PROTOSTARS IN THE ORION MOLECULAR CLOUD COMPLEX

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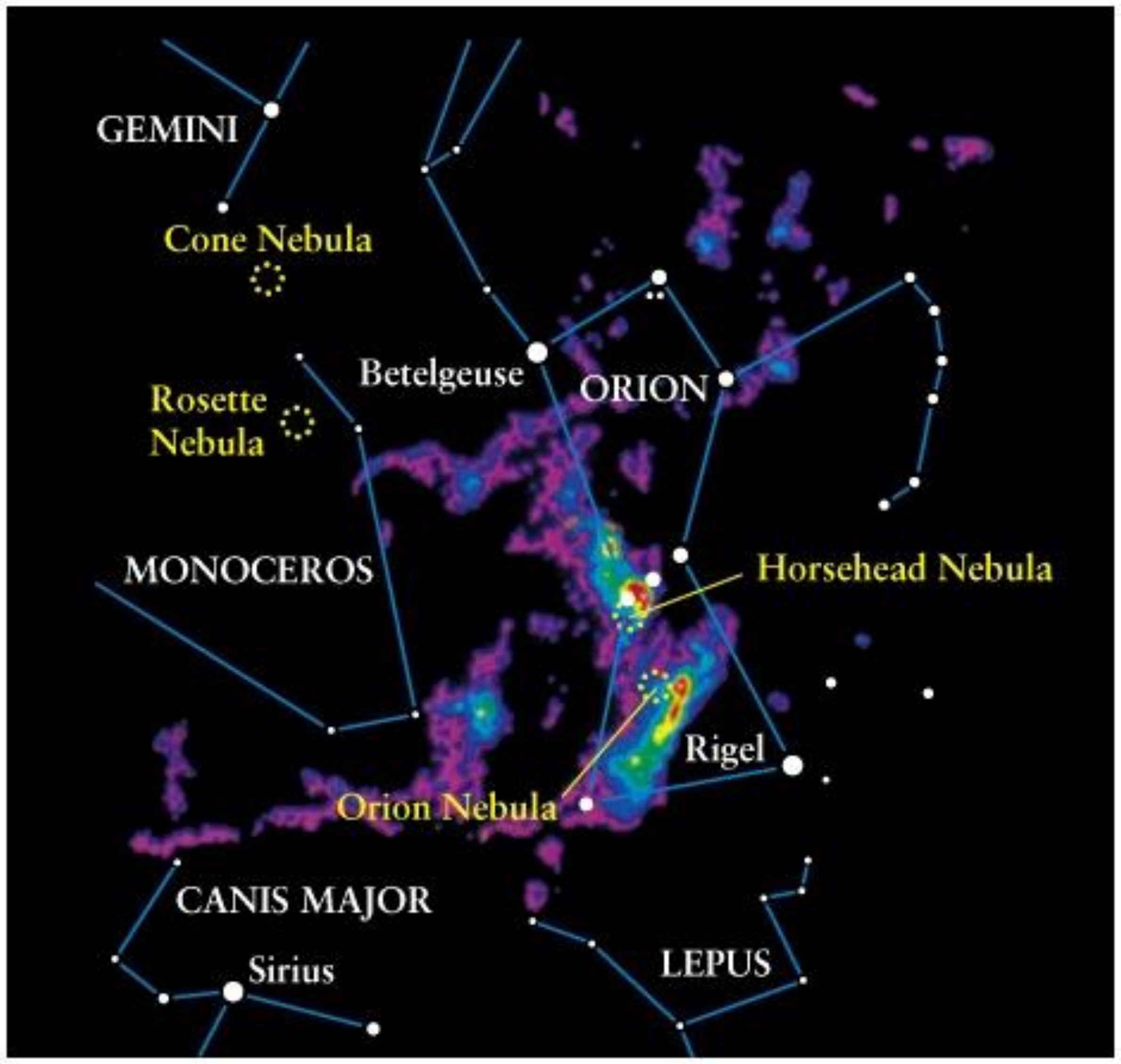
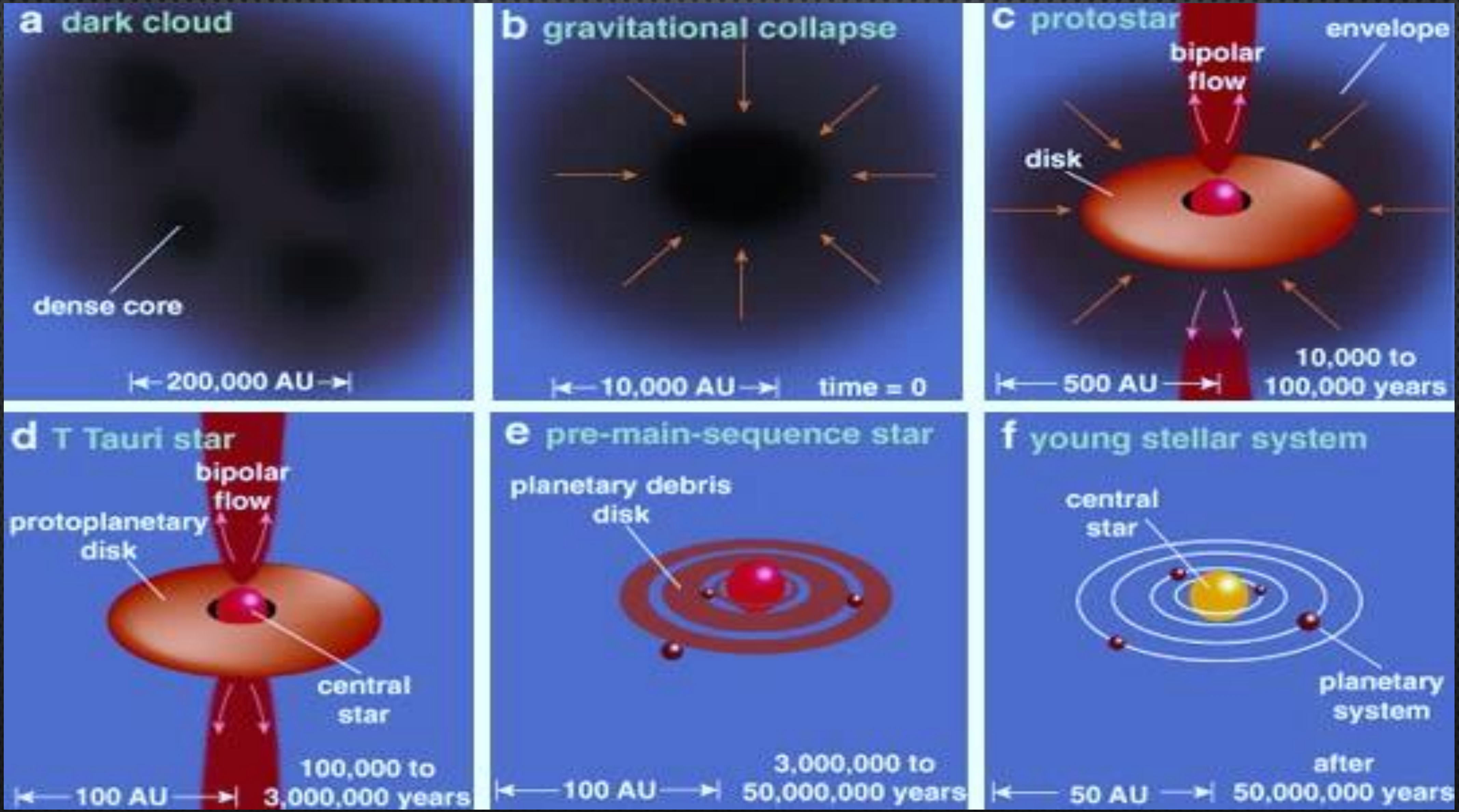
GIANT MOLECULAR CLOUDS

