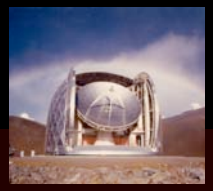









Submm Galactic Surveys: Current and Near-Term

Wayne Holland
UK Astronomy Technology Centre
Royal Observatory Edinburgh

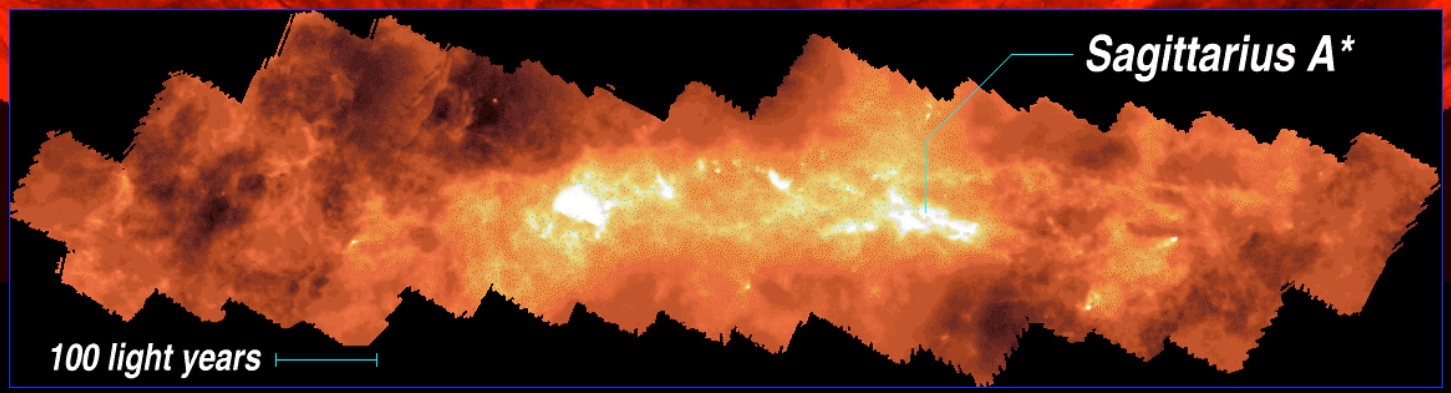
Acknowledgements: Mark Thompson, Jason Glenn, Bill Dent, Mike Fich, Dave Nutter, Jane Greaves, Brenda Matthews, Bruce Sibthorpe

Galactic Surveys: a brief history

Large-scale surveys of phenomena in our Galaxy have, until relatively recently, been impossible to undertake:

- Cameras (and telescopes…) have had small fields-of-view
- Sensitivity (per pixel) has been poor

Pioneering cameras such as SCUBA on JCMT and BoloCAM on CSO have started to address these issues



2.5 × 0.6 deg SCUBA 850μm image of the Galactic Center (Pierce-Price et al. 2001)

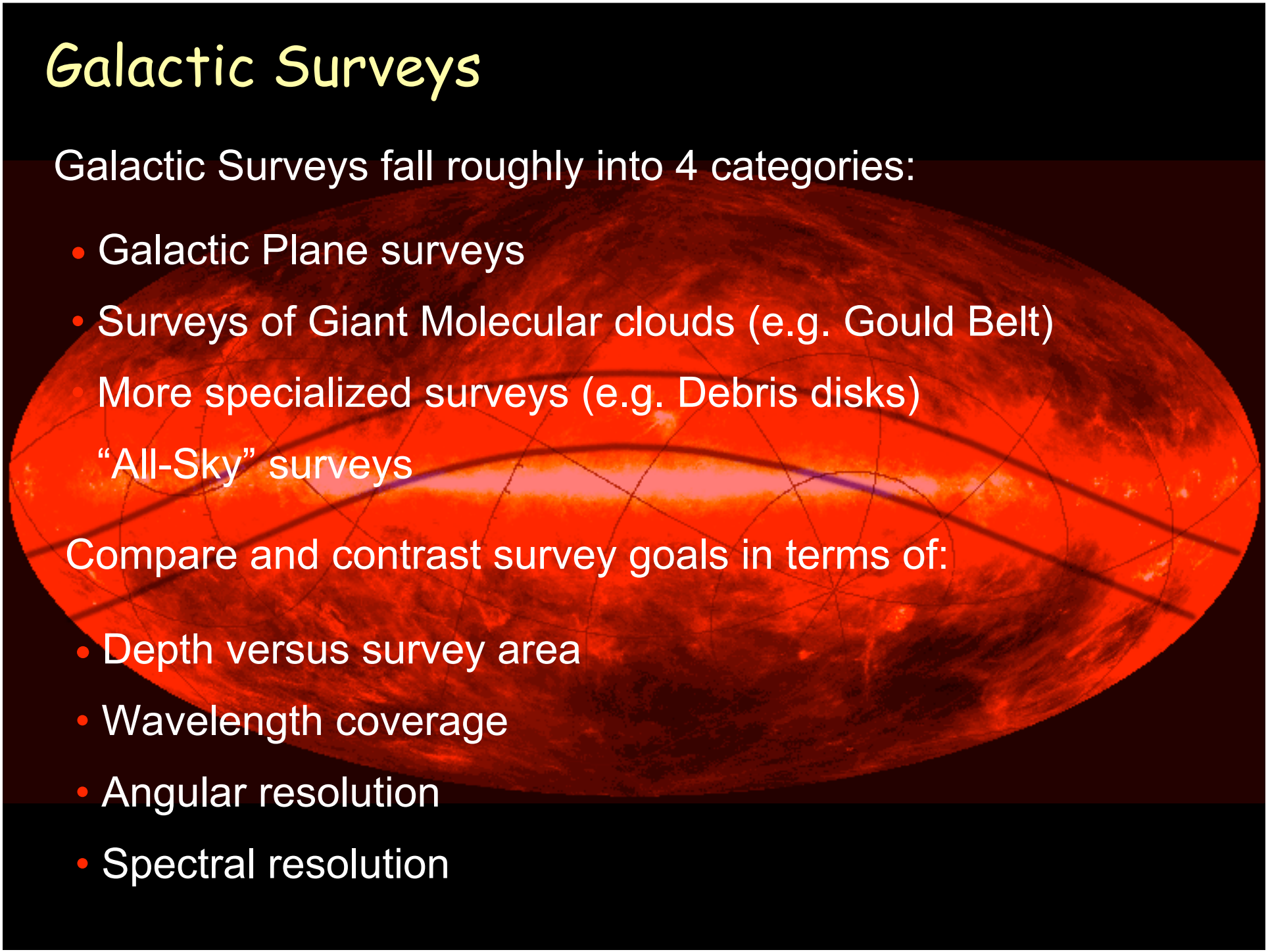
Galactic Surveys

Galactic Surveys fall roughly into 4 categories:

- Galactic Plane surveys
- Surveys of Giant Molecular clouds (e.g. Gould Belt)
- More specialized surveys (e.g. Debris disks)
- "All-Sky" surveys

Compare and contrast survey goals in terms of:

- Depth versus survey area
- Wavelength coverage
- Angular resolution
- Spectral resolution



