EPoS: The Earliest Phases of Star formation
Mapping and analysing extended emission and point sources

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on behalf of the EPoS group:
EPoS: The Earliest Phases of Star formation

- *Herschel* guaranteed time key programme (112 hours, PI: O. Krause, MPIA)
- to map well studied *cloud cores* across the entire mass range (no blind survey)
- separated into a *low* (12 cores) and a *high-mass* (45 regions) part
- to determine the *dust temperature and density distribution* of 12 near and isolated low-mass cores (e.g. Stutz et al. 2010, Nielbock et al. 2012, Launhardt et al. 2013)
- to characterise the *embedded core populations* of 45 high-mass SF regions and IRDCs (e.g. Beuther et al. 2010, 2012, Henning et al. 2010, Linz et al. 2010, Ragan et al. 2013, Pitann et al. 2013)
- used *PACS* and *SPIRE* bolometers at 70, 100, 160, 250, 350, and 500 µm
- *small* (< 10’) and *deep* (6 and 30 reps per map) to be sensitive for extended emission, PACS and SPIRE in *prime* observing mode (opposite to Gould Belt, HiGal surveys)
- added ground-based (sub)mm and NIR extinction data

http://www.mpia.de/IRSPACE/herschel/epos
Observational setup

- no parallel mode
  - spatial distortion of point sources (scanning speed, on-board averaging)
  - digitisation noise of faint extended emission (bit rounding in parallel mode)

- small but deep maps
  - just large enough to assess background emission (isolated low-mass cores)
  - small map pixel size at 70 µm (high spatial coverage/sampling)
Data reduction

- identical for both EPoS branches
- standard L1 processing (incl. 2nd level/map deglitching)
- branched out to Scanamorphos/IDL for processing to L2 (settings: galactic, noglitch, nzdata='yes')
- highpass filter + photProject (PACS) unsuitable for extended emission
- Mad Map had issues with point sources; pre-processing of signal drifts not deterministic (much better now)
- At that time: Scanamorphos best compromise between recovering faint extended emission and, at the same time, resolving point sources
- Scanamorphos was applied to all PACS and SPIRE data to maintain consistency, but the decision was mainly driven by the PACS data quality.
- alternative mappers too late; changing would break consistency with already published results
Data reduction

B 68

HPF (100), photProject

PACS 100 µm

PACS 160 µm

Scannamorphos

present-day Mad Map
Data reduction

IRDC 316.72
HPF (100), photProject

PACS 70 µm

PACS 160 µm

Scanamorphos
present-day Mad Map
Data analysis – extended emission

- **Final goal**: to derive dust temperature and particle density maps

- **convolved data** to same resolution; **regridded maps** to same pixel size using IDL (Aniano et al. 2011, circularised convolution kernels)

- **background subtraction** using identical area in each map

- **ideally**: to model background (zodiacal, cirrus, cosmic), but turned out to be negligible
Data analysis – extended emission

• spatially resolved SED fitting (Launhardt et al. 2013)

• only correct for single $T$ component along LoS (averaging effect)


• RT fit yields central $T_{\text{dust}} = 8$ K, smaller by 2 K than with LoS averaged SED fitting
Data analysis – PSF photometry

• target regions located in complex environments with high dynamic range

• compact emission sources
  – on top of structured extended emission
  – embedded within extinction structures

• aperture photometry unreliable ⇒ PSF photometry
  (Starfinder / IDL; easy to use, other tools not available/reliable/validated at that time)

• PSF templates reproduced from Vesta calibration observations (not circularised)

• PSF template rotated to match position angle of observation
  (rotation angle = position angle as given in metadata, counter clockwise)

• Iterative approach:
  1) run starfinder on unsharp-masked version of science data to detect point sources
  2) detection list as input for PSF fitting and photometry on original science data
Data analysis – PSF photometry

- original PACS 70 µm map
- IRDC with embedded point sources
- H II region to the SE
- LBV shell to the NW

- point sources detected with IDL starfinder
- false detections in LBV shell and H II region
- all visible point sources in the IRDC detected
- altogether 496 confirmed point sources in 45 IRDCs (Ragan et al. 2012)

- background image with point sources removed
Data analysis – PSF photometry

- **One goal**: characterise embedded core population

  - **Core sizes**: 0.05 – 0.3 pc
  - **Core luminosities**: $0.1 - 10^4 \, L_\odot$
  - **Core masses**: 0.1 – a few $10^3 \, M_\odot$
  - **Core temperatures**: 13 – 30 K

Ragan et al. (2012)
Summary

• EPoS designed to investigate galactic low/high mass star forming sites

• rather high S/N and structure/point source detection instead of large fields ⇒ PACS/SPIRE individually instead of parallel mode

• data reduction aimed at doing equally well for extended emission and point sources ⇒ standard L1 processing in HIPE + Scanamorphos in IDL

• resulted in high quality maps suitable for fitting dust properties ⇒ resolved dust T and n distributions of isolated low-mass cores

• resulted in high point source detection rate (469) in 45 complex high-mass SFR IRDCs ⇒ catalogue and characterisation of cores embedded in IRDCs

• Generally, Herschel mapping data are of very high quality for achieving EPoS goals.

Possible improvements worth reprocessing:

• better noise handling (faint extended emission, detection of even fainter sources)

• corrections for pointing jitter and improved PACS FPG characterisation (smaller FWHM, consolidation of flux calibration, revise source associations)