A Cosmic History of Molecular Gas (with Intensity Mapping)

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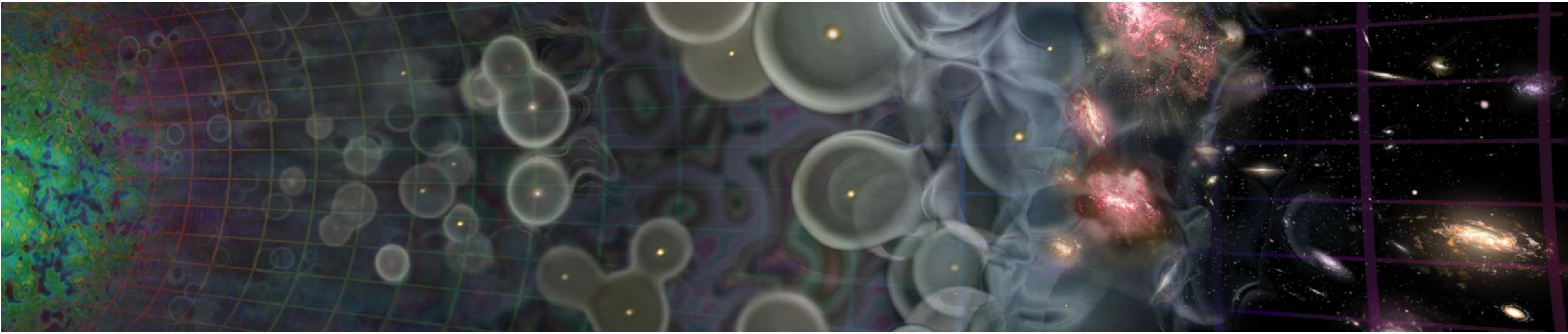
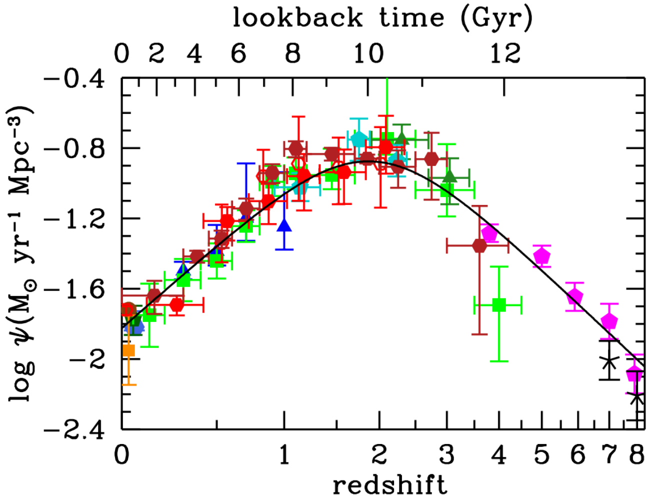
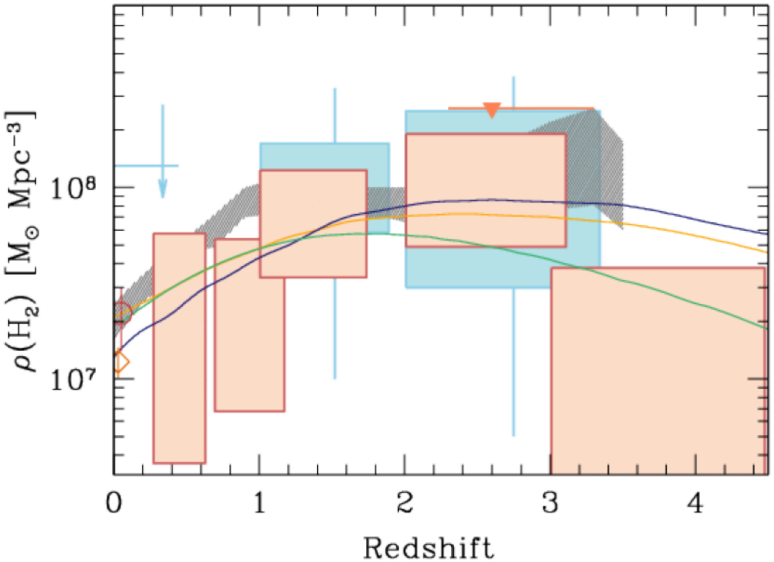
SMA External Advisory Meeting
July 17th, 2018

