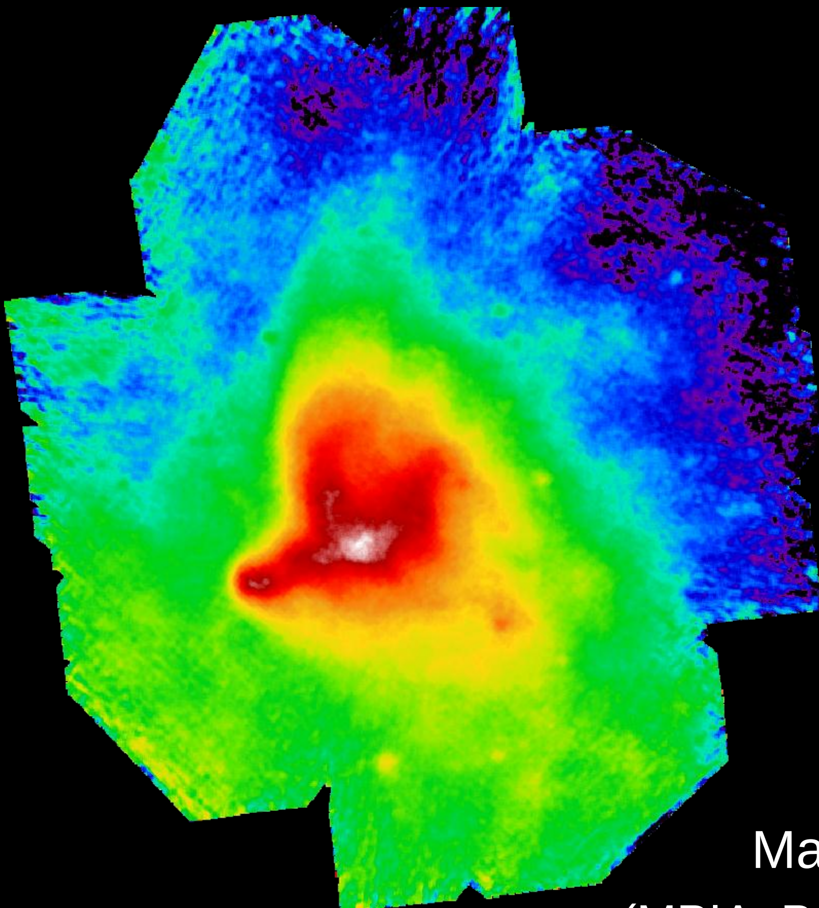
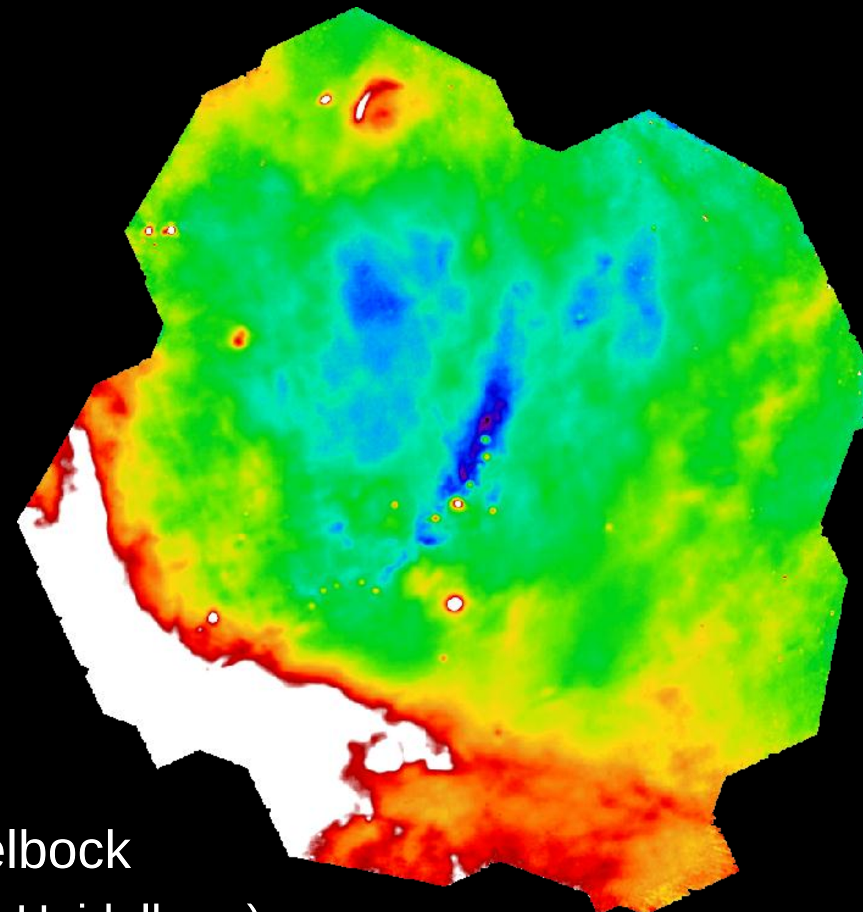
EPoS: The Earliest Phases of Star formation

