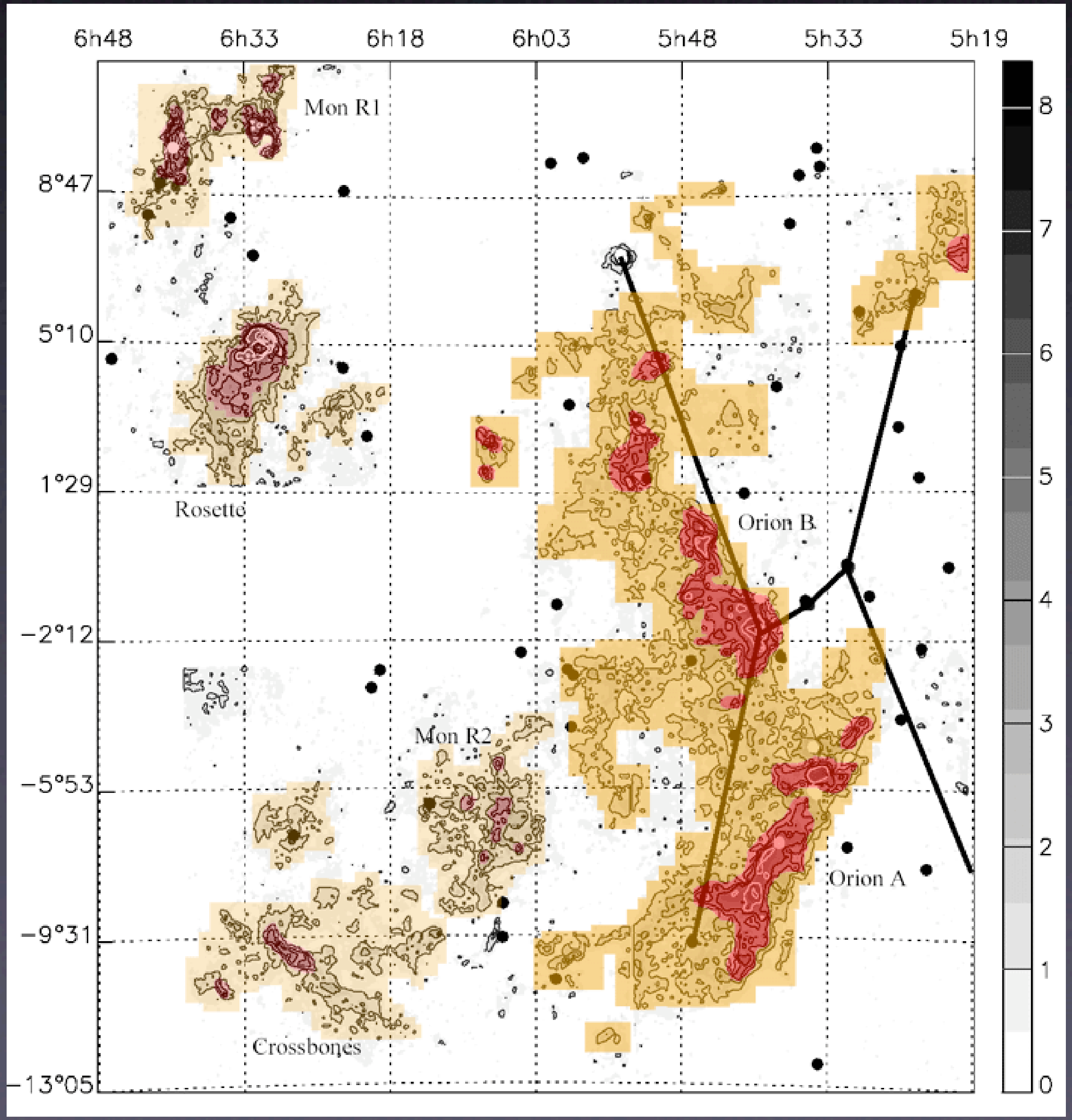
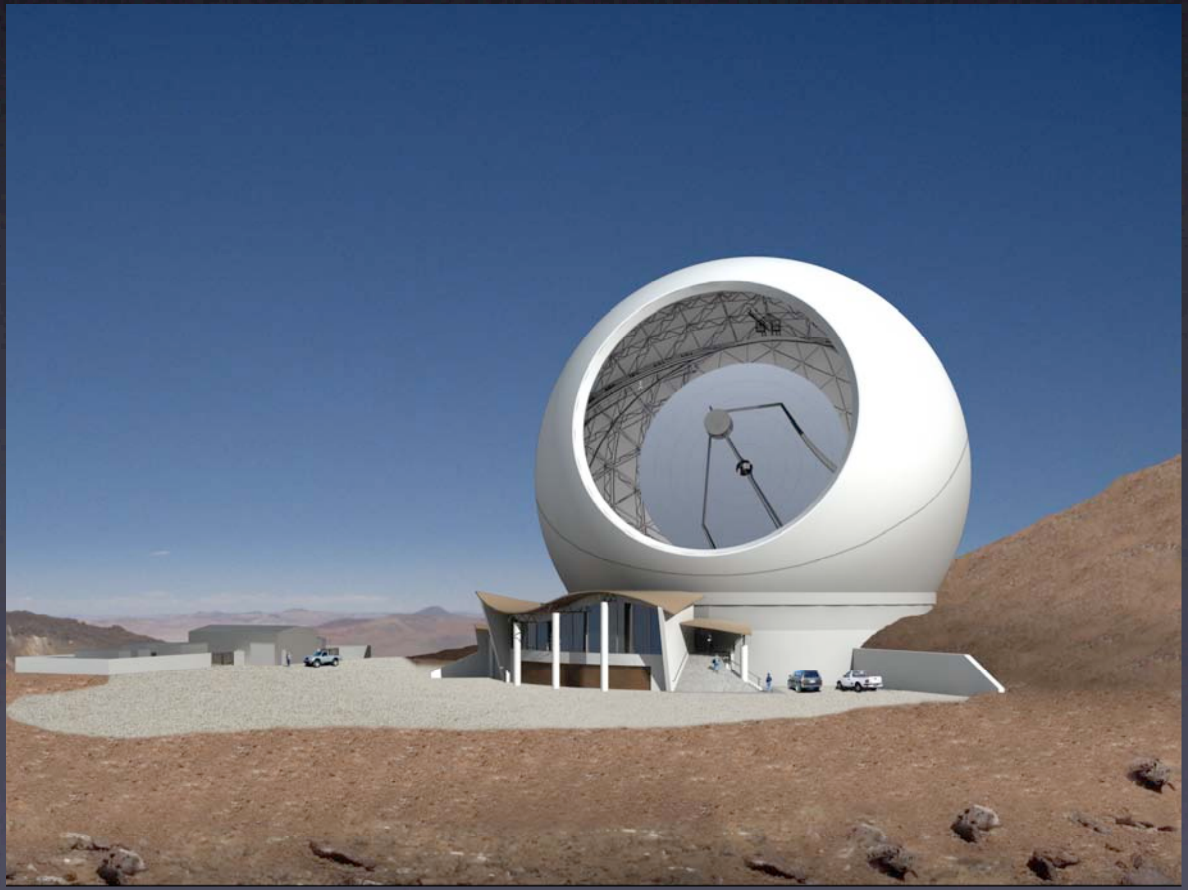
Star formation surveys: present and future





