1. INTRODUCTION

1.1 Purpose of this Document

The purpose of this document is to provide the inputs required by HSC for SPOT phase 1 proposals for the spectrometer observing modes of SPIRE.

1.2 References

RD1: Note on defining SPOT OR input for Delivery to HSC, by Sarah Leeks (7 Sept. 2004);
RD2: AOT Status Review, by D.L. Clements (11 August 2004);
RD3: SPIRE PHOT AOT Definition, by M. Fox, S. Leeks, D. Clements (Draft 1.1, 10 Aug 2004);
RD4: SPIRE SPOT OR Input: Point Sources, by D. L. Clements, Draft 0.3, 5 Oct 2004)
RD5: Notes from the meeting on AOTs for the FTS, May 17, 2004, by M. Sauvage

1.3 Document history

Draft 0.1	09/10/2004	Creation and circulation of the document
Draft 0.2	11/10/2004	Include a section and a discussion on input units. Changed the front-end section following comments from S. Leeks.

1.4 Layout conventions

For clarity I have tried to consistently show the user inputs in **boldface**.

2. FRONT END OPTIONS

Here we simply discuss the first SPOT actions that the user will have to do to reach a form that can actually be filled with information that define an Observing Request (OR).

The first choice to be made by a SPIRE observer will be the basic observing modes:

PHOT *or* SPEC – the choice between these is exclusive, one or the other. In fact this is already present in the SPOT prototype that is available in the HSCDT, under the *observation* pull-down menu and is more detailed than that since the available options are in fact all the Herschel observing mode.

There is thus here a philosophical question: on the photometer side, the first turning point deals with the mapping strategy, i.e. to map or not to map? This is probably a valid approach for photometry but if one turns to the SPEC decision tree in RD5 and to the discussion on the possible mapping modes, we see that all mapping modes lead to the same entry point to the spectrometric strategy and that we had remarked that all the mapping modes were in fact concatenations of the "staring" mode (this was because we considered it unwise to entangle spatial and spectral sampling). I am therefore inclined to have the mapping strategy as a "parameter" of the OR input. I think this also allows us more margins to decide what to implement as far as allowed mapping strategy (remember that the baseline is still point source spectroscopy, even though we were instructed by the PI to keep all options open).

Note: because I suggest having the mapping strategy as a "sub-choice" of the OR, this implies that the OR accept point or extended source inputs for the flux. All OR should have a box or radio button to specify that the fluxes refer to a **point or extended source**.

All this aspects considered, this would lead to three possible modes or OR for the spectrometer:

- SPEC – Lines and continuum
- SPEC – Lines
- SPEC – Continuum

This list of options is more science-oriented than instrument-oriented. At that point it hides the alternative between the continuous scan and the step-and-integrate scan modes of SPEC. I think it is probably better to do it this way as it puts the science goals up-front and when observers start SPOT for the first time, their science goals will be clearer than their knowledge of the technical capacities of SPIRE.

Coming back to the issue of philosophy I would argue that the equivalent of the alternative point or extended source in photometry is in fact more lines or continuum in spectroscopy rather than again point or extended. Hence the change in perspective that I propose here.

It is clear (see RD5) that in some cases it will be impossible to obtain a good measure of the lines and continuum simultaneously. In that case observers will have to do them separately. I don't think it is necessary to include a mechanism in SPOT to automatically re-direct the user to the correct OR. I my mind we can assume that users will consider this the only logical way. However this points to a possible frustrating implementation of the ORs: let's take the case of an observer who wants to perform a line and continuum observation. He/she enters SPOT, selects the line and continuum OR, enters all the details about the targets (among others the fluxes of the line and continuum goals), only to find out that it is not possible to reach the goal signal-to-noise ratio on the continuum. If the ORs are implemented as listed above, then he/she will need to cancel that OR, and select another one, quite possibly loosing all the source information he/she had entered…

Thus it probably makes more sense to have these three modes as an option of **a single spectroscopy OR**. Once selected this OR would basically be divided in two sections: one for the **spectroscopic goal**, with three options: **line and continuum**, **lines**, and **continuum**, and one for the **mapping options**.

Entering the user-input parameters for the spectroscopic goal would always open the same sub-panel, with some boxes greyed-out according to which make sense for the selected goal. Changing the goal would not erase the content of the already-filled boxes.

As will be seen later on, this implementation makes sense because the user-input parameters that relate to the spectroscopy goal are very similar from one mode to the other.

Note: I assume that the definition of the main pointing (e.g. source coordinates, visibility estimation, background estimation) is out of the scope of this document. Judging from the SPOT prototype this is dealt with its own interface.

