[N II] 205 μm Science Cases for the Greenland Telescope

Hiroyuki Hirashita
Satoki Matsushita, Patrick M. Koch
ASIAA GLT Single Dish Science Discussion Group
(ASIAA, Taiwan)

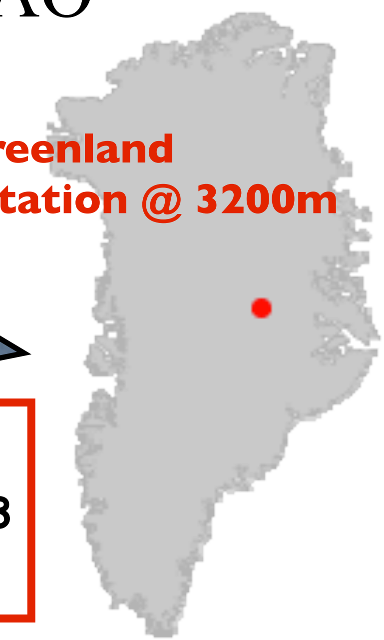
Topics

1. GLT Project
2. THz Science
3. [N II] 205 μm Surveys
4. Conclusion

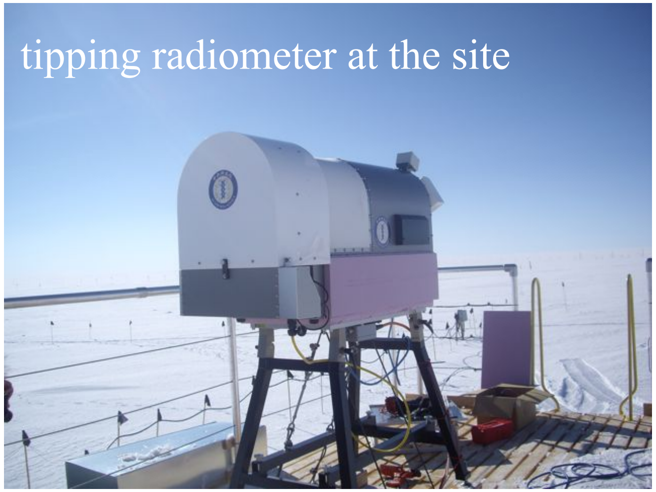
1. Greenland Telescope (GLT) Project

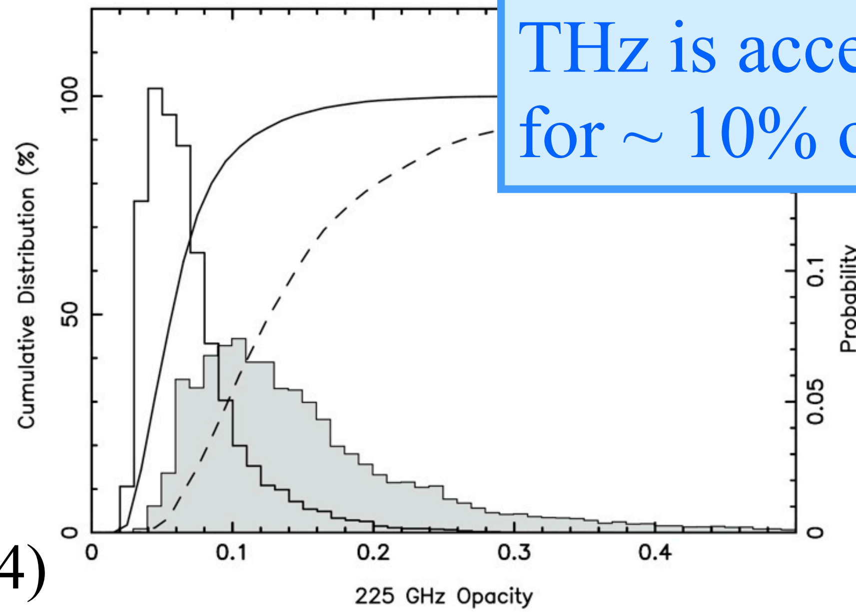
• ALMA-NA Prototype 12 m Antenna
• To be placed in Greenland Summit Station @ 3,200 m
• Main purpose: submm VLBI (imaging of the M87 black hole) starting around 2016.
• ASIAA, SAO, Haystack Observatory, and NRAO

current antenna status:
- antenna disassembled 2012/2013
- cold weather retrofit ongoing