Mark Thompson
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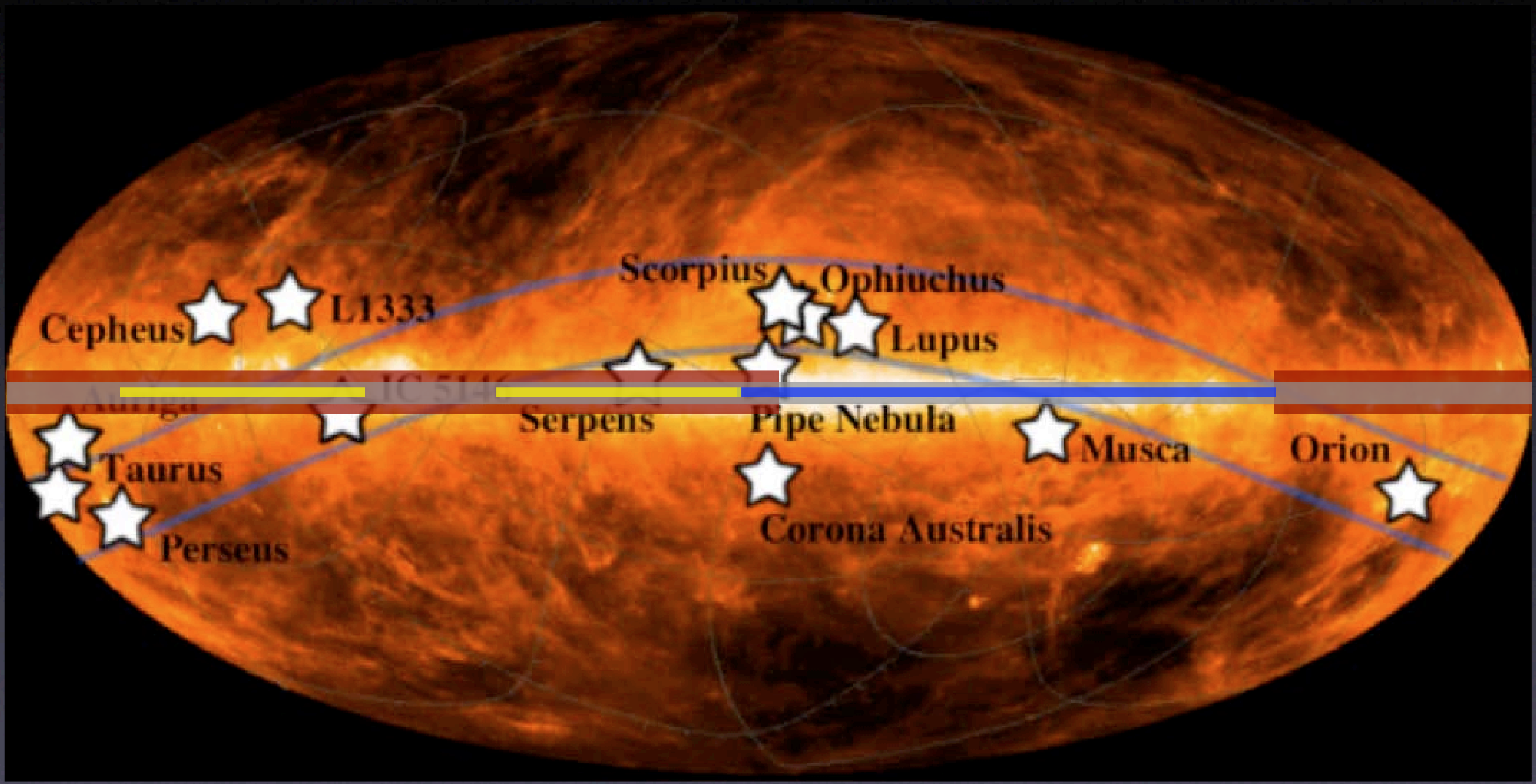
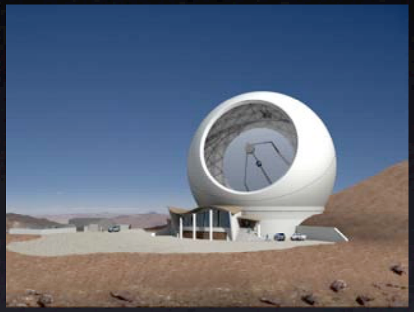
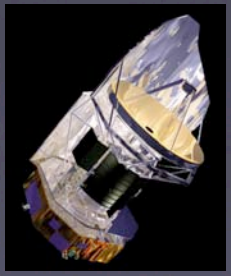
Surveys surveys everywhere...

