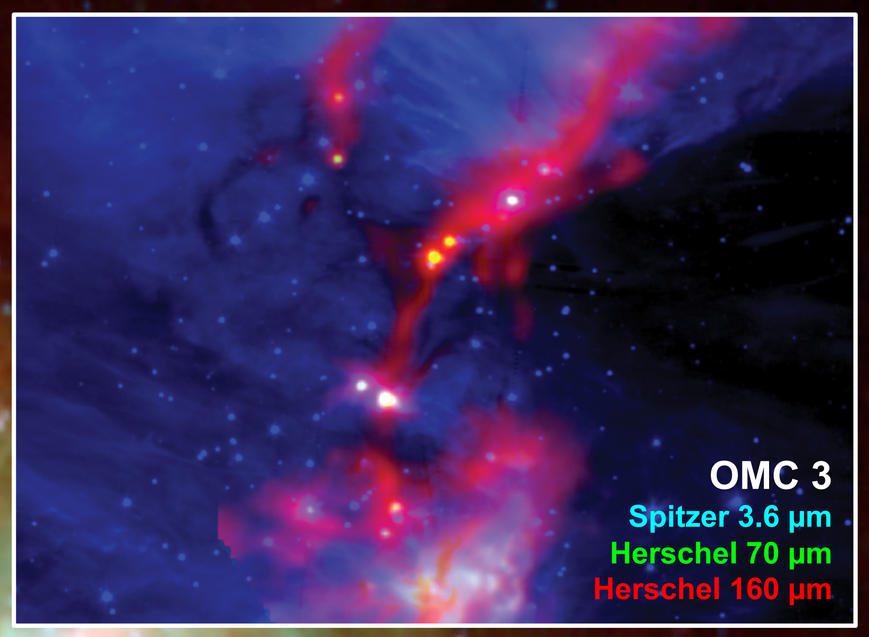
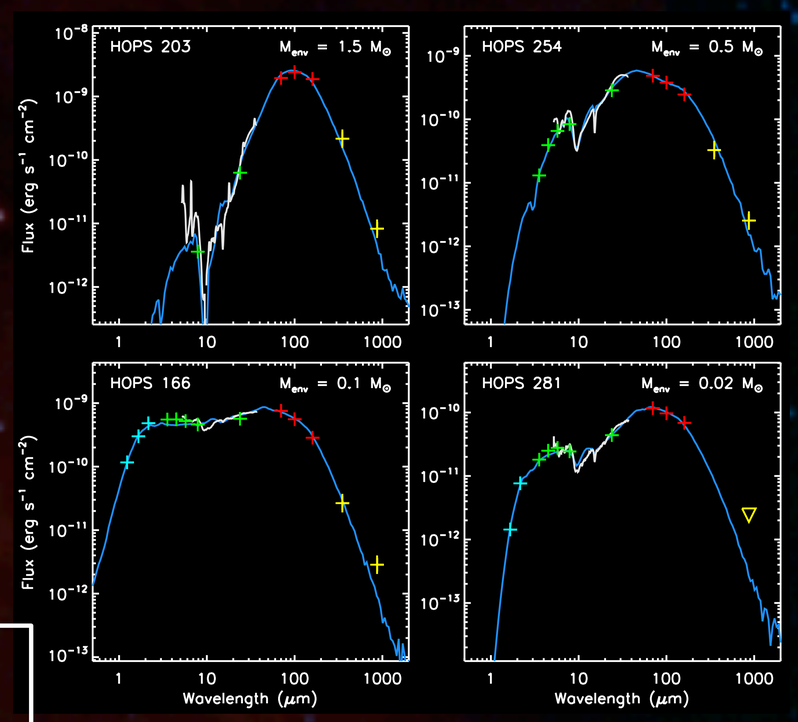
Tracing Protostellar Envelope Evolution with HOPS, the Herschel Orion Protostar Survey