Galactic Plane Surveys

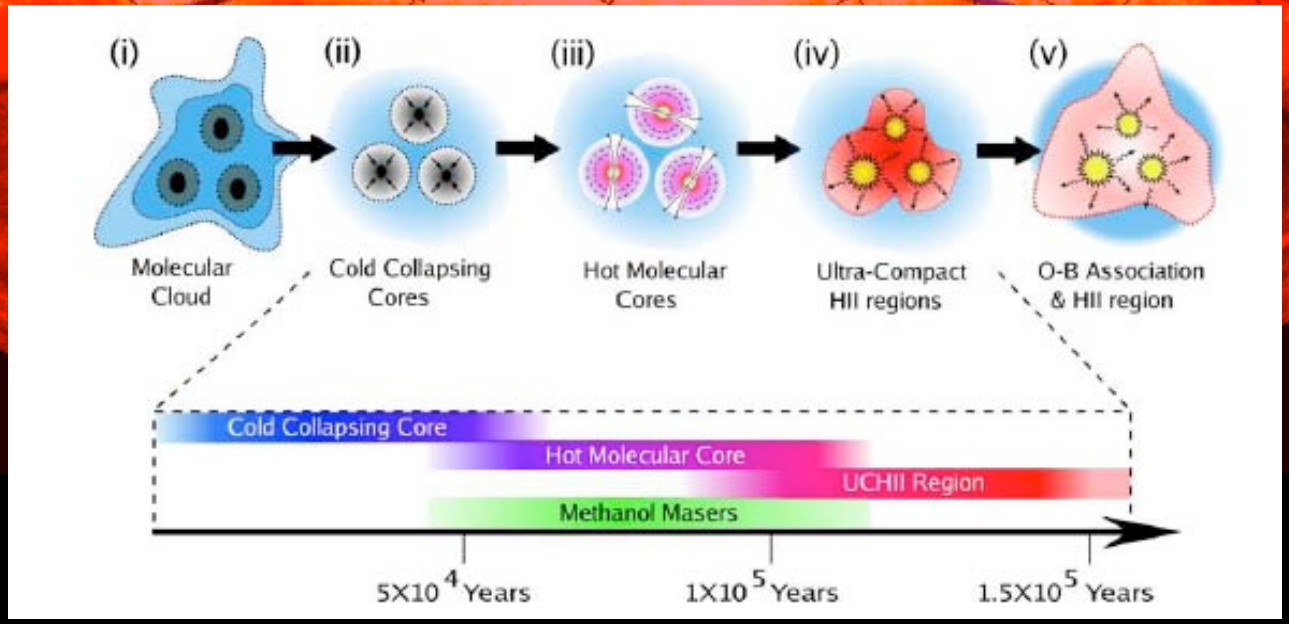
Survey aims

To provide complete samples of high-mass YSOs and proto-clusters in a complete range of Galactic environments

How do massive stars form and how does their evolution influence the environment around them?

Evolution of high mass stars

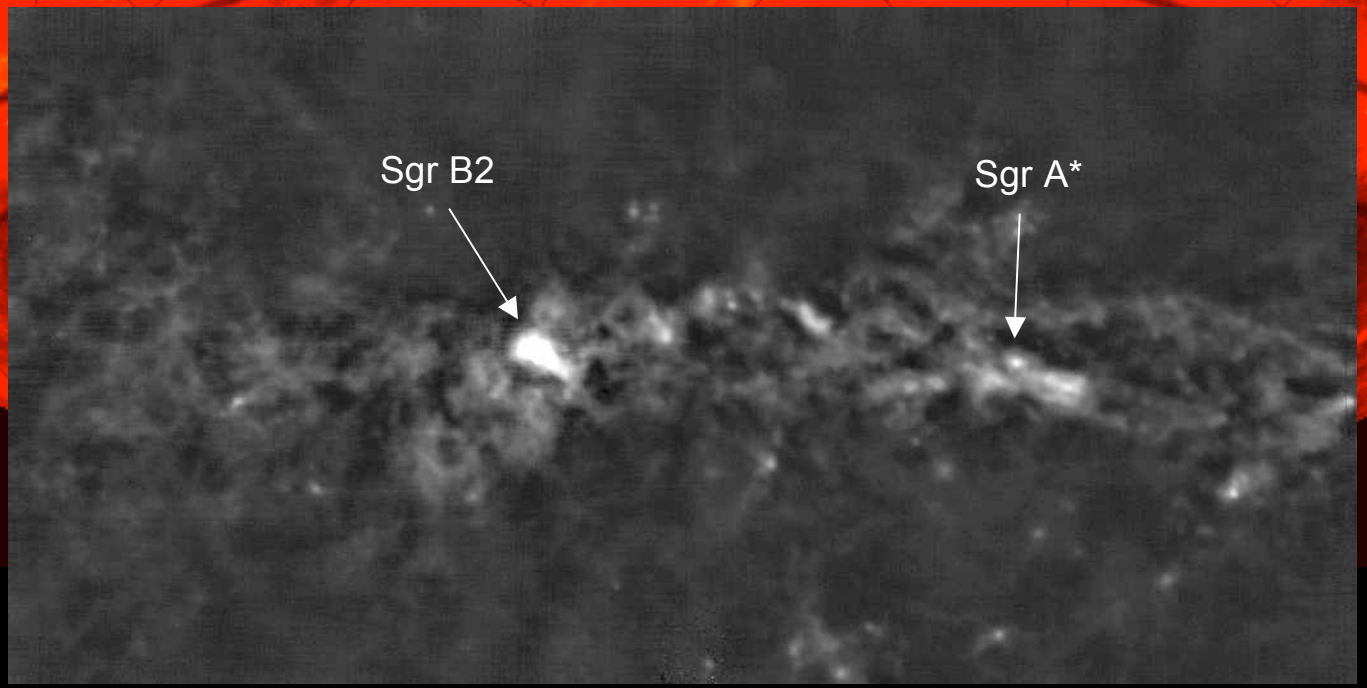
- What are the earliest phases?
- What is the evolutionary sequence for massive stars?
- Triggered star formation and feedback effects?



Graphic:
Cormac Purcell

BoloCAM Galactic Plane Survey

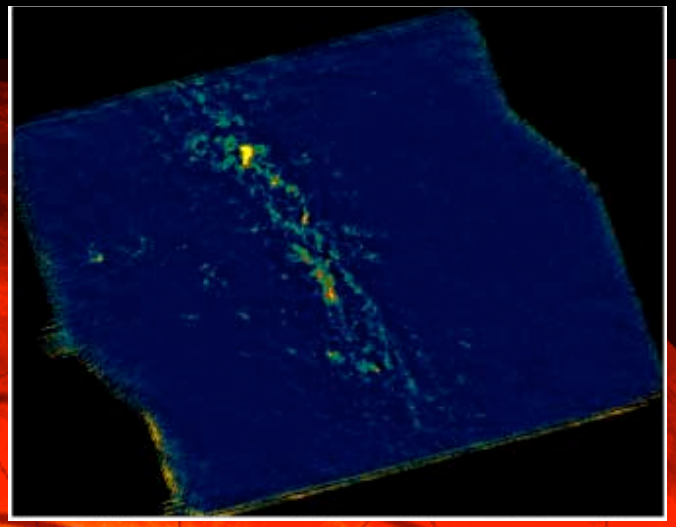
- Dec 2007: ~150 sq-degrees of the Galactic Plane surveyed
- Detected >5,000 dense cloud cores (3σ = 15−30 mJy)
- Follow-up SHARC observations of selected cores (CS 5-4)



Galactic Center with BoloCAM at 1.1mm (Courtesy John Bally/Jason Glenn)

ATLASGAL on APEX

- Unbiased mapping of the inner galaxy at 870μm with Laboca
- First look survey nearing completion: area 120 sq-deg, |l| ≤ 30° and latitude |b| ≤ 1° with 1σ sensitivity of 50mJy

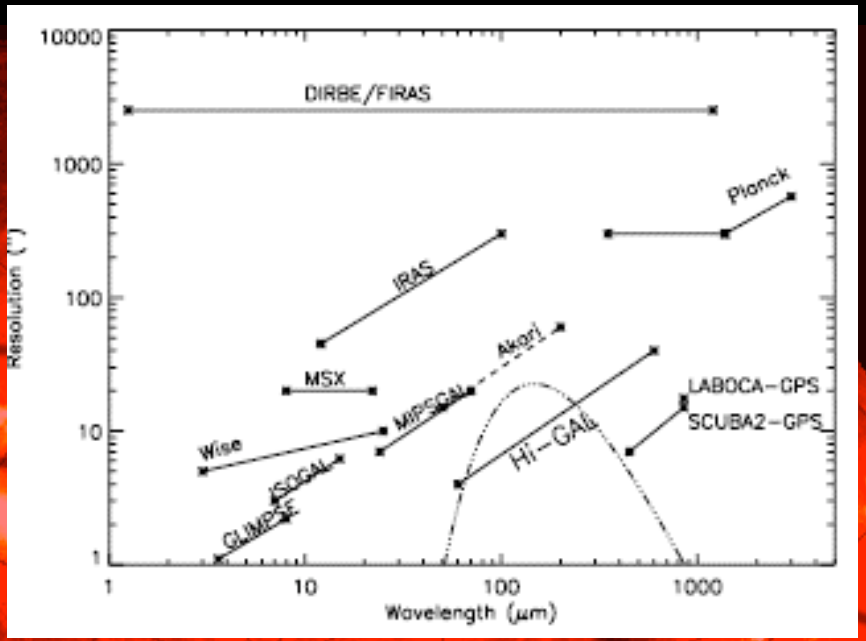


Approx 3 × 3 deg field at the Galactic Center
Courtesy: ATLASGAL team

- Shallow survey: Total area 320 sq-deg, |l| ≤ 80° and |b| ≤ 1° with 1σ sensitivity of 50mJy
- Deep survey: Total area 120 sq-deg, |l| ≤ 30° and |b| ≤ 1° with 1σ sensitivity of 10mJy

