resolved protostellar populations: far-infrared versus meter waves

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measuring star formation in radio—mm—submm (MSFRMS)
Manchester, 2017 Jul 25th

how sun-like stars form

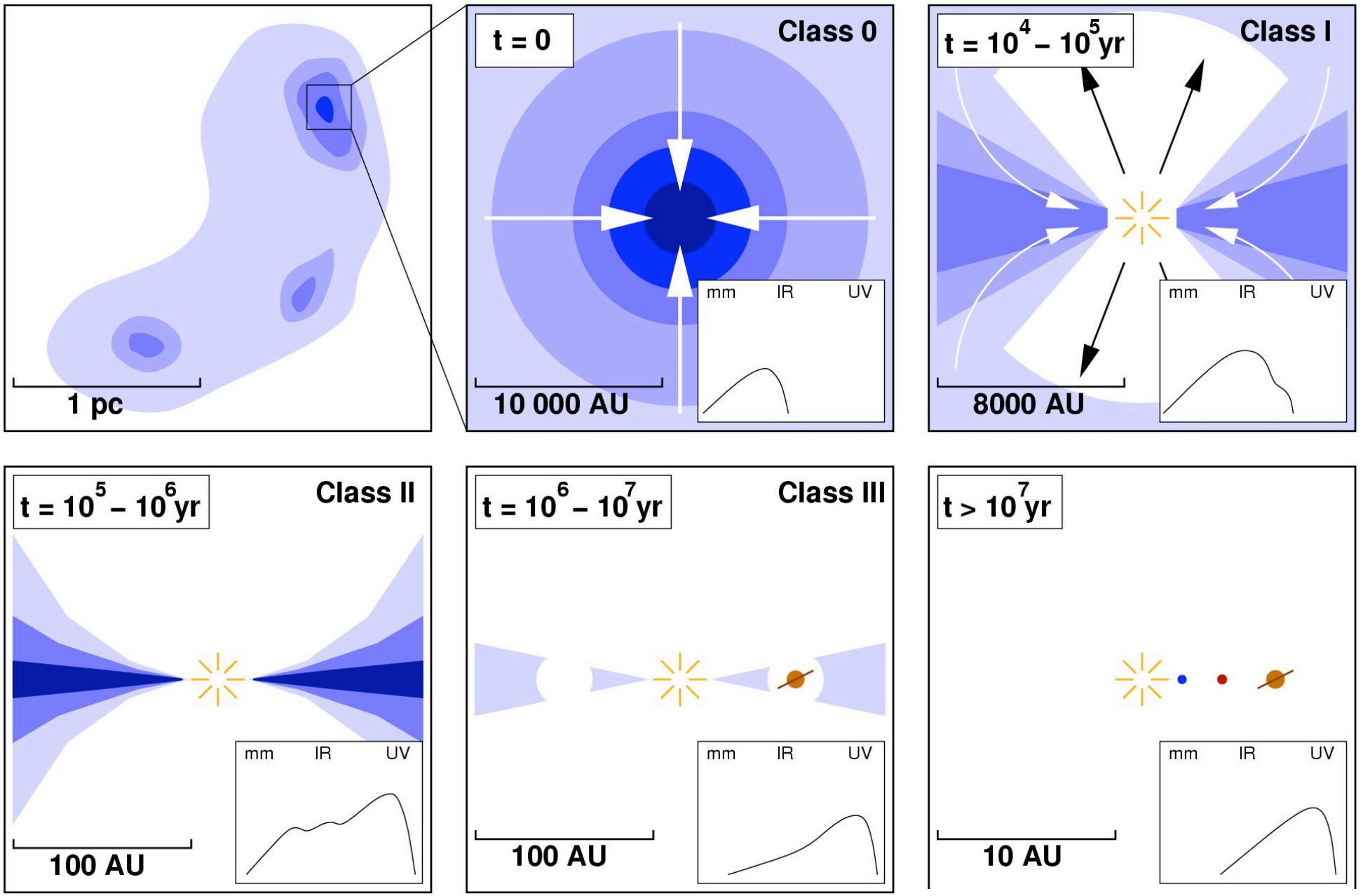
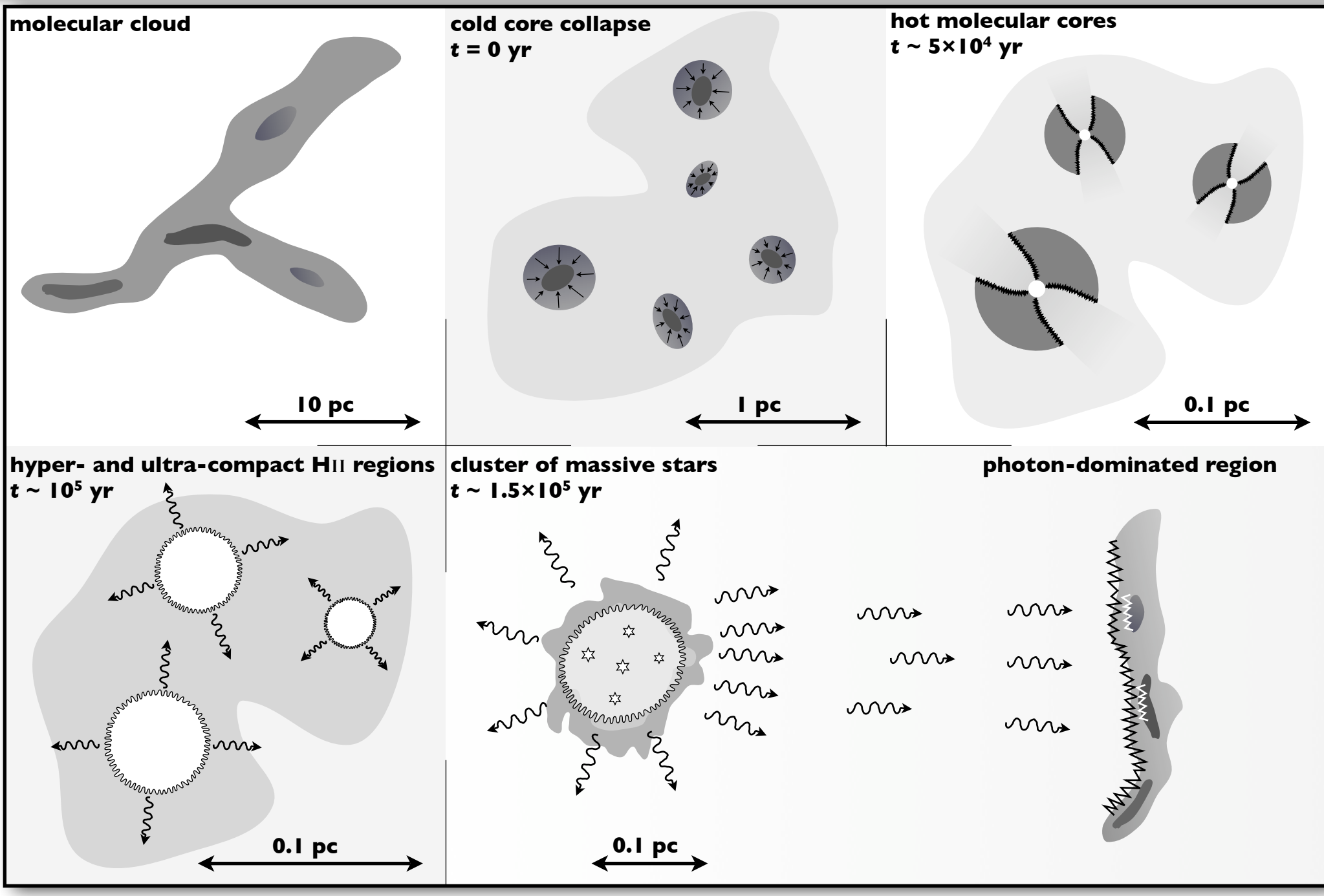
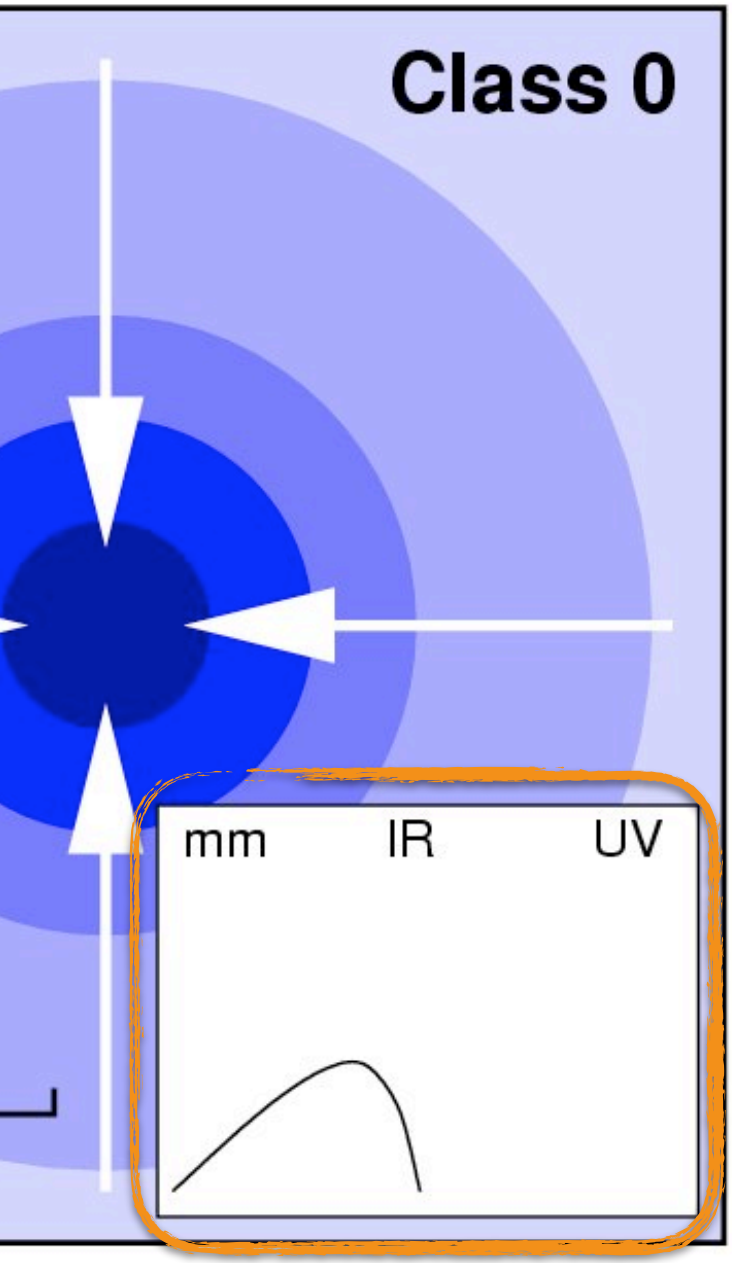


