JAMES CLERK MAXWELL TELESCOPE
APPLICATION FOR TELESCOPE TIME

Read 'The JCMT Newsletter' on the the World-Wide-Web (http://www.jach.hawaii.edu/JACpublic/JCMT/) for up-to-date information	For office use only REF:-

1 **Semester: 05B** (last 2 digits of year, followed by 'A' for Feb – Jul; or 'B' for Aug – Jan semesters)

2 i) Principal Investigator:

Surname: **Kirk** Title & Initials: **Helen** Possible Observer? **YES**

Address: University of Victoria ELL404, 3800 Finnerty Rd, Victoria BC V8P 5C2 Canada

Full Internet E. Mail address: hkirk@uvastro.phys.uvic.ca

Fax: 250 721-7752

Telephone & Ext: 250 721-8845

ii) Collaborators (state institution and country)

Collaborator	Possible Observer?
Doug Johnstone NRC-HIA Canada	Yes
James DiFrancesco NRC-HIA Canada	YES
Alyssa Goodman Harvard USA	NO
The Rest of the COMPLETE Survey Team	

Joint Proposal? NO

Other Queues:

Student Thesis Project? NO

Completion Date?

3 TITLE **The End of the SCUBA COMPLETE Survey: Final maps of the Perseus and Serpens clouds**

4 ABSTRACT OF PROPOSED OBSERVATIONS

The COMPLETE (Coordinated Molecular-Probe Line Extinction and Thermal Emission) Survey consists of observations of three star-forming regions (Perseus, Serpens, and Ophiuchus) also included in the Sptizer 'c2d' Legacy program. No previous survey has covered a single ∼10 pc region comprehensively. The statistical constraints offered by this survey will be of great interest to both the Milky Way and high-redshift star formation communities. SCUBA is the optimal instrument for obtaining the large-area, sensitive submm dust thermal emission maps required for COMPLETE. The SCUBA survey will be over an order of magnitude larger than previous submm molecular cloud maps (∼1.5 sq.deg in Perseus, ∼1 in Serpens, and ∼8 in Ophiuchus), detecting many new sources, often without near-IR or molecular line counterparts. In this final SCUBA proposal, we request 36 hours to complete our coverage of the Perseus molecular cloud and to map the required region of Serpens.

5 LONG TERM STATUS: NO If yes, give total number of useful shifts needed to complete programme:

6 RECEIVERS:

	○ A-band 208-280 GHz	○ B-band 315-373 GHz	○ C-band 430-510 GHz	○ D-band 625-710 GHz	○ SCUBA continuum camera	○ Other	○ Pol'n het/scuba + pol.
# HOURS:					36		

7 DETAILS OF OBSERVING TIME

i) Total number of hours requested: 36 ii) LST Range:

iii) Flexible Scheduling ○ NOT wanted

iv) Required Weather Quality ○ 1 (very dry) $\tau_{225} < 0.05$ ⊗ 2 (dry) $0.05 < \tau_{225} < 0.08$ ⊗ 3 (medium) $0.08 < \tau_{225} < 0.12$ ○ 4 (wet) $0.12 < \tau_{225} < 0.2$ ○ 5 (very wet) $\tau_{225} > 0.2$

8 LIST OF PRINCIPAL SOURCES (exact coordinates required, continue on Figs & Tables page if necessary)

Name	RA (hh mm ss)	Dec (dd ' ")	Epoch	Intens.	Priority
Perseus	03:36:00	31:00:00	J2000		1
Serpens	18:29:00	00:09:30	J2000		2

9 RELATED APPLICATIONS (over last 4 semesters (include unsuccessful applications))

Complete Ref (ie: M/94A/U22)	Allocated	Useful Shifts	Comments
m05ac21	5.5		highly ranked proposal; waiting for data
m03bc29	8	4	not completed(SCUBA unavailable)

