ATLASGAL: APEX Telescope Large Area Survey of the Galaxy

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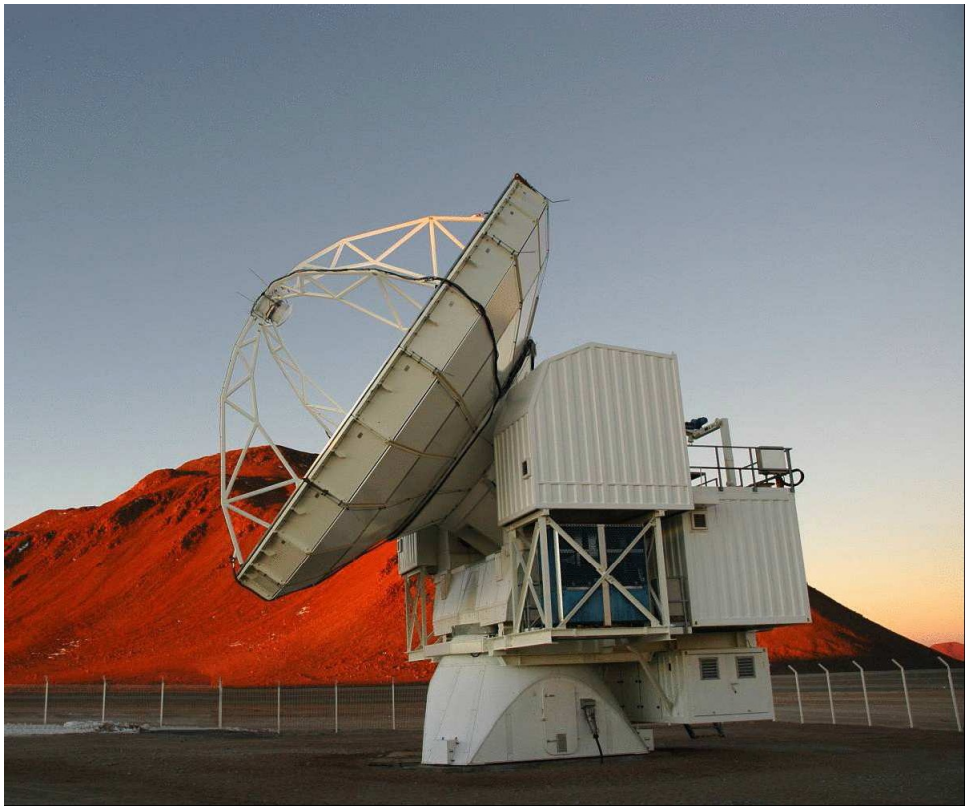
+ A growing number of students !

Early stages of MSF

- High-mass stars evolve quickly, are rare and at large distances
  - ➔ only Galaxy-wide survey can get significant samples
- Evolution sequence in high-mass star formation and associated timescales not understood yet
- Up to now, samples biased towards evolved stages, e.g. IR-bright color selected, cm continuum, masers
- High-density gas is representing the gas which is going to form stars soon:
  - ➔ Need for large scale survey in (cold) dense gas tracer, submm dust continuum !

APEX in a nutshell

- 12m, modified copy of ALMA prototype antenna
- At 5100m on Chajnantor Plateau (ALMA site)
- MPG/ESO/OSO/Chile
- Base in Sequitor @ 2500m with control room etc.
- Surface ~ 15 micron
- BEs: 1-2.5 GHz FFTSs
- FEs (→ Talk Heyminck) :
  - Heterodyne Rxs: 230GHz - THz
  - Bolometer arrays: 850/350micron



LABOCA

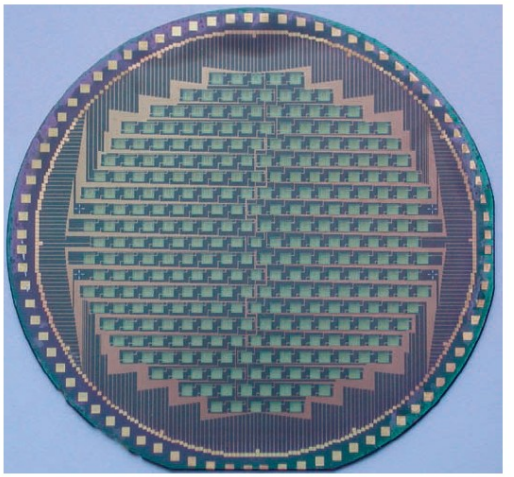


Figure 1: A 'naked' LABOCA silicon wafer. Each small square is a bolometer.

Figure 2: LABOCA in the Cassegrain cabin of the APEX telescope. The receiver is in the centre of the picture. Four of the five mirrors used for the optical coupling are visible.

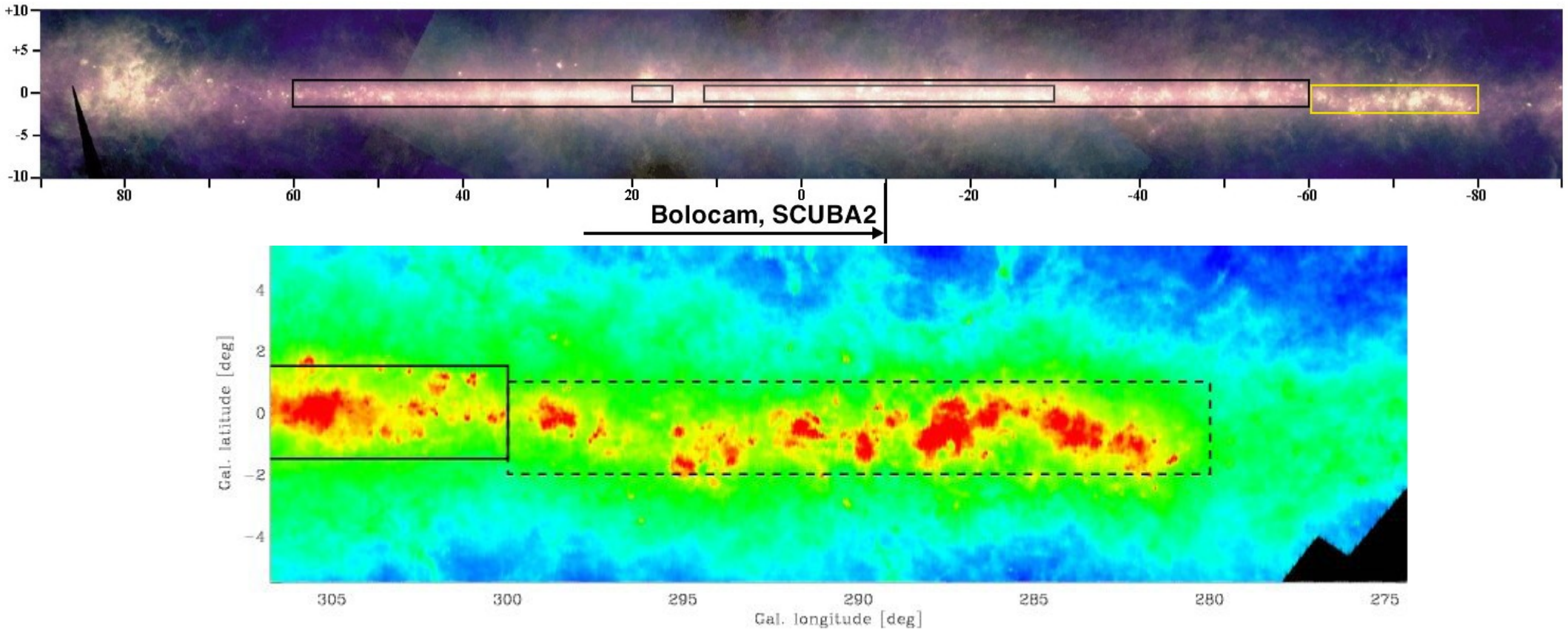
- Built @ MPIfR
- 295 bolometers @ 870mu
- FOV: 11 arcmin
- Beam: 19 arcsec
- Observing modes:
  - Large OTFs
  - Spirals/Rasters
  - Photometry

ATLASGAL:

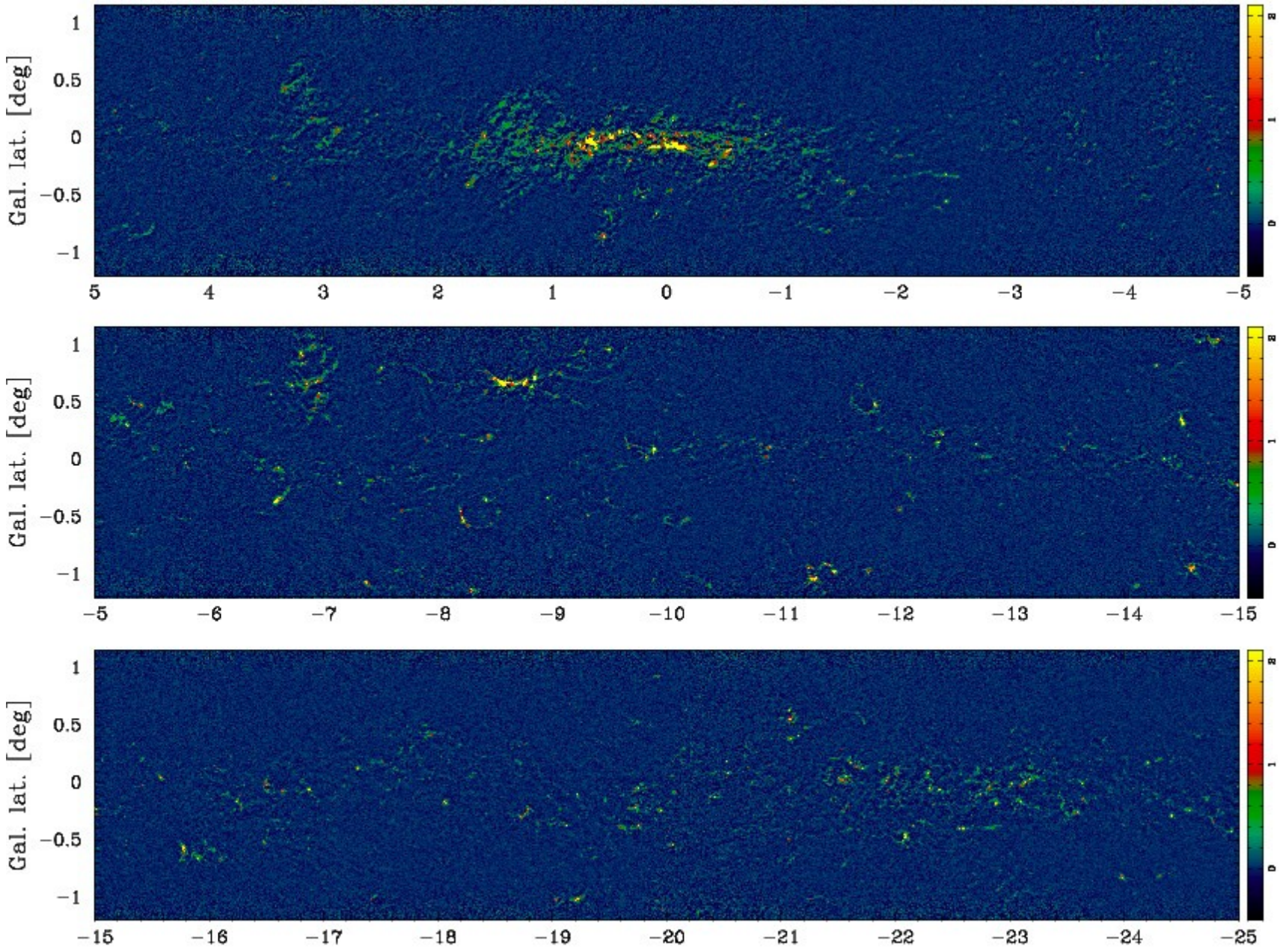
- Unbiased survey of the inner Galactic Plane at 870µm
  - study massive star formation throughout the Galaxy
  - pre-stellar initial mass function down to a few $M_\odot$
  - study large scale structure of the cold ISM
  - associate w. other Galactic surveys (VLA, Spitzer, MSX, Hi-GAL)
- Mapping |l| < 60, |b| < 1.5
  - sensitivity 1σ = 50~mJy/beam
  - 3σ: 1 $M_\odot$ ~ at 500 pc, 35 $M_\odot$ ~ at 3 kpc, 240 $M_\odot$ ~ at 8 kpc
- Complementary to:
  - 1.1mm BGPS in the north
  - Ongoing Hi-Gal
  - Soon Scuba-2

ATLASGAL Status

- 2007: Coverage: 95 deg^2, ~75~hours observing
- 2008: additional 300 sq.deg (60-100mJy/bm)
- 2009: - Oct: 90% of requested observations (430h)
- 2010: finish main survey, continue to -60 - -80deg in longitude
  - Data will become public incrementally (images, catalog)

