

SPICA and Radio (mm/sub-mm) Astronomy

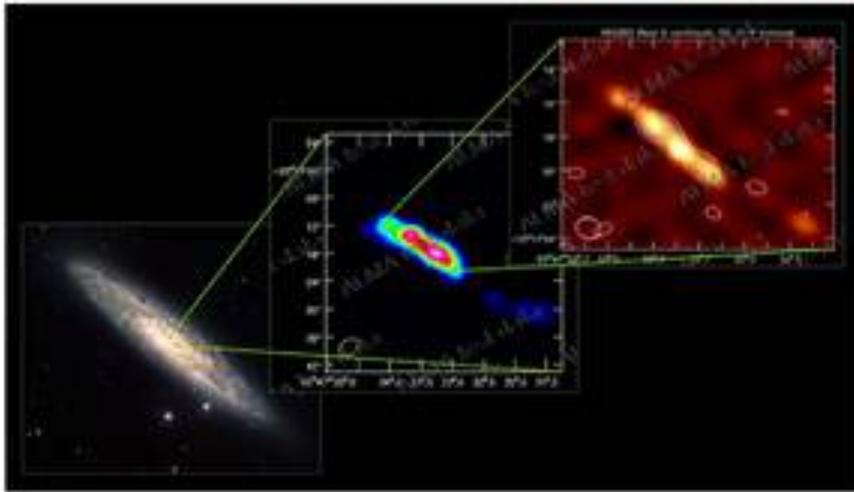
Ryohei Kawabe

NRO, NAOJ

Dec. 16, 2010

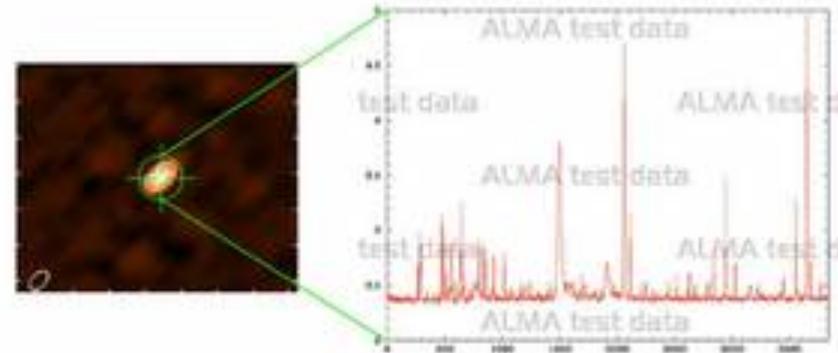
ALMA will come soon!

ALMA CSV Test Images

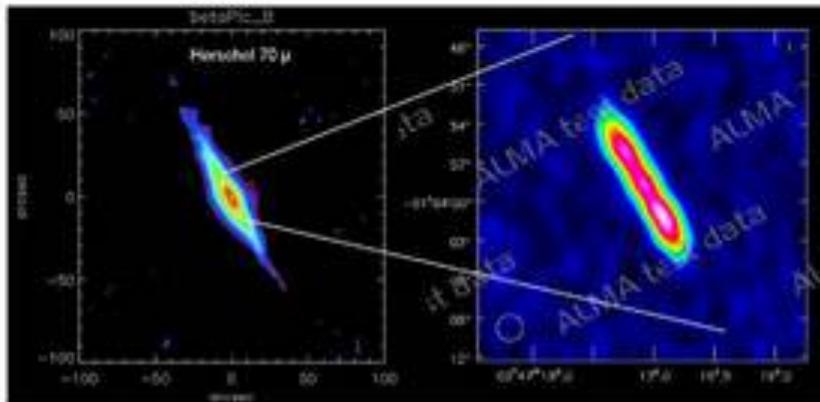


テスト画像1：渦巻銀河NGC253（左：可視光）（中央）230GHzのCO(2-1)輝線画像（右）690GHzの連続波画像とCO(6-5)輝線画像

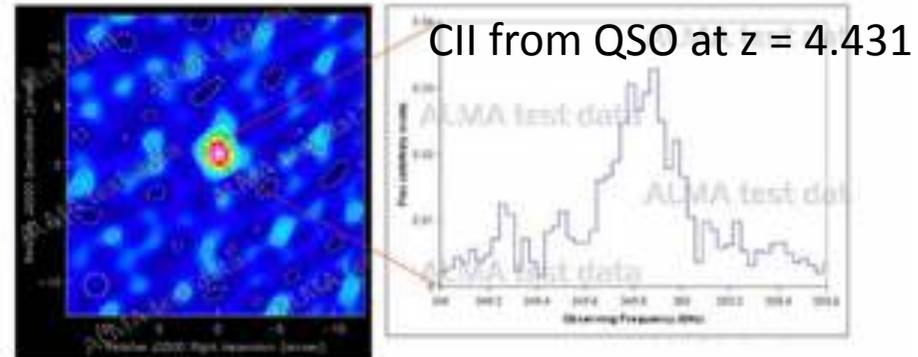
Credit: ALMA (ESO/NAOJ/NRAO)



