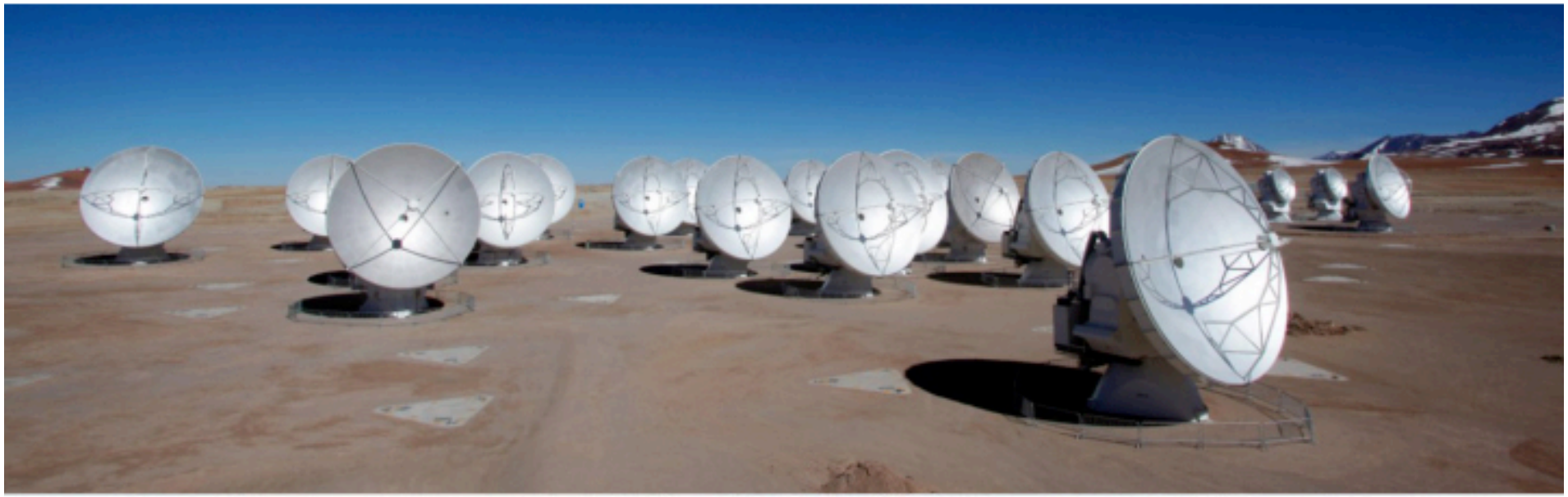
NRAO Instruments Provide Unique Windows On Star Formation

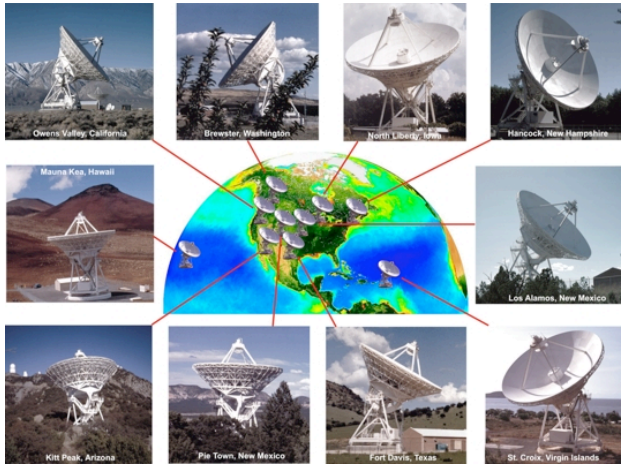


Crystal Brogan
North American ALMA Science Center

Atacama Large Millimeter/submillimeter Array
Expanded Very Large Array
Robert C. Byrd Green Bank Telescope
Very Long Baseline Array

NRAO

Unique Windows on Star Formation:



VLBA: Exquisite astrometry

GBT: Sensitivity to large scale structures and fast mapping

ALMA: Revealing the dust and gas within the obscured heart of star forming regions