HiGAL Galactic Plane Survey

- Open Time Key Project – proposal submitted
- Herschel PACS and SPIRE instruments from 70 to 500μm in 5 bands



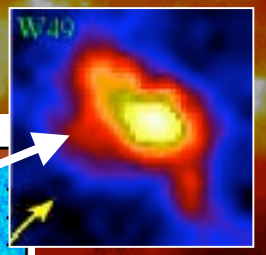
- Survey regions with longitudes ranges 120° < l < 120° and latitude |b| ≤ 1°
- Sensitivity (1σ) of 20mJy
- 700 hrs of Hershel observing time and would start in 2009

JCMT Galactic Plane survey

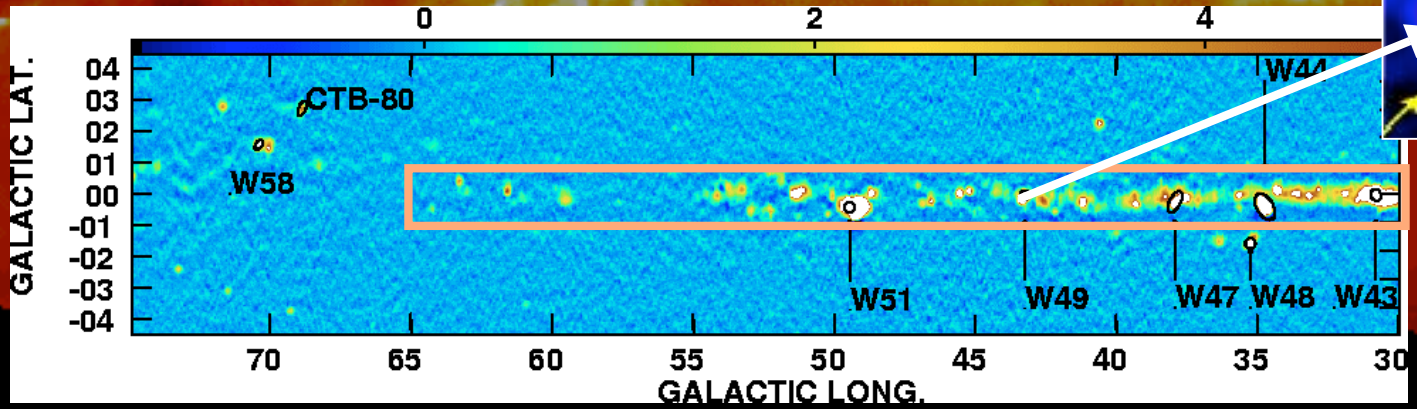
- The survey will map the regions with longitudes ranges 10° < l < 65° and 102.5° < l < 141.5° and latitude |b| ≤ 1°

- Total area covered will be 512 sq-degrees to a 1σ sensitivity of 4mJy

SCUBA-2 camera



W49

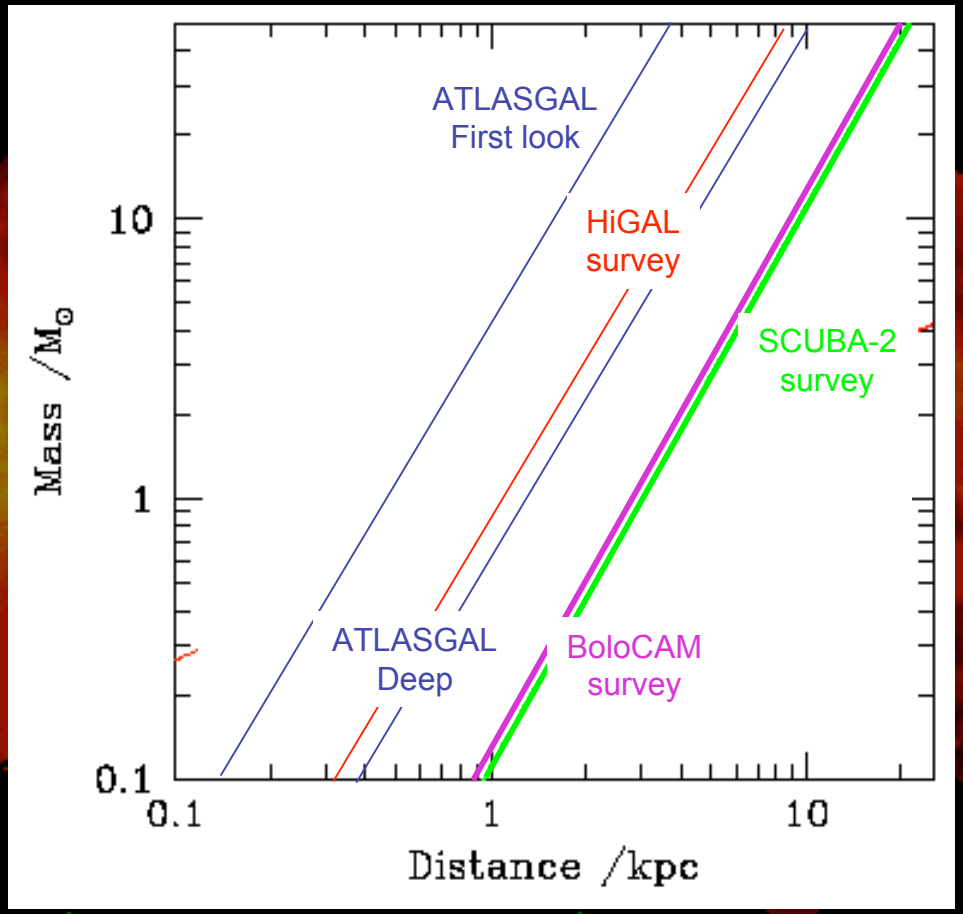


8.4 GHz Galactic Plane survey by Langston et al. Orange box shows SCUBA-2 survey area for this region

- Designed to have synergy with other GP surveys (BoloCAM, GLIMPSE, UKIDSS, Herschel etc)