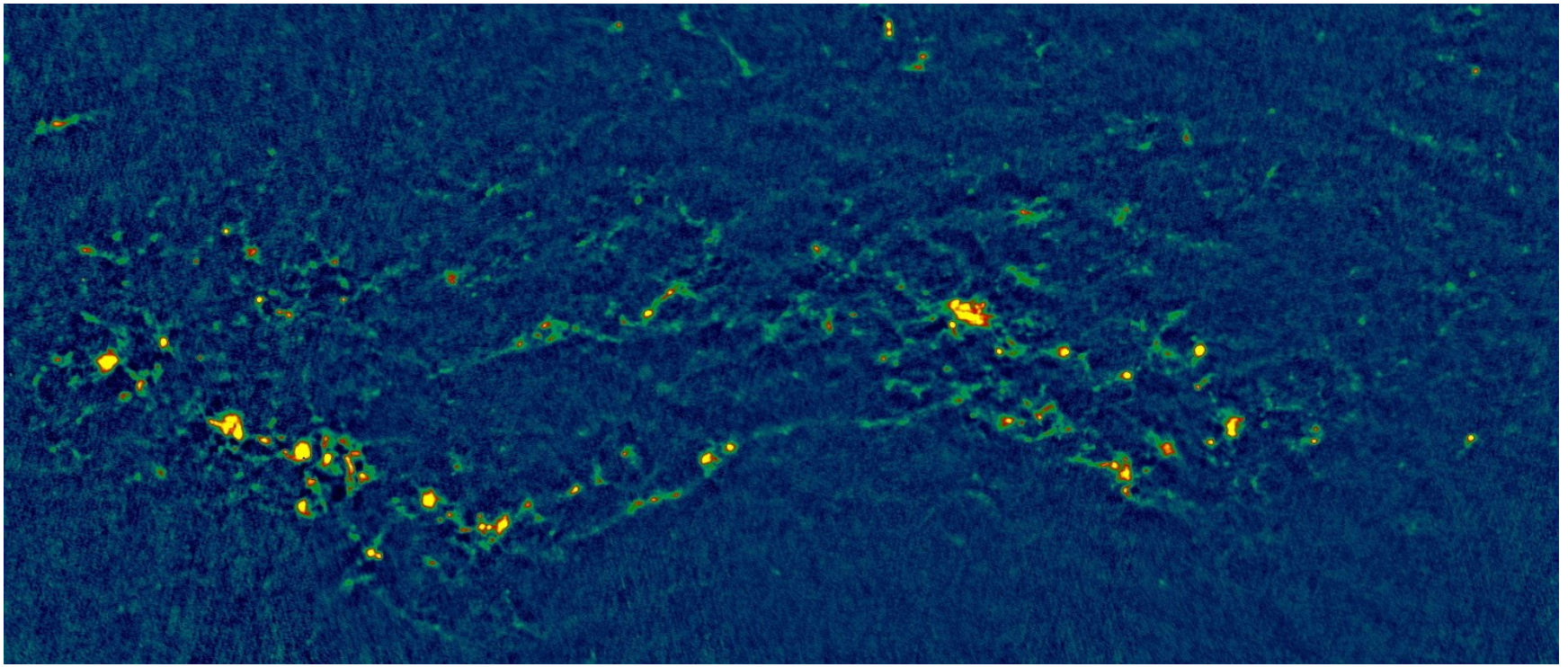


Example maps: 60deg^2

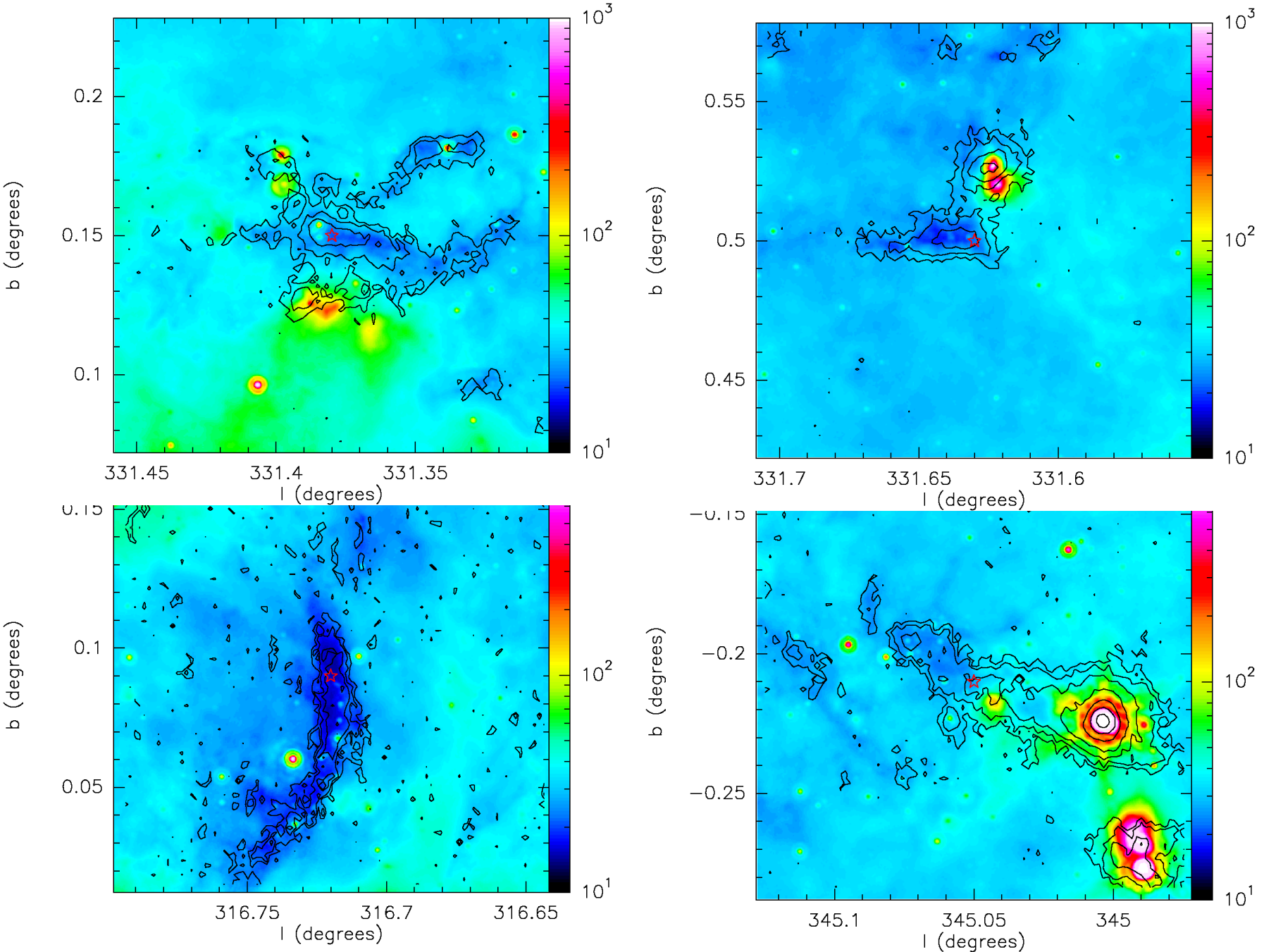


Norma arm: compact sources and long filaments

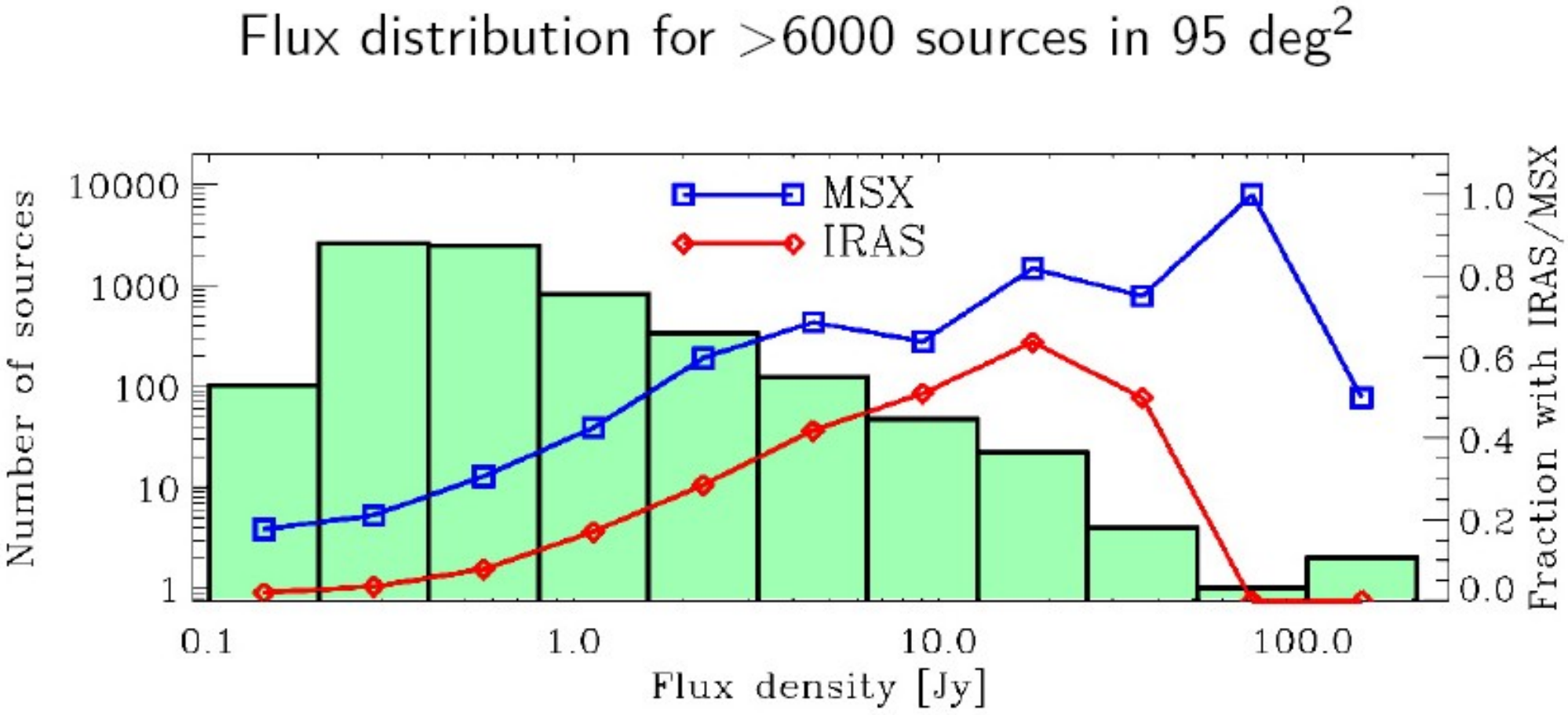
- Extended objects on arcmin scale
- Very long filaments, up to the degree scale!



