Observing the early phases of massive star formation

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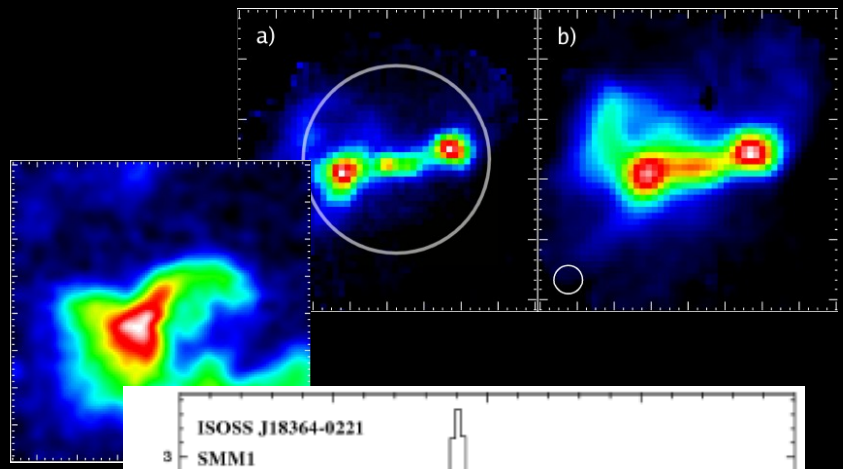
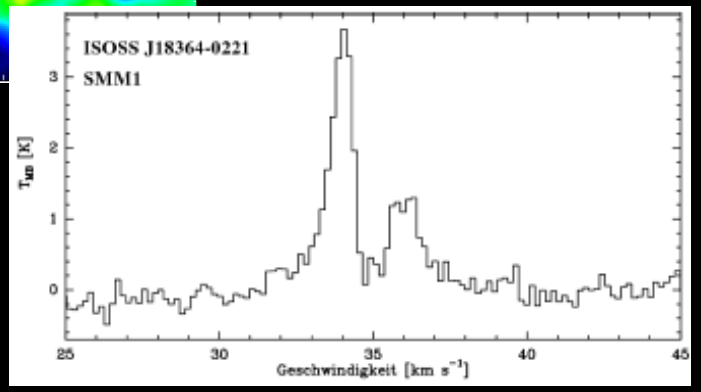
Massive Star Formation

- Why?
  - important for energy and turbulence feedback
  - enrichment of ISM with metals
  - two competing formation scenarios
- Observing the early phases is difficult
  - highly obscured
  - far away
  - short timescales
- Large scale surveys to find massive SFRs
  - ISOSS !!
  - 50 candidate regions

Observations

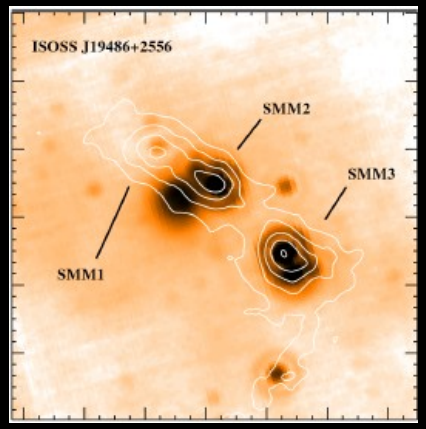
- Thermal dust emission in the (sub)mm regime
  - good spatial resolution
  - determination of dust masses
- CO(3-2) observations
  - outflows and gas masses
- Molecular line observations
  - temperatures, masses, densities
  - gas kinematics (infall / outflows)
- Near infrared observations
  - search for embedded YSOs
  - extinction maps and shocks



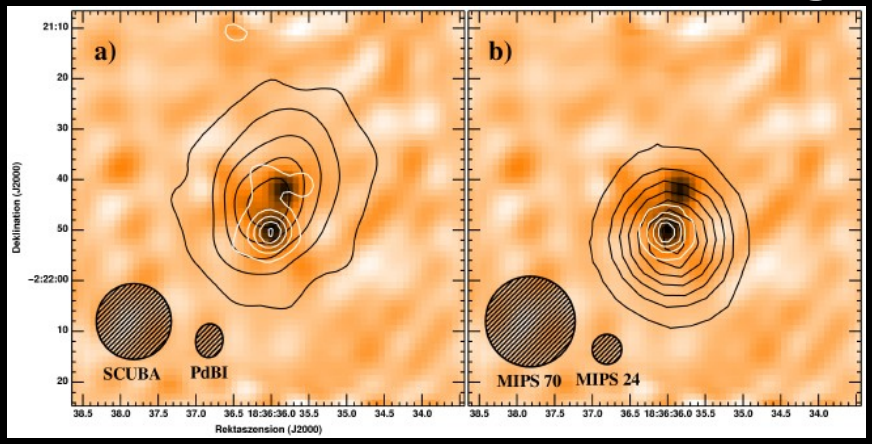


Observations

- Observations with the *Spitzer* space telescope
  - mid infrared with IRAC
    - search for YSOs
  - far infrared with MIPS
    - characterization of pre/protostellar cores
    - search for embedded protostars



