PT head position adjustment procedure

1 The PT head issue

The KID detectors of NIKA2 can be severely affected if vibrations propagate to the coldest stages of the cryostat. For this reason, a dedicated system has been developed to decouple the coldest stages from the Pulse Tube cooler which, for its very own nature, causes vibrations at around 1.4Hz and harmonics of this value. To obtain this decoupling, the cold flange of the PT is not directly screwed to the 4K plate of NIKA2. Instead, the thermal contact between the PT flange and the 4K plate is achieved thanks to interleaved concentric cylinders (see figure 1). The separation between the cylinders of the PT flange and of the 4K plate is very small ($\sim$hundreds of microns), and in the space between cylinders there is some helium, which grants the thermal contact between these two components thanks to convection.

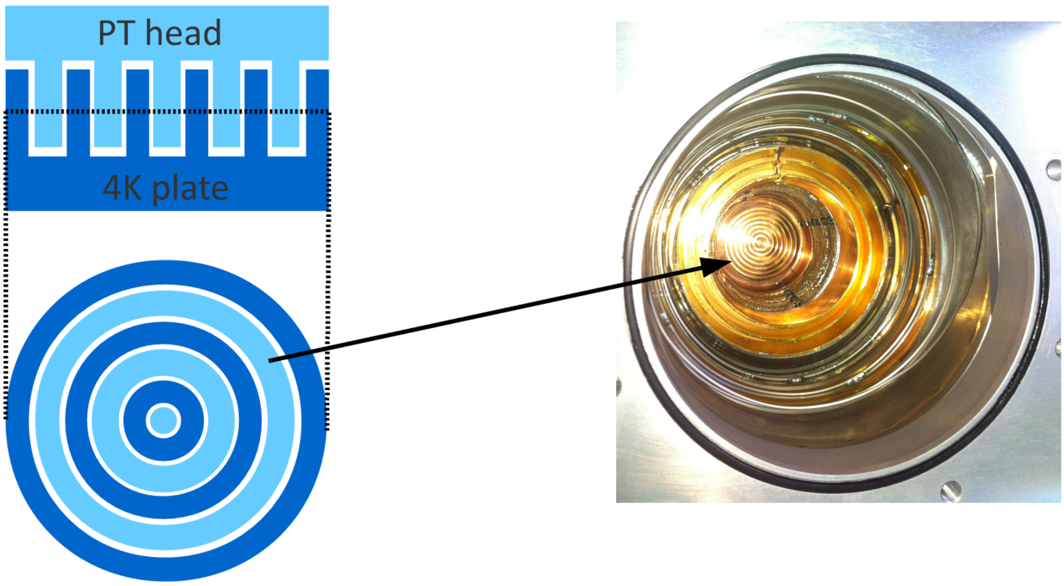

Figure 1: On the left, a schematic representation of the interlevad cylinders that are used to put in thermal contact the PT head and the 4K flange. In the space between cylinders the presence of He gas grants the thermal contact through convection. On the right, a picture of on of the flanges with the concentric cylinders.

Now, in the good configuration (the one shown in figure 1), there is no physical contact between the 4K plate and the PT, so while the thermal contact is good, the vibrations of

