The APEX telescope large area survey of the Galaxy and its follow-ups

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Outline

- Searching for early stages of MSF with Galactic plane surveys
- The APEX telescope and its instrumentation
- The ATLASGAL survey
- ATLASGAL follow-ups
- Prospects for Mopra

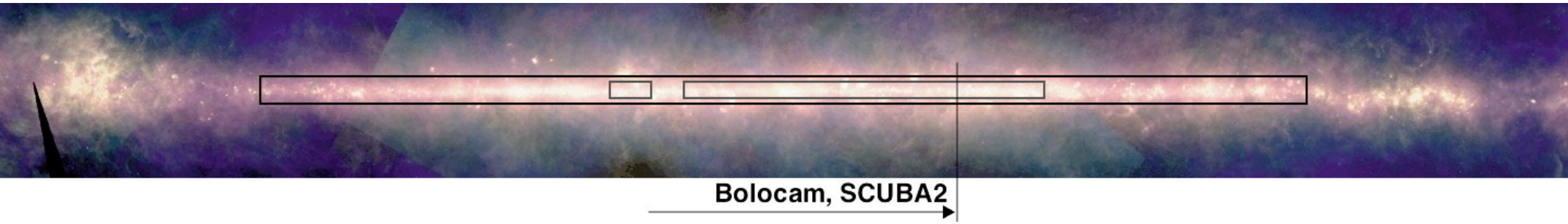
Early stages of MSF

- 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 !

Galactic Plane surveys

- ATLASGAL
  - LABOCA @ APEX, 850μm
- BOLOCAM – CSO, 1200μm
- JCMT legacy surveys:
  - SCUBA-2 all sky survey, 850μm
  - SCUBA-2 Galactic plane survey 450+850μm (4mJy/bm)
- Spitzer:GLIMPSE/ MIPSGAL, 3.6 – 70μm
- Herschel: SPIRE/PACS, 60 - 600μm

ATLASGAL marked



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 ~ 17 micron
- BEs: 1, 1.5 GHz FFTSs
- FEs:
  - Heterodyne Rxs
  - Bolometer arrays -->

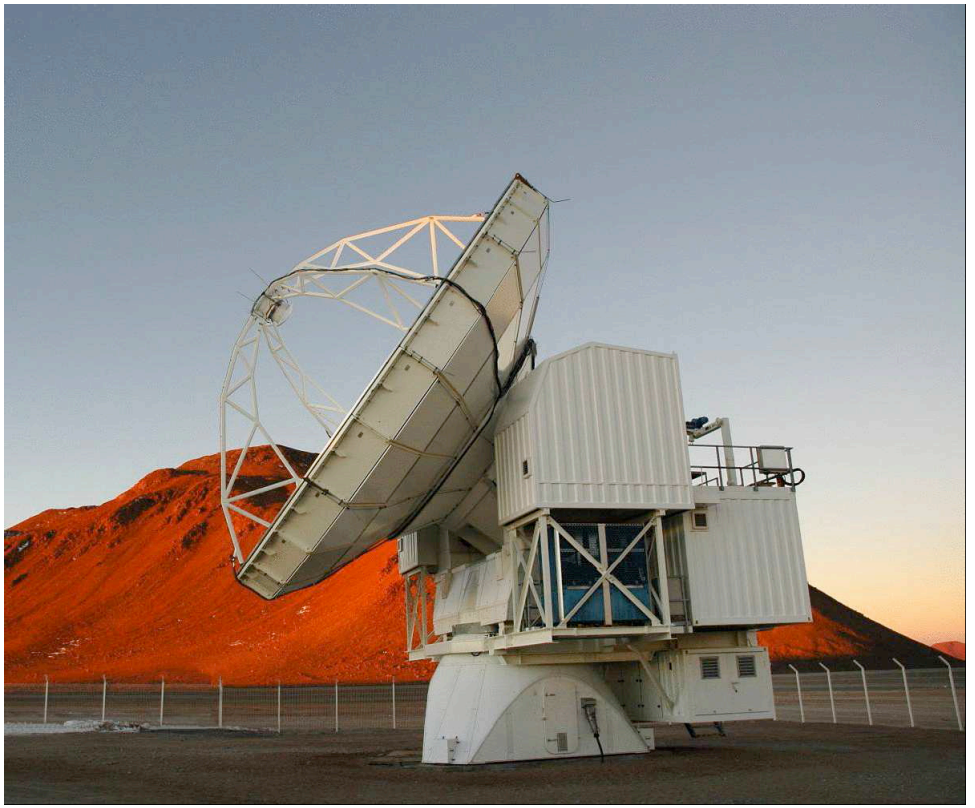


Table 2. Telescope efficiencies

ν [GHz]	θ_{mb} ["]	η_f	η_a	η_{mb}	η_M	Receiver
352	17.3	0.97	0.60	0.73	0.85	APEX-2a
464	13.3	0.95	0.51	0.60	0.81	FLASH-I
812	7.7	0.95	0.35	0.43	0.79	FLASH-II

Atm. Transmission and RXs

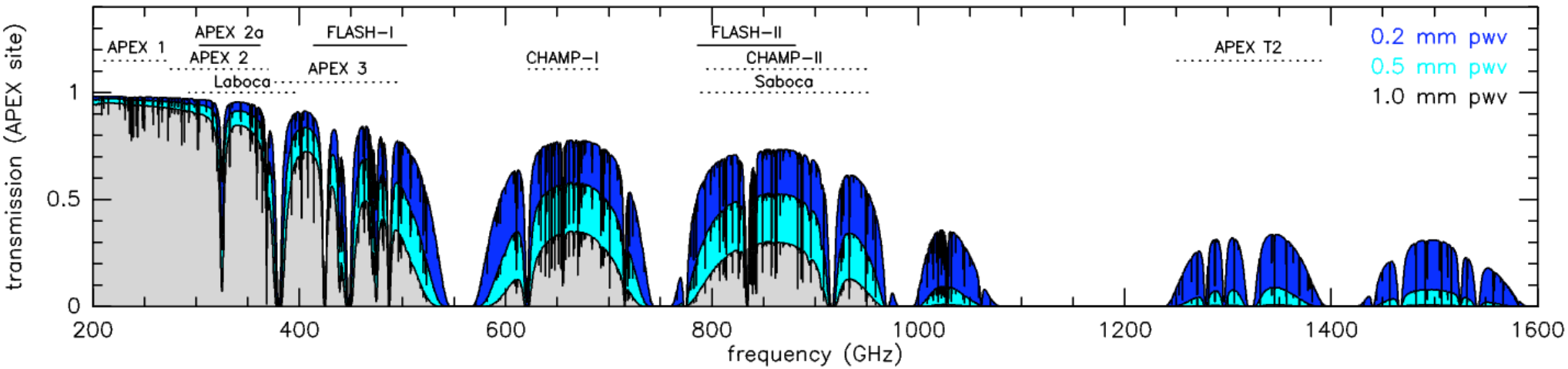


Fig. 1. Zenith transmission of the atmosphere above Llano de Chajnantor at submillimeter wavelengths. Using data from the ALMA site characterization data base covering the years 1995 to 2004, we calculate that the median column of precipitable water is about 1.2 mm and the 25 % quartile about 0.7 mm, including data taken during the Bolivian winters. During the winter months the median drops by a factor 2-3. The project plan requires that all atmospheric windows accessible from ground shall be covered by state-of-the-art instruments. We superimpose the frequency coverage of the APEX facility and PI receivers, as they are in operation now (solid lines) and as committed for delivery (dotted). Several contributions to this special issue are dedicated to our instruments.