ATLASGAL IRDC (24mu) examples

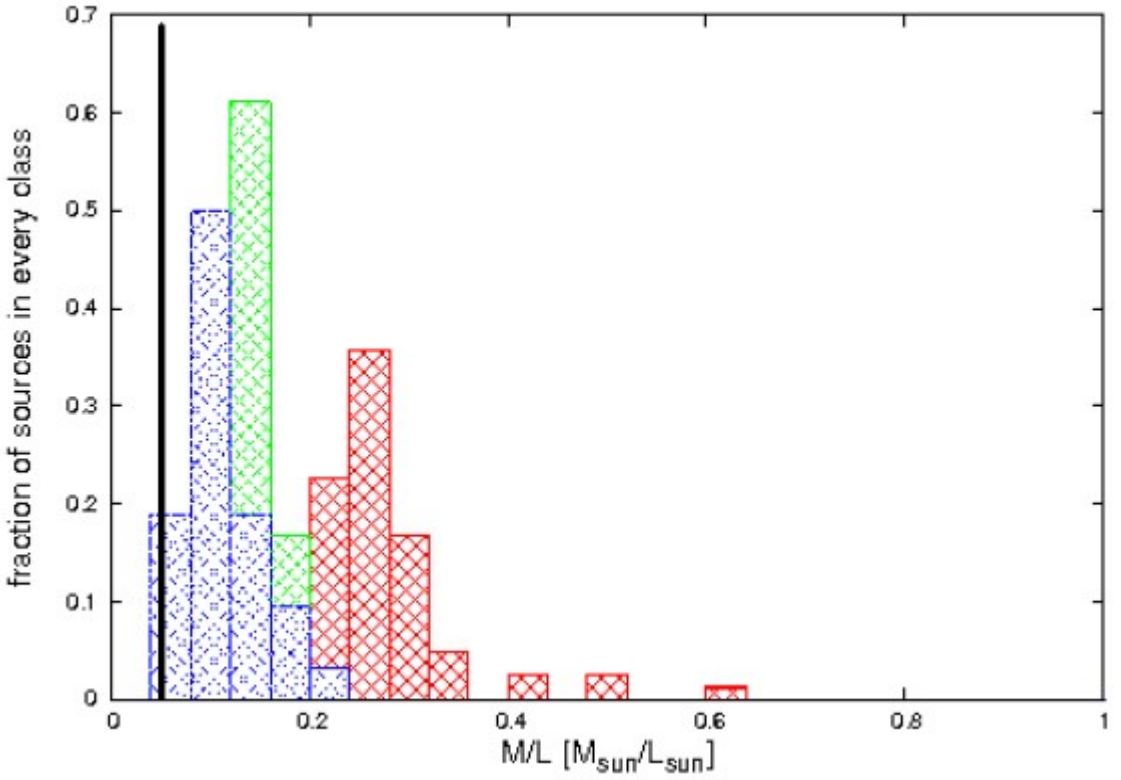


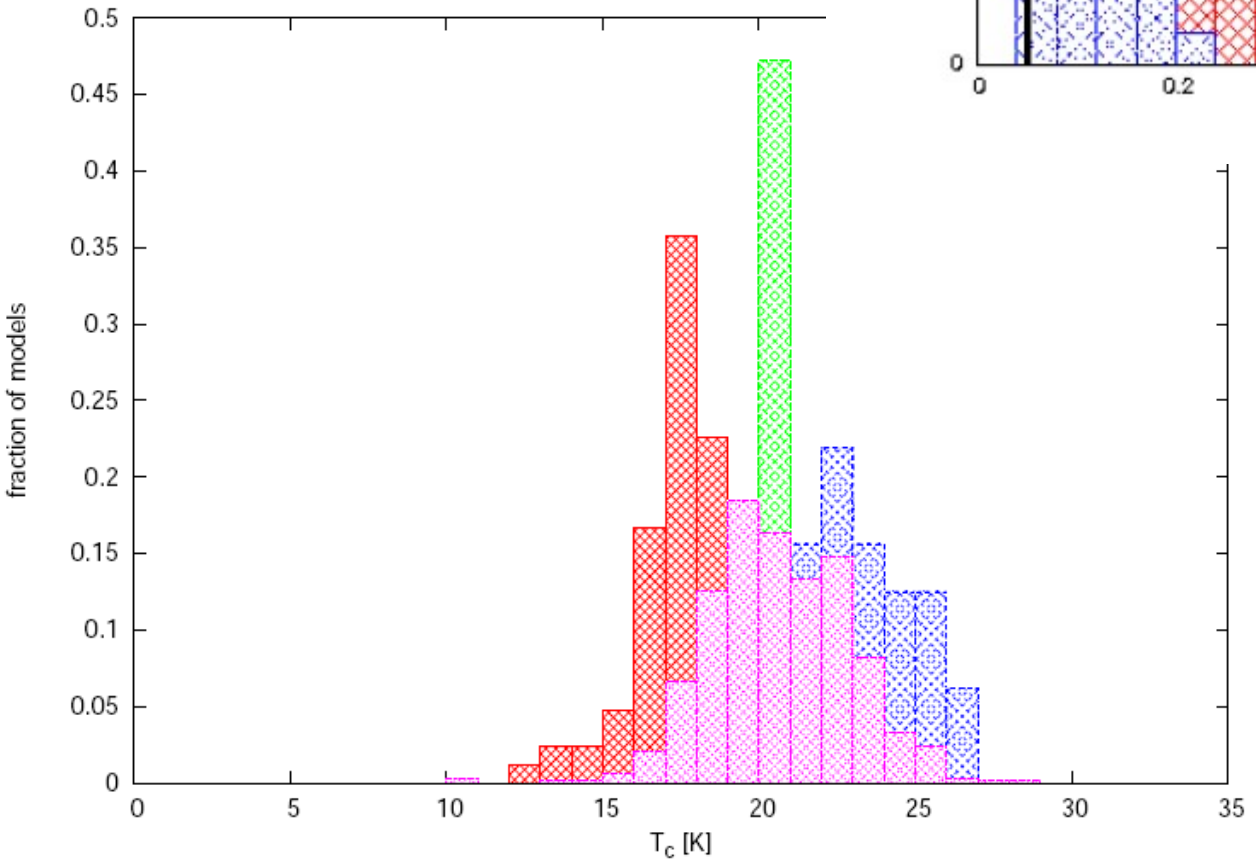
ATLASGAL compact sources



- Compact source catalog (Contreras+ in prep.) 60% no bright IR (IRAS/MSX)
- ATLASGAL/MIPSGAL SEDs (Troost+)

SED fitting results (Troost 2009)

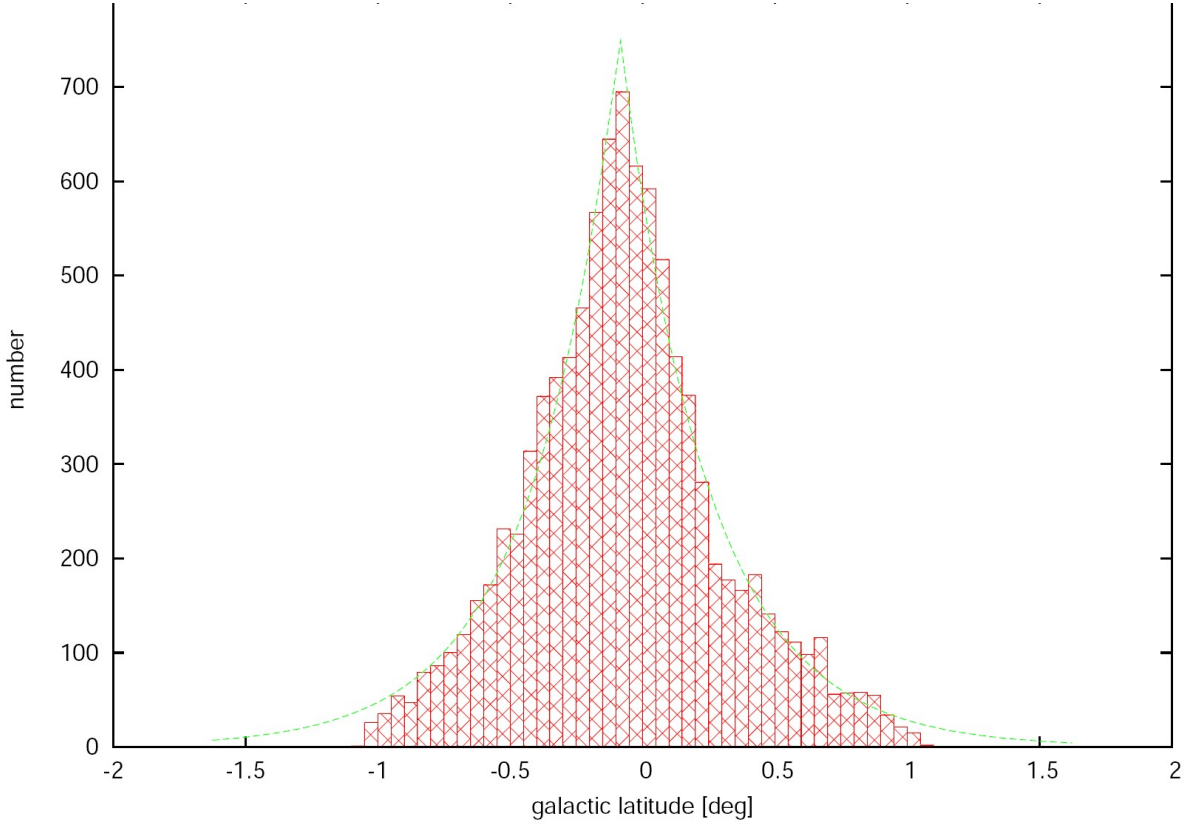




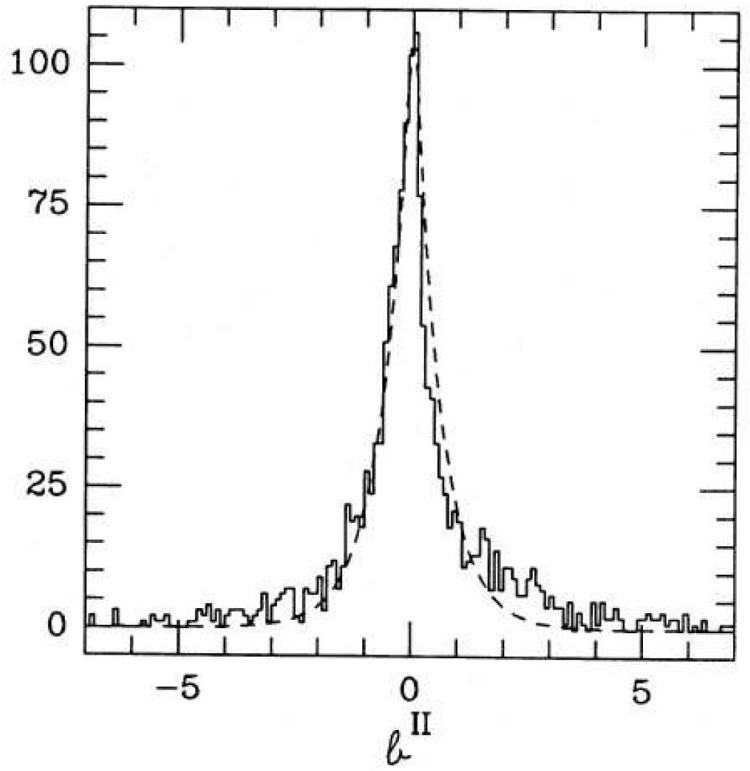
Norma arm @ 7kpc:

- M~200-5000 Msol
- L~1000-50000 Lsol

Latitude distribution



(a)



(b)

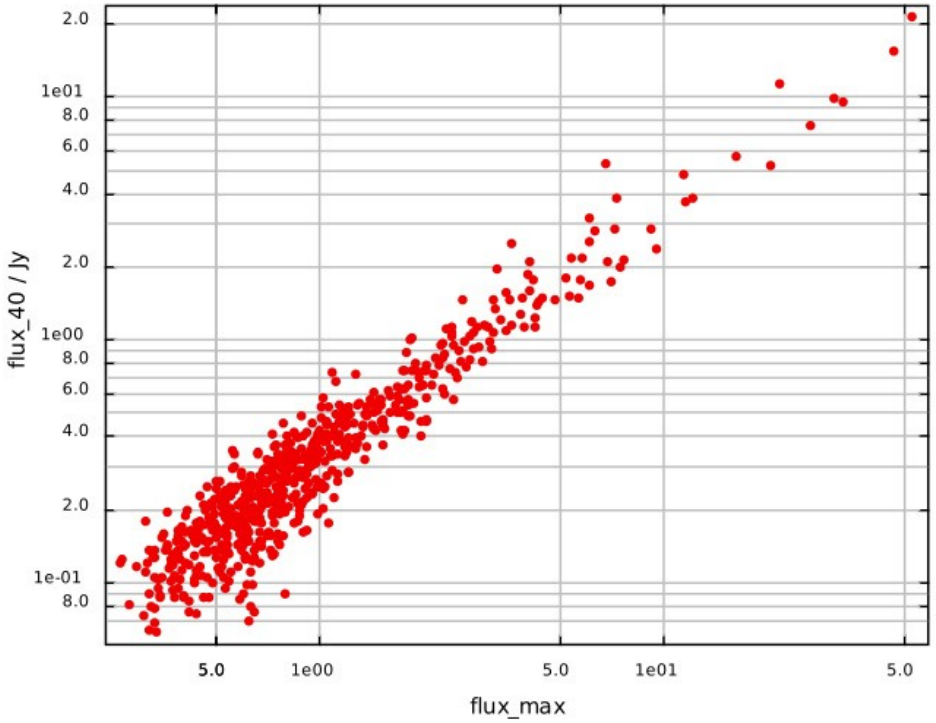
Figure 6.1: (a)Latitude distribution of ATLASGAL compact sources. Assuming an exponential decay a scale height of 0.33° is determined. (b) Latitude distribution of "embedded OB protostellar candidates" (WC89). A scale height of 0.6° is determined.

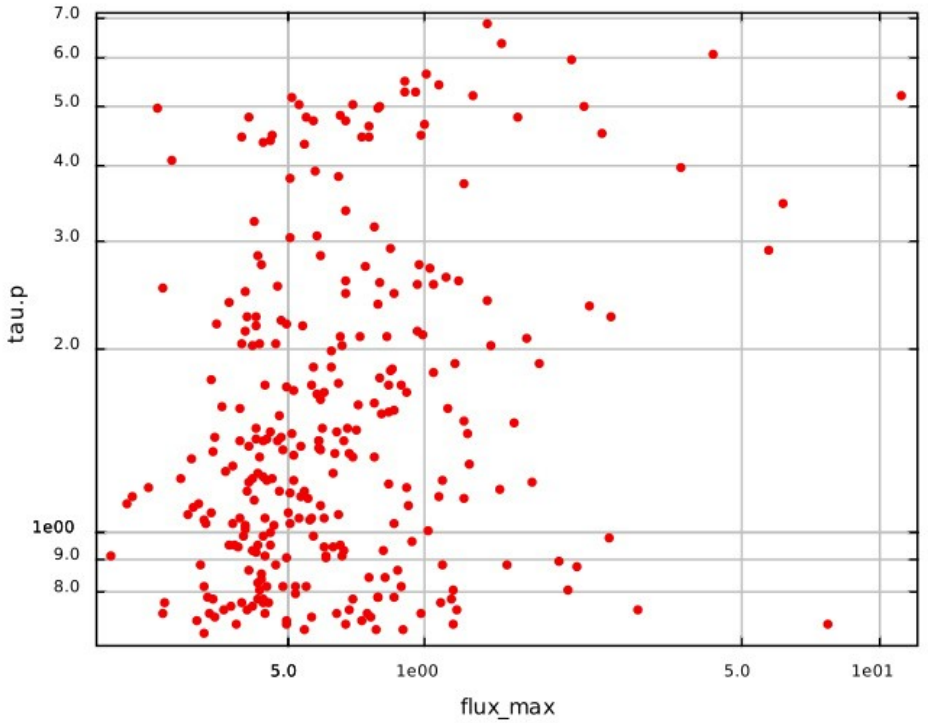
Some statistics

- 60 % no IRAS/MSX
- 35 % associated with IRDCs (within radius of Peretto & Fuller 2009)
- 71 % of MMBs within 20” of ATLASGAL peak, 96% associated with submm
- 6 % within 20” of Becker+1994 cm source
- Deharveng+2010: HII regions enclosed by bubbles
  - 40% surrounded by collected material
  - 28% interaction with dust condensations
  - Rest: uncertain or no association

More correlations

- BGPS (1.1mm Rosolowsky+2010) vs. ATLASGAL (870 µm)
- tau_peak IRDCs (Peretto&Fuller 2009) vs. ATLASGAL peak fluxes