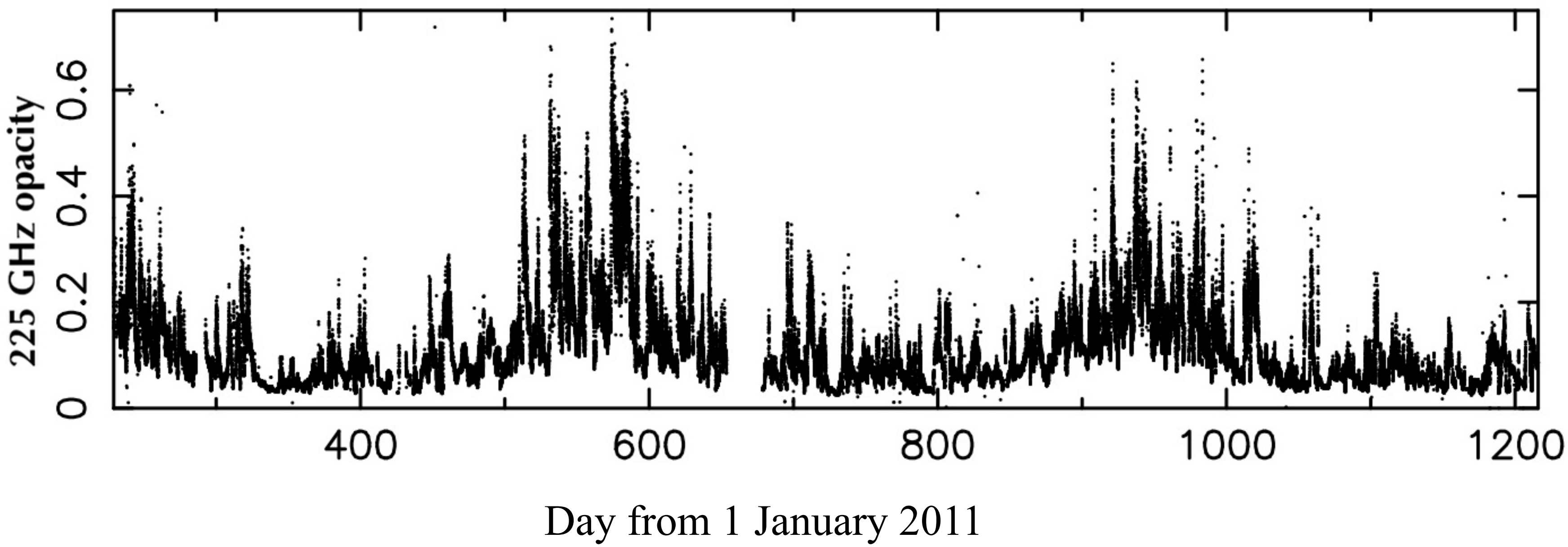
Site Testing at Summit Station in Greenland





THz is accessible for ~ 10% of winter.

Martin-Cocher et al. (2014)