APEX Instrumentation

- Bolometers
  - LABOCA: 295 element at 870μm, FoV = 11'
  - SABOCA: 37 element at 350μm (MPIfR), FoV = 1.5' Super-conducting bolometers (TES), multiplexing (SQUIDS)
  - PI Instrument (Berkeley): APEX SZ Camera, 330 TES bolometers, = 1.4 + 2 mm, FoV = 20' at 2 mm
  - In development (Saclay): ARTEMIS (cf. PACS / Herschel) = 450 + 350 + 200μm
- Heterodyne instruments
  - Facility: 230 GHZ, 345 GHz, (490 GHz), 1.3 THz
  - PI: Cabin A (490+1050GHz),
  - PI: CHAMP+ (2×7 pixels, 670+860 GHz)

ATLASGAL: APEX Telescope Large Area Survey of the Galaxy

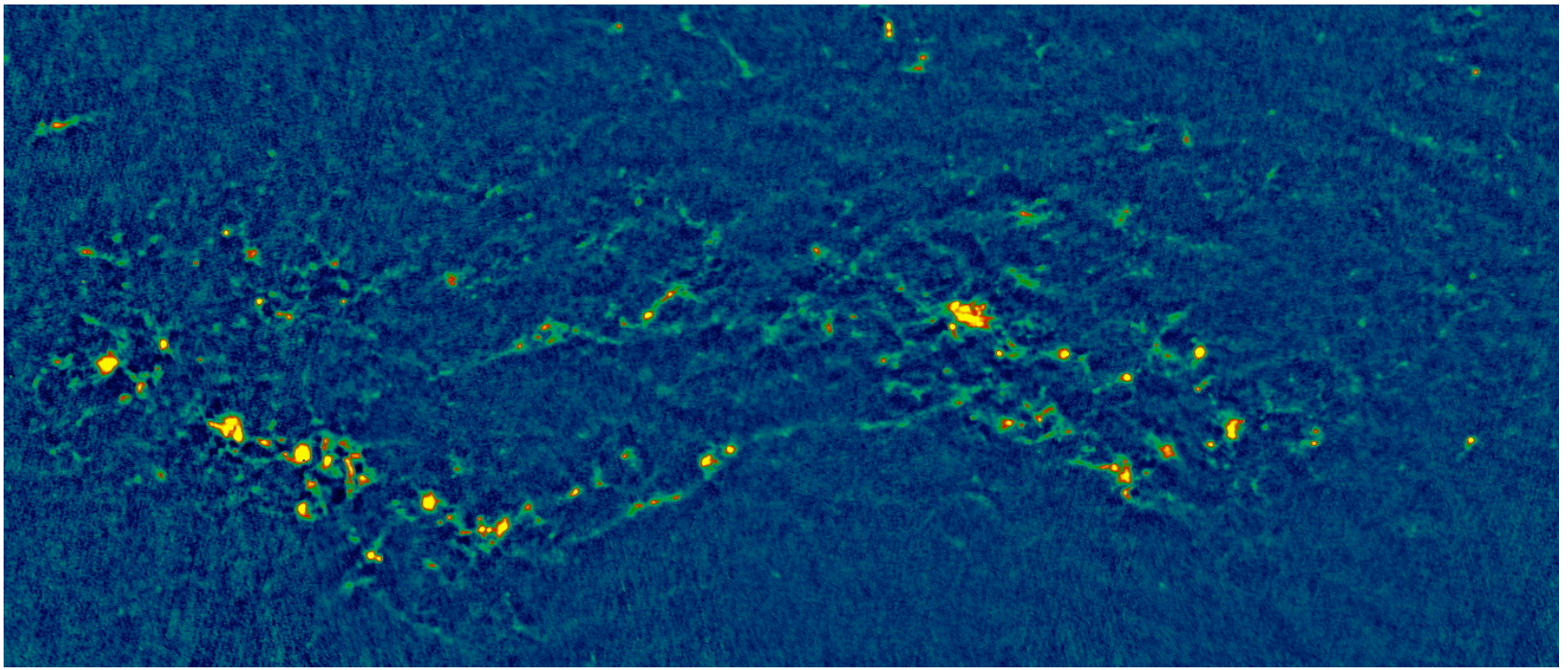
- MPG:
  - F. Schuller (PI), K. Menten, P. Schilke, F. Wyrowski, H. Beuther, T. Henning, H. Linz
- ESO:
  - M. Walmsley (co-PI), S. Bontemps, R. Cesaroni, L. Deharveng, F. Herpin, B. Lefloch, S. Molinari, F. Motte, V. Minier, L.-A. Nyman, V. Reveret, C. Risacher, N. Schneider, L. Testi, A. Zavagno
- Chile:
  - L. Bronfman (co-PI), G. Garay, D. Mardones
- \+ A growing number of students !

ATLASGAL: APEX Telescope Large Area Survey of the Galaxy

- 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 (Spitzer, MSX, Hi-GAL)
- Mapping $|l| < 60$, $|b| < 1.5$
  - sensitivity 1σ = 50~mJy/beam
  - 3σ detection:
    - 1 $M_\odot$ ~ at 500 pc,
    - 35 $M_\odot$ ~ at 3 kpc,
    - 240 $M_\odot$ ~ at 8 kpc

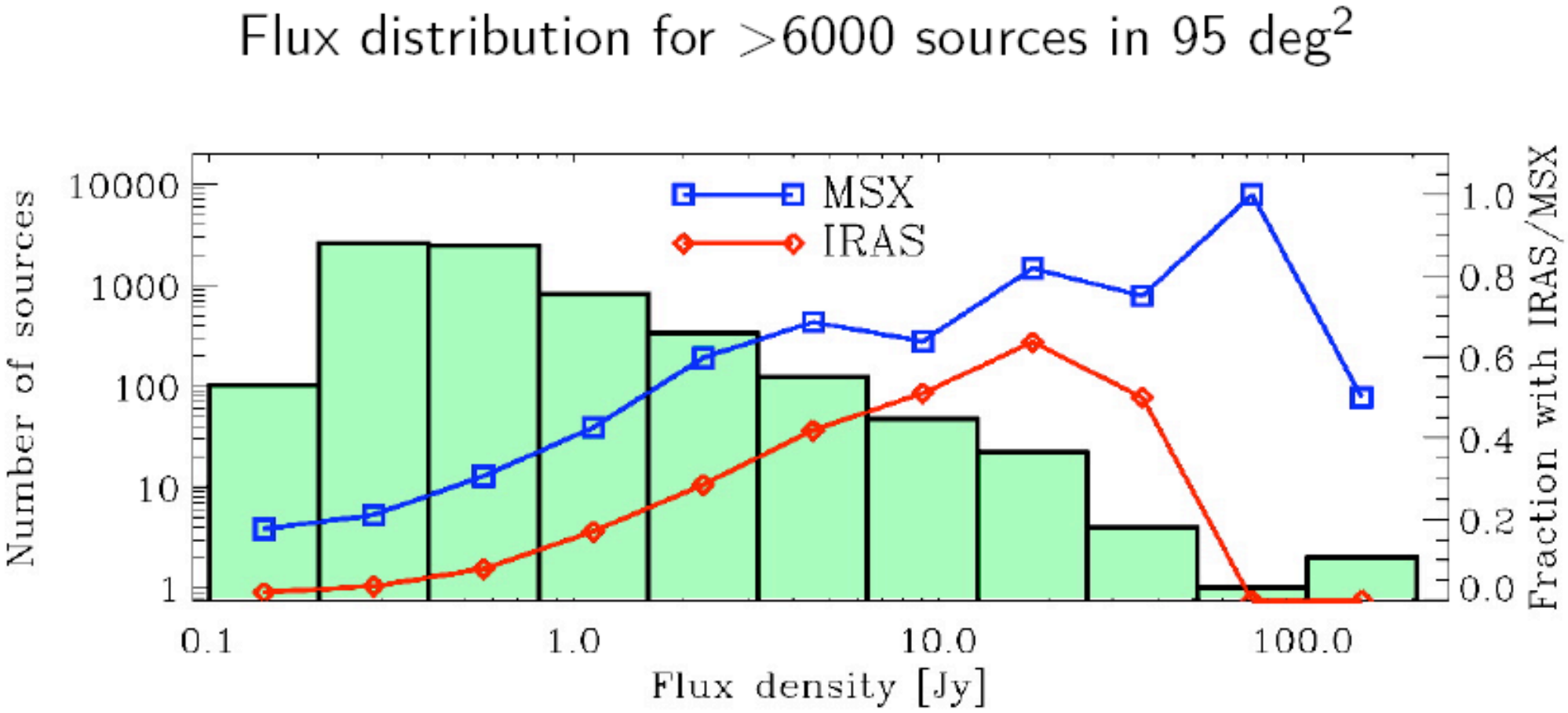
ATLASGAL Status

- 2007: Coverage: 95 deg^2, ~75~hours observing
  - ~5000 compact sources, brighter than 300~mJy
  - extended objects on arcmin scale
  - very long filaments, up to the degree scale
- 2008: Apr-Sep, additional 300 sq.deg (60-100mJy)



Norma arm: compact sources and long filaments

ATLASGAL compact sources



- Compact source catalog (Contreras+)
- ATLASGAL/MIPSGAL SEDs (Troost+)

