CCAT Surveys of Molecular Clouds

John Carpenter (Caltech)

On behalf of the CCAT star formation/ISM group

CCAT

Key Questions

CCAT

What controls the star formation rate in clouds?

- How do clouds accrete their material?
- What is the lifetime of clouds?
- How do filaments and cores form and evolve?
- What is the role of turbulence in star formation?

What is the origin of the stellar mass function?

- Is the stellar IMF imprinted in the cloud structure?
- What is the mass-evolution of circumstellar material?

- < 6″ resolution images now available for λ ≤ 70 μm

- Trace the stellar content over entire clouds

Spitzer

NASA/JPL, Caltech, & R. Gutermuth

WISE

NASA/JPL - Caltech/WISE Team

Herschel

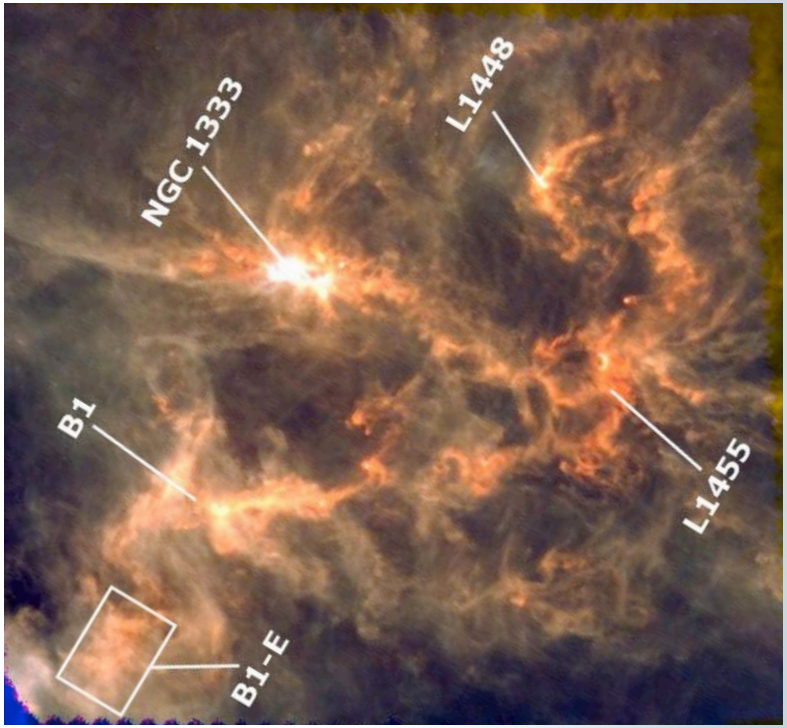
ESA; the PACS, SPIRE and HSC consortia; F. Motte for the HOBYS team

Gas and Dust in Clouds

FCRAO ^{12}CO 1-0

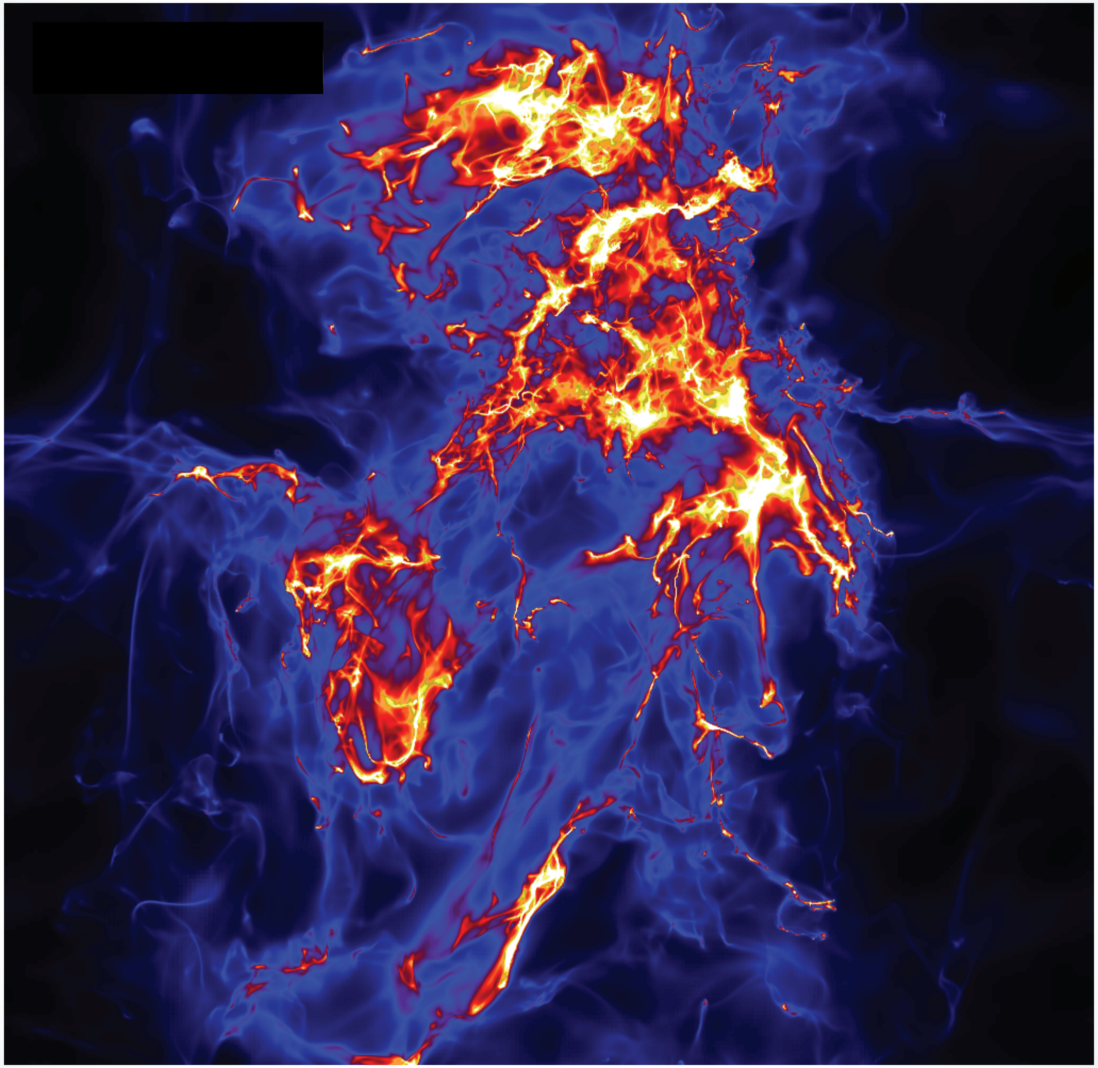
Goldsmith et al (2008)

Herschel continuum



Sadavoy et al (2012)

Supersonic MHD Turbulence



Model from Padoan, Haugbølle, Nordlund

Why CCAT?

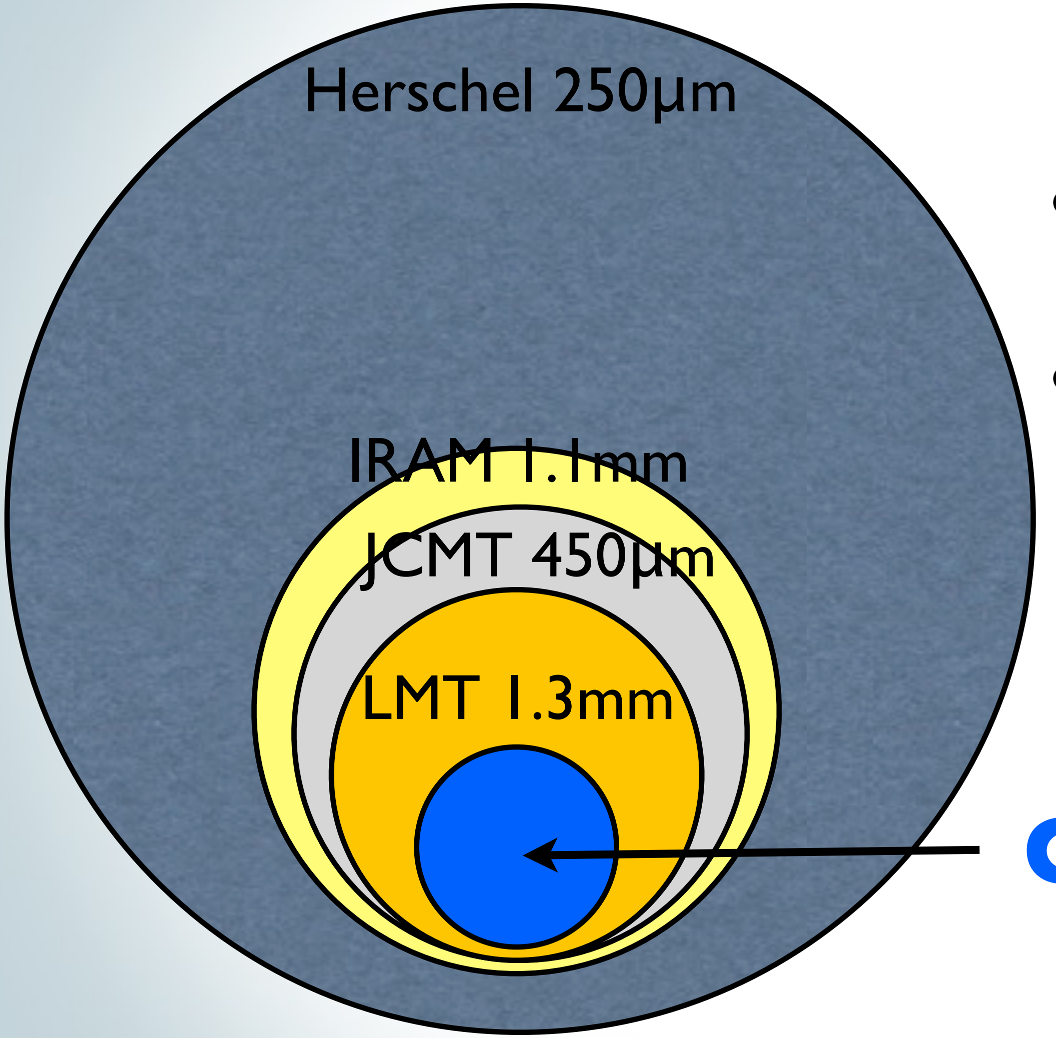
Angular resolution AND large area AND sensitivity

Resolution	:	Resolve protostar envelopes and cores
Area	:	Map entire clouds
Sensitivity	:	~ 1 mJy RMS at 350 μm