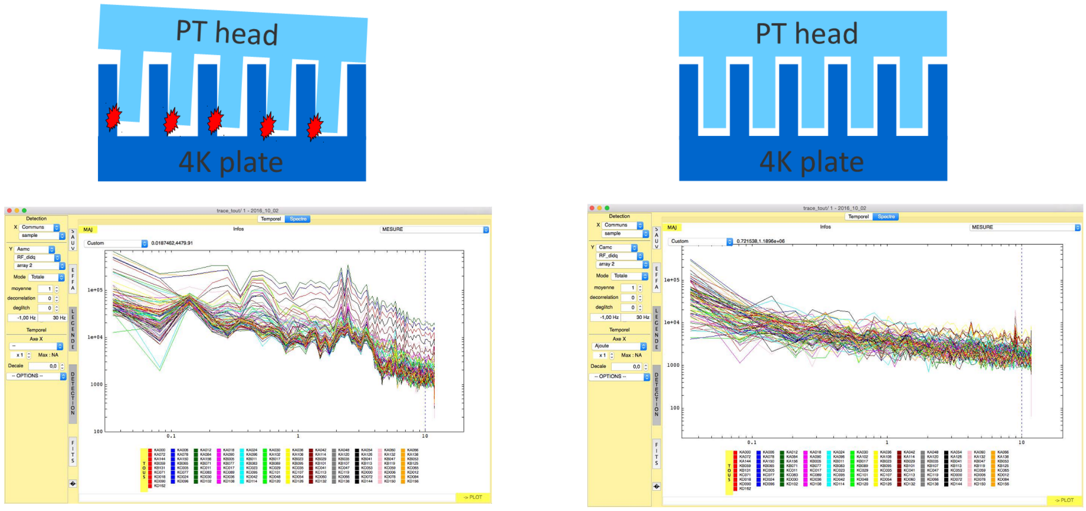

Figure 2: On the left, top part: an artistic representation of the PT position when a tilt is causing a touch between the PT head and the 4K plate. The vibrations induce a big increase in the noise, visible on the noise spectra of the KID detectors shown below. On the right, the PT in a perfectly aligned position, and the correspondingly flat noise traces of the KID.

the PT do not affect the 4K stage (and all the colder ones). So this is exactly what is needed. Sadly, the position of the PT is not completely fixed, as, always in the optic of decoupling its vibrations from the cryostat, it is hold in place using some rubber spacers. As a consequence, over time the position, or, more likely, the inclination, of the PT can change slightly. The interleaved cylinders can then end up touching (see figure 2). In this case, the vibrations start to propagate to the cold stages of the cryostat and a big increase in the detectors noise is observed. Note that, as a side consequence, the 4K stage of the cryostat will actually cool down more, as a physical contact between the PT and the 4K plate clearly grants a better thermal contact (along with the vibrations..) and a more efficient cooling of the 4K plate.

2 Adjusting the PT position

Before starting any work on the PT head, please keep in mind that, due to the dimensions of the pieces in play, a change of the position of the PT by less than half a millimeter in the wrong direction could already cause big problems. Such problems can in general be solved by simply go back to the previous position (everything is quite reproducible), but if you start to change a lot the position of the PT then one can completely loose the 'official' reference position and then it's a mess. That being said, if one does the intervention slowly and with patience, then it should go smoothly, so don't worry!

To adjust the PT position, 4 screws are available, shown in figure 3 (note that only 3

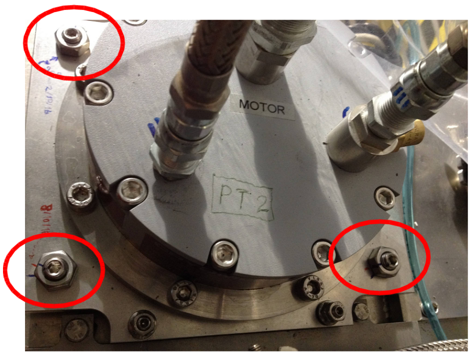

Figure 3: Image of the PT flange with the screws used to adjust its tilt. Note that the nuts are only there to block the screws in place but do not play an active role in adjusting the PT position: what counts is the screw itself, that can be turned using an M6 Allen key! A fourth screw is present, but is not visible in this picture.

screws are visible in the picture, but there is a 4th one as well!). Starting from April 2017, these screws have been numbered (1 to 4) to make tracking the intervention(s) easier (see figure 4. Turning these screws you will pull up or push down the PT head, thus changing its tilt and making it possible to get rid of the unwanted contact. The procedure to follow is briefly described below. Note that nothing compares to a good 'hands-on' session with someone expert on the subject forming you. So, *only people having had a 'training session' at Pico are authorized to adjust the PT position!* The following notes are only a guideline/reminder.