Molecular line follow ups

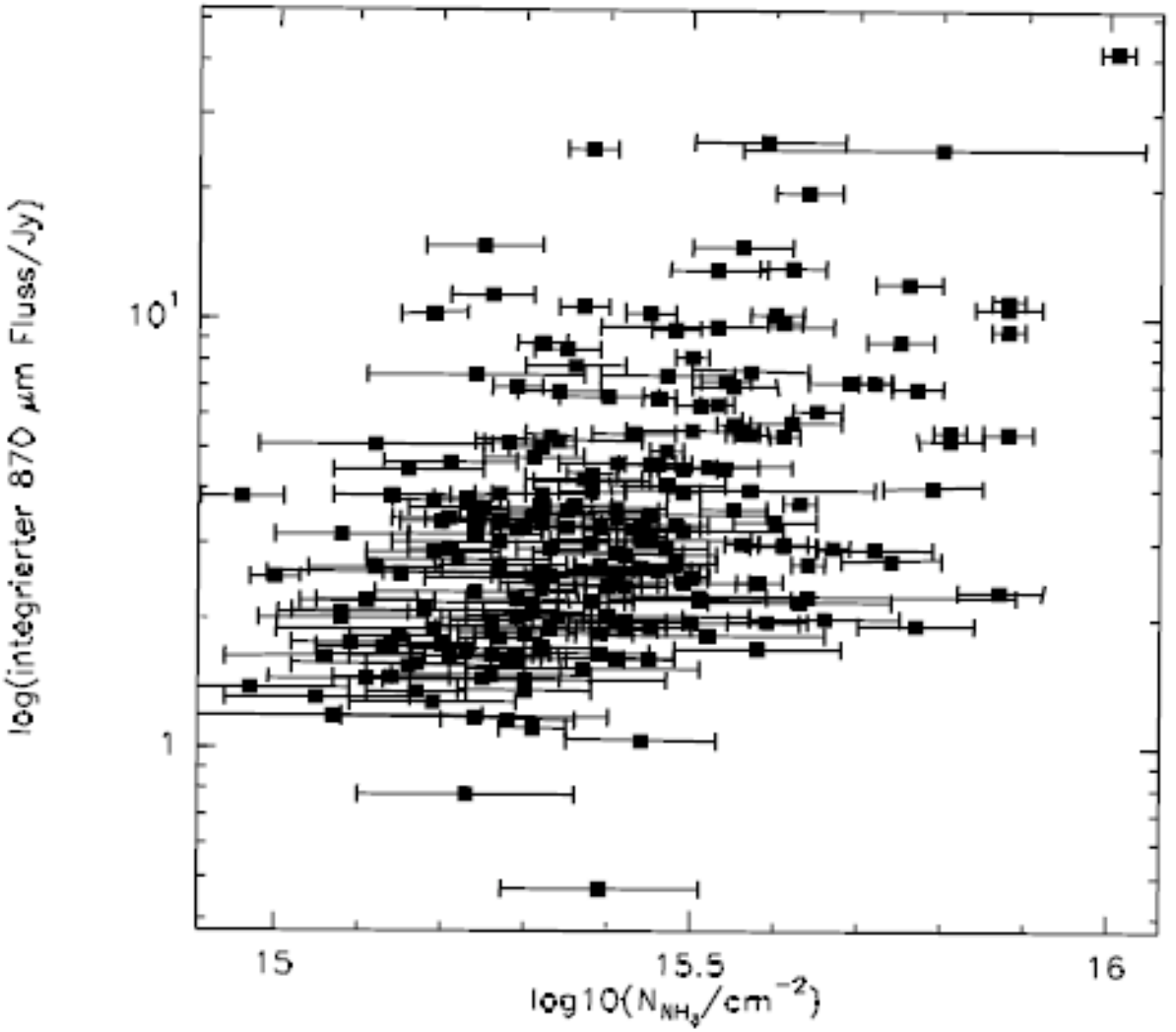
- Dust continuum is important but molecular line information is indispensable !
- 100m Effelsberg Ammonia (Wienen+):
  - Kinematic distances, temperatures
- 30m IRAM CS/$C^{34}S$ (Morales+):
  - Densities
- ATNF/Mopra (Wyrowski, Brooks+):
  - Physical & chemical conditions
- APEX (Wyrowski+):
  - Higher J lines, complementary to Mopra
- Specific source groups:
  - star clusters/bubbles/IRDC follow ups (Morales+/Gomez+)

Ammonia line observations

- Effelsberg: 40” beam
- NH3 (1,1) – (3,3)
- So far (diploma thesis Marion Wienen):
  - 310 sources
  - l = 5 – 20 deg
  - 1 (0.5) Jy/bm flux limit

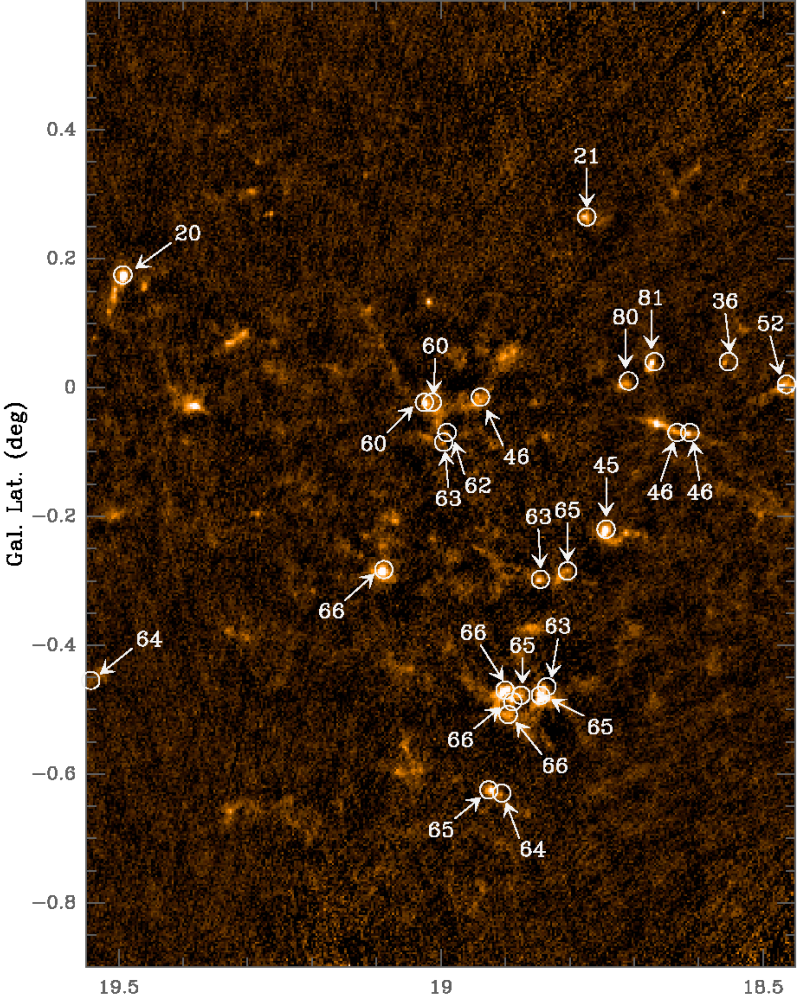
➔

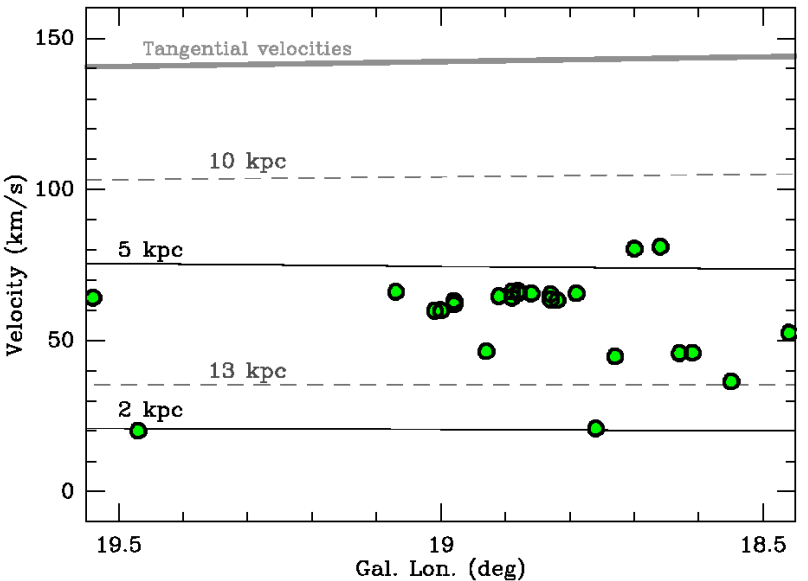
  - Distances
  - Temperatures
  - Virial masses