Exploring the Early Universe



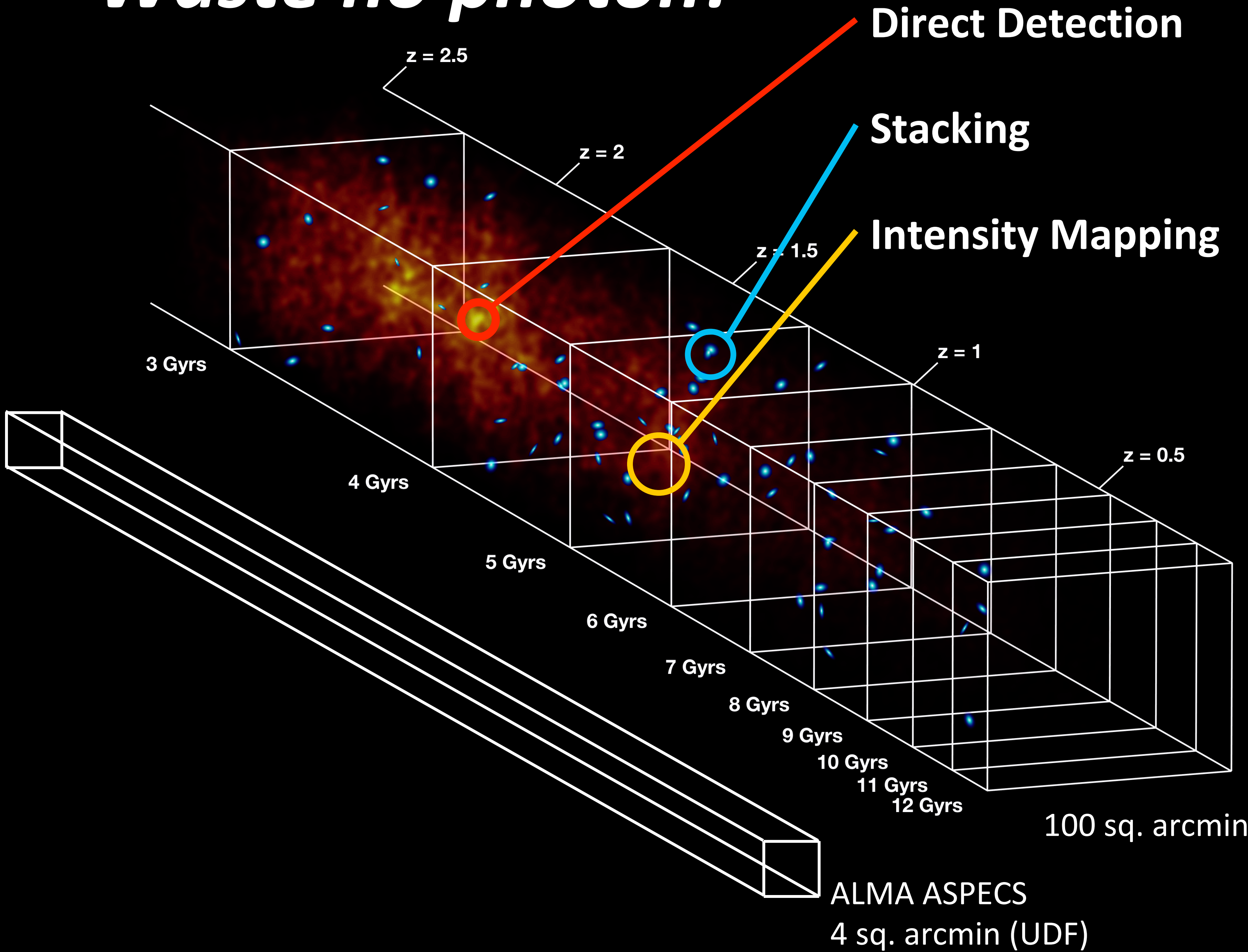


Madau and Dickinson, 2014



Decarli et al. 2016

Waste no photon!



Other Benefits of Large Volumes

Understanding the complexity of molecular gas

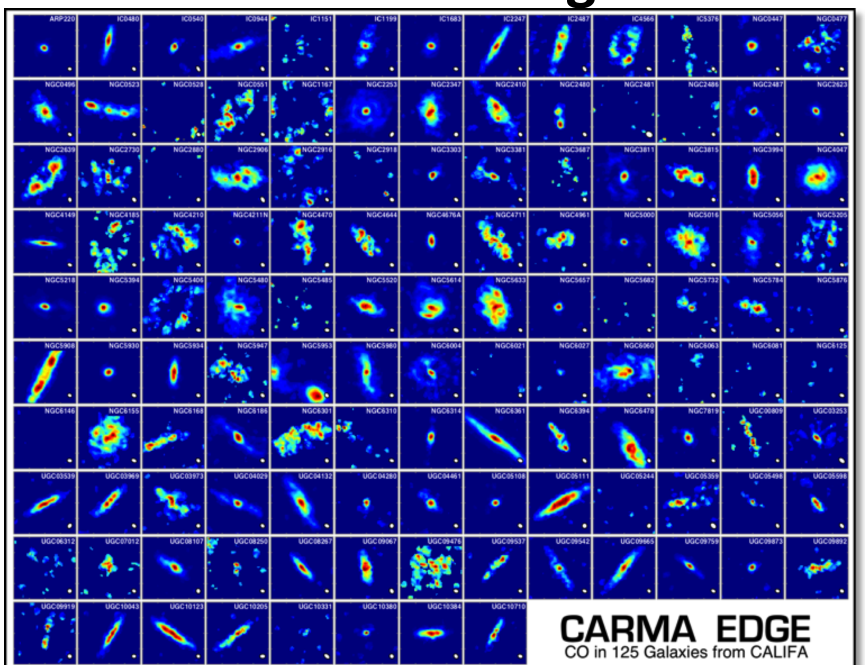
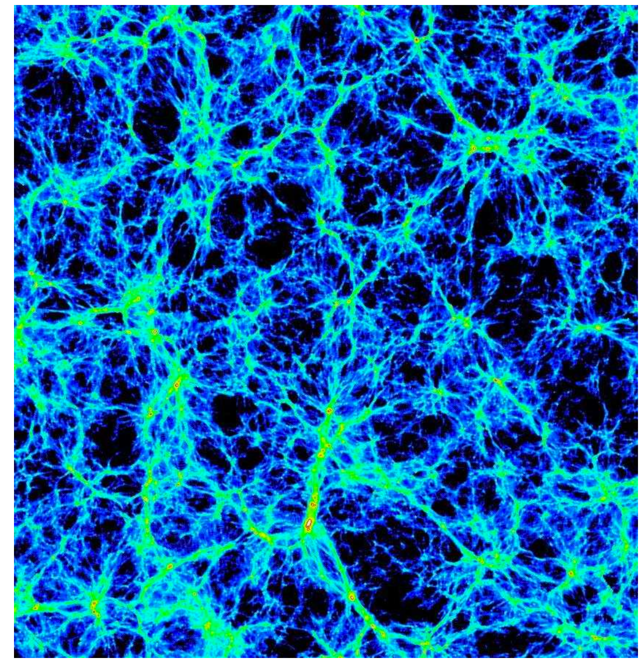


Image Credit: Alberto Bolatto

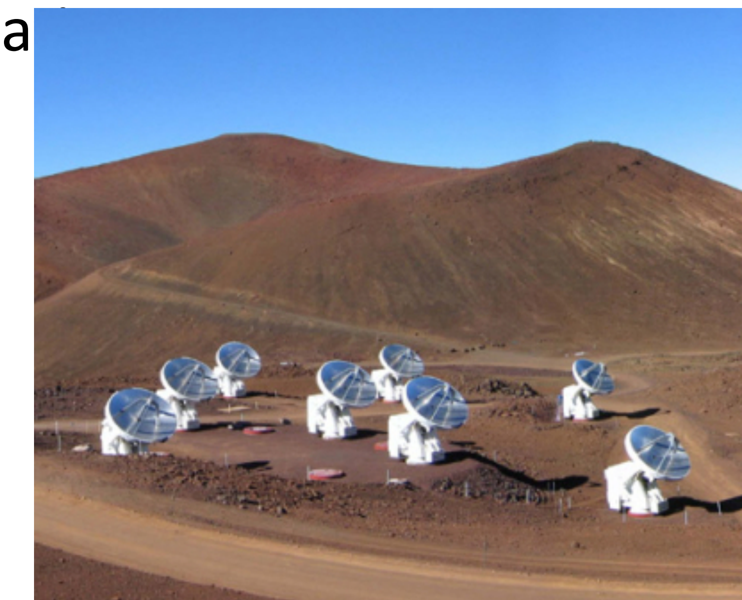
Cosmological applications at high redshift



A wealth of existing and upcoming high-redshift extragalactic data

Defining an optimal instrument

- Frequency coverage between ~ 1 cm and sub-mm
- Moderate spatial resolution (1”-3”)
- Moderate spectral resolution (< 300 km/s)
- Good survey speed ($\propto N_{beam} [N_{ant} D_{ant} / T_{sys}]^2 B$)
- Good amount of integration time
- Good control over systema
- Large FoV + bandwidth



SMA suited for conducting large-volume surveys, particularly in the wSMA age (and beyond)