First of all, do a series of preliminary steps that will then allow you to check the effect of the screws you'll touch. Note that some of the steps require some knowledge of the

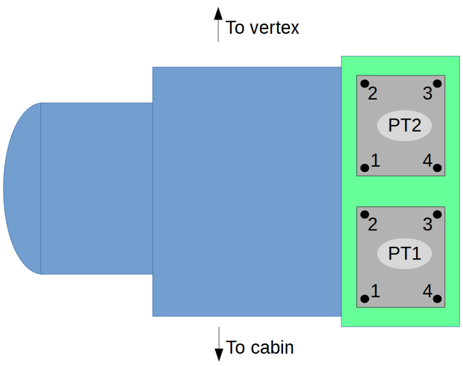

Figure 4: Schematic image of the NIKA2 cryostat with the numbering of the PT screws. Note that **only PT2 plays a role** as far as the vibrations are concerned. So PT1 can be neglected in the PT adjustment procedure.

Camadia software, so if you are not at ease with it ask the help of a member of the NIKA2 team: most of them will know what to do!

1. Close the NIKA2 cryostat window with the dedicated metal disk. Take care to close it well, without letting access to the light: any incoming light arriving from the cabin can introduce a signal and pollute your traces, in some cases introducing artefacts in the noise spectra that might look like a PT issue!

2. Make sure that the KIDs are well tuned. Then, if the 'autotuning' option of Camadia is active, turn it off.

3. Now prepare a series of windows on the portable black Mac that is always kept in the cabin. You have to:

   - Open a VNC window on the Mac12: 'open vnc://192.168.1.12'. Note that it is likely to be already open.
   - On this window, you should find the cryostat interface. Up on the left, where it says '6 : level attente', click and choose '0 : manual'.
   - Look for the window called T4Kplate reading the temperature of the NIKA2 4K plate. Put it in some place of the screen where it will be visible: this temperature will be the first indicator telling you if you're are going in the good direction (T4Kplate increases) or in the bad one (T4Kplate decreases)
   - Always on the window connected to the Mac12, launch the Camadia 'trace' program and open a 'tracetout'. Click on 'detection' and 'legende'. Then choose, on the left, for the Y variable, one of the first 4 amc (A-D), then 'RFdIdQ' and **'array2'** (array 2 is in fact the most sensitive one so the vibrations on it are more evident). Just below to where it says 'deglitch' write '-1' and enter (this resets the KID traces to 0, making it easier to see if they have moved around a lot), then 'efface' to clear the graph. Now, double click on Yaxis and Xaxis to autoscale.
   - Put this window in a well visible position. By pressing 's', then clicking on the beginning of the desired time span and then on the end of it, you'll get the noise spectra of the detectors over the selected span. **This is the fundamental information that will tell you if the noise is good or if there still is an excess contribution due to the PT**
   - With the 2 windows 'T4Kplate' and 'tracetout array2' well visible, you have the tools to get a feedback on what you are doing.

Ok, now you are ready to go and can proceed to the following step, that is playing with the screws and try to get rid of the excess noise. To do this:

1. Loosen, or better take completely out, the nuts that are used to 'fix' the position of the screws. These should not be to strongly tightened, so you should be able to unscrew them by hand.

Reference PT plate positions for PT1 and PT2				
Screw number	1	2	3	4
Height PT1 (μm)	32.00	32.05	32.45	31.95
Height PT2 (μm)	37.40	36.55	36.40	37.20

Table 1: Reference heights of the PT plates at the four corners, as measured the 06/04/2017.

2. **Mark the current position of the screws**, so as to have a reference! What counts is the position of the screw itself with respect to the PT plate, the nut is unimportant (actually, you should already have taken it out!). As said before, the screws have been numbered (figure 4) and the height of the PT flange with respect to the cryostat has been recorded. The current reference values are reported in table 1.