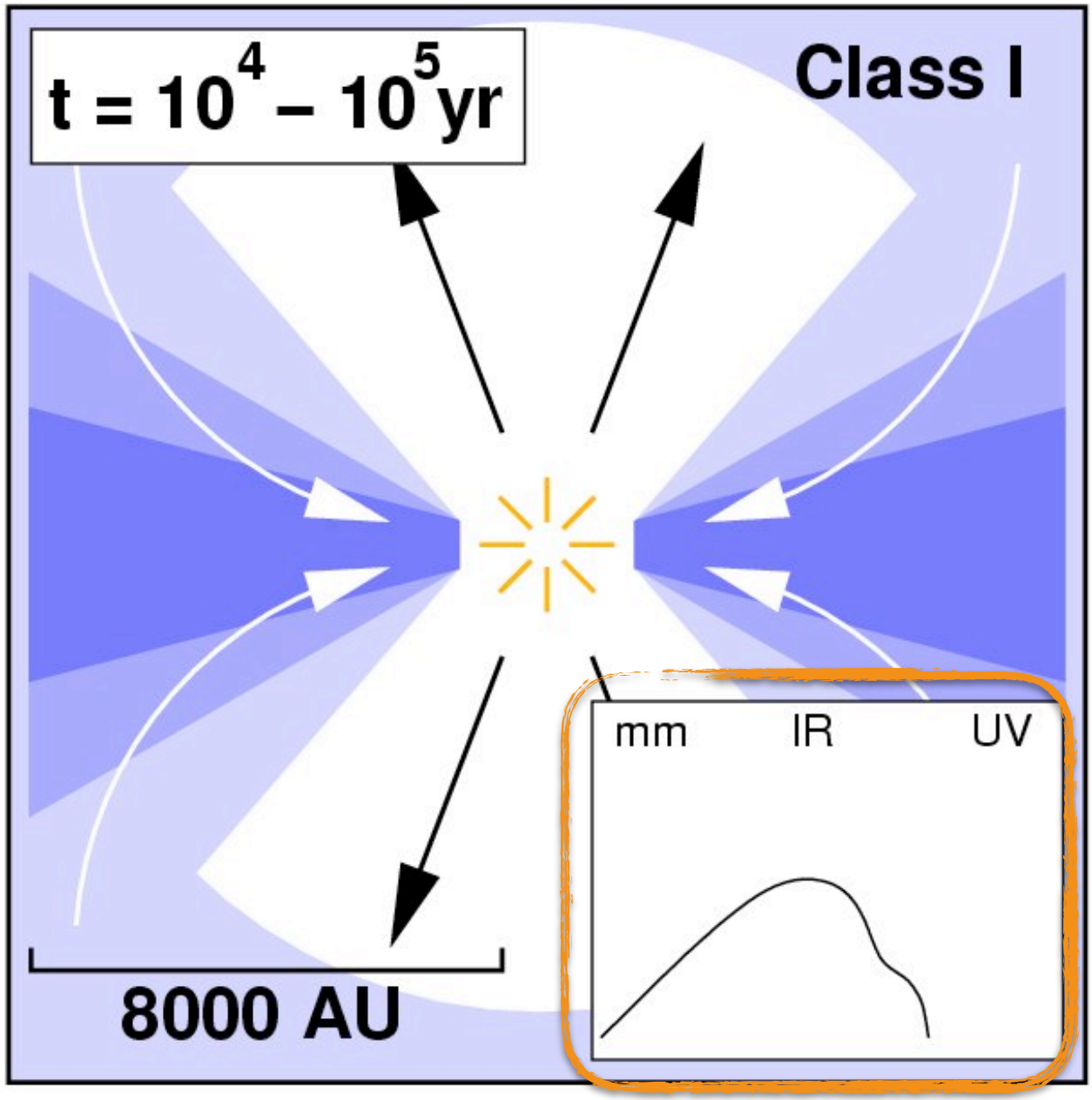
Figure by B. Jonkheid, after Shu+ (1987)