EVLA: Probe optically thin dust, as well as molecular and ionized gas

…critical to answer key NWNH questions on star formation

Key Science: Bar and Spiral Structure Legacy (BeSSeL) Survey

VLBA

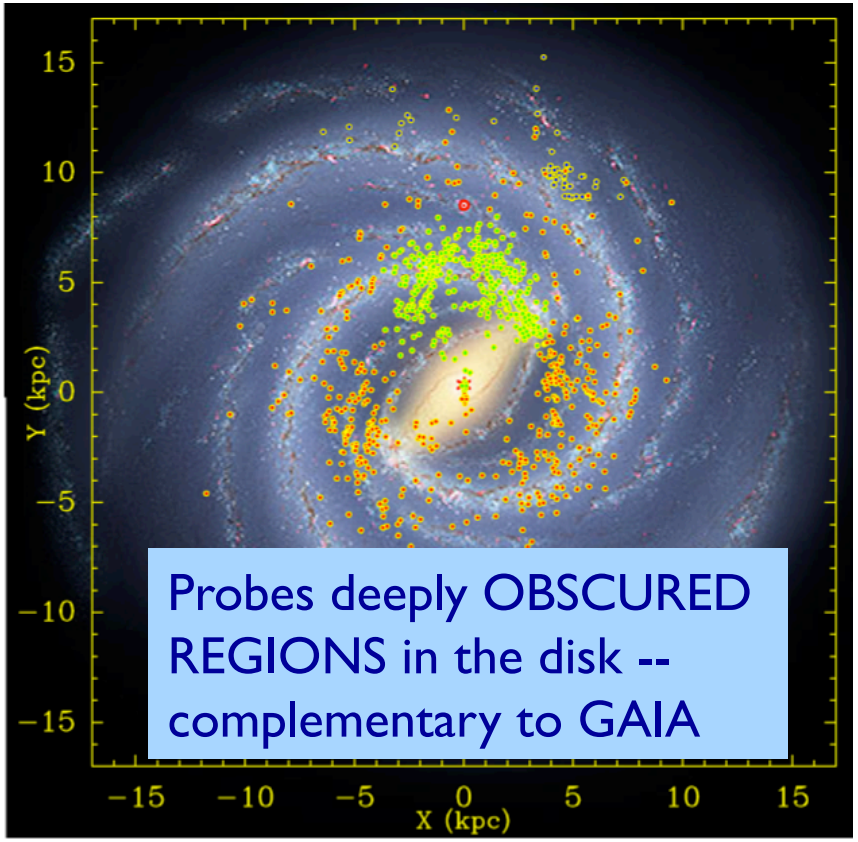
Goal: Determine trigonometric parallax and proper motions for up to 400 massive star forming regions in the Milky Way via strong methanol and water masers

Accurate measurements of:

- Distance to the Galactic center (Ro)
- Milky Way rotation velocity (Θ_o)
- Milky Way rotation curve
- Spiral structure

Results so far suggest:

- Milky Way 2x heavier
- Ro=8.3 kpc (vs 8.5 kpc)
- Θ_O=239 km/s (vs. 220 km/s)
- Previous values can yield kinematic distances in error by factor of 2



(Brunthaler et al. 2011)

http://www.mpifr-bonn.mpg.de/staff/abrunthaler/BeSSeL

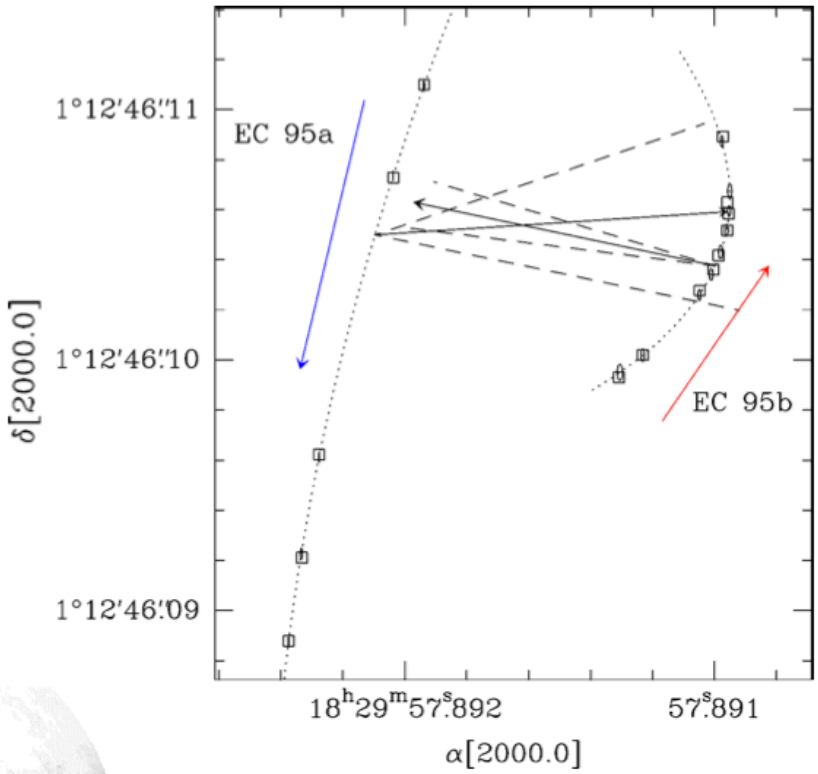
Key Science: Gould's Belt Distance Survey

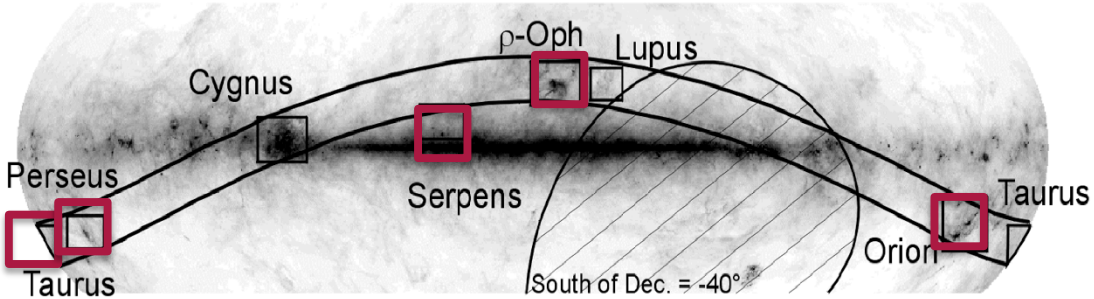
VLBA

Goal: Determine trigonometric parallax and proper motions for ~200 young magnetically active low mass stars in Gould's Belt star forming regions (d< 500pc) via gyrosynchrotron continuum emission to few percent accuracy

Example: "EC 95" in Serpens:

- Parallax Distance = 429 +/- 2 pc (0.5%!)
  - Previous extinction estimate d~ 260pc
  - Luminosities in error by factor 2.7!
- A tight binary with EC 95a = intermediate mass protostar and EC 95b = low mass T Tauri star
- Distance to Serpens Molecular cloud likely 429 +/- 20 pc.



