The APEX Telescope
Large Area Survey of the Galaxy

Status, first results and prospects

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Introduction

Context: Formation of massive stars is poorly understood

- High-mass stars evolve quickly ⇒ rare ⇒ large distances + confusion
- Evolution sequence in high-mass star formation?? time-scales??
  ⇒ Need for large scale surveys in dense gas tracers

- **NEW**: Spitzer surveys (3–8 μm, 24+70 μm), inner Galactic Plane but miss the coldest objects (earliest stages)
- **Coming soon**: Hi-GAL (Herschel PACS+SPIRE), $\lambda = 60–500$ μm mid- far-IR ⇒ Temperature, YSO stages

Dust emission in the submm = the only optically thin tracer
  ⇒ direct measure of column densities ⇒ masses

**Unbiased view, detect all stages, all objects** (to given sensitivity)
  BOLOCAM@CSO, SCUBA-2@JCMT, LABOCA@APEX
The Large APEX BOlometer CAmera

\[ \begin{align*}
\text{Frédéric Schuller} & : \text{ATLASGAL} \\
\text{IAU General Assembly 2009 – Special Session 8}
\end{align*} \]
APEX Telescope Large Area Survey of the Galaxy

- Systematic survey of the inner Galactic Plane at 870 $\mu$m, with LABOCA (295-bolometer array) at APEX (beam: 19$''$)
  - massive star formation throughout the Galaxy
  - large scale structure of the cold ISM

IRAS 12+60+100 $\mu$m, $|l| \leq 90^\circ$, $|b| \leq 10^\circ$

- Mapping $|l| \leq 60^\circ$, $|b| \leq 1.5^\circ$, sensitivity 1-$\sigma \leq 50$ mJy/beam
  $\Rightarrow$ 360 deg$^2$, 5$\sigma$ detection:
  0.5 $M_\odot$ at 500 pc, 20 $M_\odot$ at 3 kpc, $\sim$100 $M_\odot$ at 8 kpc
  (9 years lifetime of SCUBA : 30 deg$^2$ covered)

- Observing mode: on-the-fly maps (1×2–3 deg$^2$), fast scanning.
  At least 2 coverages per position, with $\neq$ angles
First results

2009, August 1st:
80% of observations completed

Early results:

- First unbiased view of high density gas in the Galaxy
- Nature of the compact sources
- Distance determination and Galactic structure
Example maps: 72 deg$^2$

longitude $+11^\circ \rightarrow -1^\circ$

longitude $-1^\circ \rightarrow -13^\circ$

longitude $-13^\circ \rightarrow -25^\circ$
Example maps

Norma arm: compact sources and long filaments

- Extended objects on arcmin scale
- Very long filaments, up to the degree scale!
- $\Rightarrow$ Large scale structure of the cold ISM
Survey for the earliest phases of high-mass stars and cluster formation

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

- 6000 compact sources: unresolved ($<19''$) to a few beams ($150''$)
- 2000 with MSX, 600 with IRAS, 2/3 no bright IR from IRAS/MSX (Contreras et al. in prep.)
Compact sources

HII regions, YSOs, IR-quiet sources, IRDC...

GLIMPSE 8 µm + ATLASGAL

Spitzer + ATLASGAL
Heterodyne follow-up with MOPRA

- λ = 3 mm, broad band spectrometer: 85.2–93.4 GHz, δν = 0.9 km/s ⇒ CS, SO, HCN, HCO⁺, HNC, N₂H⁺, SiO, CH₃CN, NH₂D...
- Kinematic distances + Physical conditions (virial masses, T, n) + infall, outflow, shocks + chemical conditions, deuteration + ...

First results: follow-up of >300 ATLASGAL sources

Work in progress! (Wyrowski et al., in prep.)
Distance determination and
Galactic structure
(Bontemps, Wyrowski et al.)

1\textsuperscript{st} method: using existing data, e.g. CS cores, Galactic Ring Survey + extinction maps to recognize coherent complexes.

2\textsuperscript{nd} method: heterodyne follow-ups, e.g. NH$_3$ at Effelsberg.

Beyond the kinematic distances: trigonometric parallaxes, spectro-photometric distances (limited samples)
Distance determination

Kinematic distances using GRS data ($^{13}$CO)

- $870 \, \mu m$
- $^{13}$CO 45–70 km/s
- $^{13}$CO 75–85 km/s
Distance determination

Solving for near/far ambiguity

$A_V$ (2MASS)

870 $\mu$m

Spitzer GLIMPSE
Kinematic distances derived from NH$_3$ spectra (Effelsberg)

**First results**

- **New complexes revealed!** Example around $l = +19^\circ$, $D \sim 4$ kpc
Perspectives

Plans after 2009: extending to outer Galaxy
+ going deeper in limited areas

Follow-ups with:

– APEX bolometers + heterodyne
– IRAM 30 m and PdBI
– Near future: ALMA, Herschel
– Synergy with Herschel (Hi-GAL)
Follow-ups with APEX

- **SABOCA** = Submillimeter APEX BOlometer CAmera
- 37 element TES bolometer array
- \( \lambda = 350 \ \mu m \Rightarrow \text{Beam} = 7.5'' \)
- FoV = 1.5 arcmin \( \Rightarrow \) mapping limited areas at 350 \( \mu m \)
- Small scale structure; Spectral index, dust emissivity, temperature
- Heterodyne instruments: \( \nu = 230 \ \text{GHz} \leftarrow 1.3 \ \text{THz} \)
Large program with HERA at IRAM 30 m
(F. Motte, P. Schilke, et al.)

- **The W43 molecular complex**: several $10^6 \ M_\odot$, 200 pc wide at 6 kpc
- Transition Galactic bar/ring/spiral arms $\Rightarrow$ extreme and complex velocity field
- Formation of molecular clouds from HI flows?
- HERA to map entire complex in $^{13}$CO + $^{18}$O and map densest regions in HCO$^+$ and H$^{13}$CO$^+$ $\Rightarrow$ kinematics on **small + large** scales
Near future: High resolution mapping with ALMA

IRAS 05358+3543; Beuther et al. 2007, A&A 466, 1065
**Legacy value**

- **Unbiased survey**, the only one covering ±60° in Gal. longitude ⇒ Statistical studies on the scale of the Galaxy
- Well developed synergy with the Herschel KPs HOBYS and Hi-GAL
- Compact source catalog will be merged with MIPSGAL and Hi-GAL → ultimate homogeneous, complete, continuous database from 24 to 870 µm at similar spatial resolution (∼20″)

**Data products**:  

- **Coming soon**: calibrated maps  
- Compact source catalog ver. 1, cross-id. with IRAS/MSX  
- Catalog of extended objects  
- Source catalog + line identifications + Spitzer, Herschel ⇒ **SEDs from 3 to 870 µm + distances + sources nature**

High legacy value
Introduction
Observations
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Perspectives
Conclusion

The true pathfinder for Galactic Star Formation
First unbiased Galactic plane survey at submm $\lambda$

- Characterize large scale structure of the Galaxy
  (cold ISM + star forming regions)

- Only a systematic survey can provide well controlled samples
  for follow-ups with ALMA

- Only optically thin dust continuum can detect high column density
  objects in an unbiased way

- Only ATLASGAL will be complete (and completed !) in 2012
  $\rightarrow$ thousands of targets for high-resolution studies

Pathfinder for ALMA, Herschel and EVLA