Distance estimates

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

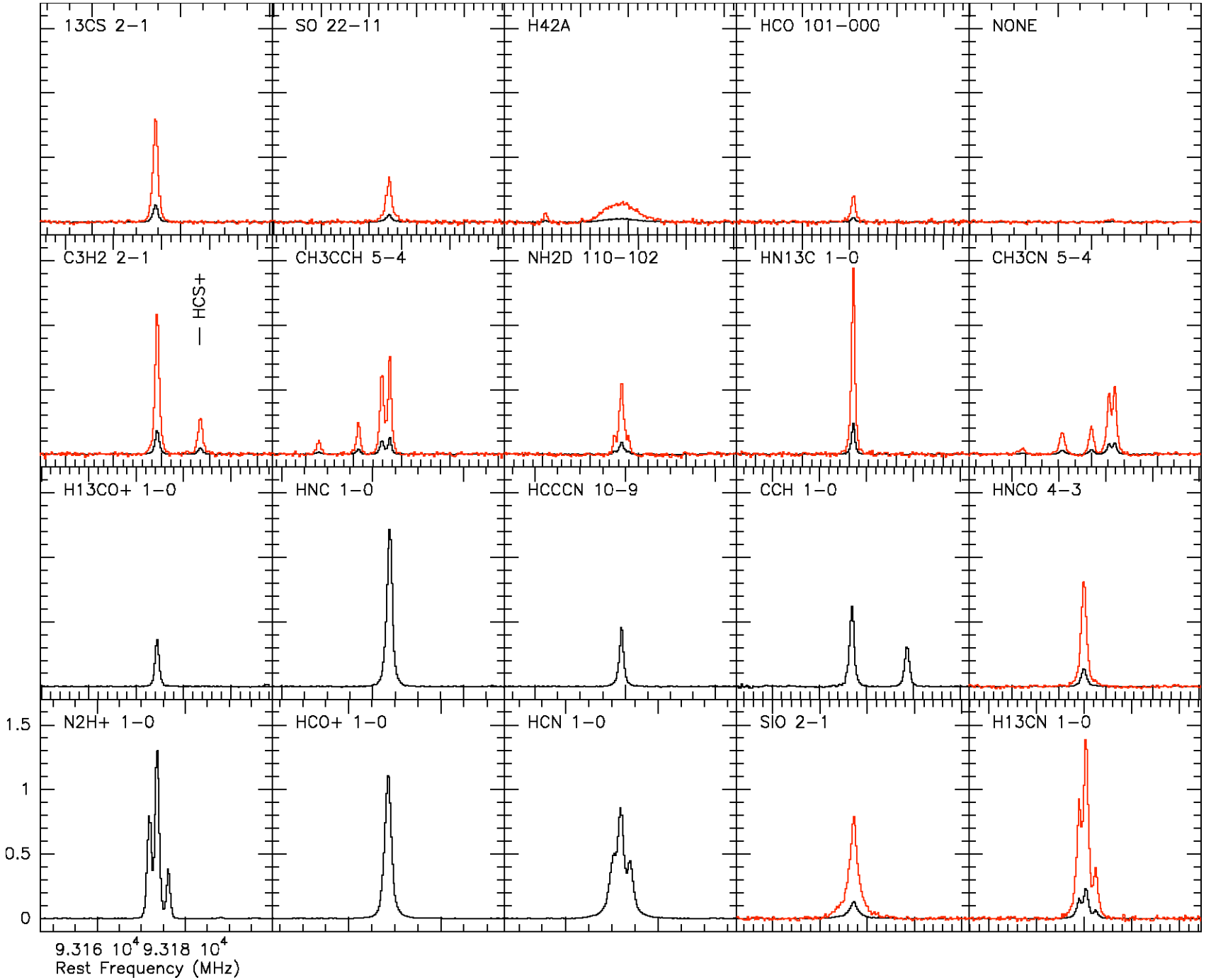




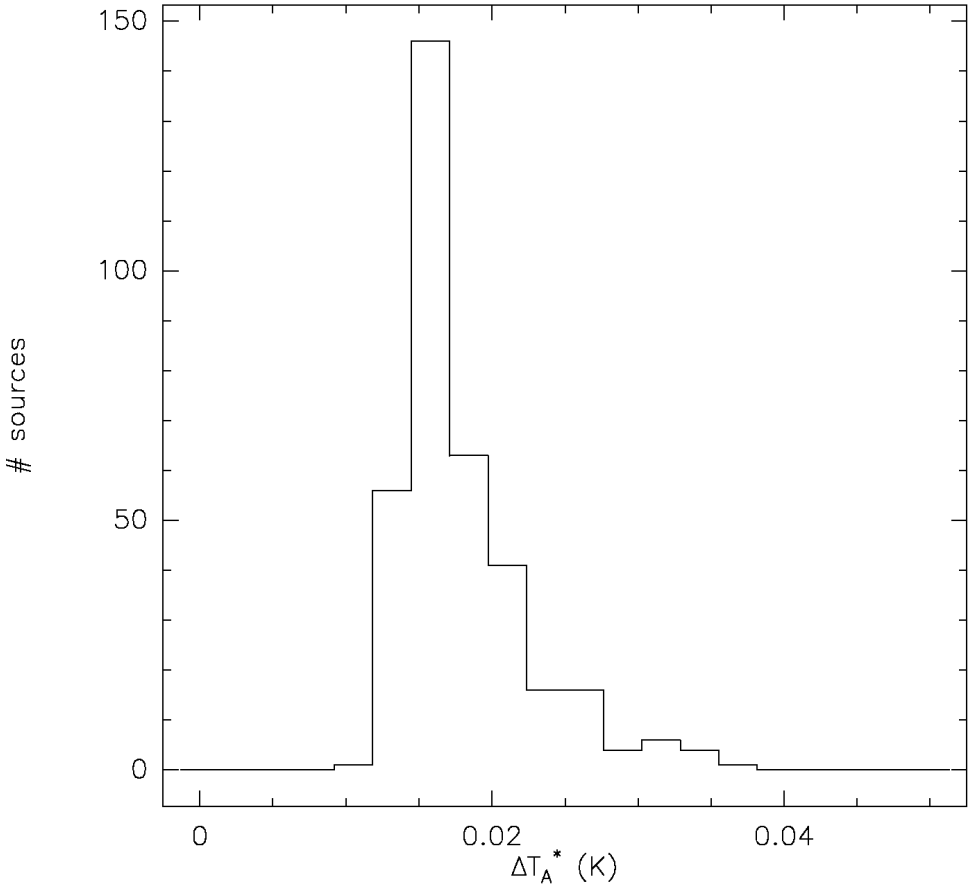
Mopra meets ALTASGAL

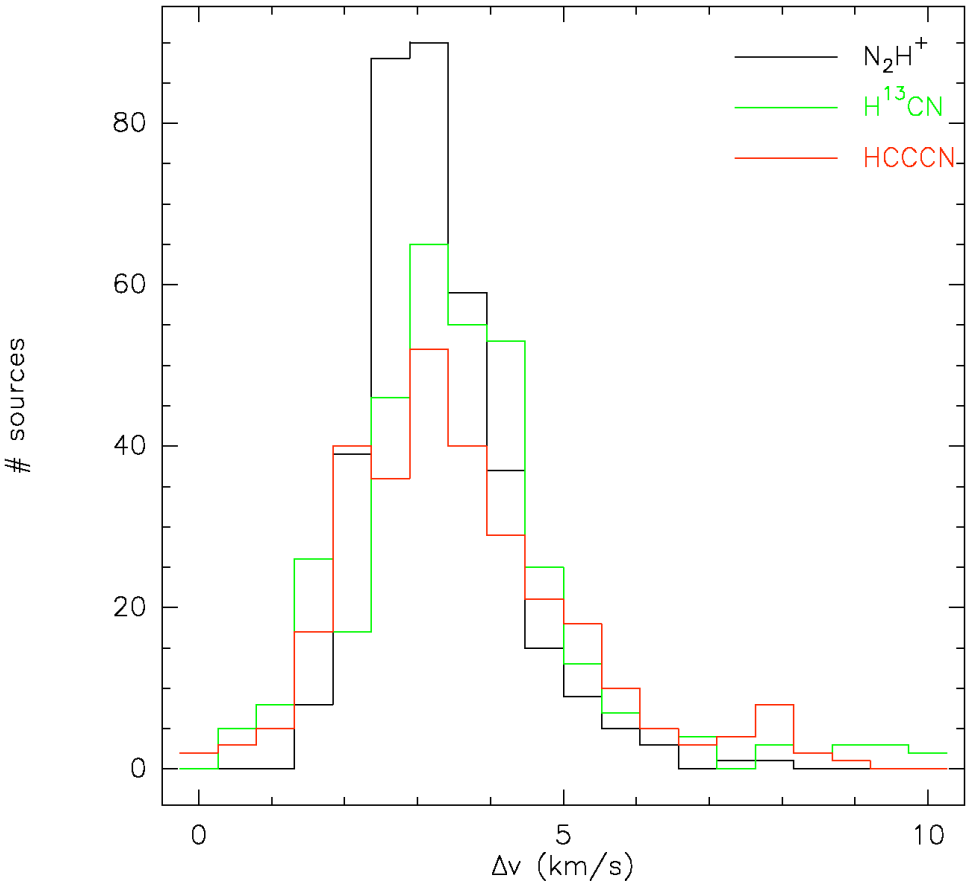
- May 14-26, 10/12 nights useful
- 343 sources
  - 160 with emb. MIR
  - 49 close to MIR
  - 134 without MIR
- Flux limited sample:
  - 1.75 Jy/bm with MIR
  - 1.2 Jy/bm without MIR
- l=330-358, |b|<1
- 36” beam (LABOCA 18”)
- MOPS broadband:
  - 85.2 – 93.4 GHz
  - ~ 0.9 km/s resolution
- Average noise: 20 mK @ 200 K Tsys
- 1 non-detection: PN NGC 6302
- Lost time almost only due to bad weather but not hard-/software problems !