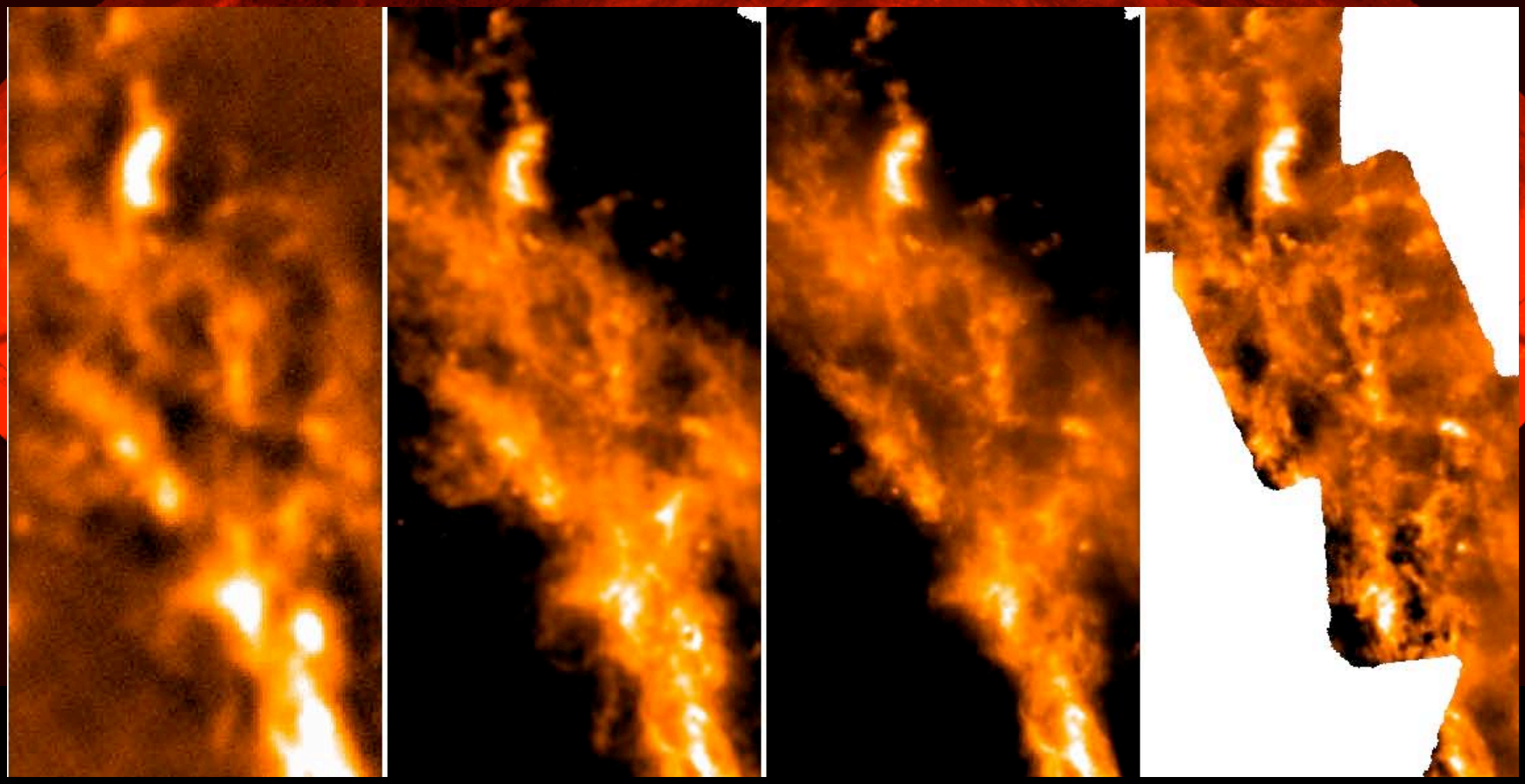
Detection Limits

- SCUBA-2 survey sensitivity will be 4mJy at 850μm – a factor of ~10 lower than the SCUBA Galactic Center dataset
- Corresponds to a mass sensitivity of ~1M_{sun} at 3kpc and 40M_{sun} at 20kpc (shown in green)



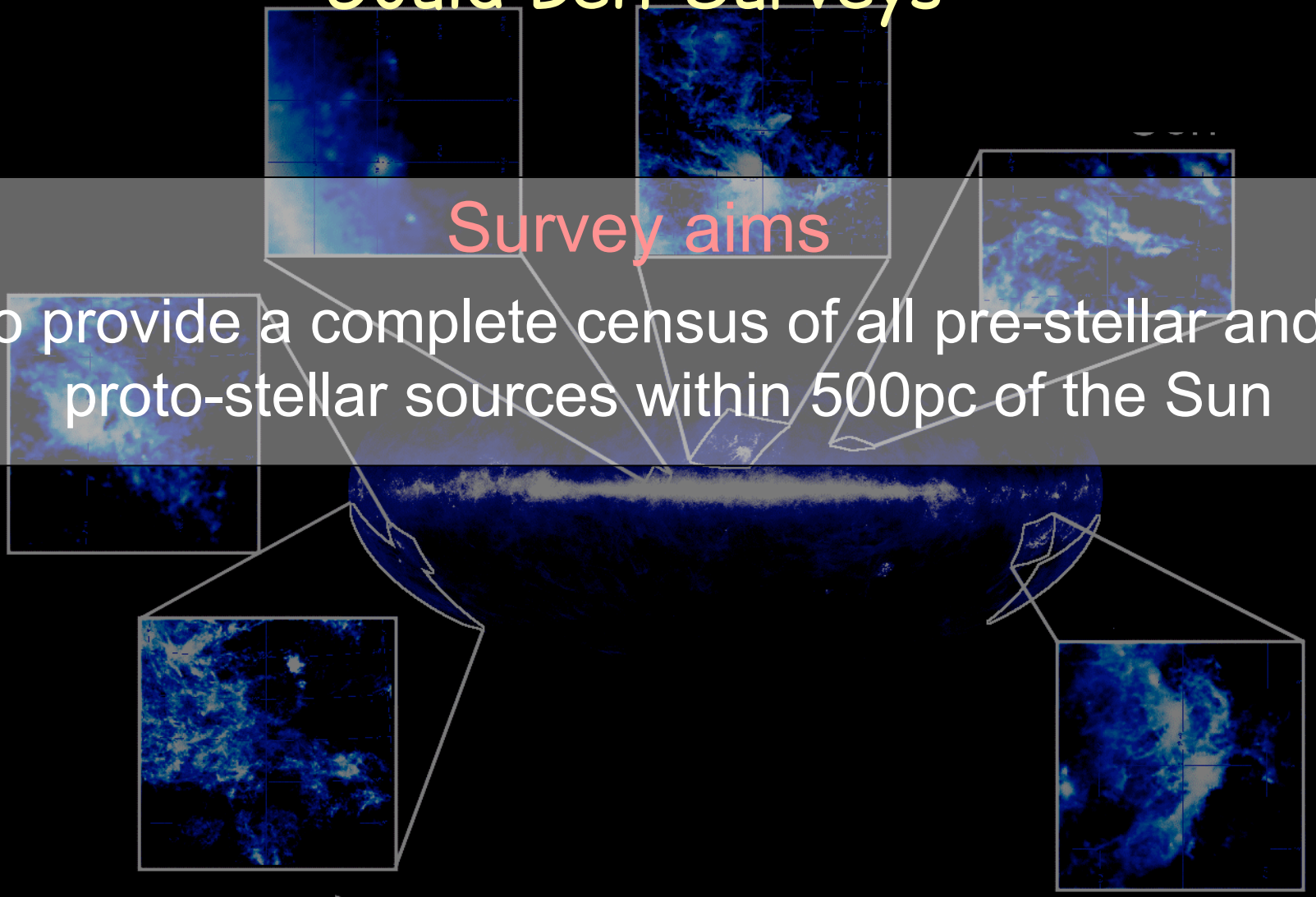
- Will detect all the significant high-mass and cluster-forming regions throughout the Galaxy