Defining an optimal instrument

+ ★ *2-mm(+3-mm?) or 490 GHz guest instrument*

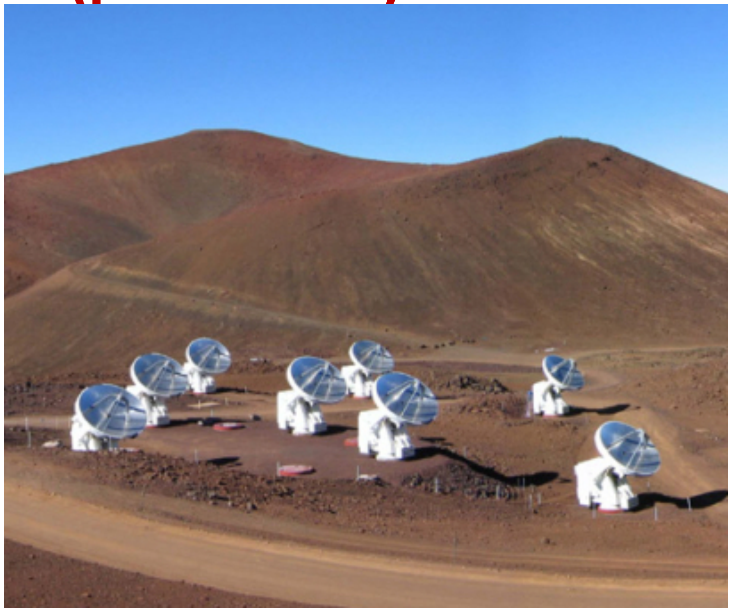
+ ★★ **wSMA receiver + correlator upgrades + *multi-beam***

+ ★ **OTF + total power measurements, expanding hours**

+ ★ **Ongoing hardware upgrades (pre-wSMA)**

+ ★ **wSMA + *multi-beam***

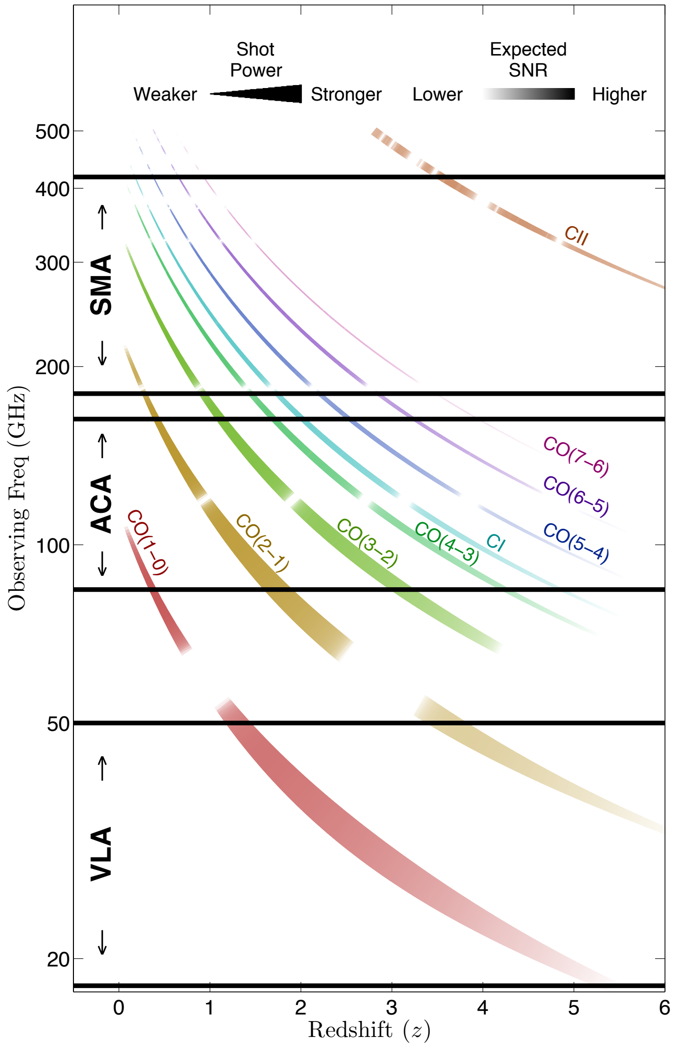
SMA suited for conducting large-volume surveys, particularly in the wSMA age (and beyond)

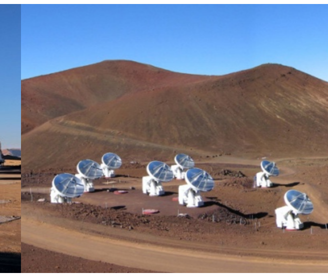


CO/[CII] Intensity Mapping

The Millimeter Intensity Mapping Experiment (mmIME):

"It only looks like there's nothing there"





VLA (1cm) **ACA/ALMA (3mm)** **SMA (1mm)**

VLA, ACA and SMA are **well-suited** for intensity mapping cross-correlation studies!