- An enormous, cold and dense cloud of gas and dust
- Mass can range up from 10^3 to 10^7 solar masses
- Composed mostly of molecular hydrogen but difficult to observe
- Why Orion?
  - Nearest site of massive star formation
  - Largest population of protostars within 400 pc
  - More representative environment

[1]



STAR FORMATION



[2]

ATACAMA LARGE MILLIMETER/SUBMILLIMETER ARRAY (ALMA)

- In the Atacama desert of northern Chile, 5000m in altitude
  - Avoids atmospheric water vapor
- Consists of 66 antennas, observing at millimeter and submillimeter wavelength
  - Main array – 50 antennas , each 12m in Diameter
- interferometer – Acts as a single telescope with a much bigger diameter and reconfigurable
- Provides molecular line spectroscopy for 12CO and 13CO

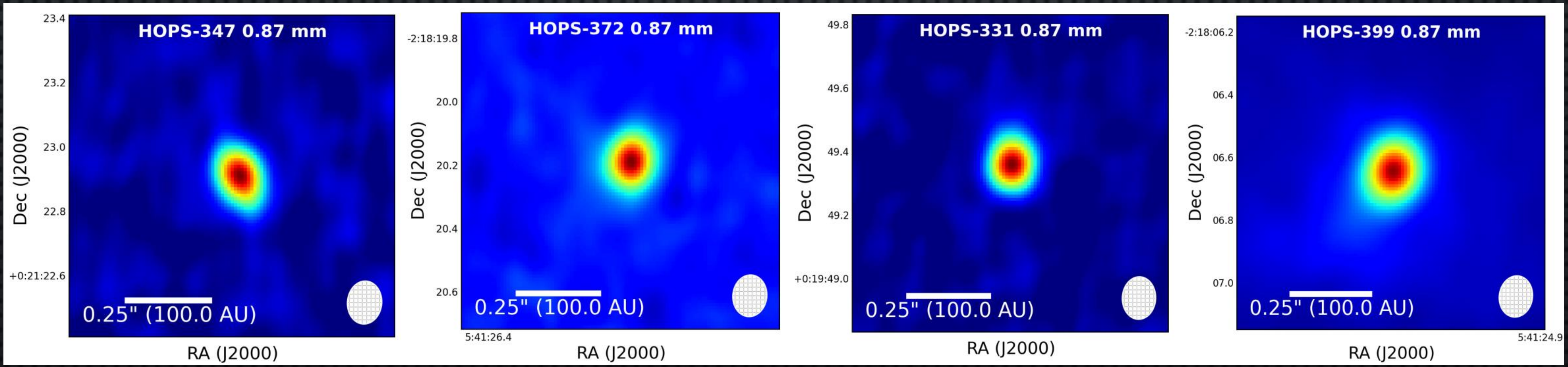
[3]