10 RECENT PUBLICATIONS

Johnstone, Di Francesco, & Kirk; 2004, An Extinction Threshold for Protostellar Cores in Ophiuchus, ApJL, 661, 45

Walawender, Bally, Johnstone, Kirk, & Reipurth, Multiple Outflows and Protostars in Barnard 1, 2005, in prep

Fiege, Johnstone, Redman, & Feldman, A Genetic Algorithm-Based Exploration of 3 Filament Models: A Case for Magnetic Support in the G11.11-0.12 Infrared-Dark Cloud, ApJ, 616, 925

Johnstone, Matthews, & Mitchell, Large Area Mapping at 850 Microns. IV. Analysis of the CLump Distribution in the Orion B South Molecular Cloud, 2005, ApJ, submitted

11 JUSTIFICATION (Add no more than 1 page for each of Scientific case + Technical details + Figures & Tables. See partner web pages or JCMT web pages for *exceptions* to this limit.)

SUBMISSION OF APPLICATIONS

Electronic Submissions:

CANADA: Consult http://www.hia-iha.nrc-cnrc.gc.ca/mag/ctag-policy_e.html for information on Canadian submissions and deadlines.

UK & INTERNATIONAL: Send the latex template and completed postscript files (concatenated into one file) to the email address below. The SUBJECT line of the email submission must say **NEW SUBMISSION UK** or **NEW SUBMISSION INT** for UK and International proposals respectively. UK proposers must complete the separate signatures page and send by regular mail or courier to *PATT Secretariat, PPARC, Polaris House, Swindon SN2 1SZ, UK*.

NETHERLANDS: Send the latex template and completed postscript files (concatenated into one file) to the email address below. The SUBJECT line of the email submission must say **NEW SUBMISSION NL**

Latex templates, style files and instructions may be obtained by sending the message *request templates* to "jcmtprop@jach.hawaii.edu".

Hardcopy Submissions:

Hardcopy submission are no longer accepted to any queue.

CANADA	NETHERLANDS	UK & International
consult HIA website for details www.hia-iha.nrc-cnrc.gc.ca /mag/ctag-policy_e.html	proposal@astron.nl	jcmtprop@jach.hawaii.edu

CLOSING DATES

'A' SEMESTER: FEBRUARY – JULY
Applications must be received by:
15 SEPTEMBER

'B' SEMESTER: AUGUST – JANUARY
Applications must be received by:
15 MARCH

SCIENTIFIC JUSTIFICATION

We request time to complete our observations of the Perseus molecular cloud and to cover the c2d region in Serpens, the final observations remaining in our long term SCUBA project. These observations are a part of the CO-ordinated Molecular Probe-Line, Extinction and Thermal Emission Survey of star forming regions, whose goal is to use a carefully chosen set of observing techniques to map the density, temperature, and velocity structure of the large nearby star-forming complexes Perseus, Serpens, and Ophiuchus, also being observed in the Spitzer Legacy Survey 'c2d'. For details on the COMPLETE Survey and its science case, please refer to `cfa-www.harvard.edu/COMPLETE`. The thermal emission SCUBA surveys will delineate where clumps form and find new sources, some undetected in the near IR or molecular line data, allowing the determination of the physical conditions within each clump and an investigation into the environmental constraints on clump formation (for example, see Johnstone et al 2000b; Johnstone, DiFrancesco, & Kirk 2004). Sources will serve as targets for follow-up dense-gas tracer observations such as CS and N_2H^+. Together, these data sets connect the clumps' spatial and velocity structure with environment. For example, Tafalla, Kirk, Santiago, Johnstone, & Friesen applied for time this semester at IRAM for N_2H^+ observations, using the SCUBA sources found in Perseus and Ophiuchus to trace the cloud velocity structure and measure the sources' internal turbulence level. For a similar analysis to be possible in Serpens, submillimetre observations are needed now. Additionally, the SCUBA maps will be used to determine the local environment of Spitzer point sources as the two surveys combined probe the thermal emission of embedded sources across the peak of their SED. Thus, the submm maps obtained with SCUBA will play a crucial role even where no new submm sources are discovered.