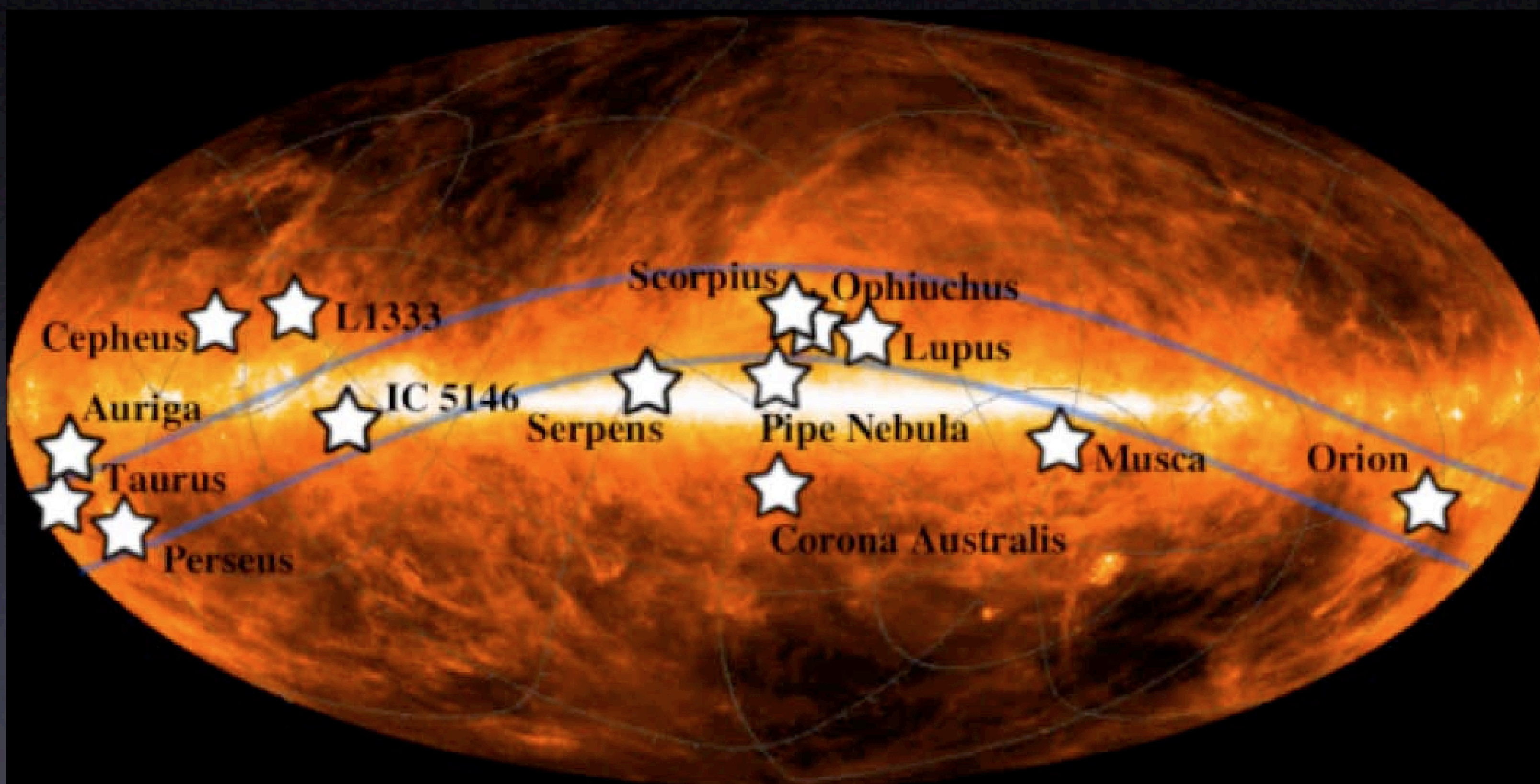




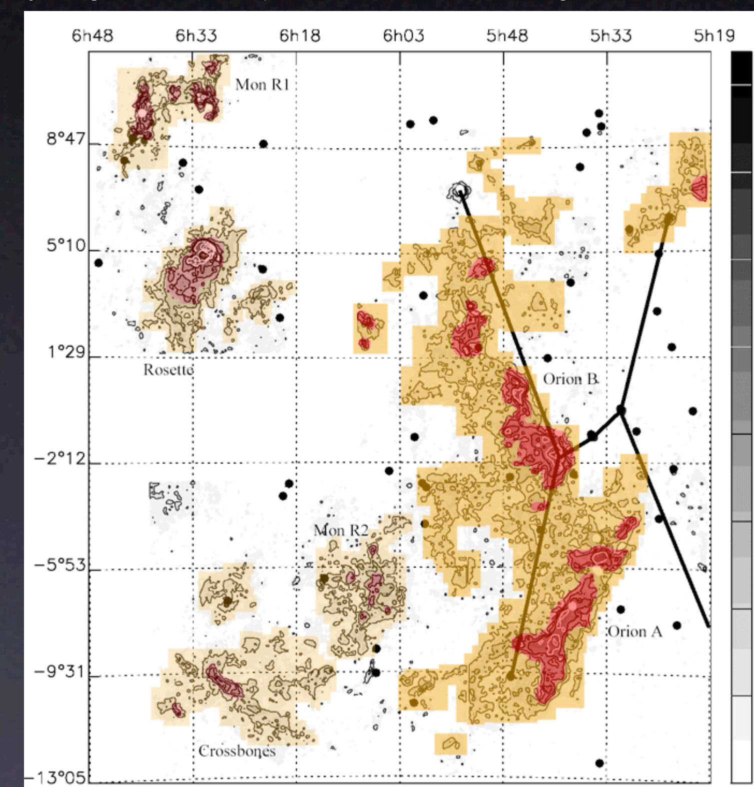


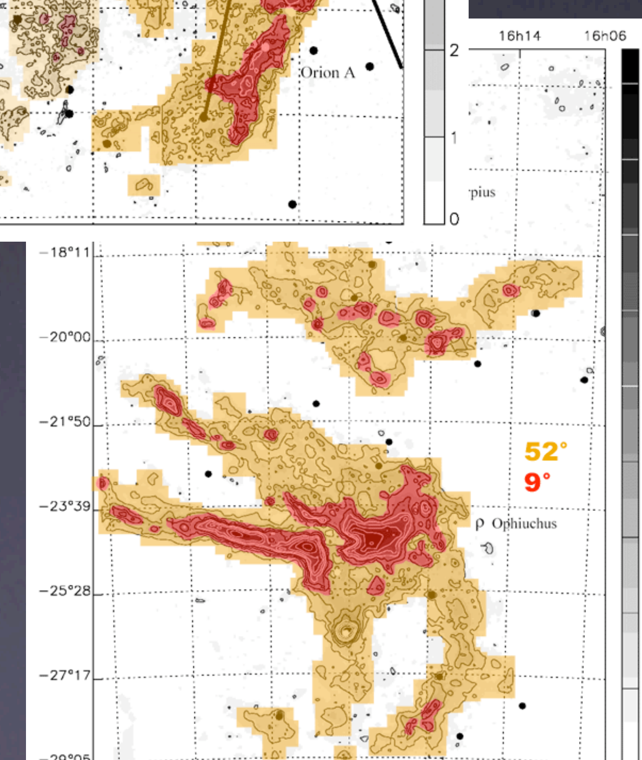
IRAS 100 μm Gould Belt image courtesy Dave Nutter, Cardiff

Local star formation: the Gould Belt surveys



Images courtesy JCMT Gould Belt Legacy Survey (http://www.jach.hawaii.edu/JCMT/surveys/gb/)