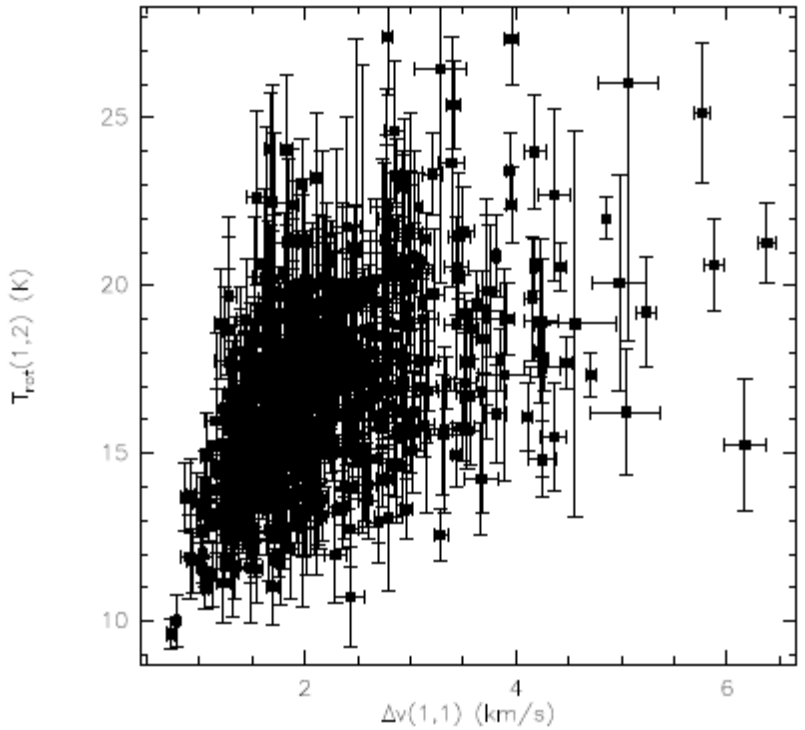
Molecular line follow ups

- Dust continuum is important but molecular line information is indispensable !
- Effelsberg/Parkes Ammonia (Wienen+):
  - Kinematic distances, temperatures
- 30m IRAM CS/$C^{34}S$/H_2CO/CH_3CCH (Morales/Wienen):
  - Densities, temperatures
- ATNF/Mopra (Wyrowski+): Physical & chemical conditions
- APEX (Wyrowski+): Higher J lines, complementary to Mopra
- 30m/HERA large program: large scale molecular mapping (Motte+, Schilke+, → Poster Carlhoff+ P-IV-7)
- Mopra: MALT90 (Jackson+): Mopra Galactic Plane Survey of high density regions

Ammonia line observations:
kinematic distances & temperatures

- Wienen+ in prep.:
- Effelsberg & Parkes
- NH_3 (1,1) – (3,3)
- Flux limited sample of ~1000 sources

➔ Distances, Temperatures, Virial masses



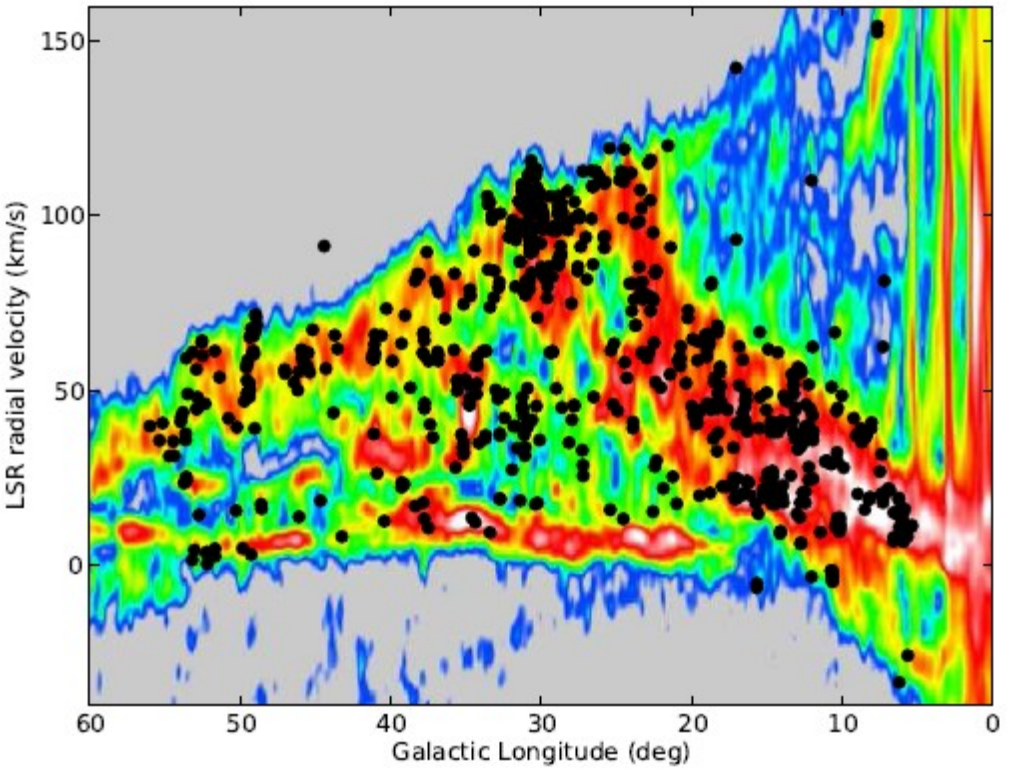
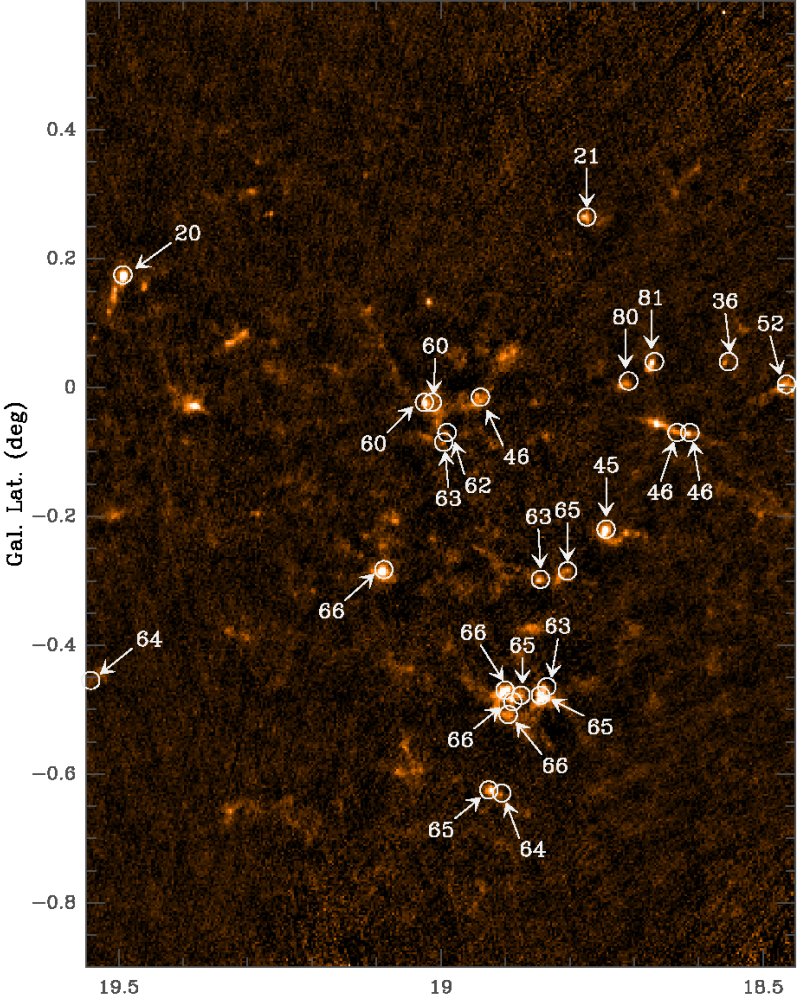
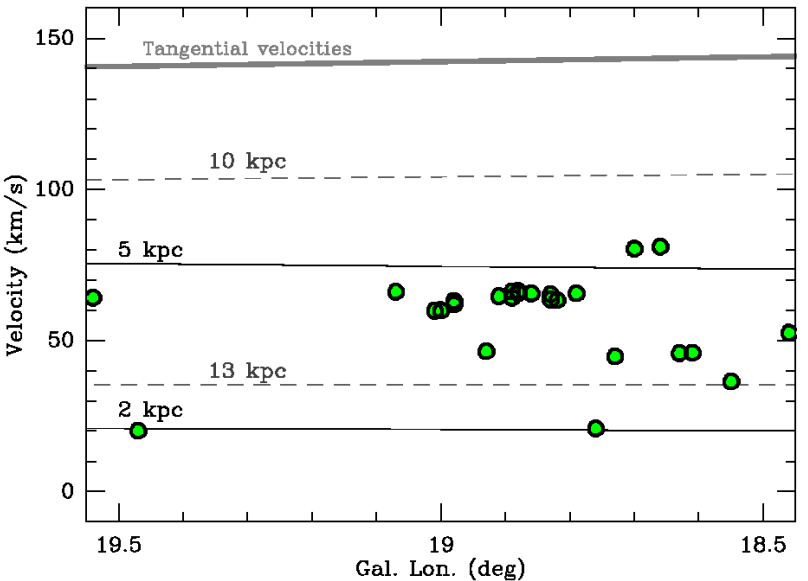


Fig. 3. The radial velocities of the observed sources are plotted against the Galactic longitude with CO emission (Dame et al. 2001), which is shown in the background.

Distance estimates

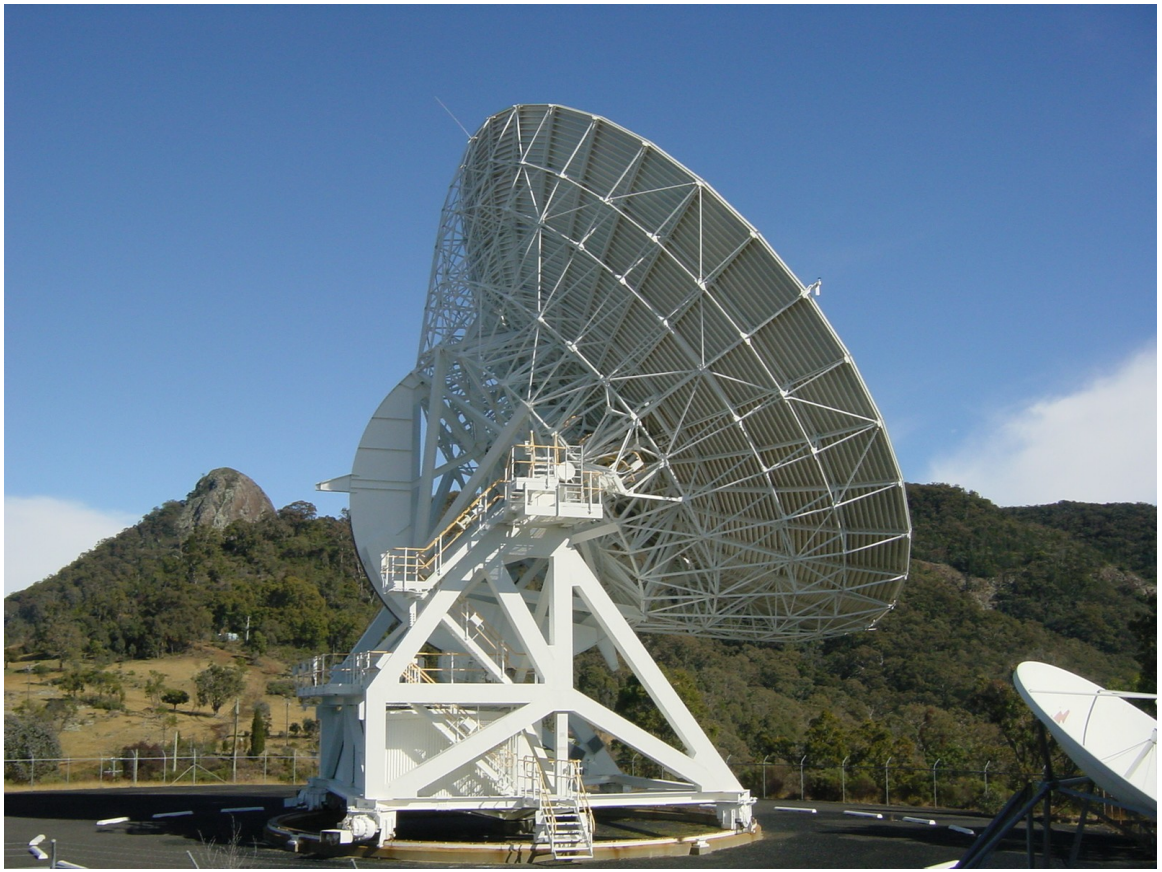
- Using velocities from molecular line follow ups
- Bontemps+:
  - Grouping
  - Solving near/far ambiguity with extinction maps and HI absorption

