University of Hertfordshire

UH

or "Hopes, dreams, webpages and a dash of navel gazing"

An embarrassment of survey riches

Sensitive wide-area instrumentation + dedicated survey time

Vast majority of massive SFRs now have routine archival multi-wavelength imaging

Galactic Plane/All-sky*

IPHAS/VPHAS+
UKIDSS/VVV
GLIMPSE/MSX/WISE*
AKARI*/Herschel
APEX/JCMT/CSO/Mopra/NRO45
Planck*
JVLA/GBT/Parkes/ATCA
…

Targeted regions

(Gould Belt) Spitzer
(Gould Belt) Herschel
HOBYS
MALT90
MALT45 (Shari's talk)
CMZoom (Cara's talk)

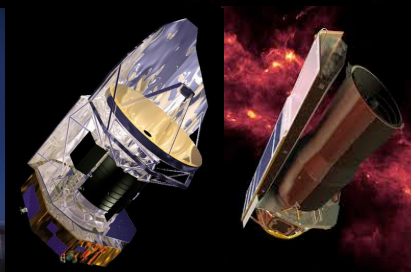HRDS (Loren's talk)
SOFIA SOMA
ALMA-IMF
…

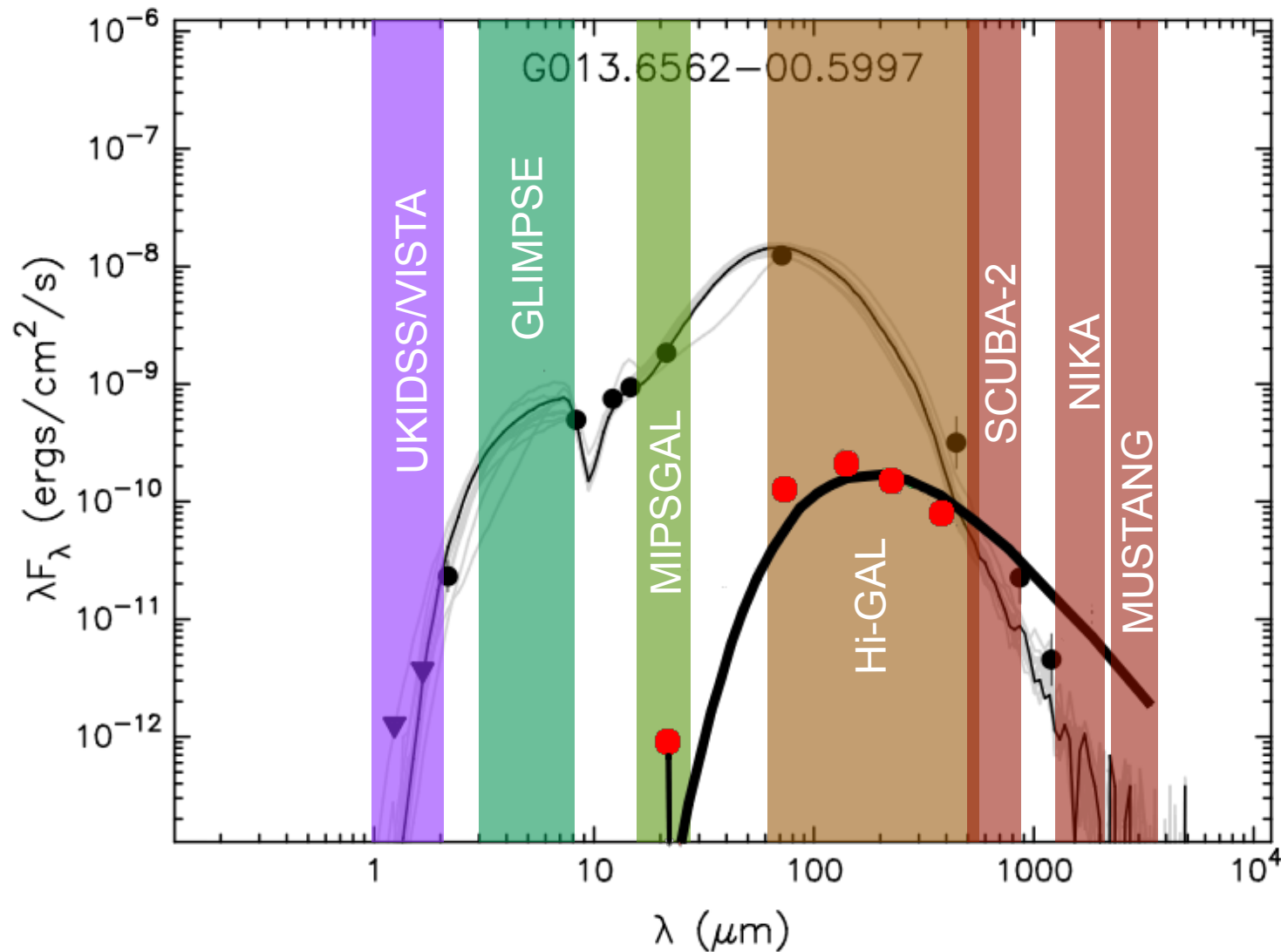**Disclaimers:** 30 minutes is too short to cover everything
Resulting (personal) bias to the Galactic Plane
If I miss your favourite survey/acronym please don't hold it against me!

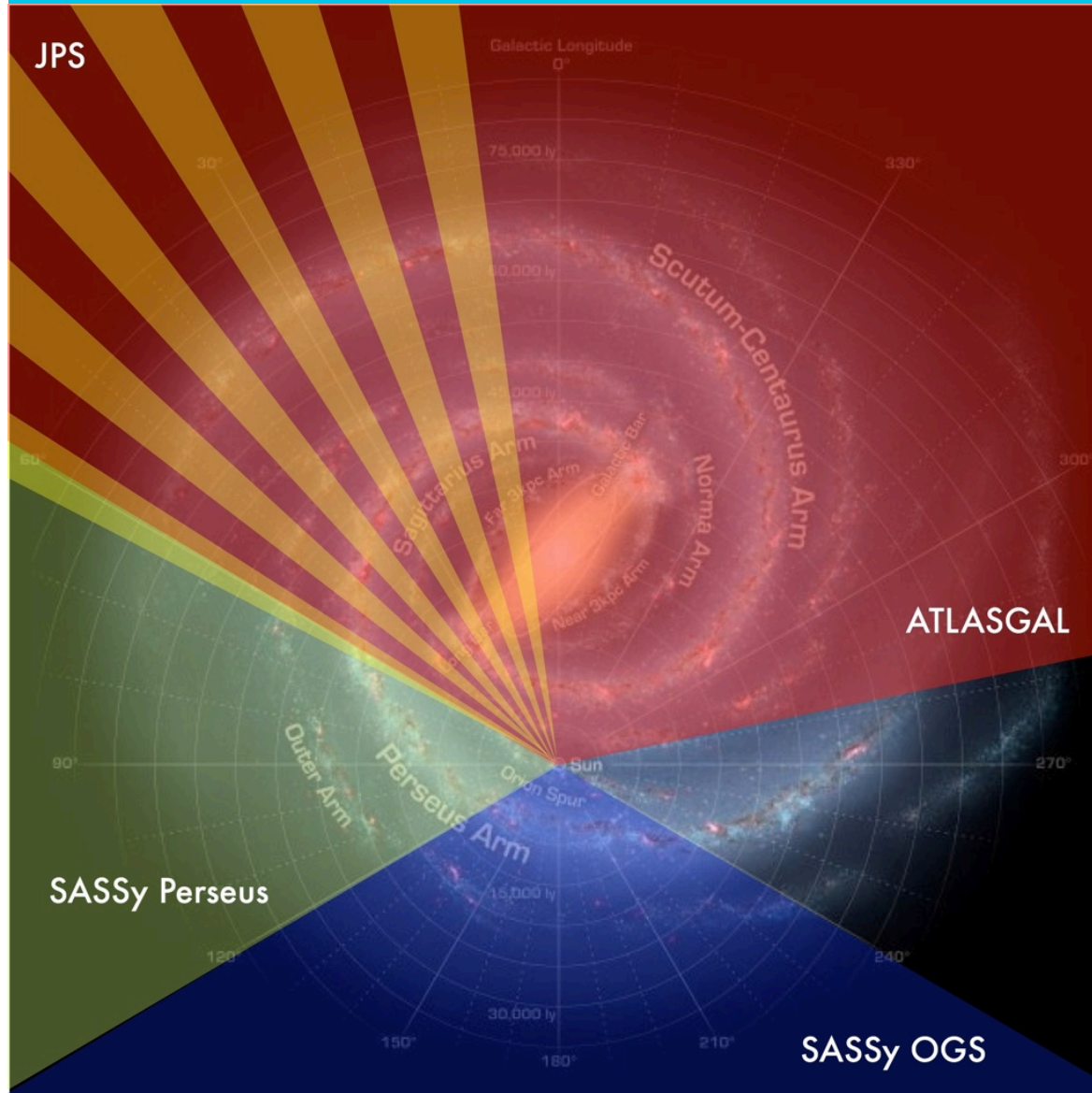# Galactic Plane Surveys are like buses

Herschel Hi-GAL

Continuum: SEDs for all

Massive Young Stellar Object SED model from Mottram et al 2011

Prestellar core model from Motte et al 2011

ATLASGAL, JPS & SASSy

ATLASGAL:

870μm, 280 ≤ I ≤ 60, |b|~1.5
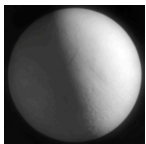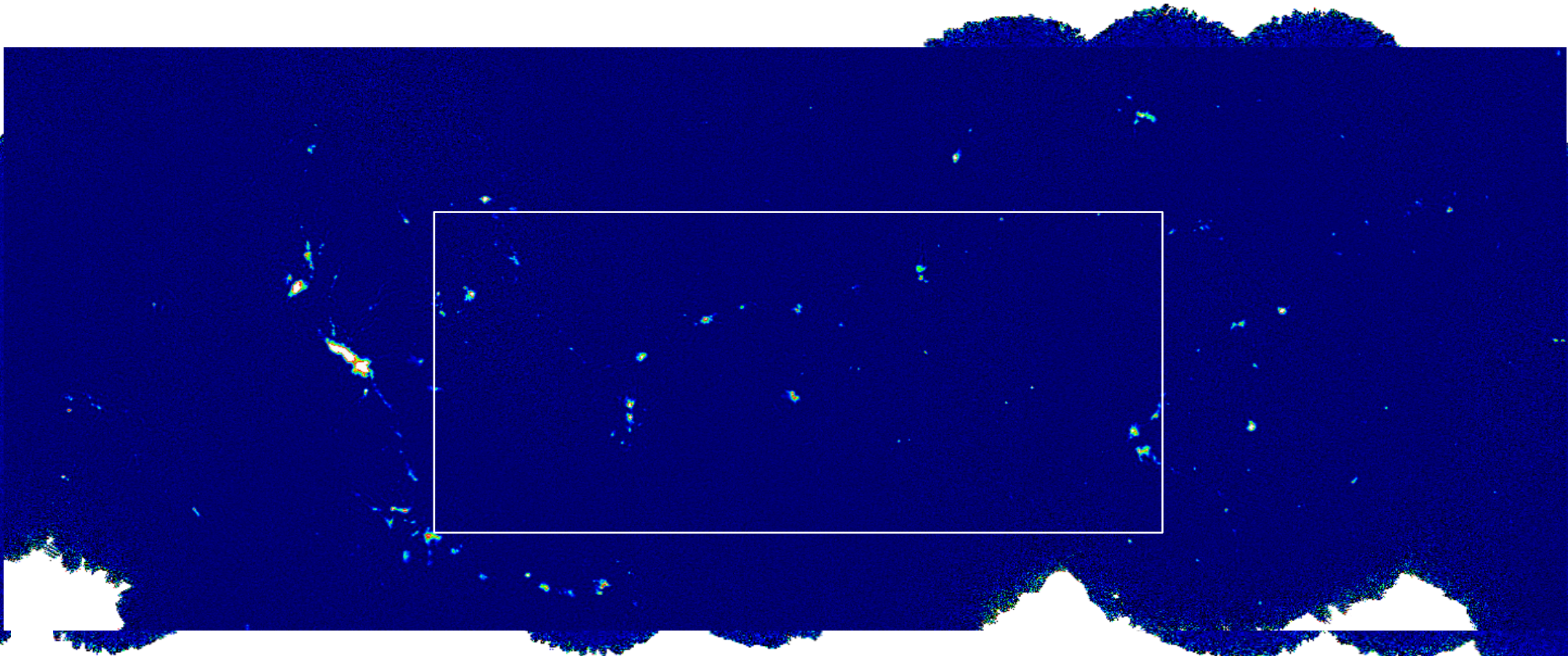
JPS: JCMT Plane Survey

Deep strips at 850 μm

SASSy:

All 850 μm

60 ≤ I ≤ 120, |b| ~1 (Perseus)

120 ≤ I ≤ 240, |b|~3 (OGS)
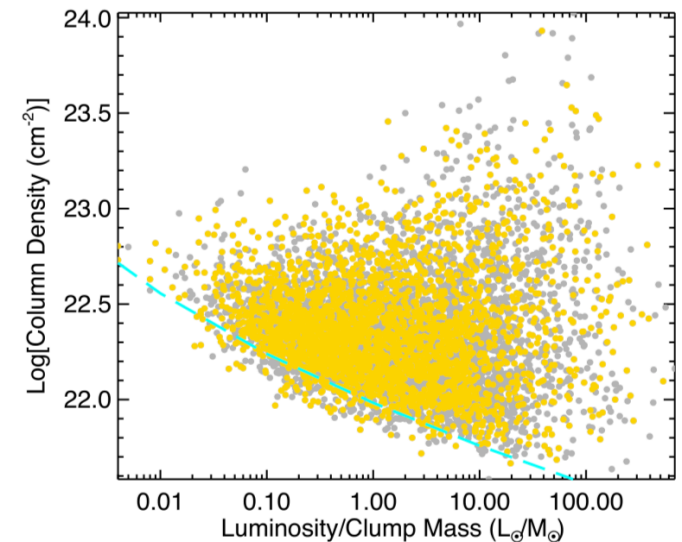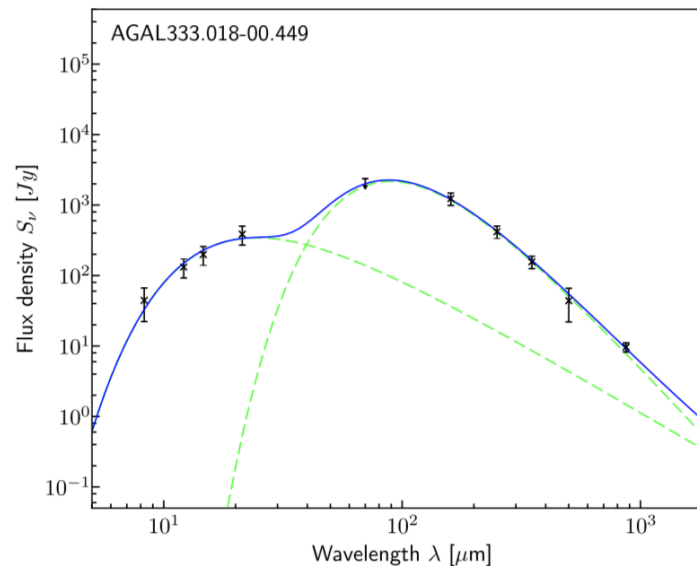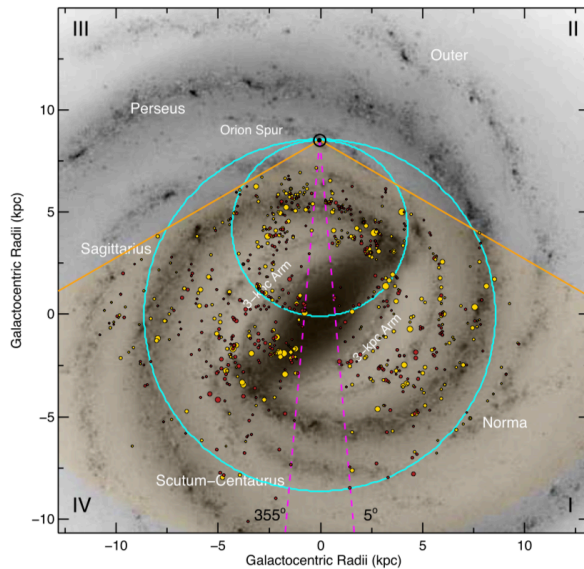
Images from SASSy

All in all about 3000 sources (blobs) in the Outer Galaxy

Vast majority in Cygnus-X

Survey paper coming soon

ATLASGAL + HI-GAL data fusion

Combination of multiwavelength photometry & spectroscopy & careful distance assignment

Complete sample of massive star forming clumps with distances, luminosities, column densities, mass, evolutionary indicators…

See James Urquharts talk & Urquhart+ (2018)
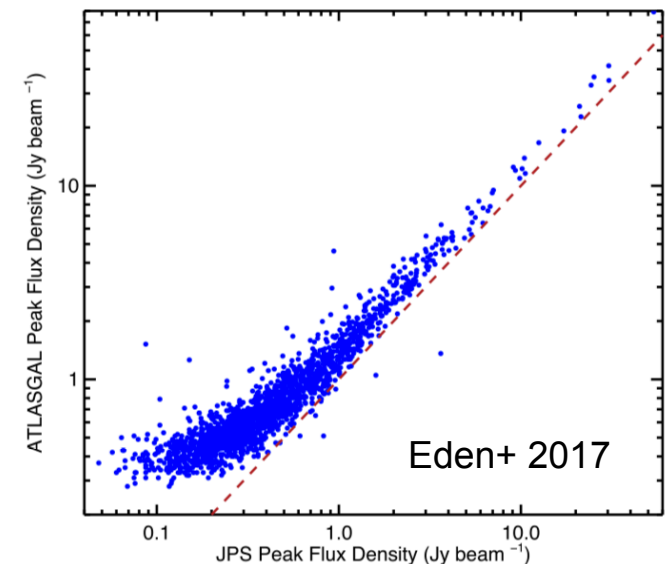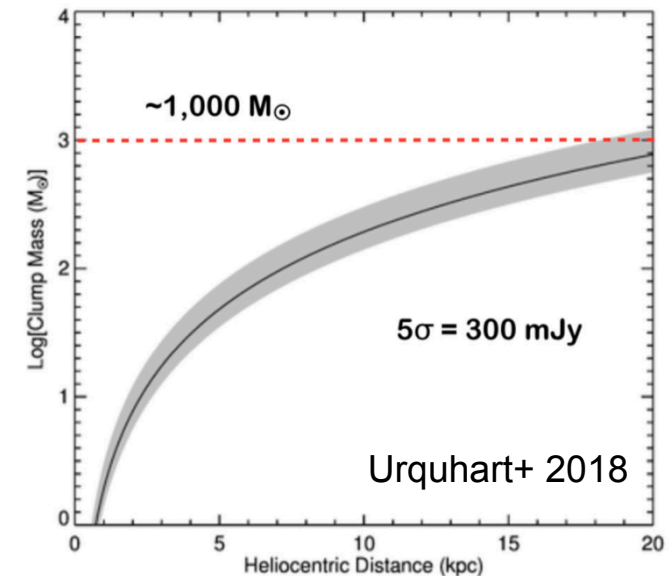
Do we need any more continuum surveys?