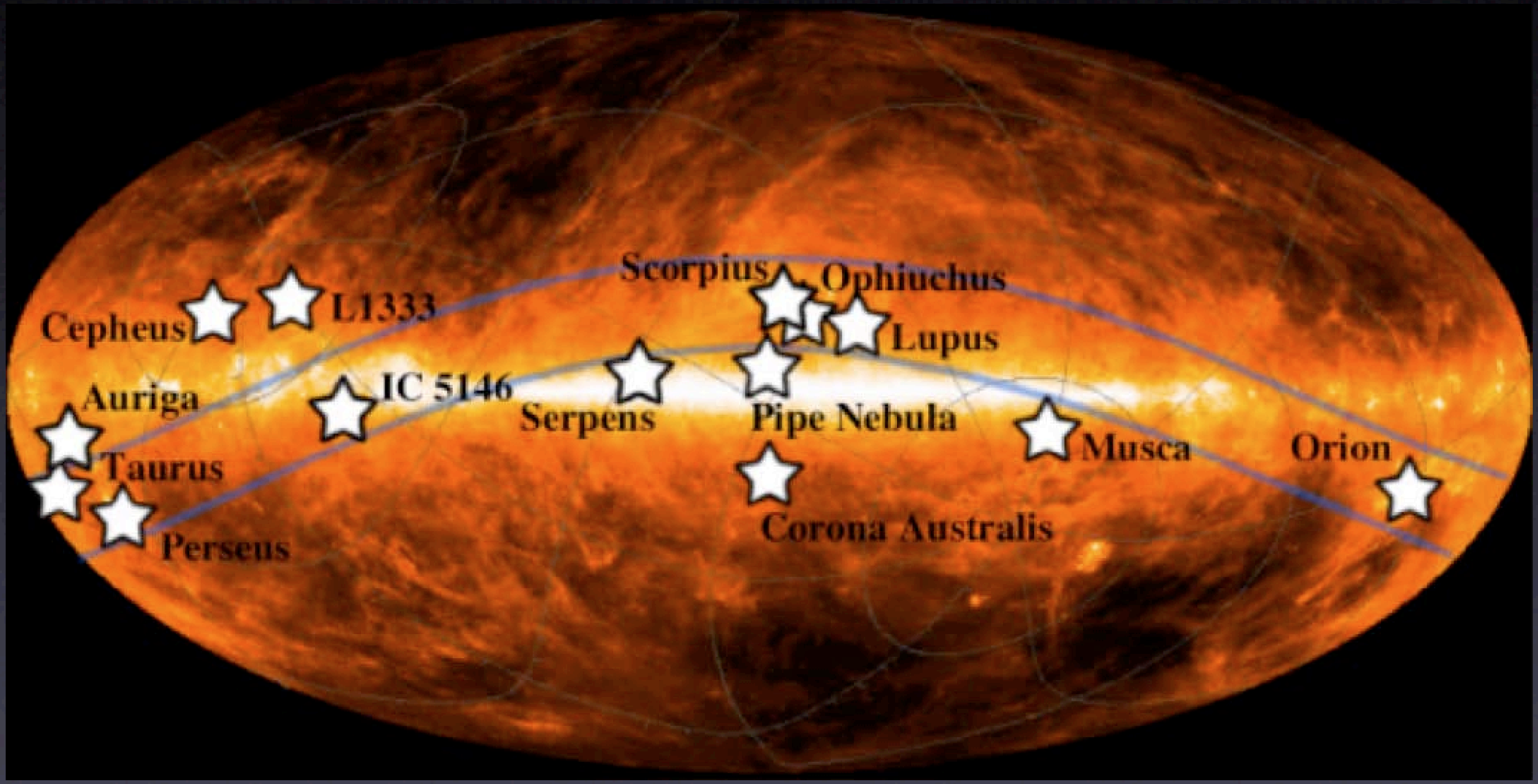


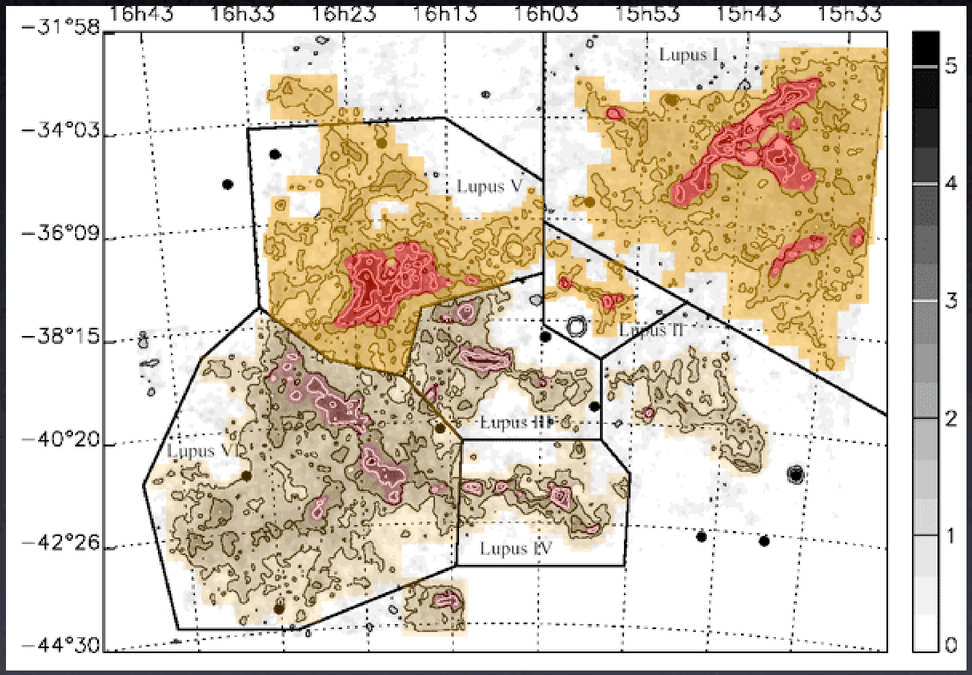


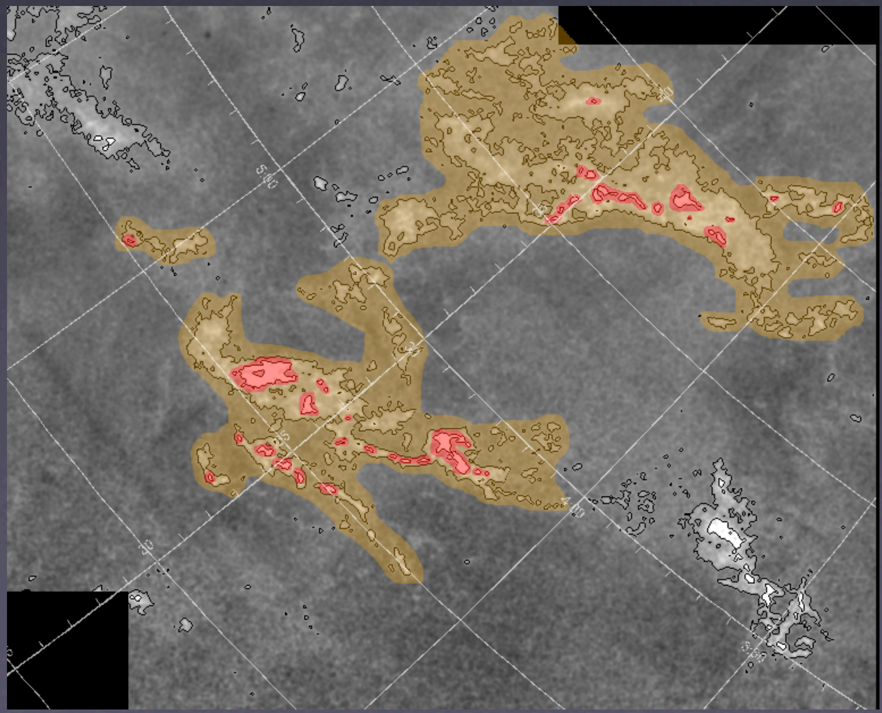
JCMT & APEX Gould Belt Legacy Surveys

- SCUBA-2 450 & 850 μm maps of nearest SF regions
- LABOCA on APEX covering southern clouds
- HARP CO maps of ~ 1000 detected cores
- SCUBA-2 polarimetry of ~ 100 detected cores

Local star formation: the Gould Belt surveys



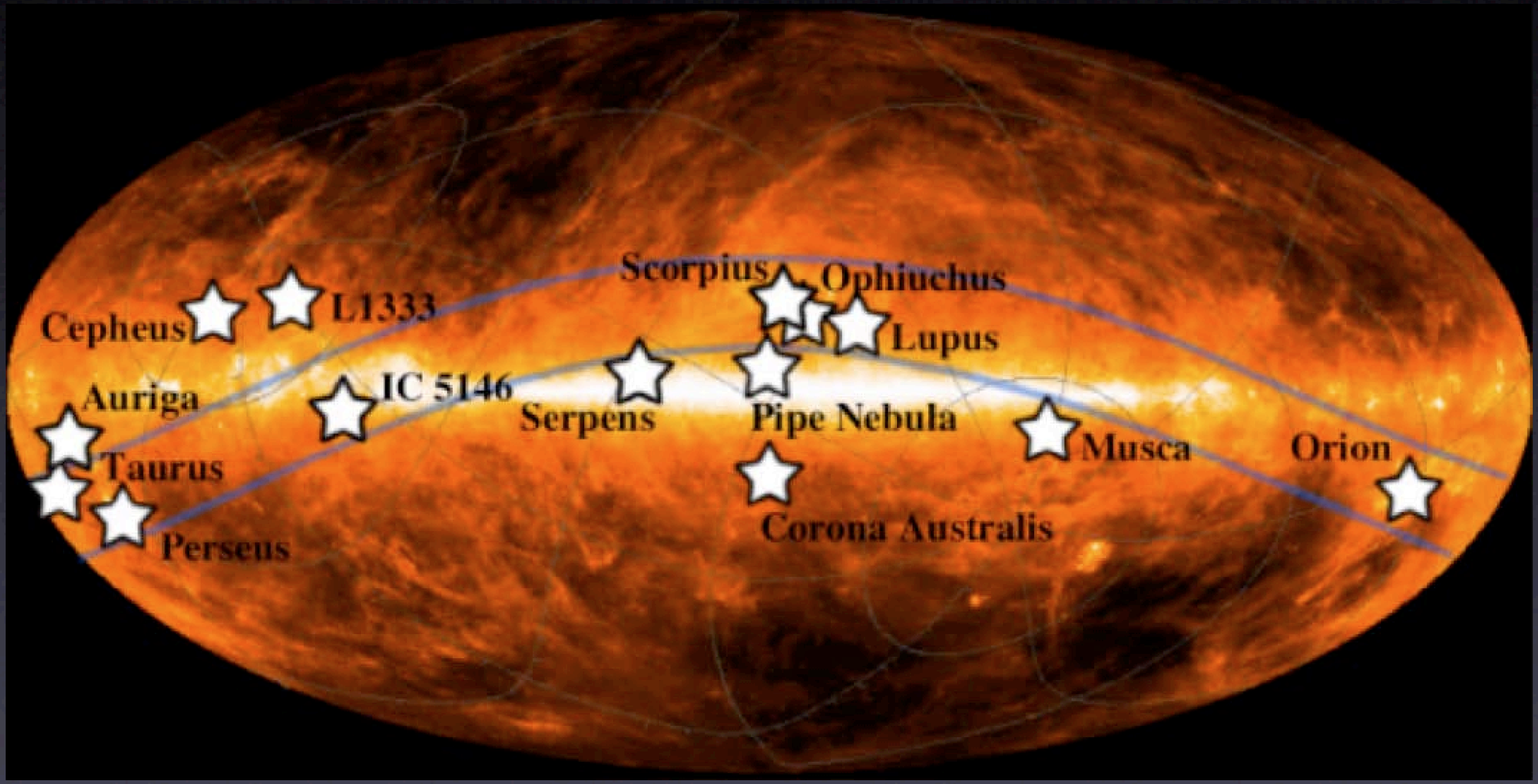




Herschel Gould Belt Legacy Survey

- Guaranteed Time Observation Key Project
- PACS & SPIRE maps of the nearest SF regions
- 70 to 500 μm wavelength coverage
- angular resolution from 6” to 43”