Tracers

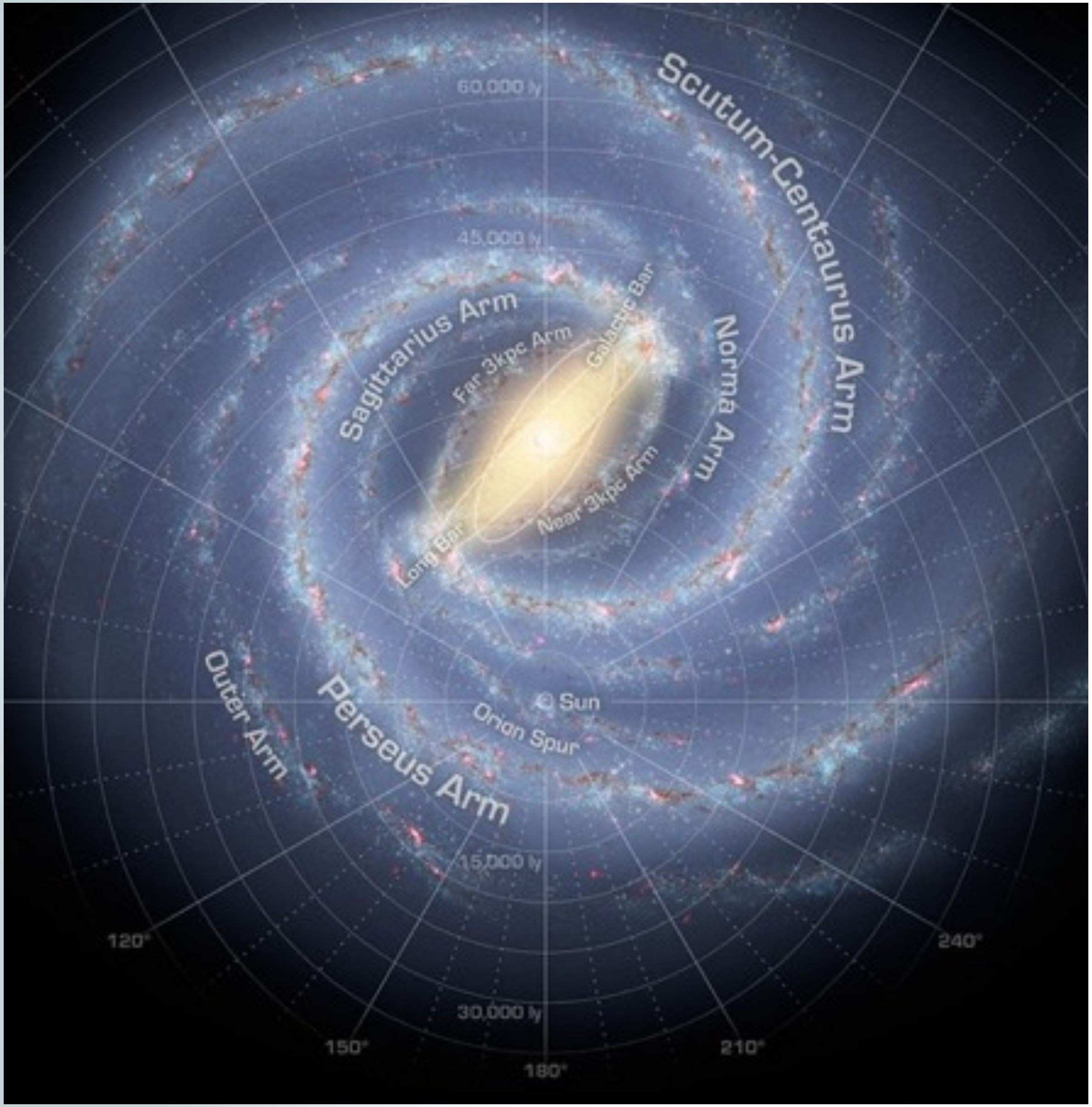
Continuum	:	Dense cores
Neutral Carbon	:	Transition from atomic to molecular gas
CO J=4-3, 7-6	:	Outflows, warm dense gas