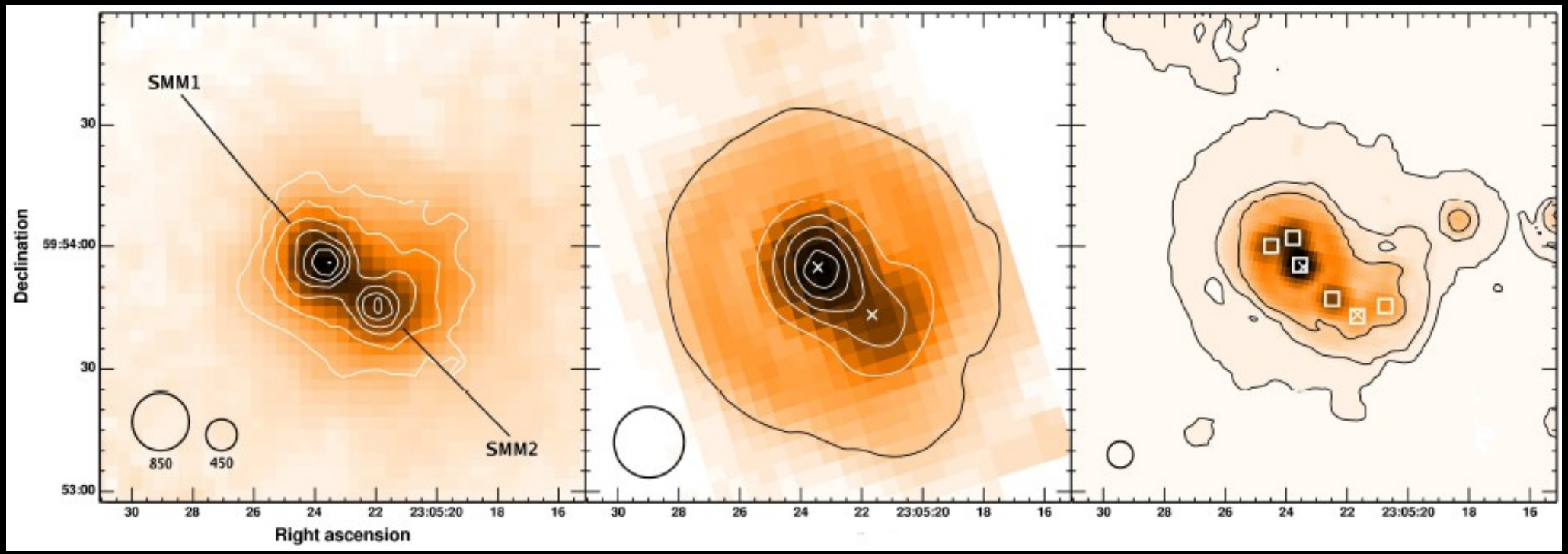
- Interferometric observations with the PdBI
  - mm continuum and molecular lines with high spatial resolution



Observations

(Sub)millimeter continuum	40 regions
CO(3-2) survey	99 regions
NIR observations	22 regions
IRAC observations	8 regions
MIPS 24 & 70 μm observations	8 regions
MIPS SED observations	13 cores / 8 regions
Molecular line observations	28 cores / 17 regions
Interferometry with the PdBI	3 cores / 2 regions
IRS spectroscopy	6 protostars / 4 regions