テスト画像2：ホットコア分子雲G34.26+0.15の画像と周波数100GHz付近の分光スペクトル。多数の輝線が見える。



テスト画像3：がく座ベータ星の円盤。（左）天文衛星ハーシェルの70 μ m画像（Olofsson他）。（右）870 μ mのALMAテスト画像。



テスト画像4：赤方偏移 $z=4.431$ のクエーサーBRI 0952-0115の画像と158 μ m電離炭素輝線の分光スペクトル。

CII from QSO at $z = 4.431$

SPICA roles in ALMA Era

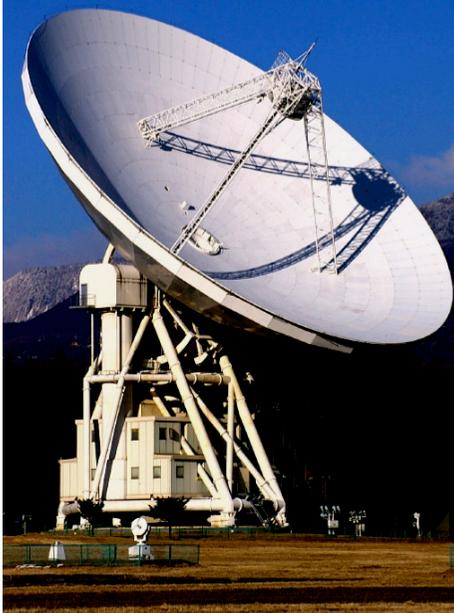
- SPICA and ALMA Synergies exploited as much as possible
 - Synergies with next generation mm/sub-mm single dish telescopes, e.g., CCAT, AS²TE
 - ALMA is not a Survey Telescope but an Imaging Telescope with high-sensitivity, and SPICA Survey can supply intriguing JP-original targets for ALMA observations; high-z galaxies
 - Coordinated Studies with ALMA/CCAT, ASTE2
e.g., SPICA Deep Field with SAFARI (see ADF-S results!)
 - SPICA “follow-up” observations
e.g., redshift determination with spectroscopy

ALMA/SPICA Synergy Telescope (AS²TE)

(仮称)

- A Large Sub-mm Single dish
 - complement to ALMA
 - opening new discovery space in ALMA/SKA- era
- Wide Field Imaging & Wide Spectroscopy

NRO 45m Telescope



Natural Evolution

ASTE 10 m Telescope
In Chile



D ~ 30-40 m
350 μ m – 4 mm?
Completion ~ 2018??

● "Wide Field"
Imaging

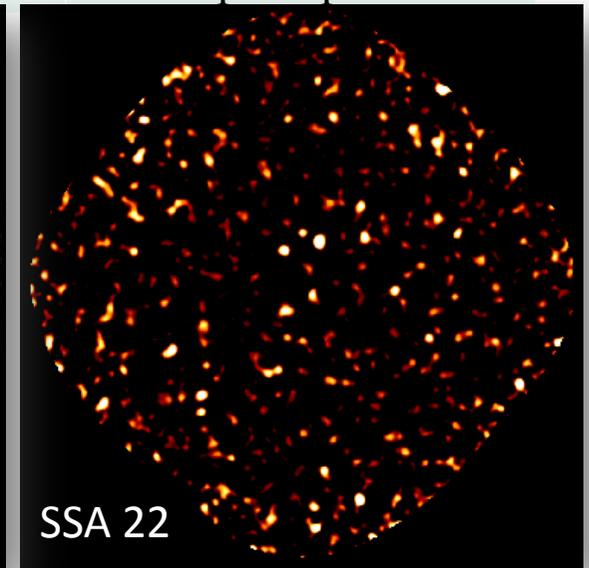
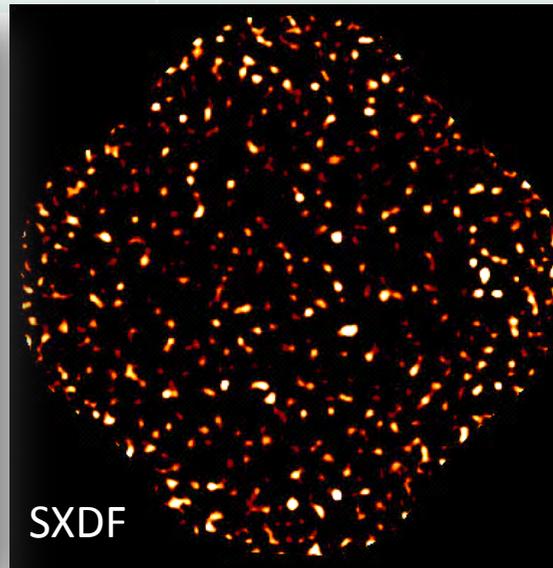
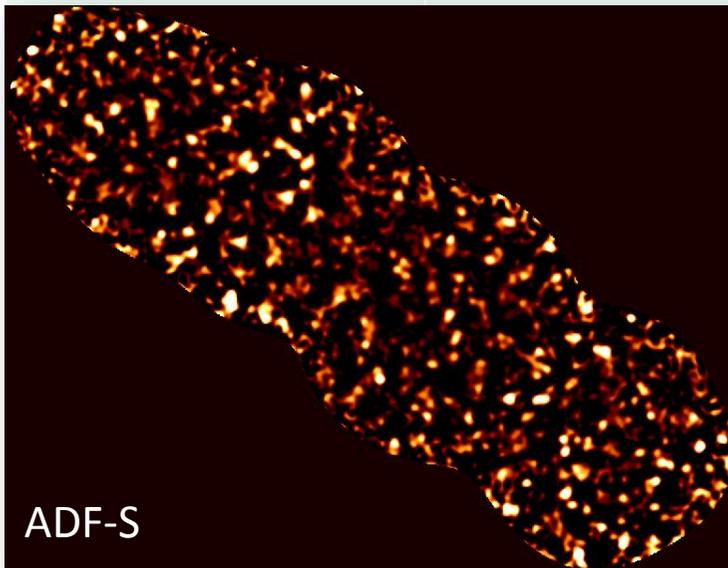
● Census in
the Universe