OBSERVATIONS WITH ALMA

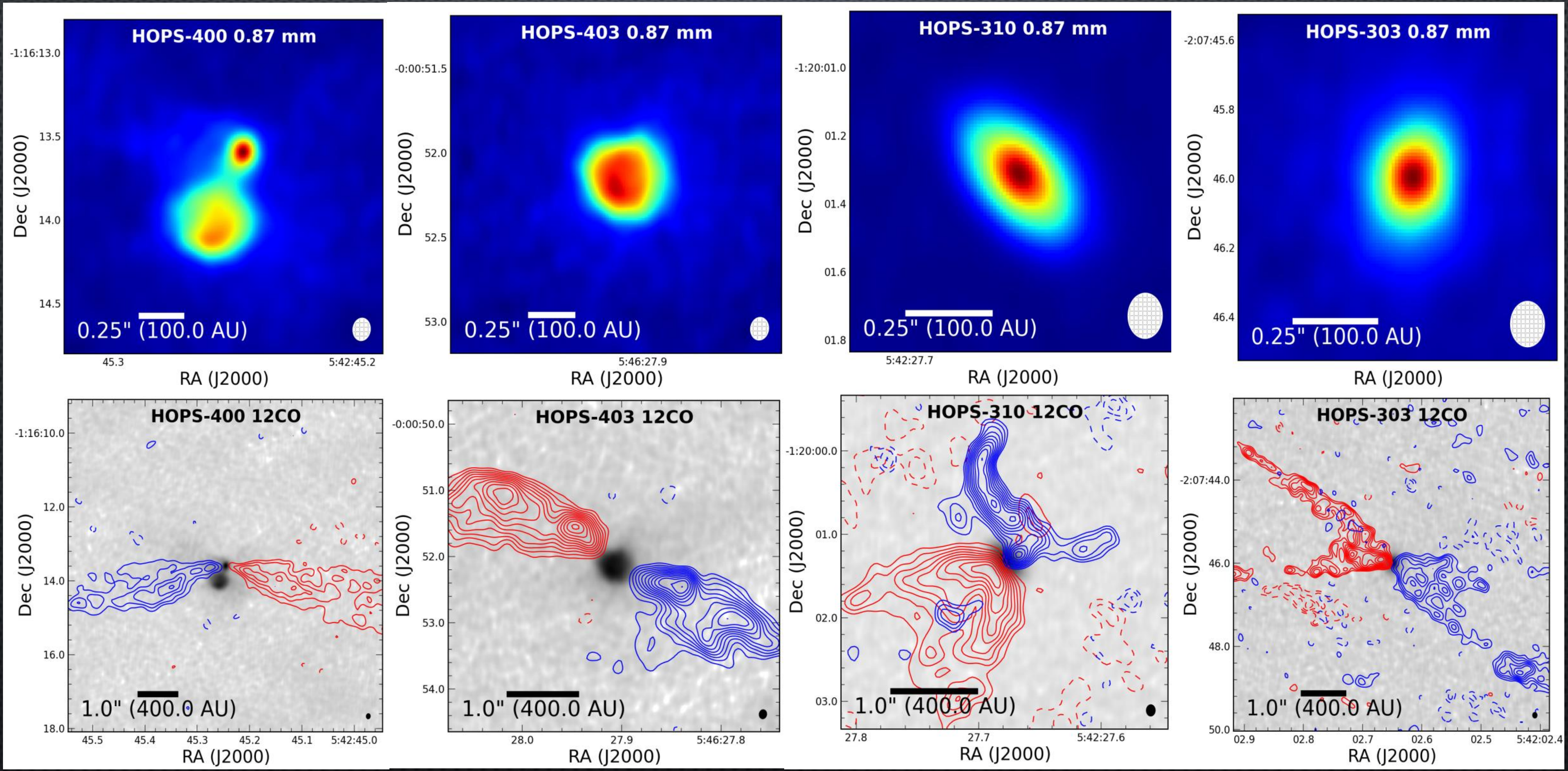
- A survey of 330 protostars in the Orion A and B clouds at 0.09” (38 AU) resolution
  - Largest and relatively unbiased sample with high resolution and sensitivity
  - Worked with ~80 sources
- Observe:
  - Dust Continuum – Evidence of multiplicity and compact, resolved structures
  - CO Emission Lines – Trace the compact outflow emission, estimate disk orientation, observe Disk kinematics like rotation

Dust Continuum Images

- Interactively clean each source individually – Use CASA
- Self-calibration – refined process used to find systematic phase shifts of our source
    - Phase shifts caused by atmosphere and observation conditions
- Difficult to gain more information about any structures
    - Need to compare to VLA data at different wavelengths

