A Note on SPIRE-PACS Parallel Mode

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1. Introduction

This note is in response to Herschel Science Team Action FST6-A6. It is intended to justify the proposal that PACS-SPIRE Parallel mode should be retained as a possibly optimal way of carrying out large-area photometric surveys with Herschel.

2. Definition of Parallel Mode

- Both the PACS and SPIRE ^{3}He coolers are cycled and operating.
- PACS and SPIRE are both operating in photometry mode, carrying out large-area mapping observations.
- No SPIRE mechanisms are operating (the Beam Steering Mechanism is powered and holding at its central position). All three photometer arrays are passively taking data. The SPIRE instrument configuration is identical to that for Scan-Map mode (see *Operating Modes for the SPIRE Instrument*, SPIRE-RAL-DOC-000320) except for the reduced data rate, as noted below.
- PACS is taking data with the red photometer (170 µm). Blue photometer (75 or 110 µm) operation is TBD (depending on scientific and data-rate criteria that need to be studied).
- PACS would also very likely operate without mechanisms (i.e., chopper not operating)
- Both instruments are operating with somewhat less than the full data rate and the scanning strategy may not be optimum for both instruments; this may mean that full sensitivity is not possible - but that is not be required for certain programmes.
- For instantaneous full sampling of the SPIRE field of view, the scan direction with respect to the telescope axes must be at the appropriate angle. The detailed scanning strategy may therefore be determined by SPIRE (TBD).

3. Constraints

- **Thermal dissipation:** The combined thermal dissipation of PACS and SPIRE when operating together should be such that the instrument temperatures remain within acceptable limits. This needs to be confirmed by system-level thermal modelling
- **Data Rate:** The available data rate must be sufficient for the two instruments to collect the appropriate data. This too needs to be confirmed, but should not be a major problem. For PACS red photometer only, the required data rate could be around 50 kbs. Provided the scan rate is not too fast, SPIRE can telemeter data from all three arrays with 50 kbs or less. Hopefully, both PACS arrays and all three SPIRE arrays can be operating.
- **Microphonics and EMC:** Instrument mechanisms or electronics should not cause excessive interference to each other. This needs to be confirmed by system-level testing.
- **Compatibility of integration times:** Significant time is only saved if the required integration times for separate observations by both instruments are comparable - otherwise serial rather than parallel observations will be better.

4. Scientific utility of Parallel mode

For Parallel mode surveys, it may not be feasible to achieve the full sensitivities or to optimise the observing strategy for both instruments simultaneously. However, this will not be necessary for some very large-area shallow surveys. As an example of this we consider a large-area multi-band survey of the galactic plane with the following characteristics:

Survey area		2000 square degrees (e.g., 360° strip of width 5.5⁰)
Survey bands		SPIRE: 250, 350, 500 μm PACS: Red photometer (170 μm) Blue photometer (75/110 μm) - TBC.
Required sensitivity	(a)	100 mJy 5σ (i.e., 20 mJy rms)
PACS sensitivity (1σ; 1 s)	(b)	36 mJy over fully sampled 1.75 x 3.5 arcminute fov
Time for PACS map	(c)	76 days
Time for SPIRE map	(d)	90 days

Notes: (a) The instruments could achieve this level of performance without necessarily having the full data rate or optimum observing strategy
(b) As presented at the Toledo Symposium
(c) Assumption of 80% detector yield and 20% overlap for both. The overlap is to take into account the need to patch together scans and sub-maps, and represents a simple multiplication factor of 1.2 applied to the total area to be covered.
(d) Based on SPIRE sensitivity as presented at Toledo [same yield and overlap assumptions as for (b)]

The table above, based on recent sensitivity estimates, implies that the integration times required for the two instruments are comparable. The observations could be done sequentially or in parallel. The (identical) SPIRE and PACS ^{3}He coolers are energy devices. Operating the two instruments together increases load on the helium tank by a factor much less than two, because the total load is largely from the cryostat parasitics. Parallel operation is thus potentially very favourable in terms of science per litre of helium. The simultaneous operation of the coolers makes no overall difference: each time a cooler is cycled, a fixed amount of energy is deposited into the helium tank, so each operation of a cooler costs the same amount of cryostat life.

5. Additional benefits of parallel mode

- Parallel mode would allow more efficient use of helium in the event of high cryostat boil-off due to excess parasitic load.
- Joint SPIRE and PACS observations made in parallel mode will have more accurate co-registration of the images, because the relative angular offsets between the two arrays will be fixed and accurately known.

6. Conclusions and recommendations

The potential advantage of Parallel mode depends critically on the relative sensitivities of the PACS and SPIRE in operation, and on other factors such as the thermal behaviour of the system and the compatibility of the instruments and their operating modes. It is entirely possible that in practice, sequential observation could be the best choice. However, the analysis above shows that that may not necessarily be the case. As there are substantial scientific benefits at stake, it would be premature to rule out SPIRE-PACS Parallel mode at this time. The definition of the instrument operating modes and the Ground Segment should therefore proceed under the assumption that support of Parallel mode is a requirement for Herschel.

As the instruments and the Ground Segment continue to be developed, it should be possible to make a more detailed and reliable assessment of the trade-offs that dictate whether or not Parallel mode could be beneficial. It is possible (but not guaranteed) that a clear decision could be made before launch. It is certain that a decision can be made after in-flight performance verification.

Appendix: Large galactic survey with SPIRE-PACS Parallel Mode

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PACS integration time

PACS 170-mm field of view (sq. deg.) $Pfov := \frac{1.75 \cdot 3.5}{3600}$ $Pfov = 1.701 \times 10^{-3}$

PACS sensitivity (mJy 1s; 1 s) from Toledo presentation figure of 3 mJy 5s 1 hr) $P\_1\sigma\_1s := \frac{3}{5} 3600^{0.5}$ $P\_1\sigma\_1s = 36$

Required rms sensitivity (mJy) $\Delta S := 20$

Detector yield $Yield := 0.8$

Overlap $Overlap := 1.2$

Time to map fov to DS mJy 1s (sec.) $t\_P\_fov := \left(\frac{P\_1\sigma\_1s}{\Delta S}\right)^2 \cdot \frac{Overlap}{Yield}$ $t\_P\_fov = 4.86$

Time to map 1 sq. deg to DS mJy 1s (hrs.) $t\_P\_1SG := \frac{t\_P\_fov}{Pfov} \cdot \frac{1}{3600}$ $t\_P\_1SG = 0.793$

Time to map 2000 sq. deg to DS mJy 1s (21-hr days) $t\_P\_2000 := \frac{t\_P\_1SG \cdot 2000}{21}$ **$t\_P\_2000 = 75.6$**

SPIRE integration time

Time to map 1 sq. deg to 3 mJy 1s (days) (from Toledo paper; includes same yield and overlap assumptions as above) $t\_S\_1SG := 2$

Time to map 2000 sq. deg to DS mJy 1s (days) $t\_S\_2000 := t\_S\_1SG \cdot \left(\frac{3}{\Delta S}\right)^2 \cdot 2000$ **$t\_S\_2000 = 90.0$**

Conclusion

* Required integration times can be comparable