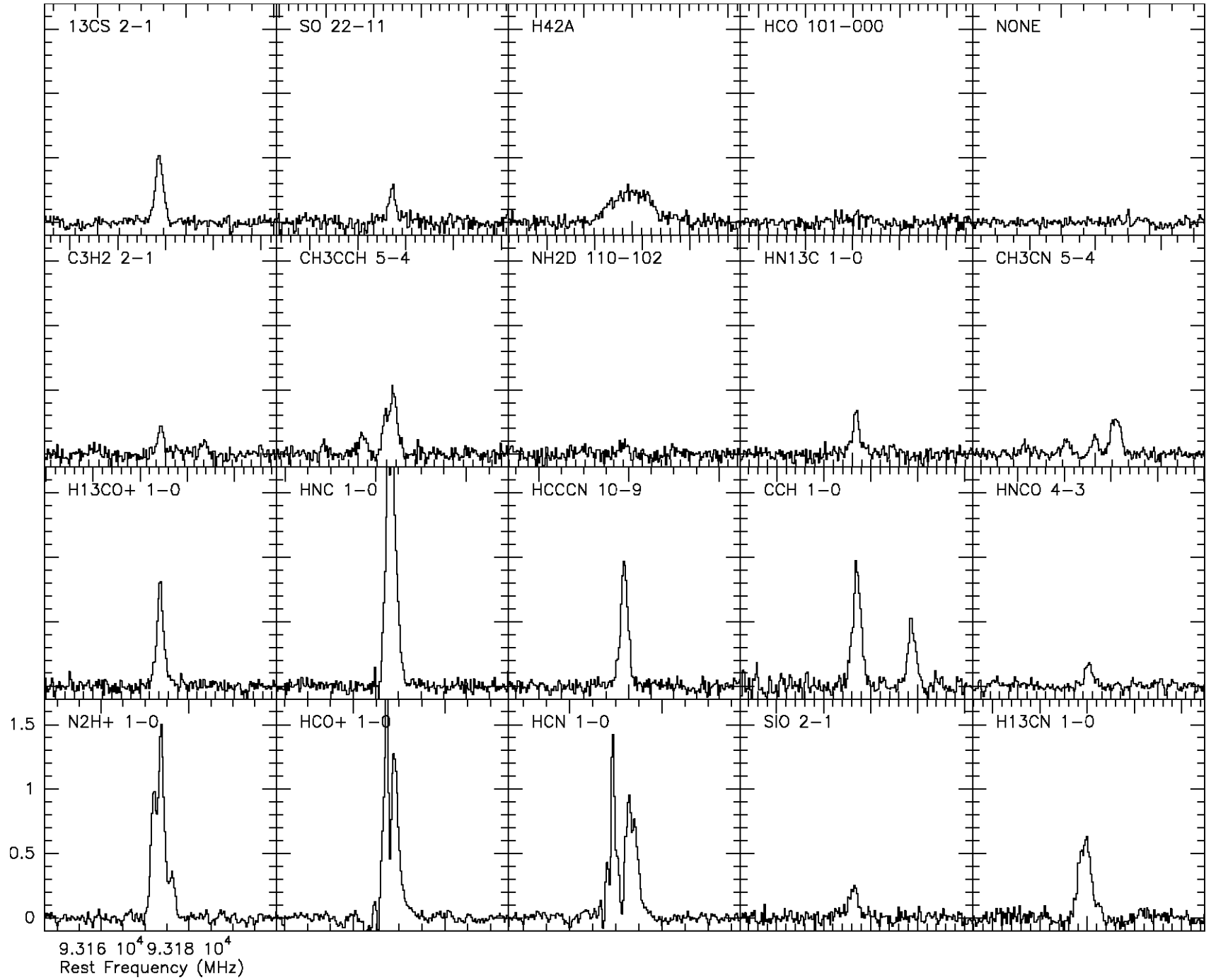




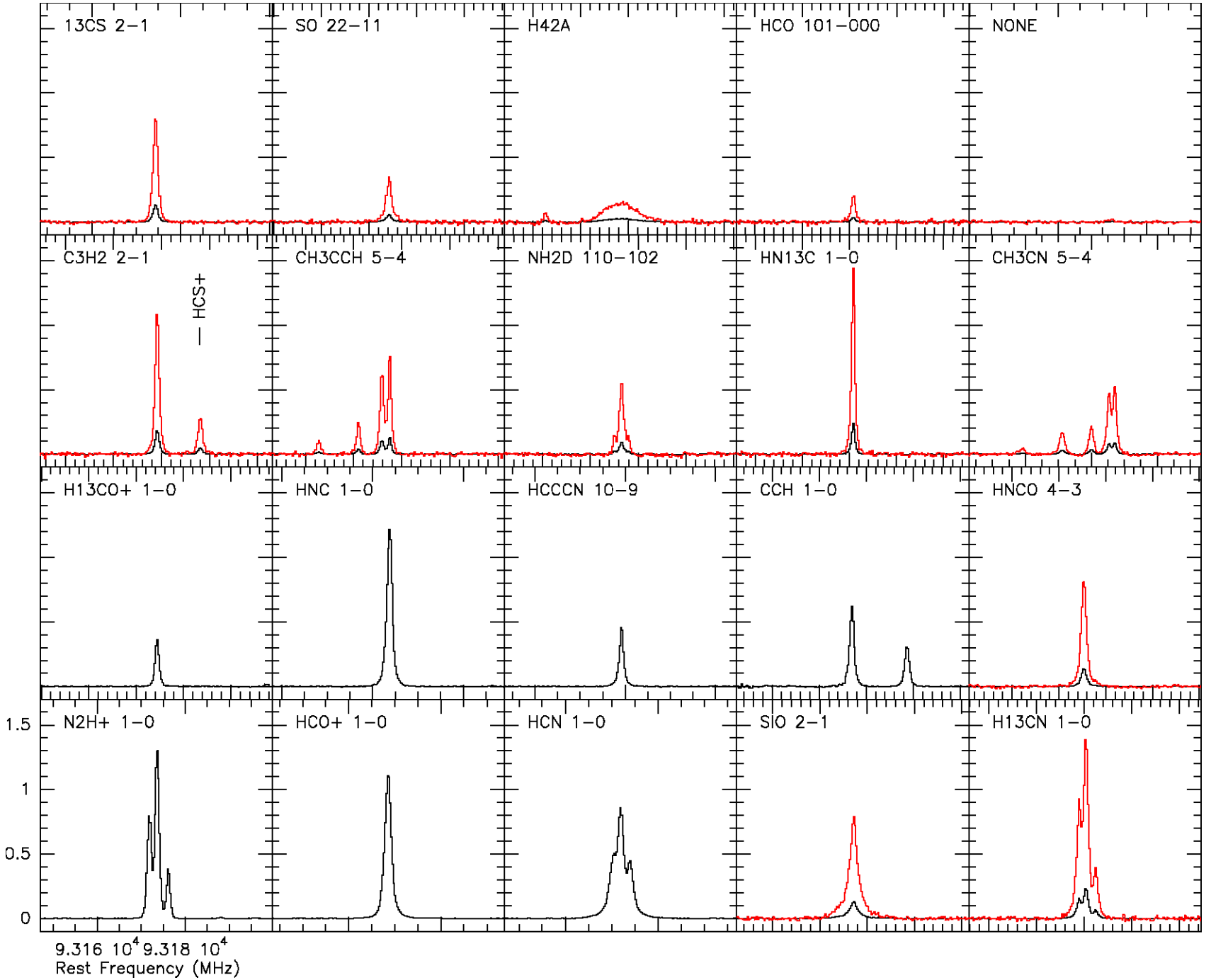
Mopra meets ALTASGAL

- 2008: 343 sources
  - 160 with emb. MIR
  - 49 close to MIR
  - 134 without MIR
- Flux limited sample:
  - 1.75 Jy/bm with MIR
  - 1.2 Jy/bm without MIR
- l=330-358, |b|<1
- 36” beam (LABOCA 18”)
- MOPS: 85.2 – 93.4 GHz
- Continued Aug 2009 in l=300-330 !

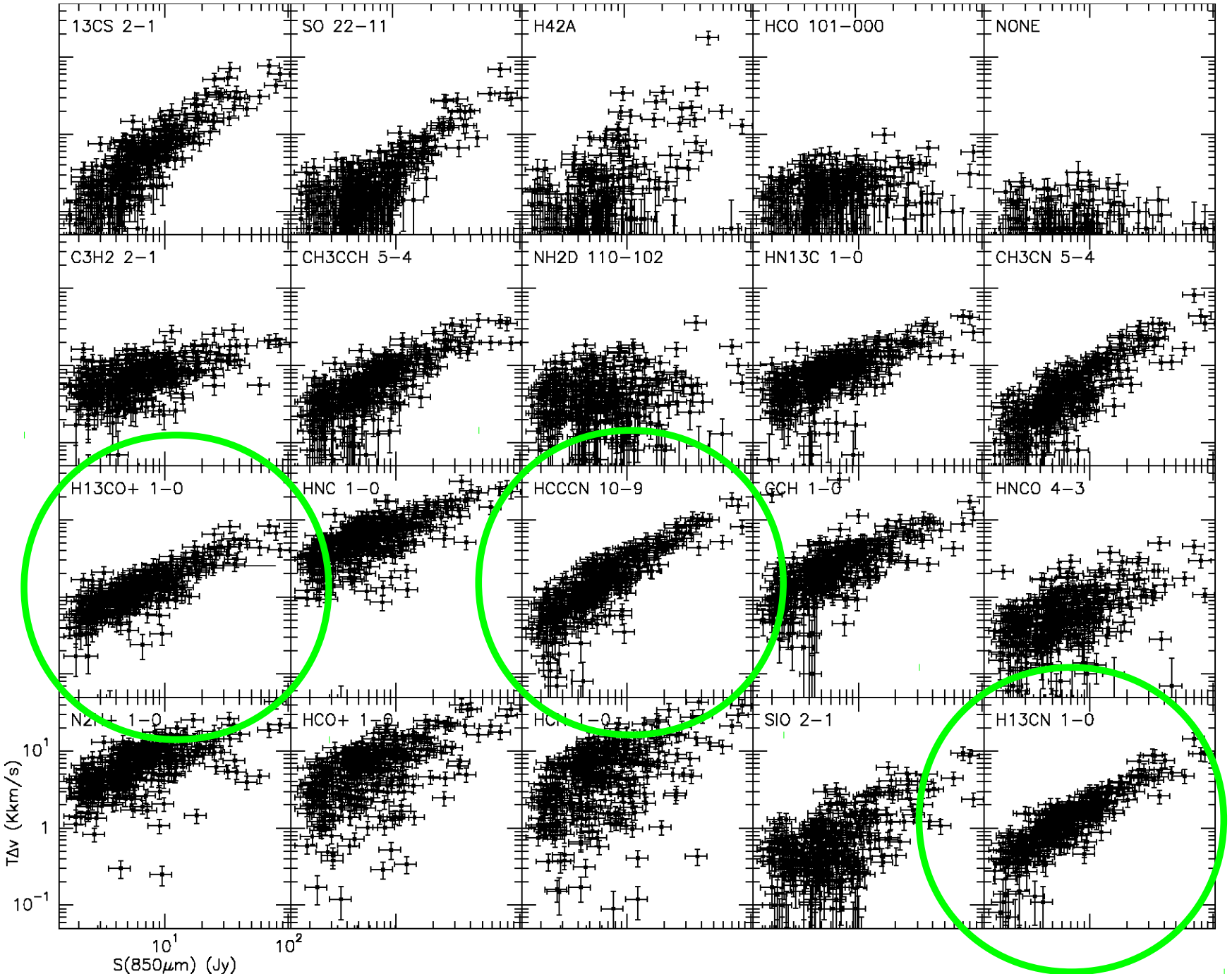



13CS 2−1
SO 22−11
H42A
HCO 101−000
NONE
C3H2 2−1
CH3CCH 5−4
NH2D 110−102
HN13C 1−0
CH3CN 5−4
H13CO+ 1−0
HNC 1−0
HCCCN 10−9
CCH 1−0
HNCO 4−3
N2H+ 1−0
HCO+ 1−0
HCN 1−0
SiO 2−1
H13CN 1−0
1.5
1
0.5
0
9.316 10^4 9.318 10^4
Rest Frequency (MHz)