Not for clumps - existing single dish surveys complete to ~1000 M$_\odot$
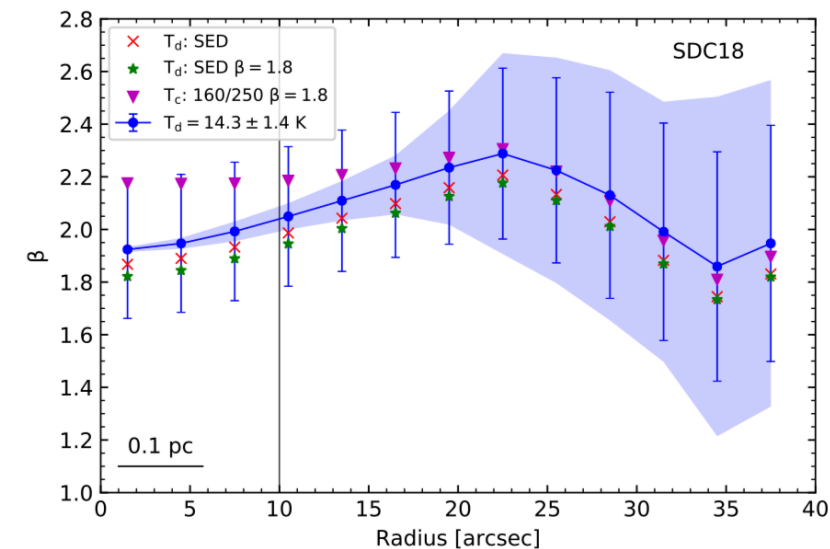
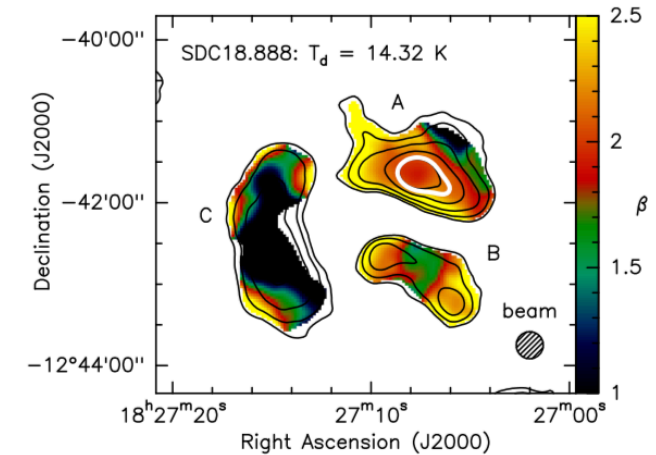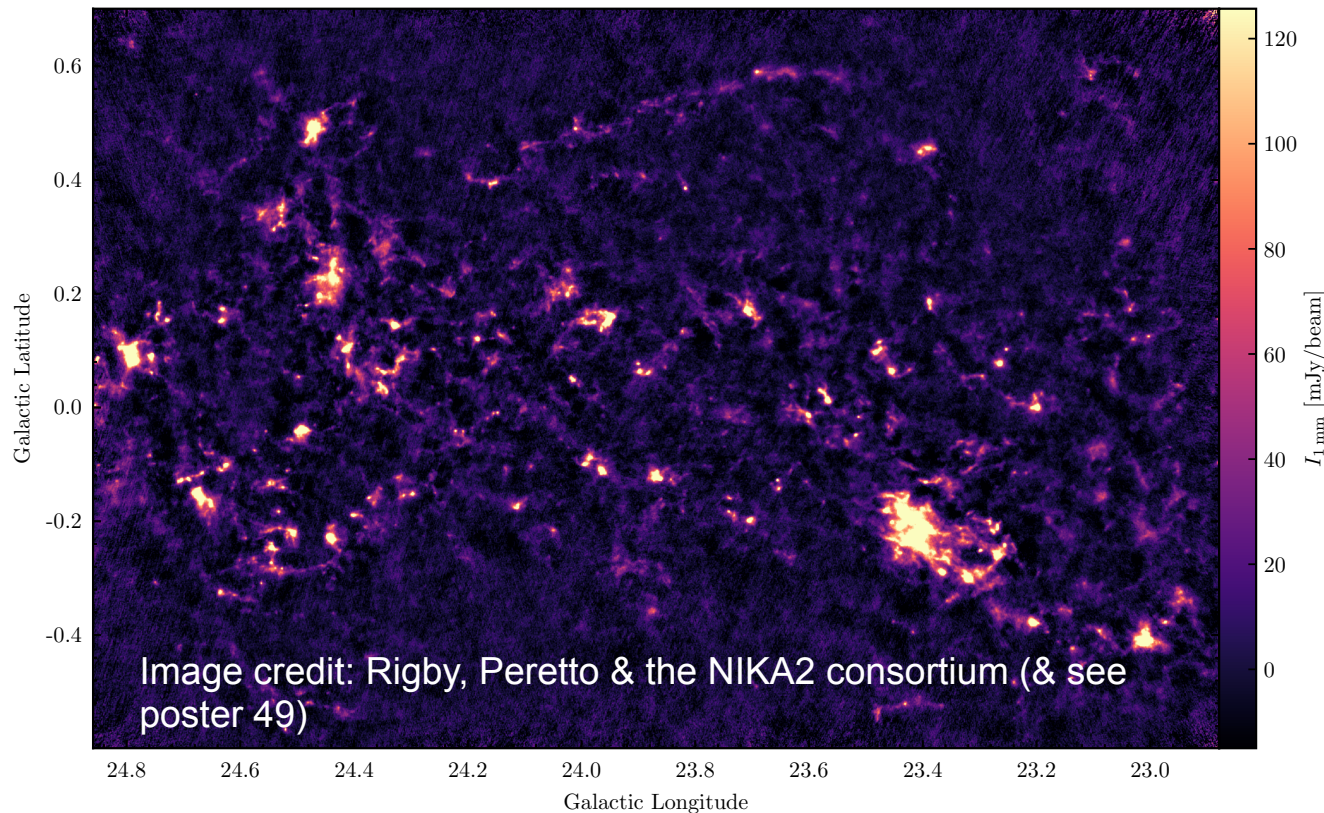Maybe for low surface brightness filaments

Exceptions:

- Millimetre-wave largely unexplored (dust properties)

- Polarimetry

- Time domain?

Will return to interferometry & radio continuum later

Urquhart+ 2018

Eden+ 2017

Dust continuum properties from GASTON

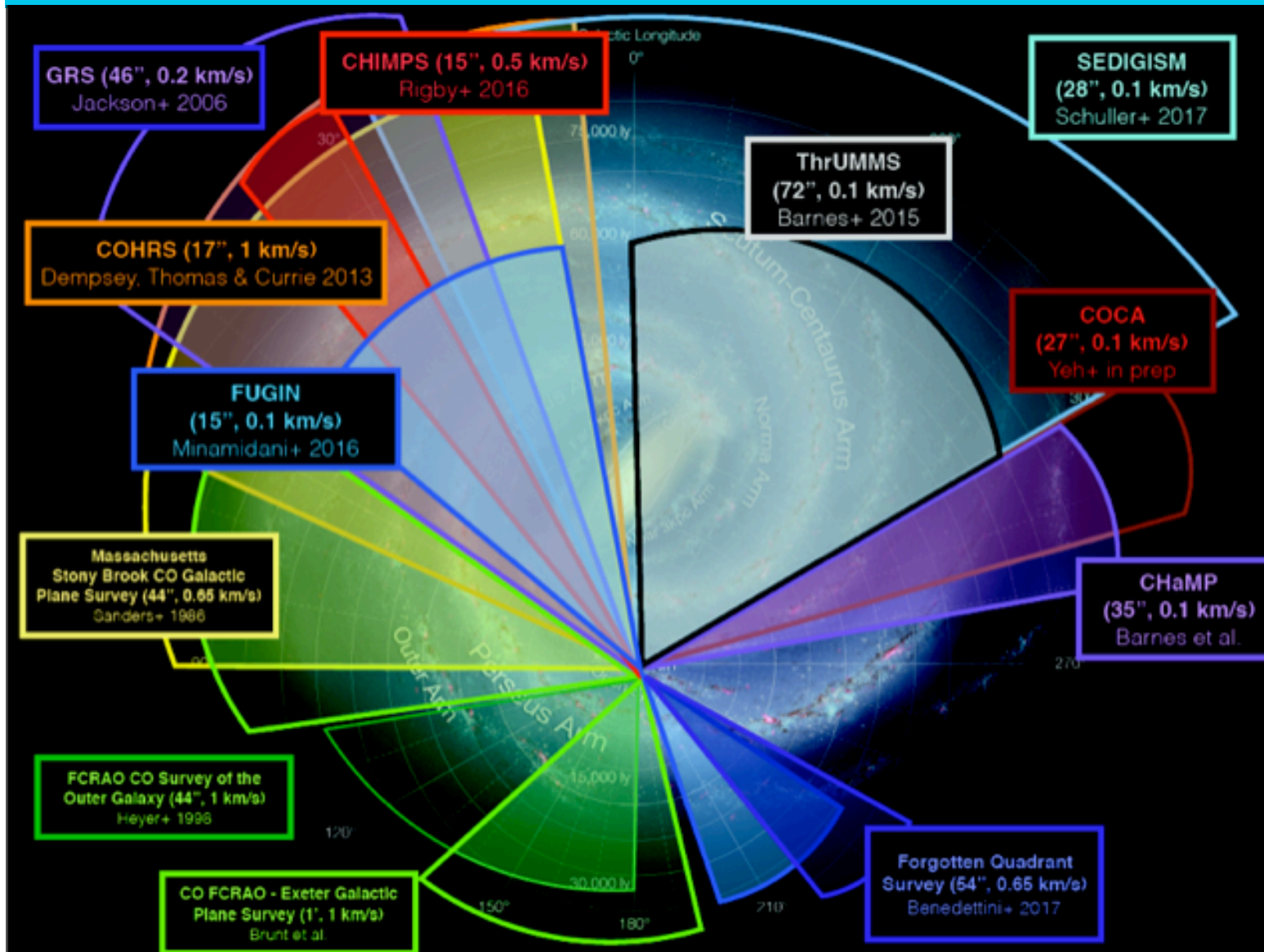Image credit: Rigby, Peretto & the NIKA2 consortium (& see poster 49)