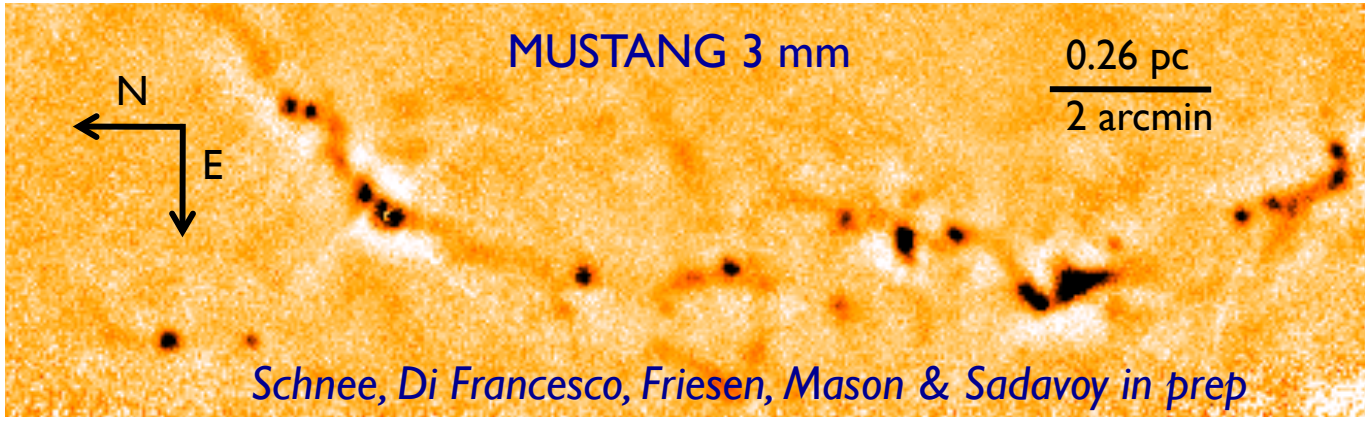


(Dzib et al. 2010, 2011; Loinard et al. 2011)

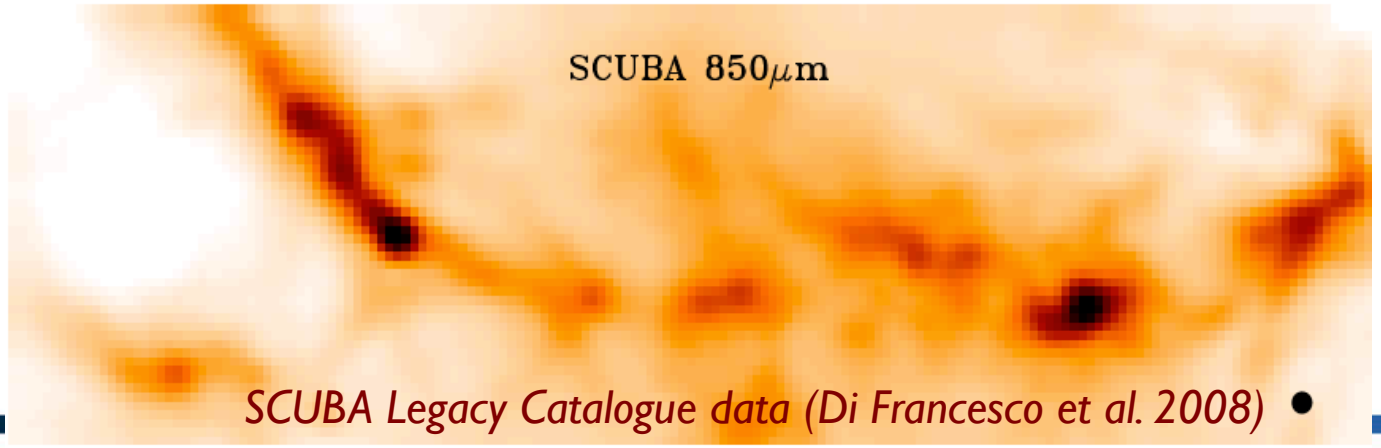
MUSTANG - Orion Molecular Cloud

GBT

Goal: Multi-wavelength study of the dust properties and core masses of OMC2/3 from 70μm to 3mm. The greatest uncertainty in measuring dust masses is in the dust emissivity ($\kappa = \kappa_o[\nu/\nu_o]^\beta$); adding long wavelength data (3mm) to the SED is essential to add the long lever arm necessary to accurately constrain β.