● Serendipity

● Incubate
Original Ideas

AzTEC/ASTE Deep Wide-field SMG Surveys

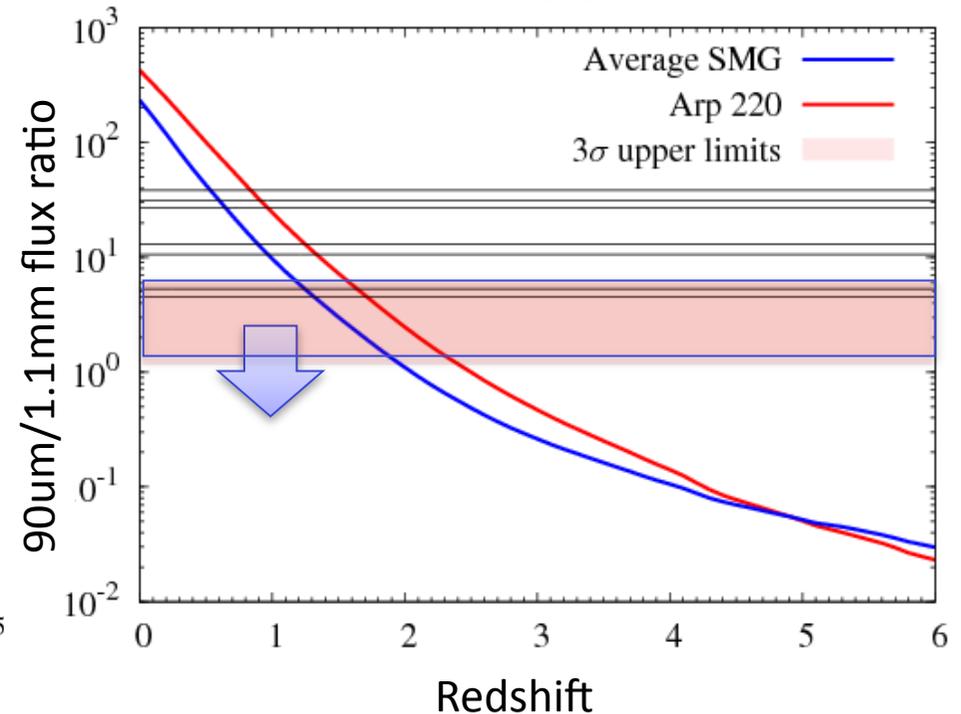
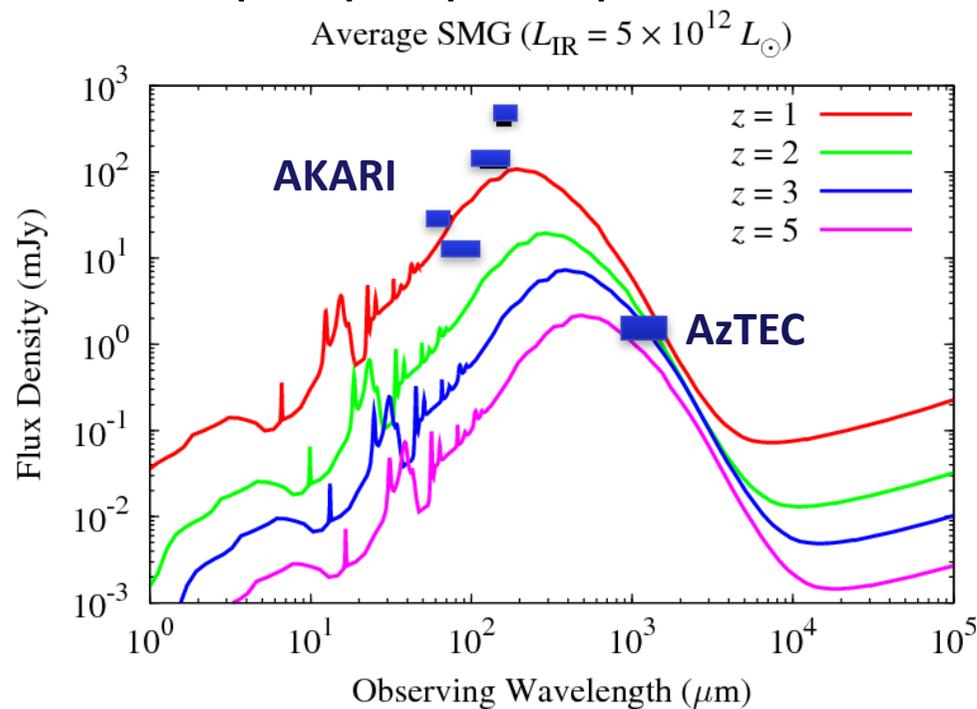
| | AKARI Deep Field South (ADF-S) | Subaru/XMM-Newton Deep Field (SXDF) | SSA22 |
|------------------------------------|--------------------------------|-------------------------------------|---|
| Coverage (arcmin ²) | 909 | 956 | 992 |
| Depth (1 σ , mJy) | 0.43-0.78 | 0.46-0.87 | 0.62-1.2 |
| No sources (>3.5 σ) | 198 | 206 | 127 |
| reference | Hatsukade+10 MNRAS in press | Ikarashi+10 arXiv1009.1455I | Tamura+ 09, 10 Nature, 459, 61 ApJ in press |