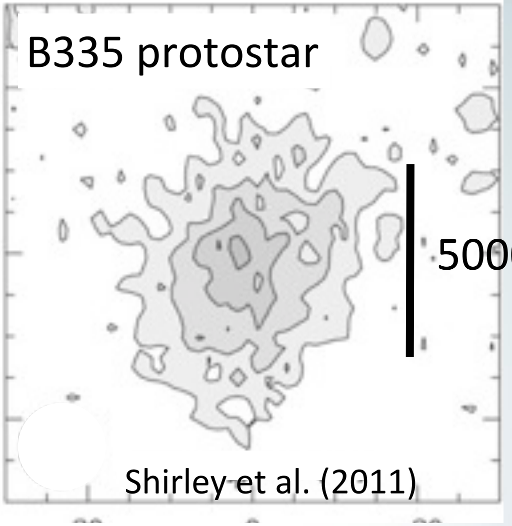
Angular Resolution

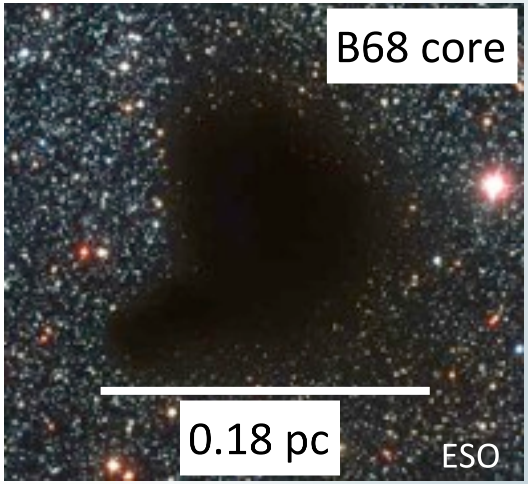


- 3.5″ resolution @ 350 µm
- Better than Spitzer (MIPS), Herschel, and WISE

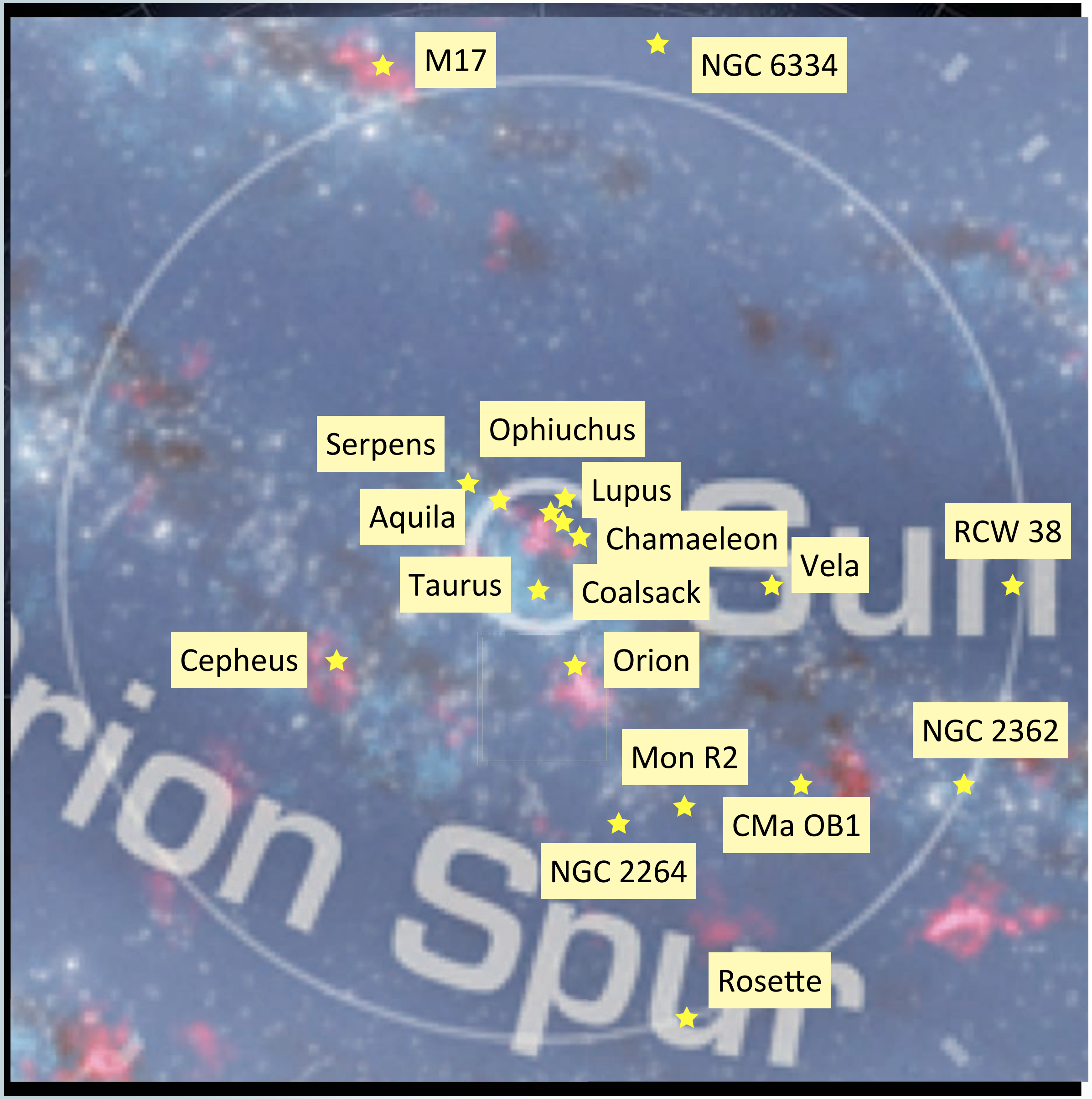
Protostars & Cores

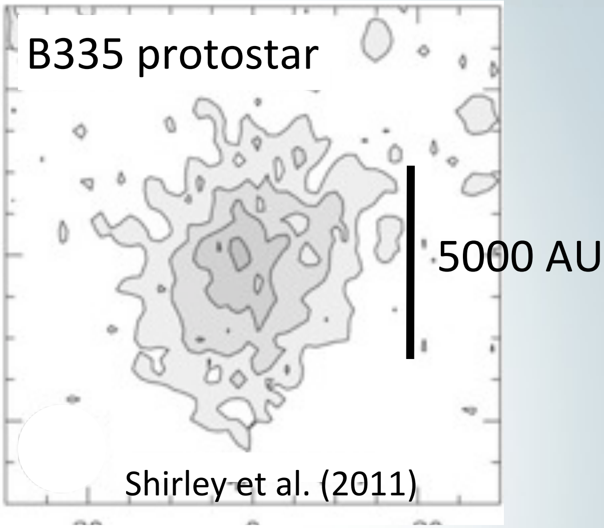




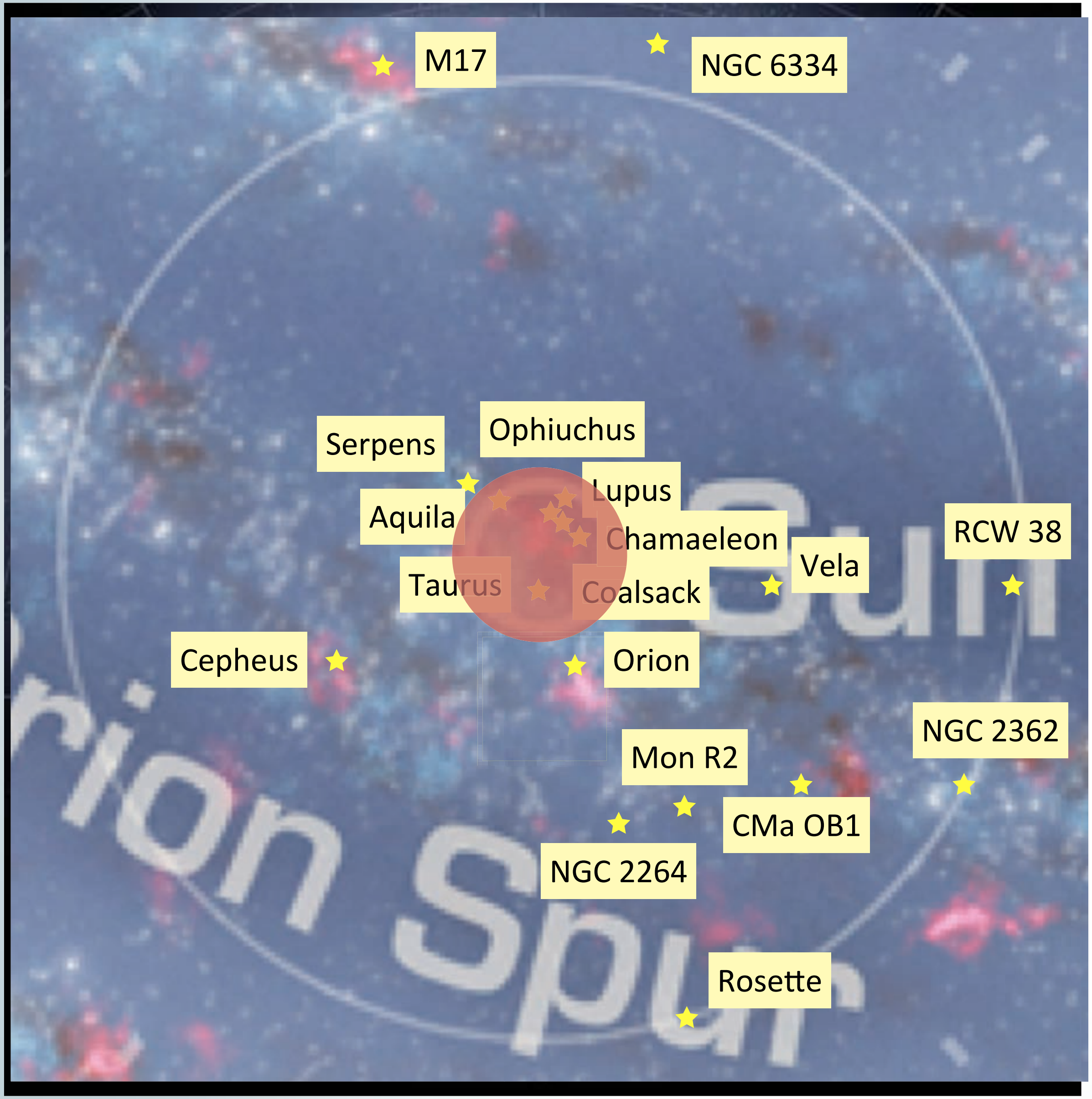


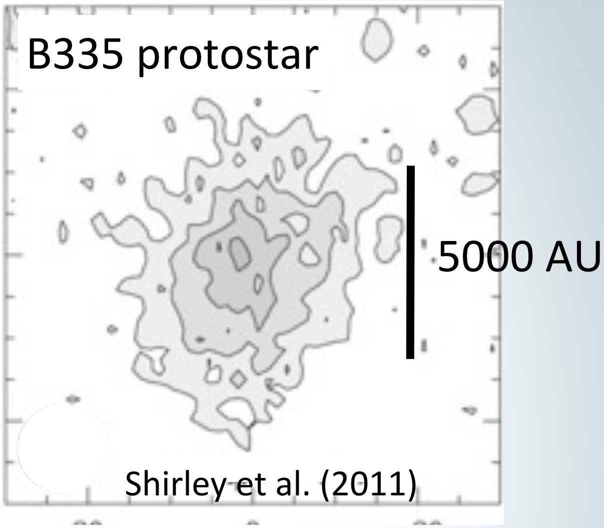
Protostars


M17
NGC 6334
Serpens
Ophiuchus
Lupus
Aquila
Chamaeleon
Vela
RCW 38
Taurus
Coalsack
Cepheus
Orion
NGC 2362
Mon R2
CMa OB1
NGC 2264
Rosette
Sun
Orion Spur


B335 protostar
5000 AU
Shirley et al. (2011)