Single Dish Use of GLT

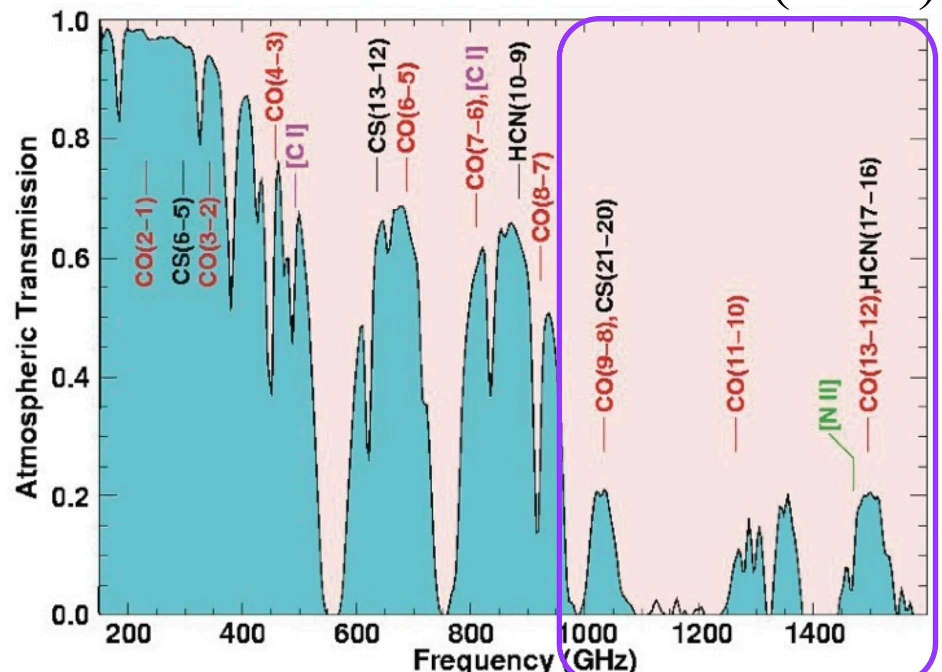
Time suitable for VLBI is limited.
⇒ Available for a large part of a year as a single dish!

Taking advantage of good atmosphere and flexible time allocation ⇒

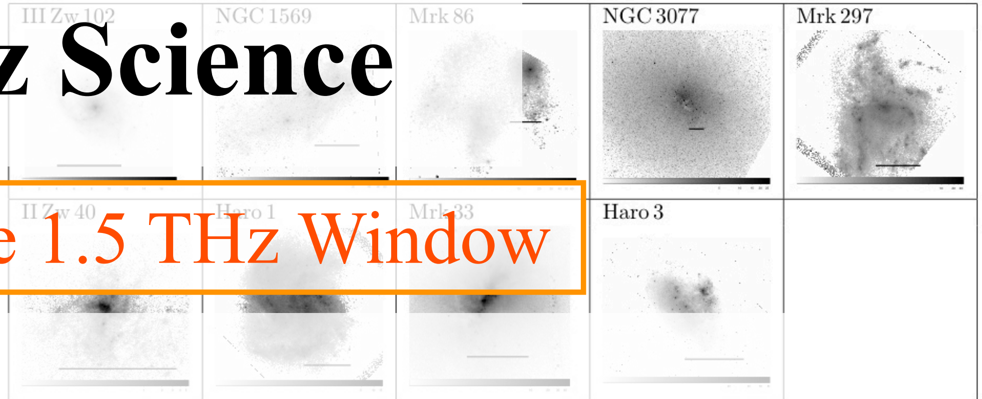
(1) Opening a new wavelength: THz.
(2) Time-consuming surveys.
(3) Monitoring.

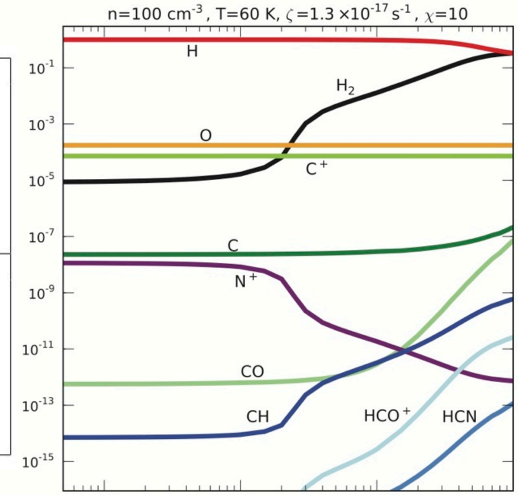
Beam ~ 4 arcsec @ 1.5 THz
Similar resolution to SMA

Matsushita et al. (1999)