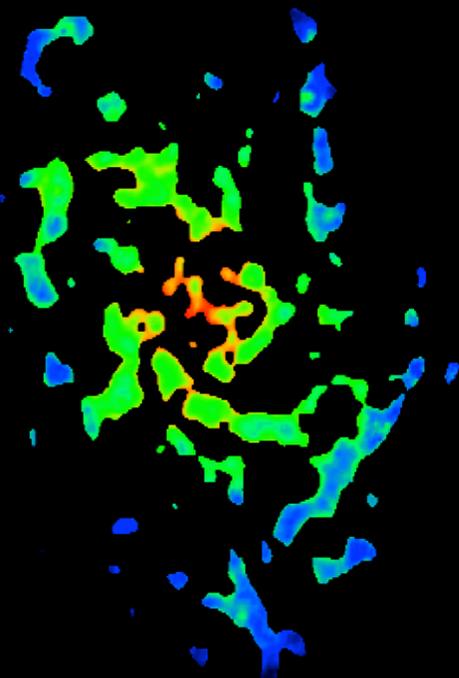
Constraints on *redshifts* of AzTEC/ASTE sources in *ADF-S*

Hatsukade + 2010, MNRAS, in press

- 90 μ m/1.1mm flux ratio
 - ➔ **most of the AzTEC sources (196 out of 198) : $z > 1$**
 - AKARI 90 μ m sources : low- z , AzTEC 1.1mm sources: high- z
- $L(\text{FIR}) \sim (3-14) \times 10^{12} L_{\odot}$, $\text{SFR} \sim 500-2400 M_{\odot}/\text{yr}$