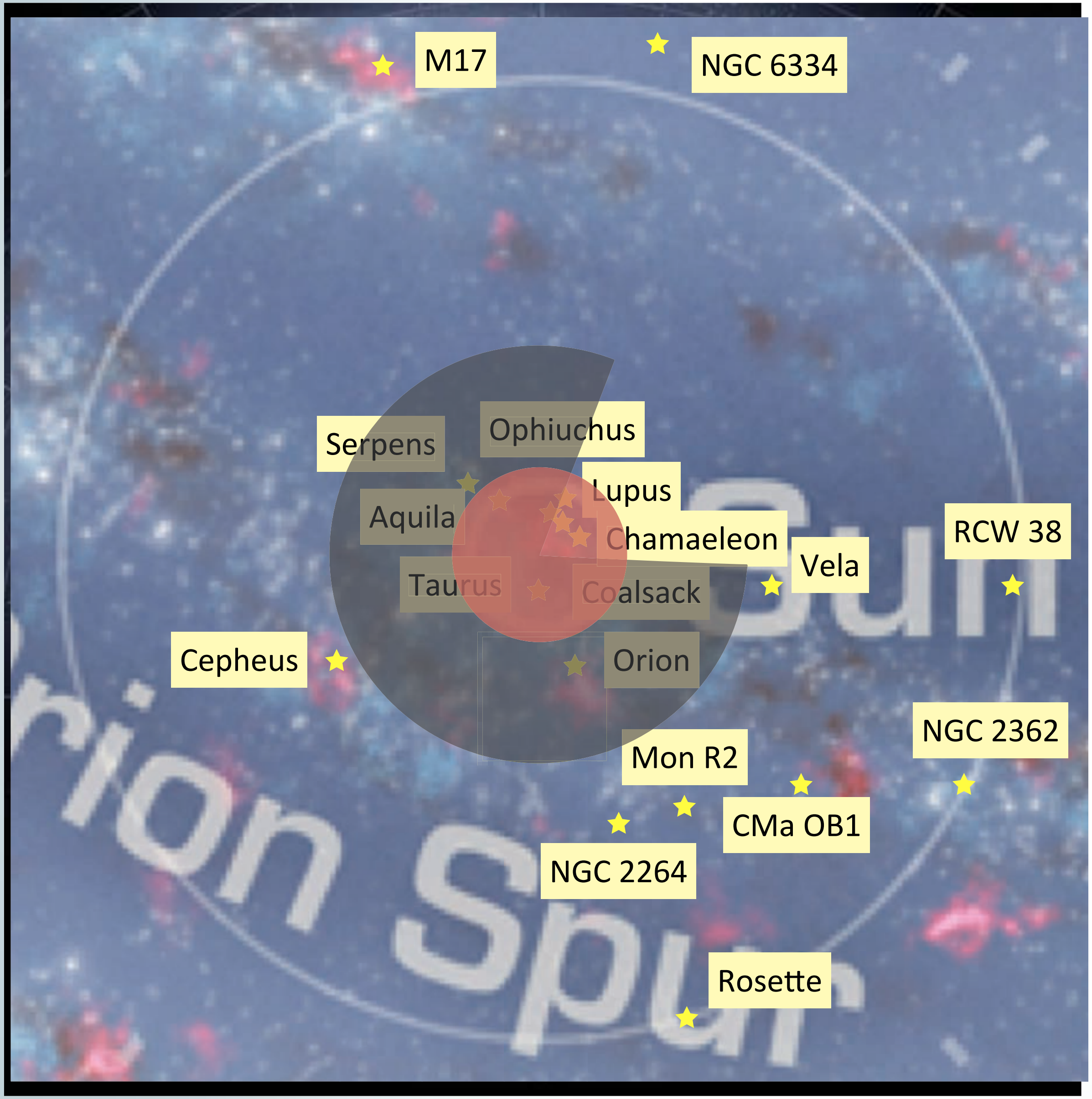
Protostars

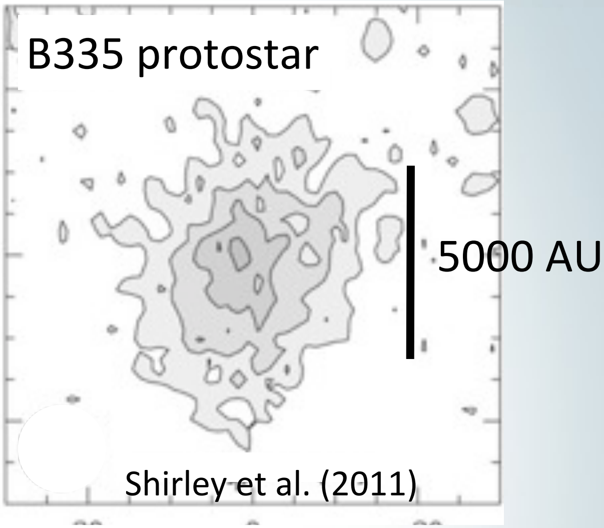




Herschel 250µm

Protostars

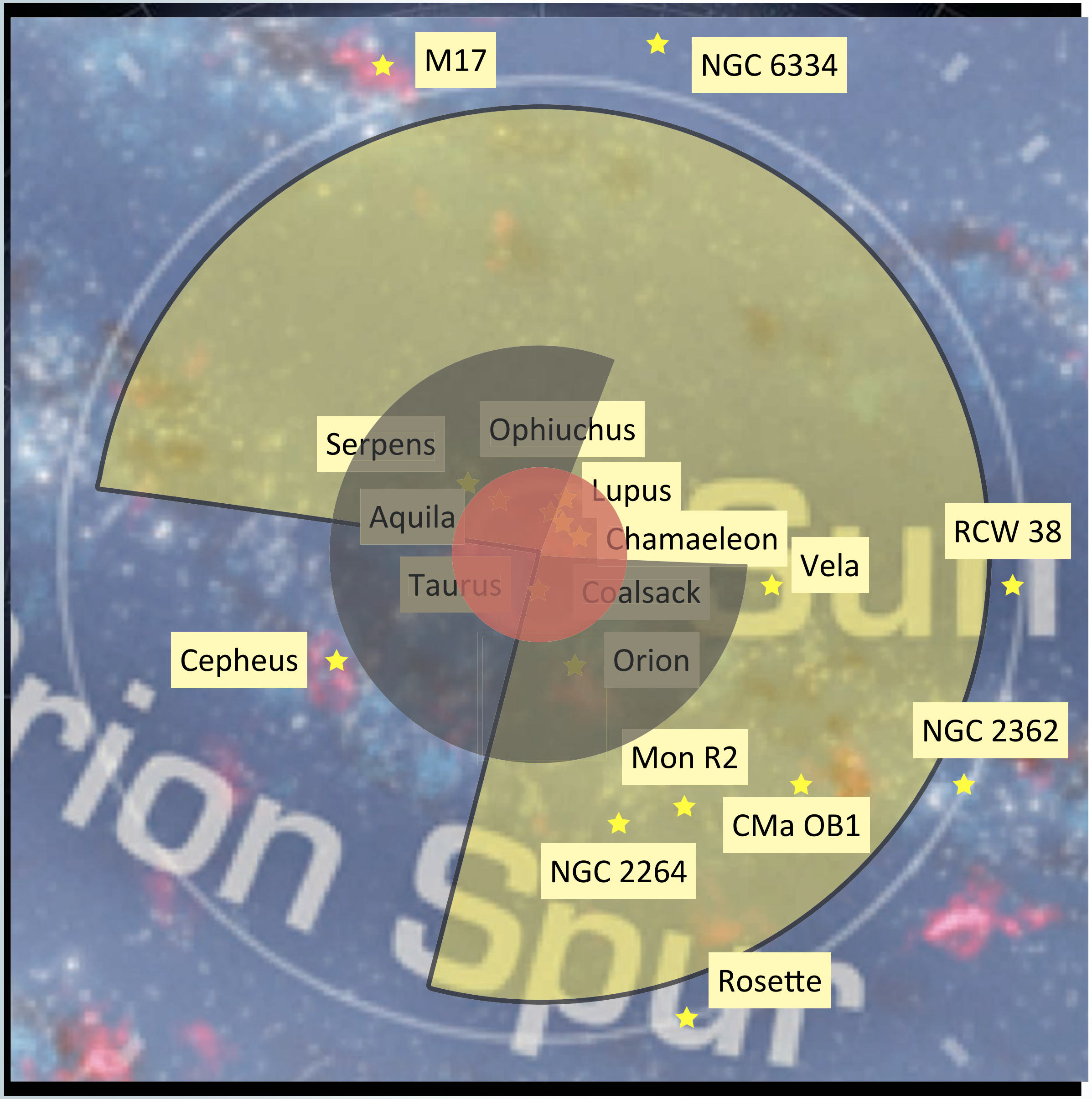




Herschel 250µm

JCMT 450µm

Protostars


M17
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Taurus
Coalsack
Cepheus
Orion
NGC 2362
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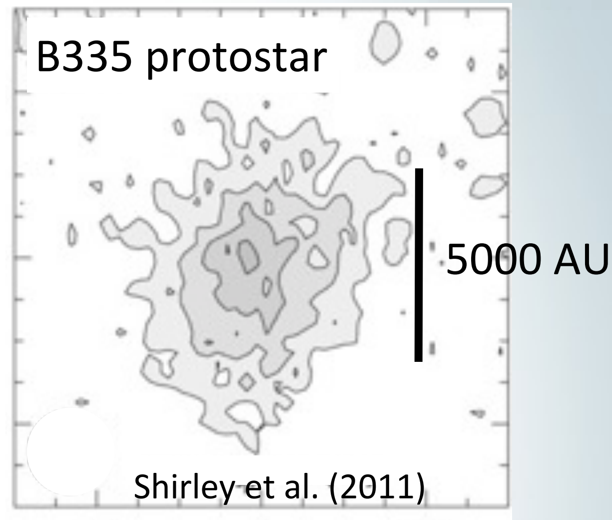
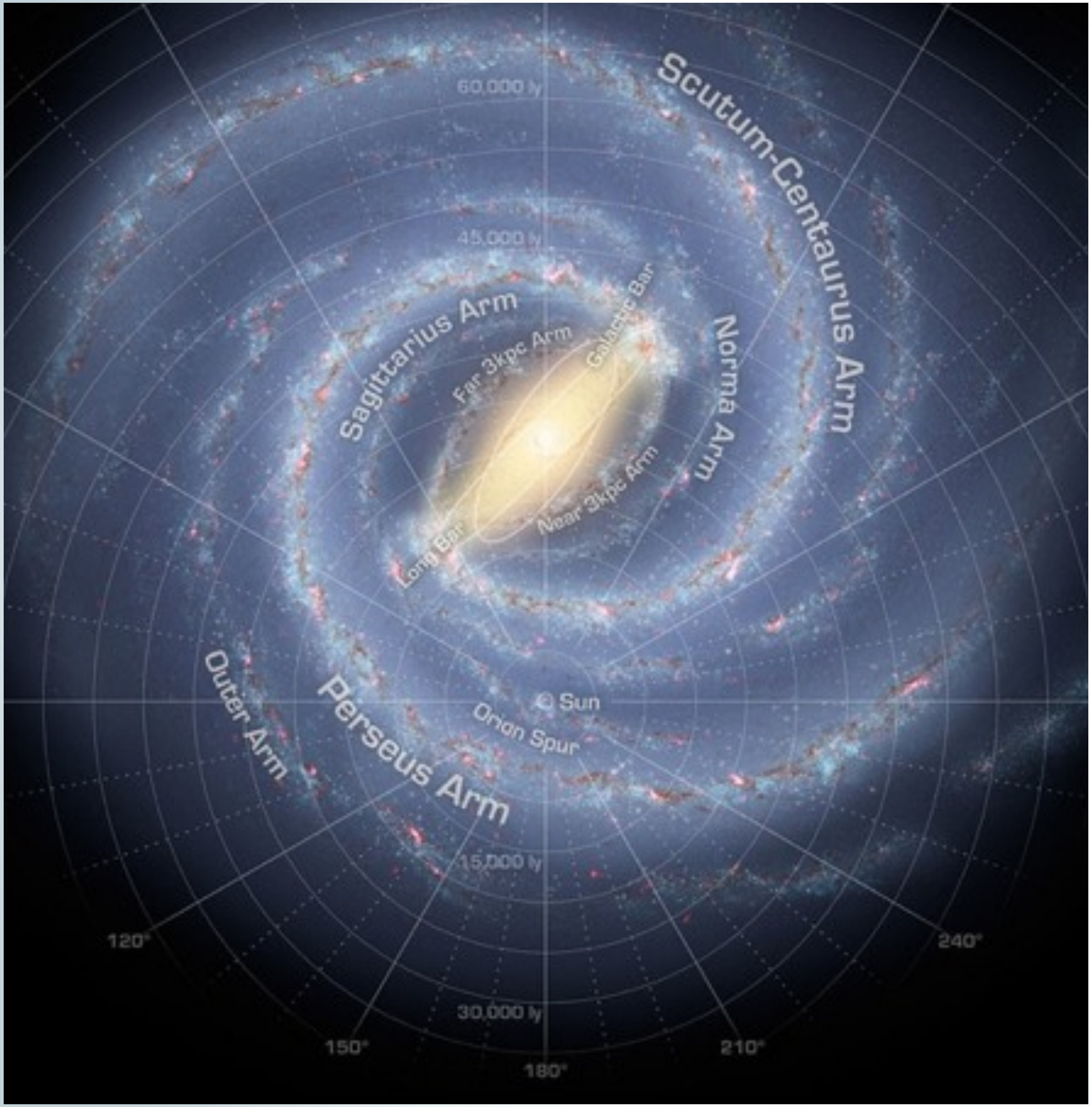
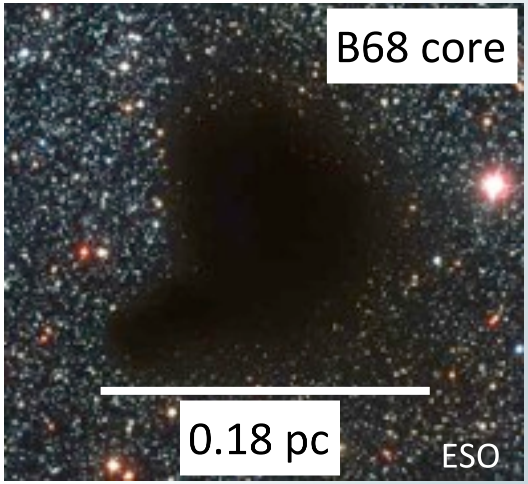
CMa OB1
NGC 2264
Rosette
Herschel 250µm
JCMT 450µm
CCAT 350µm


B335 protostar
5000 AU
Shirley et al. (2011)