Galactic Centre Revealed



A number of other surveys also planned including AzTec on LMT at 1.1mm

Local Star Formation: Gould Belt Surveys



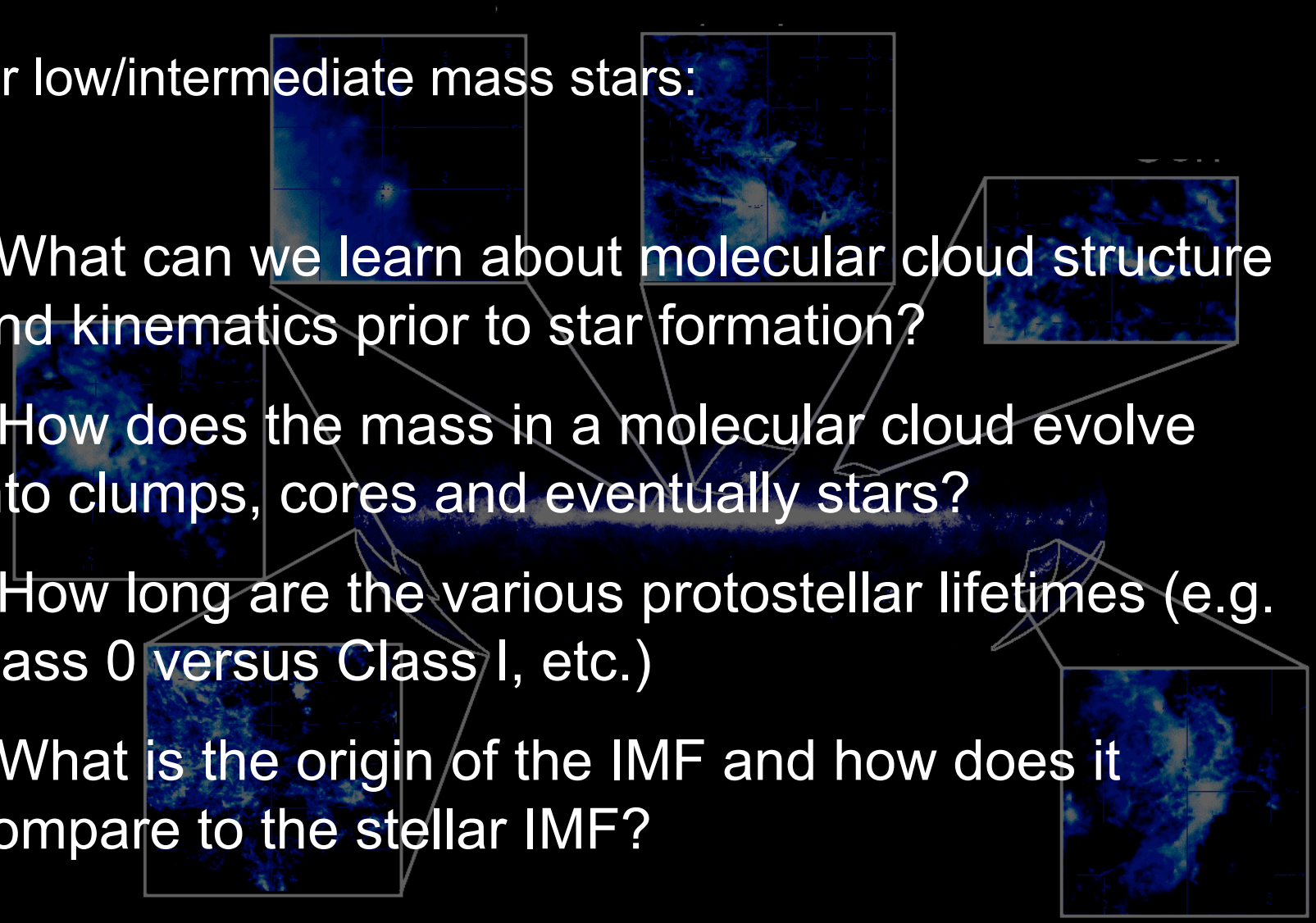
Survey aims

To provide a complete census of all pre-stellar and proto-stellar sources within 500pc of the Sun

From cores to clouds: How do stars form and evolve?

Science Drivers for Galactic Surveys

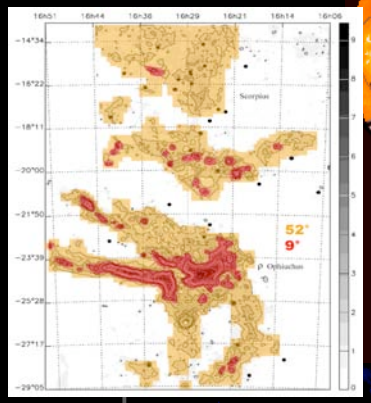
For low/intermediate mass stars:

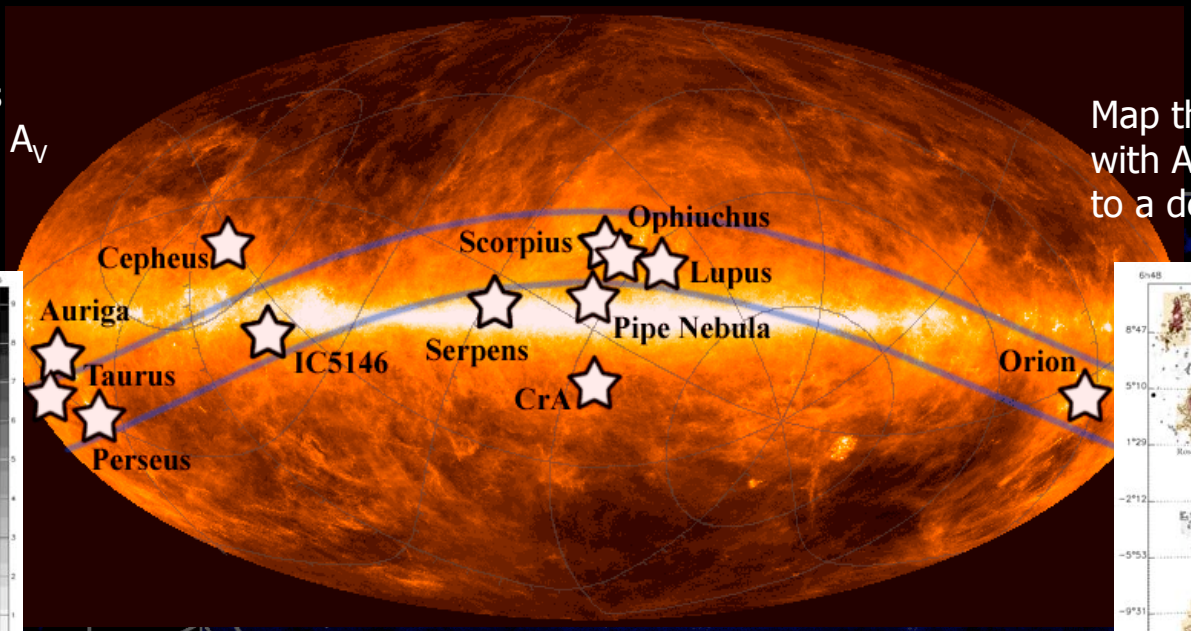


- What can we learn about molecular cloud structure and kinematics prior to star formation?
- How does the mass in a molecular cloud evolve into clumps, cores and eventually stars?
- How long are the various protostellar lifetimes (e.g. class 0 versus Class I, etc.)
- What is the origin of the IMF and how does it compare to the stellar IMF?

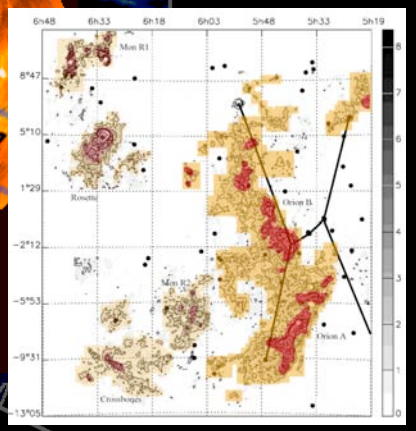
JCMT and APEX Gould Belt Surveys

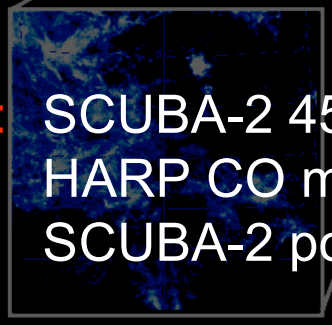
Map selected areas (100 sq-degs) with A_V > 3 at 850μm to a depth of 3mJy