3. Parameters for the spectroscopic modes

This section now indicates which user-input parameters we propose to allow in each of the three spectrometer modes. For clarity I include in each sub-section a division between the parameters that define the spectroscopic scanning method, and those that define the mapping method. Remember that these modes belong to the same OR. I've written a section per mode because I think it is easier to understand, but the similarities between all the sections will be evident.

The mapping method parameters are almost the same for all three except for the continuum mode where chopping can be allowed.

3.1 SPEC – Lines and continuum

3.1.1 Spectroscopic parameters

According to RD5, the only way to achieve this is to use the High-Resolution Scanning mode of SPEC. In that case, the only information we need to decide on the feasibility of the observation is the source characteristics and the time the user wants to dedicate to this observation.

In fact to determine the observation's feasibility, we need information on both the line and continuum objectives. So we need to be able to provide:

- **Flux estimates** for line and continuum
- **Signal-to-noise** ratio objectives for line and continuum
- **On-source time** (here there is one single time value)

The user may only fill two of these "fields" and the CUS/Time estimator will fill the missing information. CUS/Time estimator should have a way to "detect" an unfeasible observation other than through some variable over-flow, i.e. we should probably compute the performance limits of this mode (see also the open issues section).

In principle the user does not need to provide both line *and* continuum flux estimation or signal-to-noise ratio objectives: a flux estimation and signal-to-noise objective one either one is enough to compute the requested time and, as a by-product, the achieved sensitivity on the other spectral component (expressed as for instance the 1σ limit). However I think it is better to allow room for all of this information input and let the CUS/Time estimator sort things out (i.e. we will decide later what the minimum information set is).

As we have two arrays on the SPEC side, they may have different performances in which case it could make sense to duplicate again the flux and S/N fields to indicate which applies to which array.

Note: the signal-to-noise ratio that the user inputs is that measured on the spectrum, not on the interferogram.

3.1.2 Mapping parameters

In the high-resolution scanning mode, chopping is not allowed therefore the mapping possibilities are quite straightforward:

- **Point source/Sparsely sampled single field of view**: The telescope will do a single pointing. Indeed for a point source this should be enough and in fact with the same pointing we "automatically" obtain data from all the pixels in the field of view from which we can reconstruct spectra that will constitute a sparse mapping of the field of view.
  - ⇨ *No parameters.*
- **Fully sampled single field of view:** We use either the telescope or the BSM (to be decided later, this is of no concern to the user) to perform the equivalent of a 64-points jiggle map (or any other pattern that achieves full sampling of the field of view).
  - ⇨ *No parameters* (the pattern is fixed by us).
- **Sparsely sampled large map:** We use the telescope to cover a regular pointing pattern on the sky that will allow the realization of a large sparsely sampled map.
  - ⇨ *Parameters**: map size and orientation*** (for the moment I assume that we do not allow the observer to decide how sparsely sampled this map will be.).
- **Fully sampled large map:** We use the telescope and/or the BSM (since we have to use the telescope to make a large map, it may be of little interest to use the BSM as well) to create a large fully sampled map.
  - ⇨ *Parameters**: map size and orientation*** (again the pattern is fixed by us).

In the last two possibilities, the map orientation refers to both an angle and the reference of that angle (i.e. whether it is to be understood as with respect to a satellite axis or to the Celestial North). The definition of angles and their references should be uniform throughout SPOT.

Note that in all these cases a full spectral scan is obtained at each pointing (no mixing of pointing and spectral scan).

3.2 SPEC – Lines

3.2.1 Spectroscopic parameters

Again to measure lines, the only possibility is to use the high-resolution scanning mode. Therefore there is formally little difference between this section and the previous one. The only difference is that the user has no goal for the continuum and thus there are no inputs related to the continuum.

So we need to be able to provide:

- **Flux estimate** for line
- **Signal-to-noise** ratio objective for line
- **On-source time**

Again, any two of these parameters will allow the CUS/Time estimator to compute the third one.

It is also likely that we have to split the first two boxes to reflect the possibly different performances of the two arrays on the SPEC side.

3.2.2 Mapping parameters

These are exactly the same as in the line and continuum OR.

3.2.3 Note

It would probably be interesting that the CUS/Time estimator brings out the performance estimation on the continuum, given the user input on the lines. If this is implemented, then this OR becomes a special case of the line-and-continuum OR.