how massive stars form

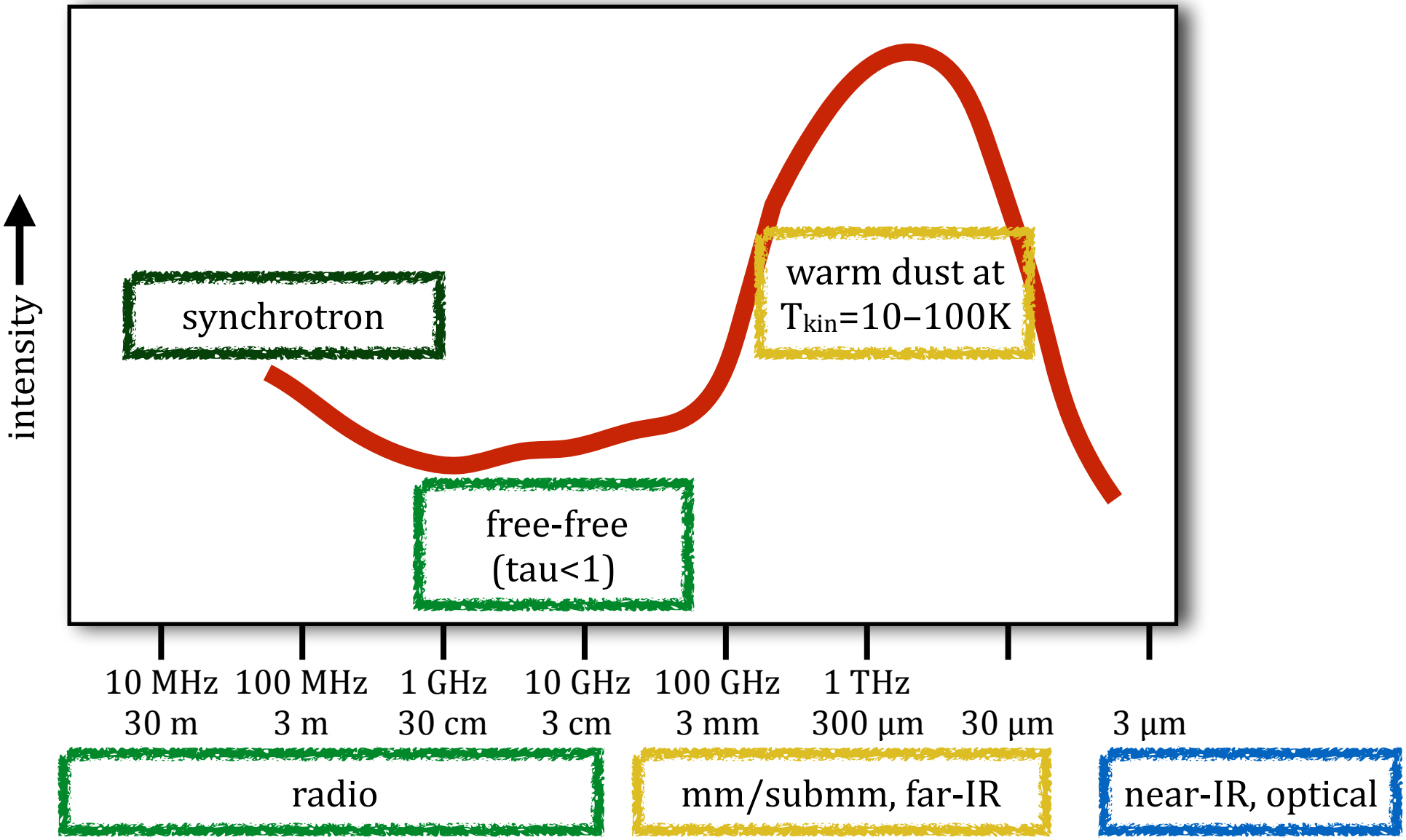


the SED of a protostar

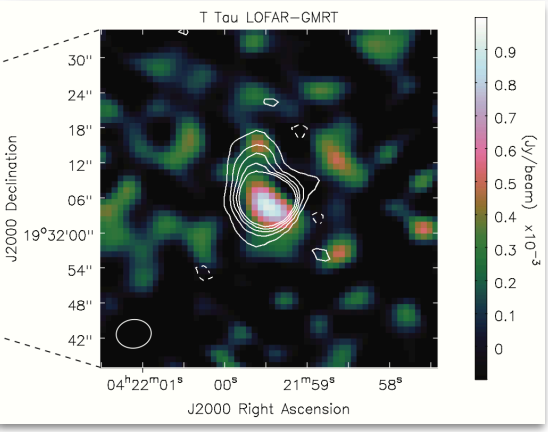




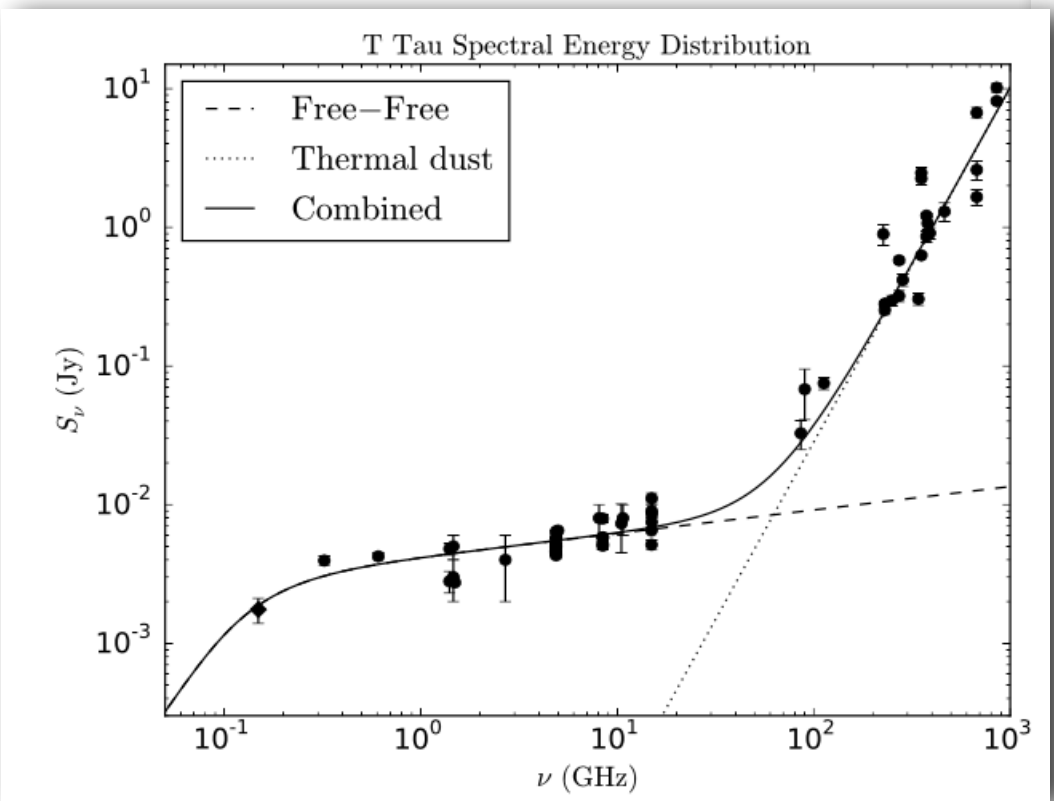