Local star formation: the Gould Belt surveys

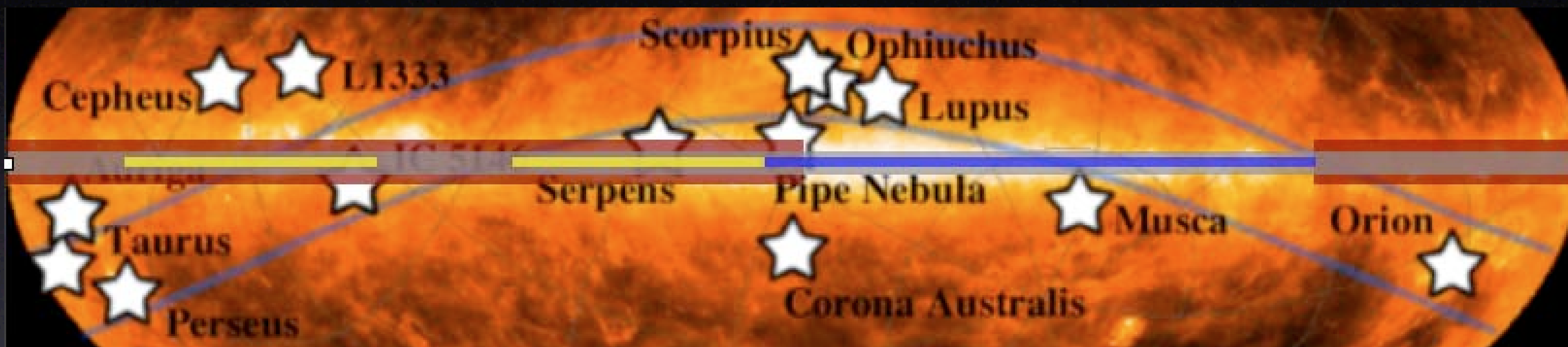


Spitzer Gould Belt Legacy Survey

IC 5416 - image credit Spitzer Gould Survey http://www.cfa.harvard.edu/gouldbelt/

- Combining c2d Legacy Project with GT, investigator observations and new observations.
- IRAC + MIPS images of the same clouds as JCMT, APEX, *Herschel*...

Not-so local star formation: Galactic plane surveys



Continuum surveys

JCMT Plane Survey (JPS) - 450 + 850 μm to ~ 40 + 4 mJy

SCUBA-2 "All-Sky" Survey (SASSy) - 850 μm to 30 mJy

APEX Plane Survey (ATLASGAL) - 870 μm to ~ 50 mJy

Herschel Hi-GAL Survey - 70, 110, 250, 350, 500 μm to 30 mJy

Plus NIR (UKIDSS, VISTA); MIR (Spitzer GLIMPSE); Hα (IPHAS, VPHAS+); radio (CORNISH); methanol masers (MMB); CO (GRS + Cepheus)...

Science drivers for star formation surveys

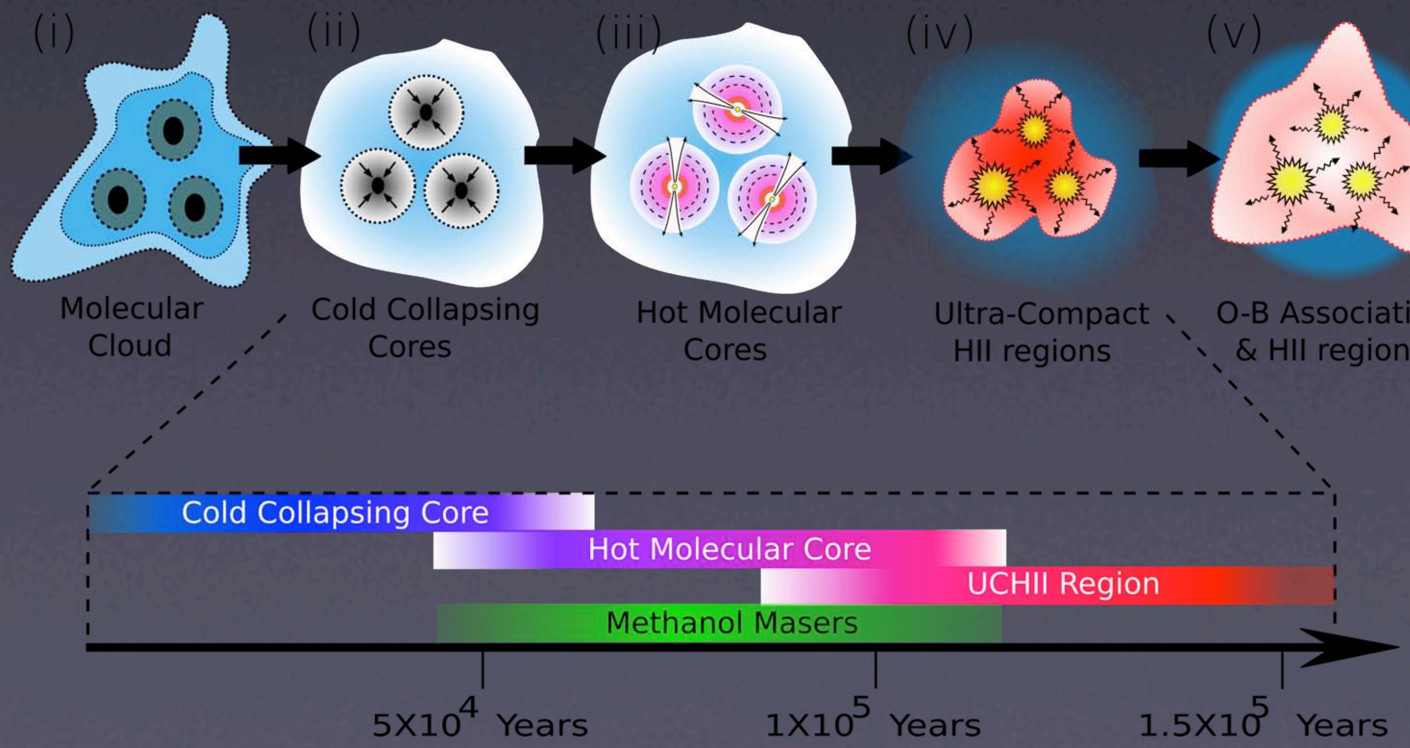
For low/intermediate-mass stars:

- How does the mass in a molecular cloud get into clumps, cores and eventually stars?
- Protostellar lifetimes (Class 0 vs Class I etc)
- Accretion & outflow rates
- Origin of the IMF (cloud fragmentation?)
- Molecular cloud structure & kinematics

Science drivers for star formation surveys

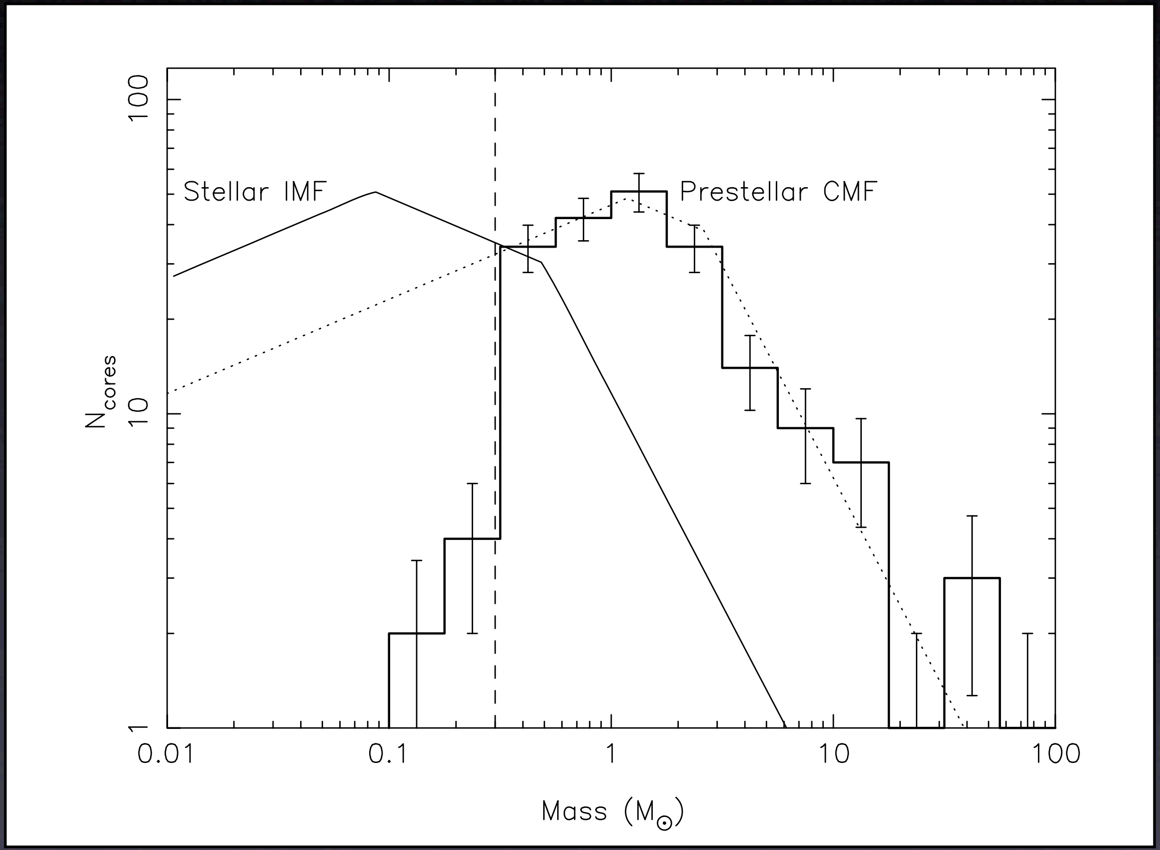
For massive stars:

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

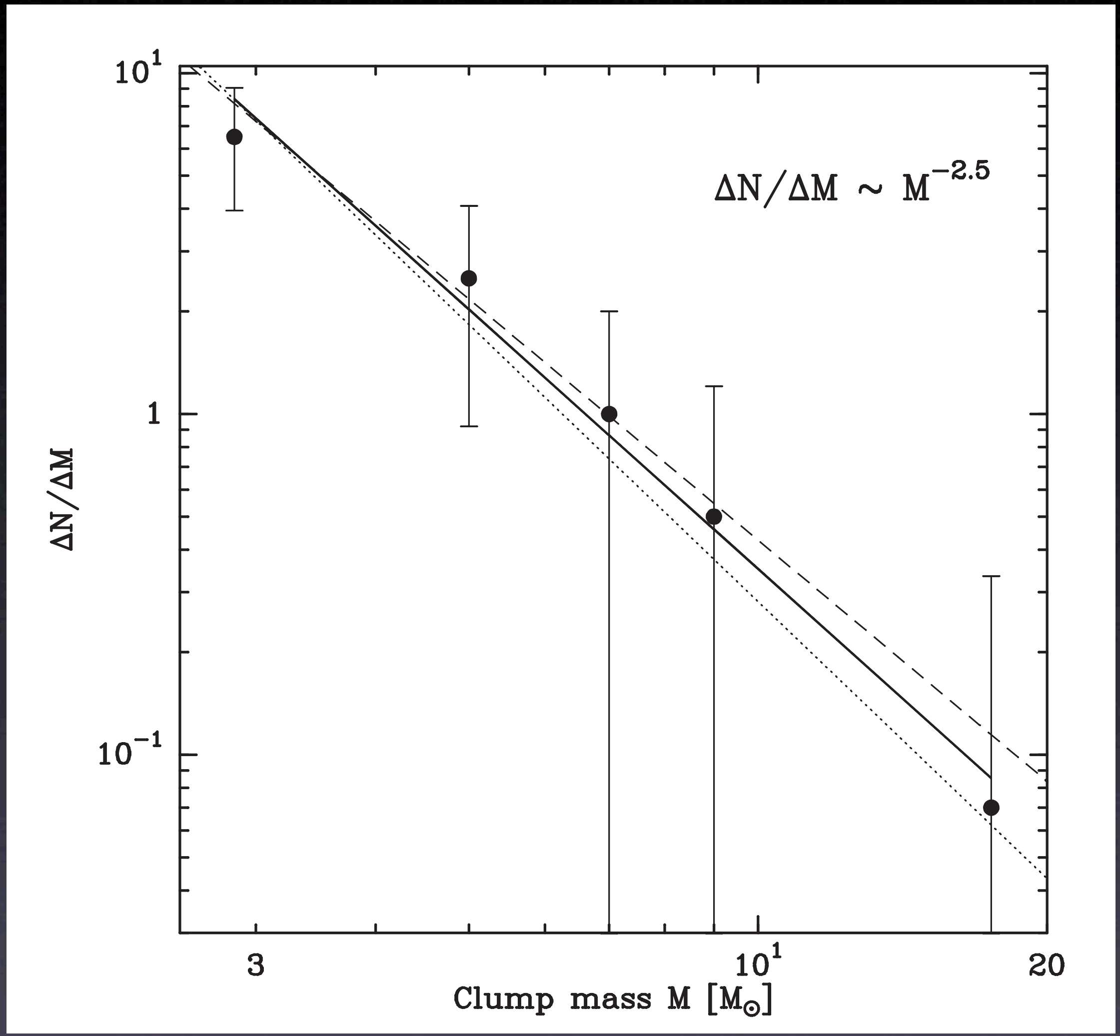


Graphic courtesy Cormac Purcell

Linking clump mass to IMF



Nutter & Ward-Thompson 2007

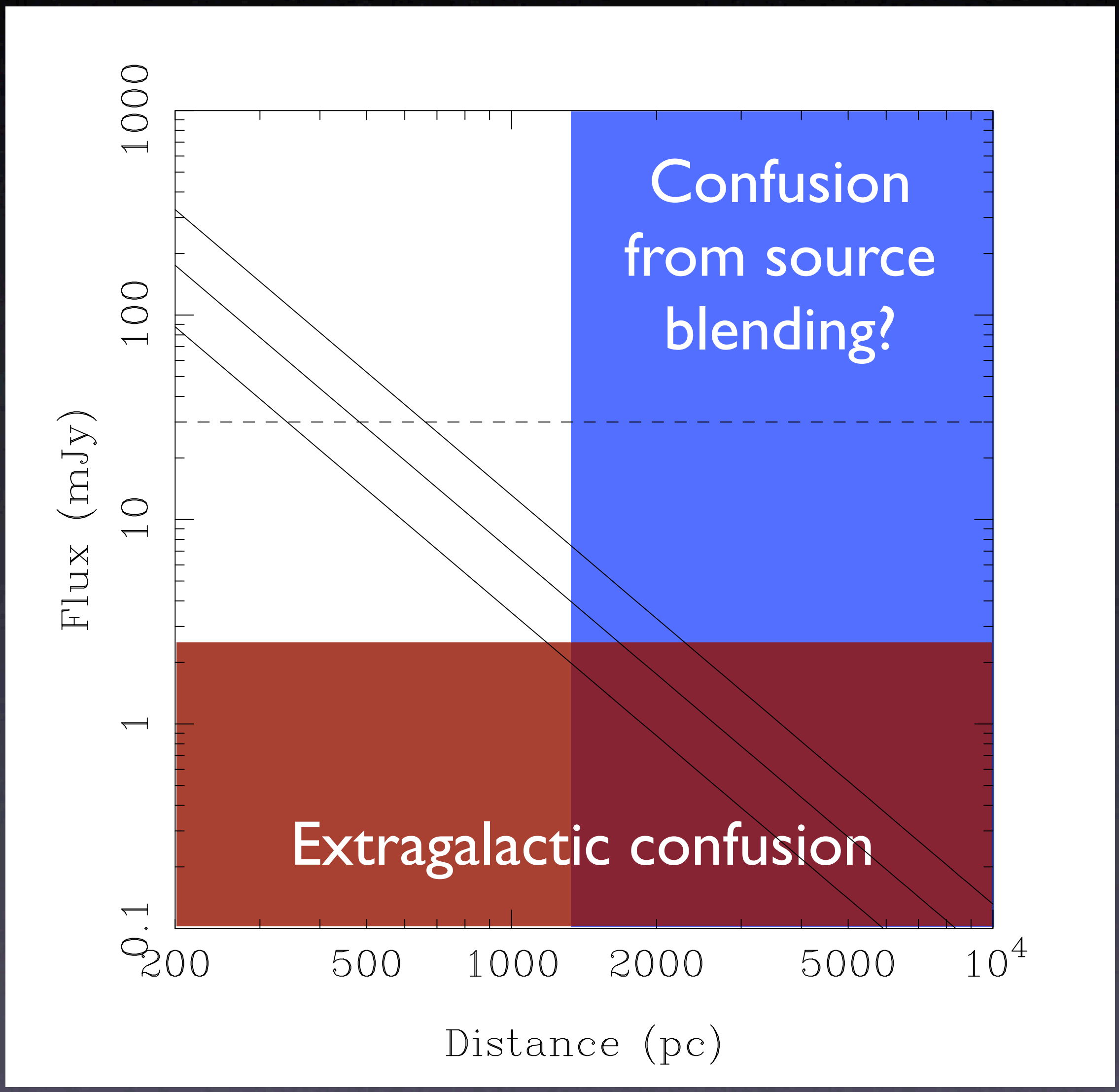


Beuther & Schilke 2004

A major goal is to understand the link between clumps and the IMF.