Cores

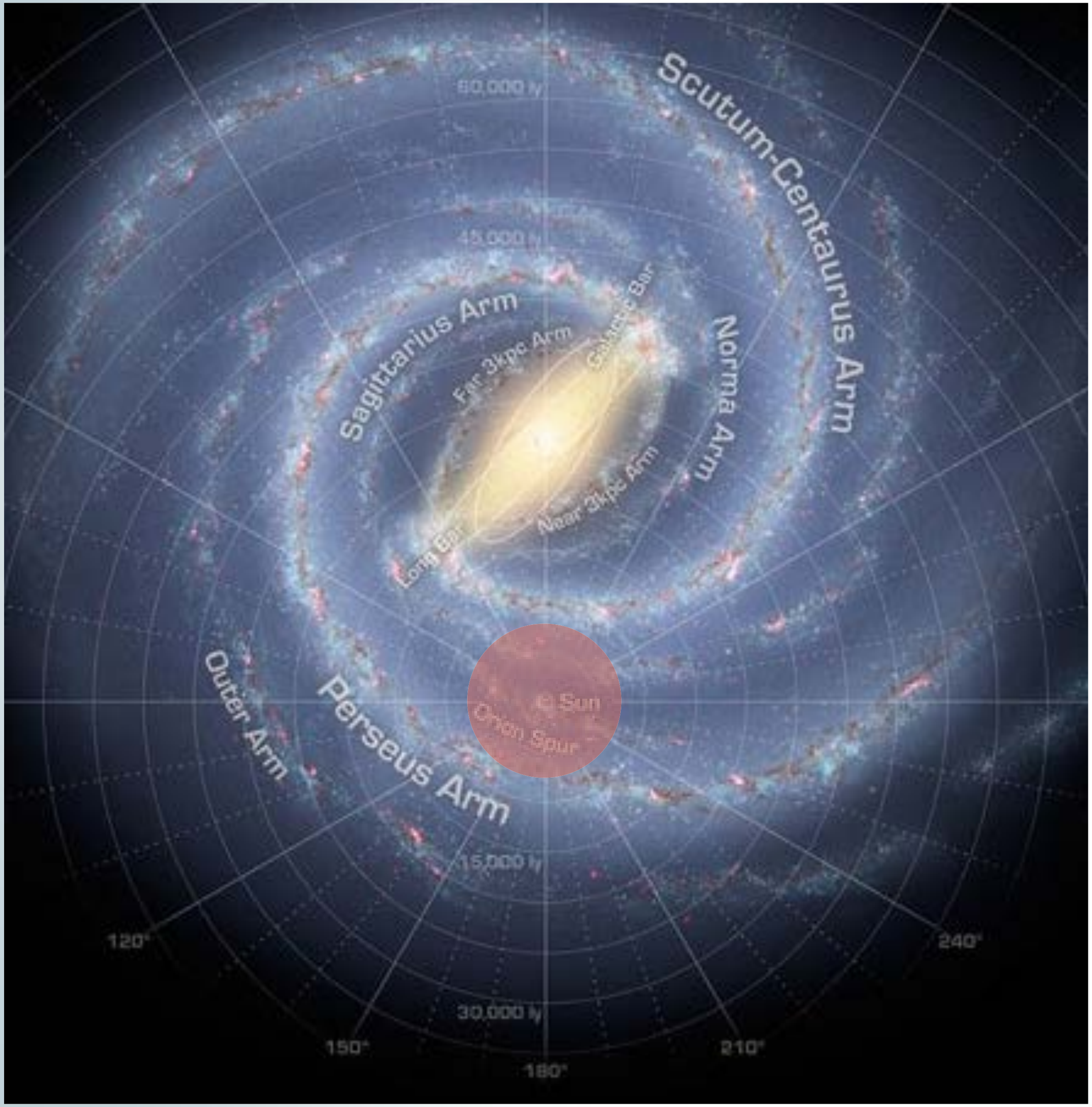


Scutum-Centaurus Arm
Sagittarius Arm
Norma Arm
Far 3kpc Arm
Galactic Bar
Near 3kpc Arm
Long Bar
Perseus Arm
Outer Arm
Sun
Orion Spur
60,000 ly
45,000 ly
15,000 ly
30,000 ly
120°
150°
180°
210°
240°