3. Now, start to play *with one screw at a time*. Each time you should turn the chosen screw in one direction *by small steps* (say 20 degrees). Then, wait a while (30 seconds or so) and see the reactions. The easiest to check is the 4Kplate temperature:

    - T4Kplate drops rapidly → the PT is touching it and cools it down, but then it also transmits vibrations... → BAD
    - T4Kplate seems to increase → in theory good.

    Note that these are indications, although they seem to be quite accurate ones. Abrupt decreases in T are surely bad; on the other hand, if the effect is very small, it's better to check with the noise on the traces of KIDs!

4. Ok, you have turned the first screw by say 20 degrees in one direction. See if it has been a good move (T goes up and noise goes down). If YES, do a bit more in the same direction until an optimum is found and then you start to see the T decrease again. If NOT, go back to the original position, verify that the T recovers its previous value, then try 20deg in the other direction. If it's good continue, if not, go back.

5. I repeat: **although the changes in the 4K plate temperature are quite accurate indicators to tell if you you're doing good or not, the fundamental answer is given <u>only</u> by the noise traces!** So give a look at them as well, especially once you think the problem has been solved, to confirm that this is really the case!

6. Now, there are different situations that might arise:

    - if the screw you have used didn't seem to have a big impact on T4Kplate and on the noise, put it back to its original position and proceed to the next one, repeating steps 3 to 6.

- if the screw you touched has solved the PT noise problem and the weather is very good/some nice observations are ongoing, stop here and proceed to point 7.
- if the weather is crappy or in any case there is no particular hurry, you can proceed to touch the other screws and optimize the position of each of them, repeating steps 3 to 6. This should probably lead to a better overall adjustment which, in turn, should grant a longer time before a potential new 'touch' of the PT is observed. Once all the screw's positions have been optimized, proceed to step 7.

7. Once you consider that a good position has been found and it is time to give back the instrument to the observer, put back in place the nuts and tighten them by hand. You don't have to tighten them very hard, just enough so as to fix a bit the screws in their positions.

8. Proceed to the final 'software' steps:

   - on the cryostat interface (you should have it on the black portable Mac), up on the left, where you had put '0 : manual', put back '6 : level attente'.
   - reopen the cryostat window.
   - using Camadia, recover the resonances.
   - reactivate the 'autotune' option of Camadia and give the green light for the start of observations.

This is the basic procedure, and should solve the problem. If it doesn't, there is one more test that can be done: you can **go back to the original position**, then try to screw/unscrew by 20deg at a time pairs of screws, in order to introduce a more marked 'tilt' to the PT head. For example, add 20deg at the 2 screws towards the cryostat nose. If it helps, goes on, if not, go back, and look for an optimum (if any). If it seems not to help, try another pair, for example the ones towards the entrance of the cabin, and so on. **CAREFUL**: this procedure has until now never been necessary, and can lead you to get far away from the official reference position, which then makes it very hard to recover a good working point. So it really should not be used unless you are really desperate!

3 Recovering a completely lost PT position

This procedure is really more complex. It implies loosing say 12hrs of observing time and putting at risk the cooldown ($\rightarrow$ the observing run if there is one ongoing!). So **this info is a reference meant only for the most experienced NIKA2 users!! Nobody else should use it, and anyone using it should in any case first of all inform A. Monfardini or A. Benoit and get their green light and assistance!**

The idea behind this 'extreme' recovery is that of being able to move by hand the PT head and 'feel' when it is well centered. This cannot be done in normal operation as the void in the mixture circuit pulls the PT head towards the cryostat with the equivalent of, say, 50kg or more. So it is mandatory to recover an equilibrium between the ambient pressure and the one inside the circuit, which implies stopping the dilution circuit..

The procedure is as follows:

1. Put the cryostat in its standard 'precool' phase (so if it's cold, that means first of all to stop the dilution and evaporate all the mixture!).