2. THz Science





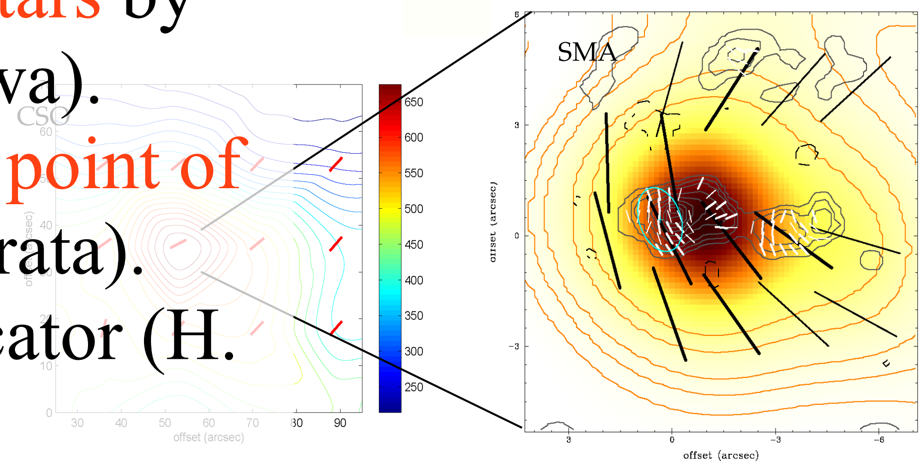
Opening the 1.5 THz Window

Lines:

(1) Vicinity of newly formed stars by highly excited CO (S. Takakuwa).

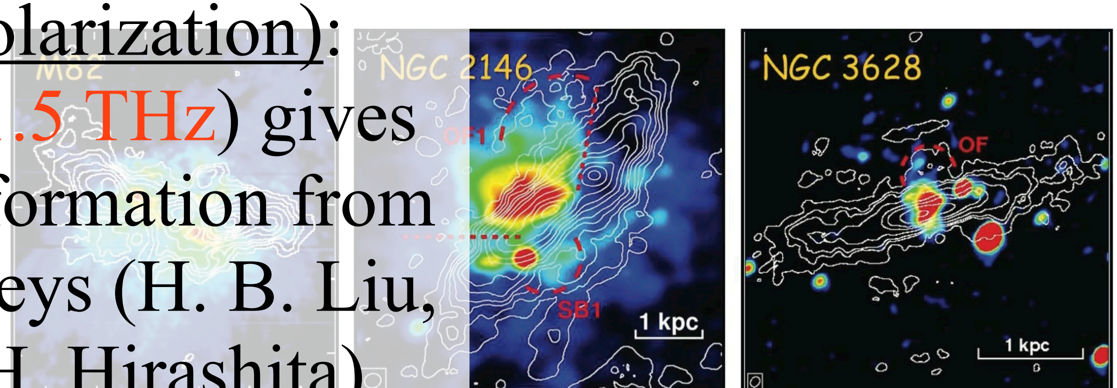
(2) Simple molecules: starting point of the chemical reactions (O. Morata).

(3) [N II] 205 μm as a SF indicator (H. Hirashita).



Continuum (including polarization):

The highest frequency (1.5 THz) gives the most independent information from the existing submm surveys (H. B. Liu, P. Koch, S. Matsushita, H. Hirashita).



3. [N II] 205 μm Surveys

(1) $E_{\rm ion}$(N) > 13.6 eV ⇒ Exists only in H II regions. ⇒ Good indicator of SFR (Inoue et al. 2014)?
(2) Metallicity dependence is also important to derive metallicities in high-z galaxies by ALMA (Nagao et al. 2012).