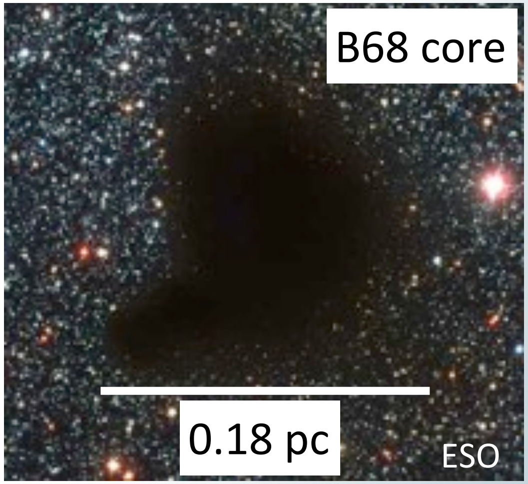


B68 core
0.18 pc
ESO

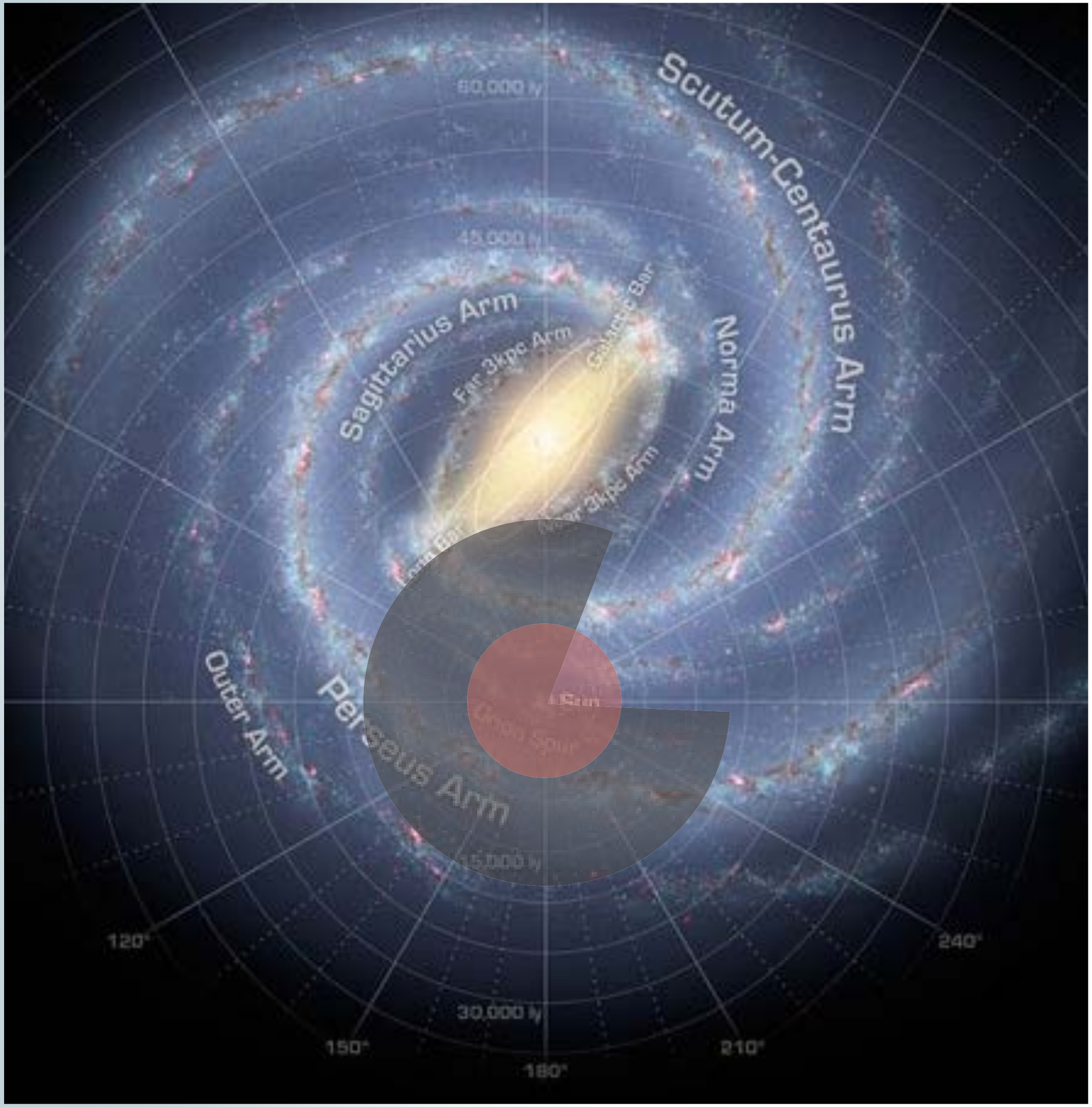
Cores



Herschel 250μm

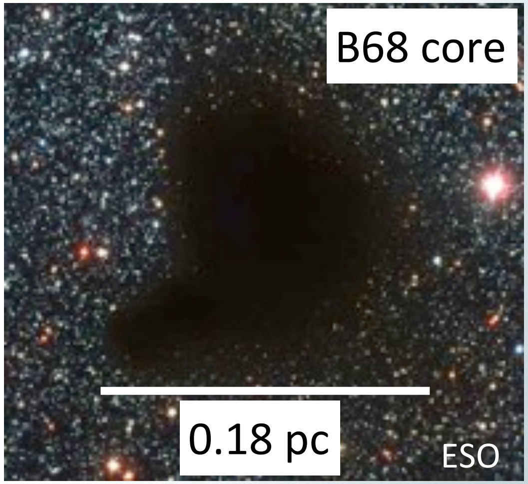


Cores



Herschel 250μm

JCMT 450μm



Cores

Herschel 250μm

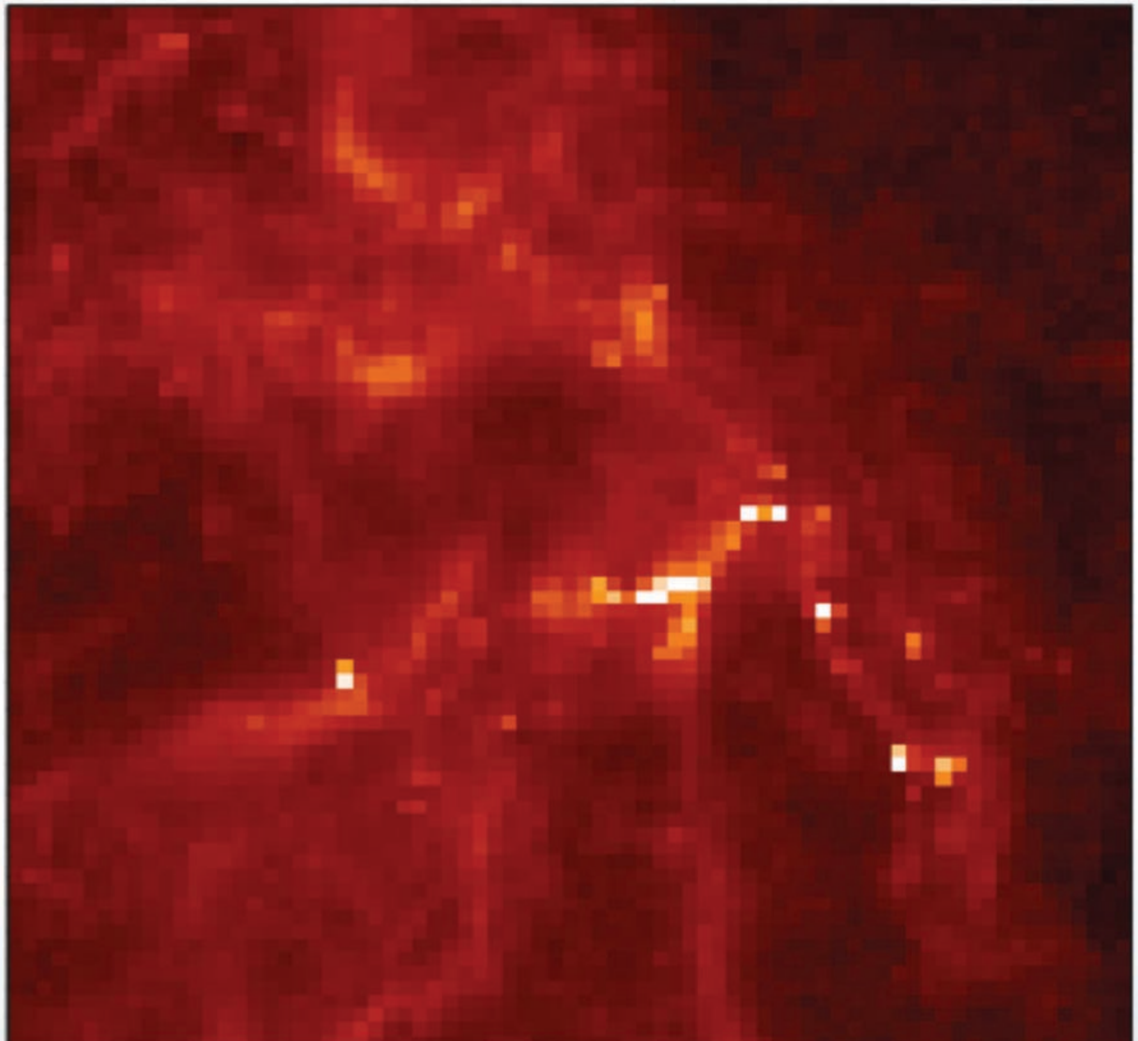
JCMT 450μm

CCAT 350μm

ESO

Tracing Dust in Clouds

Herschel 250µm

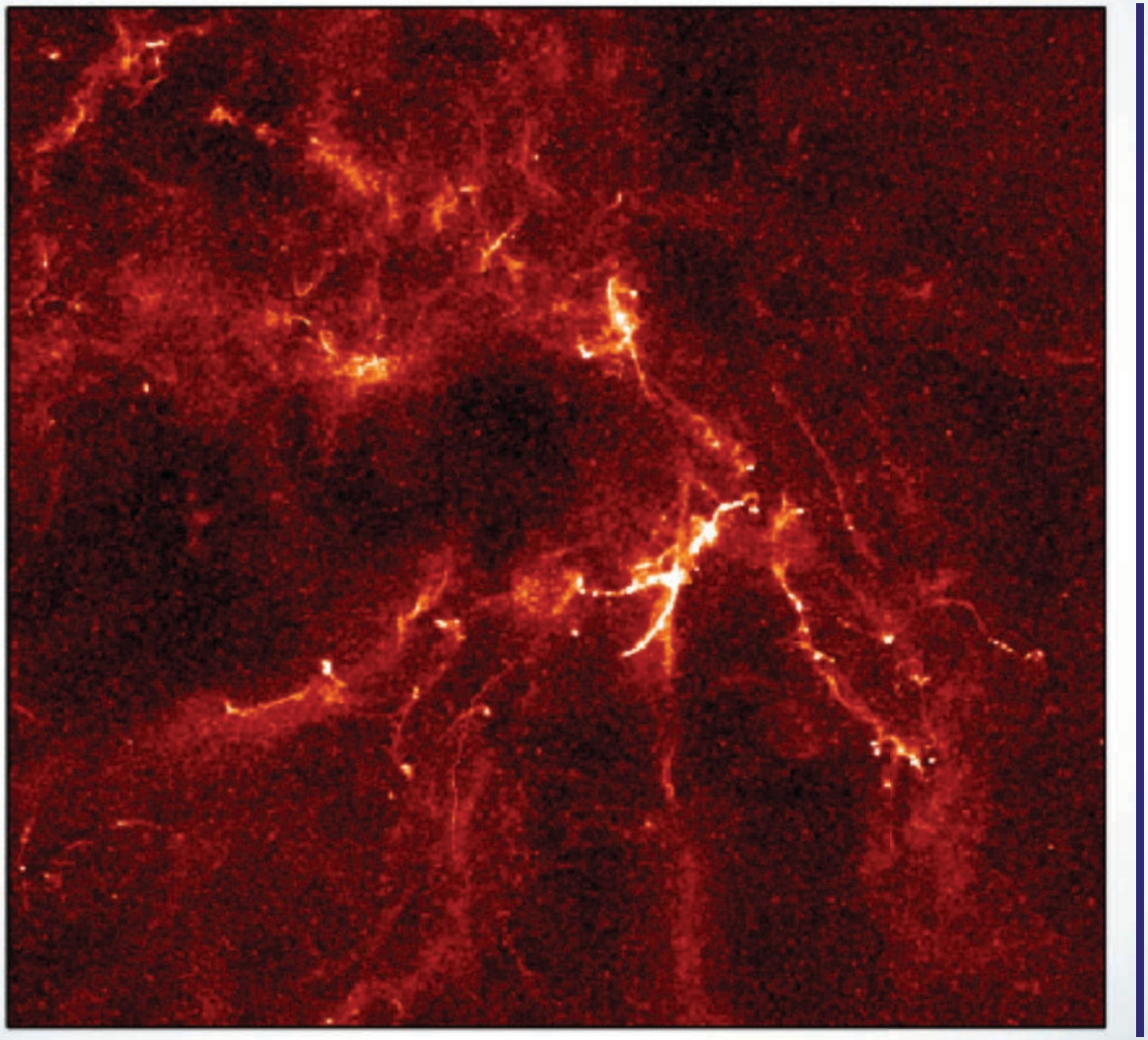


22 arcmin

Model from Padoan, Haugbølle, Nordlund

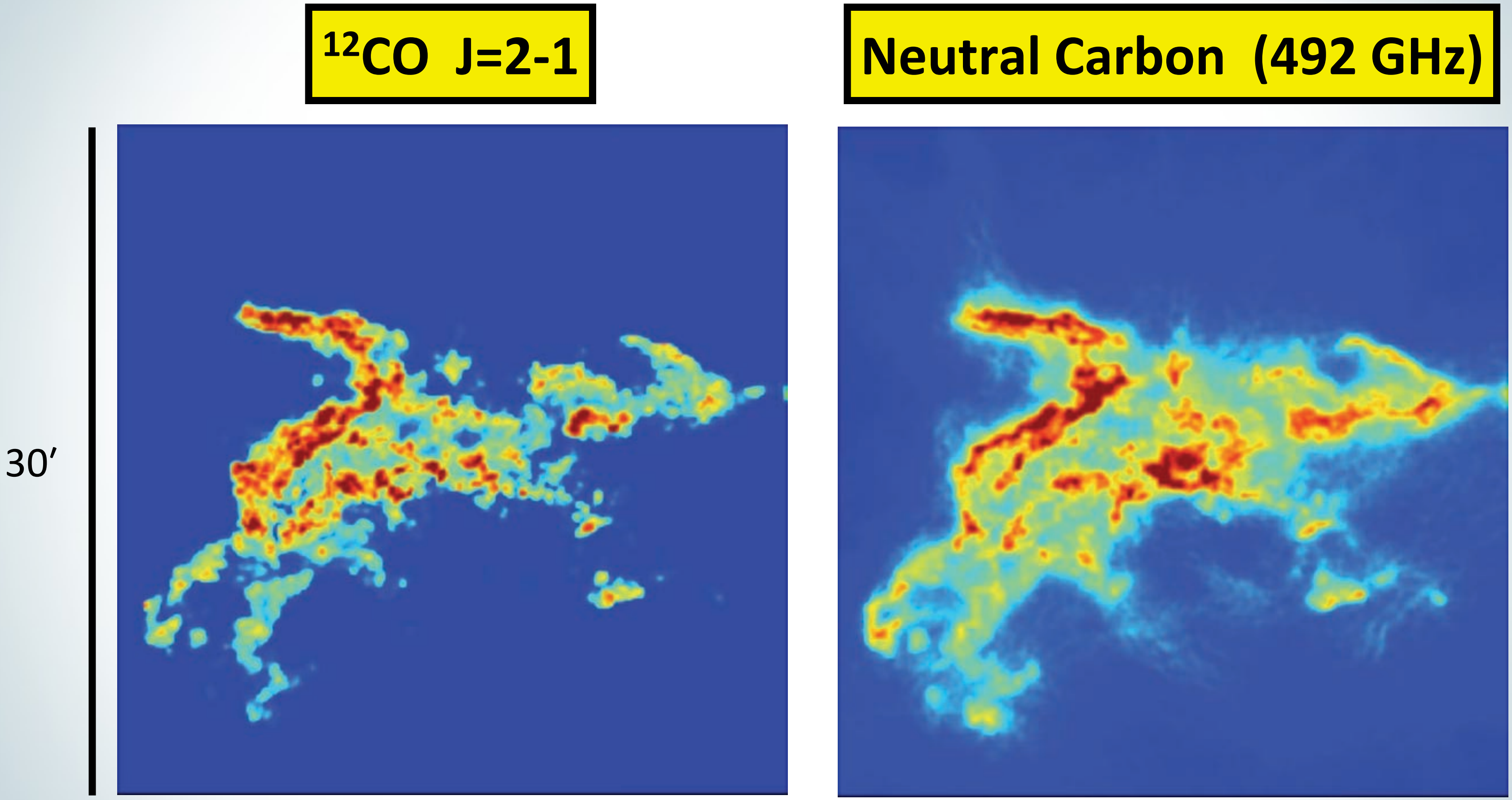
Tracing Dust in Clouds

CCAT 350μm



Model from Padoan, Haugbølle, Nordlund

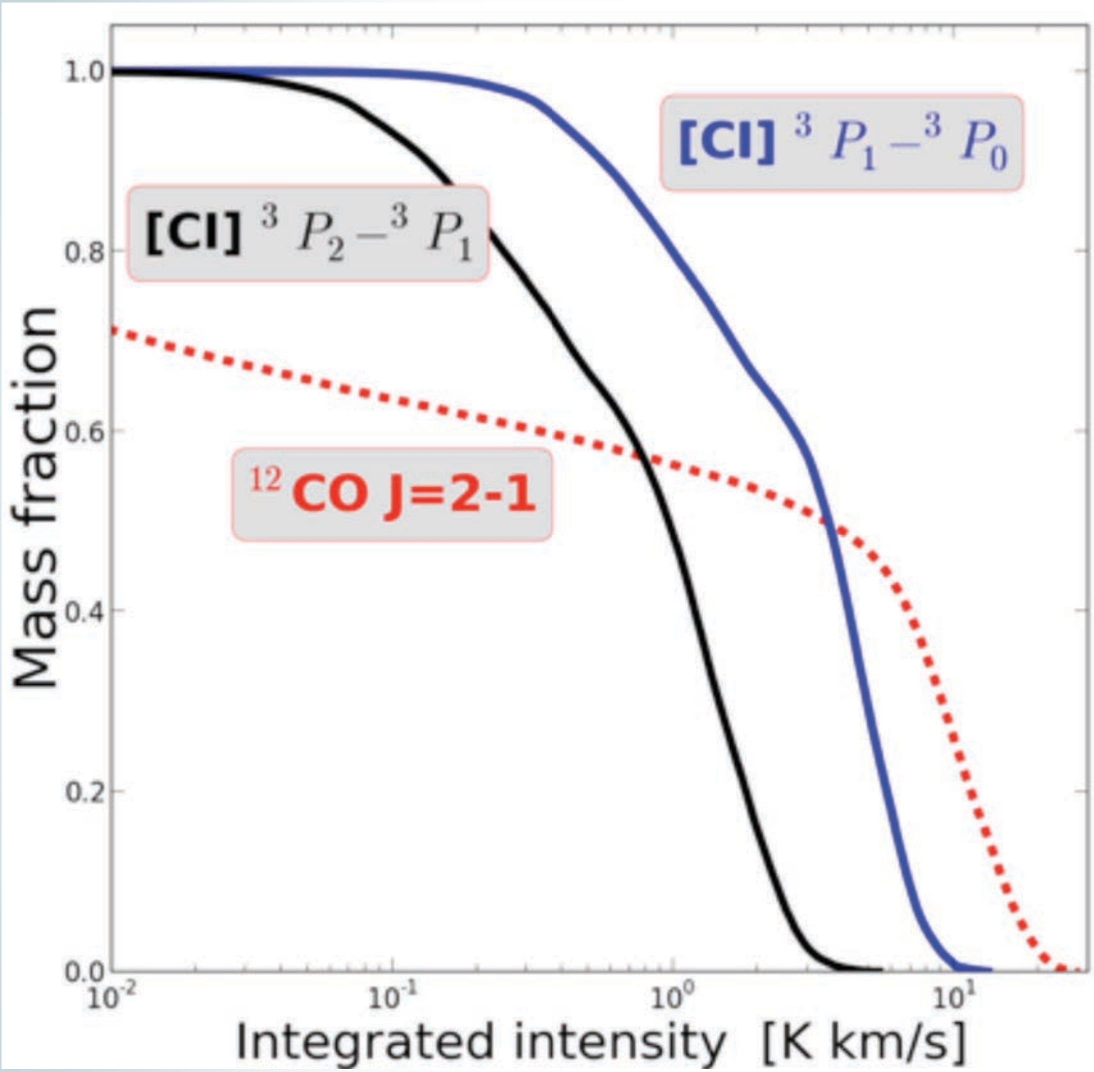
Tracing gas in clouds



Neutral carbon traces atomic and molecular regions