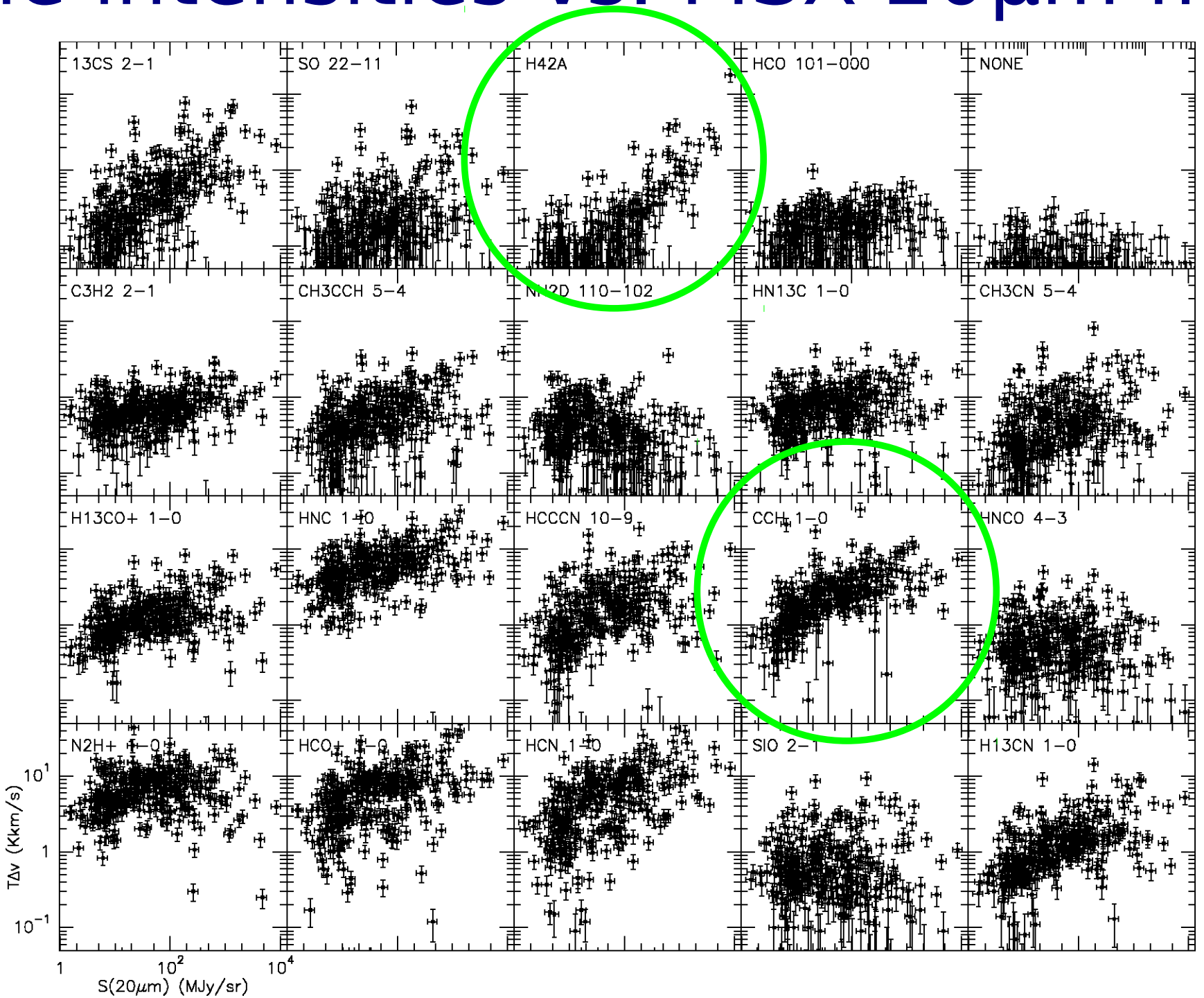
“Stacked” spectra



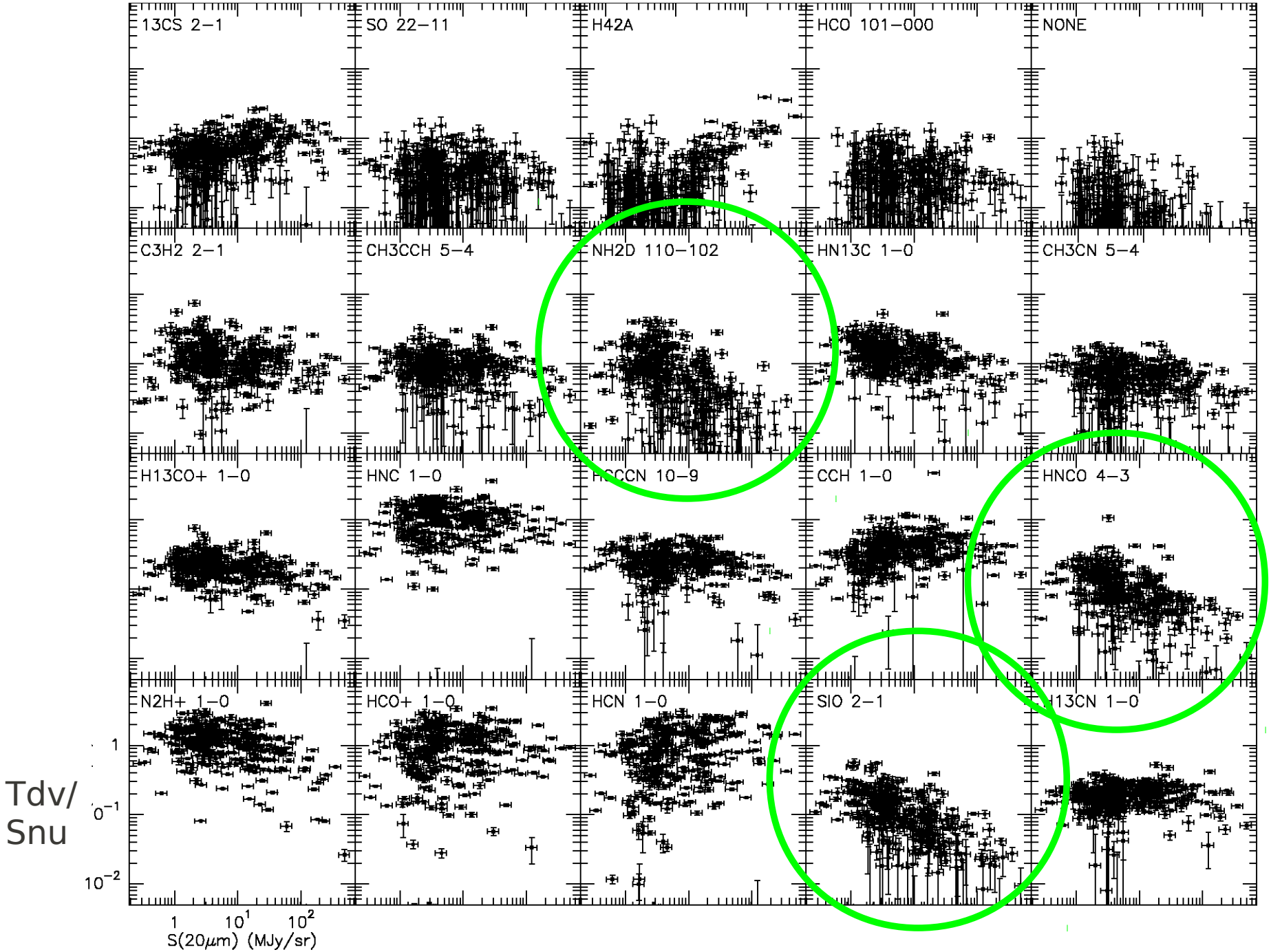
Line intensities vs. submm flux



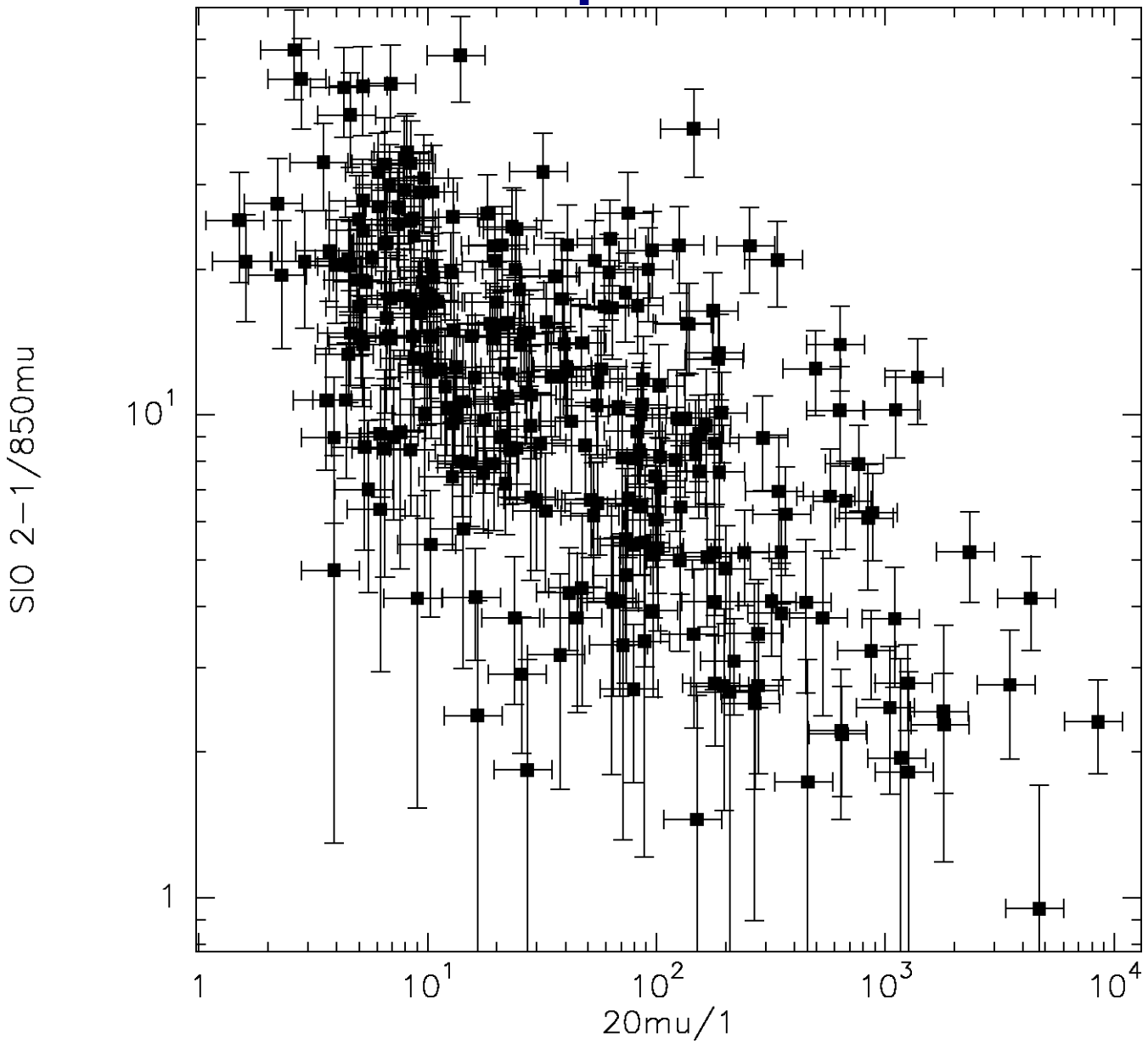
Line intensities vs. MSX 20μm flux



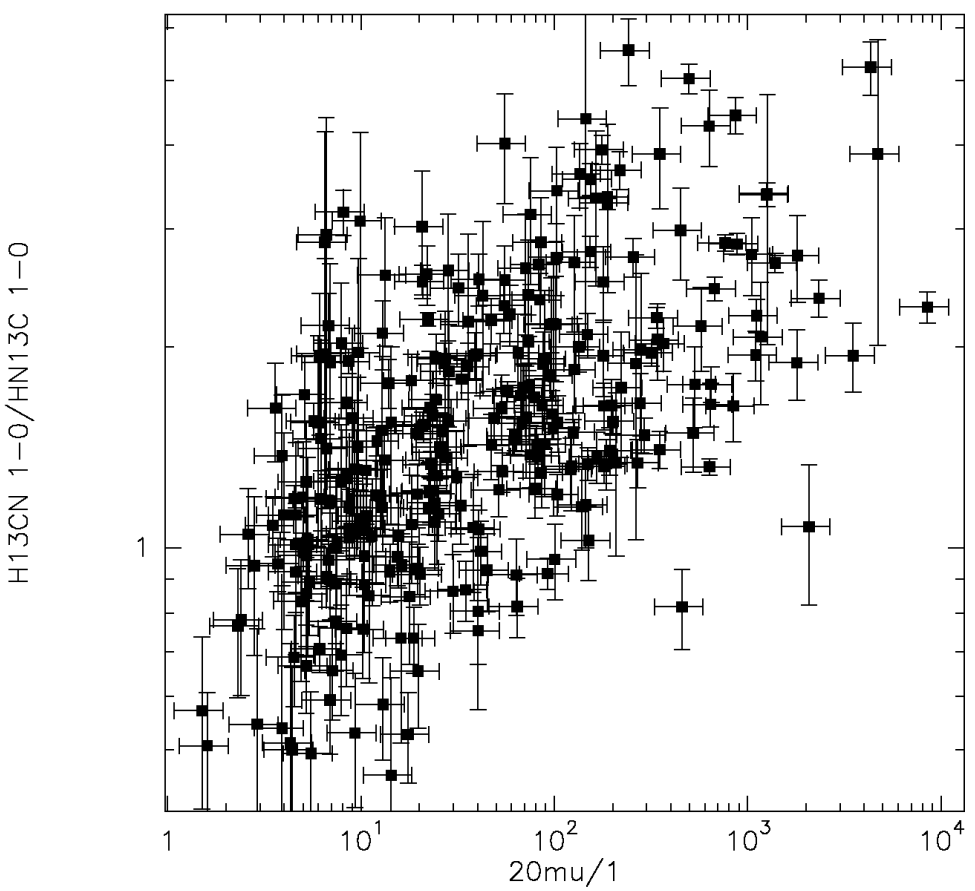
“Abundances” vs.“warm gas/mass”