16' x 5' map made in just 10 hours

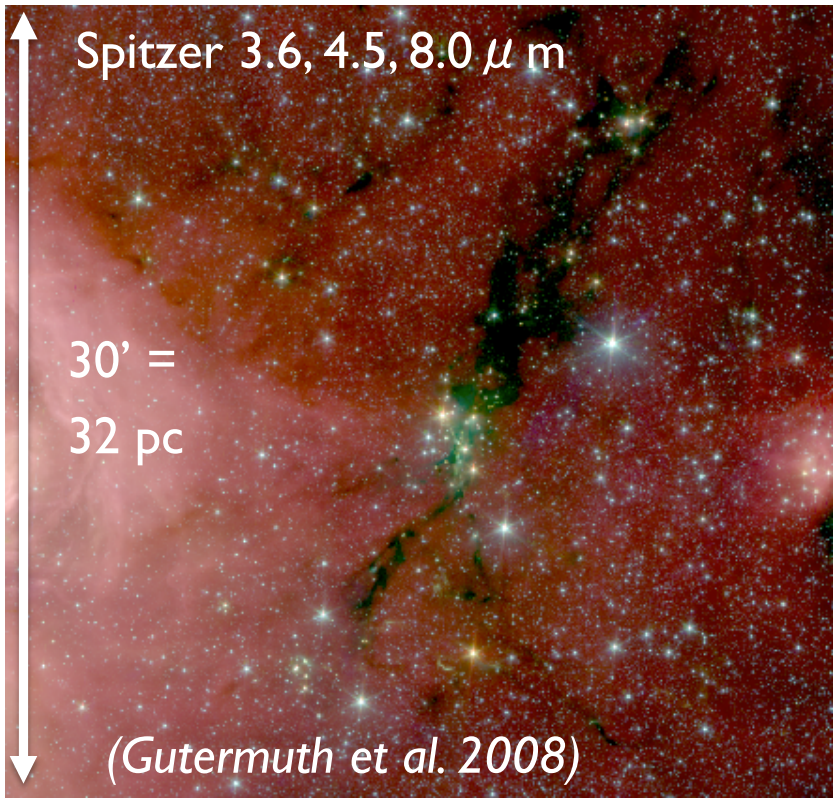


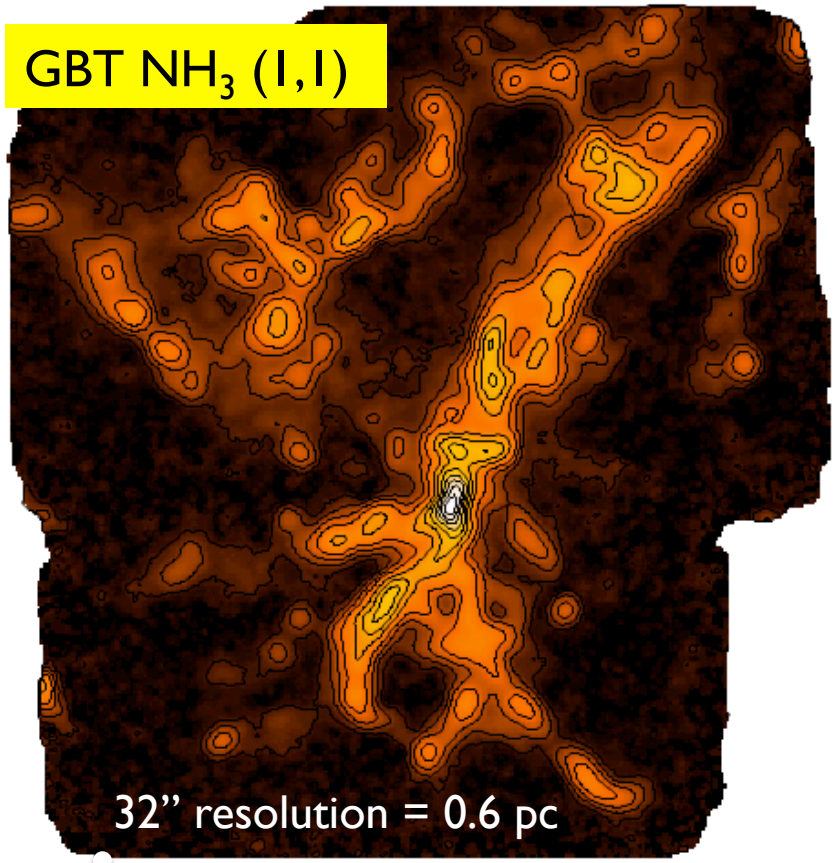
MUSTANG resolution is 9" -- 3-4x better in beam area than JCMT or APEX

K-Band Focal Plane Array: NH_3 in the Serpens South Cluster

GBT

Goal: Map the detailed temperature, density, and kinematics of clustered star formation using ammonia