Model from Faviola Molina & Heidelberg group

Tracing gas in clouds

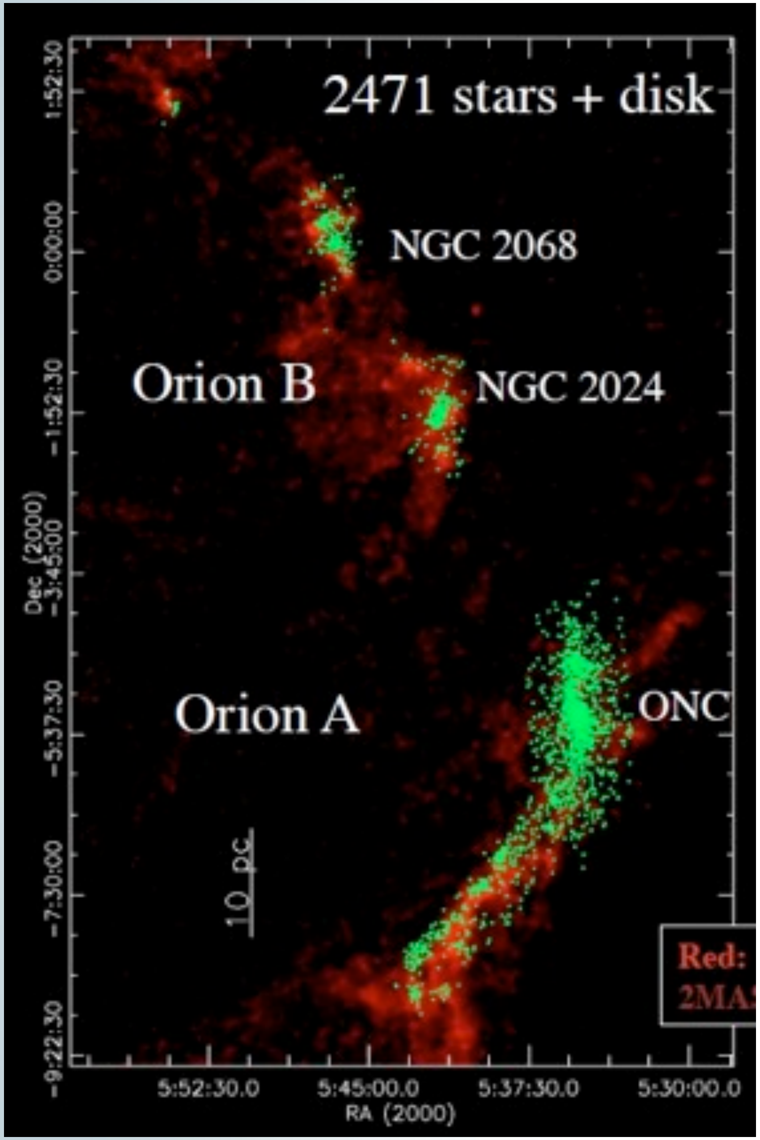


Model from Faviola Molina & Heidelberg group

- [CI] traces 93% of cloud mass (vs. 59% for ^{12}CO)

  (assumes σ = 0.1 K in 0.5 km/s channels)

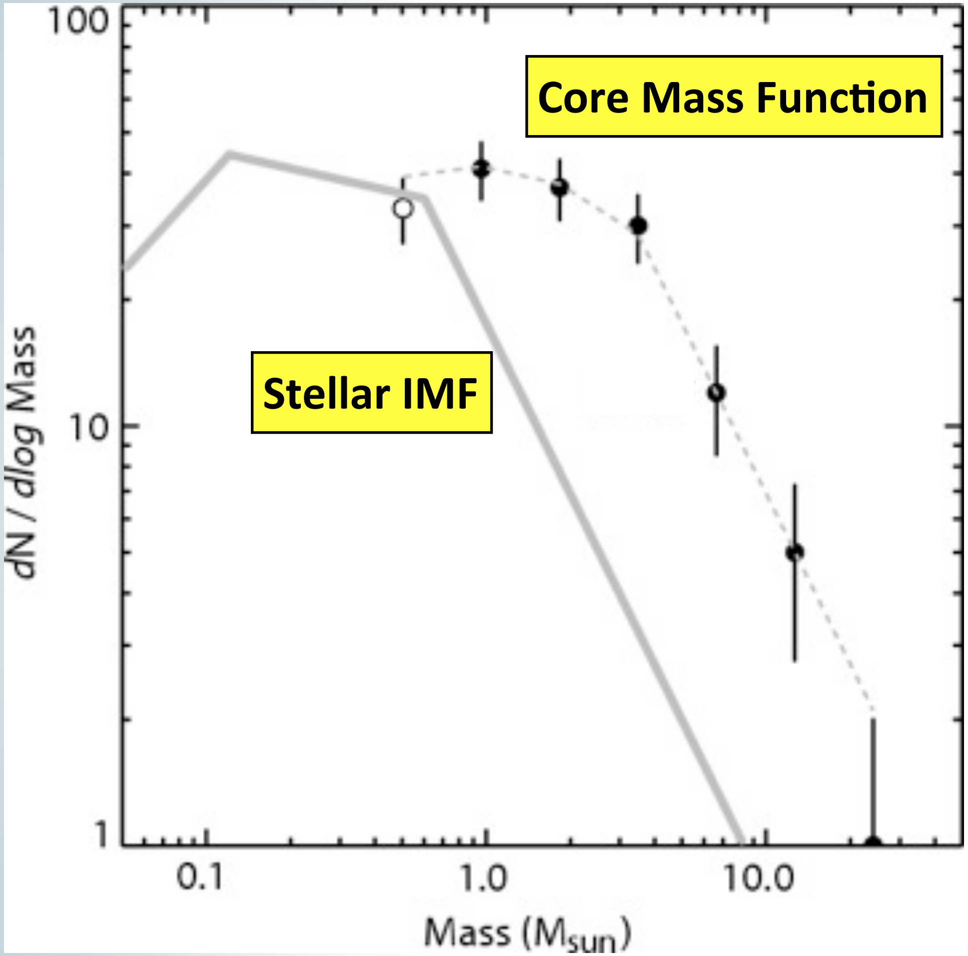
Cores, Protostars, and Disks



Megeath et al. (2012)

- CCAT will detect thousands of cores, protostars, and disks
- CCAT will trace the evolution of circumstellar matter

Core Mass Function

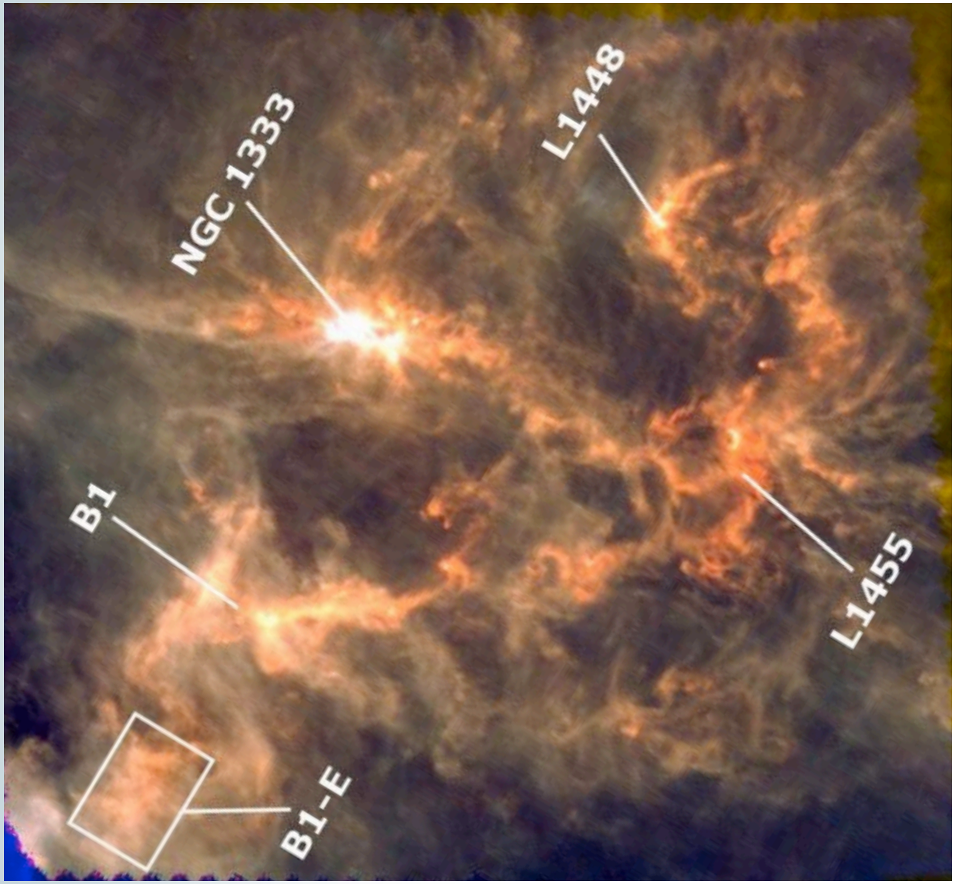


Alves et al. 2007

- CCAT will count individual cores over entire clouds
- CCAT will determine if core mass function follows stellar IMF into the substellar regime