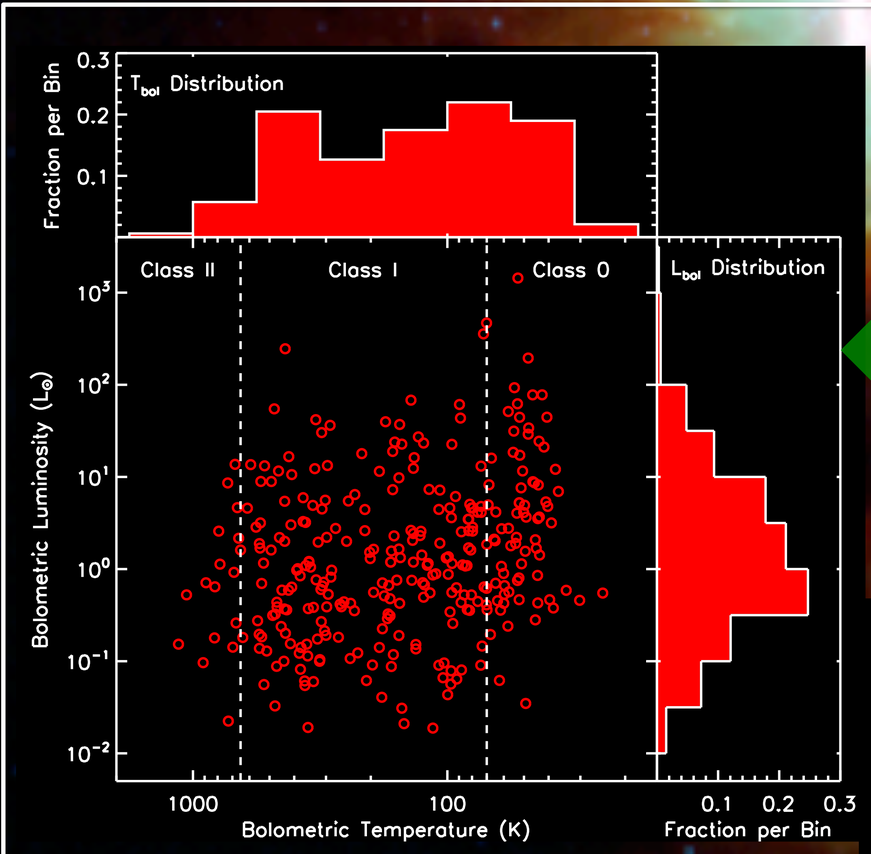
Will Fischer (University of Toledo; wjfischer@gmail.com), Tom Megeath (U. of Toledo; HOPS PI), Elise Furlan (NHSC/IPAC/Caltech/NOAO), Babar Ali (NHSC/IPAC/Caltech), Amy Stutz (MPIA), Joseph Booker (U. of Toledo), John Tobin (NRAO), Thomas Stanke (ESO), Mayra Osorio (IAA)

HOPS: Herschel Orion Protostar Survey

- 200 hour Open-Time Key Program of the Herschel Space Observatory
- Observe the Spitzer-identified Orion protostars with PACS
  - Imaging at 70 and 160 μm of >300 protostars
  - Spectroscopy from 55 to 200 μm of 33 protostars
- Extensive additional data: HST imaging, Spitzer imaging & spectroscopy, APEX sub-millimeter imaging, IRTF near-infrared spectroscopy, other ground-based imaging & spectroscopy
- A complete study of protostars in a single cloud complex





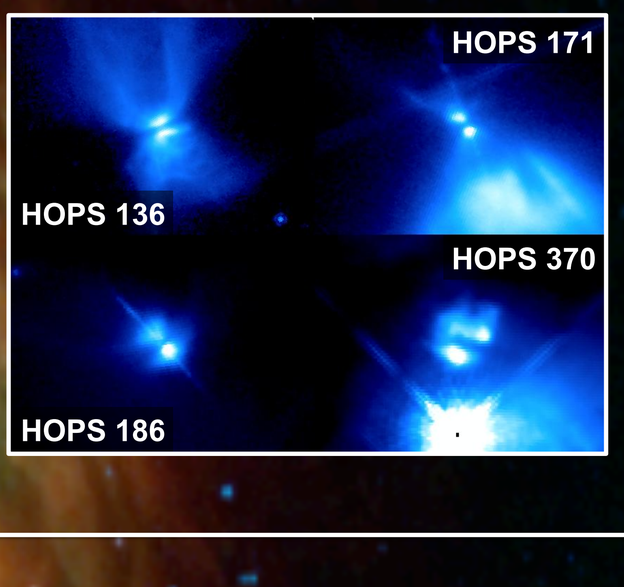


Observed Distribution

- BLT: Integrate under observed SED to calculate bolometric luminosity L_{bol} and bolometric temperature T_{bol}
- Bolometric temperature is the T_{eff} of a blackbody with the same mean frequency as the SED
- Use standard division into Classes by T_{bol}
- 30% of protostars in Class 0
- Luminosities extend from 0.02 to 1440 $L_\odot$
- Median luminosity decreases from 3.5 $L_\odot$ for Class 0 to 1.0 $L_\odot$ for Class I