- limited by lack of statistics at high & low mass end
- limited by sensitivity at low mass end
- limited by angular resolution at very high mass end

JCMT survey parameter space



Solid lines show 850 μm flux vs distance for 0.04, 0.08, 0.15 solar mass core

Dashed line is JCMT Gould Belt Survey 3σ detection limit

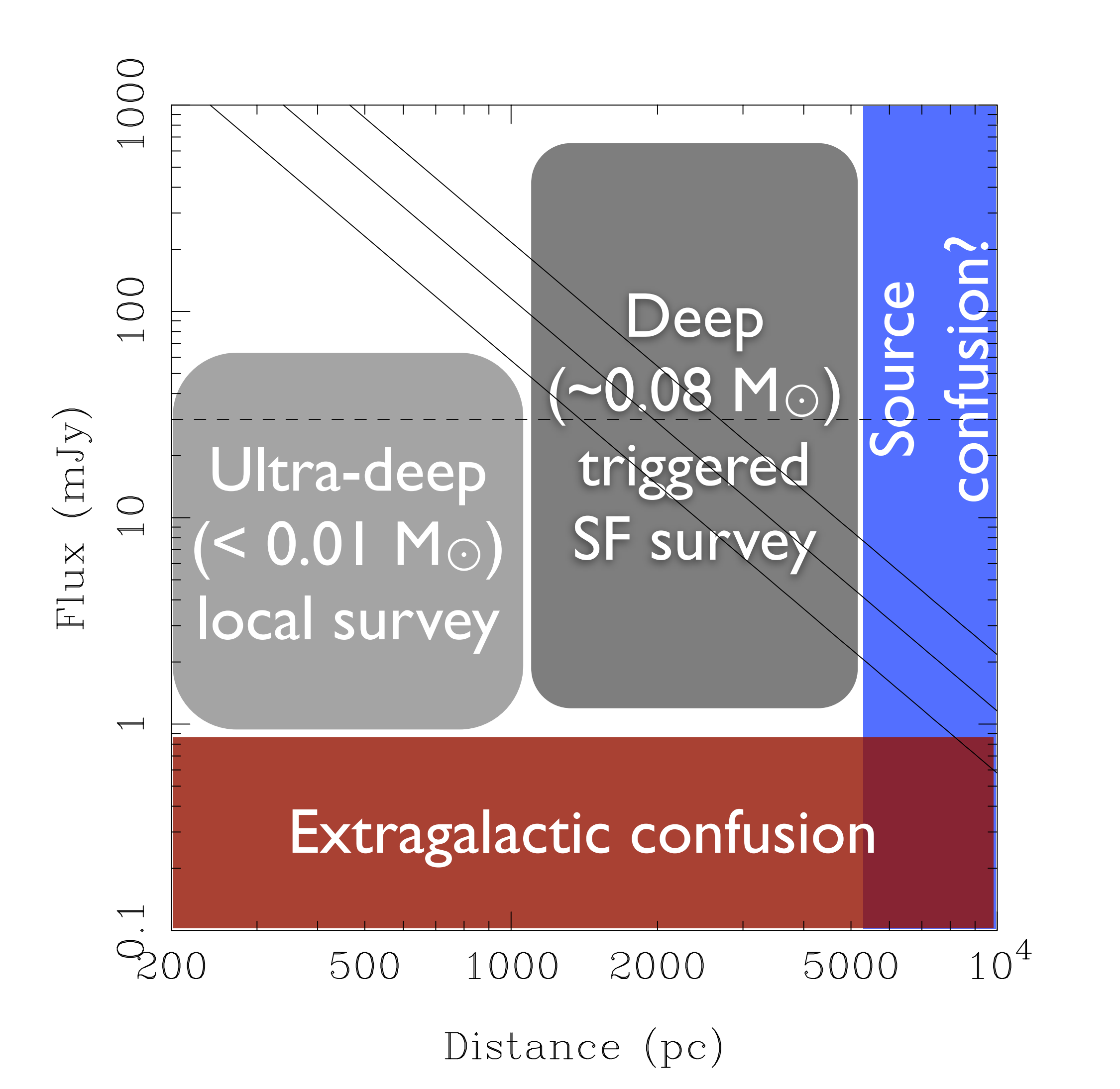
There are two major limitations to the survey parameter space.

Sensitivity: beyond ~1.5 kpc low-mass cores blend into extragalactic confusion limit.

Resolution: beyond ~ 1.5 kpc low-mass cores blend with each other. (IRAS 16293 type objects are confused even at 500 pc)

While *Herschel* is not sensitivity-limited it is very much confusion-limited.

CCAT survey parameter space



Solid lines show 350 μm flux vs distance for 0.04, 0.08, 0.15 solar mass core

Dashed line is JCMT Gould Belt Survey 3σ detection limit

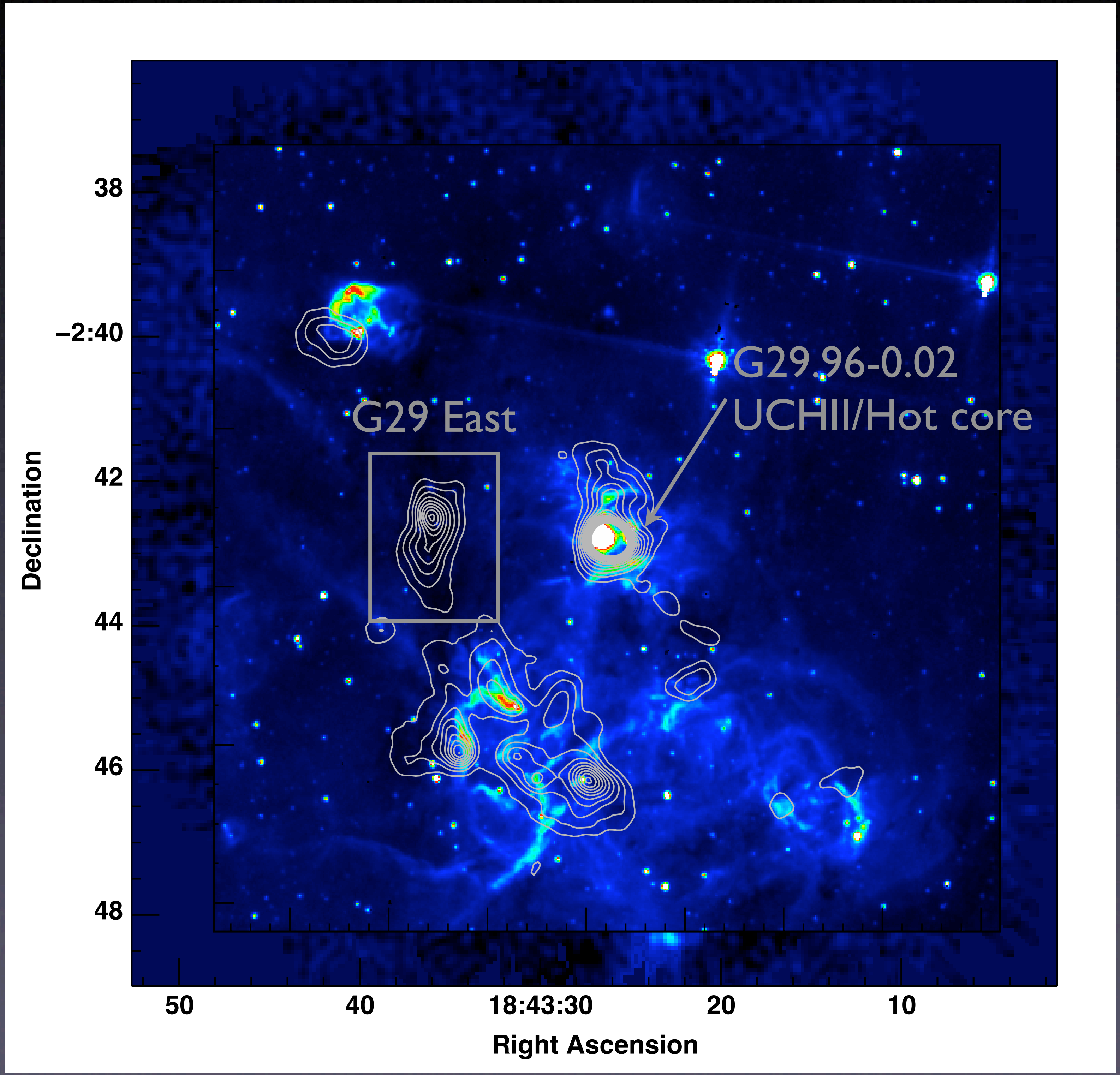
CCAT's improved angular resolution & sensitivity removes these limitations for a large fraction of the Galactic survey parameter space.