Galactic Star Formation with NIKA2

Survey in progress - goal 3mJy/beam rms

Rigby+ 2018

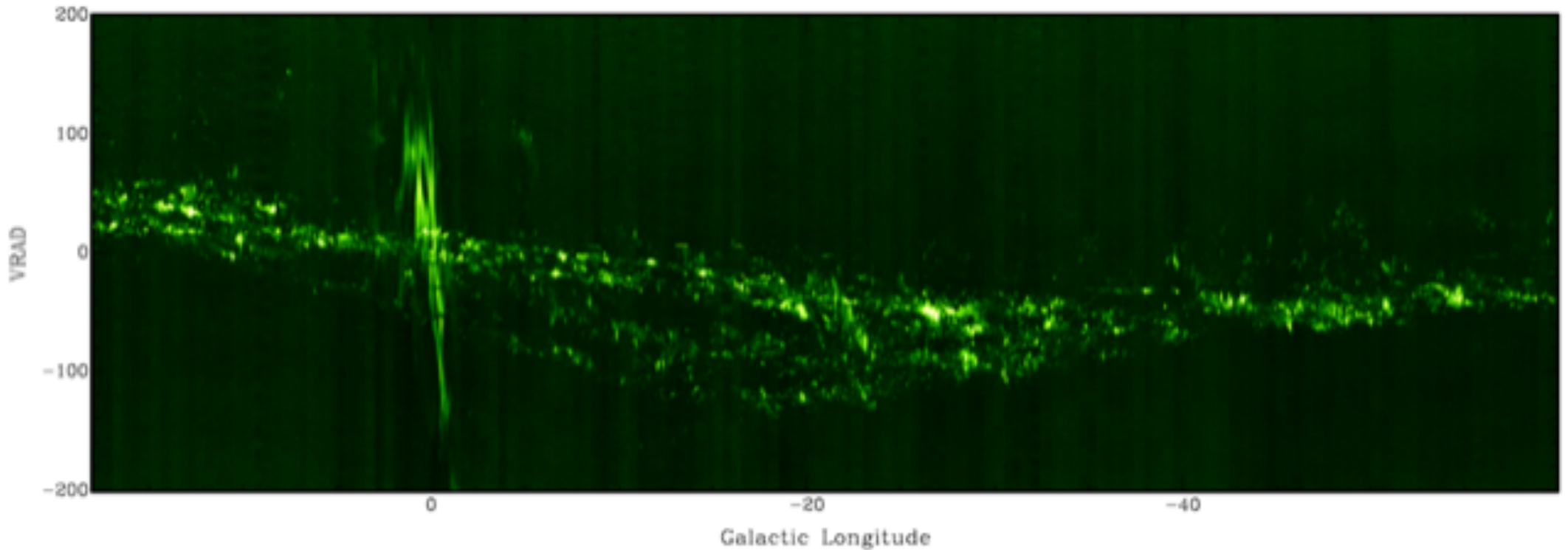# CO Galactic Plane Surveys

Graphic courtesy of Dario Colombo

CHIMPS & CHIMPS2 - David Eden's talk
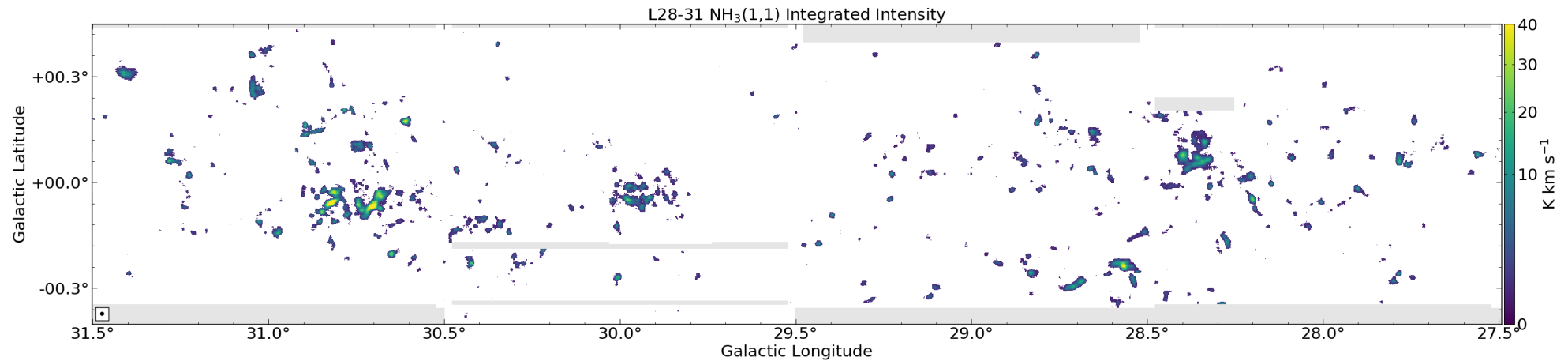
CHaMP - Peter Barnes' talk

SEDIGISM

Structure, excitation, dynamics of the Inner Galactic ISM

APEX ^{13}CO J=2-1 (+ $C^{18}O$ J=2-1) over $-60 \leq l \leq 18$, $|b| < 0.5$

28" resolution, T_{mb}(rms) ~ 0.8K in 0.25 km/s channel

RAMPS

L28-31 NH$_3$(1,1) Integrated Intensity
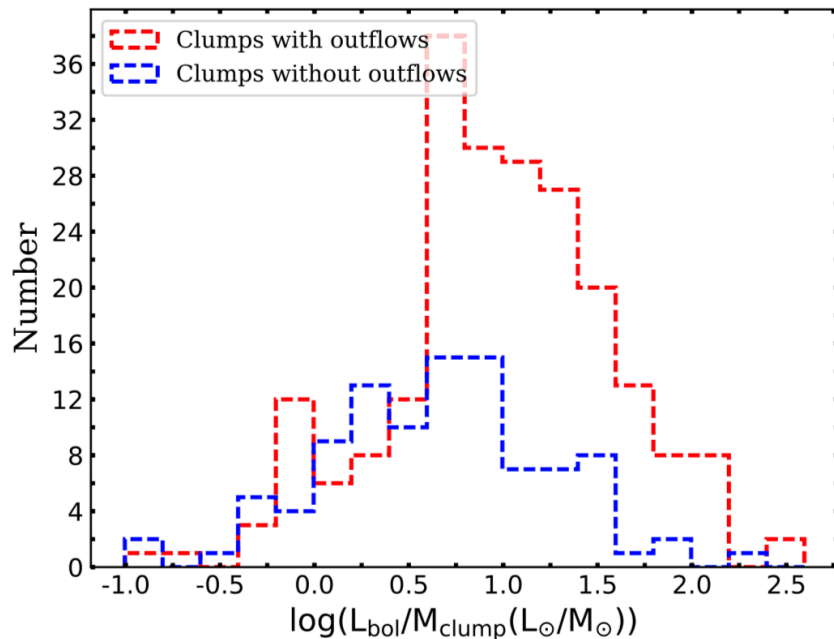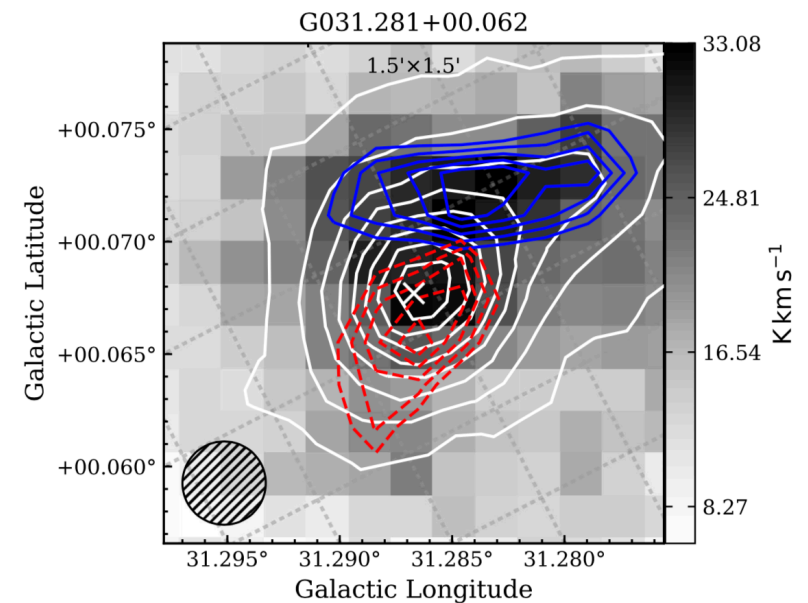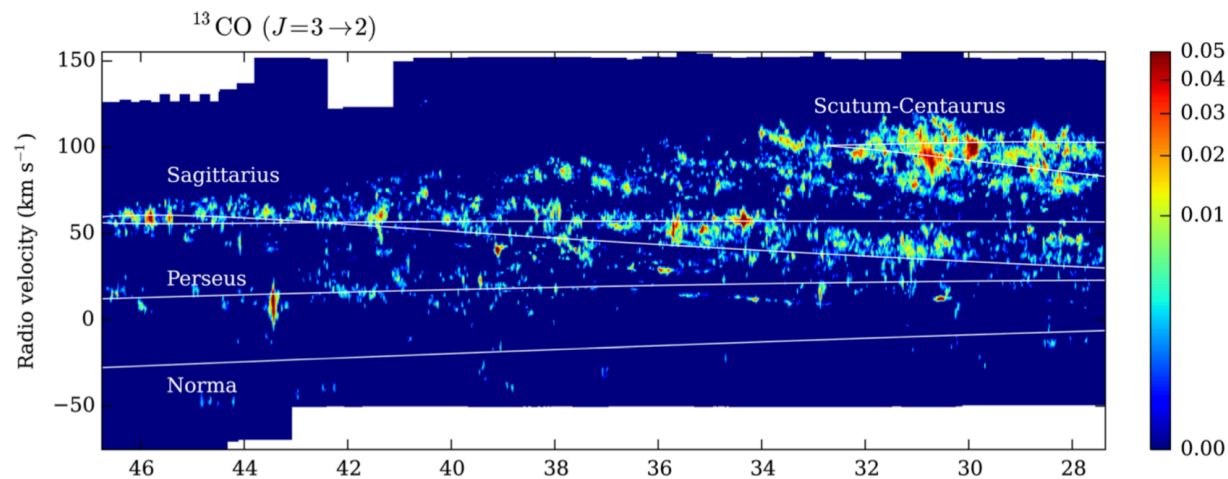
NH3 (1,1) to (5,5) blind survey using K-band FPA on GBT