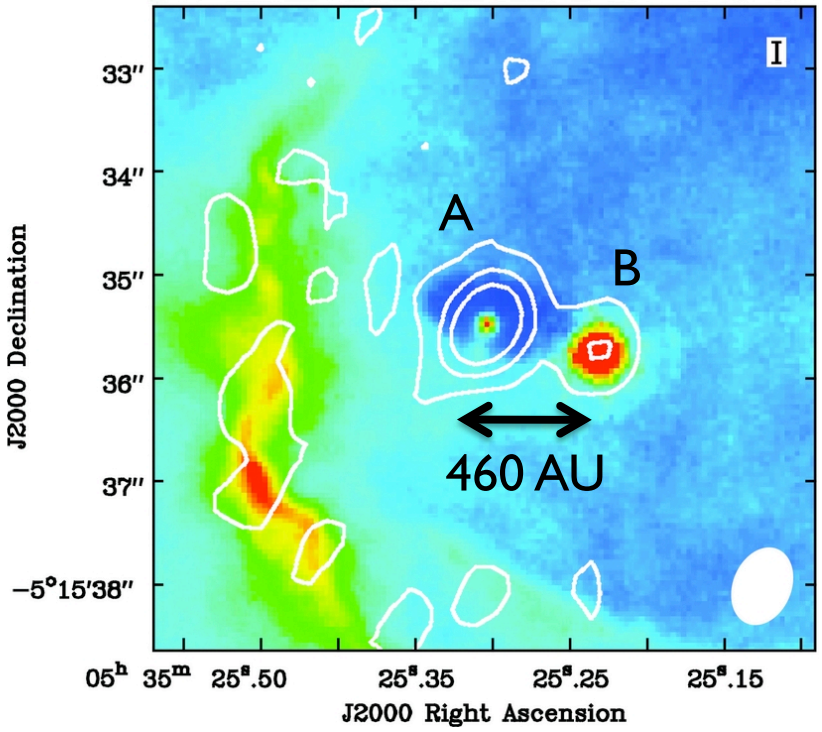
~ 30 hrs observing time

Friesen, Di Francesco, Myers, Bourke & Gutermuth, in prep.

Deep Continuum Observation Reveals the Obscured Heart of Star Formation

EVLA

Goal: Study the dust emission in the optically obscured 253-1536 binary disk system in Orion to test theories of dust evolution and grain growth



7mm EVLA (white contours)

Hα HST (colorscale)

Ricci et al. 2011

- The dust SED suggests disk A has larger grains despite its apparent lower density.
  - Could be due to viscosity variations or radial motions not included in the model
- Higher angular resolution data will help to understand this unexpected result

- C-configuration; ~0.6" resolution
  - ➢ Resolution could be 10x higher
- 256 MHz Bandwidth; 6 hour observation
  - ➢ 8 GHz soon or factor of ~6x more sensitive

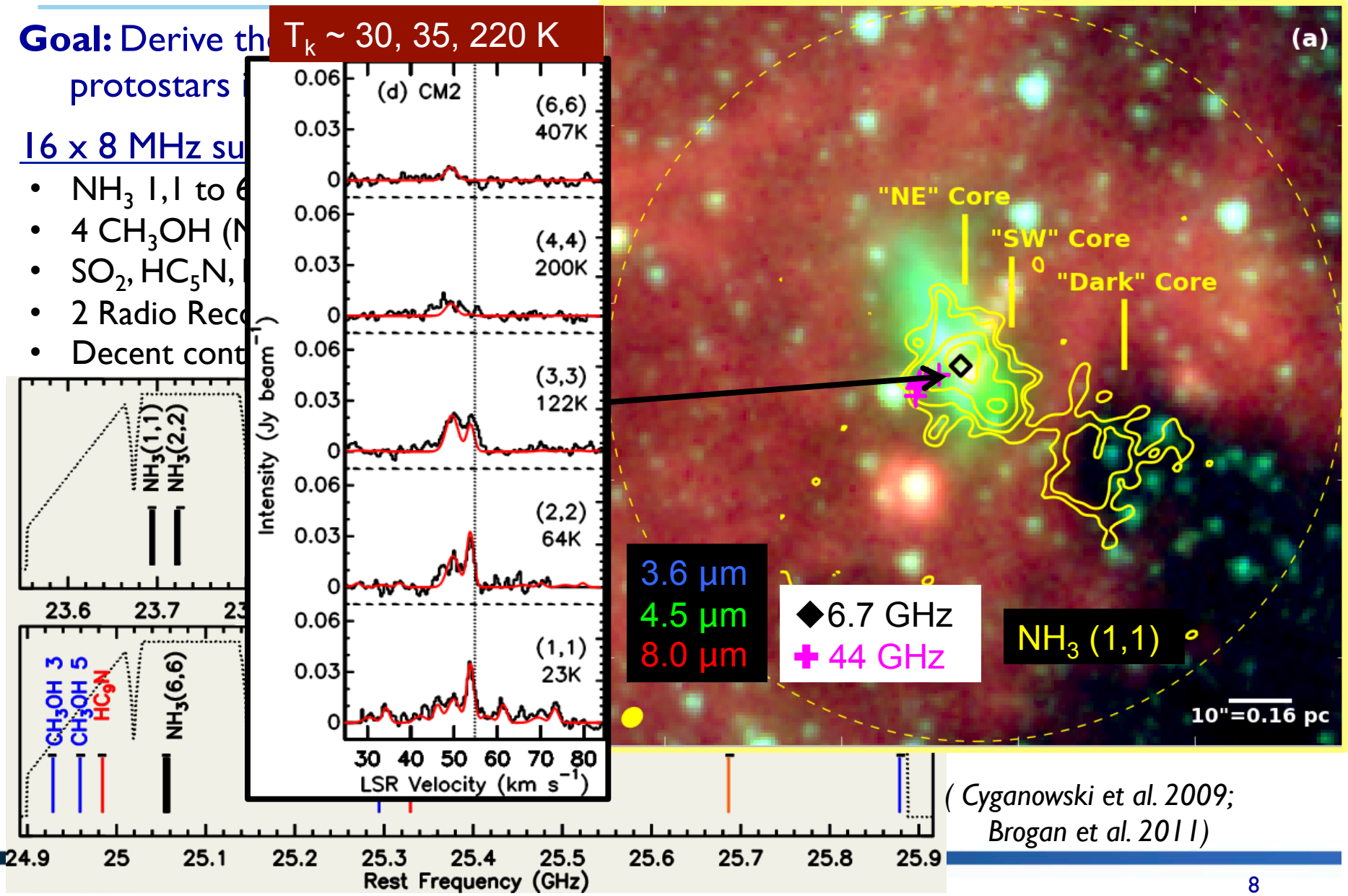
NRAO

EVLA WIDAR: Many Diagnostic Tracers Simultaneously!