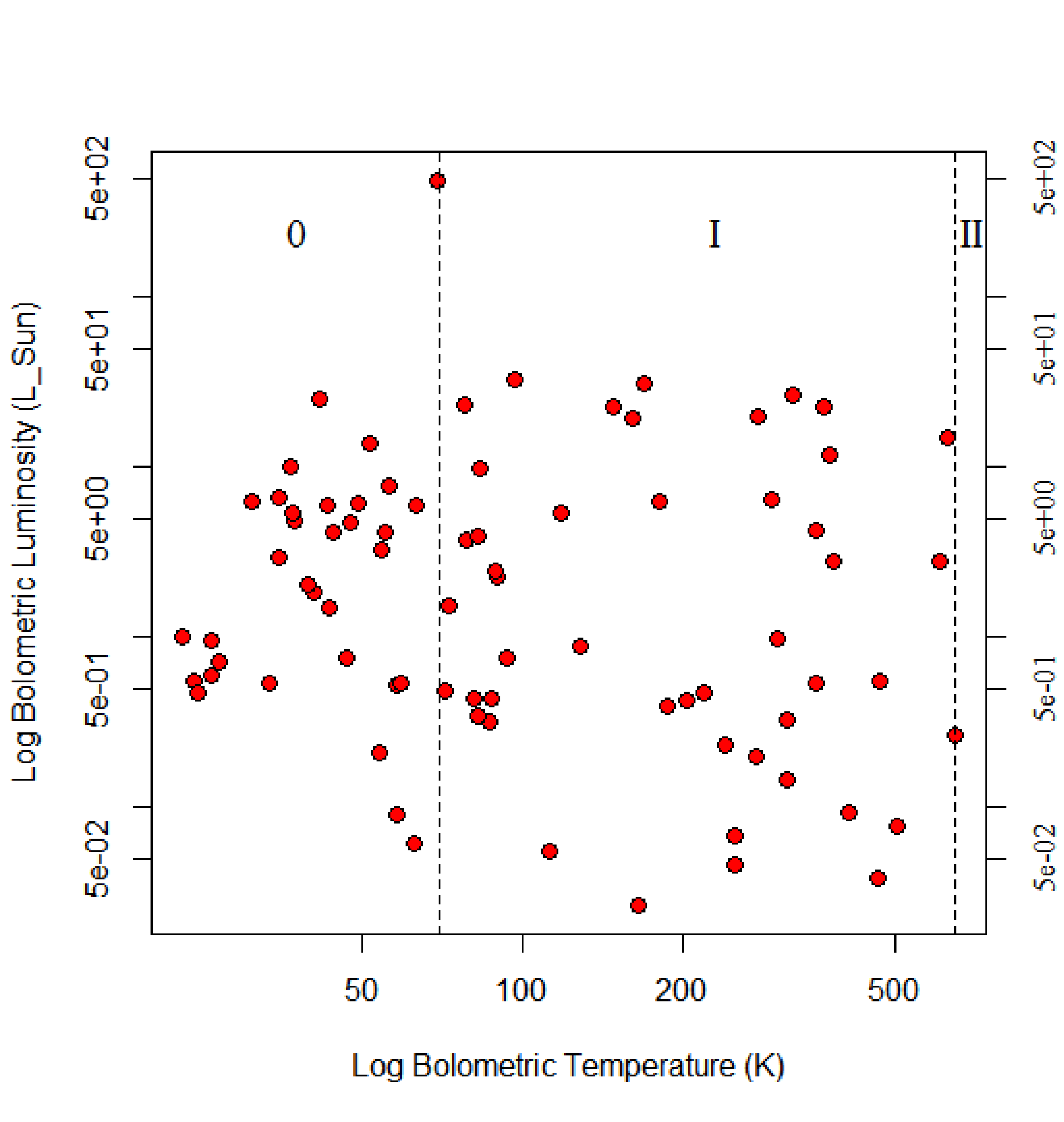


CONTINUUM AND MOMENT 0 MAPS OF 12CO



Bolometric Temperature vs. Bolometric Luminosity

- Bolometric temperature –blackbody temperature having the same frequency as the spectral energy distribution
- Bolometric Luminosity – energy emitted across the whole electromagnetic spectrum
- Both known from Herschel Orion protostar survey
  - Furlan+2016
- Tbol further divides protostellar phase into class 0 (<70K) and class 1 (<650K)
  - Chen+1995