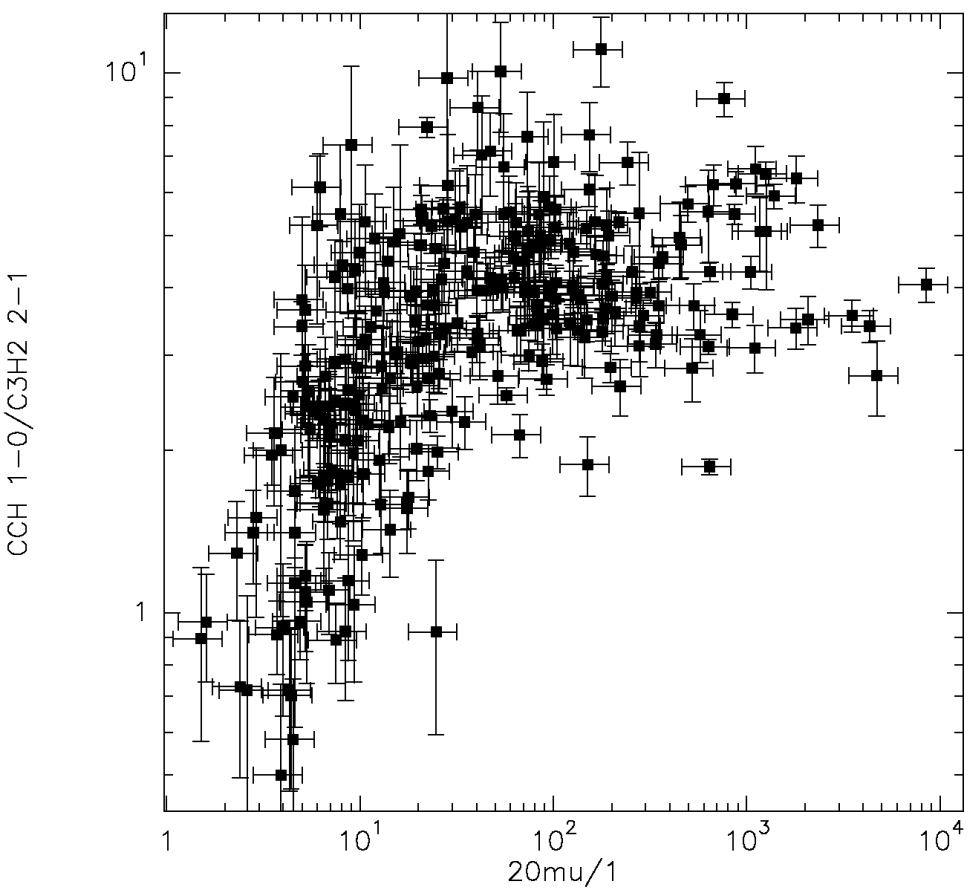


SiO “Abundance” vs. MSX 20μm flux

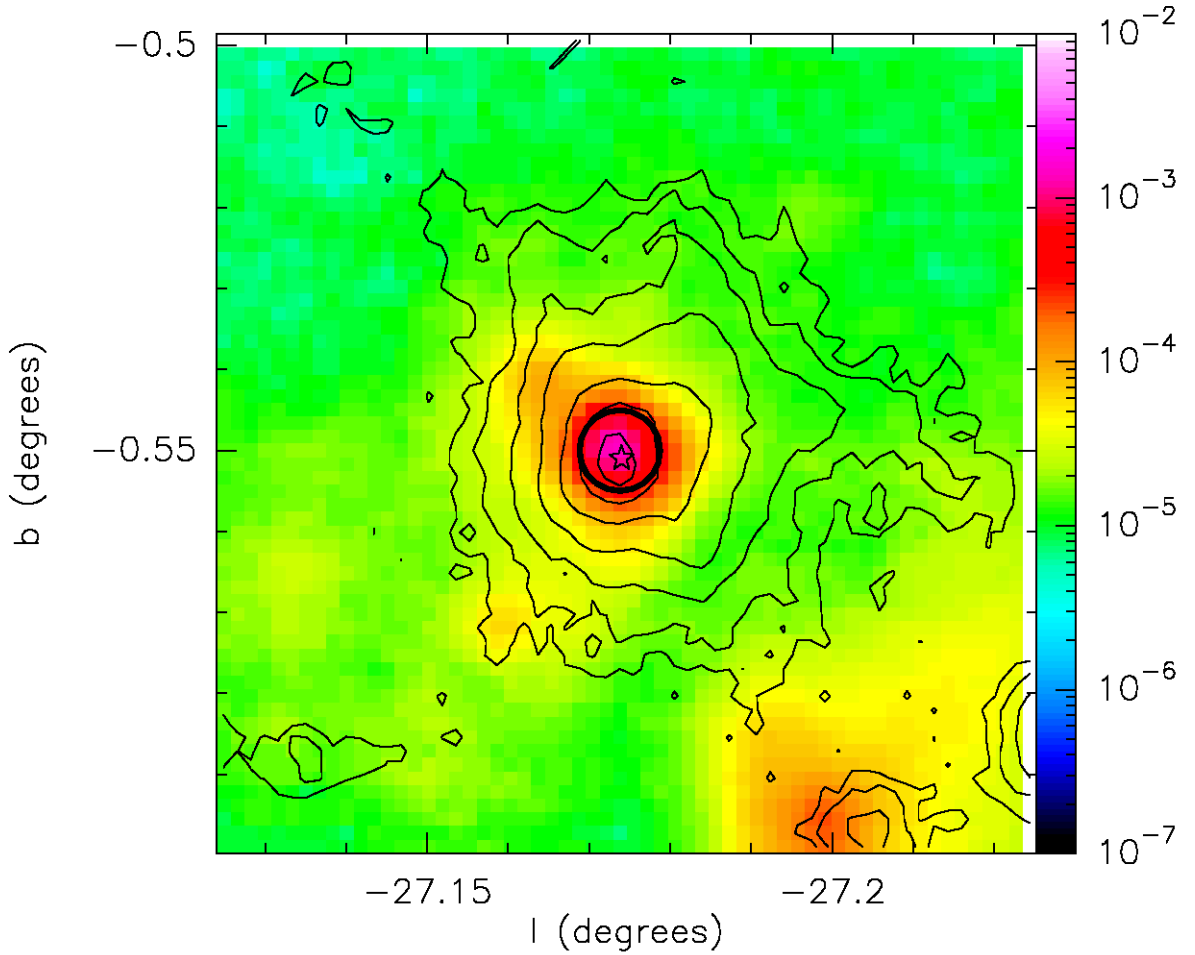


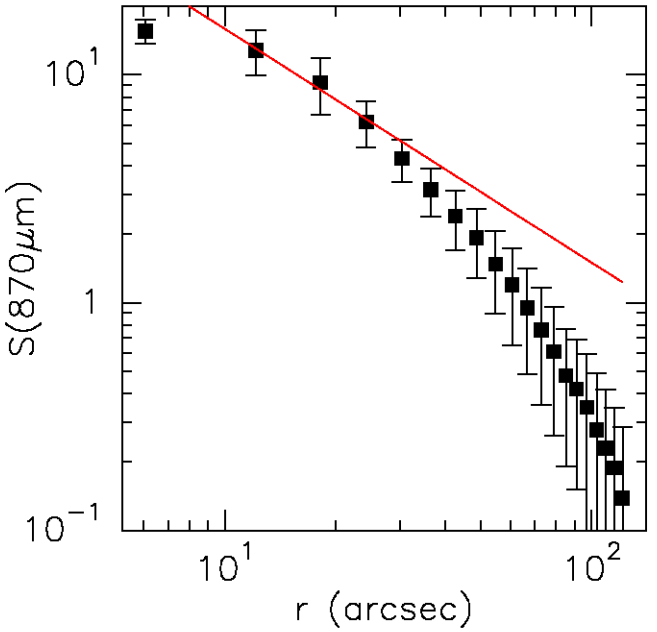
Diagnostic line ratios:
HCN/HNC & CCH/C_3H_2