the (extended) SED of a protostar



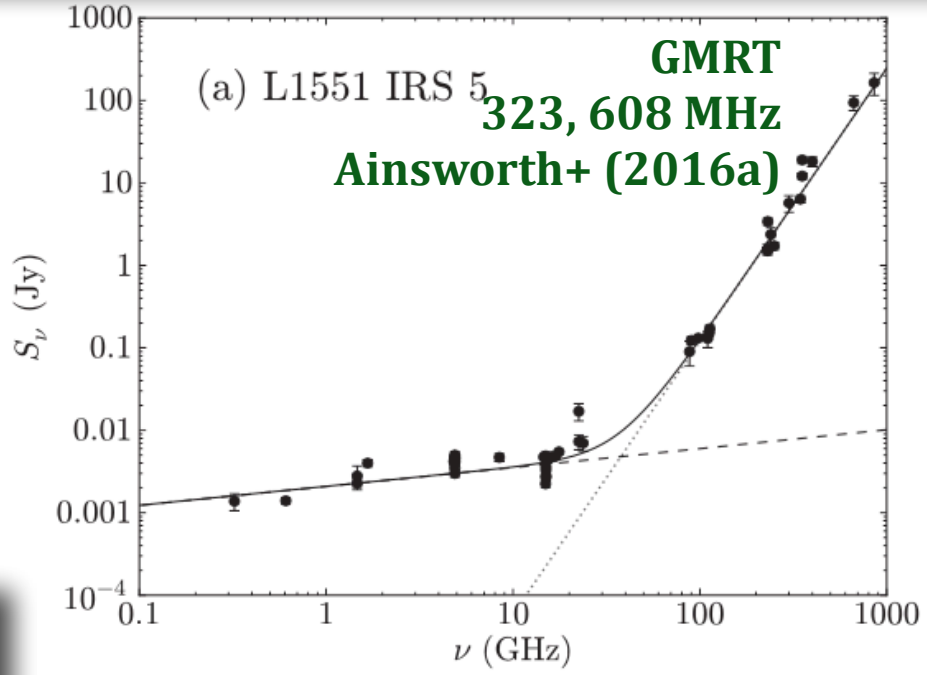
detections of protostellar free-free emission below 1 GHz

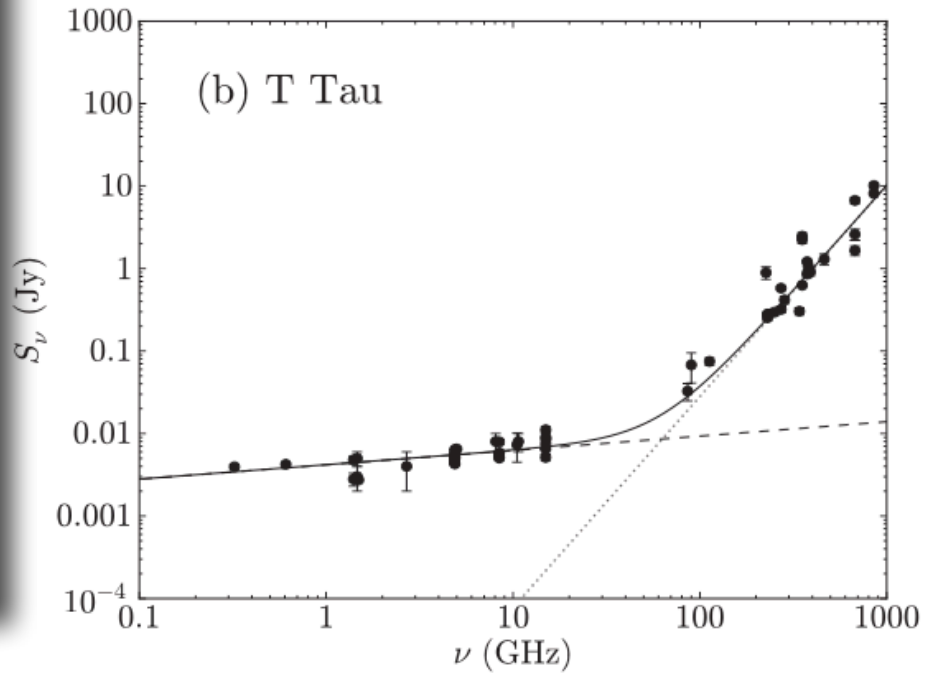


LOFAR 149 MHz
Coughlan+ (2017)