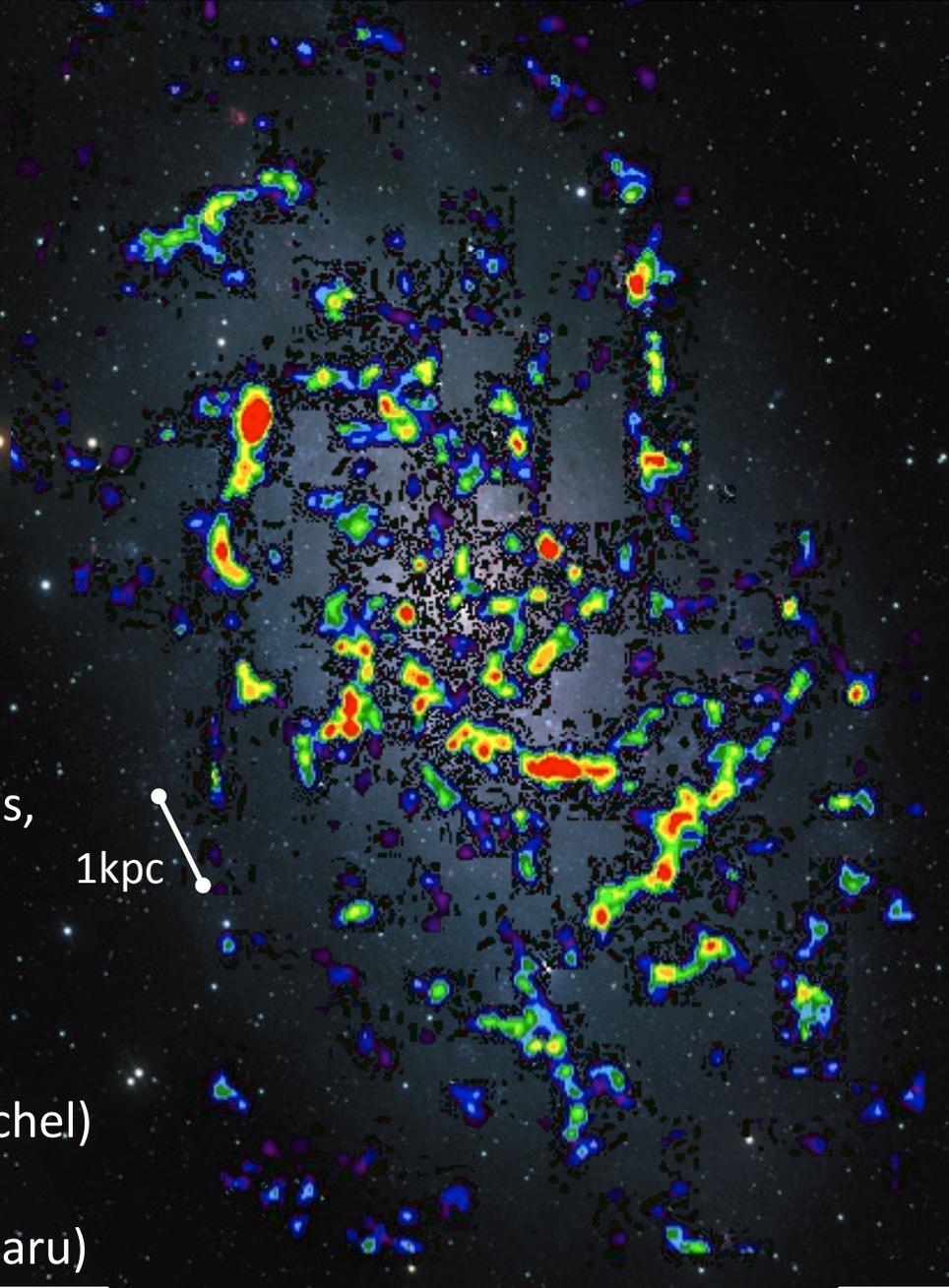


Cold dust temperature map

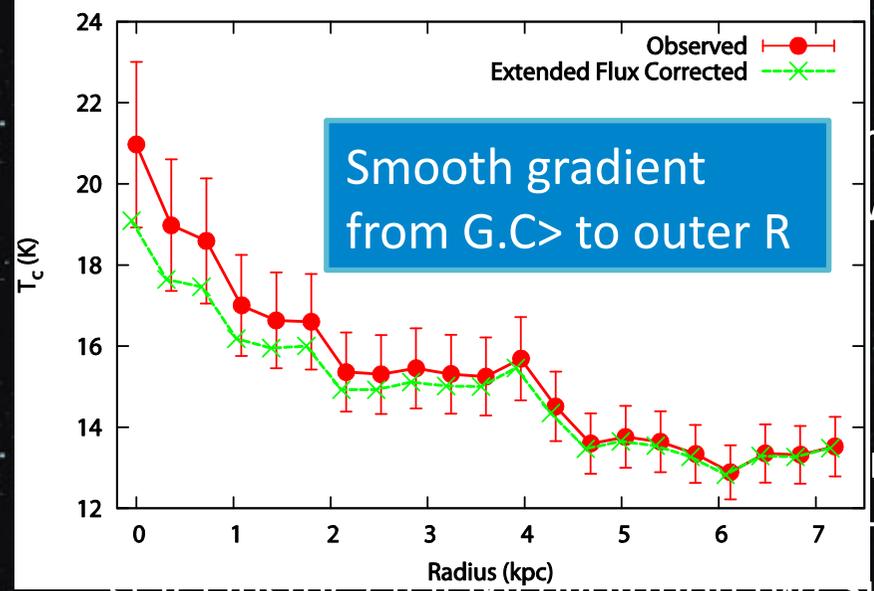


x 40'
on source
oc res.