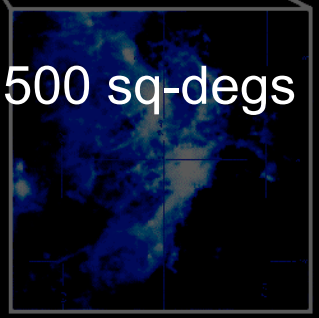




Map the entire GB areas with A_V > 1 at 850μm to a depth of 10mJy







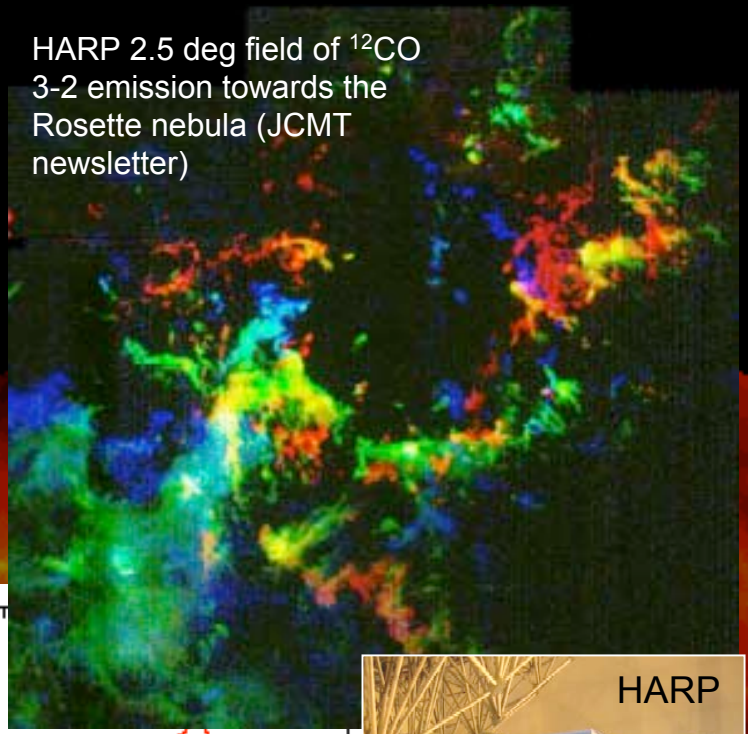
JCMT: SCUBA-2 450 and 850μm wide-field maps of 500 sq-degs
HARP CO maps of 1000 detected cores
SCUBA-2 polarimetry of 100 detected cores

APEX: LABOCA 870μm maps of southern clouds

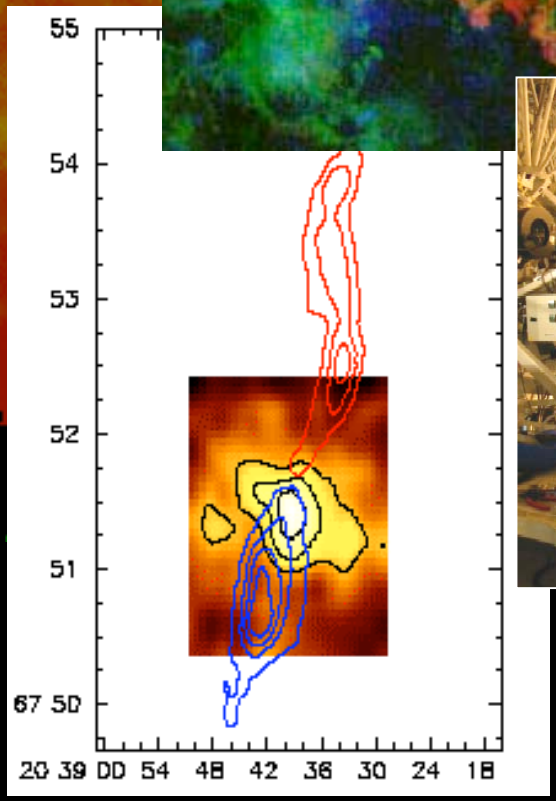
Spectral Line Surveys

- Many of the clouds will also be observed in molecular lines such as ^{13}CO 3-2 (330 GHz) searching for outflows to provide age estimates, measure line widths and velocity profiles

- HARP will measure the kinematics of these cores and clusters and will achieve a 3σ mass detection limit of 1–5 M_{sun} at a distance of 3 kpc (similar to SCUBA-2 but over limited fields

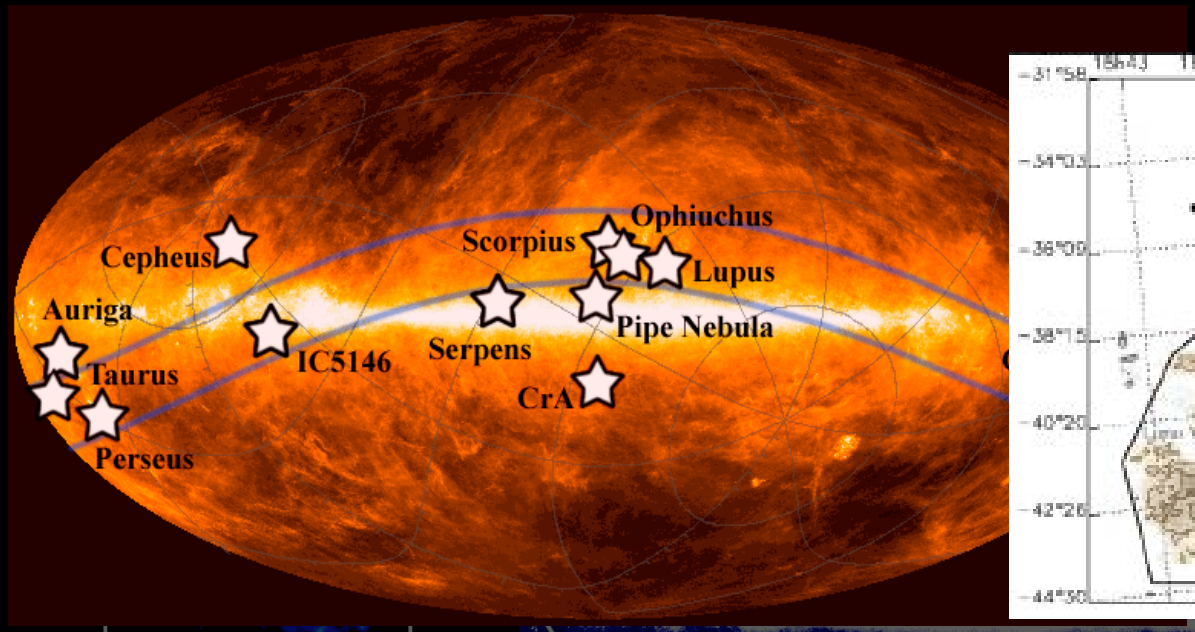


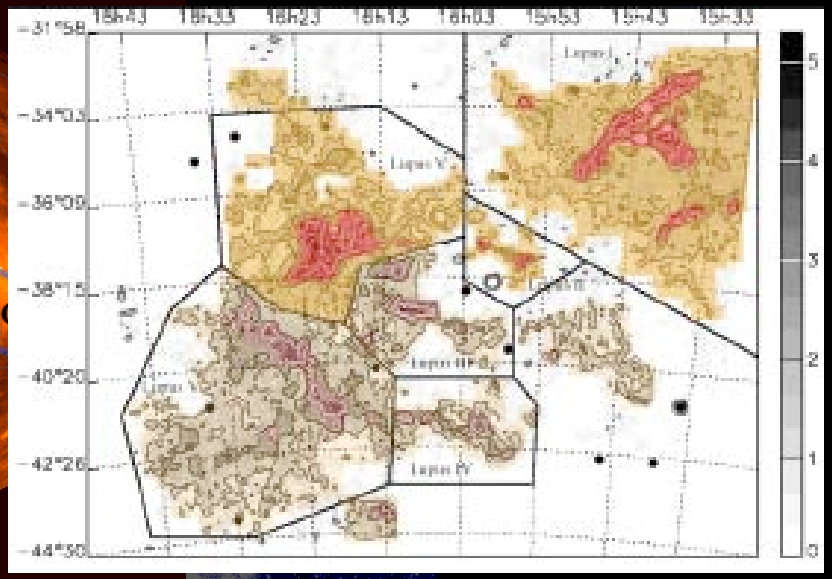
HARP 2.5 deg field of ^{12}CO 3-2 emission towards the Rosette nebula (JCMT newsletter)