[N II] 205 μm as a SF Indicator

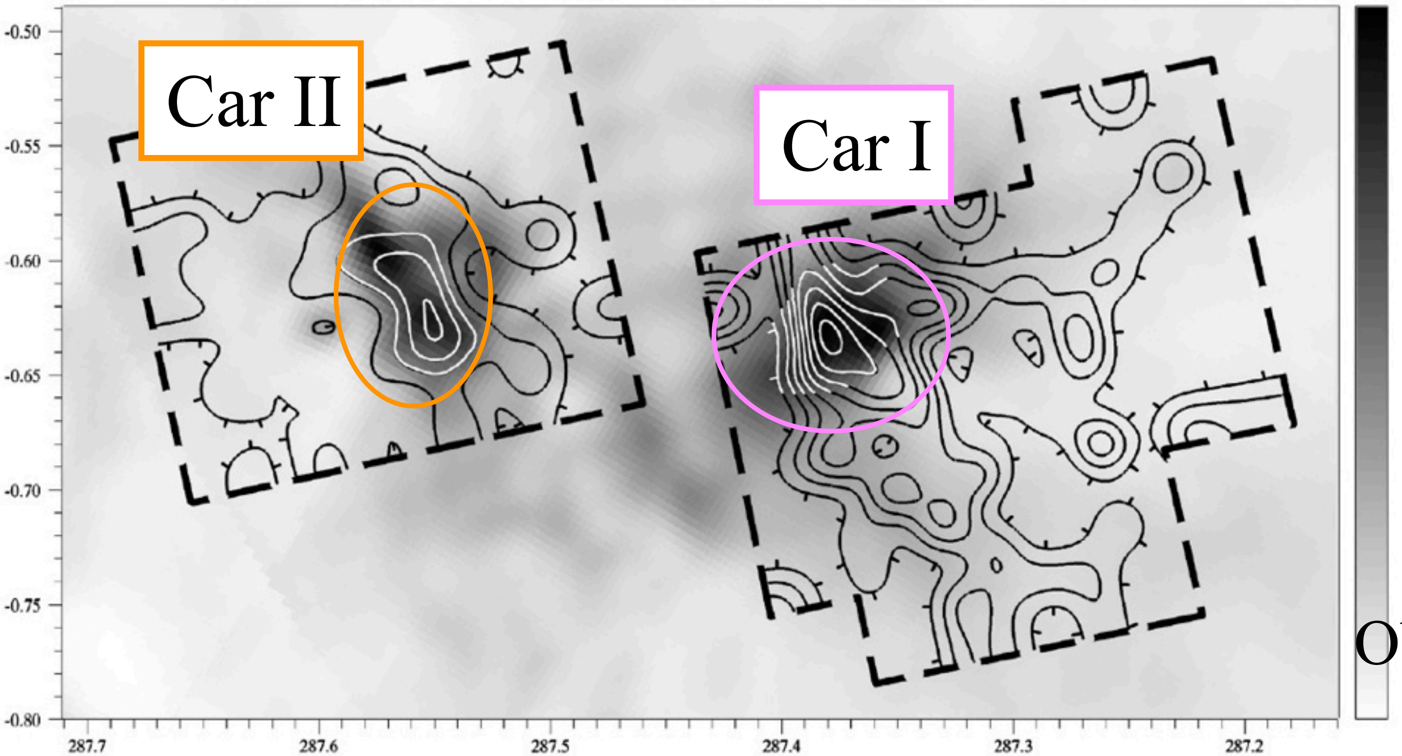
Galactic H II regions:
$L(\text{N II}) = C\, L(\text{H}\alpha)$ [or $C'\, L(\text{radio})$]
Starting point for the local calibration of FIR fine-structure line SF tracers.

Galactic H II regions to be observed by the GLT (Mathis 2000)

Name	(l, b) [a]	α (J2000)	δ (J2000)	Size[b] (arcmin)	S_ν(6 cm) (Jy)	$f_{\text{N II}}$ [c] (MJy)	$f_{\text{N II, beam}}$ [d] (Jy/beam)
W 3	133.7+1.2	02h25m30s	+62d05m19s	1.7 × 1.5	80	0.379	421
W 51	49.5−0.4	19h23m48s	+14d30m46s	complex	400	–	–
DR 21	81.7+0.5	20h39m15s	+42d19m11s	0.3 × 0.4	19	0.0900	2410
NGC 7538	111.5+0.8	23h13m21s	+61d28m32s	2.3 × 1.9	26	0.123	90.4

Sensitivity: 190 Jy/beam $(t/\text{s})^{-1/2}$
with $\Delta\nu = 10^7$ Hz ($\Delta v = 2$ km s^{-1})