Pilot regions completed - eventual aim to map 10 ≤ l ≤ 40, |b| < 0.4

Data available soon - intention to make future data public after QA

Hogge et al (2018, accepted)

http://sites.bu.edu/ramps/
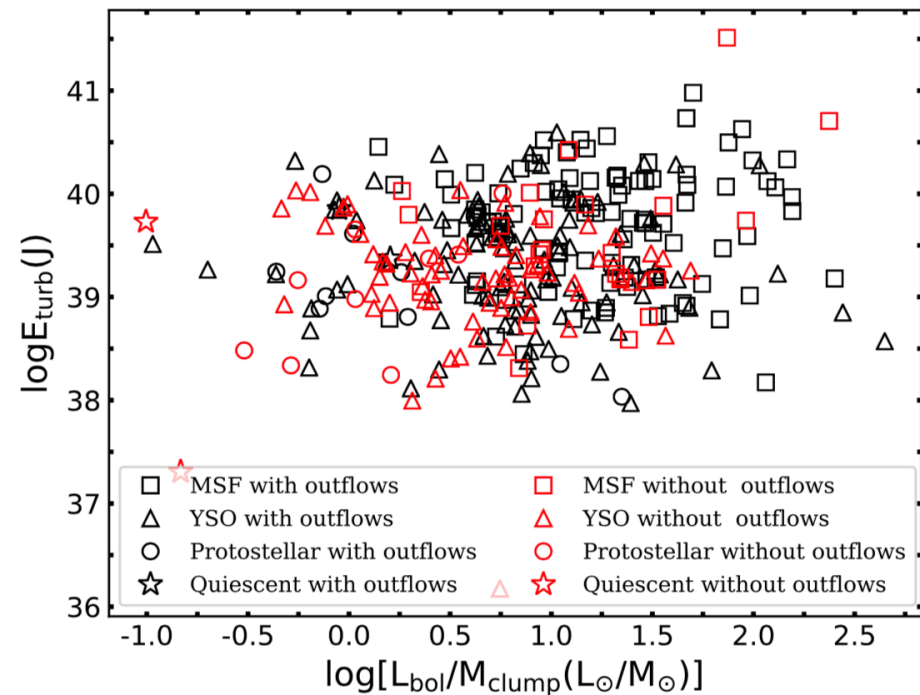
CHIMPS+ATLASGAL data fusion : Outflows

Sample of 325 ATLASGAL clumps in CHIMPS field

225 of these clumps host outflows

Higher frequency towards more massive, luminous and higher L/M clumps

A. Yang et al 2018

CHIMPS+ATLASGAL: Outflows
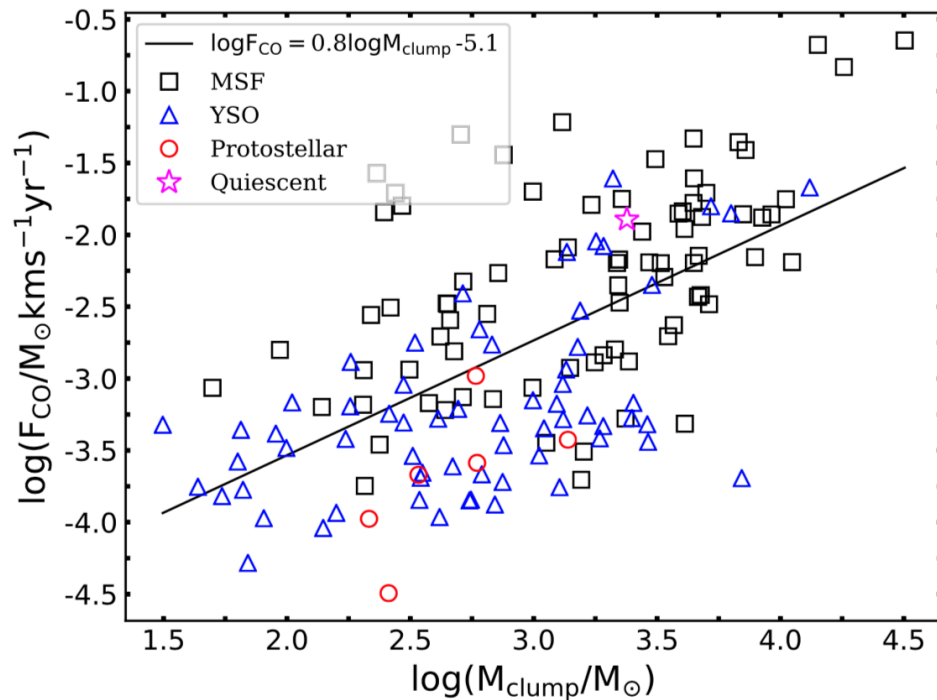
More powerful outflows found in more massive clumps with more evolved central sources

No visible difference in turbulence between clumps with and without outflows

Suggests outflows not major source of turbulence

A. Yang et al 2018

Interferometric surveys

ALMA

(ng/J)VLA

MeerKAT/SKA-1

NOEMA
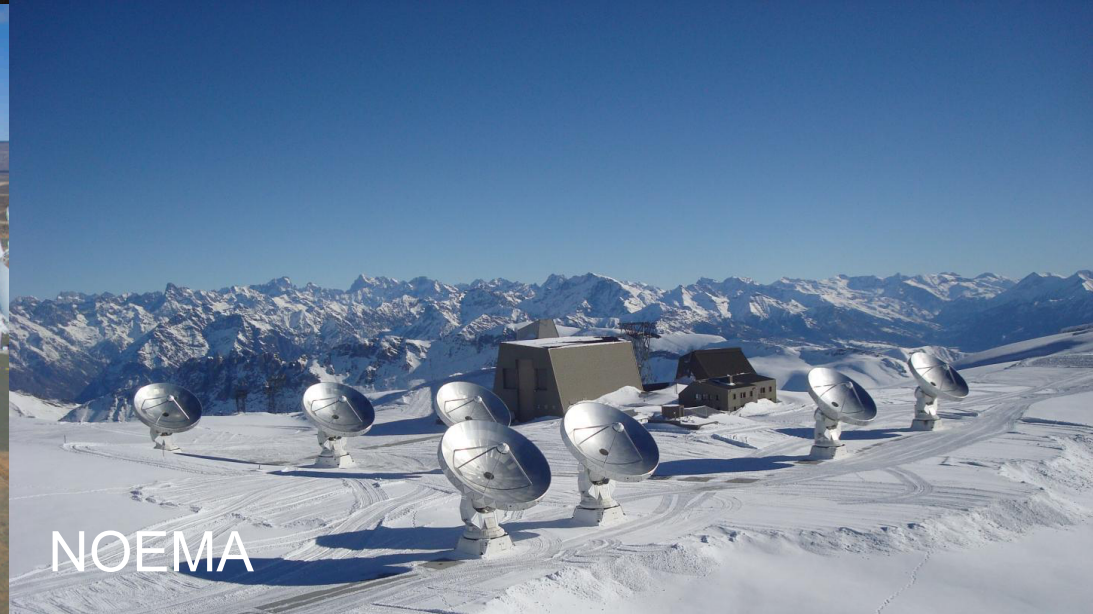
Orion Radio All Stars

Forbrich et al. (2016)
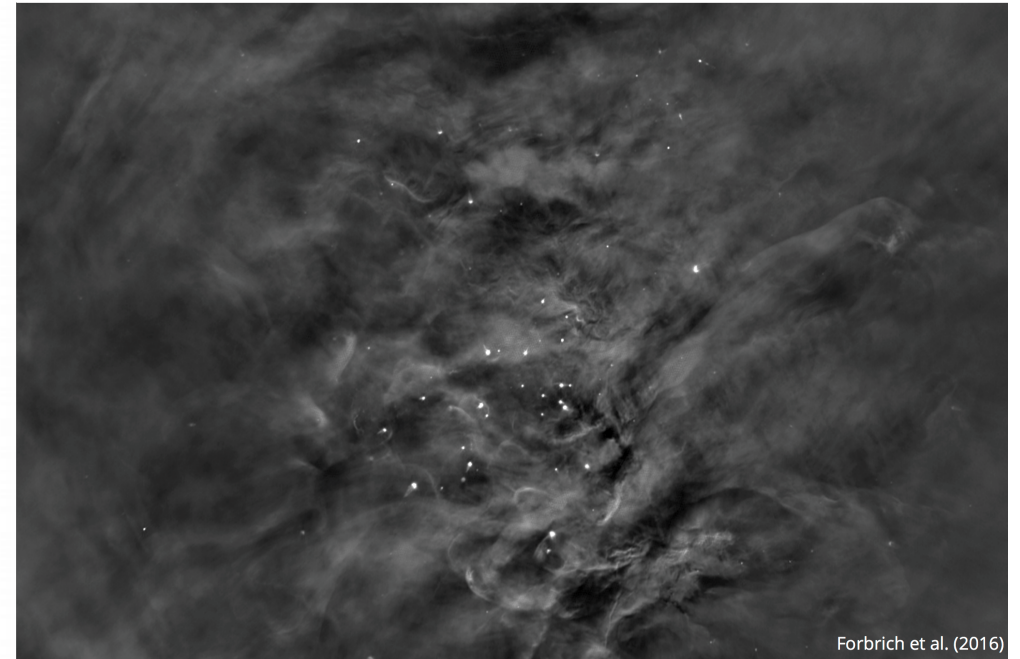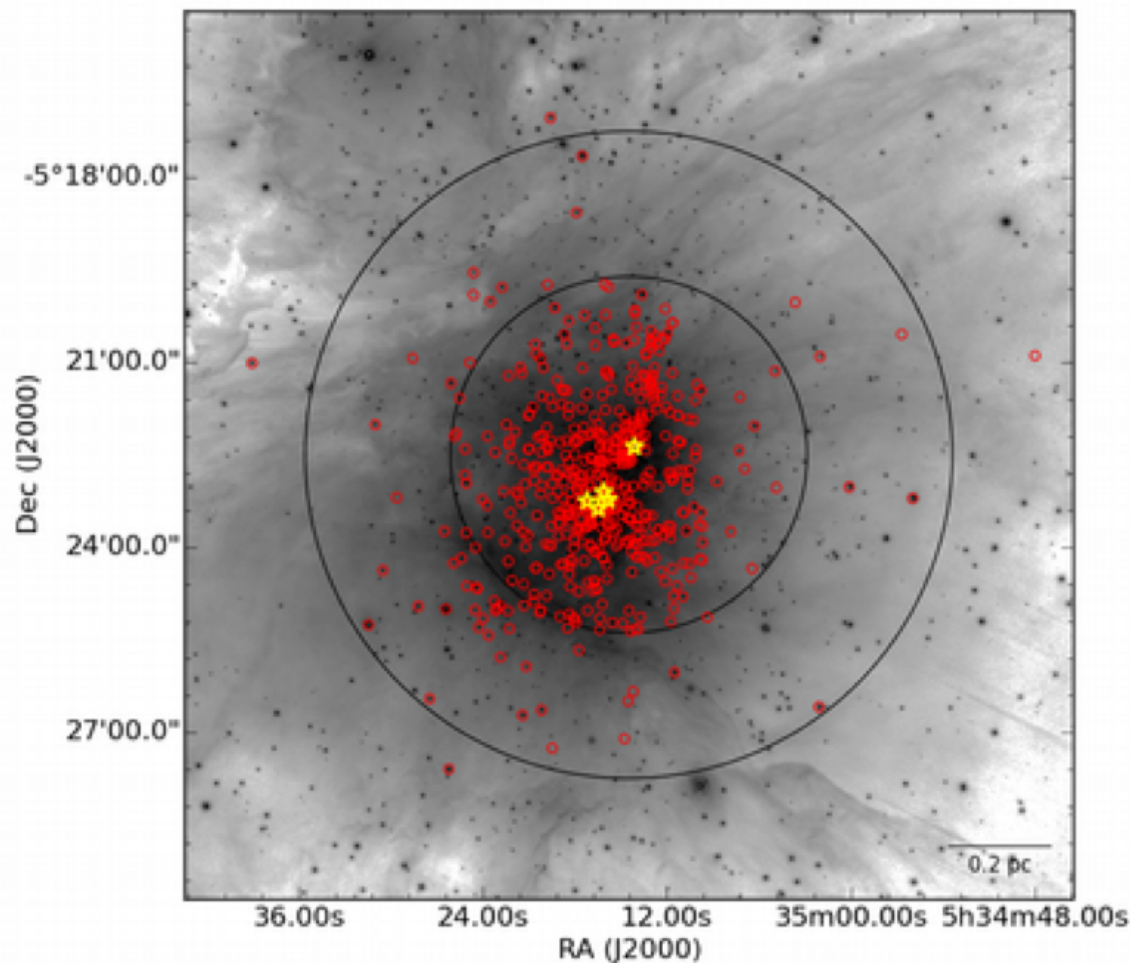
JVLA multi-epoch census of radio stars in Orion