“Stacked” spectra

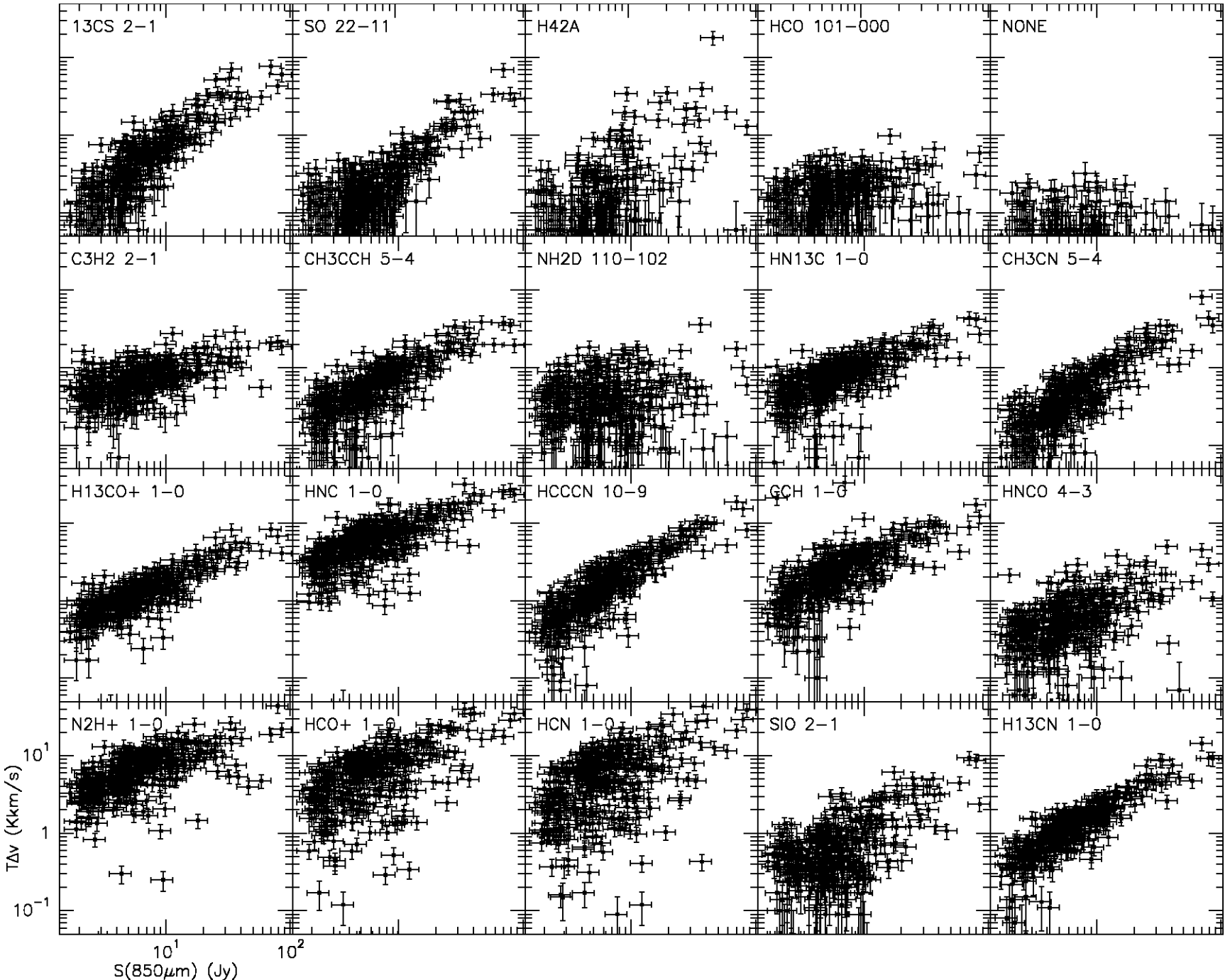


Noise and line widths

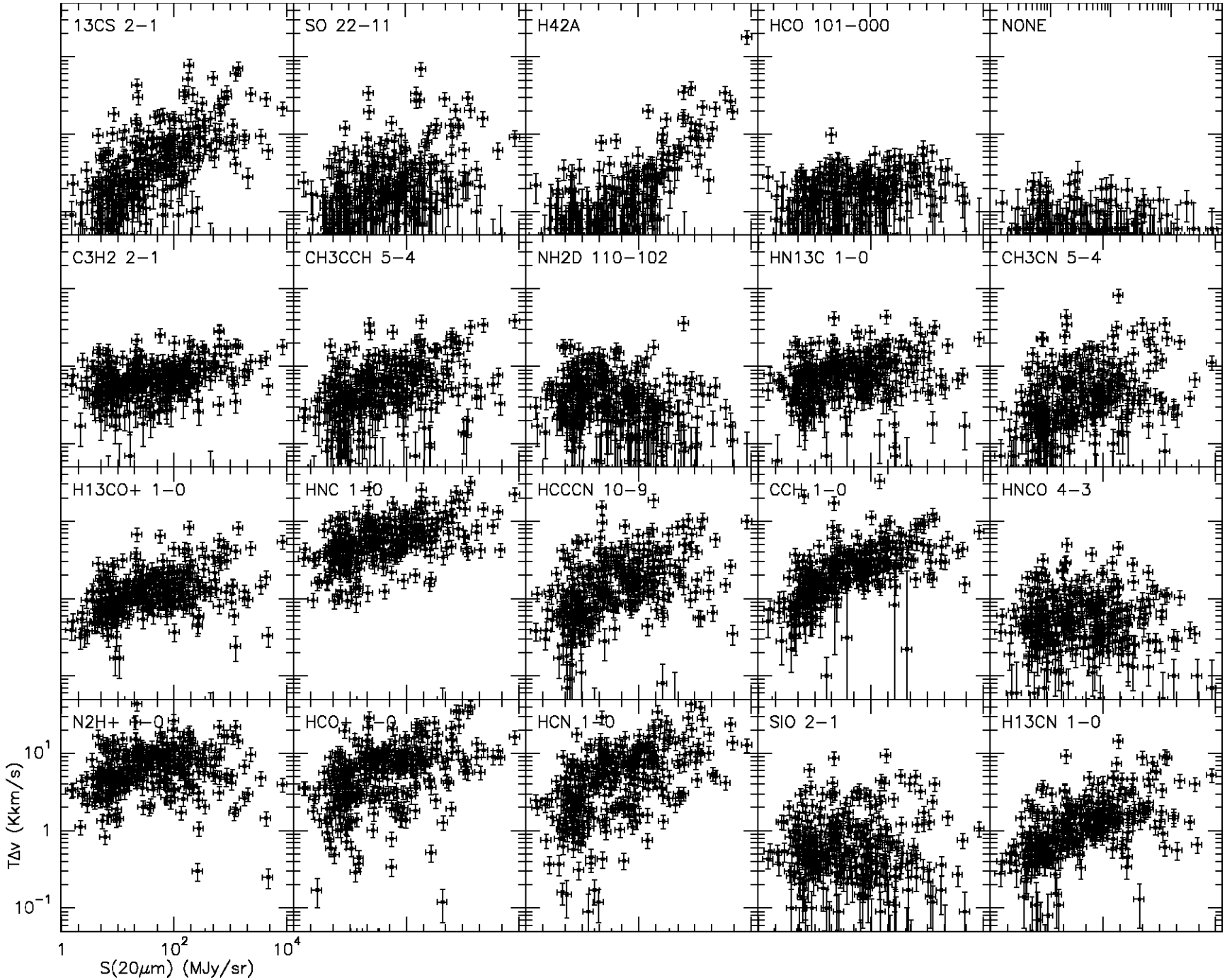




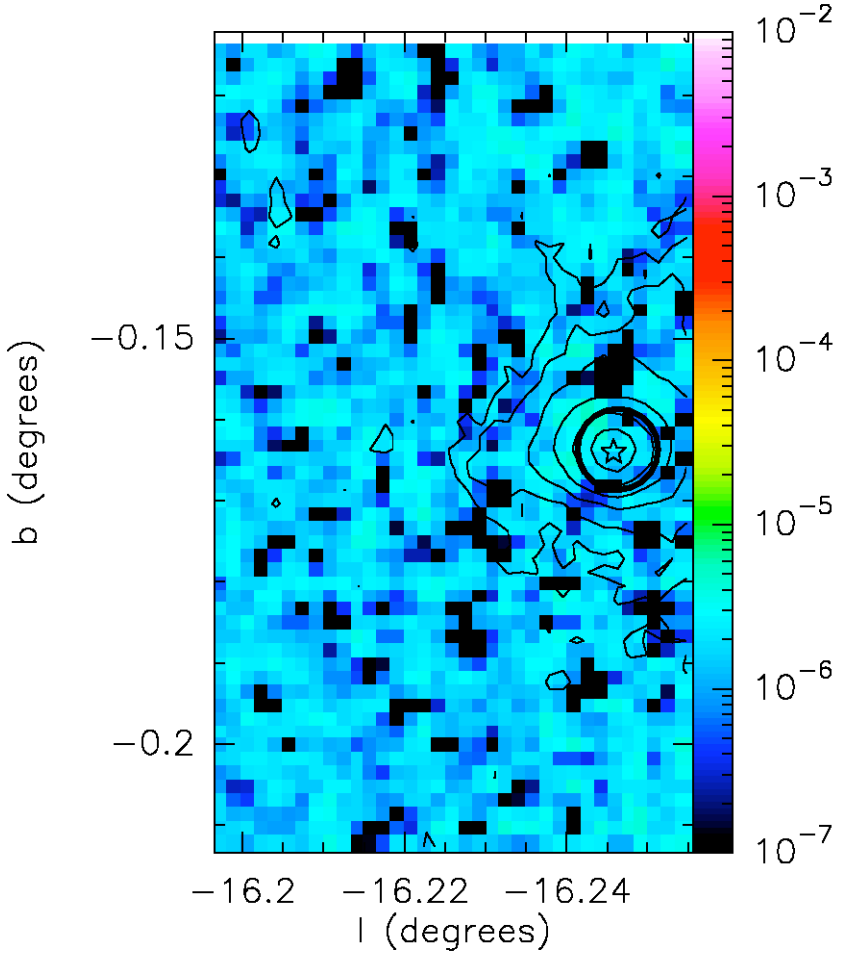
Line intensities vs. submm flux