Mapping and analysing extended emission and point sources





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on behalf of the EPoS group:

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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

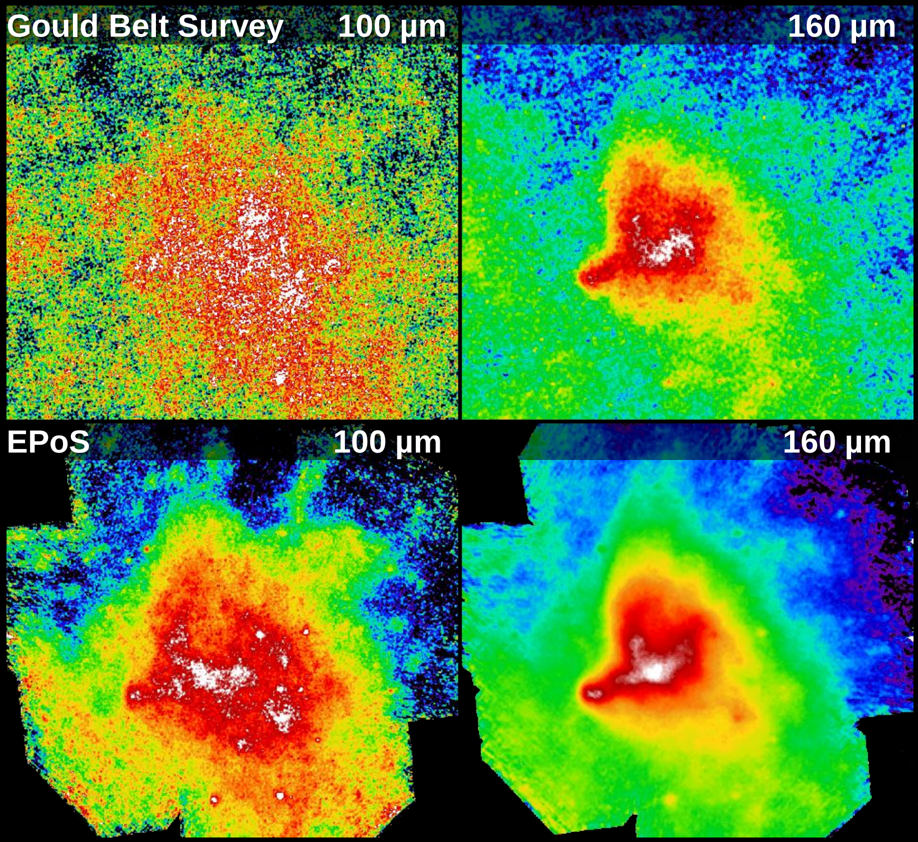
http://www.mpia.de/IRSPACE/herschel/epos

Observational setup

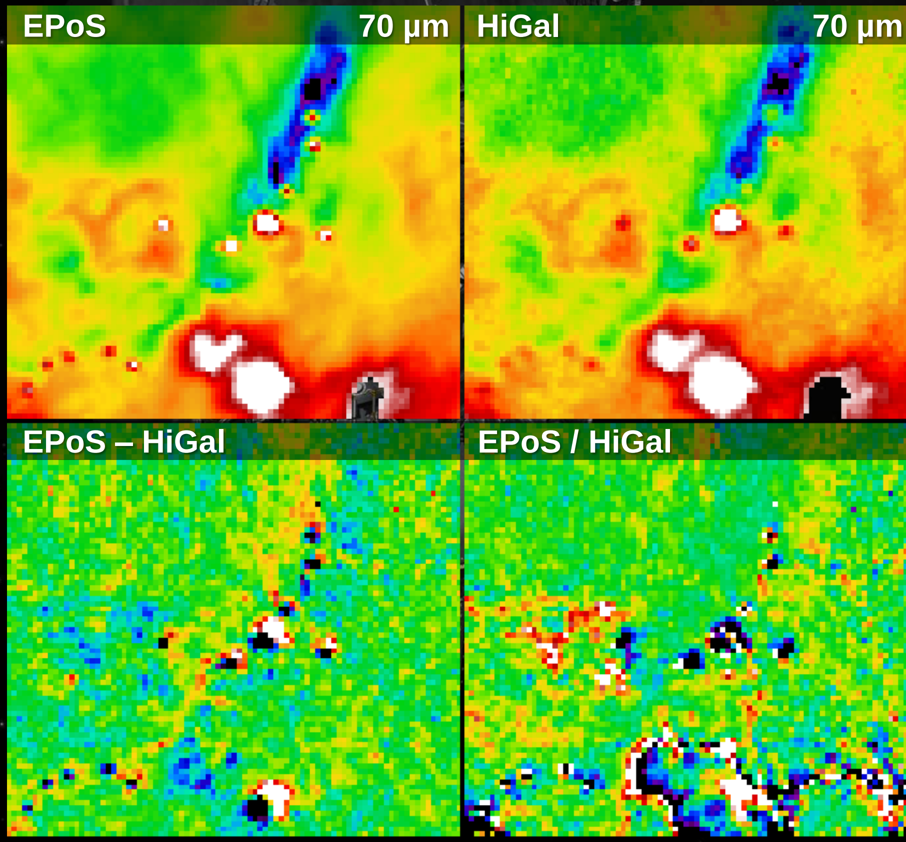
- no parallel mode
  - spatial distortion of point sources (scanning speed, on-board averaging)
  - digitisation noise of faint extended emission (bit rounding in parallel mode)