Working at 350 μm improves mass sensitivity by an order of magnitude.

Two previously unstudied regimes become accessible:

- Ultra-deep survey of local clouds for 0.01 M☉ objects (free-floating planets?)
- Surveys of nearby HII regions to study how triggering affects the formation of solar and sub-solar mass stars

The high-mass end

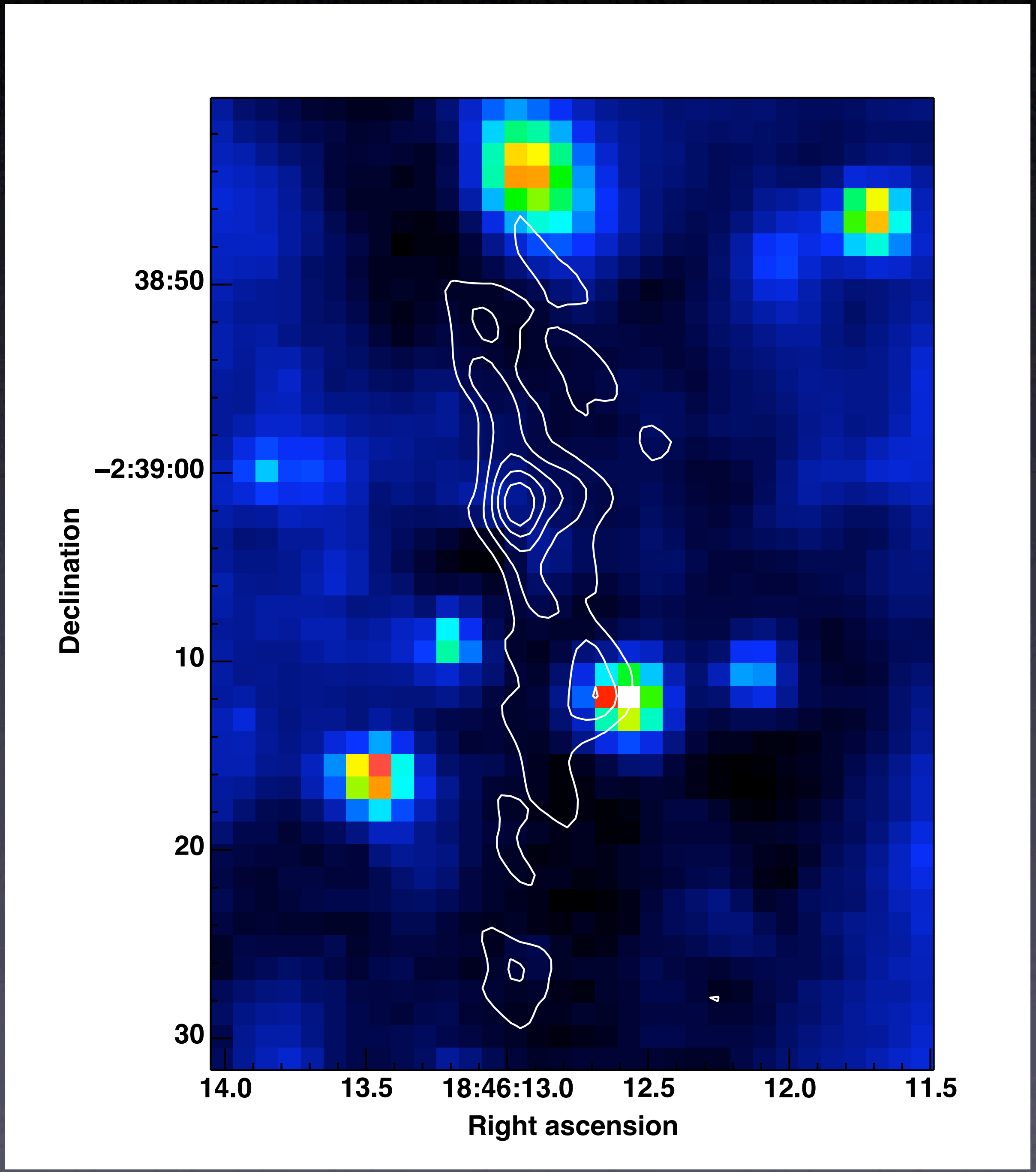


SCUBA 850 μm image from the SCAMPS survey (Thompson+ 2007, in prep).

JCMT/APEX/*Herschel* Galactic Plane surveys will find essentially all massive protocluster & cold precluster clumps (to ~10's $M_\odot$).

But high angular resolution is needed to unravel their nature...

G29 East: a massive protocluster?



PdBI 1.2 mm continuum contours
Spitzer 4.5 μm colourscale

At high angular resolution the SCUBA clump fragments into a chain of massive (25-100 $M_\odot$) cores

Early stage in formation of massive stellar cluster (protocluster)

Brightest core associated with methanol maser (massive YSO)

PdBI resolution 2.1” x 1.5” similar to CCAT at 200 μm.

CCAT can *uniquely* provide high resolution FIR data to constrain the total luminosity of each core.

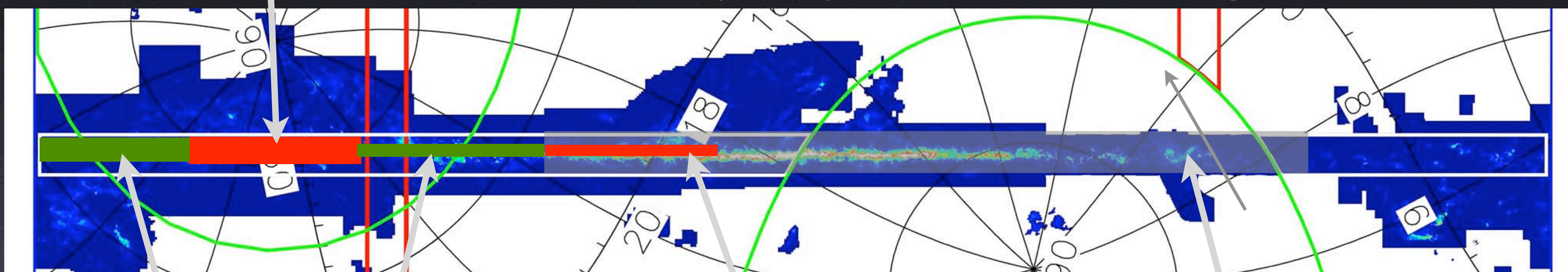
Summary

- Survey astronomy is back to the fore in star formation & a number of surveys are planned or already taking place
  - JCMT/APEX/Spitzer/Herschel surveys of local star formation in the Gould Belt
  - Galactic plane surveys from near-IR to radio & sub-mm
- CCAT has the potential to take star formation surveys into previously unstudied regimes
  - Unconfused ultra-deep surveys for very low-mass objects
  - Wide-area sensitive surveys around distant HII regions – triggering of solar and sub-solar mass star formation
  - 200 μm mapping of massive proto and pre-cluster clumps
  - Wide-area spectroscopic surveys? (GRS in the South)

Wide-area spectroscopy in the South

FCRAO Outer Galaxy Survey
(^{12}CO 1-0, with 50” spacing)

The Dame et al (2001) Galactic ^{12}CO map



Chris Brunt’s Cygnus + E-OGS Surveys
(^{12} CO + ^{13}CO 1-0, with 22” spacing)

NANTEN Galactic Plane survey region
(^{12}CO 1-0, with 4’ spacing)

BU-FCRAO GRS survey region
(^{13}CO 1-0, with 22” spacing)