Early SCUBA survey results: In the original 5.5 square degree map we obtained for Ophiuchus, we found a lack of sources at low extinction, indicating the importance of environment in the formation of small scale structure. Johnstone, Di Francesco, & Kirk (2004) showed that sources are only found in the densest parts of the molecular cloud with $A_V \geq 10$, although simple models (e.g. Bonnor-Ebert spheres) indicate they could have been detected at lower A_V had they existed. This result can be explained through a model of magnetic support for the sources; McKee (1989) argued that the ionization fraction on the molecular gas should drop off significantly above $A_V \sim 10$, which would lead to these regions having an ambipolar diffusion timescale short enough to allow such substructure to form. Analysis of our data in the Perseus molecular cloud shows a similar threshold, albeit at a lower extinction (Kirk, Johnstone, & Di Francesco, in prep). This work can be compared with Hatchell et al. (2005) which presents a similar analysis of the data and a similar interpretation.

Proposed Survey Regions: ***Perseus* -** Over 80% of the $A_V \geq 5$ region of the Perseus molecular cloud is archival data with twice the sensitivity of our fast-scan maps. In order to maximize the return on this extensive dataset, the remaining $A_V \geq 5$ observations must also extend to this depth. Non-uniform coverage leads to a bias where more structure is found within deeper portions of the map. As illustrated in Figure 1, completing the $A_V \geq 5$ region to the uniform depth of the archive data requires only 5 scanmaps to go deeper in sections we have already observed, and 11 to capture the missing sections on the edges of the current observations. Note also that most of these sections are sufficiently separated to negate the advantage of a larger areal coverage by a faster, less sensitive mapping mode. Furthermore, a comparison with 1.1 mm data (see Melissa Enoch's poster from Pasadena, 2004 at `www.astro.caltech.edu/~menoch/spitzer.pdf`) suggests that most of these sections *will* contain sources detectable at 850 μm, thus reinforcing the importance of higher sensitivity observations.

***Serpens* -** Surveying the entire Serpens molecular cloud down to $A_V \geq 5$ would require coverage of 10.5 sq. degs (a prohibitive amount of time with SCUBA), however, coverage of the region which is observed by Spitzer's c2d group ($\sim$ 1 sq deg) is sufficient for our purposes. Furthermore, this region contains an area of very high-density star formation (see Eiroa & Casali, 1992) and our observations of the surrounding region will provide a useful context in which to understand this unique location.

The SCUBA survey will complement the Spitzer near-IR observations, providing a link between the cold dust associated with the submm clumps and any energetic sources within. Our knowledge of *all* submm observations is severely limited by the lack of coordinated near-IR, mid-IR, molecular line, and submm observations. The COMPLETE Survey is revealing both the necessary environmental conditions for and the clustering nature of the submm sources, required for meaningful statistical analysis.

We request the time to finish our COMPLETE-SCUBA survey of star forming regions by completing Perseus and acquiring the required coverage of Serpens so that we will be able to constrain better the star forming environment in both molecular clouds.

TECHNICAL DETAILS & REFERENCES

COMPLETE Time and Sensitivity: Scan-mapping with SCUBA on the JCMT is now straightforward, efficiently producing large-area submm maps. A rule of thumb for scanning is that a 1σ sensitivity of ≤ 30 mJy/bm over a 10'x10' region can be obtained typically in one hour of observing. The limiting speed of these observations is set by the requirement to sample fully the sky at the Nyquist frequency of the short wavelength (450 μm) bolometer array. To obtain data more quickly, scan-mapping may be obtained in a fast-scan mode in which only the 850 μm data is Nyquist sampled. Effectively, this quadruples the speed of map-making at a cost of 2 in sensitivity due to the shorter integration time per location. The result is that a one-sigma sensitivity of $\leq$ 60 mJy/beam over a region 10'x10' is obtainable in fifteen minutes. At this rate, a full square degree will take 12 hours. With our most recent observations, we found that an additional 25% overhead was required, likely caused by a larger number of calibrations, etc required by the queue-observing procedures.