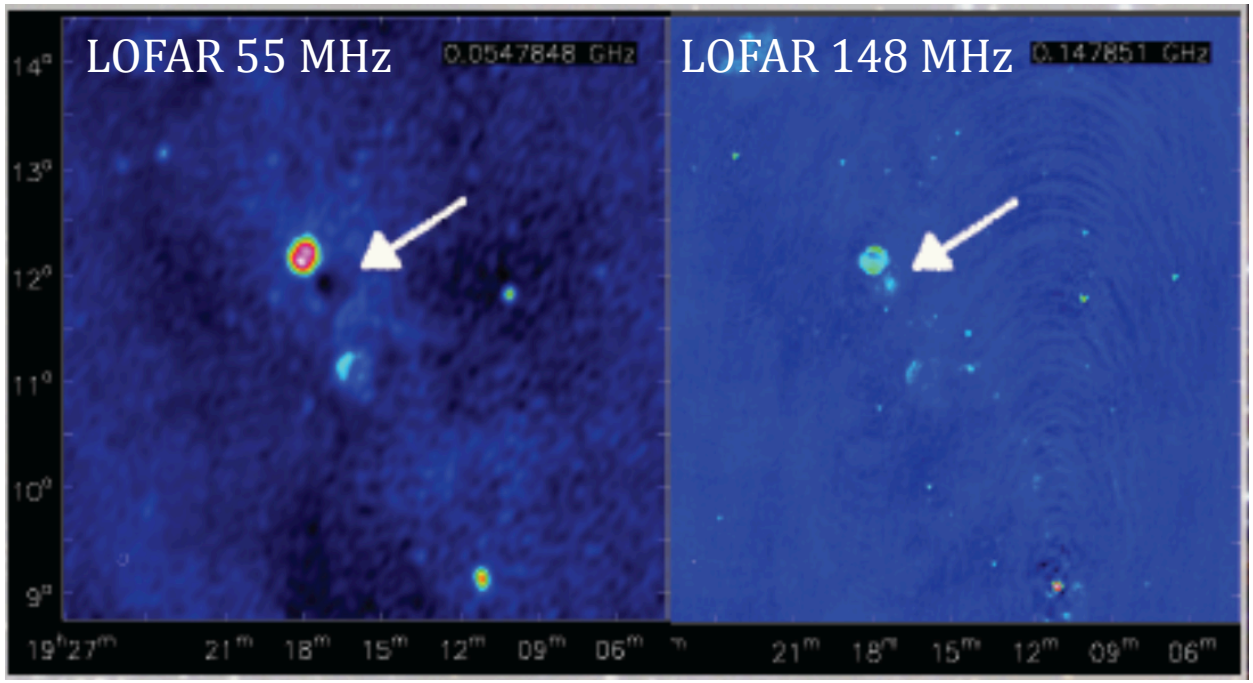


GMRT
323, 608 MHz
Ainsworth+ (2016a)





HII regions in absorption



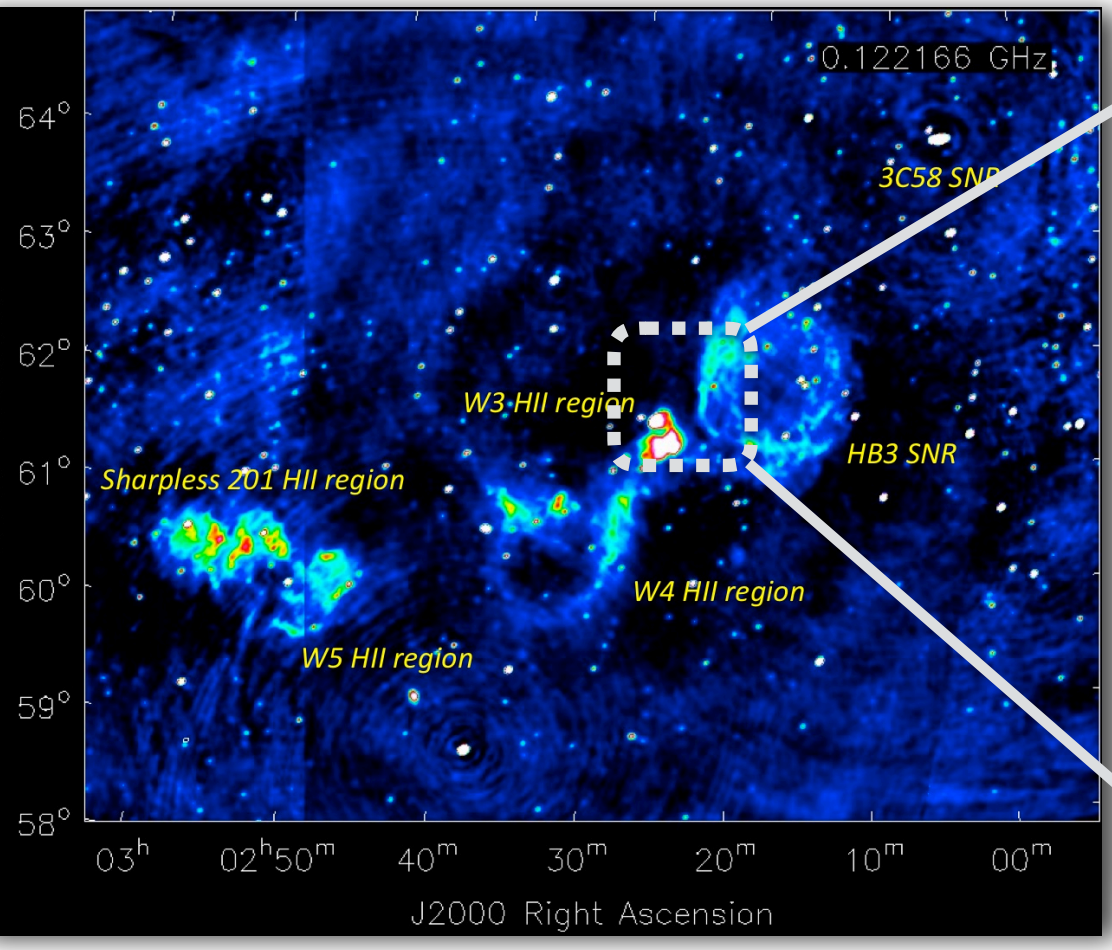
- free-free from HII regions becomes optically thick between 150 MHz and 50 MHz