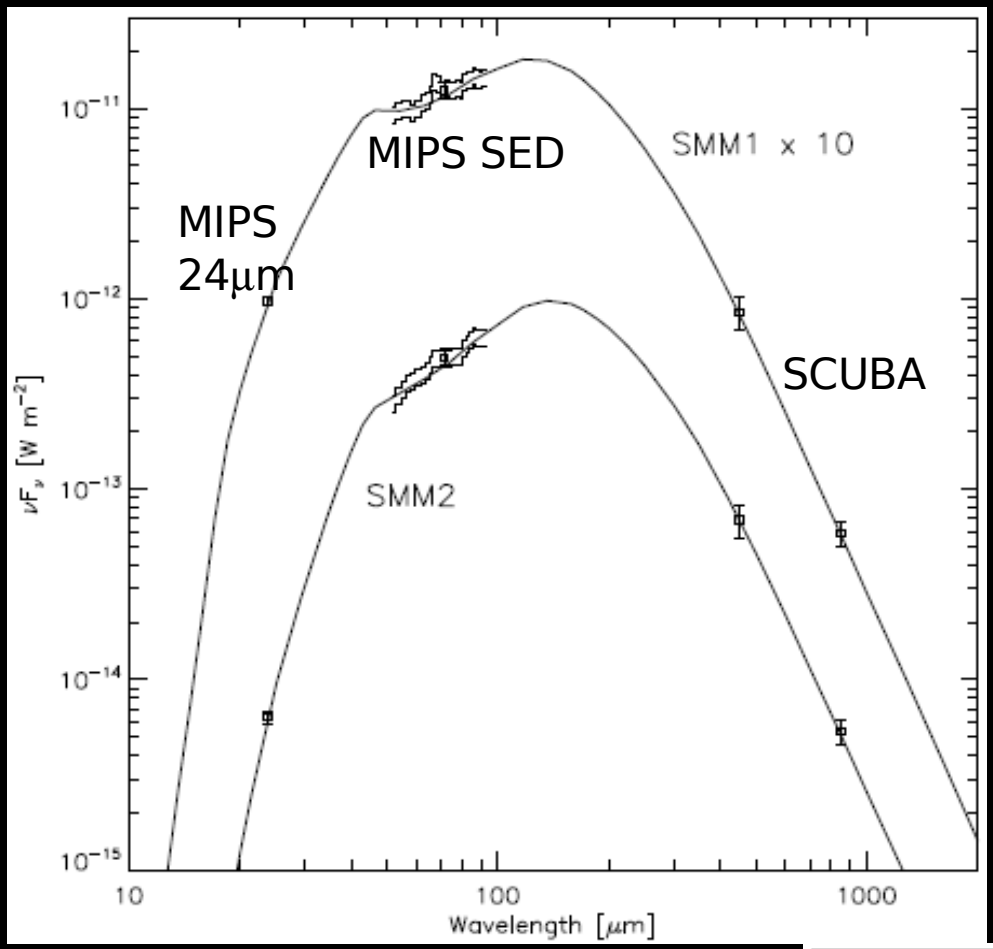
Case Study: ISOSS J23053+5953



Submillimeter (SCUBA/JCMT) | 70 μm (MIPS/SPITZER) | 24 μm (MIPS/SPITZER)

distance ~ 3.5 kpc
two cores with ~ 0.1 pc radius ➔ typical for protostellar cores
24 μm emission detected