Follow up multi epoch VLBA astrometry
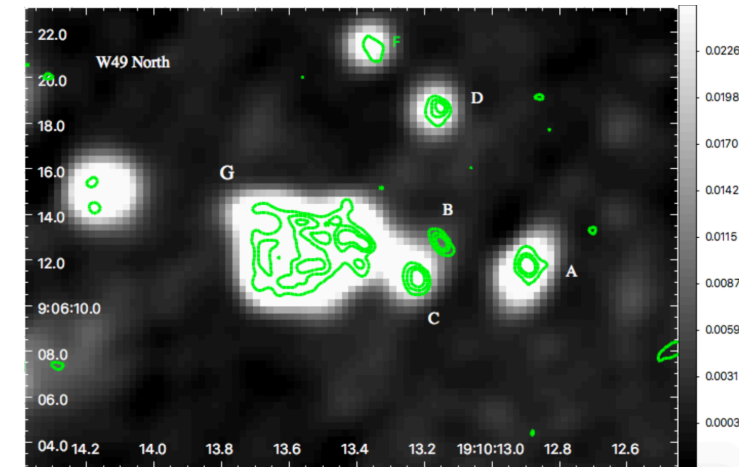
Proper motions to 0.1 km/s

Largest ever VLBA dataset

Hints to routine SKA cluster studies

Radio continuum surveys: young HII regions
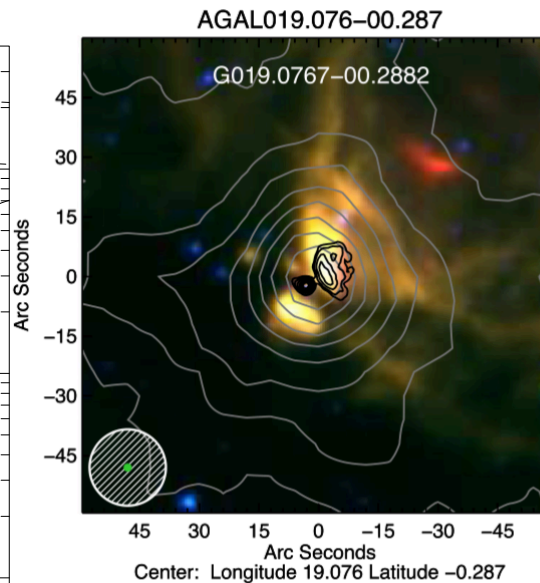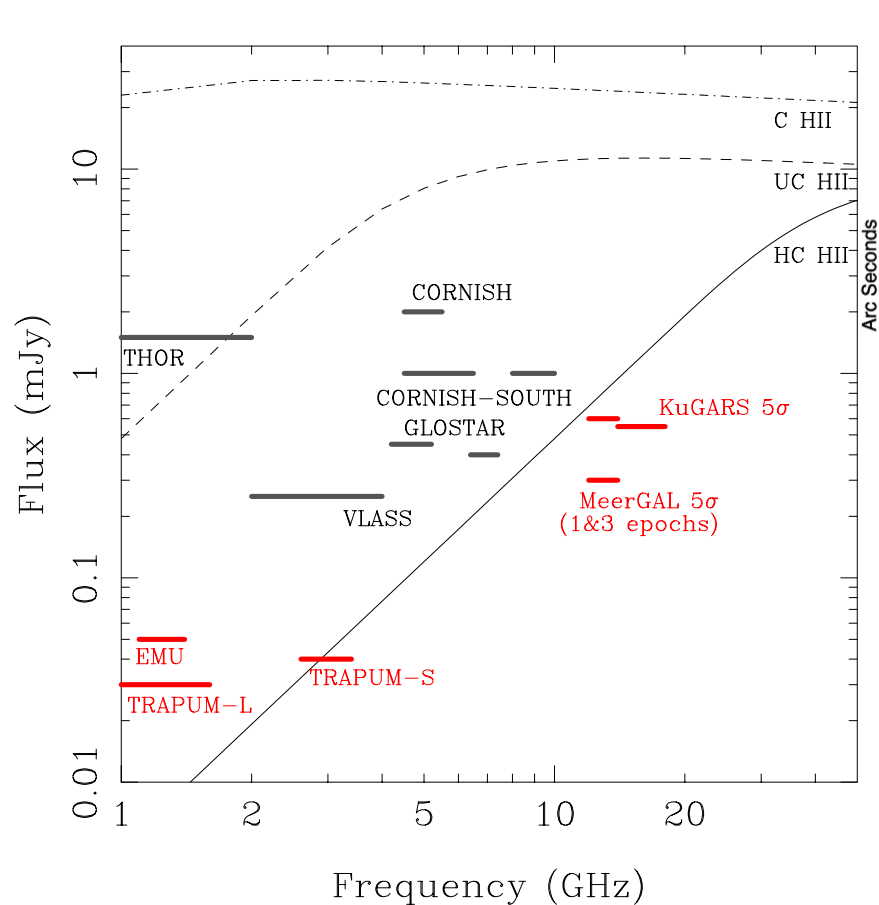
HRDS: classical HII regions (Loren's talk)

~500 young C/UC HII regions ~10^5 years identified using CORNISH/archival data (e.g. Djordjevic+ 2018 in prep, Kalcheva+ 2018, Urquhart+ 2013, …)

HC HII search in Ku band - KuGARS (Mutale et al in prep)

HI & recombination lines: THOR

THOR RRL + 8 µm

Beuther+ 2016
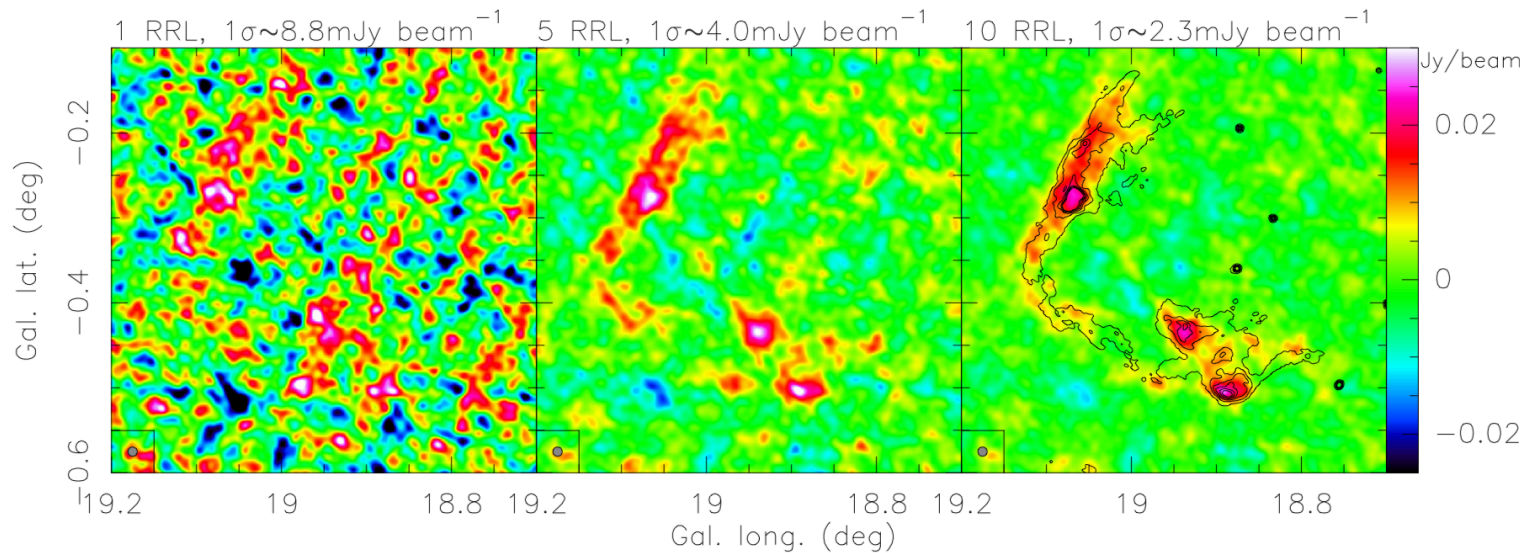
Shows power of broadband RRL spectroscopy