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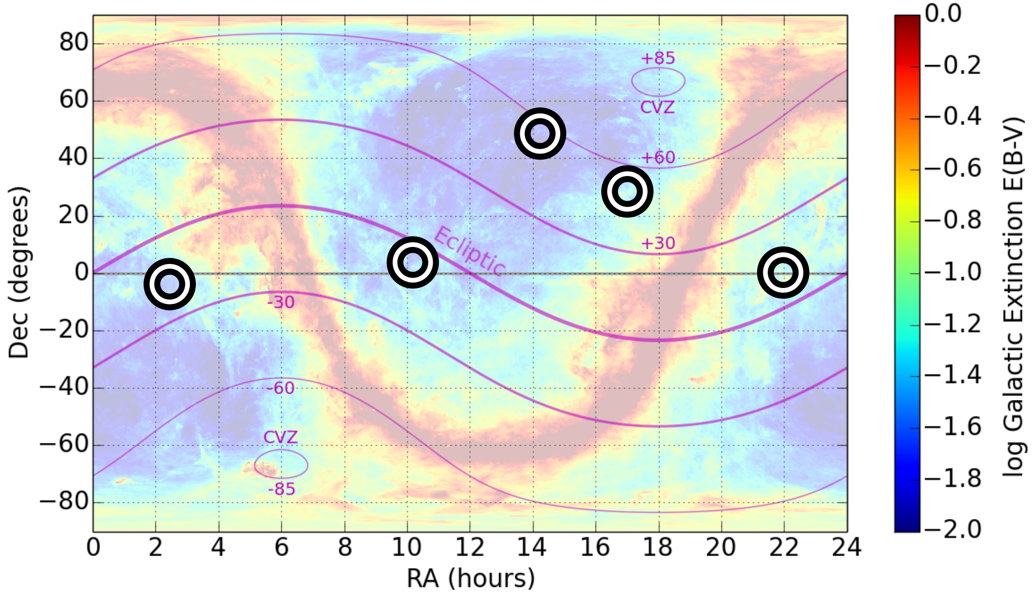
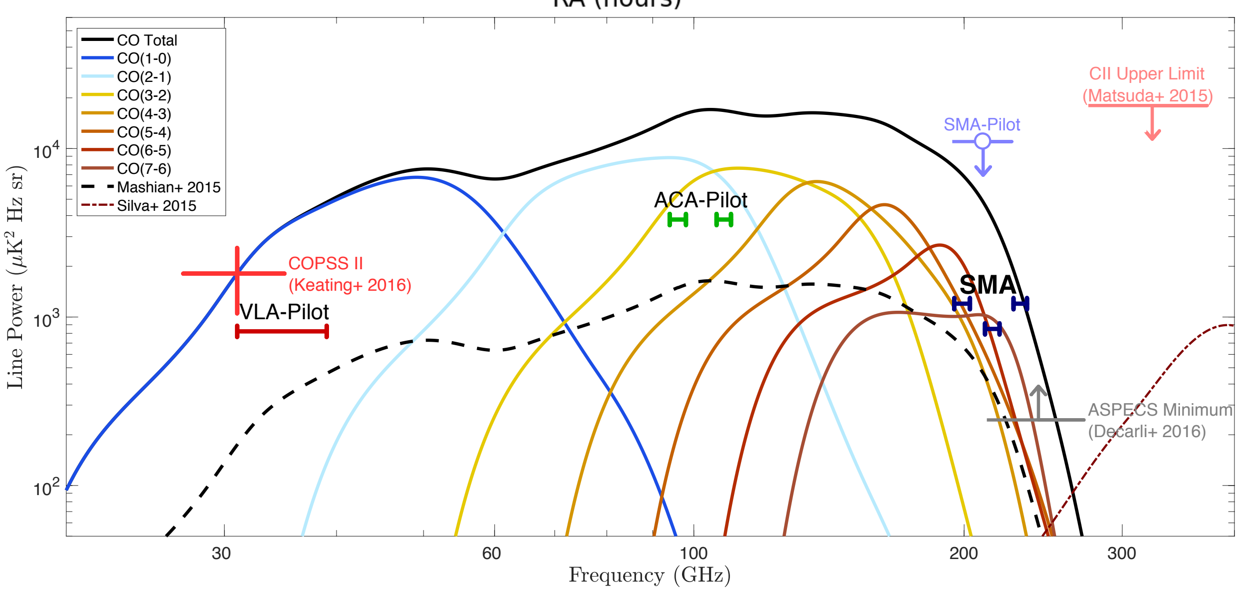
Natalie Mashian (CfA)
Dan Marrone (Arizona)
Wei-Hao Wang (ASIAA)

mmIME Survey Targets



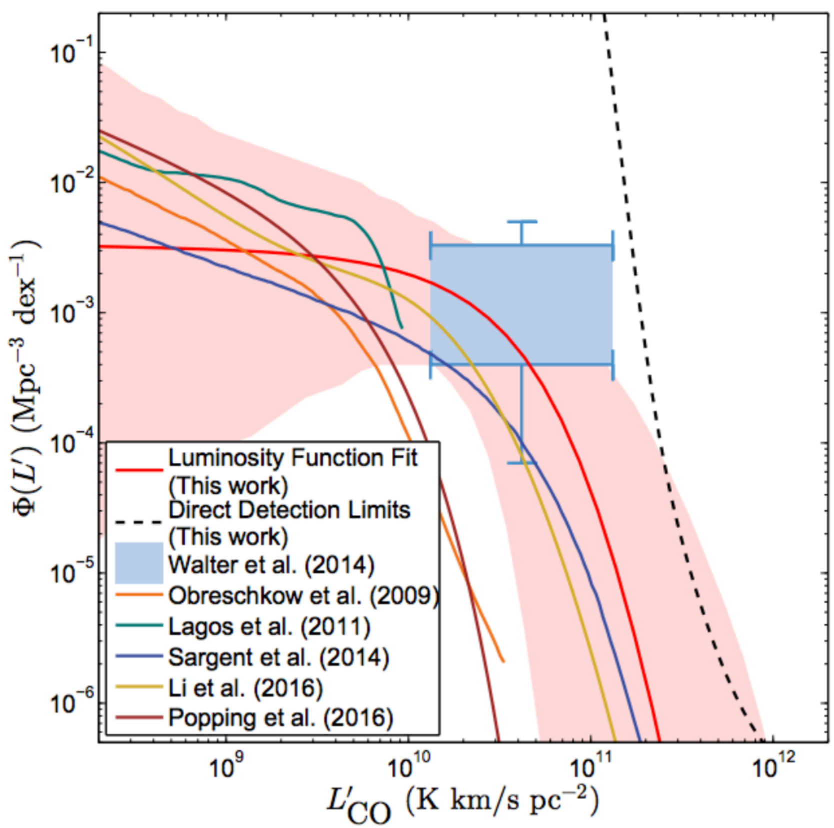


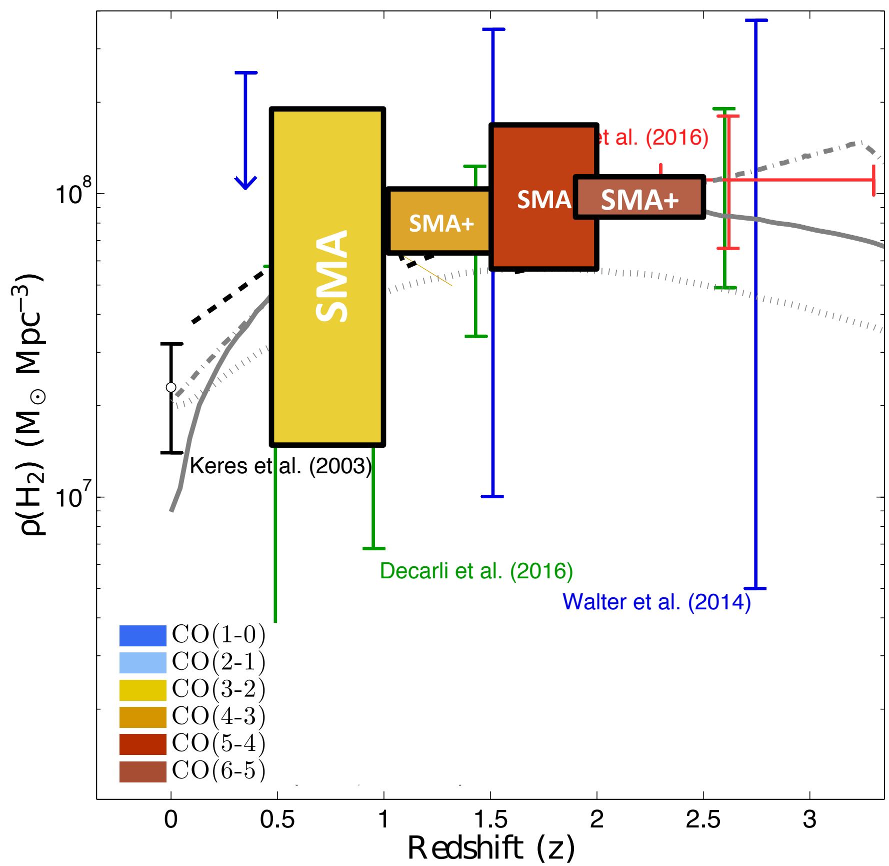
Stage I:

- Appx. 600 hours (continuous)
- 5 targets (SXDS, COSMOS, AEGIS, VIPERS, DEEP2)
- 192-242 GHz*
- 100 sq. arcmin
- ~0.5 mJy continuum detection
- ~3 Jy km/sec line detection
- Power sensitivity of $6\times10^{2}\ \mu K^{2}\ \mathrm{Hz\ sr}$

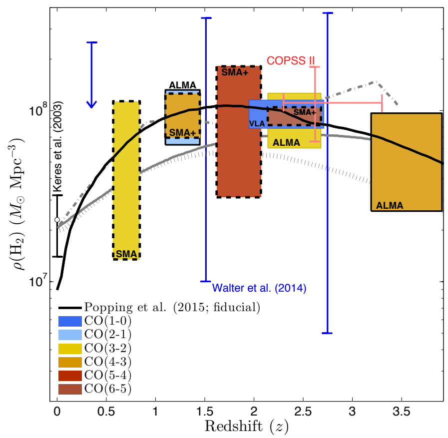
Cosmic Molecular Gas

Keating et al., 2016

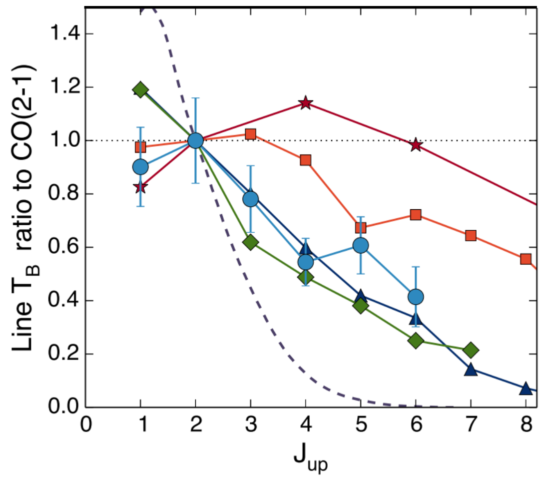




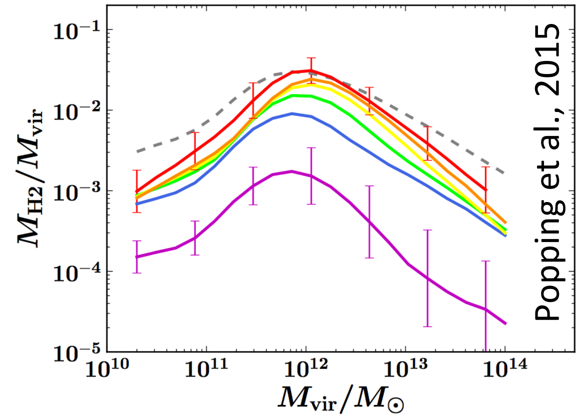
Science Goals with mmIME



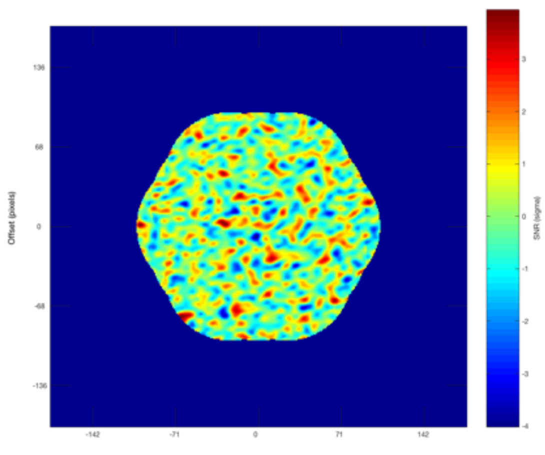
Cosmic molecular gas abundance



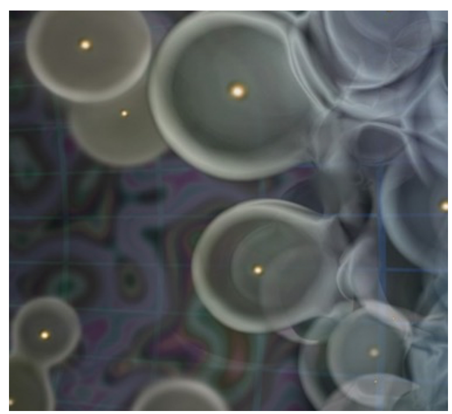
Physical conditions of high-z molecular gas



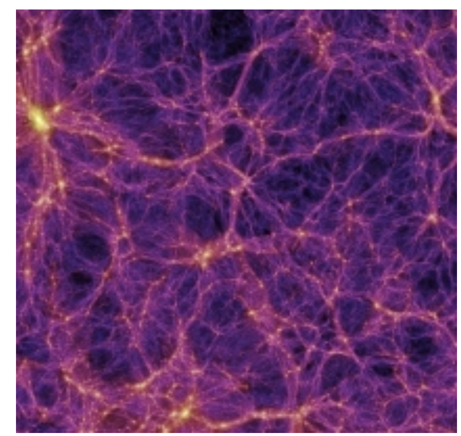
Feedback/quenching at high redshift



Resolving sources in the sub-mm sky



Probing galaxies in the epoch of reionization via [CII]