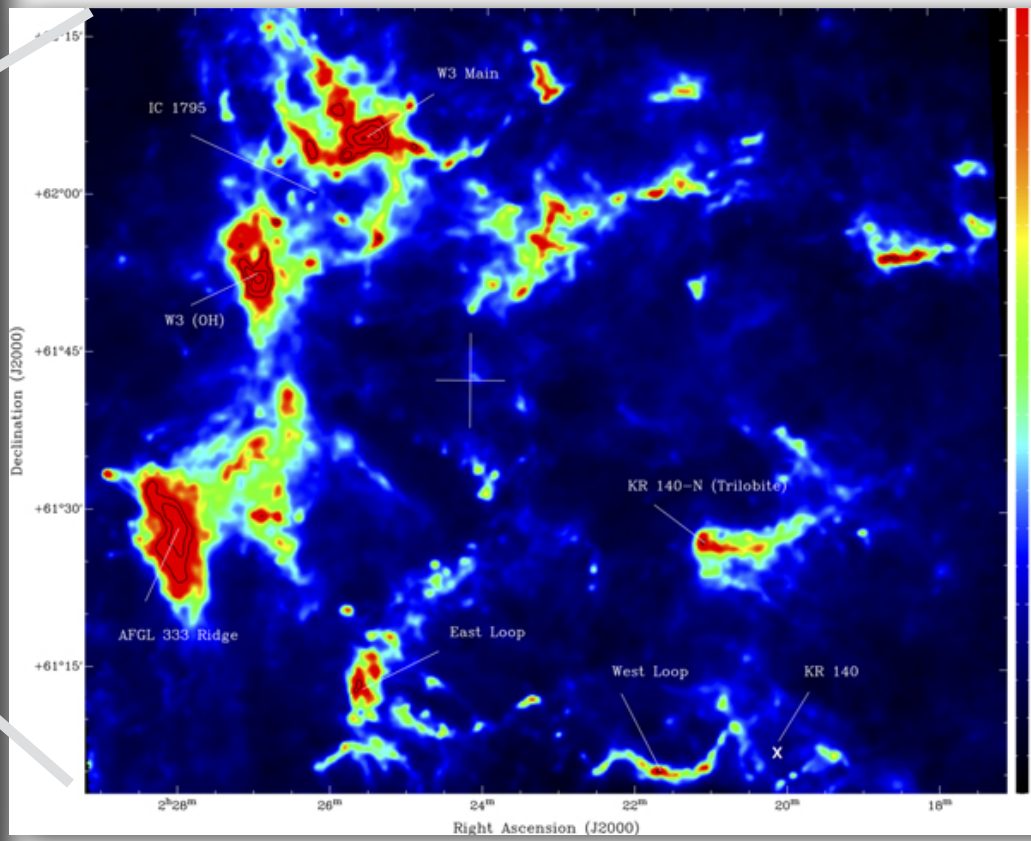
  [Polderman et al., in prep.]

plan 1: compare protostellar populations in far-infrared and meter waves

LOFAR 122 MHz
(structures: HII regions, SNRs)
[**Glenn White**, work-in-progress]

Herschel 50–500 μm
thermal dust
HOBYS key program
[Rivera-Ingraham+ 2013,2015]





W3 molecular cloud
distance ~2 kpc

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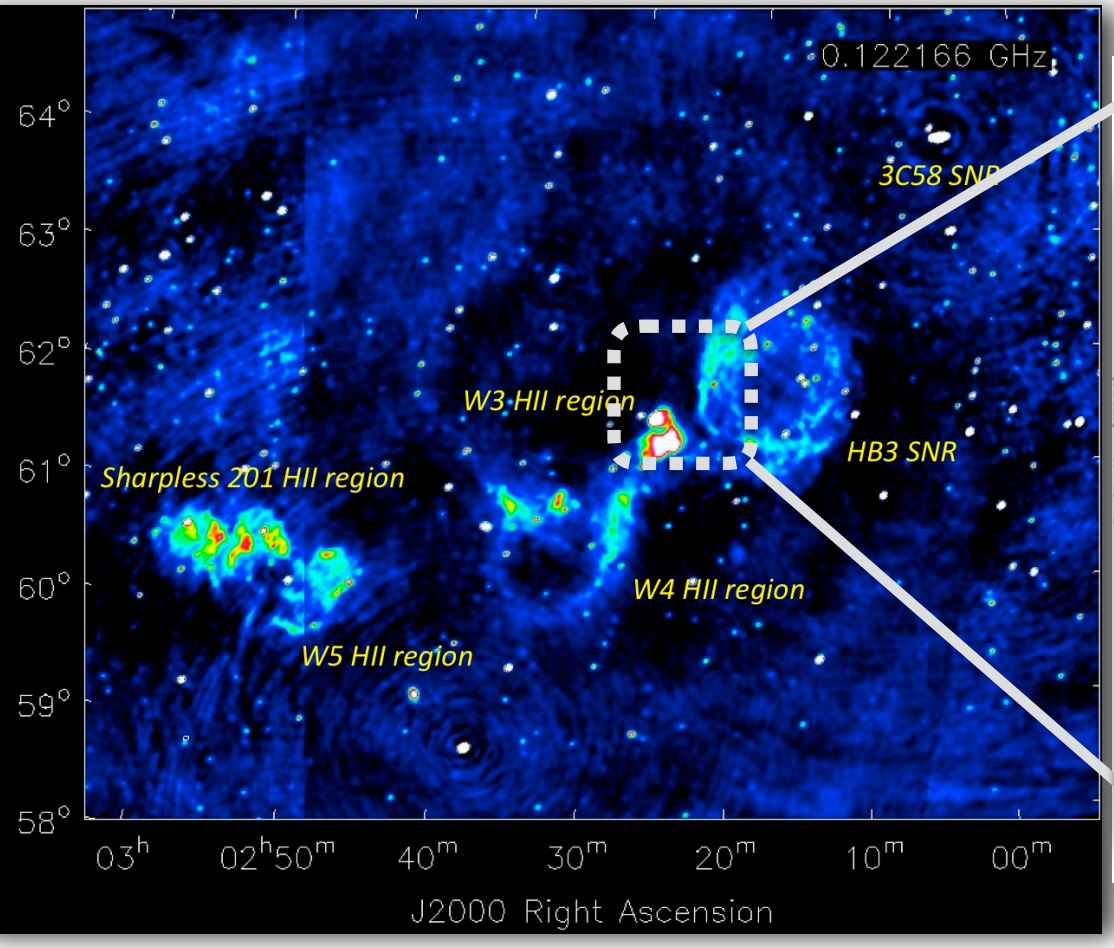
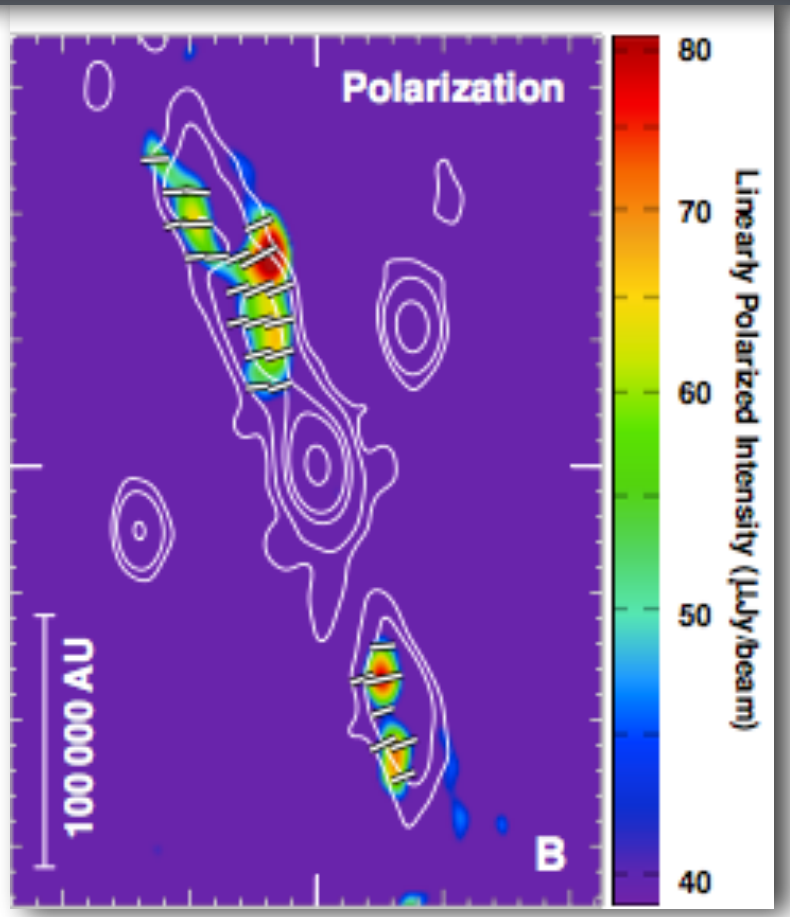