2. Starting from this condition, with PT heater off, stop one of the two PT compressors and wait for the pressure to increase. Get rid of excess mixture so that the P in the 'gaines' is slightly above external pressure. Confirm by eye that the PT heads are 'up', and by hand that it is possible to move them around.

3. In the whole process, you should only need to pay attention to the PT2 that is towards the vertex, as it is the one connected to the 4K plate and that could transmit more vibrations to the detectors. Yet, you can also apply first the full procedure to the other PT (PT1, towards the cabin) so as to 'get a feeling' of the whole thing without risking much. This will give you a bit of experience before doing the same thing to the PT2.

4. Start with the chosen PT. Unscrew completely, until they are loose, the 'dumper screws' that connect the rubber spacers. Once the black dumping rubber cylinders are free to move, stop unscrewing.

5. Move around, by hand, the PT and try to feel the 'touches' of the cold stage of the PT to the NIKA2 4K copper piece. NOTE: you can feel the touch, but it is a light effect! You really have to be attentive

6. Try to understand a bit where is the optimal centering. Screw the 'security stop screws' until they just touch the PT flange **while holding it in the optimal position**

7. Again, trying to hold the PT in the optimal position (and therefore, if you did things well, just touching the security stop screws), restart screwing the dumper screws. Screw them until you feel a bit of resistance (ie the dumping rubber is starting to touch), then give an extra 45 turn to the screw.

8. If you started with PT1, repeat steps 4 to 7 with PT2. This is the PT to which you have to pay particular attention. So take your time!

9. Once both PTs are ok, restart the second PT compressor and re-inject the mixture that has been taken out before.

10. Wait until the system has once again cooled down enough then launch the condensation.

11. Once condensation begins, you can optimize the position of the PT further by looking at the 4K temperature. When this temperature starts to be more or less stable, you can start to play with the PT2 screws. One by one try to screw/unscrew them, keeping always track of the original position (follow the indications of the previous section). NOTE!! Typically, if the PT is well centered, a $\sim 90\,\mathrm{deg}$ turn of a screw is enough to cause a direct touch between the PT and the NIKA2 4K stage! So, CAREFUL during this operation!

12. By turning the screw, you should see a clear drop in the 4K plate temperature as soon as you induce a touch with the PT. So, when you see this, turn the screw you are using in the opposite direction, so that first you no longer touch (T goes up) then you touch on the oppposite side (T goes down). Leave the screw in the middle between these two extremes and proceed to the following screw.

13. If you really want, once the four screws are optimized, you can make a second iteration. Then, tighten by hand the counter bolt. You should be ok..

14. In the time being, the cryostat is condensing. As soon as you reach the base temperature, check that the noise traces of Camadia are ok. They should be...

To give an idea of the timing, below you see the steps that had been done the only time that this procedure was adopted. The cryostat was already at the beginning in a precool stage (well cold, but no mixture condensed!).

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7h45 Switch off 1 PT compressor

8h40 P in the 'gaines' is ok, start to play around with PT head position

9h45 PT position adjusted, restart the standard cooldown by switching back on the second PT compressor.

12h00 Launch condensation. NOTE that we could do this very soon because the system had been already well precooled before starting the whole PT adjustment process. If it's not the case, wait for the correct temperatures before launching the condensation!

17h30 Switch on the turbo

20h00 Tbm at 200mK, good enough to see how things are going and if the PT lines have disappeared (but not ok for detailed tests as T is not yet stable enough)

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So basically **12 hours** have been necessary to do this procedure, and this starting with a cryostat with all mixture already evaporated! Starting from a cold cryostat, one should account for **24 hours to do the full procedure!**.

4 Sample noise traces

In the following pages you can see a few sample images of what the noise spectra of array 2 can look like in different situations (from very bad to very good), so as to have an idea of what you can expect to see.