Goal: Derive th
protostars

16 x 8 MHz su

- NH_3 1,1 to 6
- 4 CH_3OH (M
- SO_2, HC_5N,
- 2 Radio Rec
- Decent cont

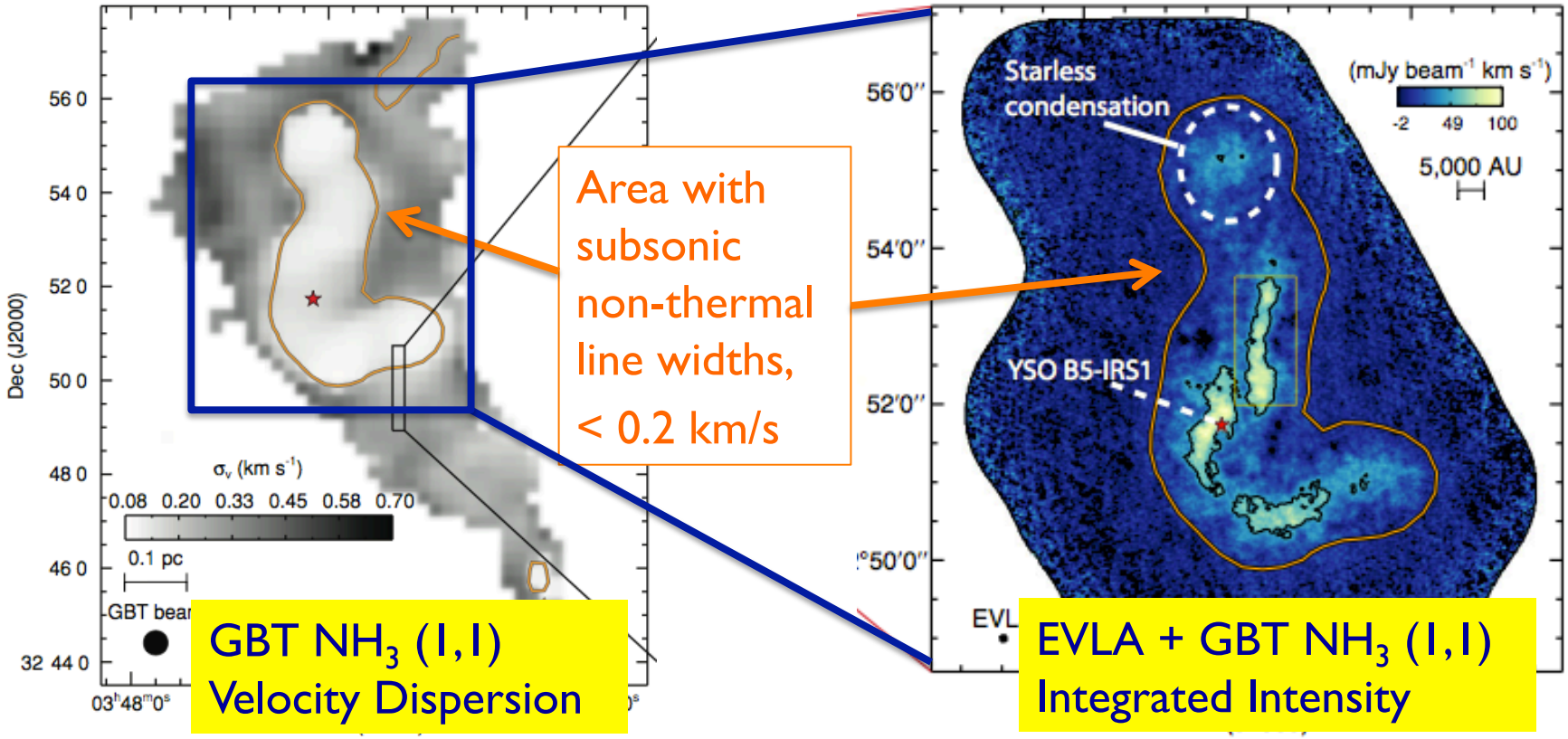


(*Cyganowski et al. 2009; Brogan et al. 2011*)

Embedded Filaments in the Perseus B5 Core

EVLA+GBT

Goal: Study the kinematics and morphology of "coherent gas" (i.e. low turbulence) using ammonia at high angular resolution



Newly discovered filament best fit with isothermal hydrostatic equilibrium model in contrast to recent Herschel results for lower density regions