3.3 SPEC – Continuum

3.3.1 Spectroscopic parameters

There are two possibilities to perform a continuum observation: A low-resolution scan or the step-and-integrate method. Using step-and-integrate requires that one has the possibility to chop. Step-and-integrate will produce a higher signal-to-noise ratio but is more time-consuming than a low-resolution scan. Therefore it is probably safer to restrict the use of the step-and-integrate method to point sources and sparsely sampled field of view observations. This is the first occurrence here of an "interaction" between spectroscopic and mapping parameters.

Therefore the spectroscopic parameters are now:

- **Flux estimate** for the continuum
- **Signal-to-noise** ratio for the continuum
- **Spectroscopic** method (low-resolution or step-and-integrate)
- **On-source time**

I've added the spectroscopic method as a parameter as I consider that SPOT should not be allowed to make this decision (again if I am correct, the choice between a low-resolution scan and a step-and-integrate measurement is a science choice and not a technical choice: a scan will be fast. is feasible in any sky configuration, and can be combined with a map, while a step-and-integrate measurement produces a much better signal-to-noise ratio but requires a blank field to chop in and cannot be combined with a map). The choice of the spectroscopic method is mandatory (no default and the user has to select one of the two possibilities).

Out of the remaining three inputs the user only has to provide two and the CUS/Time estimator will compute the missing one.

Again the source-related parameters (flux and signal-to-noise ratio) will probably have to be duplicated to treat separately the two SPEC arrays.

If the step-and-integrate method is used then a sub-panel or popup could be activated to configure the chopper (which is the BSM used as a chopper). Chopper parameters are:

- **Chop throw** (arc minutes)
- **Chop frequency** (Hz)
- **Chopper position angle** (degrees)
- **Chopper angular reference** (satellite or celestial north)

The chopper position angle and its reference should be specified following the same definitions as for the map orientation.

It is probably clear that we don't want to let all these parameters available to the user. However it is also clear that some of these parameters will have to be open for user input (see open issue on this point).

3.3.2 Mapping parameters

The mapping parameters are again the same as in the previous OR, with the added restriction that their availability depends on the spectroscopic method that has been chosen.

- **Point source/Sparsely sampled single field of view**: The telescope will do a single pointing. Indeed for a point source this should be enough and in fact with the same pointing we "automatically" obtain data from all the pixels in the field of view from which we can reconstruct spectra that will constitute a sparse mapping of the field of view.
  - ⇨ *No parameters.*
  - ⇨ This is the only available mode for the step-and-integrate method
- **Fully sampled single field of view:** We use either the telescope or the BSM (to be decided later, this is of no concern to the user) to perform the equivalent of a 64-points jiggle map (or any other pattern that achieves full sampling of the field of view).
  - ⇨ *No parameters* (the pattern is fixed by us).
  - ⇨ Not available the for step-and-integrate method
- **Sparsely sampled large map:** We use the telescope to cover a regular pointing pattern on the sky that will allow the realization of a large sparsely sampled map.
  - ⇨ *Parameters**: map size and orientation*** (for the moment I assume that we do not allow the observer to decide how sparsely sampled this map will be).
  - ⇨ Not available for the step-and-integrate method
- **Fully sampled large map:** We use the telescope and/or the BSM (since we have to use the telescope to make a large map, it may be of little interest to use the BSM as well) to create a large fully sampled map.
  - ⇨ *Parameters**: map size and orientation*** (again the pattern is fixed by us).
  - ⇨ Not available for the step-and-integrate method

4. UNITS FOR THE USER INPUTS

Most of them should be straightforward but we nevertheless need to agree on that and try, as much as possible, to have a uniform set of units throughout SPOT (e.g. a continuum flux is always expressed as mJy/arcsec^2, or as MJy/sr, or as Jy/beam…). It is probably too early to decide on this as all the inputs from all Herschel Observing modes have to be gathered first, but here is a list of suggestions to consider:

- *Continuum flux*: a natural unit for SPIRE is Jy/beam. Given that the beam size is going to change with wavelength, this may not be such a judicious choice. It is also unlikely that this will be a relevant unit for PACS. The nice property of this unit is that is does not matter whether we are talking of a point or extended source. Nevertheless we should rather consider fractions of Jy and MJy/sr as input units for the continuum.
- *Line fluxes*: Most, if not all the lines that SPIRE will observe, will be unresolved. As I am not a spectroscopy specialist, it is uneasy to present a recommendation. Furthermore, FIR astronomer tend to use different units from optical or NIR astronomers.
- *Position angles* (chopper or maps): this clearly should be degrees
- Chopper throw: this should be arcminutes, though it may create confusion with the units for position angles. The problem is that expressing the position angle in minutes will lead to very large numbers and quite possibly errors, while the chopper throw will never be larger than a few minutes.
- *Map size*: although a size should be specified in square arcminutes, but what we really want here is the map size as a product of two linear dimensions, both in arcminutes, to allow for non-square maps.
- Frequency: in case we allow it, it should be in Hertz
- *Time*: A practical unit of time, taking into account all the uncertainties, is probably in minutes, but I still suggest to count is seconds, since I think this is the standard for space.