Komugi et al. 2010 submitted to ApJ



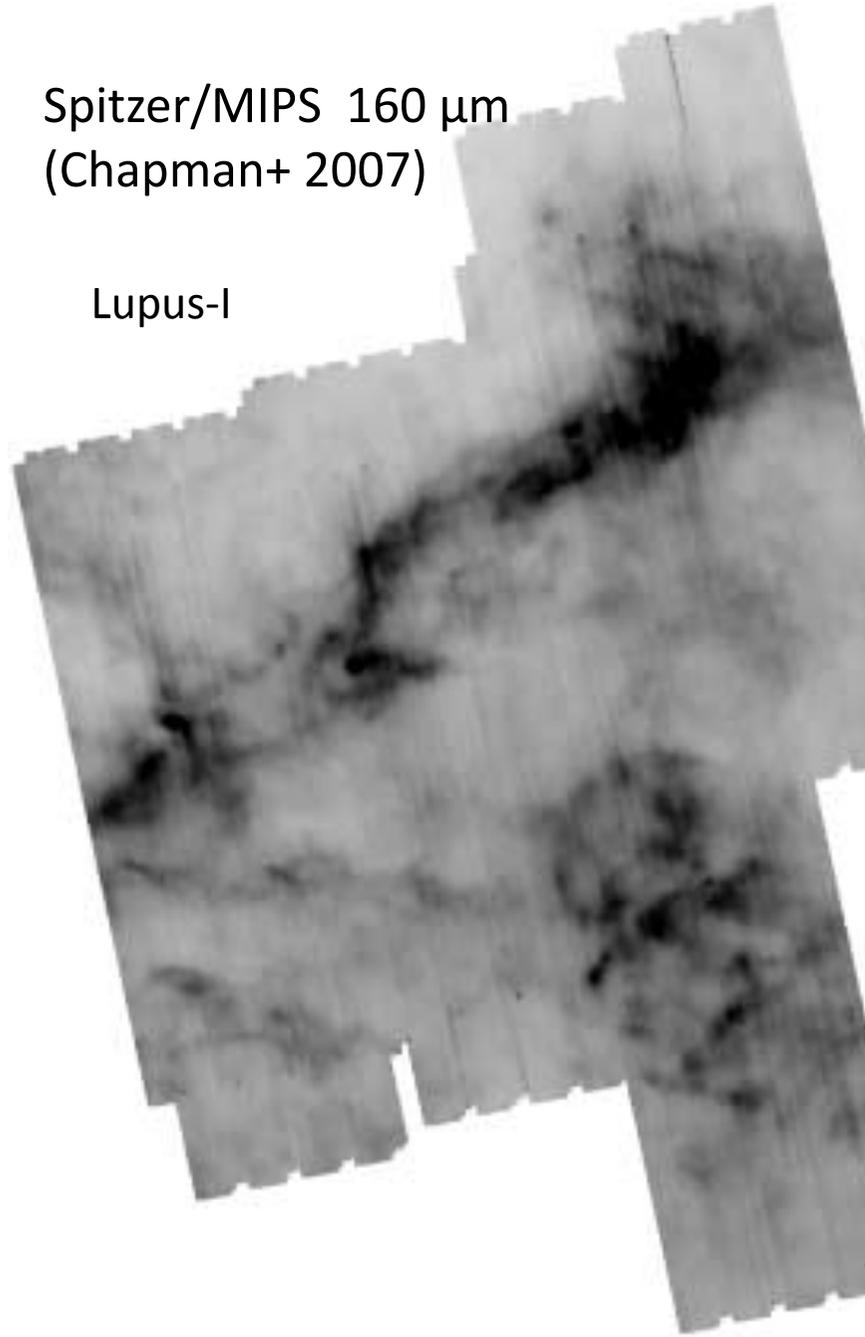
Radial Temperature Gradient



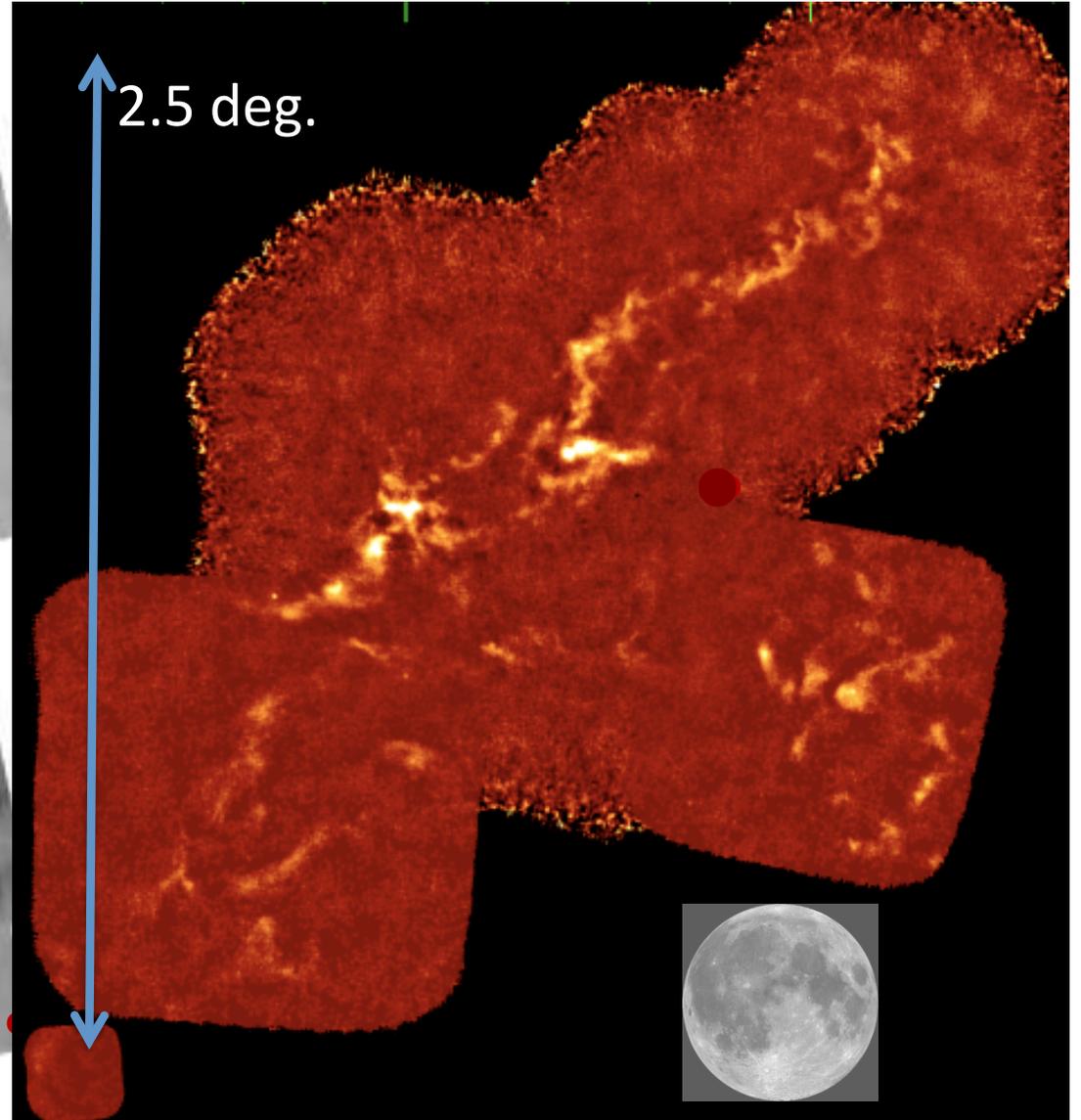
star cluster / galaxy evolution (w/ Subaru)