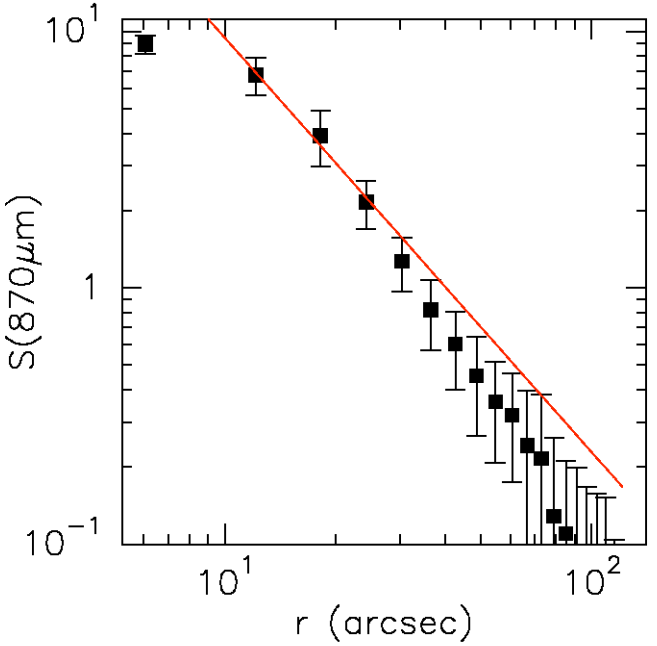


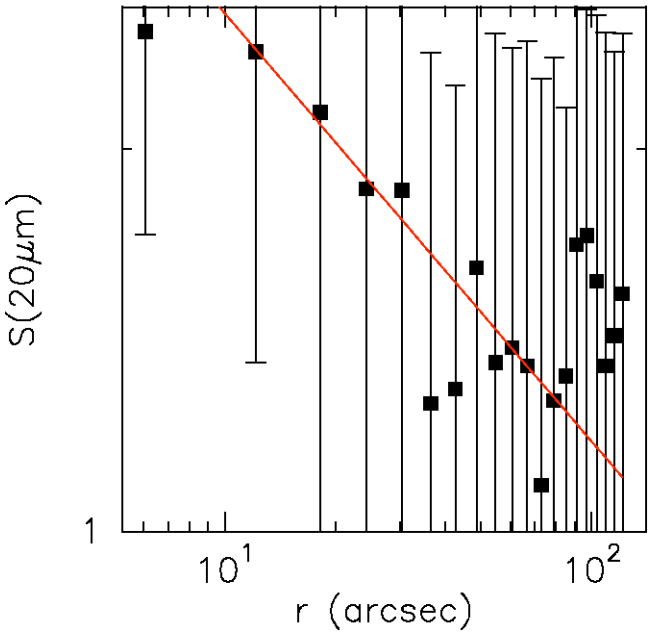
Line intensities vs. MSX 20μm flux



AG343.75−0.16





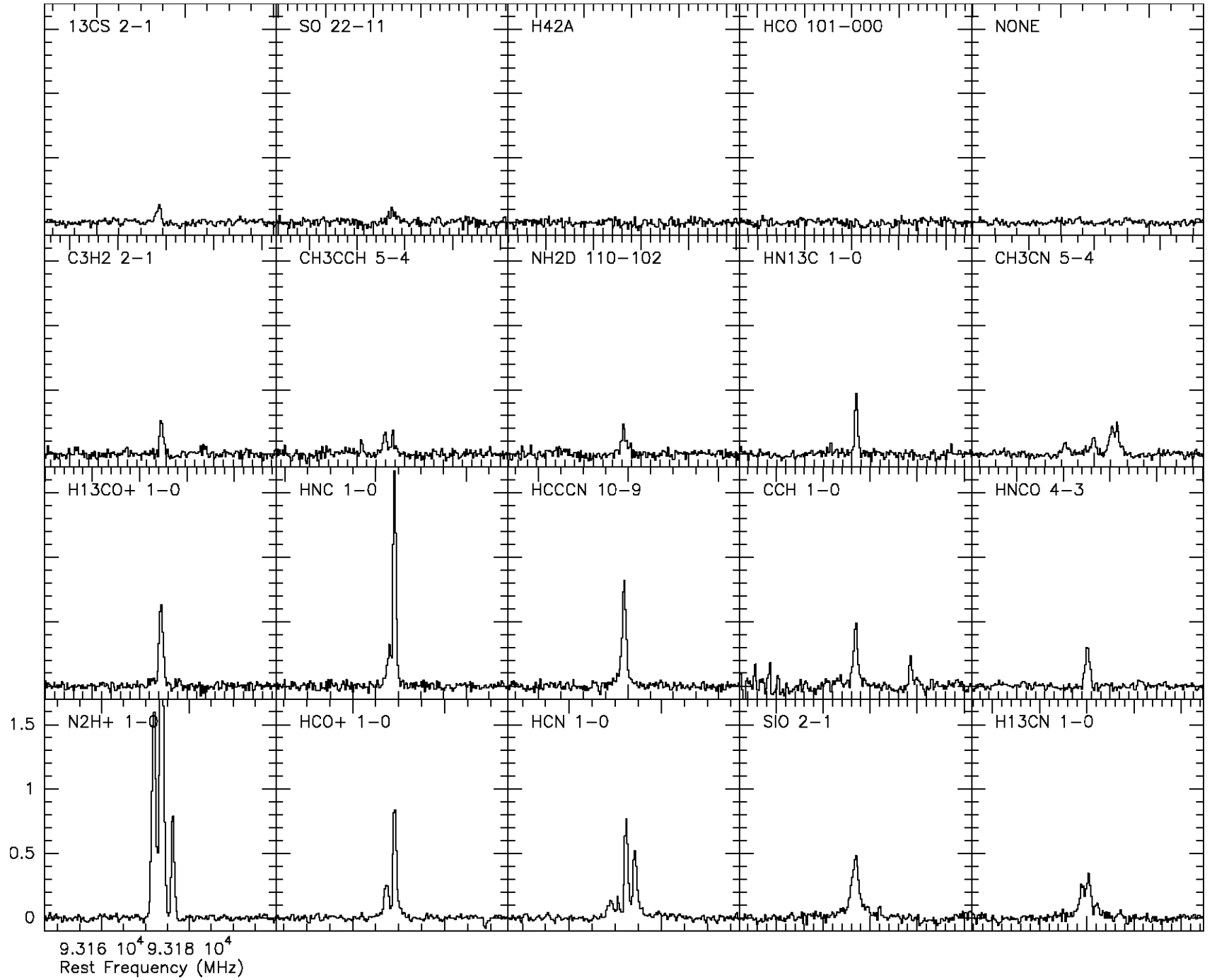


S(870μm),int = 13.8 S(20μm),int = 5.7