Large-scale flow of gas

Herschel dust continuum



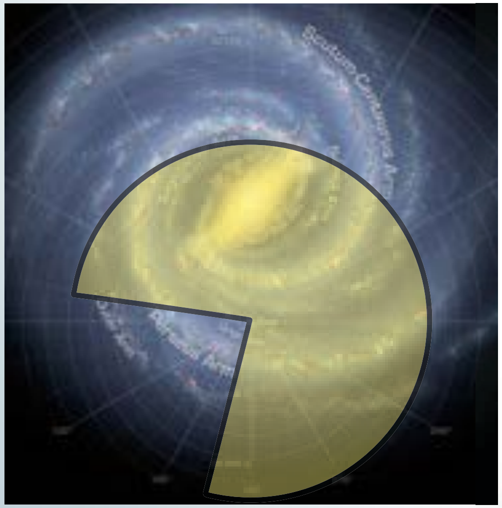
Sadavoy et al (2012)

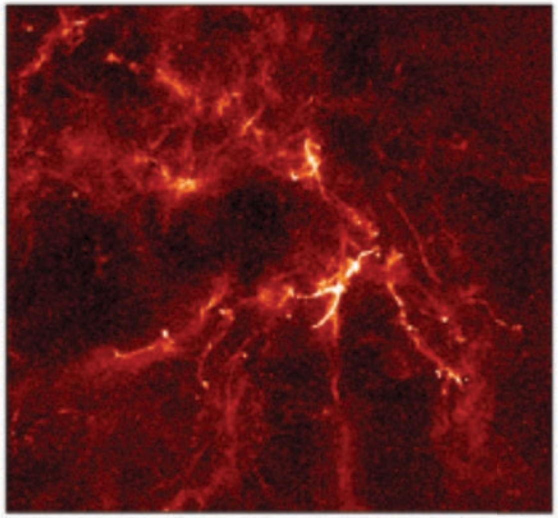
- CCAT spectroscopy will trace the flow of gas from the diffuse gas to filaments, cores, and protostars
- Unbiased surveys of outflows
- Size scales for turbulent dissipation

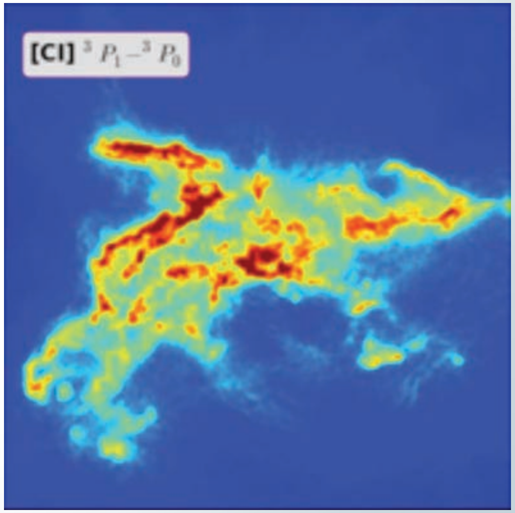
Summary

CCAT will ...

- survey dust and gas over entire molecular clouds
- detect thousands of cores, protostars, and disks
- probe the origin of clouds and stars







CCAT Posters

Poster	Author	Title
150.01	**Riechers**	Studies of the Interstellar Medium in z>5 Star-Forming Galaxies Through the 158 Micron [CII] Line
150.02	**Armus**	Observing Nearby Galaxies with CCAT
150.03	**Zemcov**	SCUBA-2 Surveys for Distant Galaxies: the SCUBA-2 Lensing Survey (S2LS)
150.04	**Carpenter**	Imaging Debris Disks with CCAT
150.05	**Lis**	Solar System Studies with CCAT
150.06	**Glenn**	The CCAT Telescope
150.07	**Stacey**	The Design of the Short Wavelength Camera for the CCAT Telescope
150.08	**Golwala**	The Design and Science Goals of LWCam, the CCAT Long-Wavelength Imager
150.09	**Bradford**	X-Spec: A Multi-Object Wideband Survey Spectrograph for CCAT

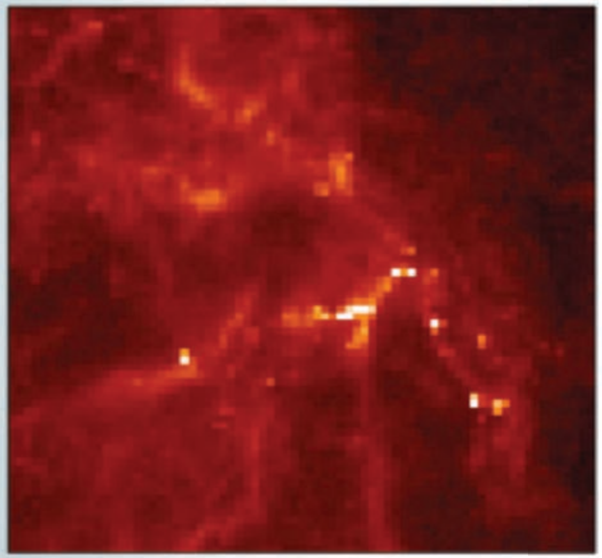
CCAT

Backup slides

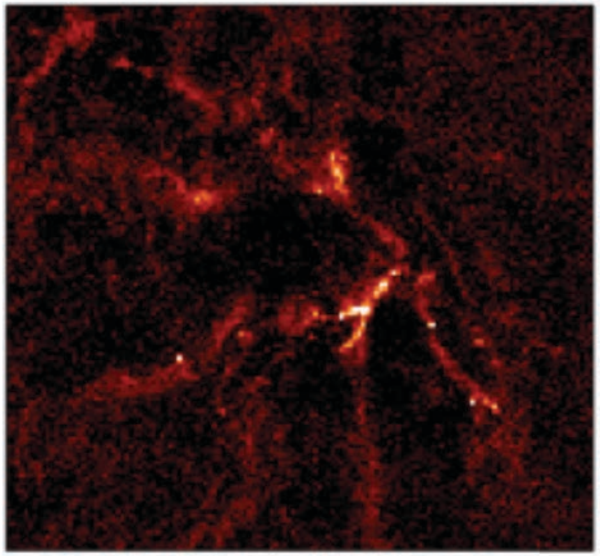
Tracing Dust in Clouds

CCAT

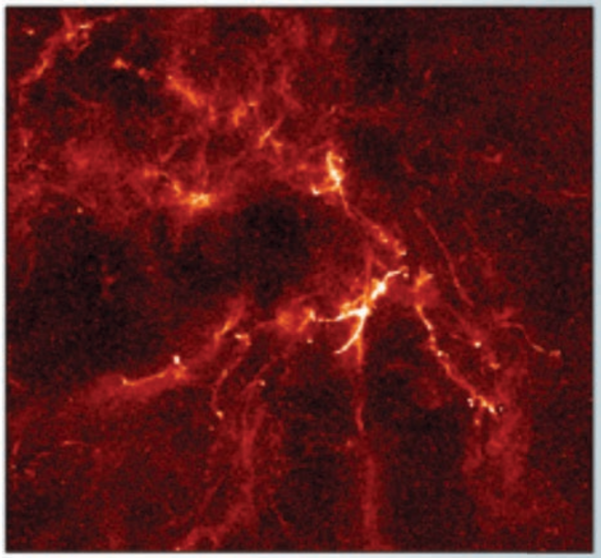
Herschel 250μm



JCMT 450μm



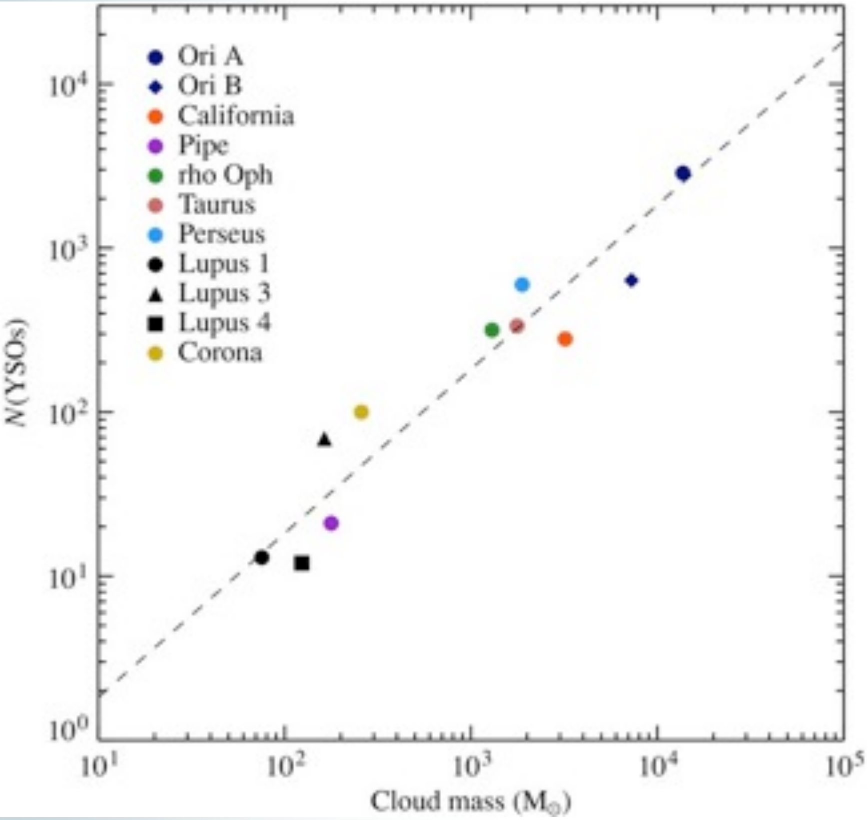
CCAT 350μm



Model from Padoan & Nordlund

Threshold for Star Formation

Number young stars vs. Mass of dense gas



Lada et al. (2010)

- Correlation between star formation rate and mass of dense gas

- CCAT will determine the densities needs to form stars on 1000 AU size scales