Outflow from Class 0 source L1157 in ^{12}CO 3-2

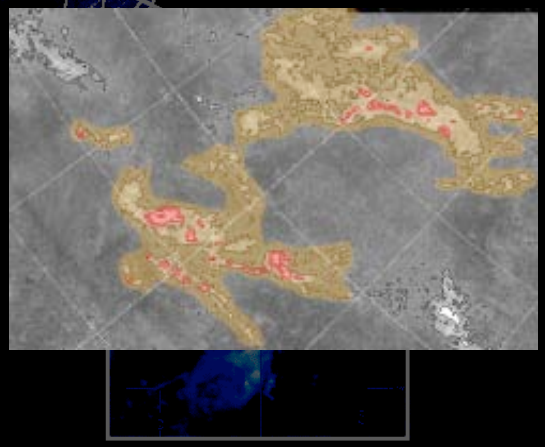
Herschel Gould Belt Surveys





Guaranteed Time Observation Key Project

- PACS and SPIRE maps of the nearest star formation regions
- 70 – 500μm wavelength coverage
- Angular resolution from 6 to 43 arcseconds



Debris Disk Surveys

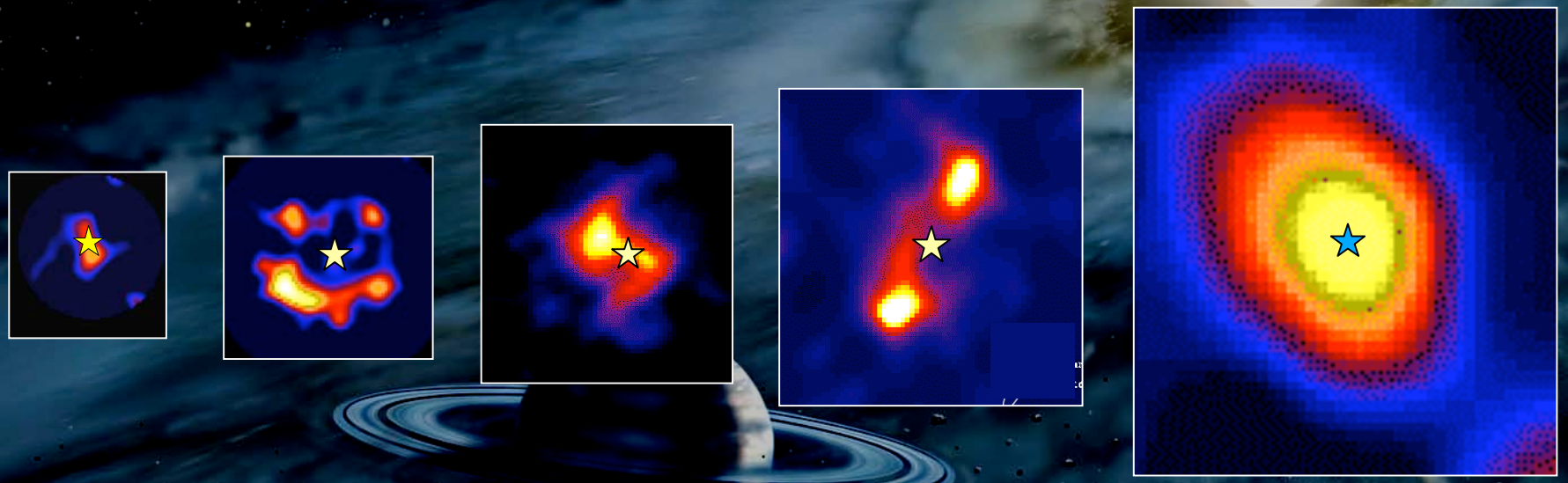
Survey aims

An **unbiased** search of hundreds of nearby main sequence stars for disk emission

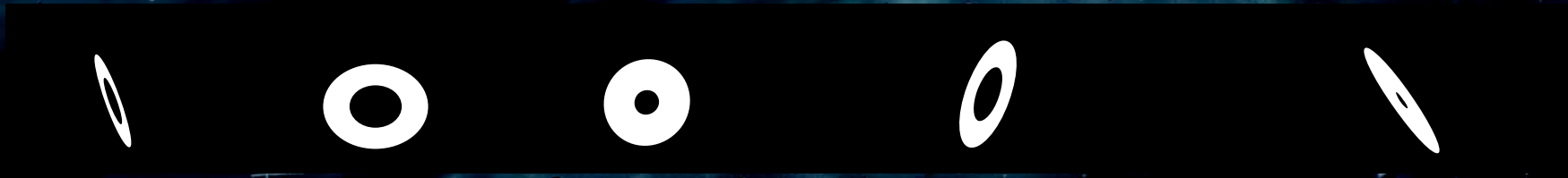
How diverse are planetary systems and where does the Solar System fit into the picture?

Scientific Goals

- To determine unbiased statistics on the incidence and diversity of debris disks around nearby stars



τ Ceti ε Eridani Vega Fomalhaut β Pictoris

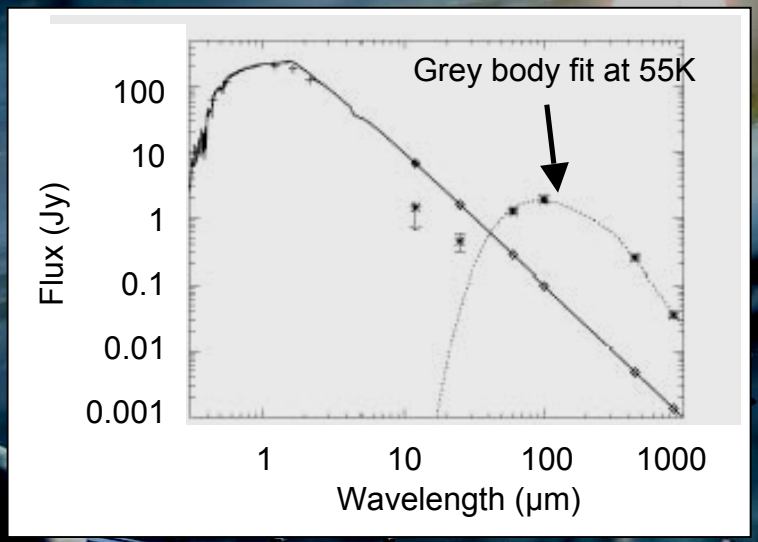


Gallery of disks (to same physical scale)

Scientific Goals (cont.)

- To constrain disk masses and temperatures for far-IR detections (e.g. ISO, Spitzer and Herschel)

ε Eridani (Greaves et al. 2005)