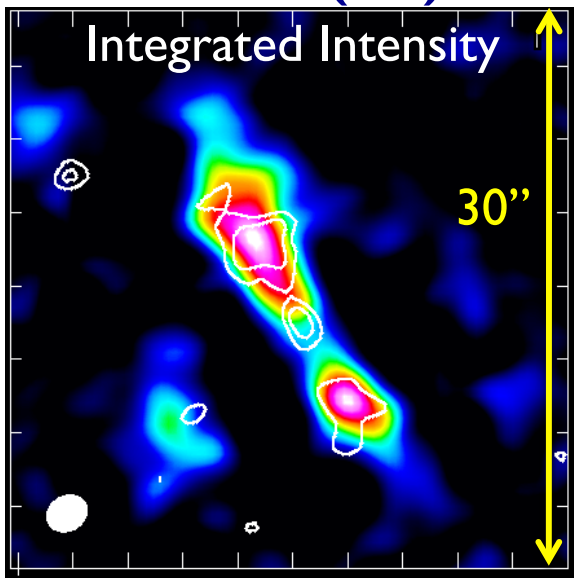
Pineda et al. (2010; 2011)

Earliest Stages of Massive Star Formation

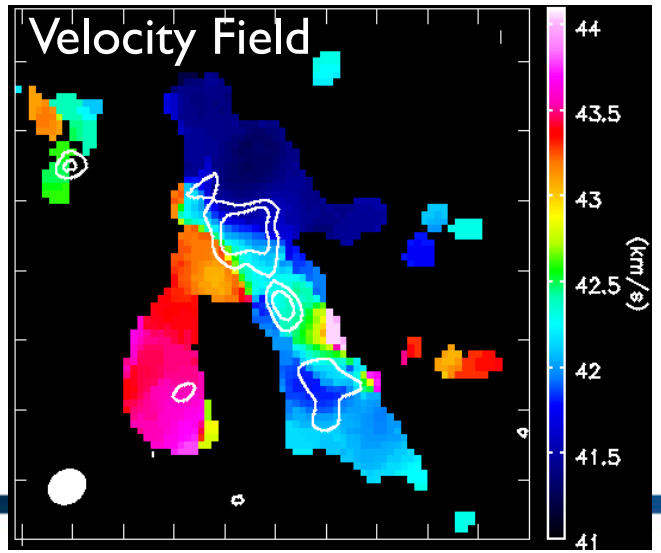
ALMA

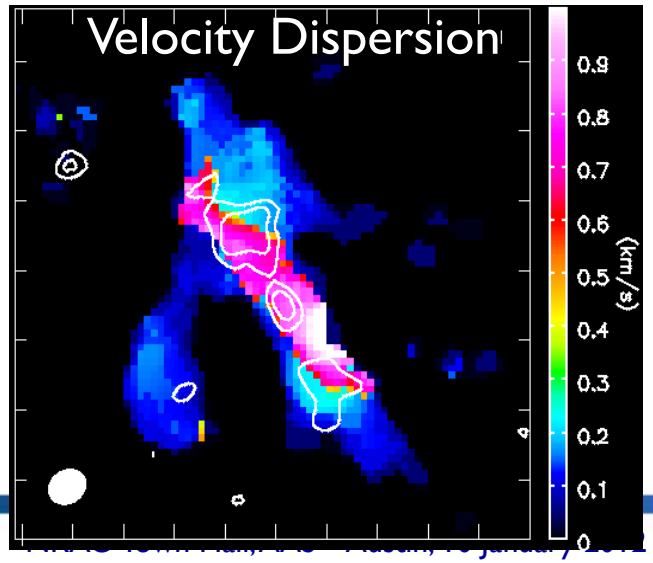
Goal: Cycle 0 project (236) to determine the dynamical state of 4 massive starless cores using several chemical tracers in order to distinguish between different theories of massive star formation. (***Tan, Butler, Caselli, Fontani***)

DCO+ (3-2)