Given the above notes on units for lines and flux it may not be a bad idea to think of a unit converter in SPOT.

5. RETURNED INFORMATION

Obviously the CUS/Time estimator returns the missing element in the triad (flux, signal-to-noise ratio, on-source time). In fact the CUS/Time estimator should return a table of the achieved sensitivity as a function of wavelength, as this parameter could have a strong wavelength dependence.

The CUS/Time estimator should also return more technical parameters, if only for educational purposes. In the continuous scan we need to have the number of scans performed while in the step-and-integrate method we need the integration time per step and the number of steps (though this will be fixed by us).

In case a mapping option has been selected, the map parameters, this time in terms of the actual pattern of pointings, should be returned. Ideally this should be done graphically by showing the detector footprint on the sky. *This is already a requirement of the SPOT visualisation tool.*

The breakdown of the total time in terms of on-source time, slew time, internal instrument buffer time, etc, should be provided to the user so that an estimation of the observation efficiency is possible (see also the open issue on time).

Given that SPEC is made of two arrays that possibly have different performances it should be made clear to the user which of the two parts of SPEC are really driving the observation. This could allow the user to relax some of its sensitivity objectives to obtain a higher efficiency.

6. Finalising an observation

Once the observer is happy with their observation they should press a button called 'commit observation'. This uploads the current observing description, with the total observing time fixed, to the scheduler and for CUS conversion. The controlling quantity at this point is the observation time, since this is what is scheduled. The flux and S/N parameters will also need to be stored so that we can monitor the effects of changes in sensitivity on the programme, but the time taken for the observation will be what controls the scheduling and allocation of time.

7. Open issues

7.1 Wavelength dependence of the sensitivity

In the above discussion, I have implicitly assumed that the wavelength dependence of the sensitivity is adequately covered by separating the input according to the two detectors of SPEC. This may not be enough. It there is a strong wavelength dependence then we will need another set of inputs from the user: the wavelength at which the input values should be considered (even if no flux is provided, the user will give a wavelength at which the signal-to-noise ratio goal should be reached).

If this wavelength dependence is strong, then it becomes specially important that the evolution of sensitivity with wavelength is part of the returned information.

7.2 Time

The user is offered the possibility of entering a time value as one of the constraints to CUS to work out the actual OR. But what should this time be? We have principally two choices: the total execution time of this OR (including all overheads), or the on-source time (i.e. the time actually spent with the target in the field of view).

In the first case we have to design the CUS/Time estimator so that it returns some measure of the observation efficiency (i.e. what fraction of the total time is spent with the target in the field of view) and in the second we have to make sure that the user is made aware of the total execution time of the observation.

I don't think one is better than the other but the choice should be made clear and consistent between instruments.

7.3 Medium resolution mode

The science case for this mode is still not closed. I've chosen not to list it here because it is formally equivalent to the high-resolution line mode: it is only feasible through the scanning method, and we will not let the user choose the spectral resolution. Implementing it in SPOT will just be a question of duplicating some forms (making it active in CUS will be more complex but we are not at that stage yet).

7.4 Chopping parameters

At the moment I have let the chopping parameters open for user input. I'm not sure this is a good idea. The reason for that is that there will be areas in the sky around the target where the observer will definitely not want to chop. By specifying the chopper position angle, the observer can make sure that these areas are avoided. Another way of implementing that is to fix all the chopper parameters and open a box for a **zone-of-avoidance**. This option puts constraints on the possibility to schedule the observation and the user should be made aware of that.

7.5 Observations that do not make sense

What should SPOT do when the user input do not make sense to us? For instance the target flux is well below the confusion limit, the flux and signal to noise ratio lead to an observing time either ridiculously short or long… It is my opinion that we would be setting to high a goal if we were trying to make SPOT provide react smartly to that by suggesting input modifications.

I rather have in SPOT a set of limits, computed by us, against which SPOT can check either the input parameters or its results. For instance we could decide that an observation that has an on-source time of less than a minute does not make sense, given that all overheads will be longer. Or we could argue that an observation that lasts more than 22 hours is not feasible for obvious reasons.

The point is that SPOT would just return an error message showing which of the elements falls outside of the "sanity" tables.