- 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)

B 68



IRDC 316.72



Data reduction

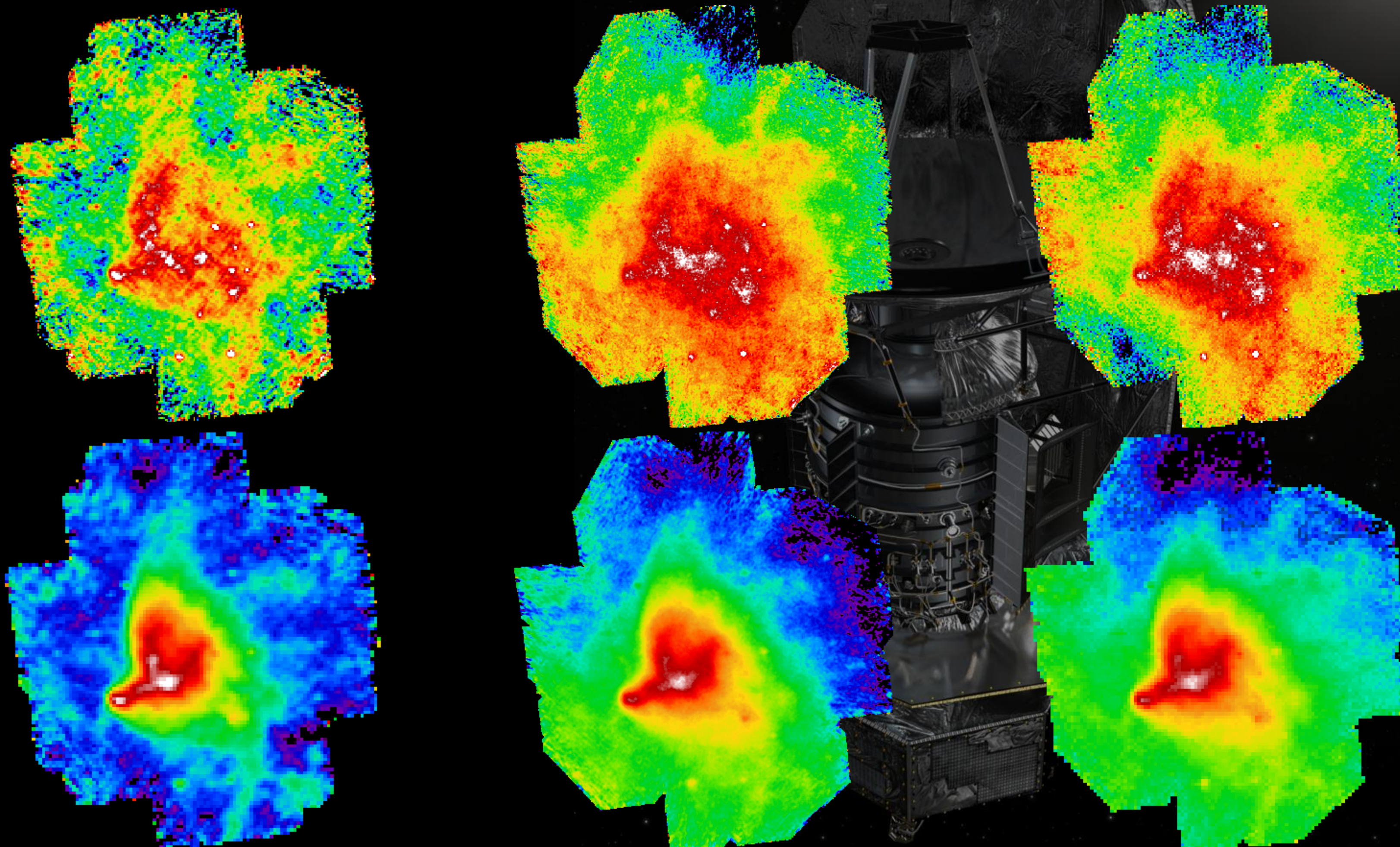
- identical for both EPoS branches
- standard L1 processing (incl. 2^{nd} level/map deglitching)
- branched out to Scanamorphos/IDL for processing to L2 (settings: galactic, noglitch, nzdata='yes')
- highpass filter + photProject (PACS) unsuitable for extended emission
- Mad Map had issues with point 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 | Scanamorphos | present-day Mad Map

