ATLASGAL: APEX Telescope Large Area Survey of the Galaxy

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- **ESO countries:**

- **Chile:**
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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

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

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.
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 $1\sigma = 50\sim$mJy/beam
  - $3\sigma$: $1\ M_\odot \sim$ at 500 pc, $35\ M_\odot \sim$ at 3 kpc, $240\ M_\odot \sim$ 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 (24μm) examples
ATLASGAL compact sources

Flux distribution for >6000 sources in 95 deg$^2$

- Compact source catalog (Contreras+ in prep.) 60% no bright IR (IRAS/MSX)
- ATLASGAL/MIPSGAL SEDs (Troost+)
SED fitting results (Troost 2009)

Norma arm @ 7kpc:
- $M \sim 200-5000$ Msol
- $L \sim 1000-50000$ Lsol
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)
- \( \text{tau}_\text{peak} \) 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$_2$CO/CH$_3$CCH (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
- $\text{NH}_3\ (1,1) - (3,3)$
- Flux limited sample of $\sim1000$ 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 $l=300-330$!
“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$_3$H$_2$
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 source loadings of the first three PCs.
Clump densities (Morales+)

- IRAM 30m observations of strong clumps
- Now working on including temperatures from CH$_3$CCH

![Graph showing density vs. total mass](image)

using RAXDEX for C$^{34}$S(2-1)/C$^{34}$S(3-2)

using submm continuum flux

○ = non-MSX
○ = MSX

Total Mass (M$_\odot$)
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