Spitzer/MIPS 160 μm
(Chapman+ 2007)

Lupus-I



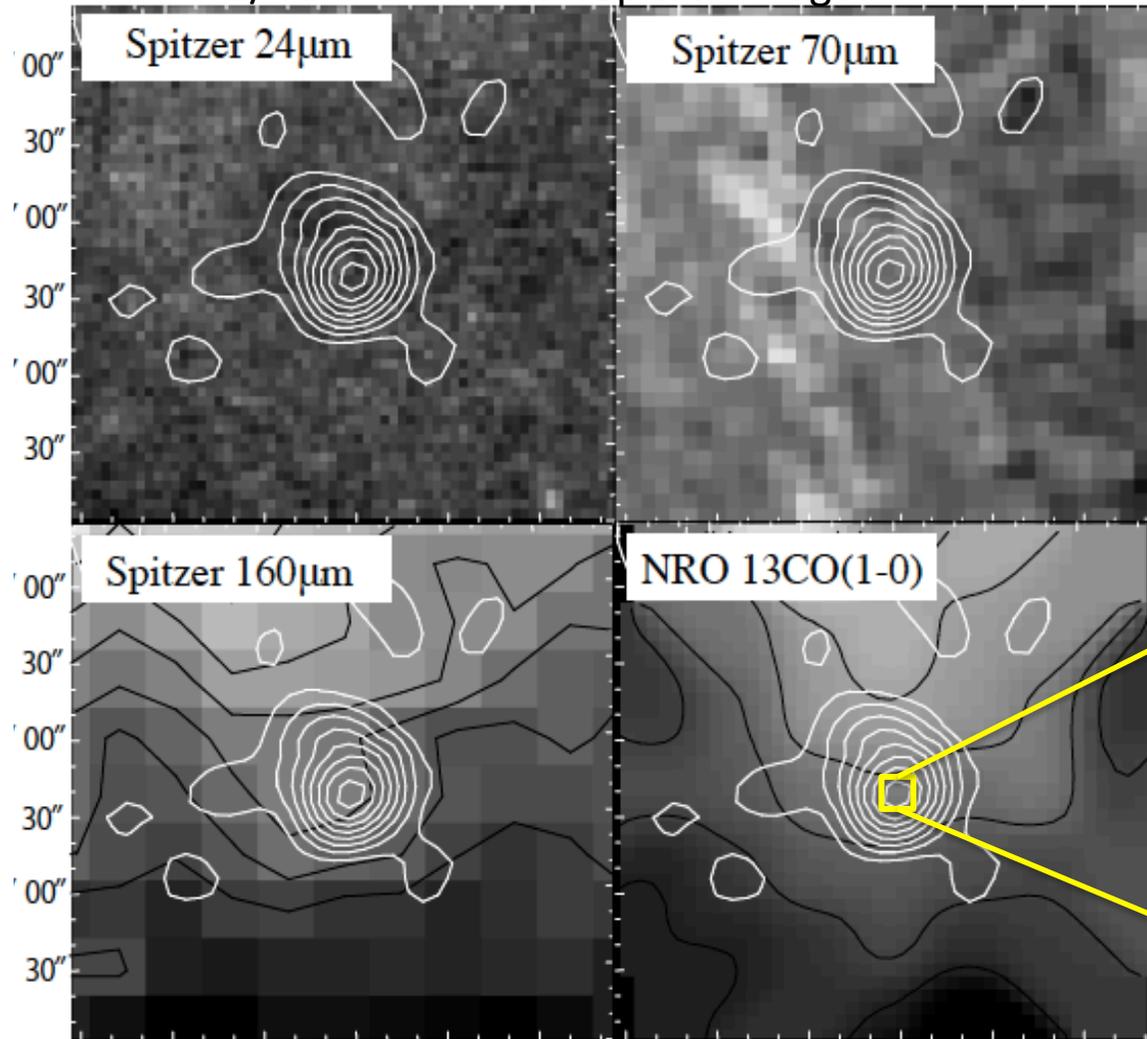
AzTEC/ASTE 1100 μm in Lupus-I;
“FRUIT” image (Kawabe+ 2011, in prep)