Carina I, II



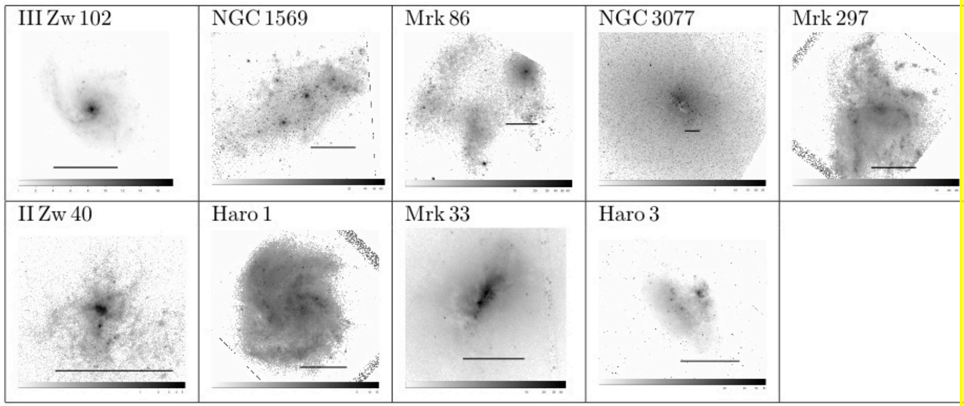
Oberst et al. (2011)

[N II]/Radio ratio provides a test for [N II] as a star formation indicator.
⇒ This ratio derived for Carina I, II is ten times smaller than that expected from Inoue et al. (2014), probably reflecting the peculiarity. ⇒ more samples by GLT

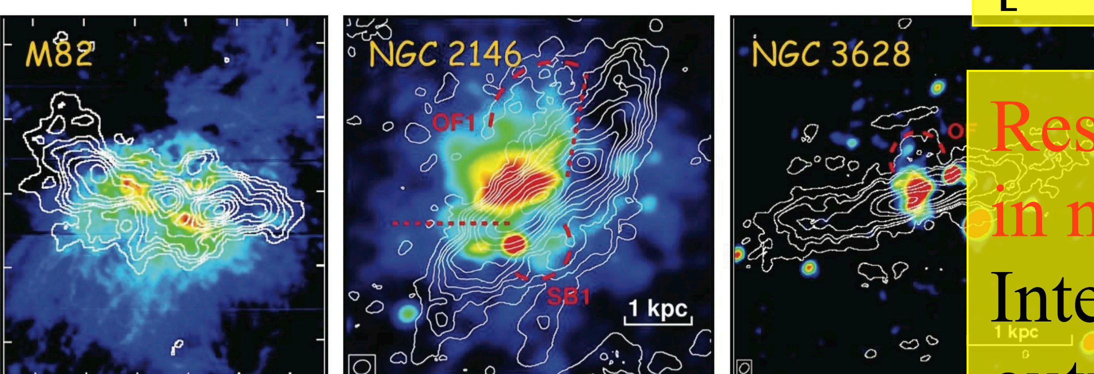
Nearby Galaxies

H. B. Liu, S. Matsushita, H. Hirashita

High-resolution (~ 4 arcsec)



Nearby blue compact dwarfs
variety of metallicities
high-surface brightness
(1) more precise dust mass (+SMA)
(2) metallicity dependence of [N II] 205 μm



Resolving interesting regions in nearby galaxies
Interaction interface of X-ray outflow and molecular outflow

Detectability of Low-Metallicity BCDs

II Zw 40:
Expected flux from SFR + scaling with metallicity (Inoue 2014)
⇒ f([N II]) = 6.5 Jy/beam for II Zw 40
with $\Delta\nu = 10^8$ Hz (20 km/s)

GLT: 1 σ 84 Jy/beam with $\Delta\nu = 5 \times 10^7$ Hz (1 sec)
⇒ 1.1 h integration can detect [N II] in II Zw 40

4. Conclusion

(1) GLT is targeting the 1.5 THz window, which has a rich science cases.
(2) [N II] 205 μm line is just in this window, and is potentially important as a metallicity/SFR indicator.
(3) GLT can test the dependence on the SFR (Hα or radio) in Galactic H II regions.
(4) The metallicity dependence is also addressed by observing nearby low metallicity BCDs.

Thank you!