W3 molecular cloud
distance ~2 kpc

- both *Herschel* and LOFAR-NL:
  ~30" resolution = 0.3pc at 2kpc
- open questions:
  - is LOFAR (HBA) sensitivity enough?
    (~0.1 mJy in surveys tier1)
  - include LOFAR LBA (30–90 MHz)?
  - what to do with diffuse structure?
  - …

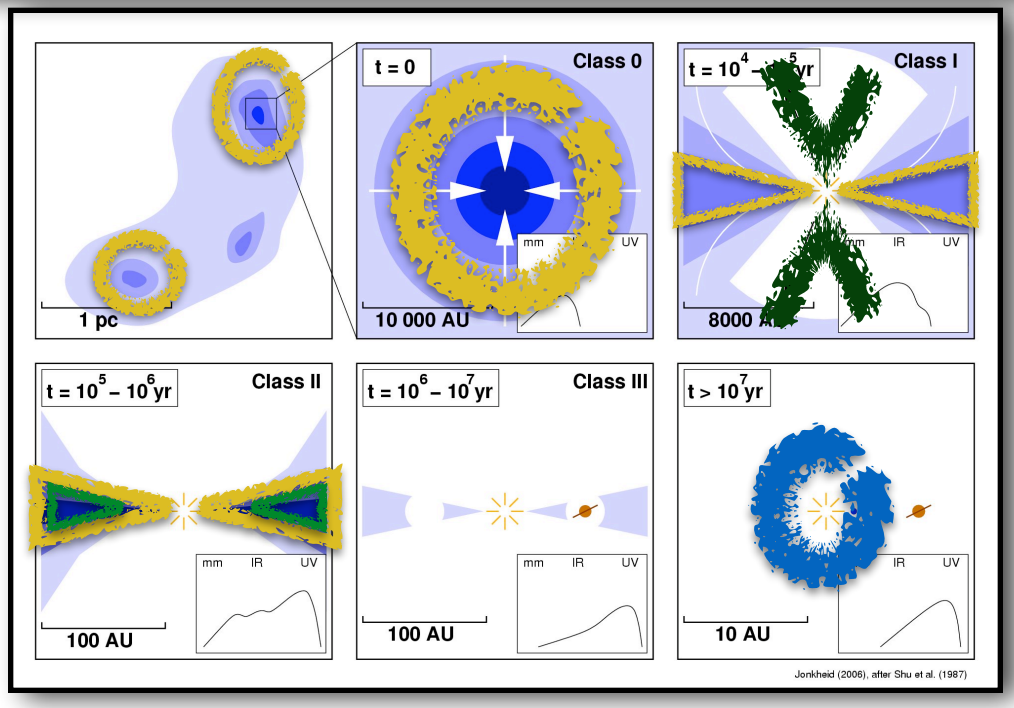
physical processes

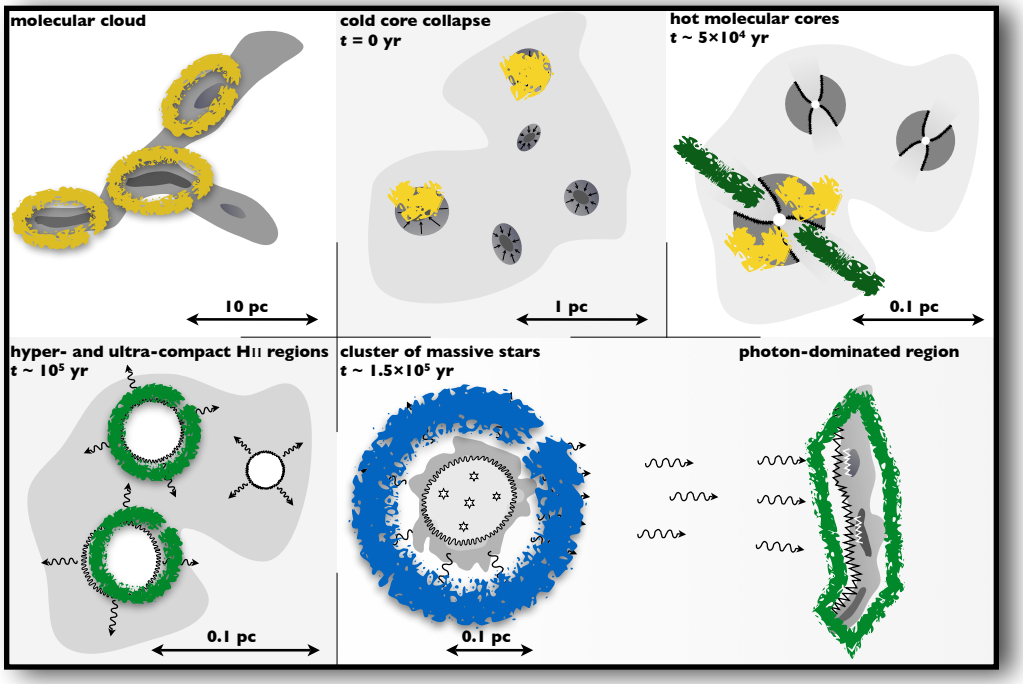
- for far-infrared emission:
  - ‘blackbody’ dust grains requirements:
    - ✓ enough dust
    - ✓ (central) heating source
    - ✓ low temperatures, 10K – 100K
- processes leading to meter-wave emission:
  - free-free ‘thermal’ emission requirements:
    - ✓ ionized medium (HII regions)
    - ✓ ***B***-field to decelerate particles
  - synchrotron ‘non-thermal’ emission requirements:
    - ✓ ionized medium,
    - ✓ high velocities
    - ✓ strong ***B***-field
    - ✓ dense ambient medium to impact on, create shocks