COMPLETE Coverage: We have extinction maps for Serpens using R-band star-count data from Cambrésy (1999). Figure 2 shows in grey scale the level of extinction over the Serpens cloud. The region of planned observations by Spitzer is indicated by the outline. Within this region, the area of extinction with $A_V \geq 5$ is $\sim$ 1 1/3 square degrees. The overlaid boxes indicate the 12 20' x 20' pointings required to observe this region utilizing the fast-scan technique. We thus require 12 hours plus 4 hours for the additional empirically determined overhead, giving a total of 16 hours.

In Perseus, a wealth of data already exists (see Figure 1), the majority at a sensitivity of $\sim$30 mJy/bm. The contours in Figure 1 show the extinction levels, derived from 2MASS observations (Alves et al. 2005). The overlaid boxes indicate the regions of required observation to map uniformly the $A_V \geq 5$ region to a sensitivity of 30 mJy/bm. There are 16 10' x 10' pointings required to do this, which translates to 16 hours plus 4 hours of additional overhead, or 20 hours in total.

In total, we require 36 hours to map both regions and thus finish the COMPLETE SCUBA survey of Serpens and Perseus.

COMPLETEness and the Archive: There is very little archive data covering the region in Serpens which we wish to observe, thus we request time to observe the entire 1 1/3 square degrees uniformly. We will utilize all archive data, however, in our analyses.

COMPLETE Map-making: The iterative map making technique (described in Johnstone et al. 2000a) allows for optimal reconstruction of the inhomogeneously acquired archive data and has been further modified to accommodate jiggle observations. Thus, *all* relevant archive data can be seamlessly stitched together yielding maximum value from the archive. Providing manpower, Masters student Kirk (Victoria) will lead both the new data acquisition and the combined data reconstruction. Her Masters thesis project involves analysis of the structures found in the Ophiuchus, Perseus, and Serpens molecular clouds and will thus greatly benefit from the completed maps.

COMPLETE Observing Strategy: Spitzer has begun observations for the c2d Legacy Project, scheduled to be completed in under a year. We request 36 hours to complete our coverage of the Perseus molecular cloud and to observe the required region in Serpens, so that we will thus finish our COMPLETE SCUBA Survey on a similar timescale to the c2d project. These observations must be completed now, before the arrival of SCUBA2, to allow time for follow-up Spitzer observations of sources found in the SCUBA surveys.

REFERENCES:(Members of the COMPLETE Survey are listed in boldface.)

Alves, et al., 2005, in prep

Cambresy, 1999, A&A, 345, 965

Eiroa & Casali, 1992, A & A, 262, 468

Hatchell, Richer, Fuller, Qualtrough, Ladd, & Chandler, 2005, ApJ, in press

Johnstone, Wilson, Moriarty-Schieven, Giannakopoulou-Creighton, & Gregersen 2000a, ApJS, 131, 505

Johnstone, Wilson, Moriarty-Schieven, Joncas, Smith, Gregersen, & Fich 2000b, ApJ, 545, 327

