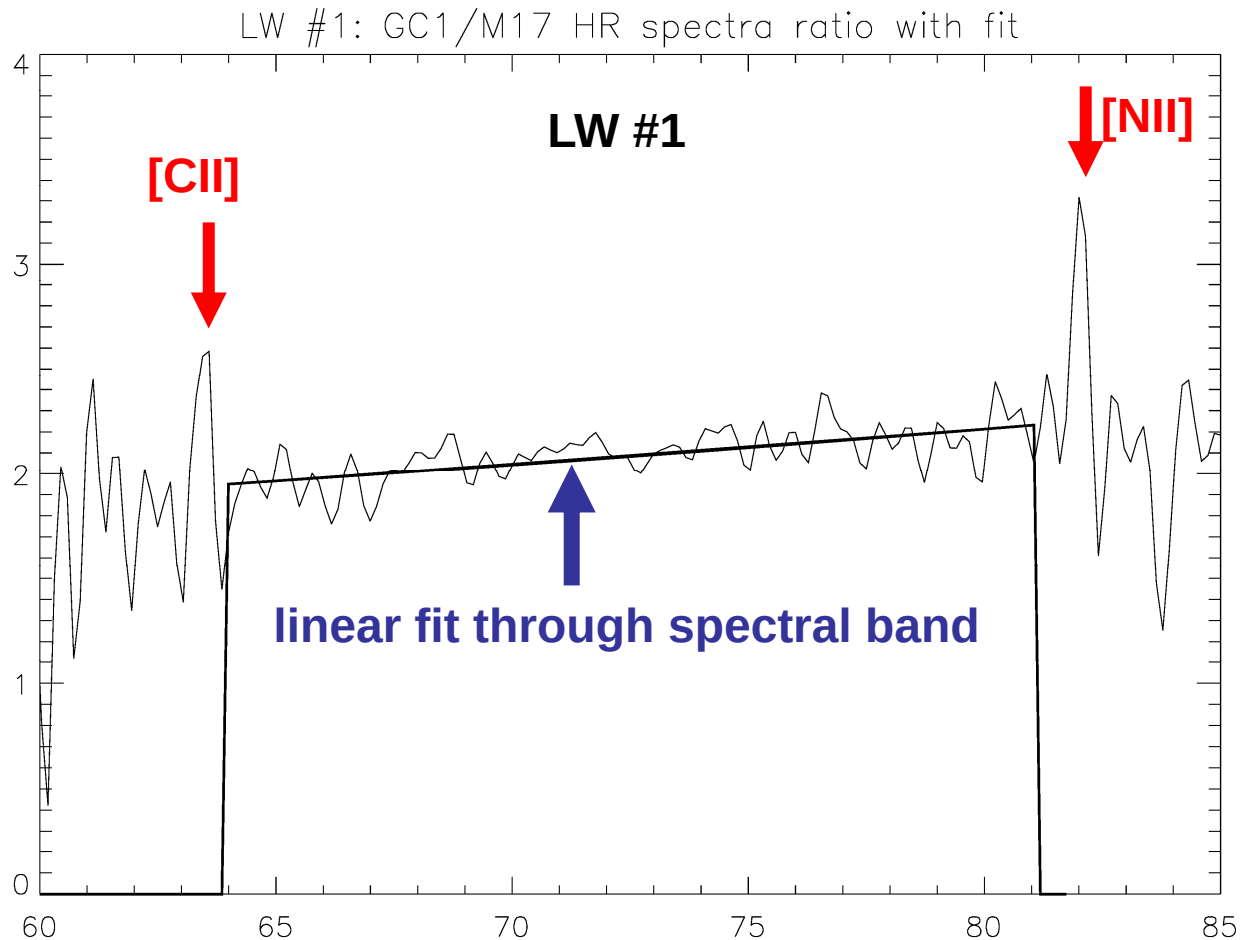
Question 3:

how much the spectral ratio (derived spectrum over actual spectrum at input port) varies with wavenumber over the actual passband and with source strength ?