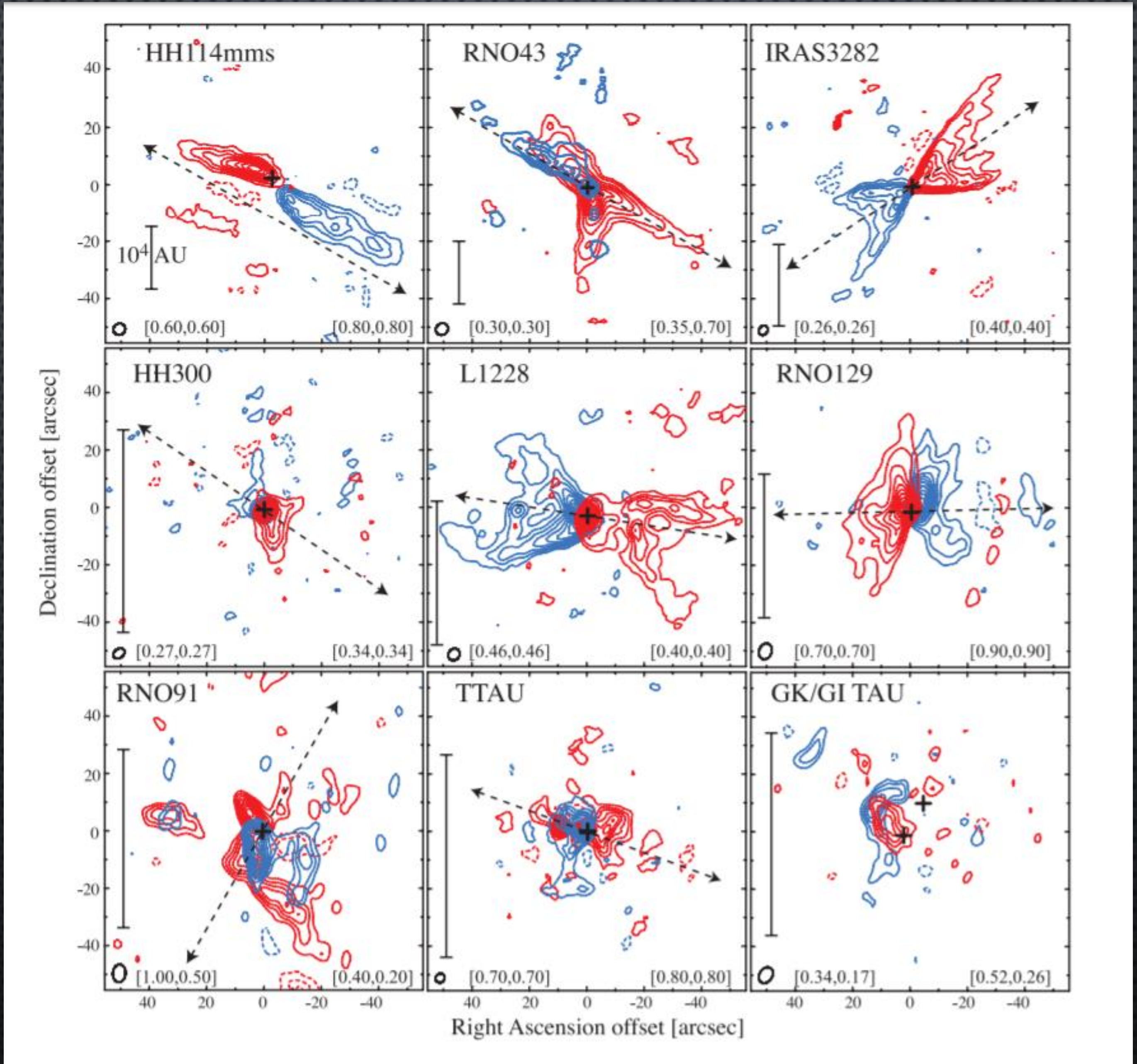


Evolution of Outflows

Class 0 →