PACS 100 µm

PACS 160 µm



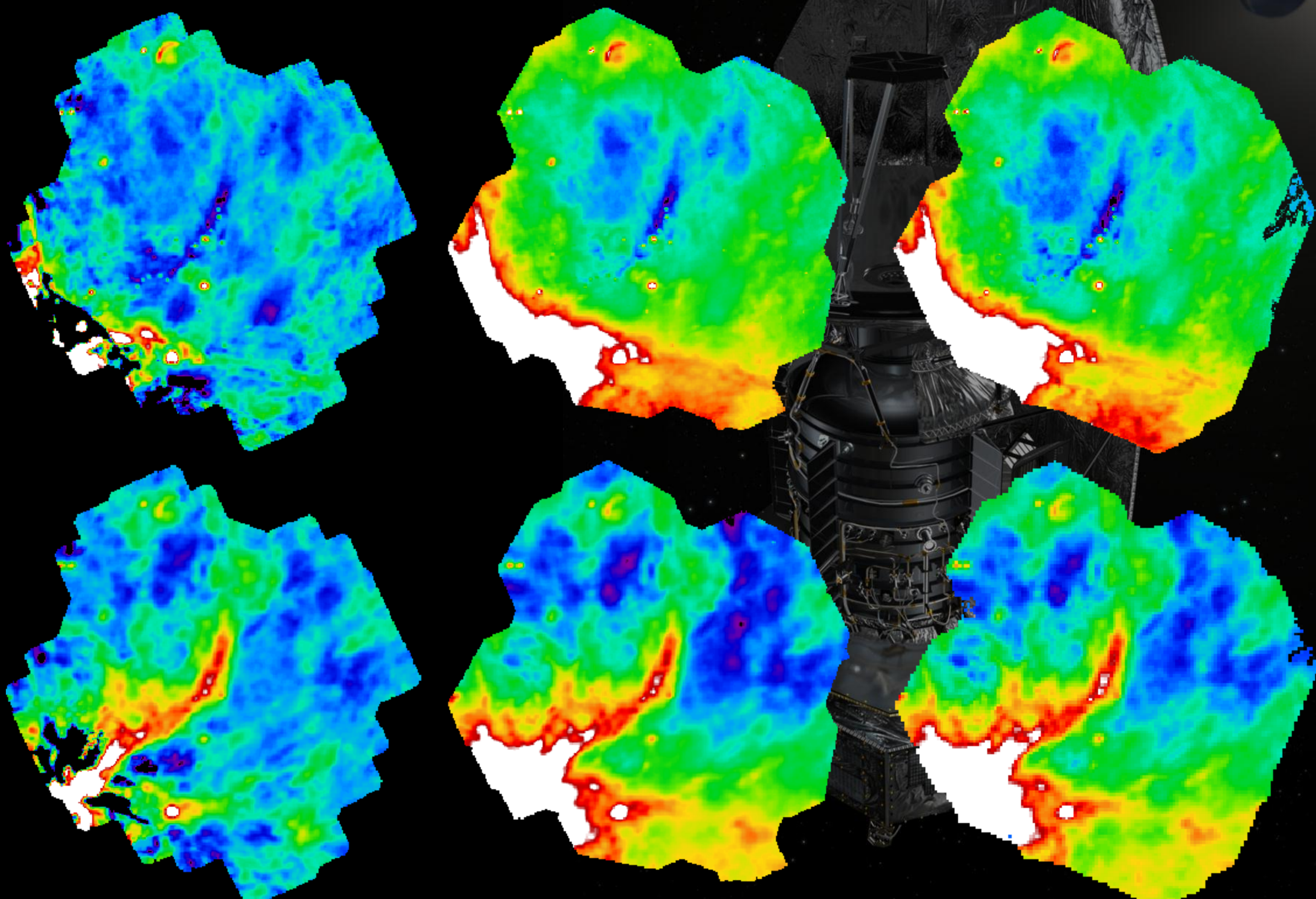
Data reduction

IRDC 316.72

HPF (100), photProject | Scanamorphos | present-day Mad Map

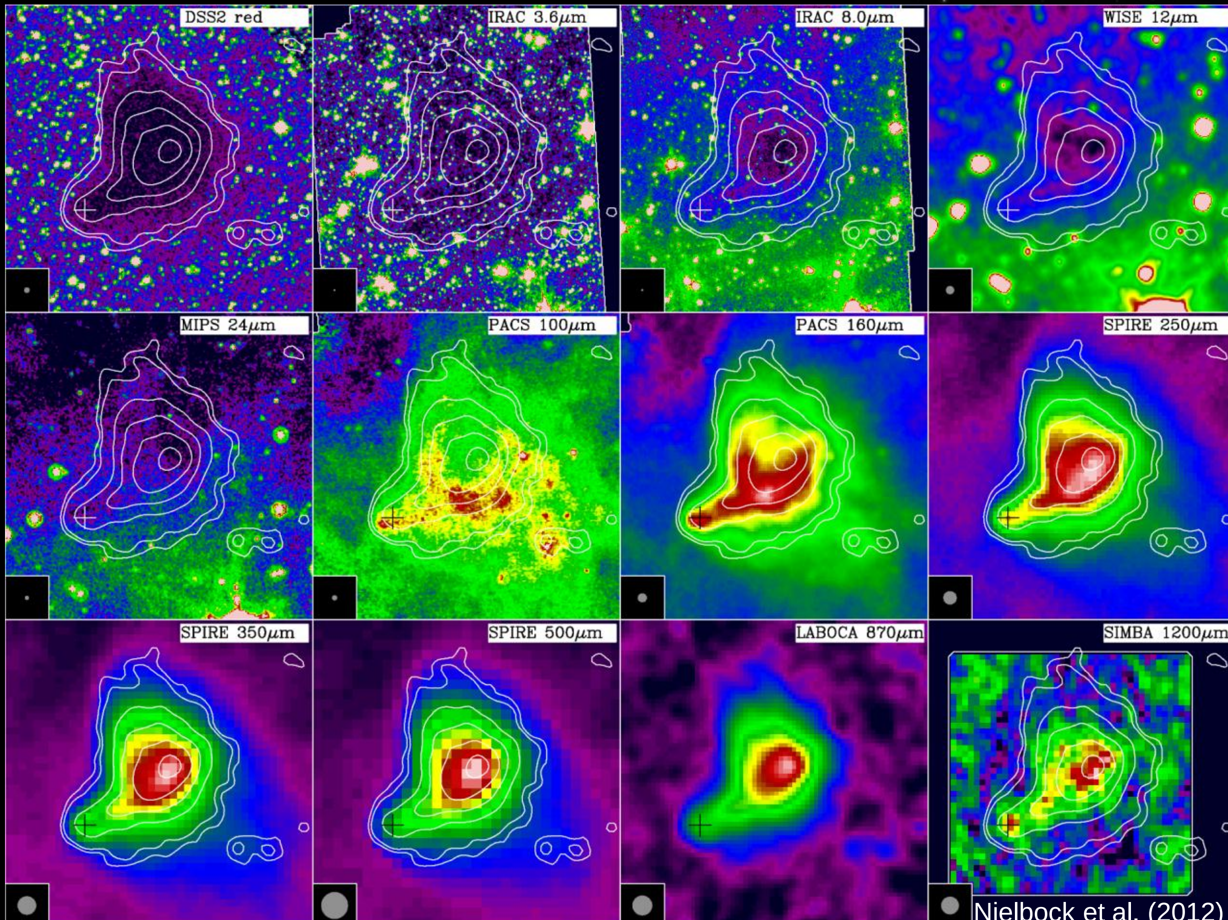
PACS 70 µm

PACS 160 µm



Data analysis – extended emission

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



Nielbock et al. (2012)

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

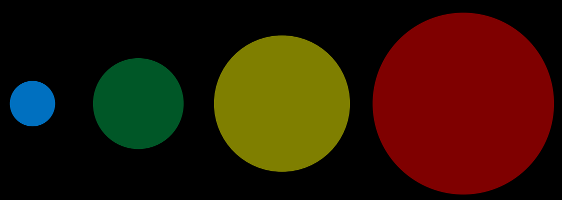
- background subtraction using identical area in each map