Recombination lines: SKA

MAGPIS 20 cm
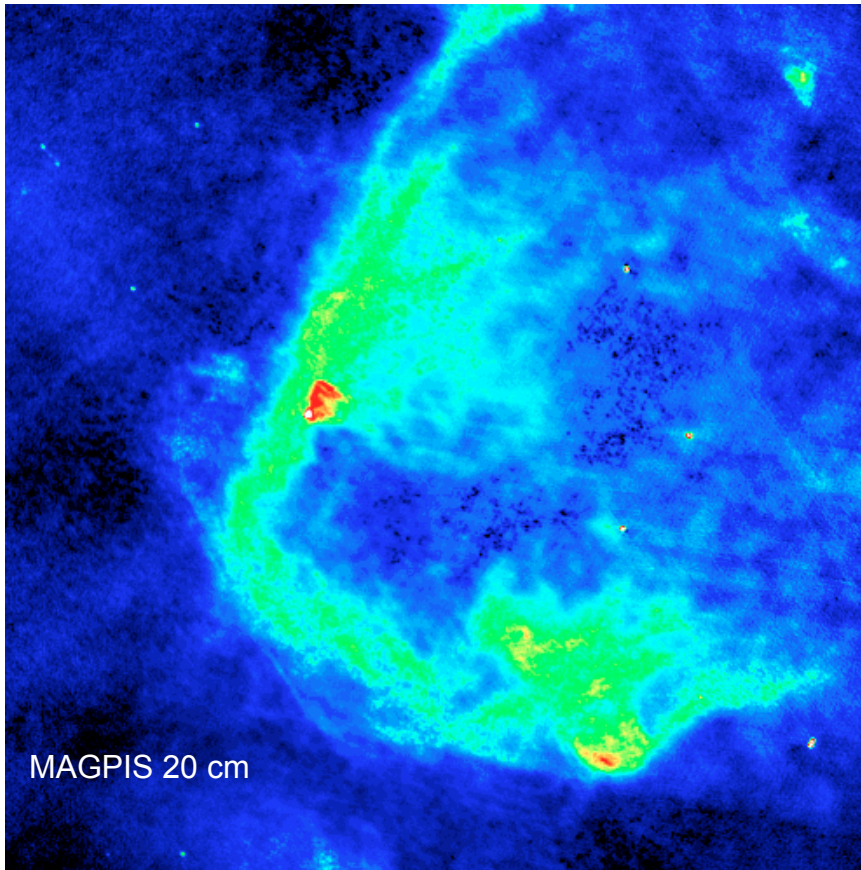
SKA will be a recombination line mapping machine:

Can simultaneously map 50 Hα (+ Heα + Cα RRLs) in Band 2 and 25 in Band 5 using "continuum" mode
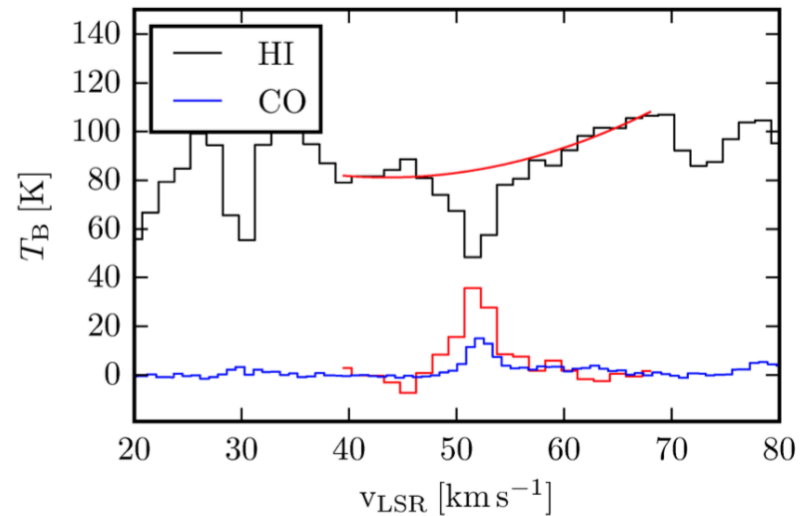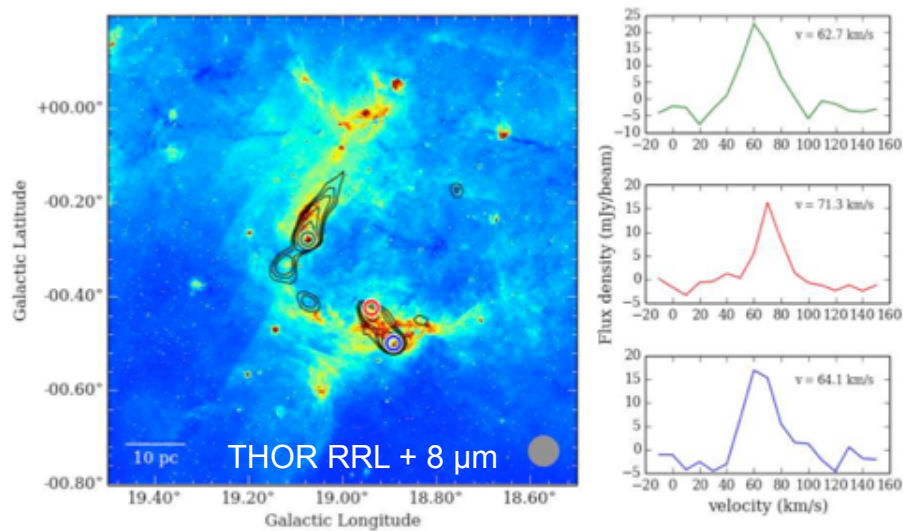
Band 2 **RRL** mapping speed of SKA1-mid comparable to VLA (not JVLA!) *continuum* mapping speed

SKA-Low unique probe of diffuse ISM via low frequency Carbon lines

Broad frequency coverage traces different electron densities

Multiple lines from multiple atoms allows metallicity, abundance, radiation field to be measured

Molecular gas with H₂CO absorption

ALMA
band 6
(traces T_{kin})

SKA
band 5a/5b
(traces n_{H_2})
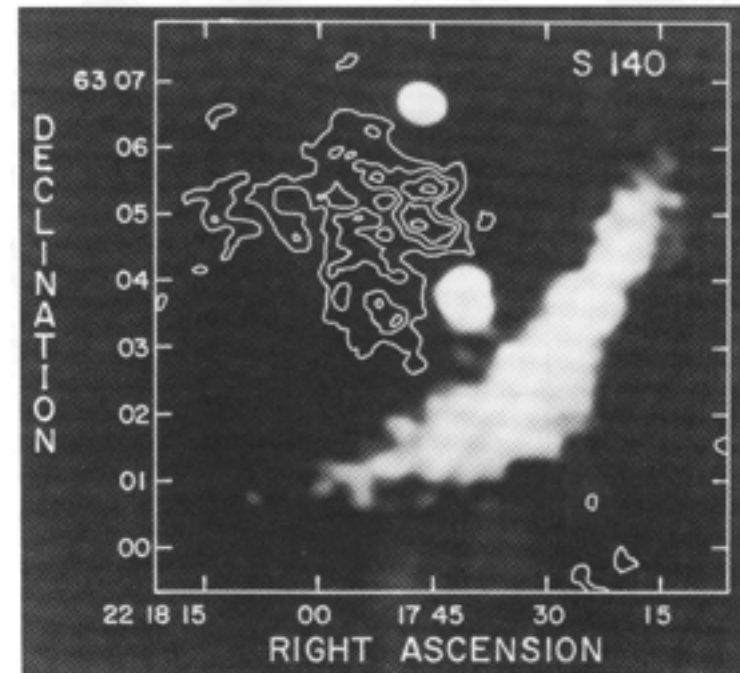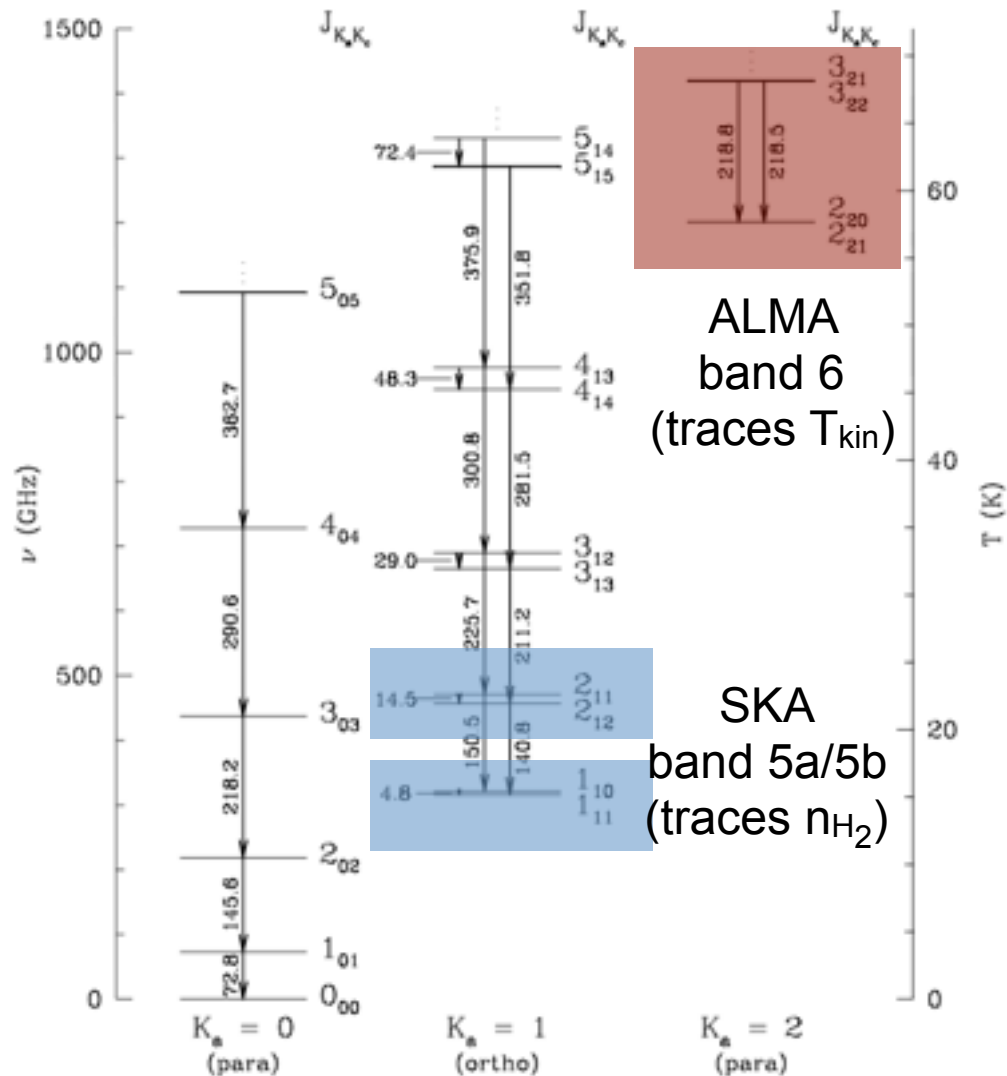
Evans et al 1987
First VLA detection