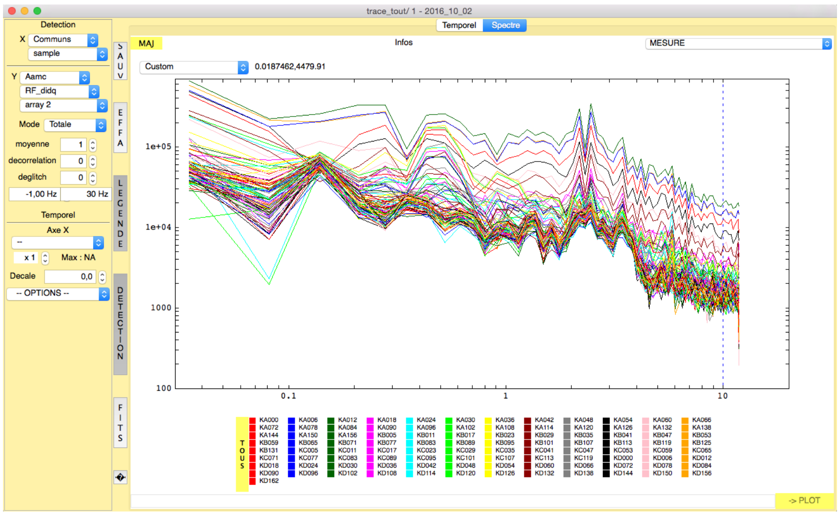

Figure 5: Noise traces in a really bad condition, with the PT strongly touching the 4K plate. You can see how the vibrations have an extreme effect on the noise traces, causing a big 'bump' on the spectrum and increasing its value by a factor 10 or more.

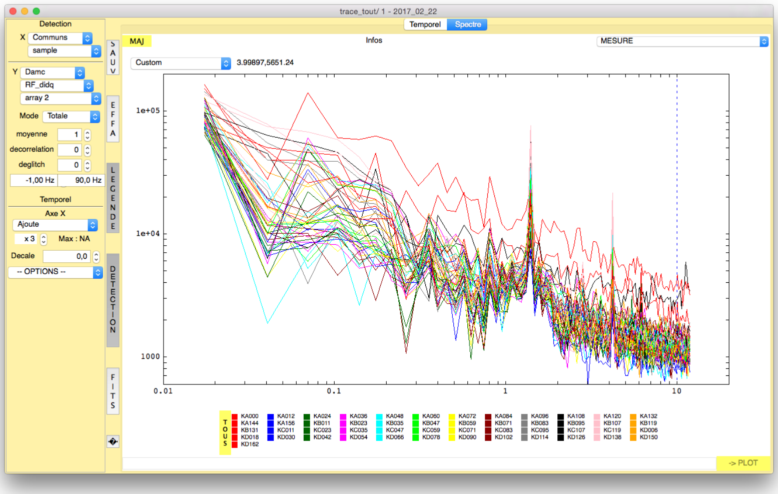

Figure 6: Noise traces in a slightly better but anyway bad situation: the PT is still touching the 4K plate. In this case you can see some peaks in the noise spectra at the PT frequency (∼1.4Hz) and its harmonics, plus already a bit of a bump on the spectrum. In a config like this, you still have to work to optimize the position of the PT.