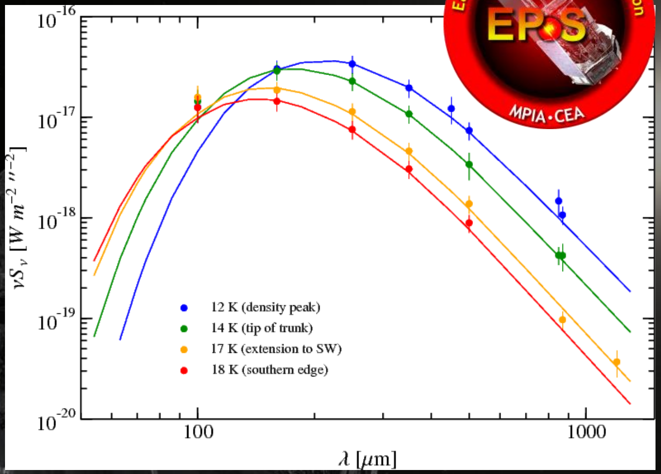
- ideally: to model background (zodiacal, cirrus, cosmic), but turned out to be negligible

Data analysis – extended emission

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

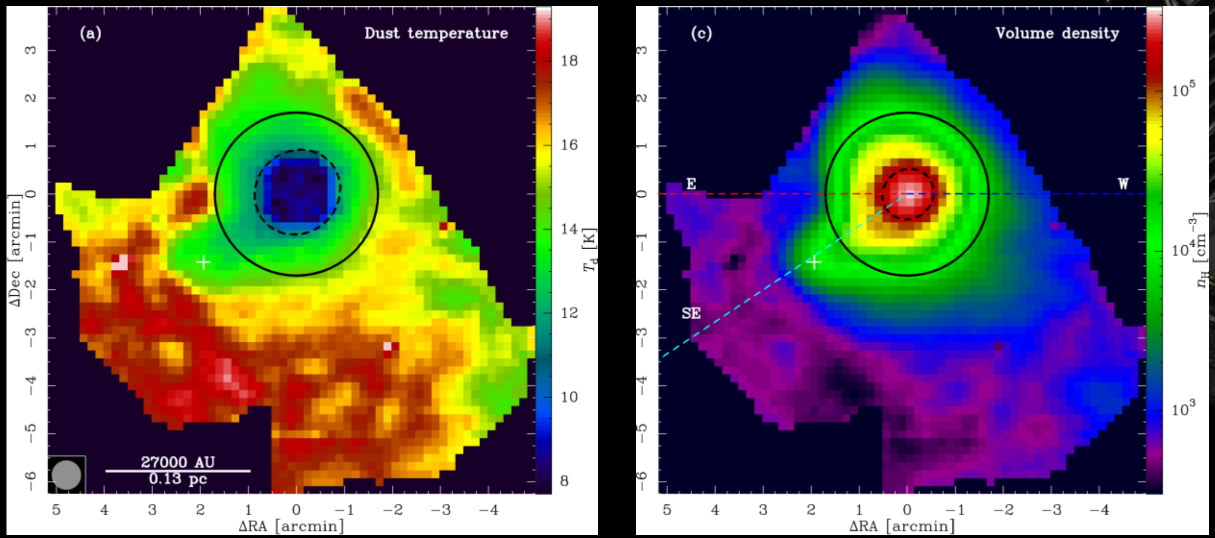
- only correct for single T component along LoS (averaging effect)

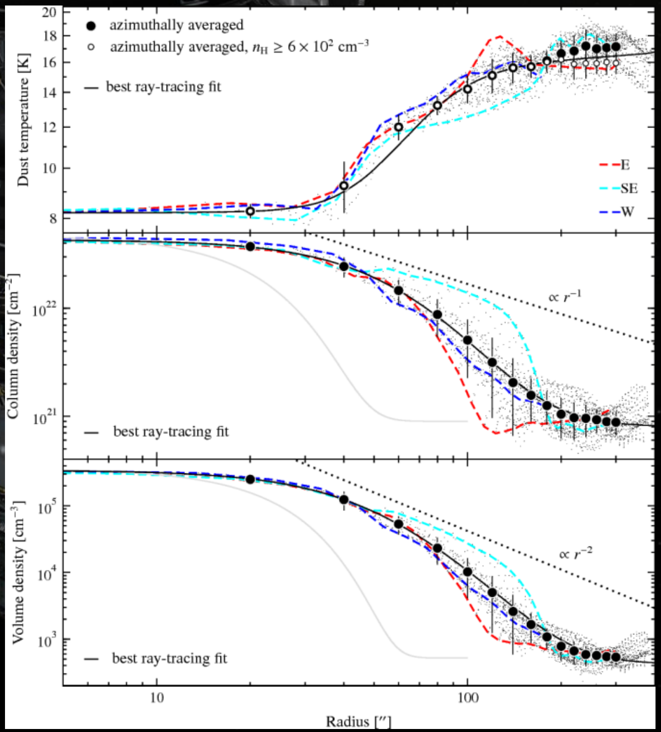




- employed ray-tracing algorithm with functional relationship for radial density distribution using GILDAS (Plummer-like profile, cf. Whitworth & Ward-Thompson 2001)