SEDs, Temperatures, Masses



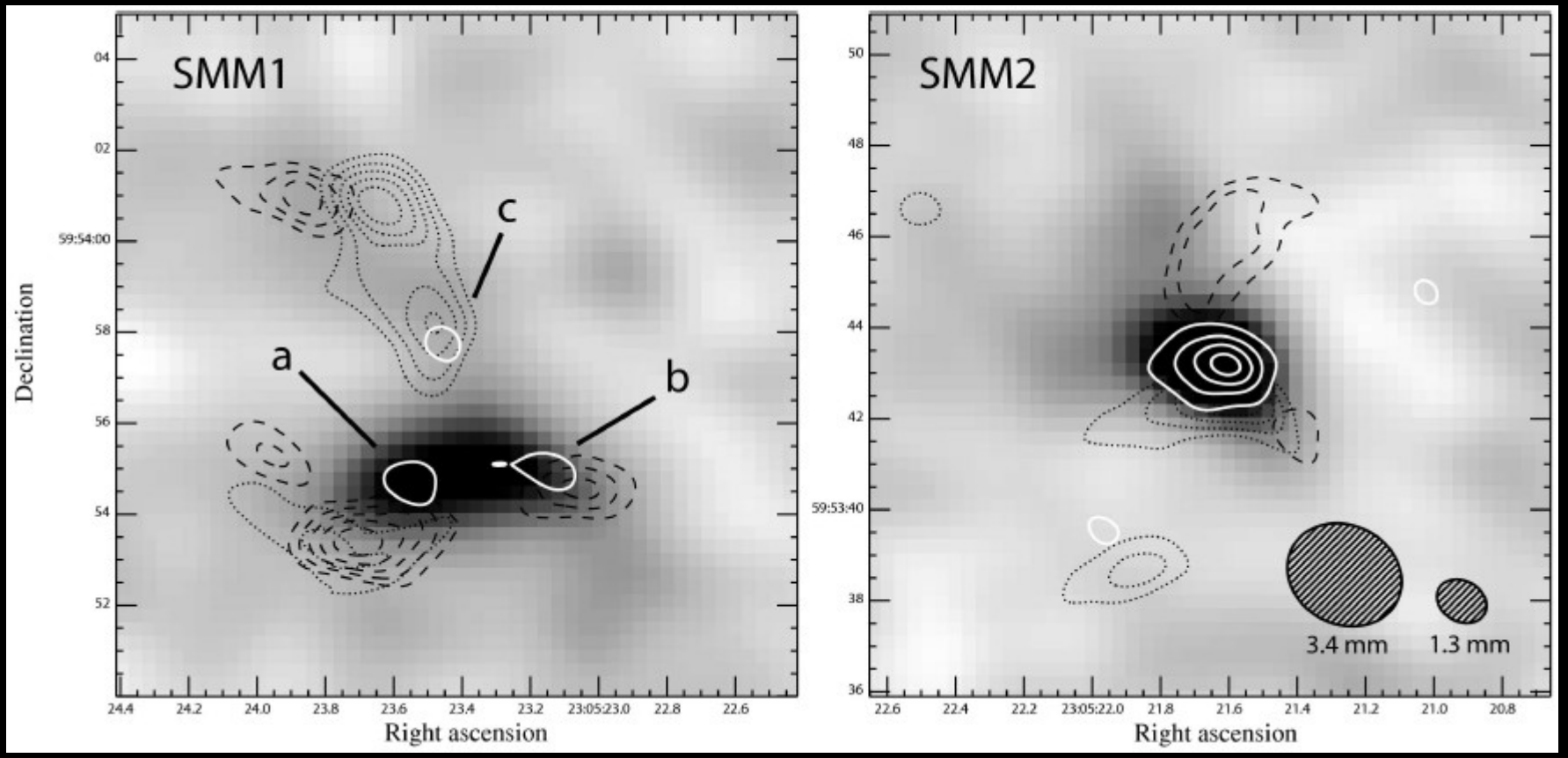
Two component fit with modified Planck curves (warm and cold dust) is sufficient for the entire region and both cores.

Total mass is confirmed by measurements of $C^{18}O$.

thermal emission is dominated by cold component

Source	Mass [$M_\odot$]	Luminosity [$L_\odot$]	T_{cold} [K]	T_{warm} [K]	M_{cold}/M_{total}
ISOSS J23053+5953	900	2100	17.1	53	> 0.99
SMM1	195	1000	19.5	51	> 0.99
SMM2	205	490	17.3	41	> 0.99