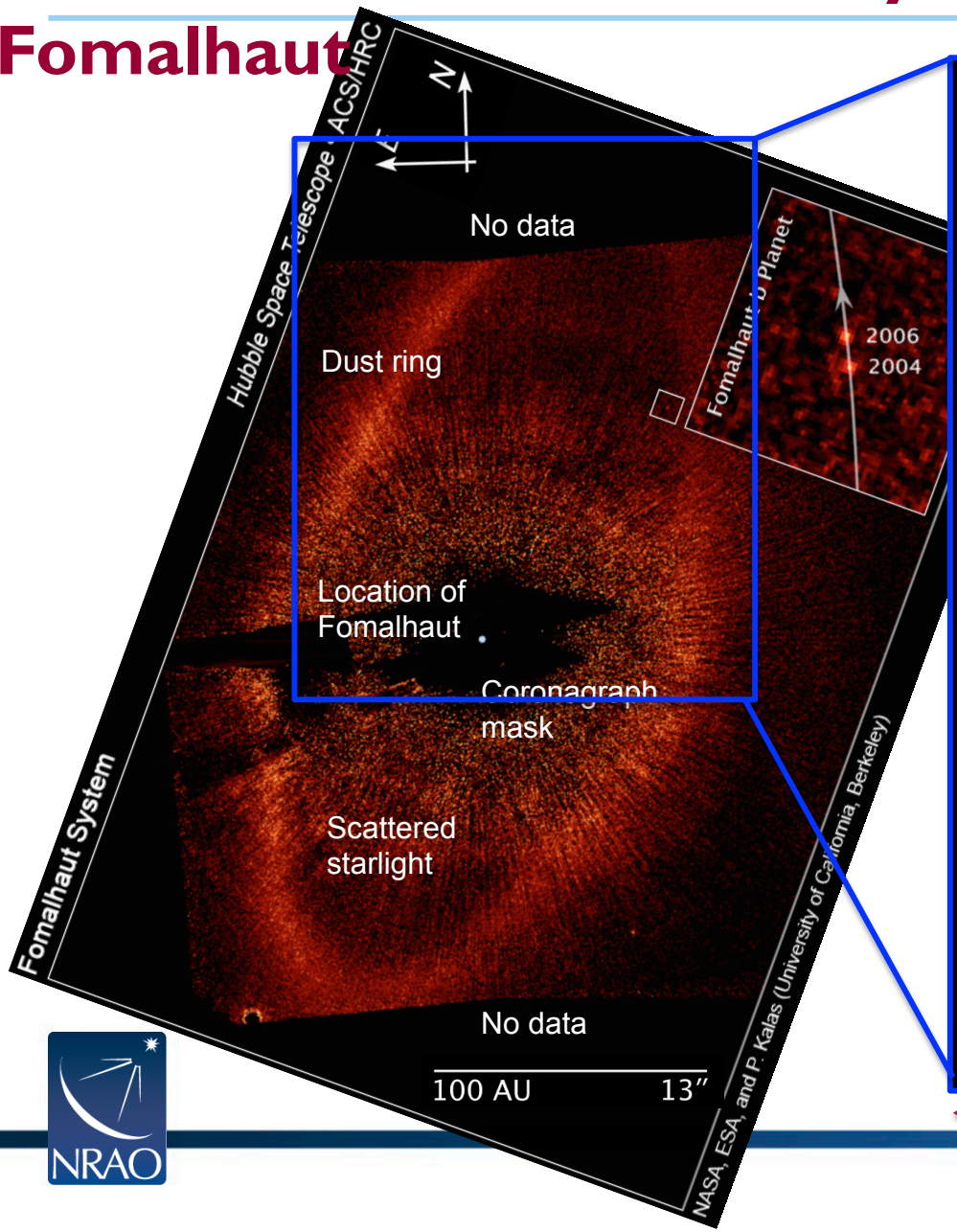
- Reference Images for target “G2”
- 40min(!) compact config; ~2.2” resolution
- White contours show 1.3mm continuum
- Velocity resolution ~0.16 km/s

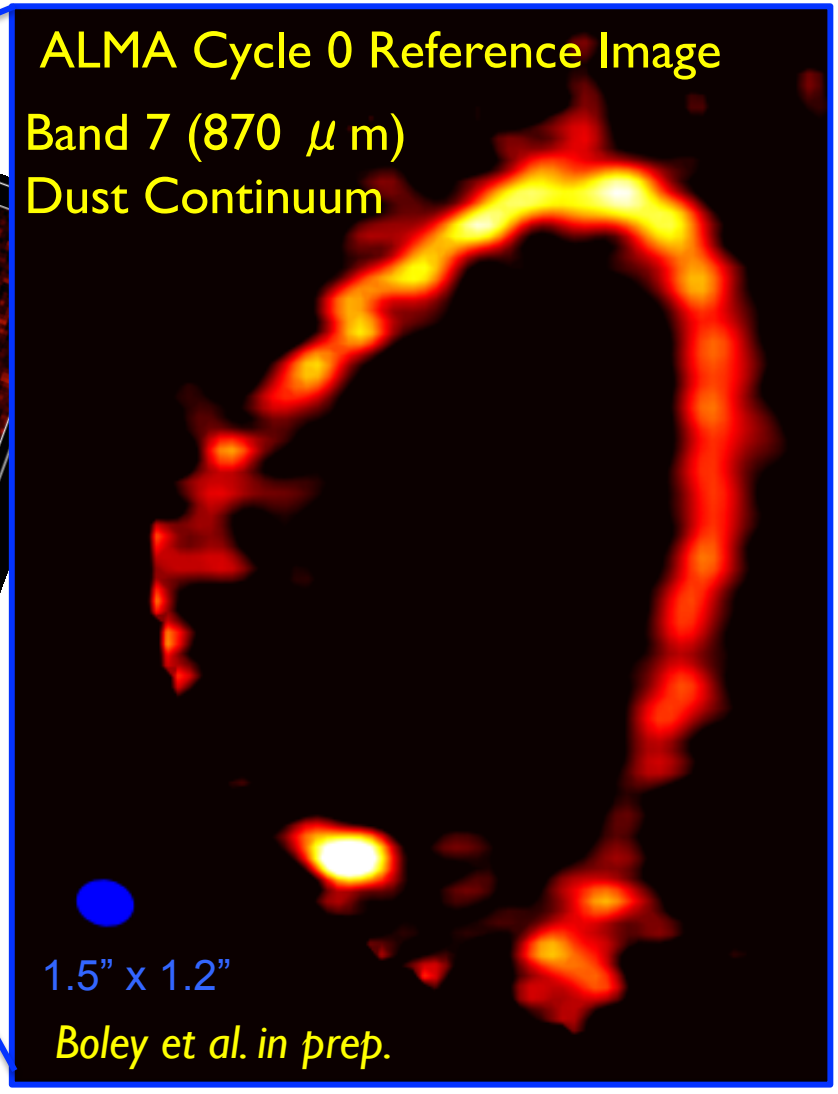




The Formation of Planetary Systems: Fomalhaut

ALMA





20 arcseconds ~ 150 AU