Suitability of cold gas tracers for cosmology

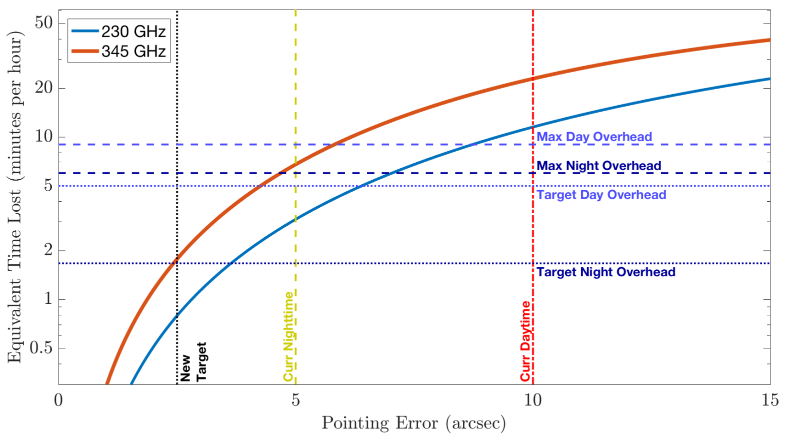
Getting to $\eta_{obs} = 1$

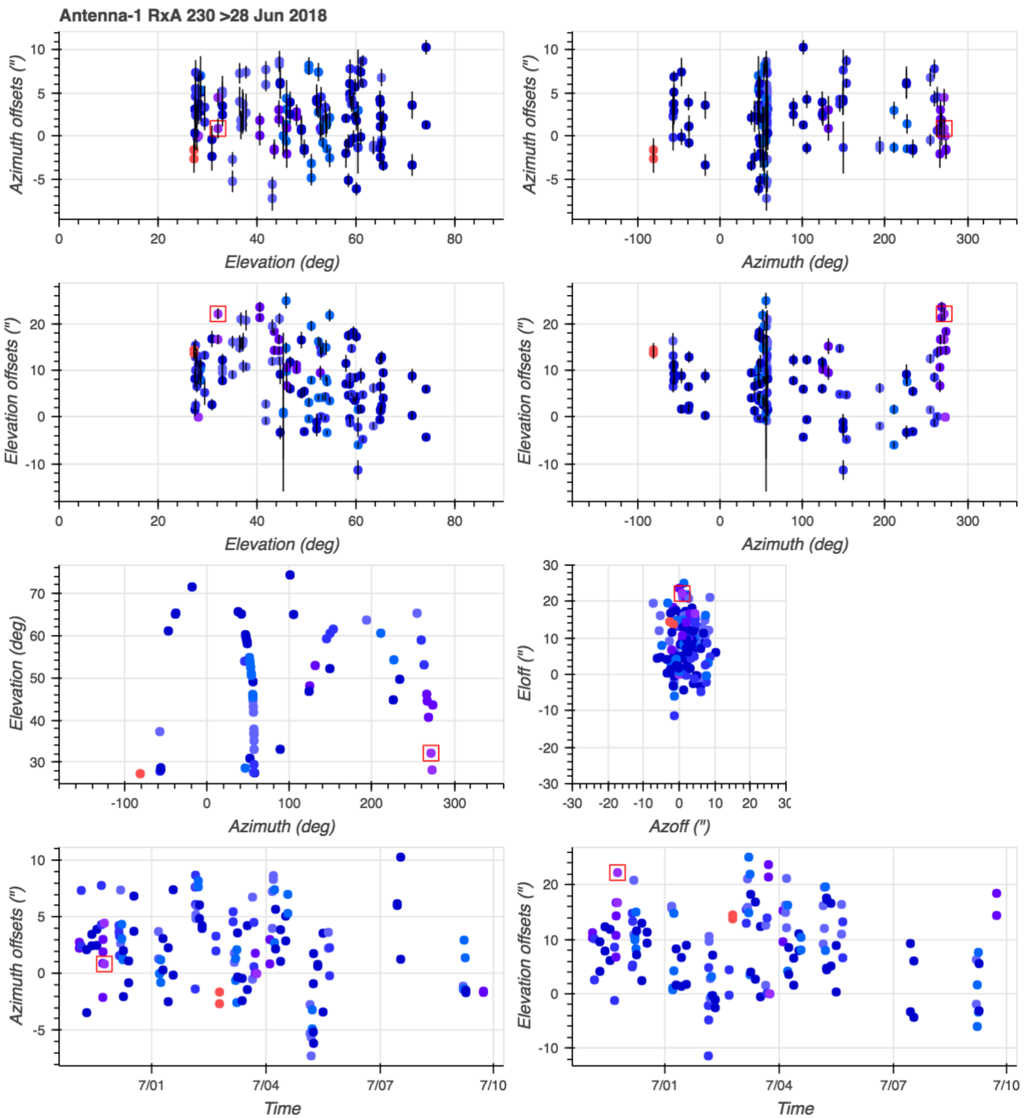
Making large-volume surveys feasible requires high operating efficiency

Improvements can be realized with:

- **Better pointing methods**
- **Methods for dealing with atmospheric phase fluctuations**
- **Better monitoring of array health status**
- Reducing time required for priming/switching projects
- Improving calibration methods (particularly bandpass)
- Reducing observing inefficiencies that cost 1-3 integrations per target switch (can be significant for mosaicking)