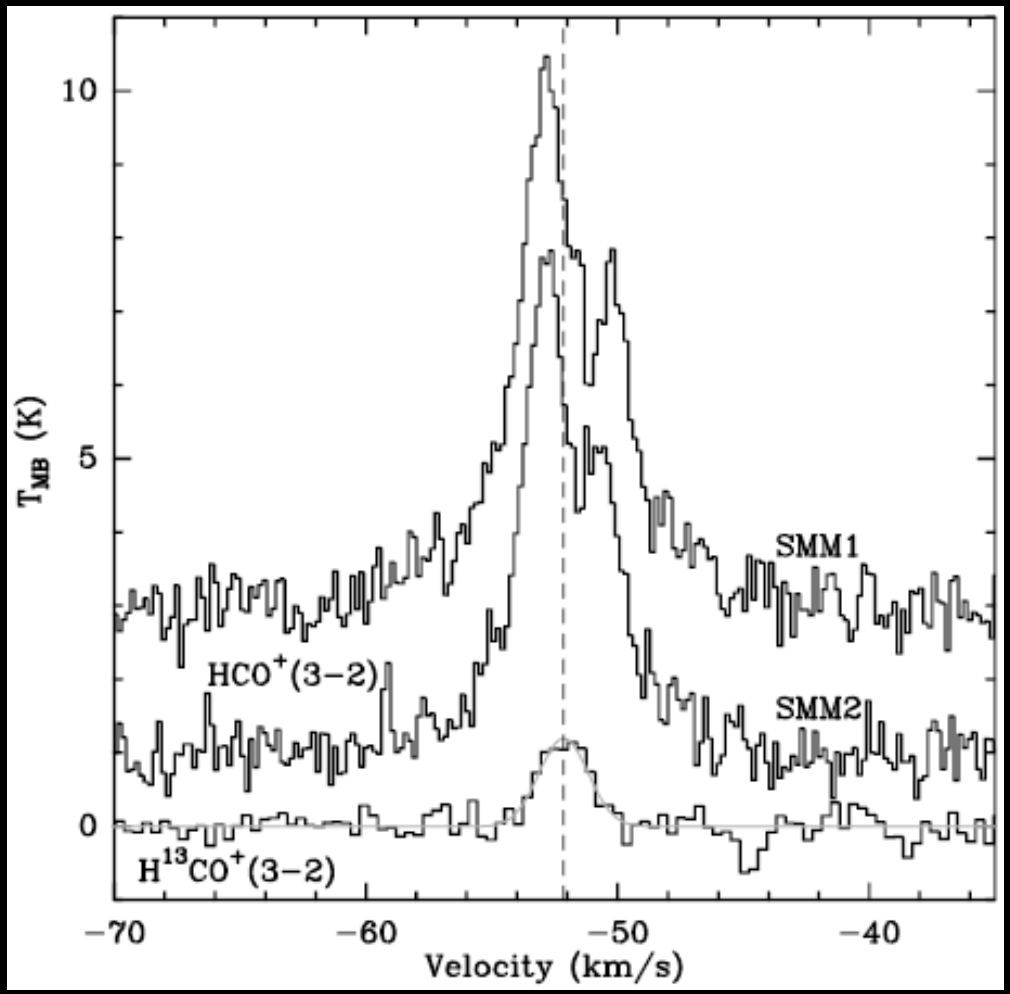
Interferometry



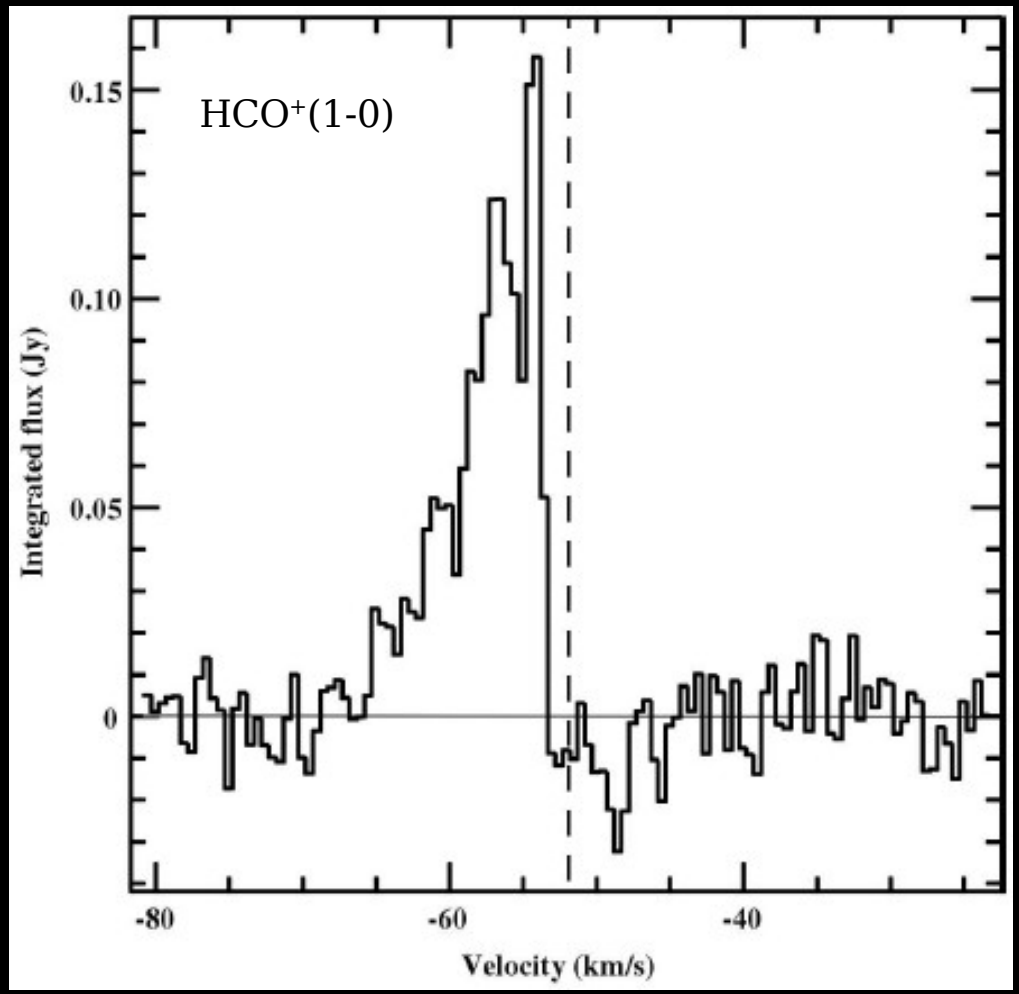
3 mm continuum (grey scales) + 1.3 mm contours (white)
dashed and dotted contours are blue and red CO lobes