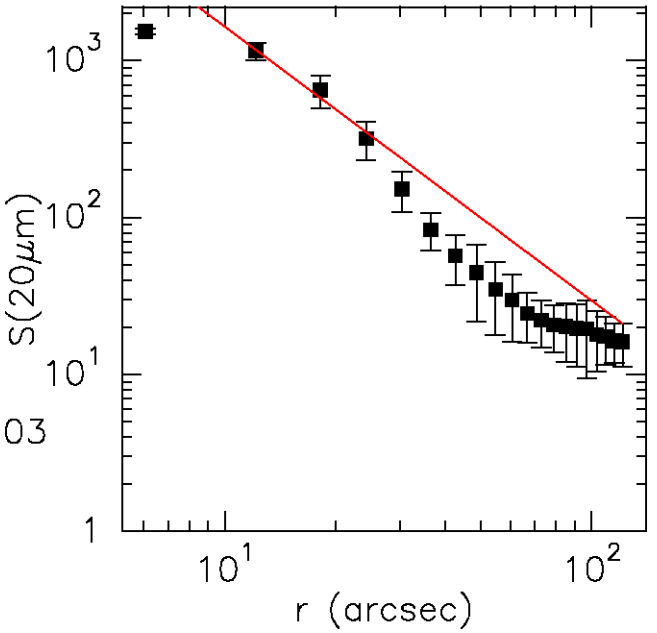




AG332.83−0.55







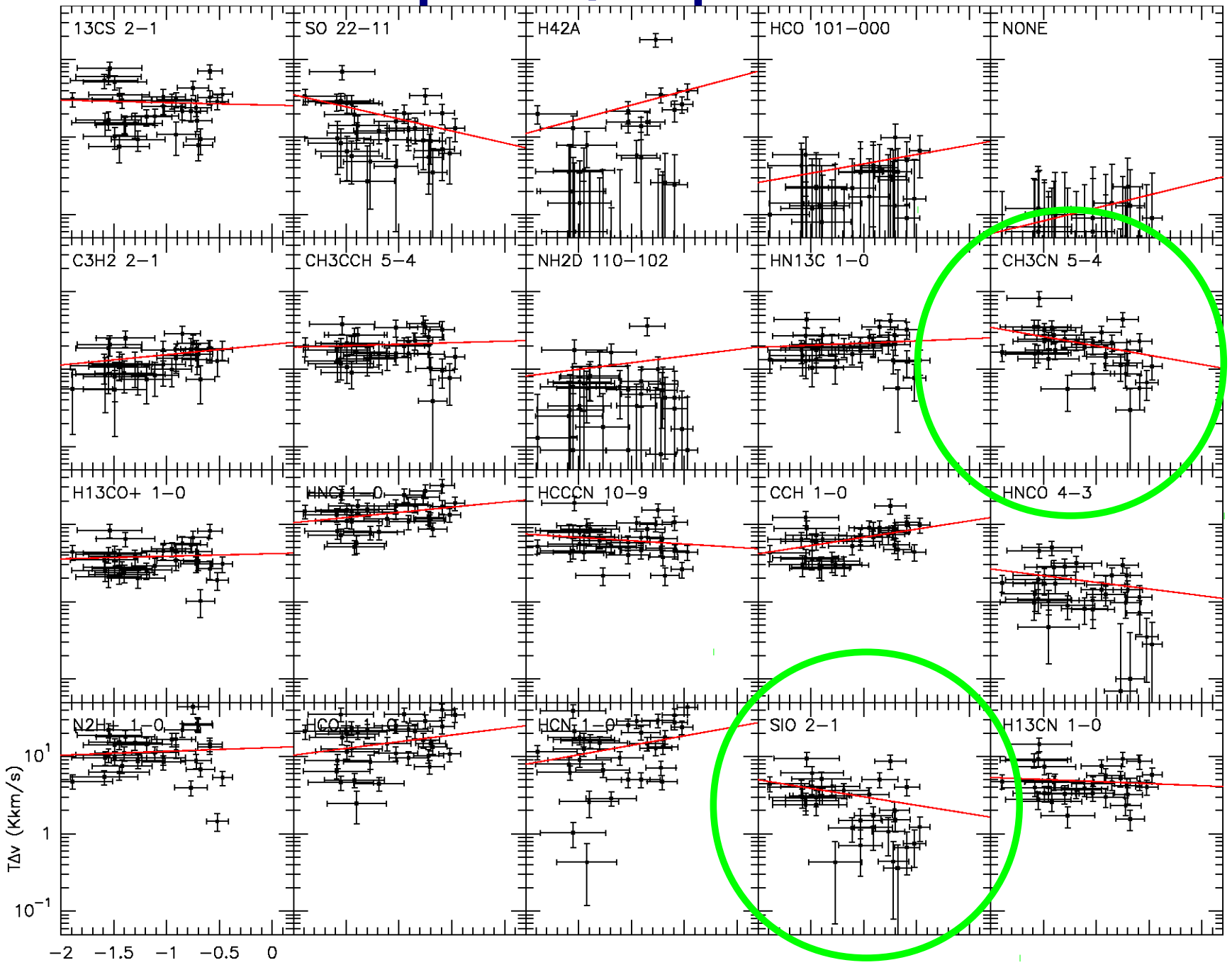
S(870μm),int = 28.4 S(20μm),int = 2334

S(870μm),peak= 17.9 S(20μm),peak= 1.6093E+03

α(870μm) = −1.1 α(20μm) = −1.8

Distances = 11.3 3.7

Line intensities vs. LOBOCA power

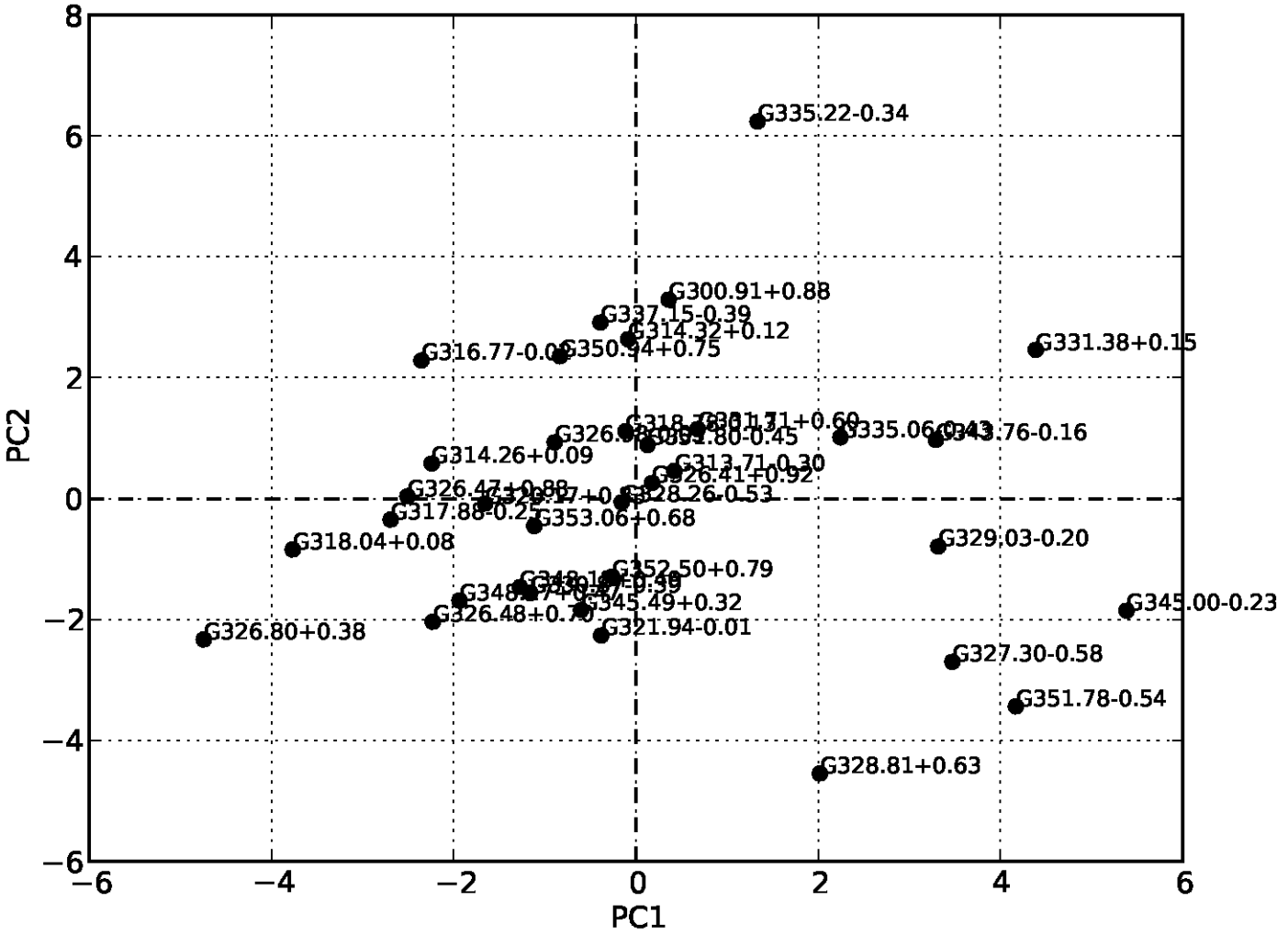


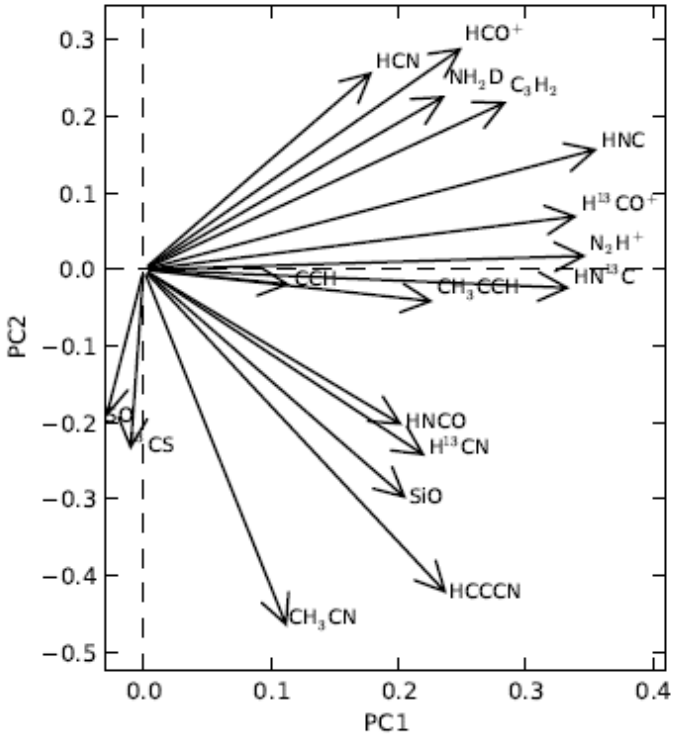
Principle Component Analysis

- Fallon+: PCA on
  - Intensities
  - Line profiles
  - Maps

➔ Find oddballs

➔ Classify sources





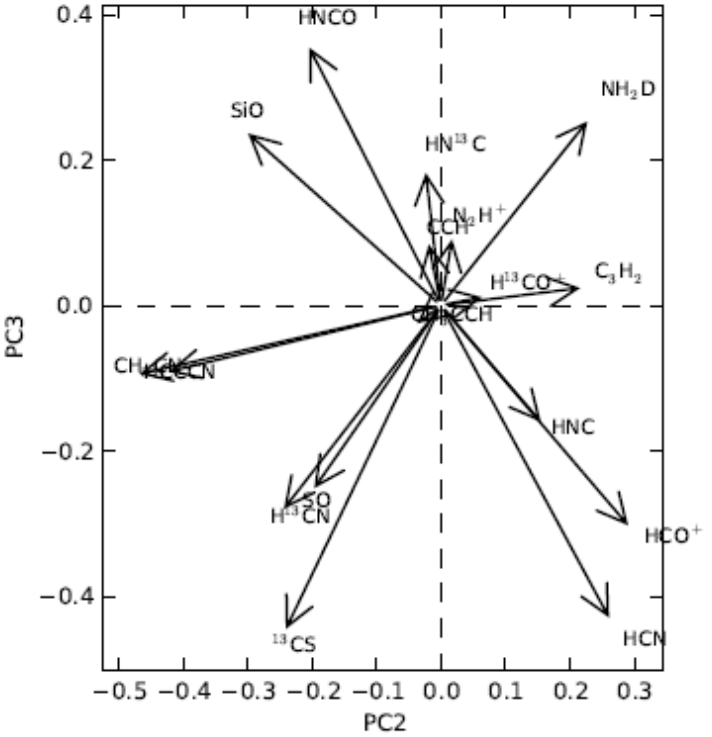
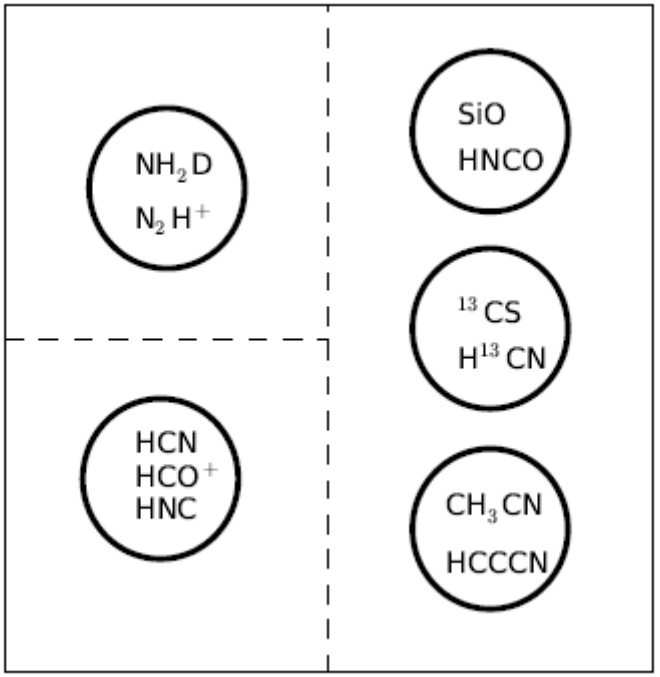
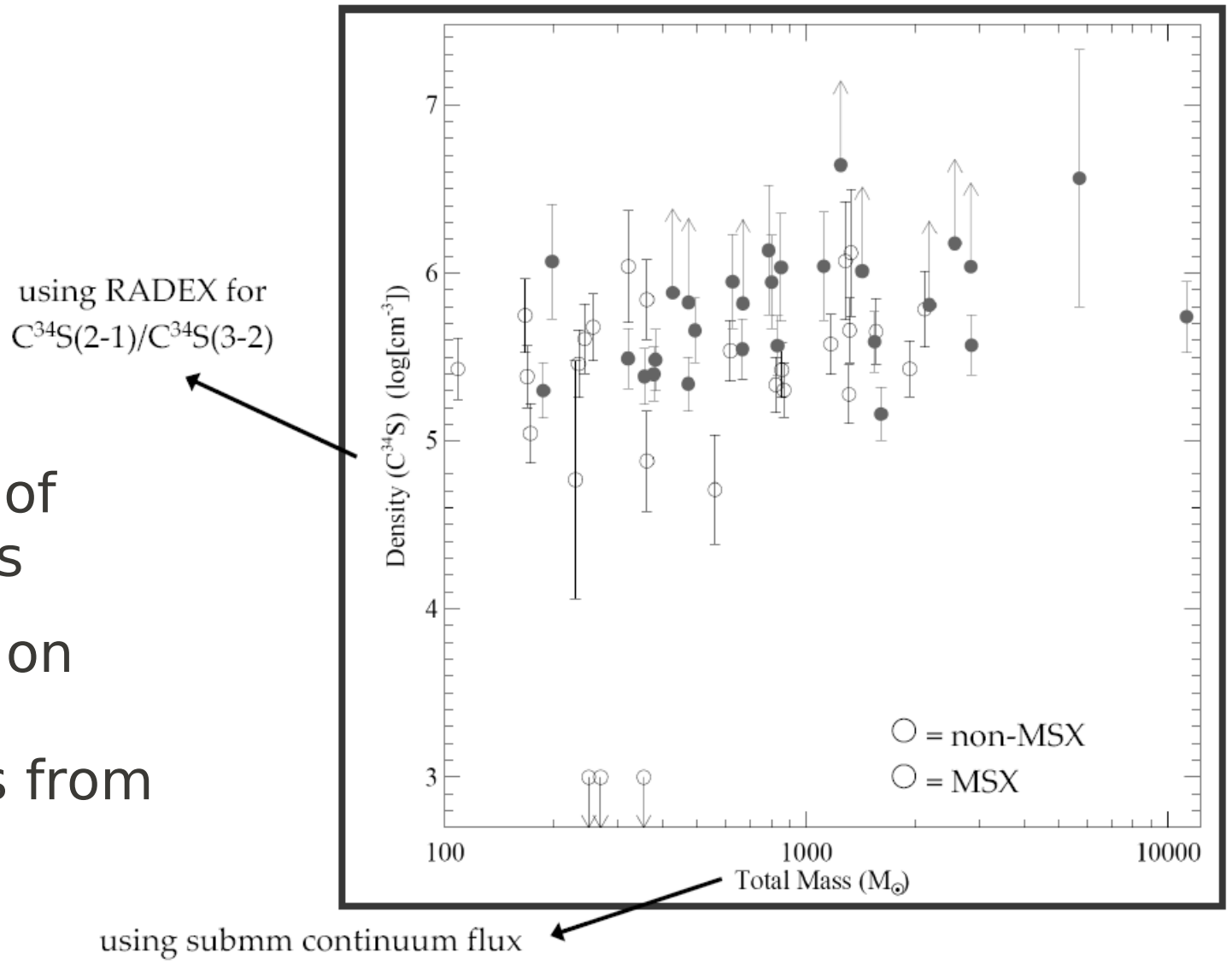


Figure 11: Submillimeter-normalized ATLASGAL-selected sources loadings of the first three PCs.



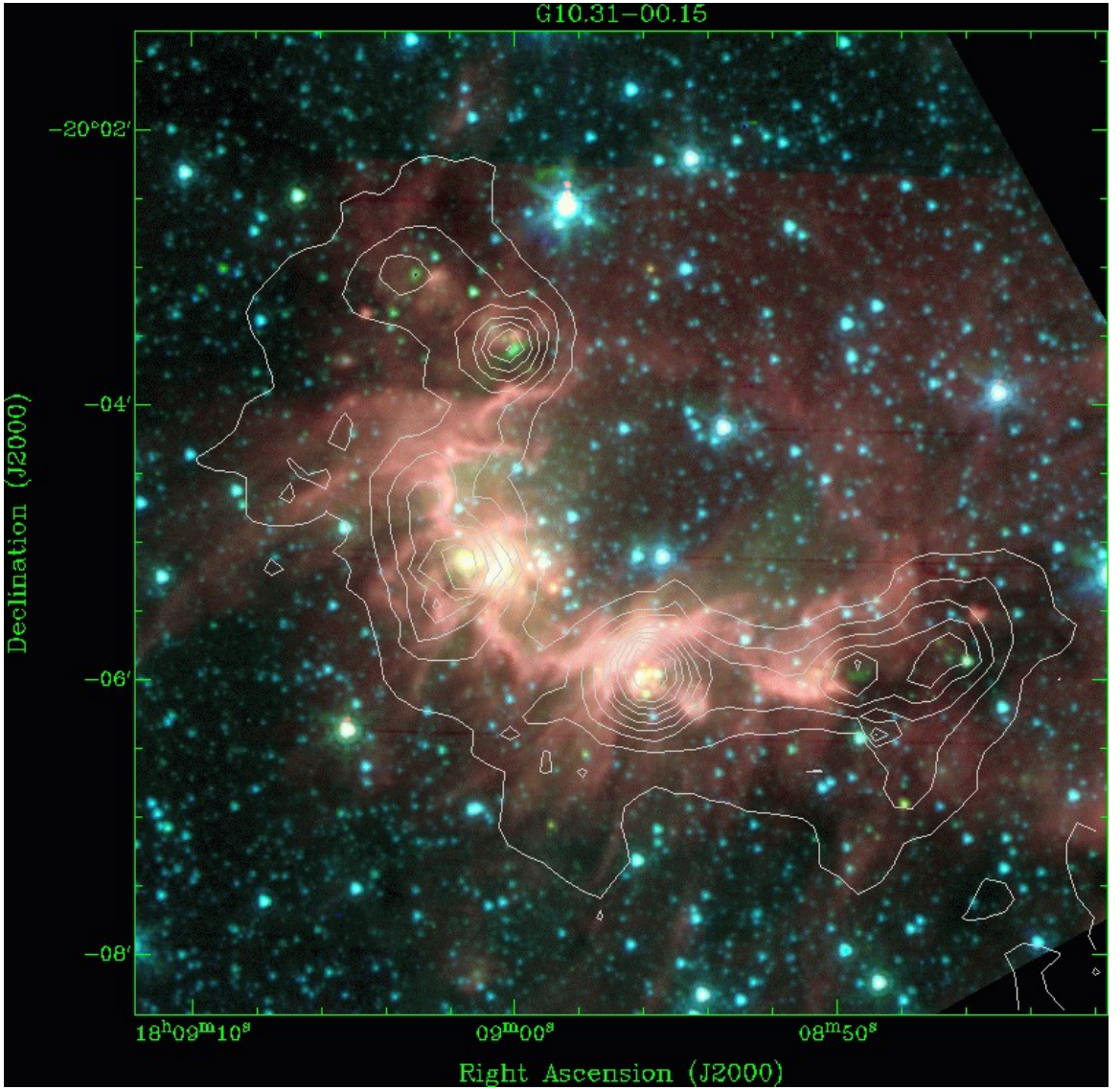
Clump densities (Morales+)

- IRAM 30m observations of strong clumps
- Now working on including temperatures from CH_3CCH



Star cluster association & follow ups

- Poster Morales (P-V-11)
  - Associations Atlasgal/star clusters
  - 60% of 2MASS clusters associated with ATLASGAL clumps
  - Many bubbles associated with both
  - Follow-ups in CO to study dynamics



Conclusions

- ATLASGAL
  - detects thousands of massive star forming clumps in a variety of stages,
  - especially cold clumps not seen in infrared surveys
- Molecular line follow ups crucial for characterization of physical and chemical conditions: e.g. distances, kinematics, temperatures
- Pathfinder for Galactic Herschel & ALMA science