Johnstone, **Di Francesco**, & **Kirk** 2004, ApJL, 611, 45

Kirk, **Johnstone**, & **Di Francesco**, 2005, in prep

McKee, 1989, ApJ, 345, 782

FIGURES & TABLES

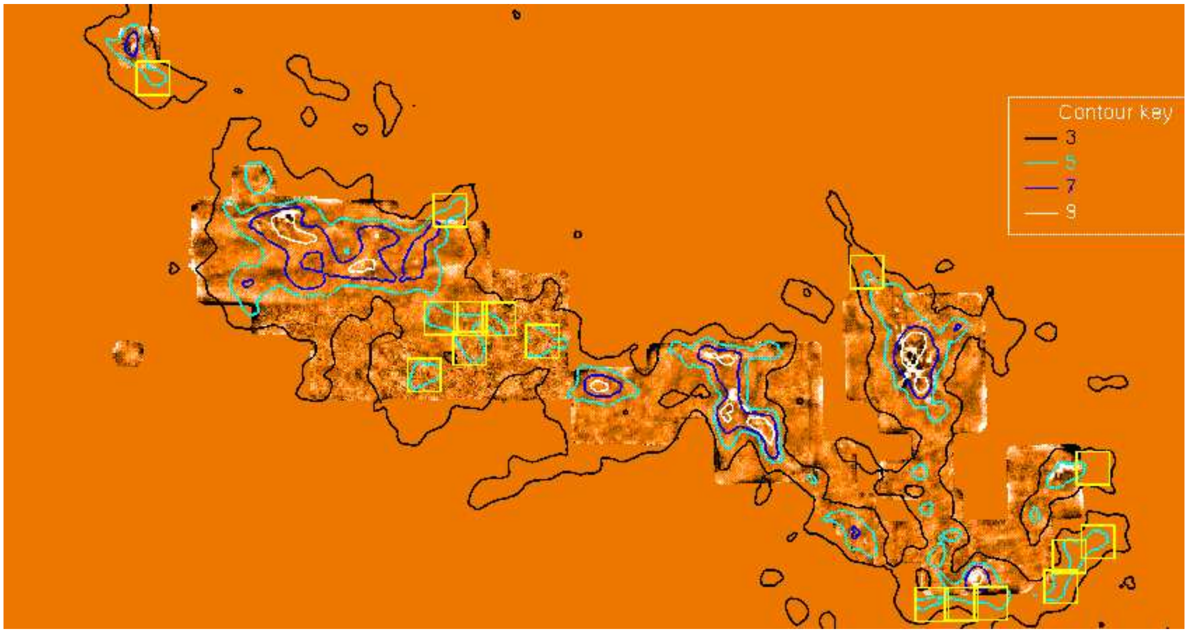

Figure 1: Perseus 850 μm data already obtained with SCUBA. The contours denote extinction levels (2MASS, Alves et al. 2005) and the overlaid squares (10' x 10') indicate our proposed observations, completing coverage of all $A_V \geq 5$ regions to a sensitivity of 30 mJy/bm. The squares overlay existing data where the sensitivity is ~60 mJy/bm from fast-scan maps.

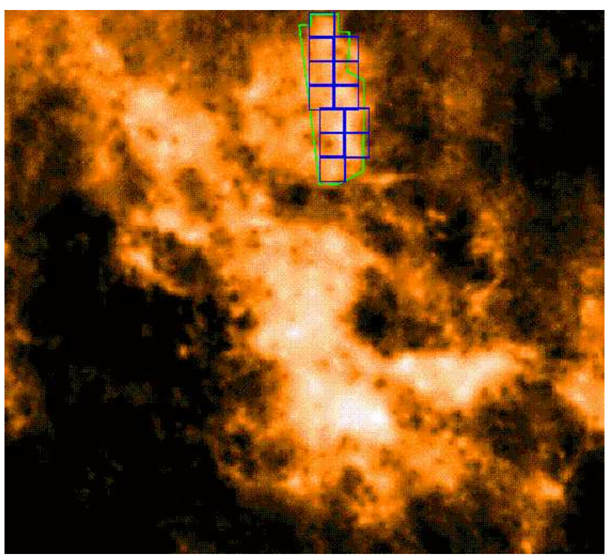

Figure 2: Serpens extinction data (Cambrésy, 1999). The boxes (20' x 20') indicate our proposed observations and outline indicates the region targeted by the c2d survey.