Mass of SMM2 ~ 26 $M_\odot$

Gas Kinematics: Signposts for Infall

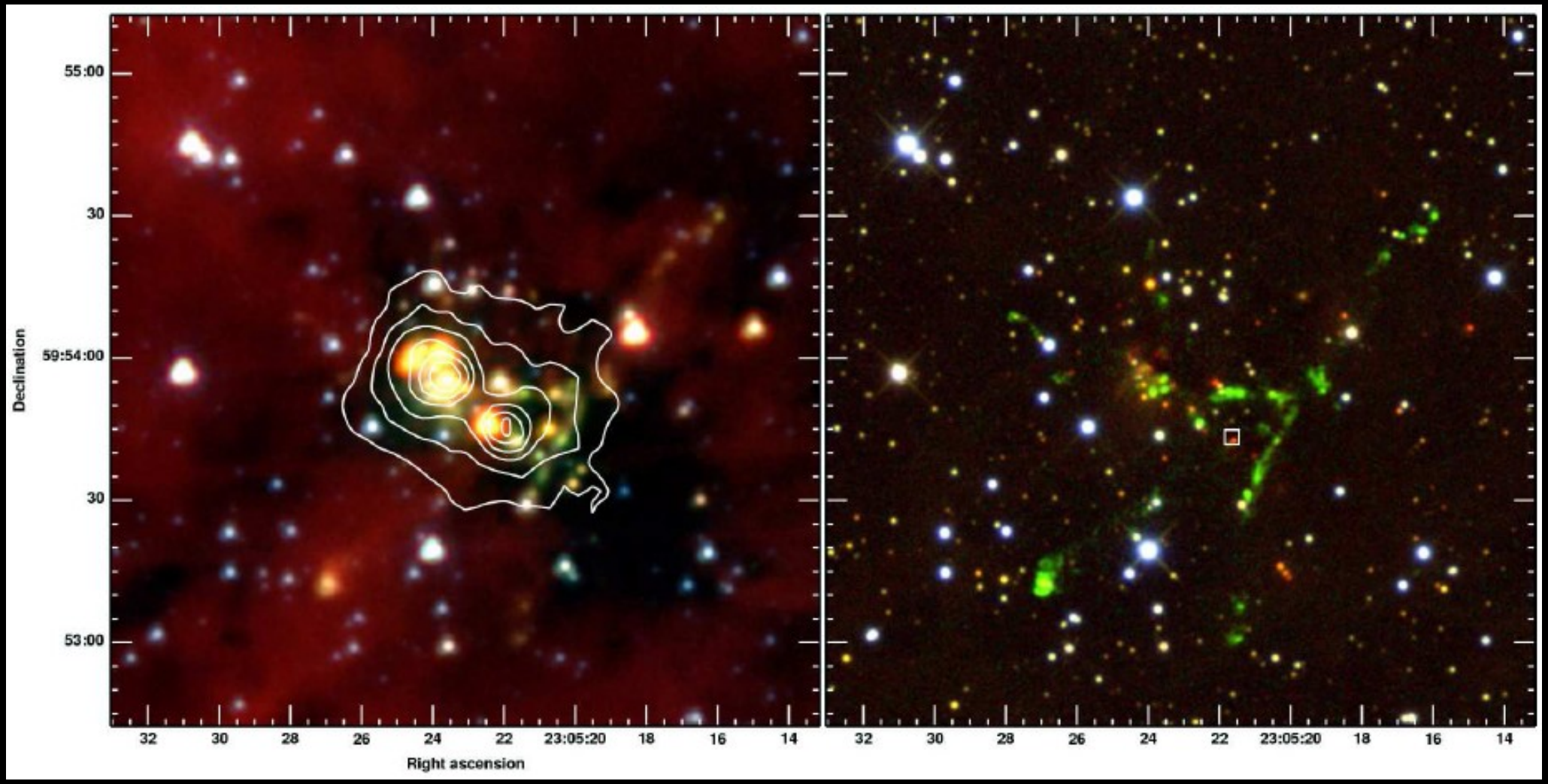


IRAM 30m single dish observations
angular resolution ~ 9.5“



PdB interferometric observations
angular resolution ~ 2.5“

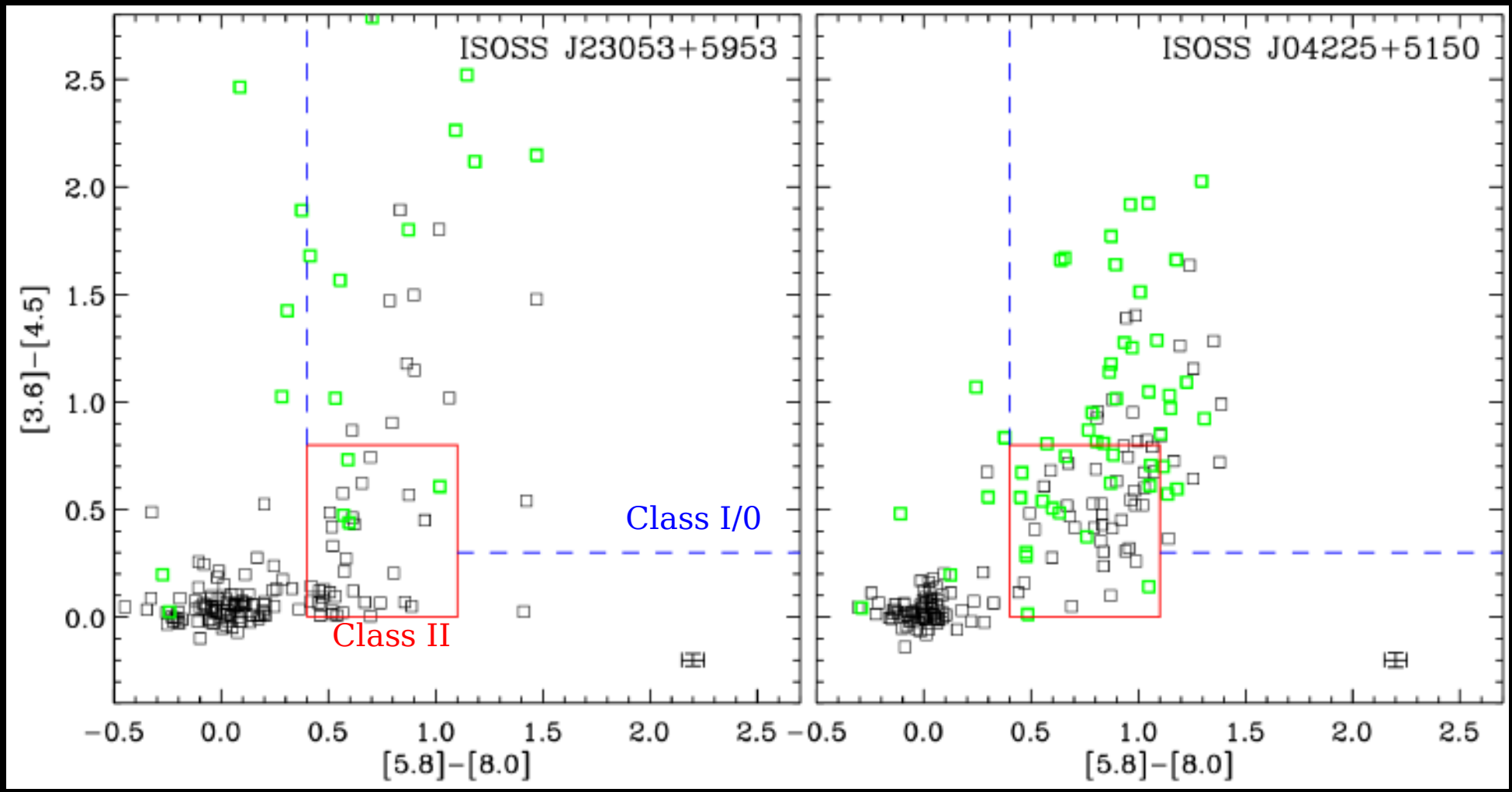
The mid- and near-infrared view



MIR color composite (IRAC)
3.6, 4.5, 5.8, 8.0 μm are
blue, green, orange, red