- RT fit yields central T_{dust} = 8 K, smaller by 2 K than with LoS averaged SED fitting





Nielbock et al. (2012)

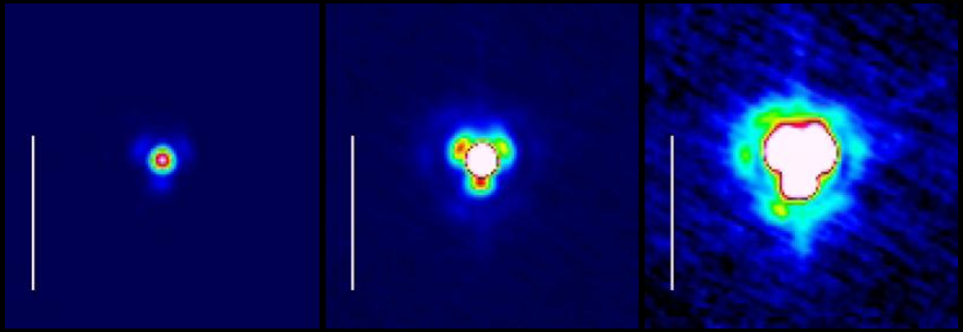
Data analysis – PSF photometry

- 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)

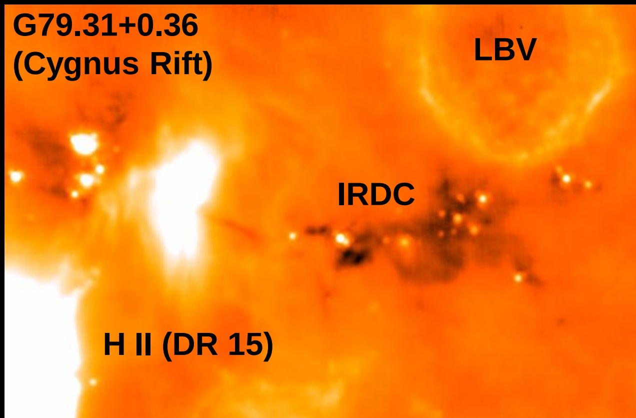
- PSF templates reproduced from Vesta calibration observations (not circularised)



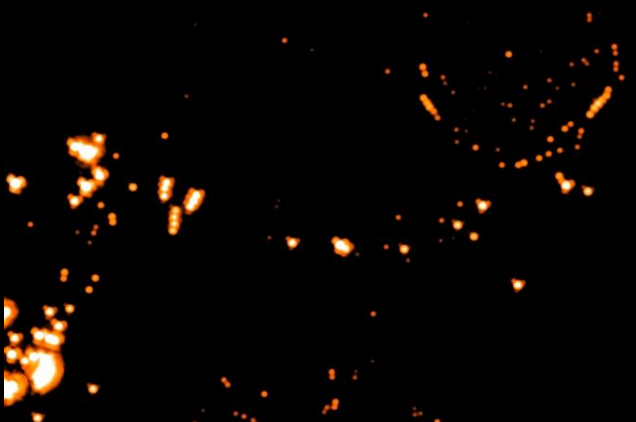
- PSF template rotated to match position angle of observation
  (rotation angle = position angle as given in metadata, counter clockwise)