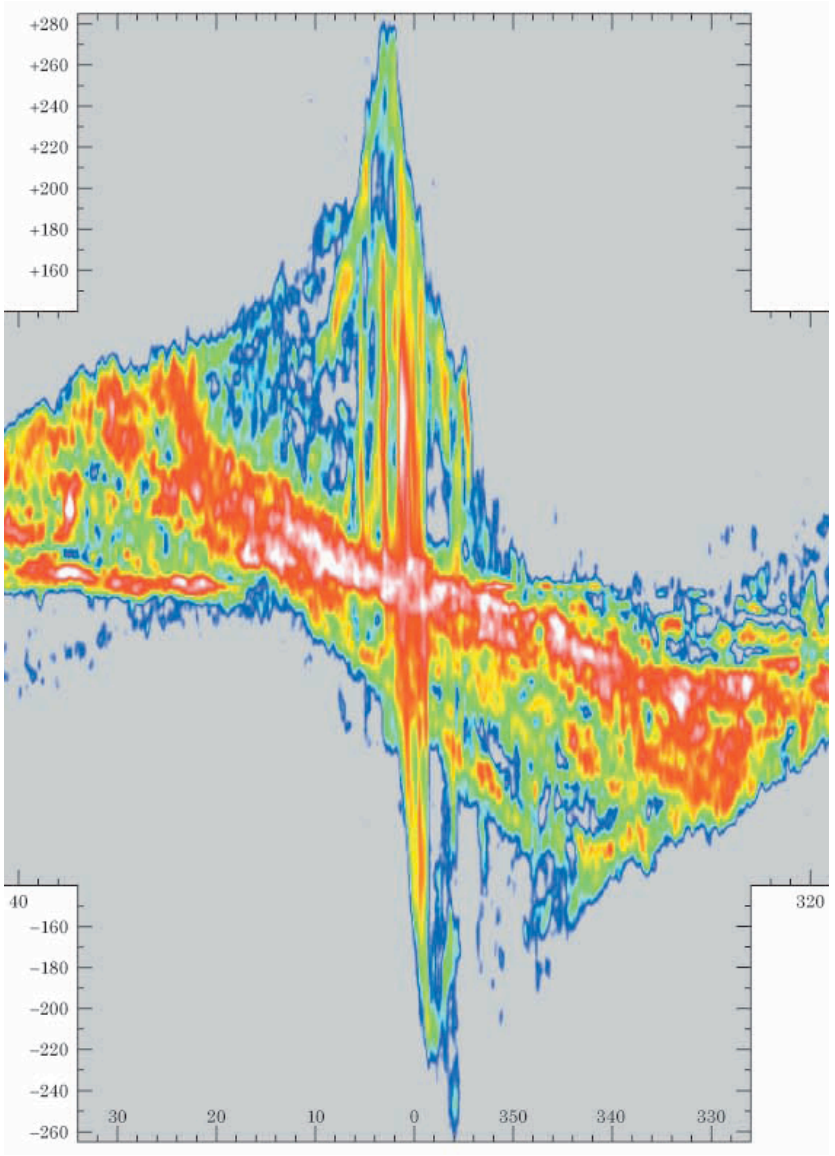
S(870μm),peak= 9.6 S(20μm),peak= 2.7

α(870μm) = −1.7 α(20μm) = −0.4

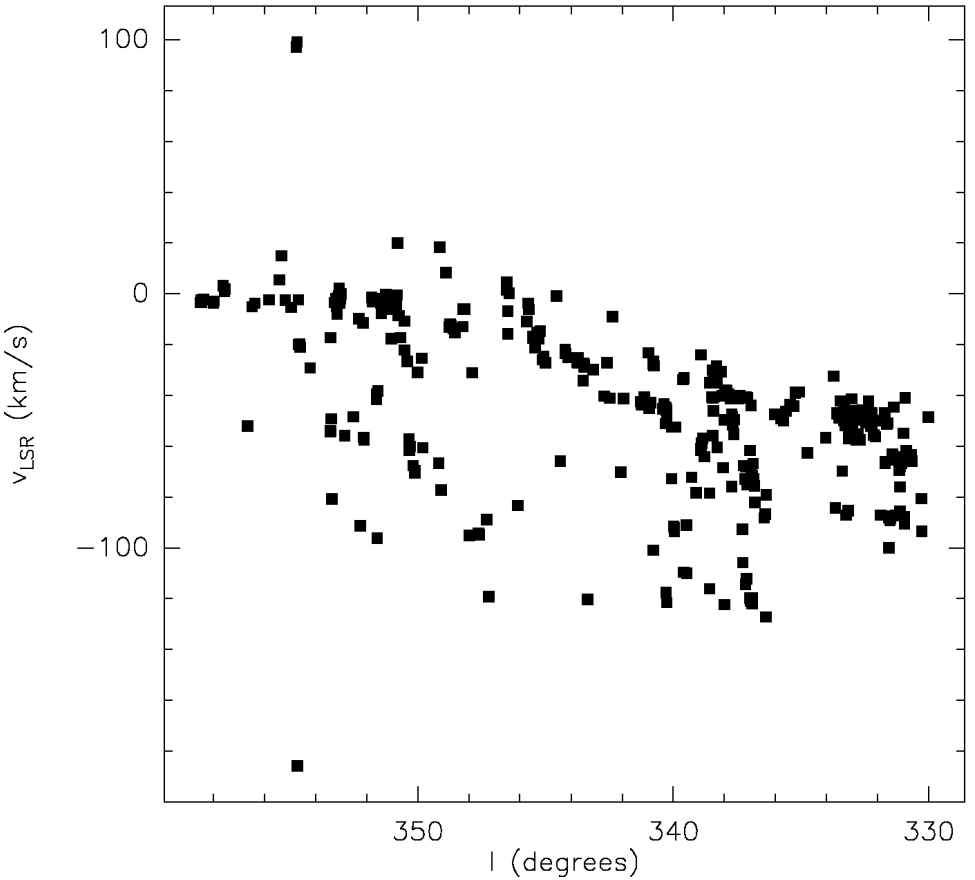
Distances = 13.5 2.7


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)