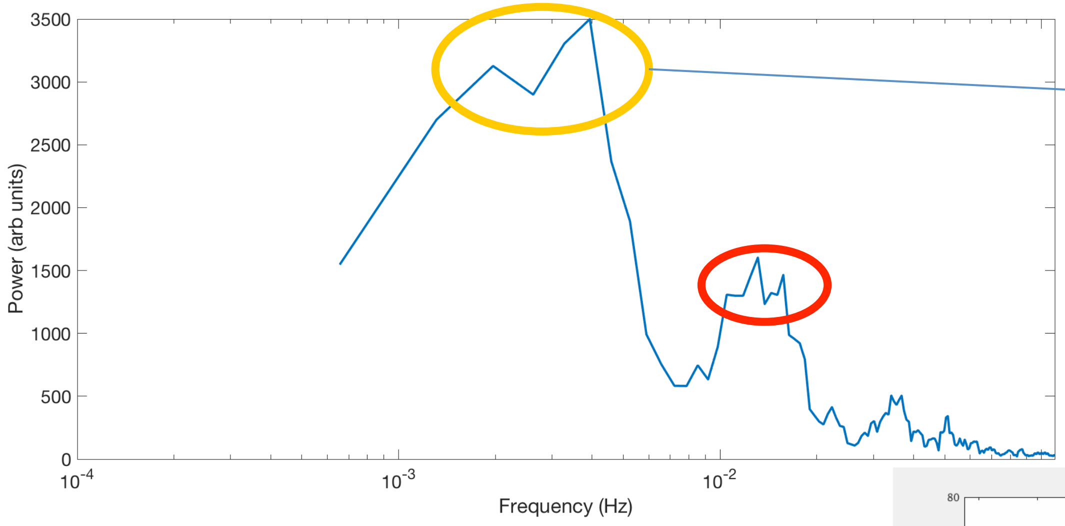
Key Technical Developments





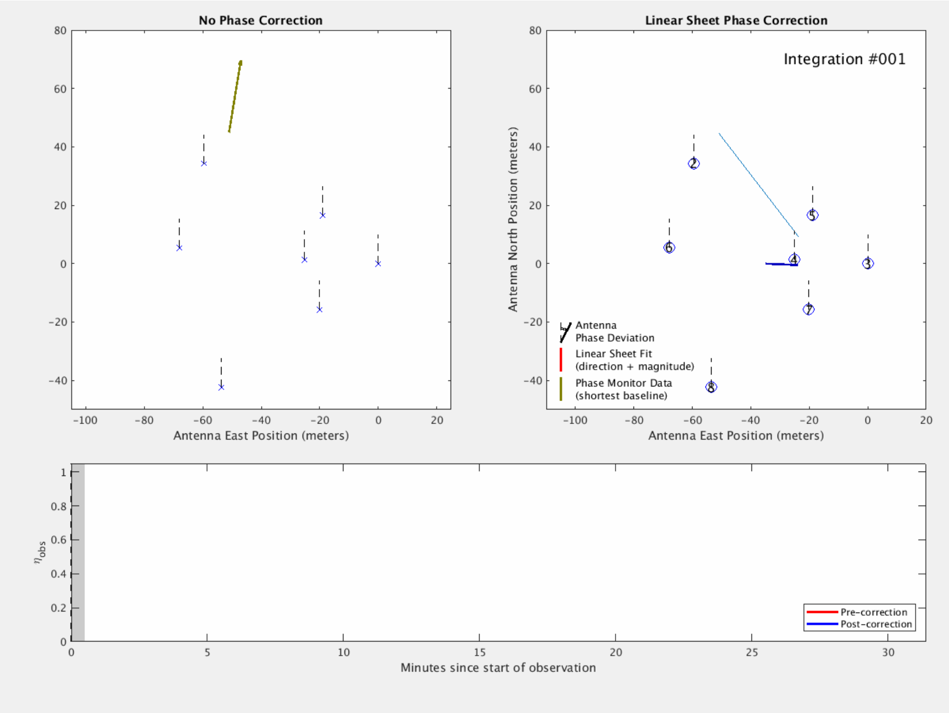
- Faster/more robust interferometric pointing
  - ➢ Dual-Rx
  - ➢ Hex-Pattern
  - ➢ Phase-solving
- Automated Pointing
  - ➢ Running since 5/2018

Key Technical Developments



~6-10 minute timescale

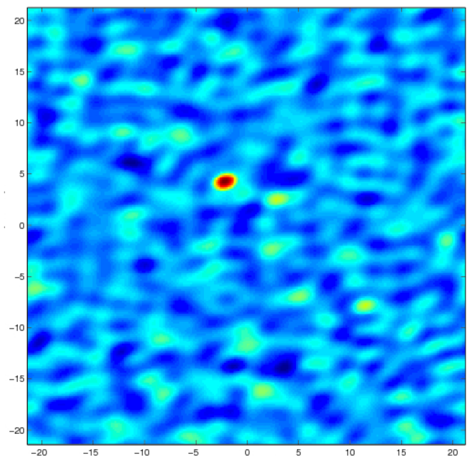
~1 minute timescale

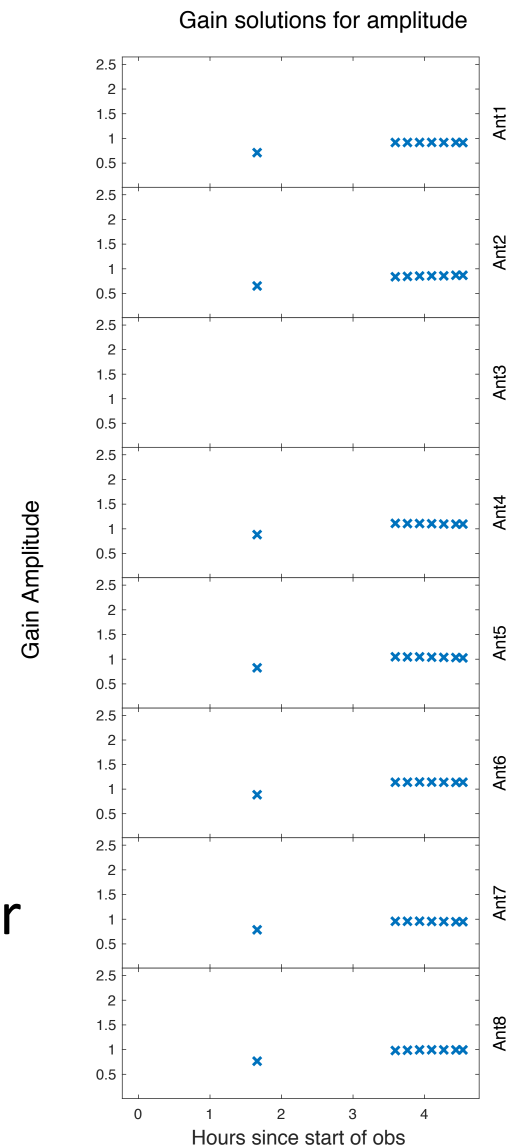


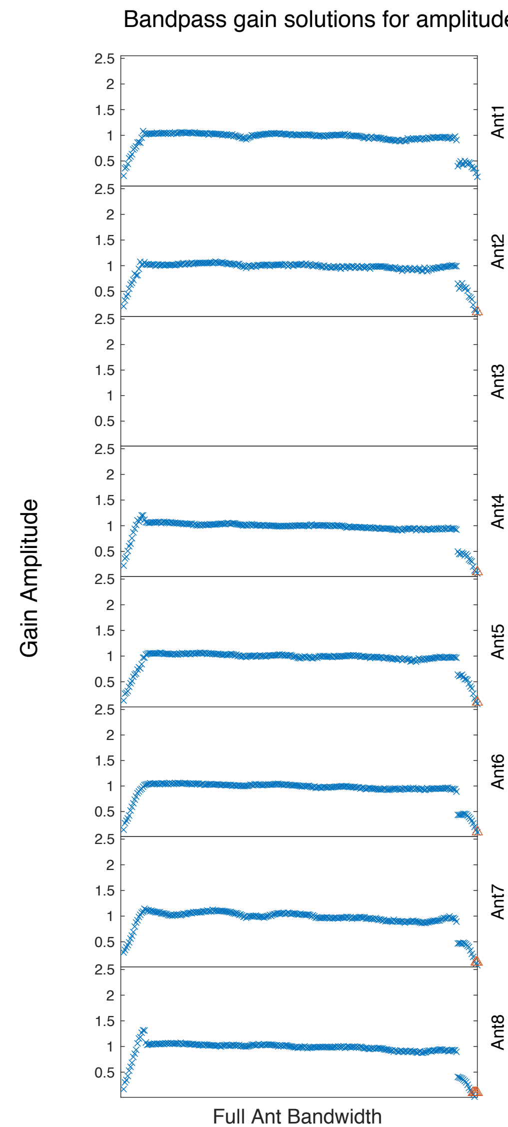
Mitigating phase fluctuations:

- *Long duration*
  - Mitigated with shorter CAL-SOURCE-CAL loop
- *Short duration*
  - Early success w/ tip-tilt model with antenna and phase monitor data