- 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

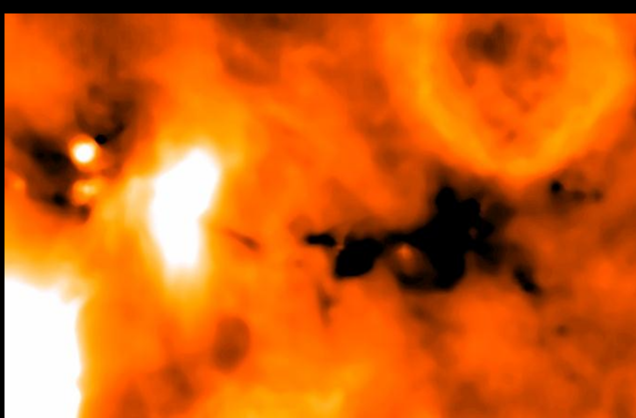
Data analysis – PSF photometry



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



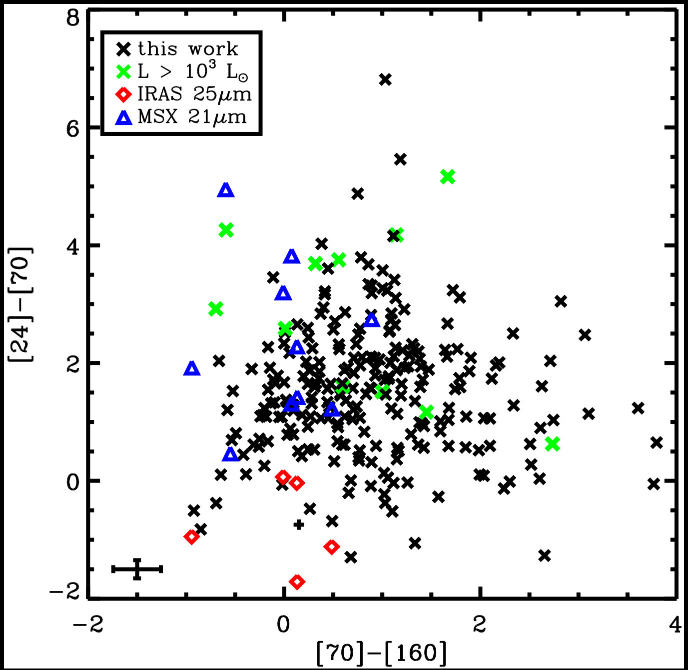
- point sources detected with IDL starfinder
- false detections in LBV shell and H II region
- all visible point sources in the IRDC detected
- altogether 496 confirmed point sources in 45 IRDCs (Ragan et al. 2012)

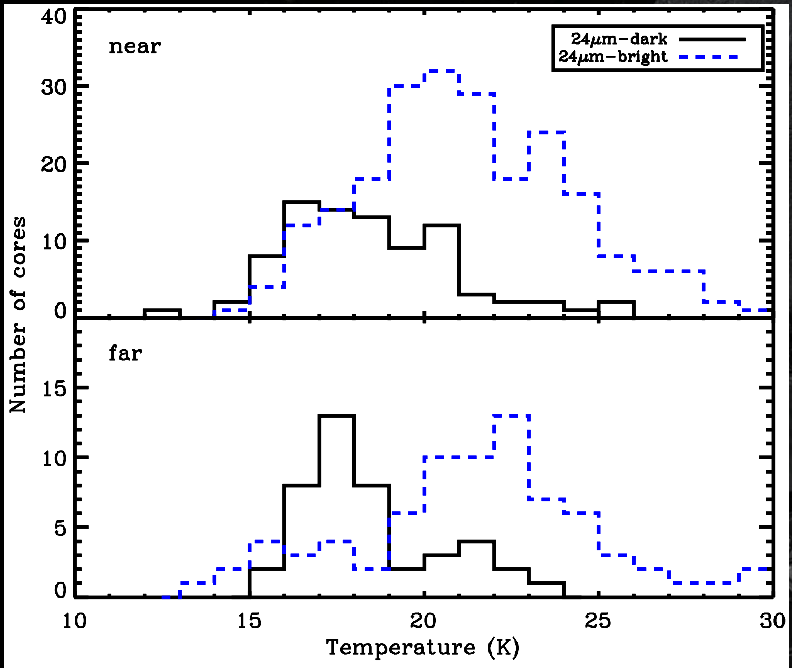


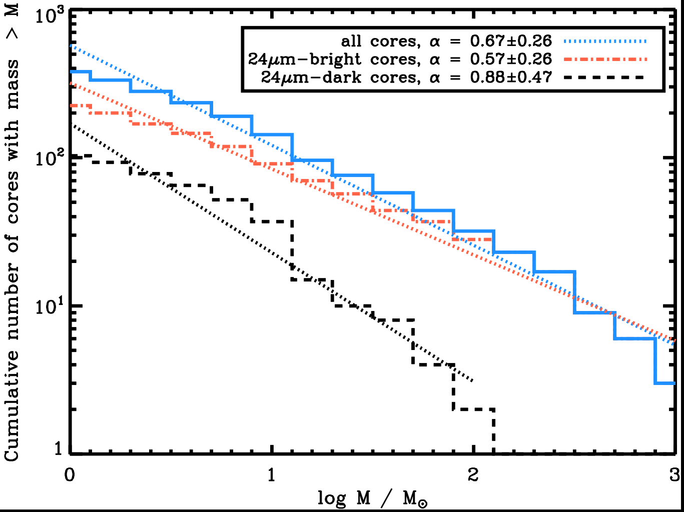
- background image with point sources removed

Data analysis – PSF photometry

- One goal: characterise embedded core population







Ragan et al. (2012)

- 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

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)