Clump velocities



Dame+ 2001

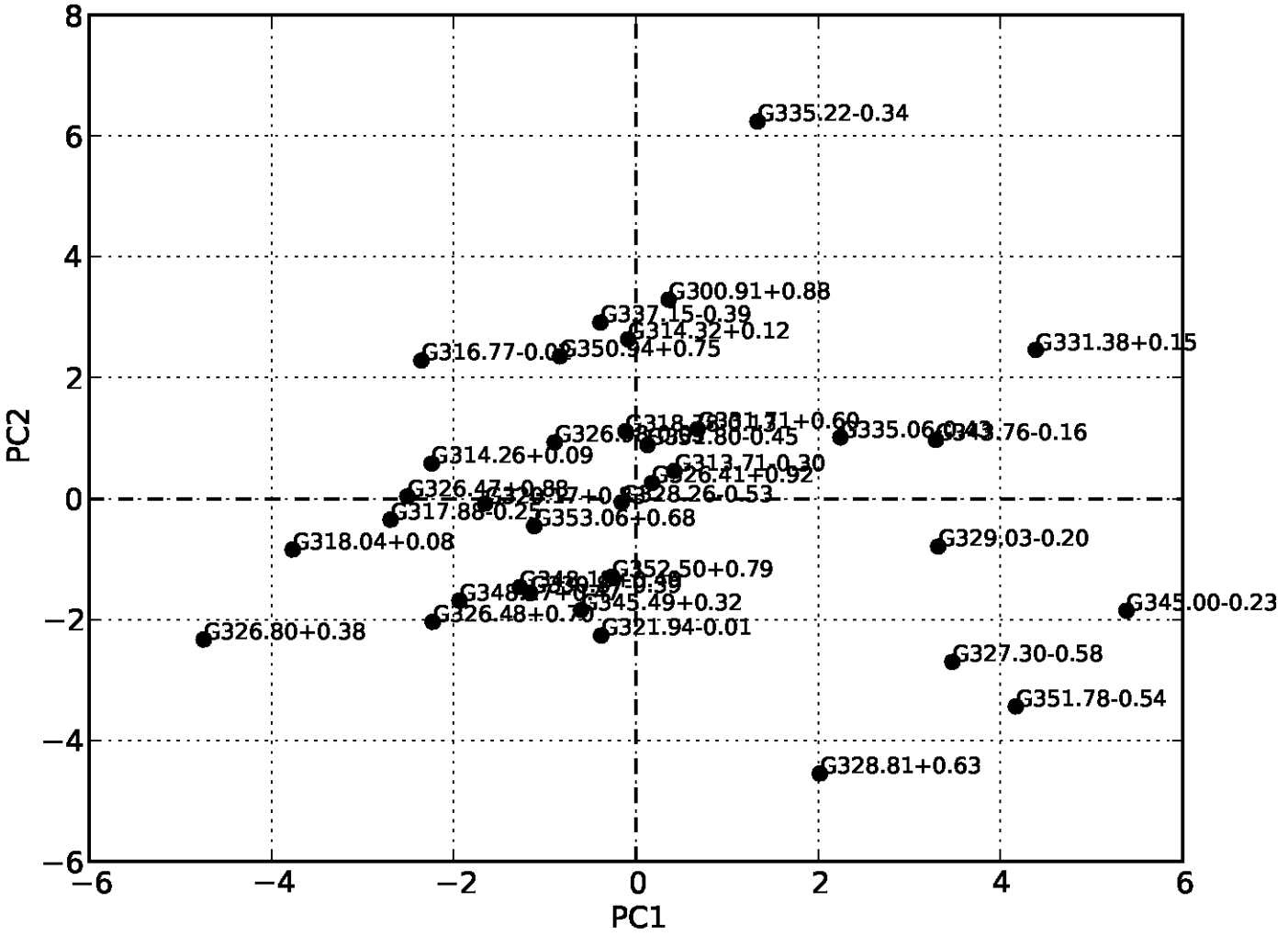


Principle Component Analysis

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

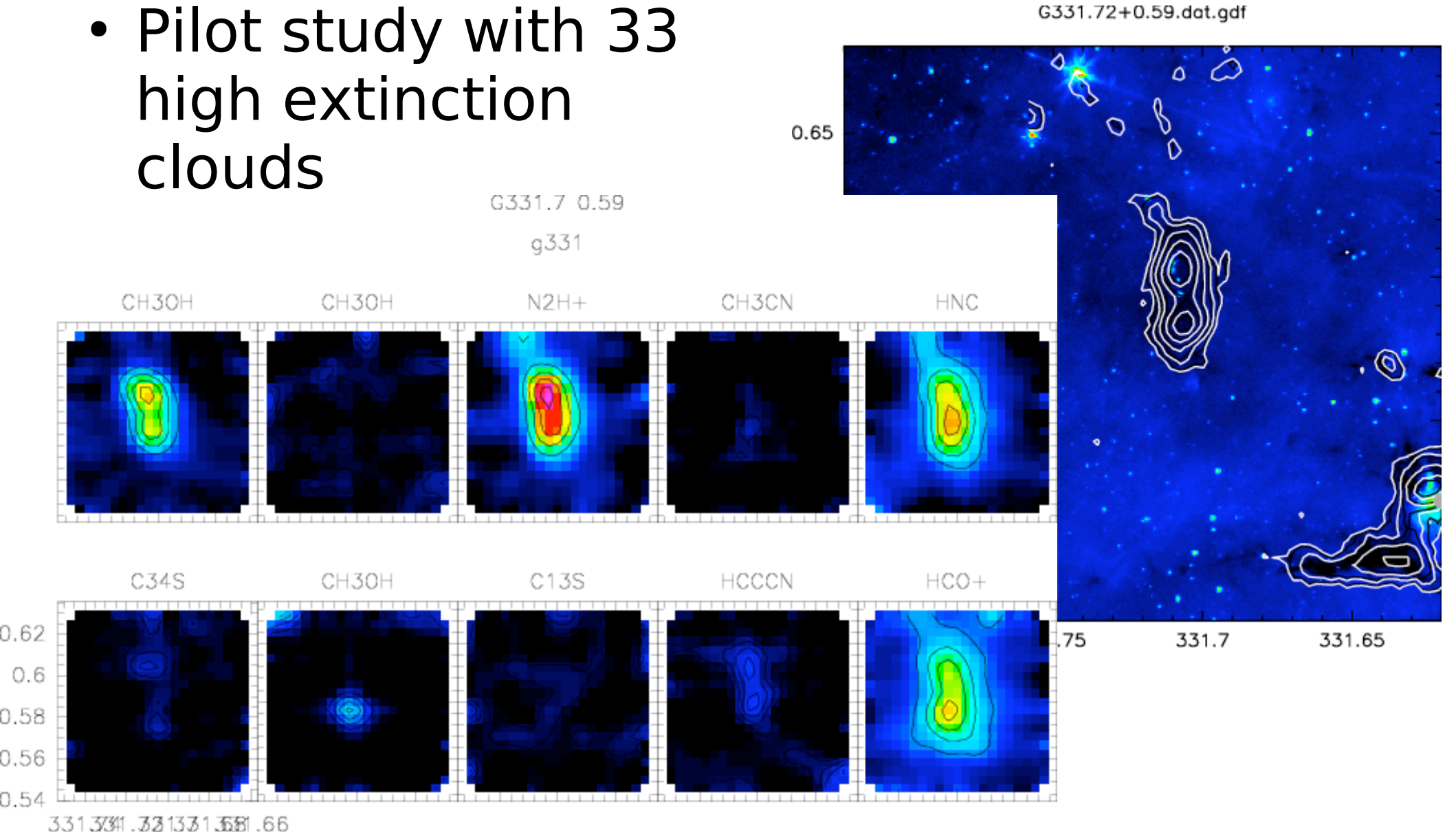
➔ Find oddballs

➔ Classify sources



Molecular line maps example:

- Pilot study with 33 high extinction clouds



Prospects for Mopra

- Continue compact source follow-up to whole ATLASGAL southern hemisphere range
- 3mm Milky Way survey:
  - Possible only as a shallow survey in optical thick lines, e.g.: HCN/HNC/HCO^+/CS/CH_3OH/N_2H^+/^{13}CO/CO
  - Would miss important optically thin lines & less abundant species, also weak sources

  ➔ Development of a multibeam instrument should be a serious consideration e.g. HEMT array with FFTS BEs