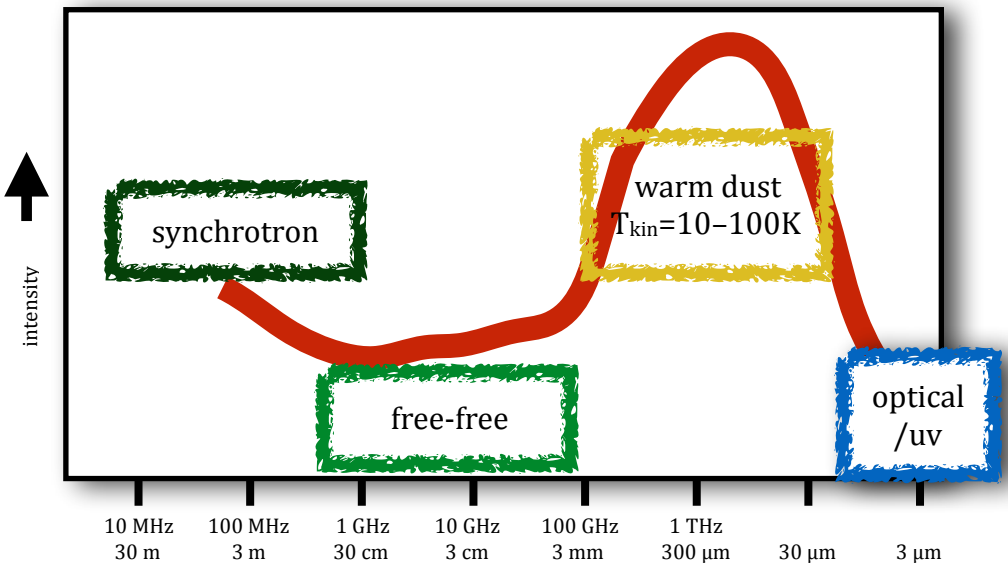
VLA, 6 cm
[Carrasco-Gonzalez+ 2010]

plan 1: protostellar emission in far-infrared and meter waves





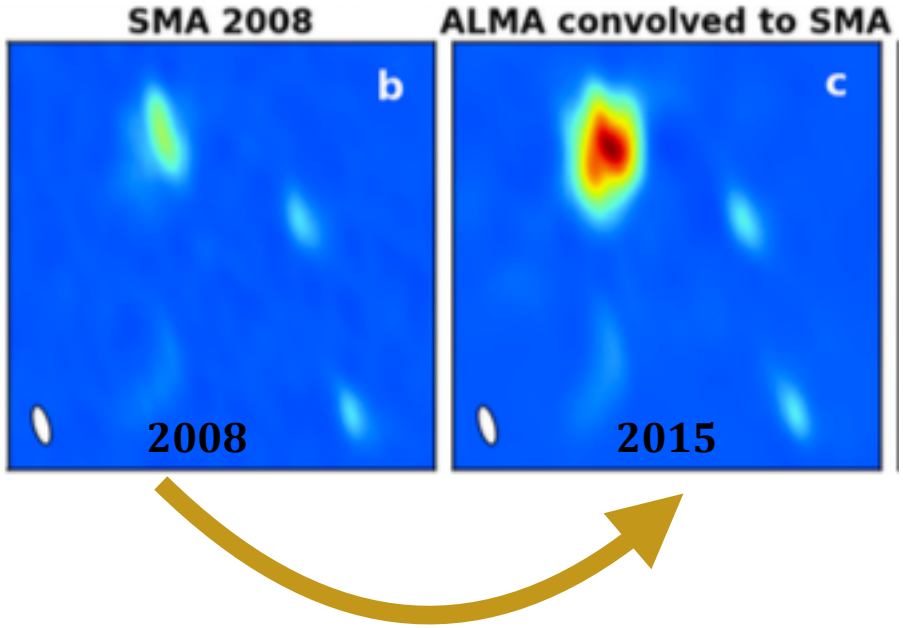
- study which processes and physical components of protostars produce emission at <300 MHz by resolving individual protostars (not just the massive ones)
- use multi-frequency to constrain spectral index: >1 GHz (VLA?), <100MHz, LOFAR LBA



plan 2: monitor star-forming clouds for bursts

- protostellar cores experience 'bursts' in bolometric luminosity
  - bursts persist for years–decades [Audard+ 2014]
  - accretion burst —> associated jet onset?
- steps:
  1. pick well-known star-forming cloud at up to 1–2 kpc distance (maybe away from Galactic plane)
  2. monitor it with LOFAR every ~month (or every semester?)
  3. reduce data quickly :-)
  4. check for differences to find bursts [new jets may spark synchrotron emission]
- open questions:
  - which first? re-radiating dust, or synchrotron jet?
  - how often do we expect protostars to burst?

NGC6334, 1.7kpc
Hunter+ (2017)



Summary

- plan 1: far-infrared – meter wave comparison of Galactic GMC
  - detect protostellar populations at meter waves
  - distinguish which components give rise to what type of emission
  - *would use existing LOFAR surveys data*
- plan 2:
  monitor a star-forming molecular cloud for flare events
  - campaign of repeated LOFAR imaging observations
  - quick reductions, compare consecutive observations, find flares
  - *needs separate (long-term) observing proposal*