Class I →

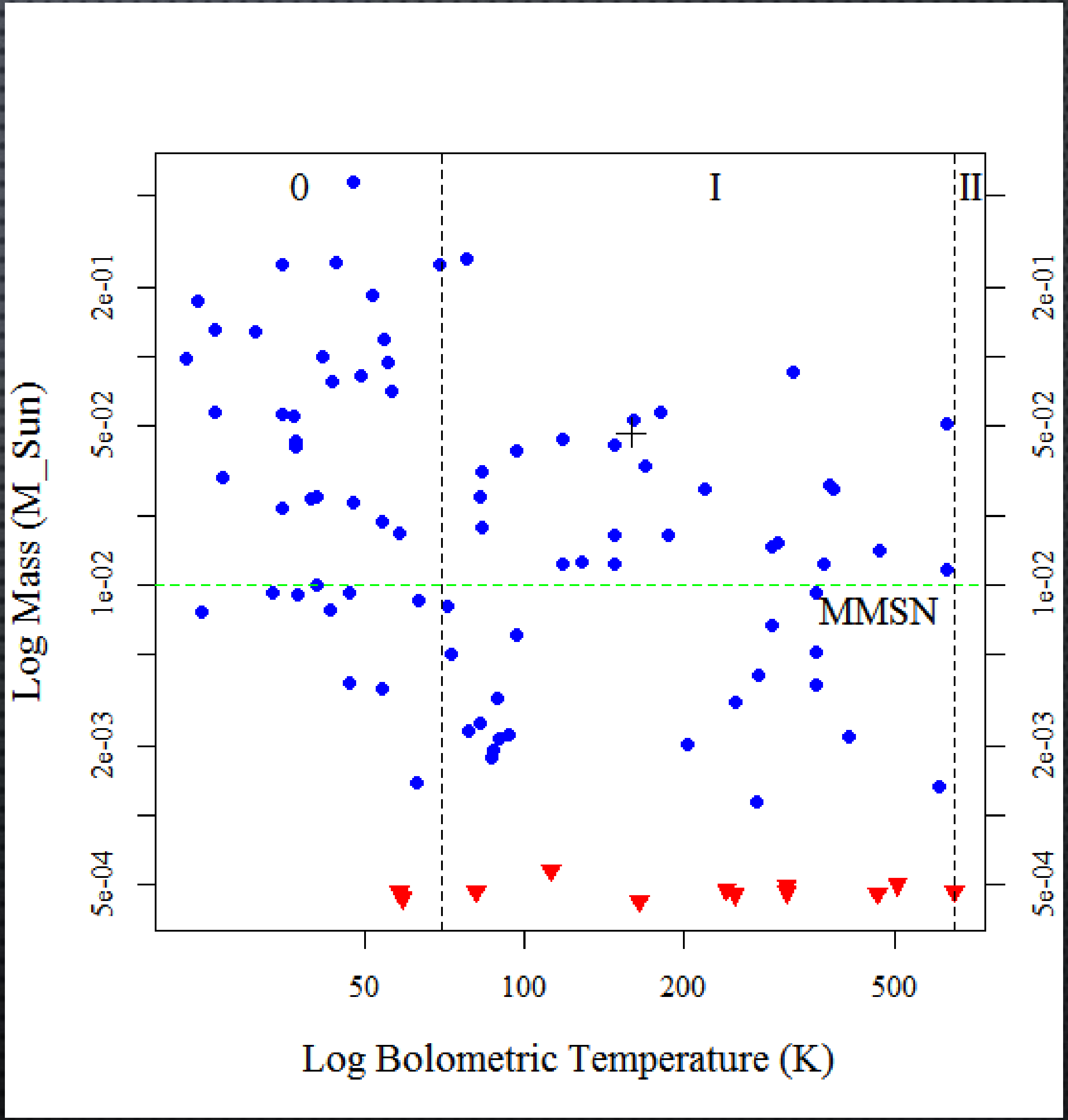
Class II →



[4]