GLT History and Status

- 2009: submm VLBI activity started at ASIAA
- 2011: acquired NA ALMA prototype in collaboration with CfA, MIT and NRAO
- 2011, August: site testing in Greenland started
- 2011: investigations for retrofitting and relocation to Greenland initiated
- 2011-now: Vertex (Germany) main contractor for antenna retrofit

ongoing efforts:
- de-ice system
- space frame
- hexapod / nutator design
- site infrastructure development

upcoming major milestones:

- shipping from US to Thule military base
- possible observations from Thule Base
- traverse from Thule to Summit station

by boat to Thule

tractor traverse from Thule to Summit

THz Lines

S. Takakuwa

Representative THz Lines

Species	Frequency (THz)	Transition	E_u (K)
CO	1.03691239 ∼ 1.95601814	9–8 ∼ 17–16	248.87486 ∼ 845.59418
HCO^+	1.06969429 ∼ 1.33671568	12–11 ∼ 15–14	333.77154 ∼ 513.41458
H_2D^+	1.37014600	$1_{0,1}$–$0_{0,0}$	65.75626
NII	1.46113141	$^3P_1$–$^3P_0$	70 K-
CH	1.47073960	N=2, J=3/2-3/2, F=2^+–2^-	96.31131
HD_2^+	1.47660550	$1_{1,1}$–$0_{0,0}$	70.86548
CII	1.90053690	$^2P_{3/2}$–$^2P_{1/2}$	91.21086
OI	2.06006886	$^3P_0$–$^3P_1$	-

Very High-J Molecular Lines → Very inner part of Star-Forming Cores

Pure Rotational Lines of Light Molecules → Chemically ``Basic'' Species
(There are lower-frequency, fine-scale lines)

Atomic Fine-Scale Lines → PDR, HII Regions

(2-d) High-z Spectral Lines

Y.-T. Lin, W.-H. Wang

[C II] at 1.9/(1 + z) THz: main coolant

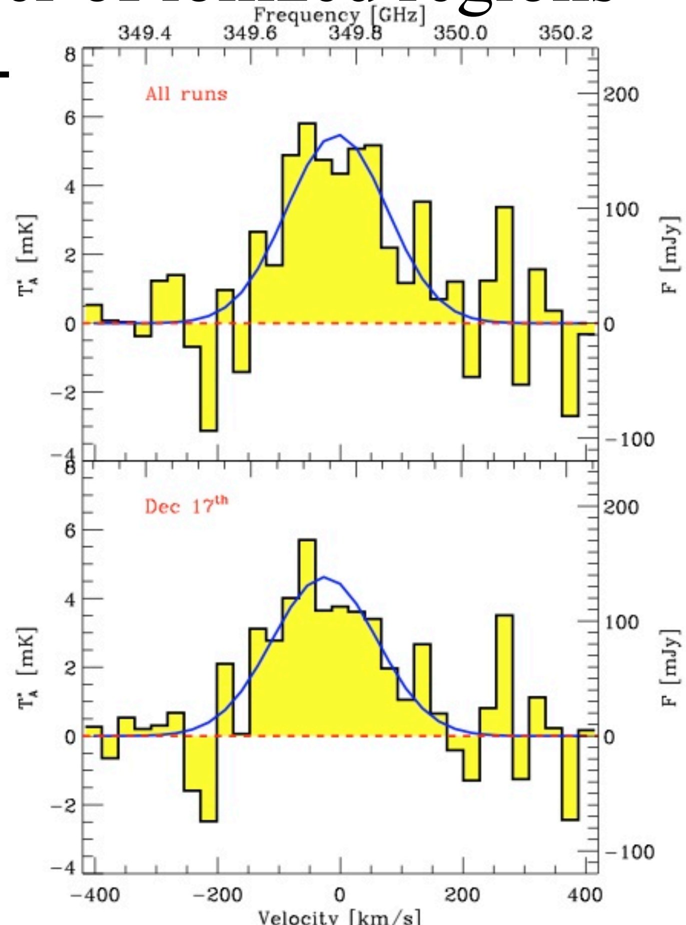
[N II] 2.5/(1 + z), 1.5/(1 + z) THz: tracer of ionized regions

Wide-wavelength spectrometer in sub-mm:

$z \sim 2$: [C II] 633 GHz,
[N II] 829 GHz, 487 GHz

$z \sim 3$: [C II] 475 GHz,
[N II] 614 GHz, 365 GHz

Area > 500 deg^2 for baryonic acoustic oscillation to determine the cosmological parameters (nature of dark energy, initial non-gaussianity, neutrino mass).



Maiolino et al. (2009)