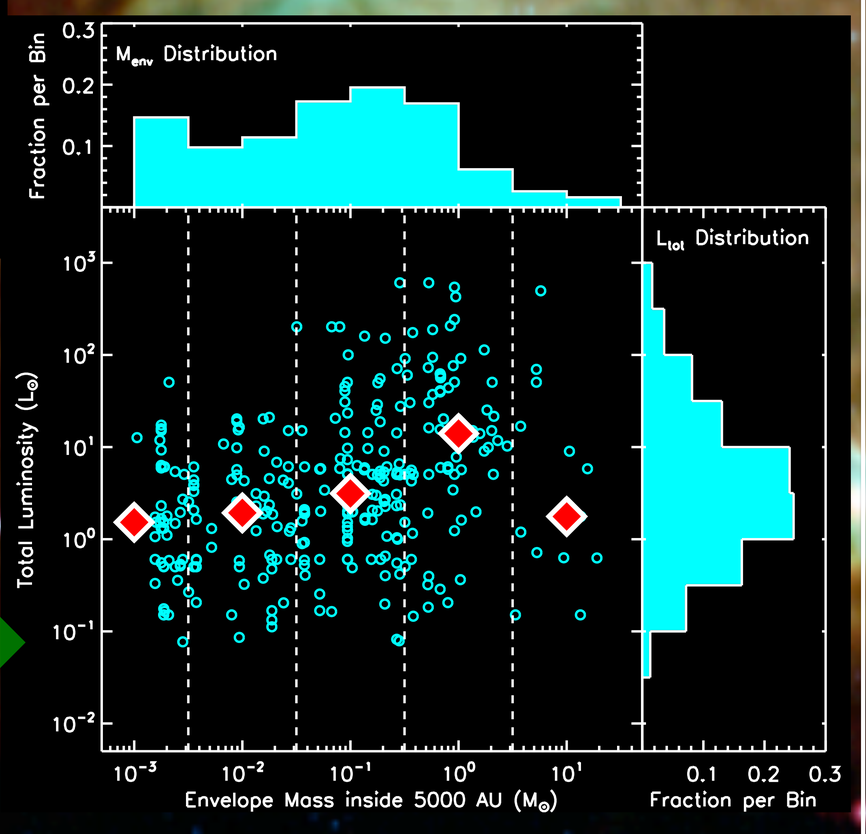
SED and Image Analysis

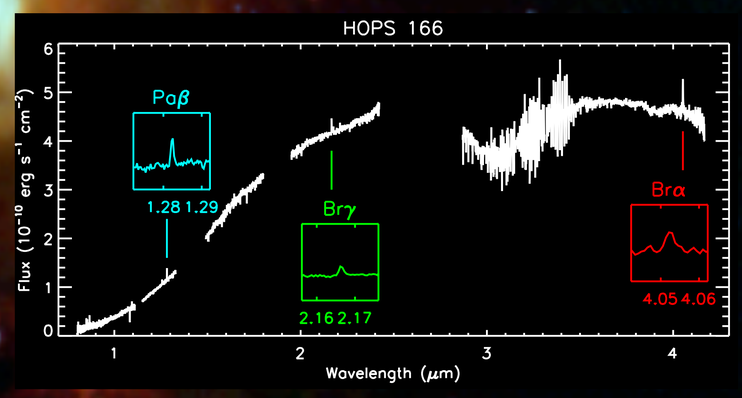
- SEDs from 2MASS, Spitzer, Herschel, APEX
- Fit with a grid of 3040 models at 10 inclinations (samples above; see poster 1H020 by E. Furlan)
- Additional constraints from HST images (samples below; see poster 2B021 by J. Booker)



Modeled Distribution

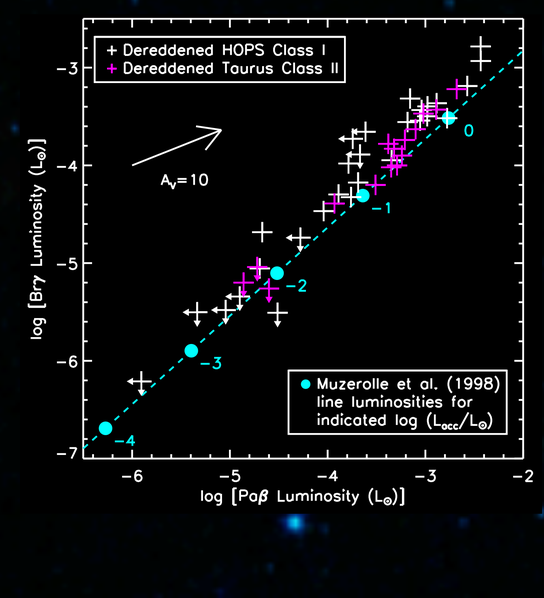
- L_{tot} is the luminosity of the best-fit model, corrected for anisotropy & foreground extinction
- M_{env} is the envelope mass (from SED modeling) inside 5000 AU, the region probed by IR observations (assumes M_{star} = 0.5 $M_\odot$)
- Median luminosities (red diamonds) peak at 14 $L_\odot$ when M_{env} ~ $M_\odot$ and fall to 1.5 $L_\odot$ as the envelopes dissipate
- Accretion rate falls over time
- Scatter in luminosity: Episodic accretion? Range in central source properties?





Conclusions

- SED and image fitting yield luminosity and envelope mass for >300 Orion protostars, more than half the total in the nearest 500 pc
- By T_{bol}, 30% of protostars are in Class 0
- Median luminosity decreases from Class 0 to I and as the envelope dissipates
- Accretion luminosities for late Class I objects are statistically indistinguishable from those of Class II objects
- Most of the stellar mass assembly appears to happen early, and then in subsequent episodic bursts



Near-IR Spectroscopy

- Near-IR spectra of 30 late Class I HOPS objects from IRTF
- H line luminosities (Paβ, Brγ, Brα) are known to correlate with accretion luminosity
- H line ratios also probe reddening
- Late Class I accretion luminosities are statistically indistinguishable from those in Class II