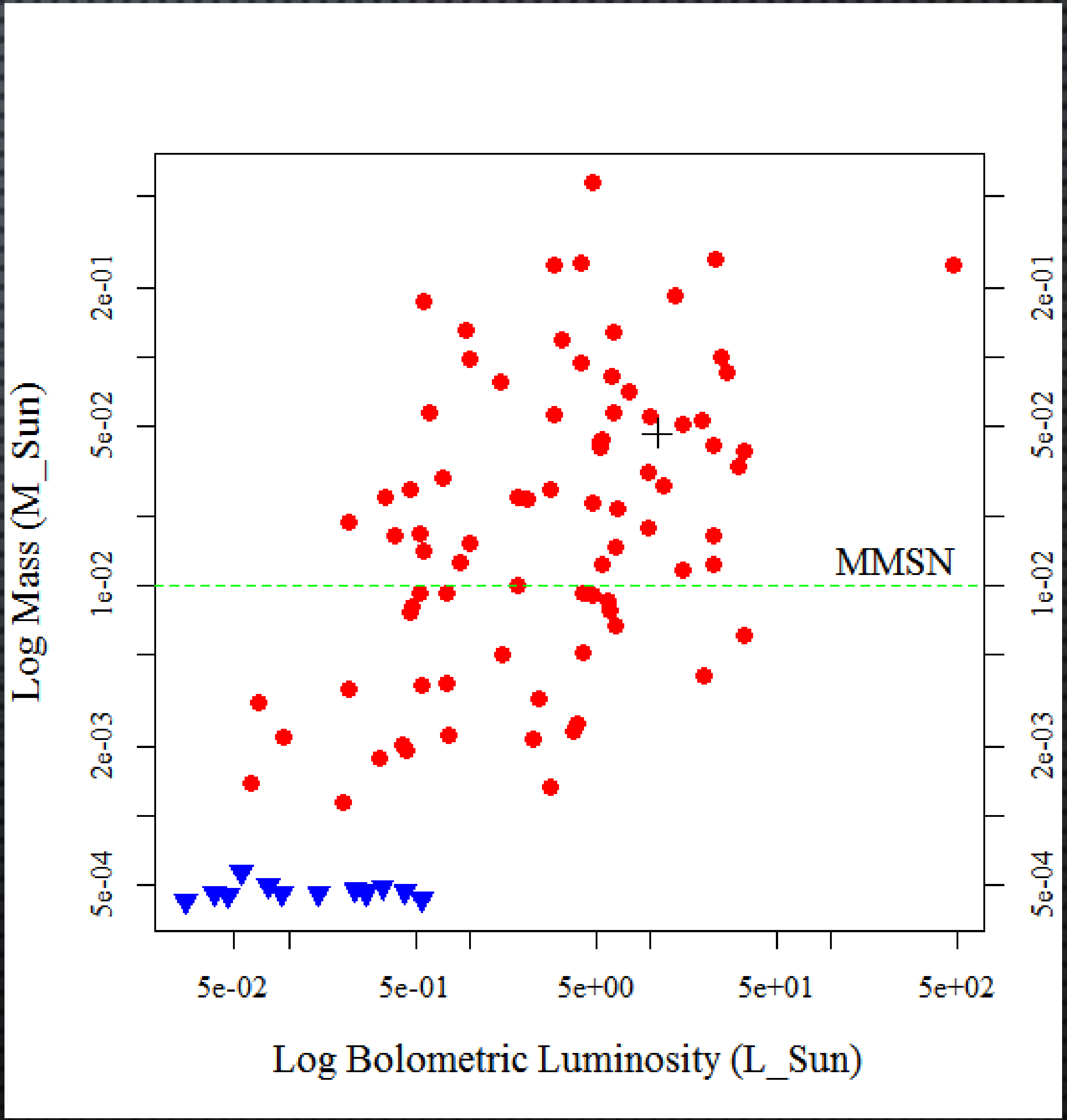
Bolometric Temperature vs. Disk Mass

- Gaussian fit → integrated flux →disk mass on <500AU radii
- Heavier source at earlier times have more mass to accrete and more raw material for forming companions and/or planets
- Mass passing through small scales on its way to the star
  - Refilled by infalling envelope
- Minimum mass solar nebula (MMSN) – minimum mass to build 8 planets
  - 0.01 Solar Masses
  - ~50 above



Bolometric Luminosity vs. Disk Mass

- Expect the mass to increase with luminosity
- Little evidence of correlation currently
- Might improve when all of the sources are calculated
- Blue triangles – non-detections



CONCLUSION

- Self-calibrated sources using CASA
- analysis of disk masses using continuum
  - Disks more massive as younger times? Yes
  - Examine systematic difference in disk mass b/w higher and lower luminosity sources
- Next, calculate disk masses for the rest of sample and analyze again
- Modify the disk mass equation parameters for each source

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