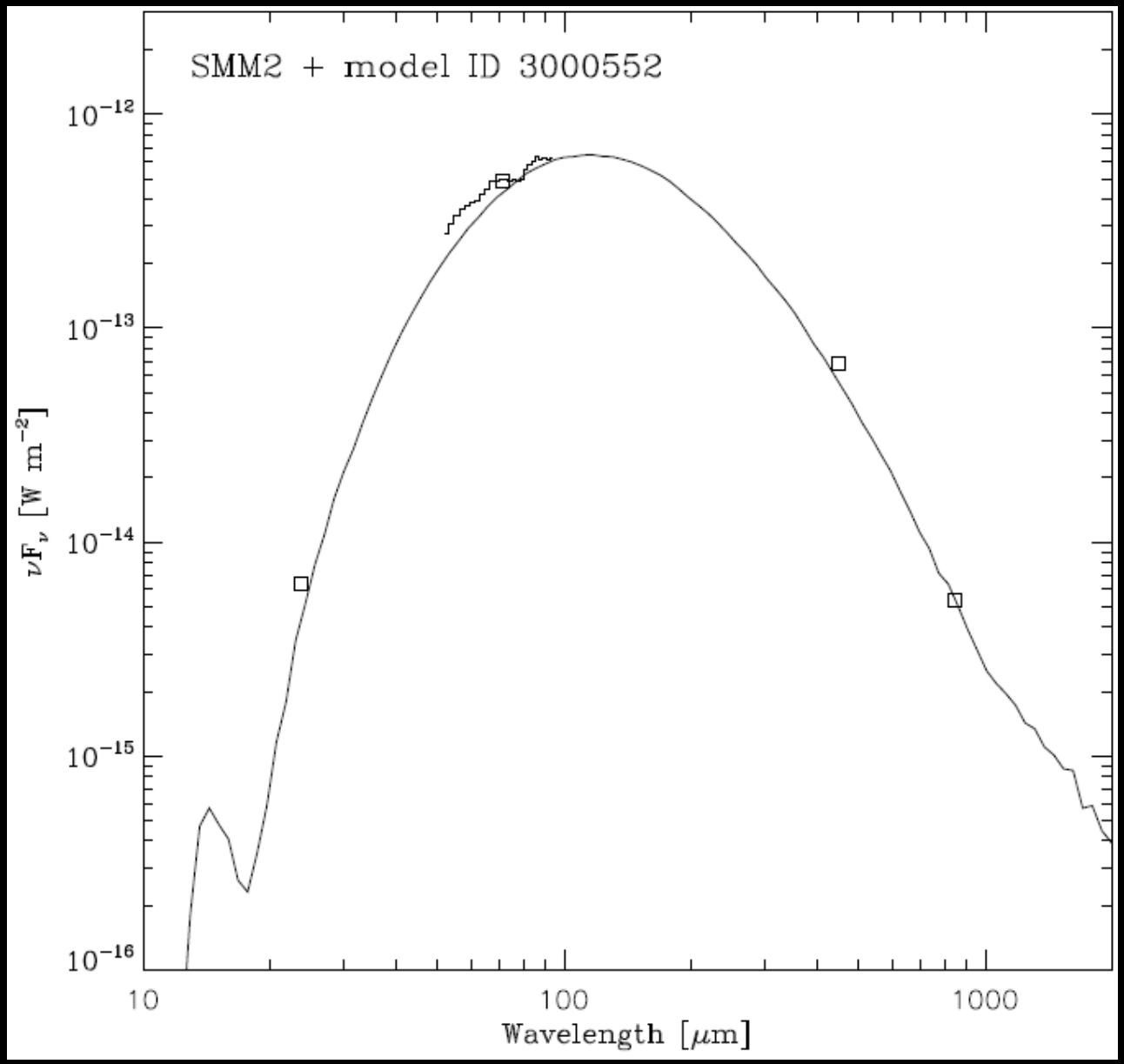
NIR color composite (Omega2000)
J,H,K_S are blue, green, red
H_2 ν=1-0 S(1) is green as well

Classification of YSOs



according to classification scheme of Allen et al. 2004

Modelling of Protostellar Cores



Compare the observed SED with radiative transfer models from Robitaille et al. 2006.

➔ determine core and embedded source properties

See talk by Martin!!

Conclusions

- Cold ISOSS sources are indeed sites of star formation
- Are massive and young
- But most show embedded 24 μm source(s)
- Thus probably not prestellar cores? Need radiative transfer modelling!
- Show outflow and jets
- Will be part of MPIA's *Herschel*/PACS GT Key Proposal on SF
- Findings support the scenario of gravoturbulent fragmentation for the fromation of massive stars