Key Technical Developments





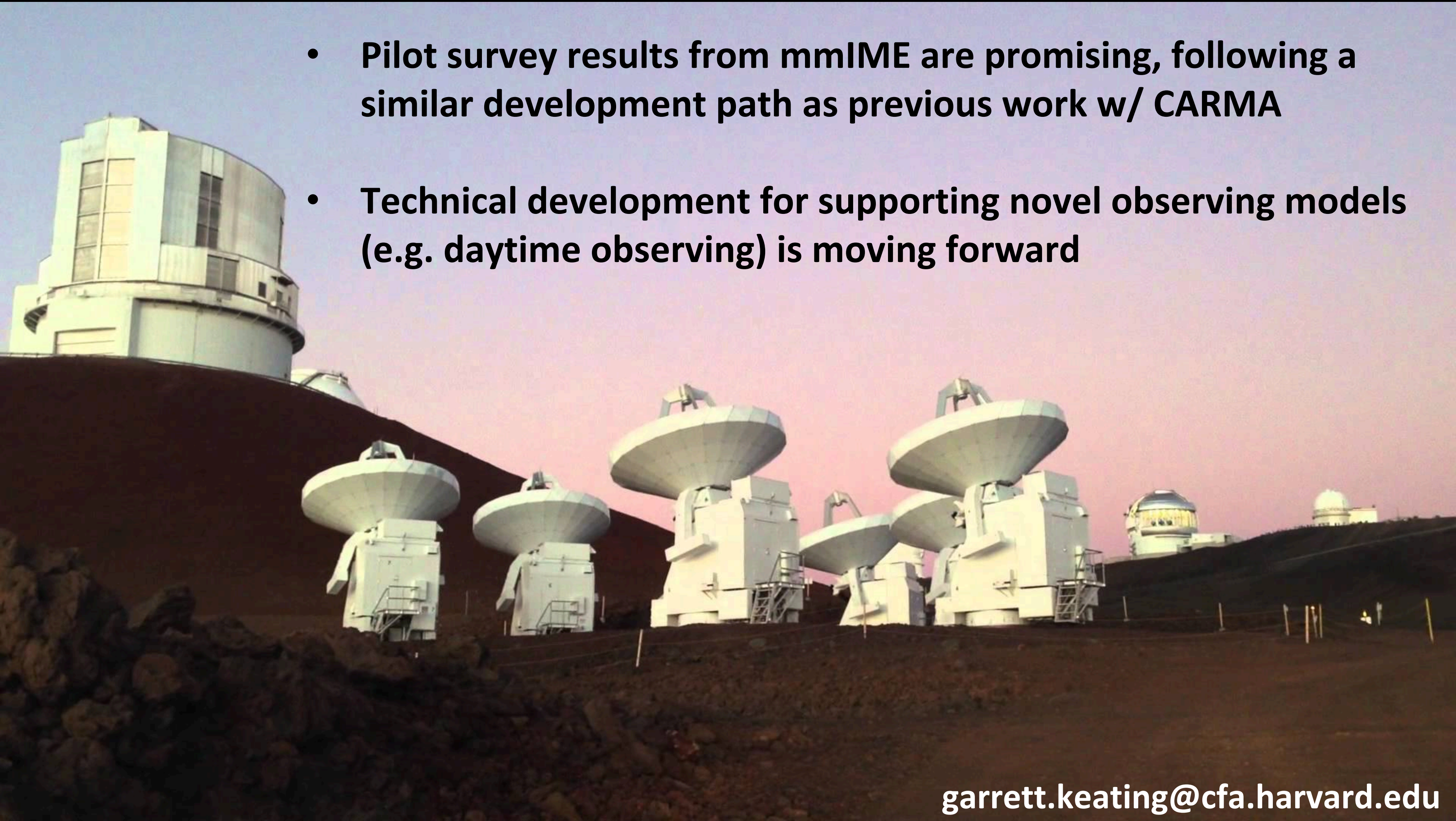


Automated processing in MATLAB (exportable to other languages)

- Valuable array health monitoring information
- Reduce potential barrier for new users (deliver gains + flags + weights)

Comments and Questions

- **IM + Direct Detection of CO/[CII] with SMA offers an inexpensive way to probe cold gas at high redshift with large-volume surveys**



- **Pilot survey results from mmIME are promising, following a similar development path as previous work w/ CARMA**
- **Technical development for supporting novel observing models (e.g. daytime observing) is moving forward**

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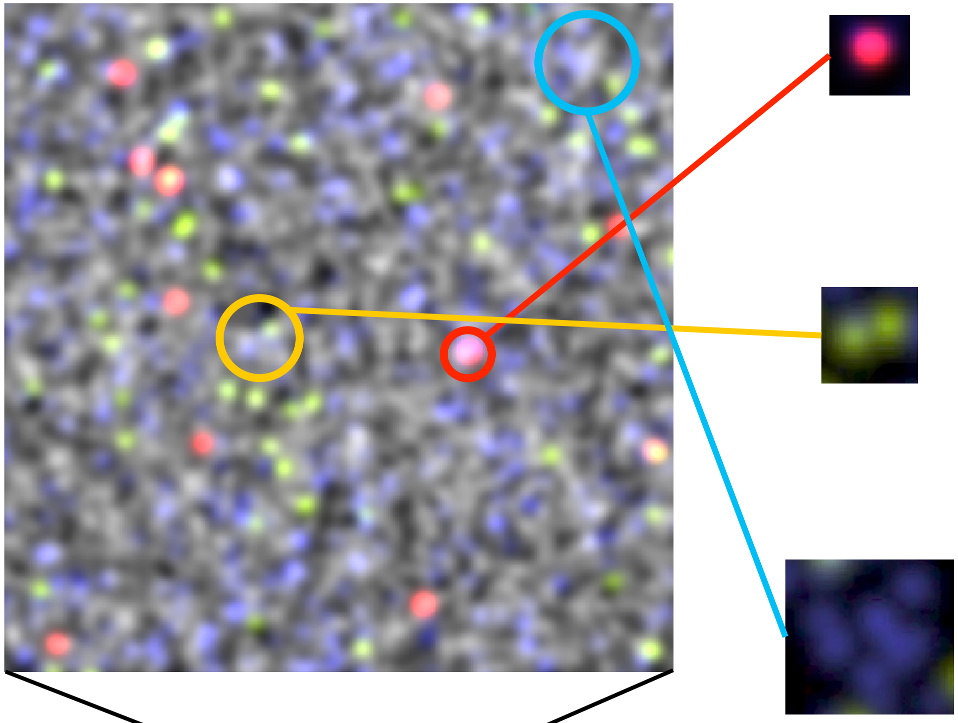
Efficiently Extracting Emission



Direct Detection: Faint objects can be prohibitively expensive.

Source Stacking: Needs ancillary data

Intensity Mapping:
Excellent for faint sources, requires strong control of systematics.