Collisional pumping drives population to lower energy states (anti-inversion)

Shows up in absorption against CMB when $T_{ex} < T_{CMB}$

Advantages of anomalous absorption

1. Distance independent tracer
   The Milky Way, nearby galaxies,
   starbursts... (Mangum et al 2013)

2. Excellent and unique tracer of gas *density*
   Line ratio between 4.8 GHz & 14.4 GHz
   fixes gas density to ~0.2 dex with good
   dynamic range: 10^3 - 10^6 cm^{-3}
   (Ginsburg et al 2011)

3. Unaffected by line trapping, sub-thermal
   excitation or high optical depths
   - unlike CO, where $n(H_2)$ may not be
   constrained within 2 orders of magnitude

4. Removing the scatter in SF "laws"
   e.g. Krumholz 2014
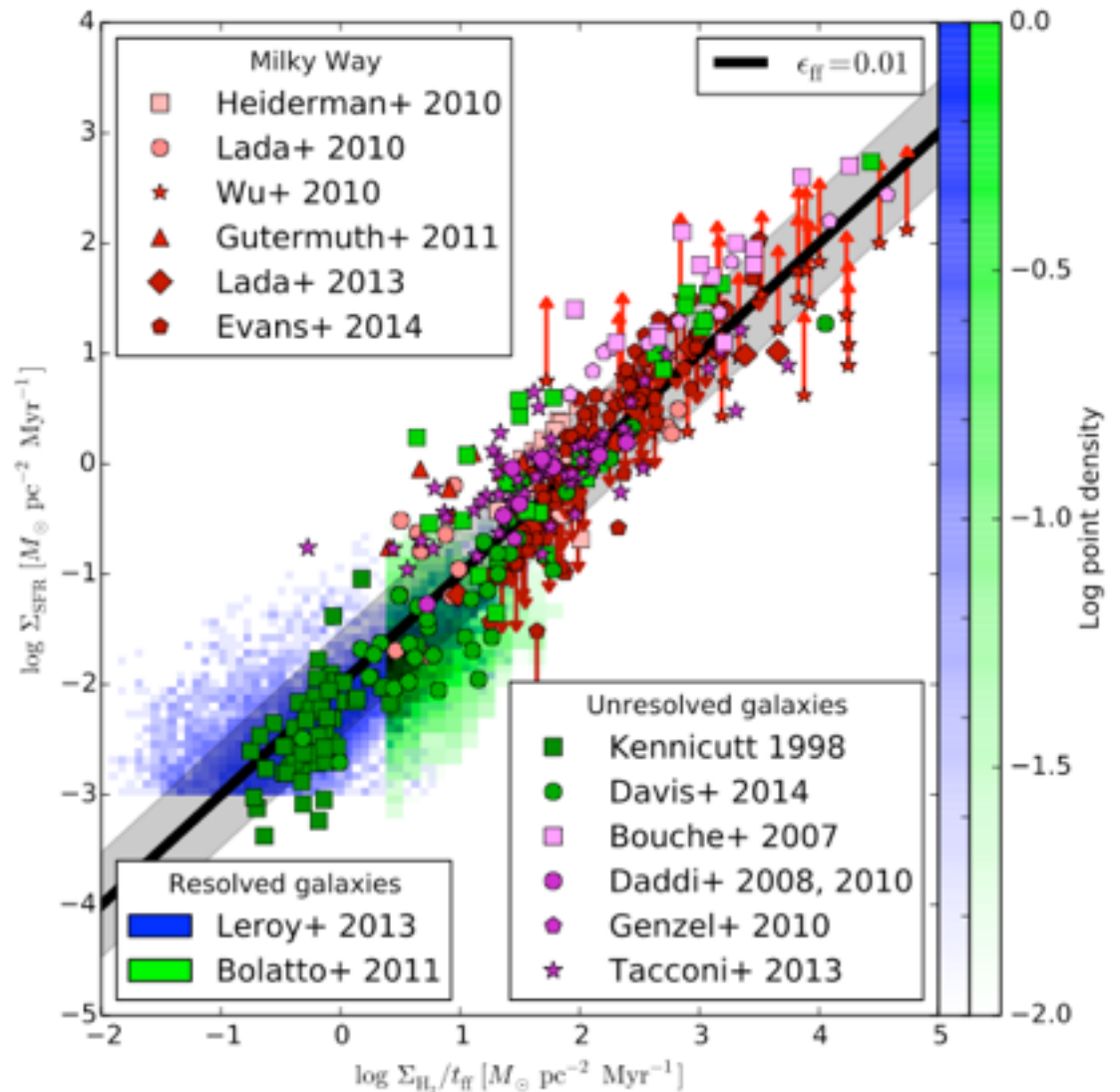
SKA Key Science Projects

~50% of SKA time will be in the form of "Key Science Projects"

KSP ideas currently being formulated by
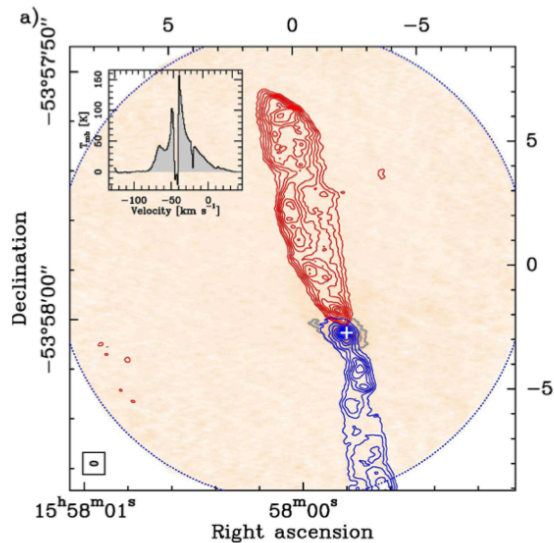Science Working Groups

Star Formation sits in the "Our Galaxy" SWG

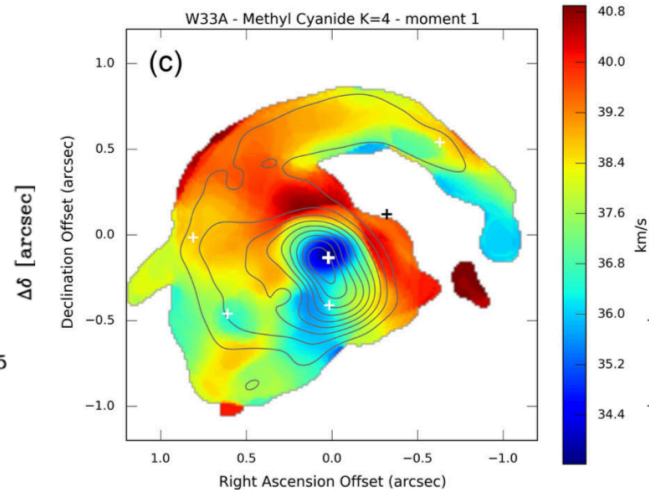 - also links to Continuum, Cradle of Life, Transients, HI, Magnetism SWGs

SWG contacts: Grazia Umana & Erik Rosolowsky

http://astronomers.skatelescope.org/science-working-groups/milky-way/

Is ALMA a survey machine?

Csengeri+ 2016

W33A - Methyl Cyanide K=4 - moment 1

Maud+ 2017

Routine sub-arcsec imaging now available from ALMA

Excellent "finder charts" from ATLASGAL/Hi-GAL (e.g. Urquhart+ 2018)

Many ALMA "mini surveys" of massive star forming cores: ALMA-IMF, Csengeri (SPARKS), Pillai, Avison samples…

But…   Heterogenous observations + many selection functions at play
        (ALMA-IMF perhaps most uniform selection- see Frederique's talk)

Are we ready for large-scale surveys with ALMA?

If SMA is looking for "Large Scale" programs why not ACA?

Summary

Incredibly rich set of survey data spanning decades in wavelength and angular resolution

Routine multi wavelength photometry of MSF regions

Single-dish continuum surveys are probably done

Rise of spectroscopic surveys from CO to dense gas

Data fusion is key to get the most out of things

Interferometry is the next survey direction (in my view)

Upcoming large project opportunities:

- NRAO X-proposals (>1000 hours)

- SMA Large Scale Science Projects (100-1000 hours)

- SKA-1 Key Science Projects