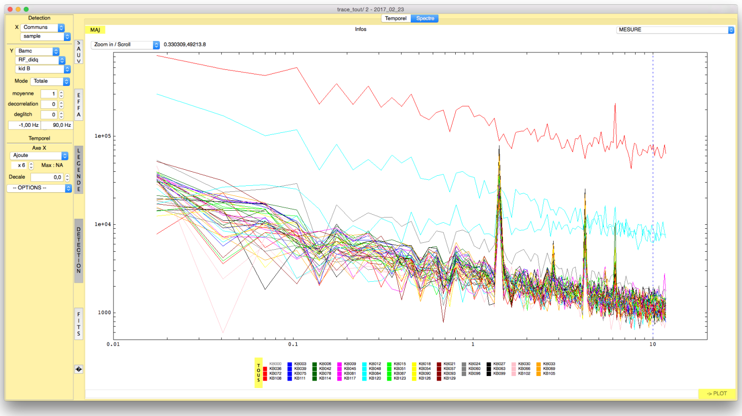

Figure 7: Noise traces in an almost (but not completely) good situation. The 'bump' due to the vibrations has disappeared but some lines/peaks in the noise spectra are still visible at the PT frequencies. This is an almost acceptable configuration (or acceptable, if it's impossible to do better), as well-defined peaks in the noise traces can be removed quite effectively during data analysis. Yet, it is recommended to try to improve further. In fact, in this case the PT is either not touching (but very near to do it), or still lightly touching. So apart from the noise peaks, it is also likely that the situation will degrade over time and a new intervention will be needed quite soon.

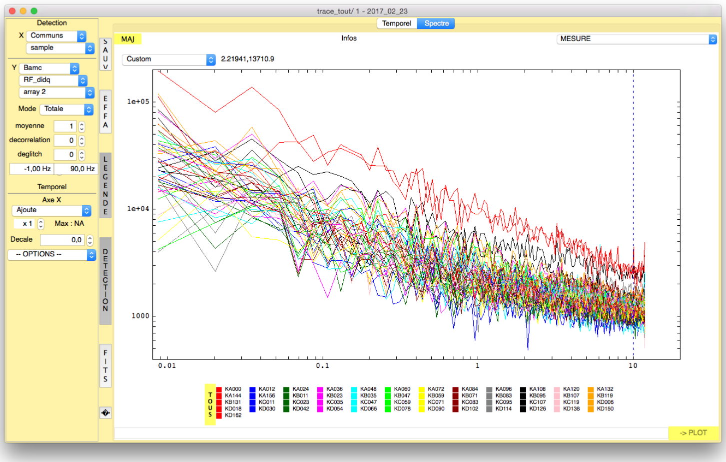

Figure 8: Noise traces in a good configuration: the PT is in this case NOT touching, so you can observe! Note how the noise spectrum is flat, its level is at around 1000–2000, increasing a bit at low frequency. Sometimes a peak in the noise is observed between 6 and 10Hz: its origin is not yet understood but it doesn't have a major impact on the data, and is any case not related to the PT.

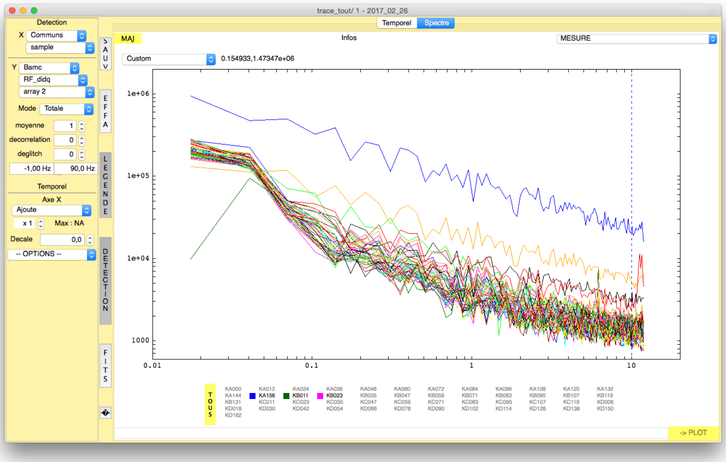

Figure 9: Noise traces, once again in a good configuration but now with the window open and looking at the sky. The variation of the incoming light (sky noise) causes the 1/f contribution at low frequencies. This must not be mistakenly attributed to the PT! If the window is open and looking at the cabin, you can also have plenty of peaks in the spectra or strange effects that can be very confusing. So, once again, **always perform the PT adjustment with the cryostat window closed!**