- **in a previous note (sent in late March '08), I started to answer this pertinent (and difficult) question**

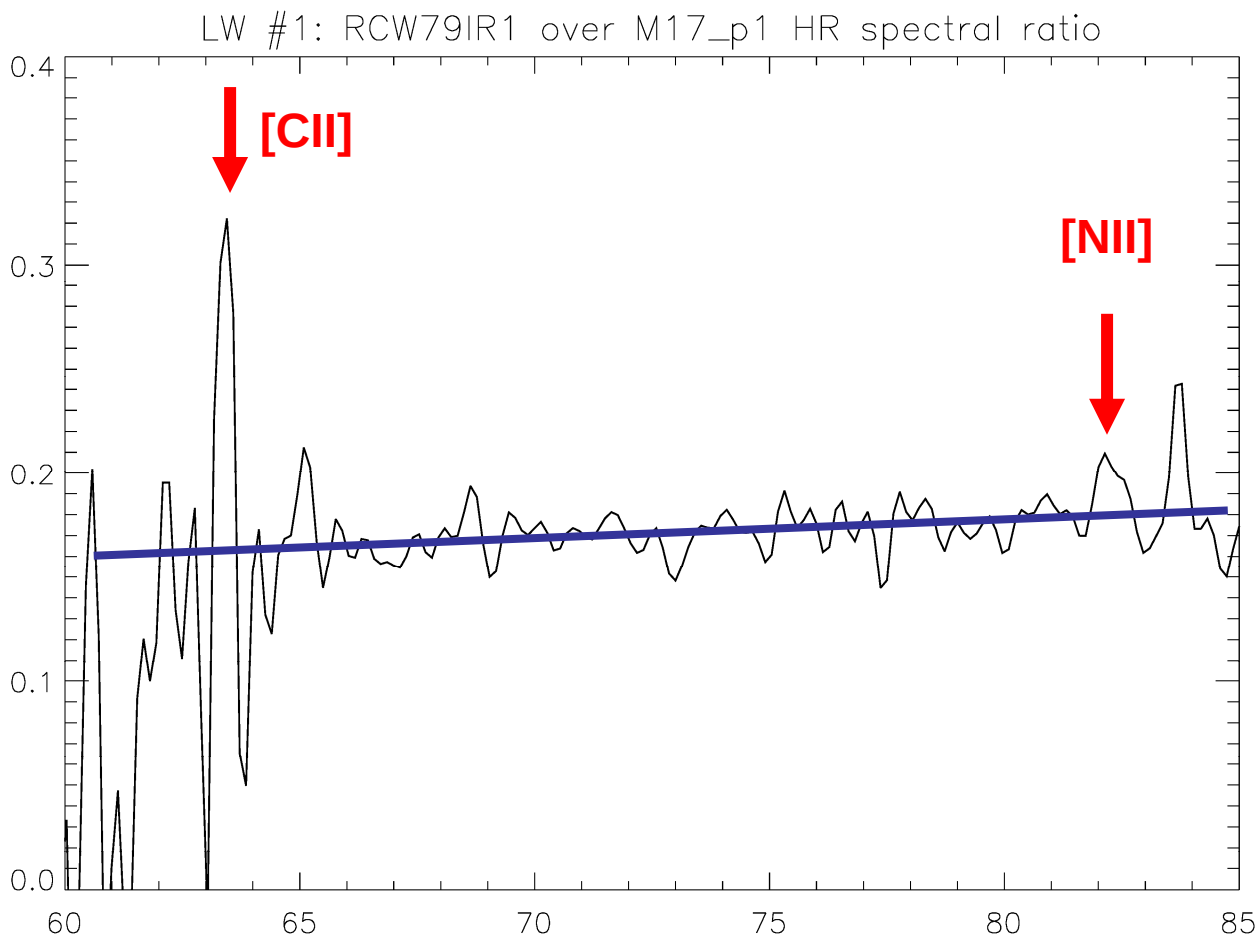
- **the next plot is taken from this note and gives the spectral GC1/M17 measured ratio for LW#1**

transient response effect on HR spectra



note that the original spectral fringing is well removed

plot of the Gc_p1 over M17_p1 HR spectra ratio vs wavenumber



plot of RCW79IR1 over M17 HR spectra ratio vs wavenumber

<u>preliminary conclusions:</u>

- **the derived spectral ratio is very smooth (deviations are due to measurement noise only) apart from the two [CII] & [NII] lines**
- **as the two sources are expected to exhibit smooth continuum spectra (dust grains emission at a given mean temperature) this finding indicates that the transient response does not introduce significant *spectral features* when comparing sources with different strengths**
- **the apparent slope in the spectral ratio (about 10% for GC1/M17 over the range 64 to 81 cm-1) may be due to a different dust temperature and/or to a change in spectral response induced by the pixel transient response**
- **M17 has been calibrated from ISOLWS but GC1 is not: to be able to put an upper limit to the spectral change induced by transient response requires that we have an other source (than M17) with known spectrum**
- **I hope to get soon this information for the OT sources mentionned here**