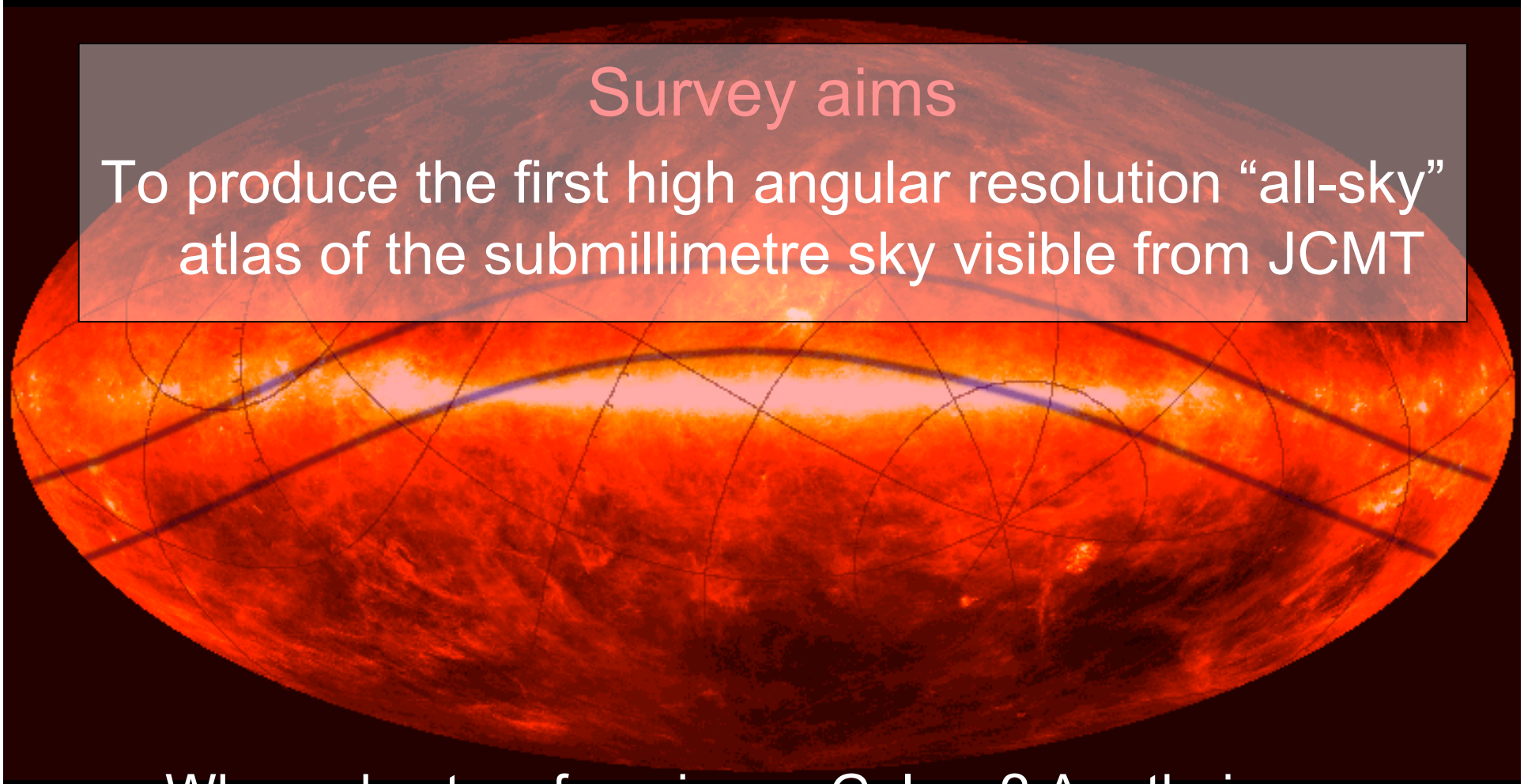
- To discover numerous disks too cold to be detected in the far-IR (e.g. by Spitzer)

- To be the basis of source lists for future observing campaigns (e.g. using ALMA, CCAT and JWST)

SUNS Survey Plan

- 500 stars comprising 100 nearest observable stars from JCMT in spectral types A, F, G, K and M
- All stars will be imaged at 850μm to the (extragalactic) confusion limit (~0.7 mJy)
- Detection rates increase sharply with lower flux limits as we probe into the mass function
- Disks with significant structure will be targets for further deep imaging at 450μm

"All-Sky" Survey (SASSy)



Survey aims

To produce the first high angular resolution "all-sky" atlas of the submillimetre sky visible from JCMT

Where do stars form in our Galaxy? Are their new populations of objects hitherto undiscovered?

Galactic Scientific Goals

To act as a detection experiment and identify infrared dark clouds, star-forming cores & dusty high-redshift galaxies in as unbiased a manner as possible.

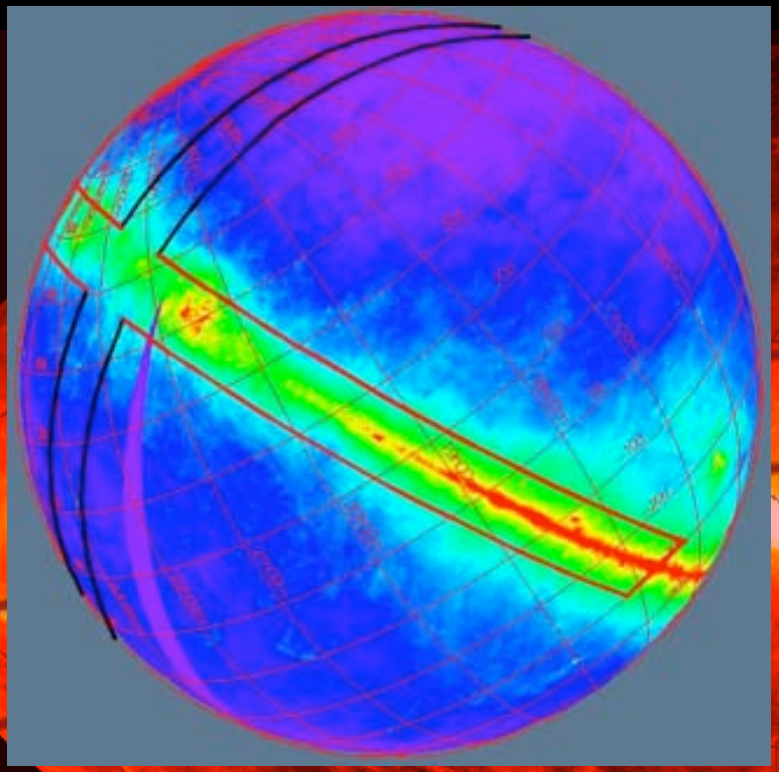
Specific galactic astronomy goals include:

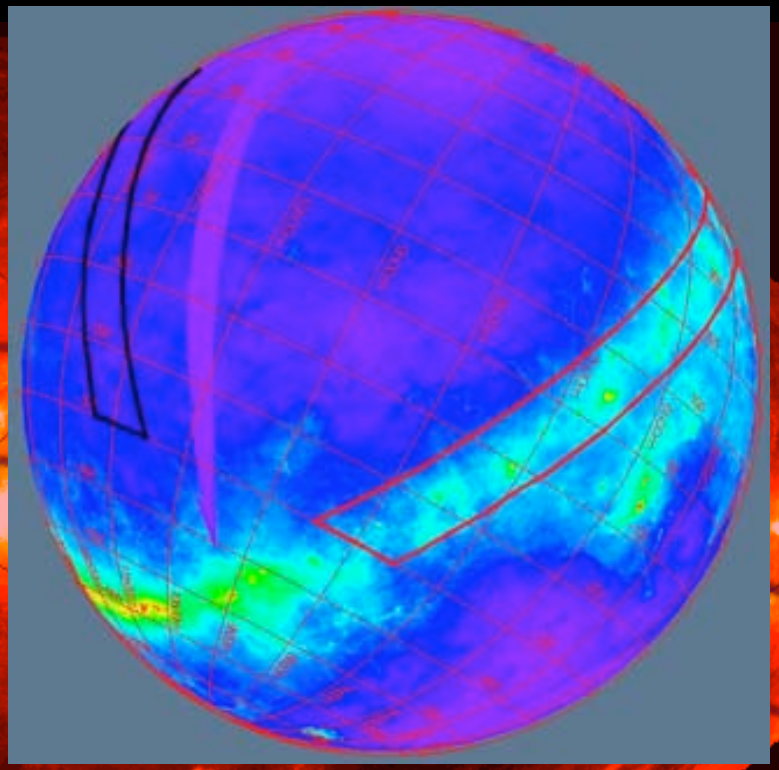
How many infrared dark clouds (IRDCs) are there in our Galaxy and how are they distributed?

- What is the relation of IRDCs to star formation and Galactic structure?

- Is there an underlying unknown population of star formation?

SASSy Pilot Study





GP-wide strip (red) covers $0 \leq l \leq 270°$ and $b \leq 5°$. The pole-to-pole strip (black) is centred at $l = 96°$ and contains the N and S galactic poles and the N ecliptic pole

Sensitivity will be comparable to the 850μm channel of Planck Surveyor with an angular resolution of 15 arcseconds

Conclusions

- Survey astronomy is very much coming of age in the submm with a number of surveys already taking place or planned in the next few years
- Galactic plane surveys are underway from the near-IR to the submm probing the properties of high-mass stars
- Surveys of local star formation sites are studying the formation and evolution of the lowest mass stars
- Surveys of discrete objects, such as debris disks, will allow the first statistical studies of the properties of such objects in the submm
- All sky surveys are planned – very complementary (and invaluable?!) to future work by ALMA and CCAT…