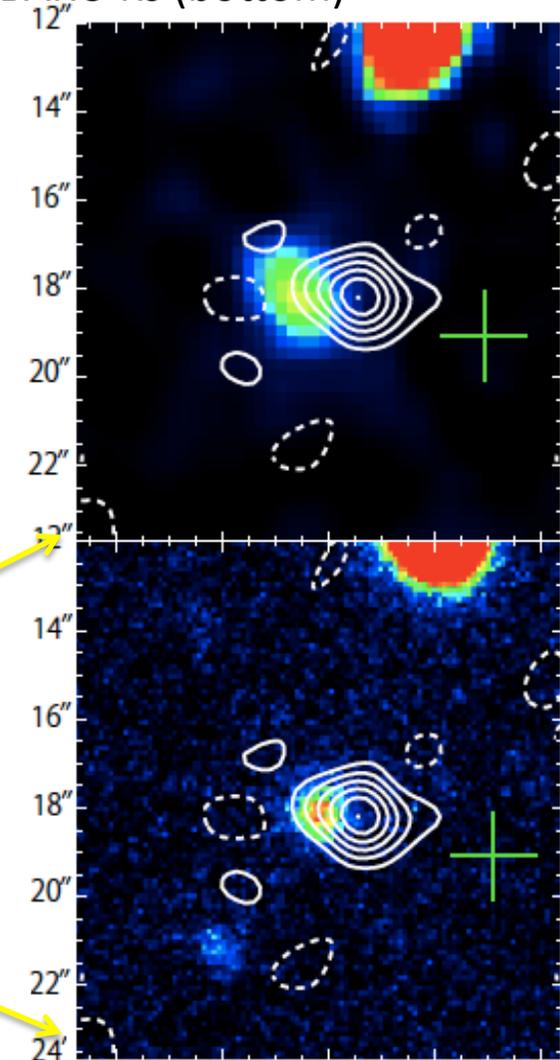
“First Core” discovered ?

$n \sim 10^{10} - 10^{11} \text{ cm}^{-3}$ $r \sim 10 \text{ AU}$
 $M \sim 0.05 M_{\text{sun}}$, $L \sim 0.03 L_{\text{sun}}$, $T \sim 1000 \text{ K} \Rightarrow \text{H}_2\text{O lines}$

AzTEC/ASTE 1.1 mm on Spitzer images



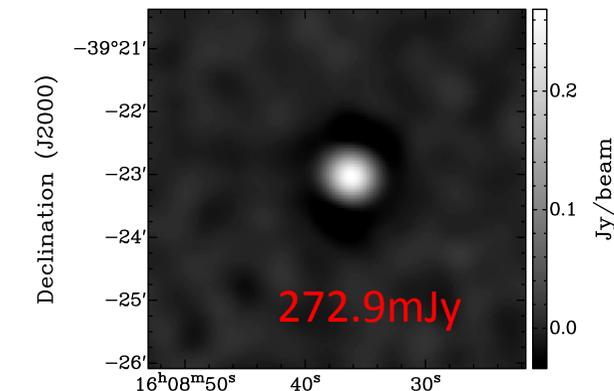
SMA 0.89 mm image; Contour
on Spitzer 3.6 μm (top)
SUBARU Ks (bottom)



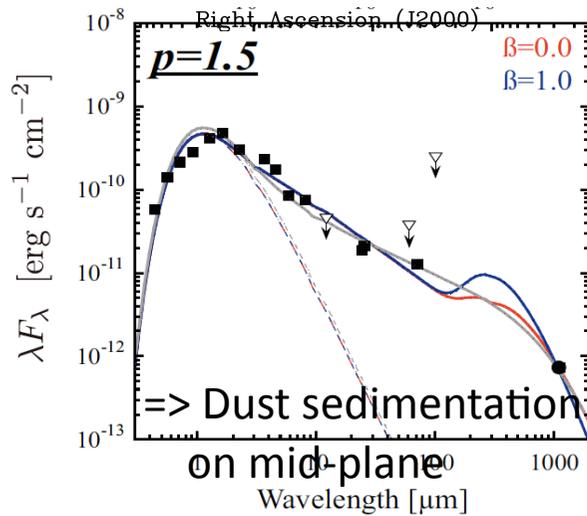
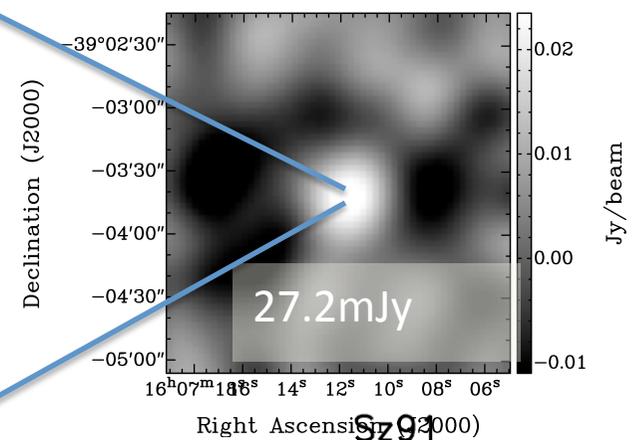
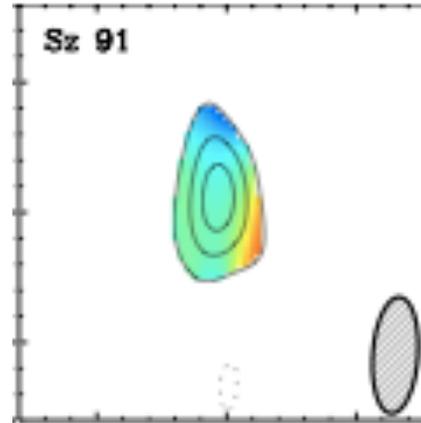
AzTEC/ASTE Discovered TTS disks in late-phases

- V1094Sco
 - flat disk?
 - rotating gas disk

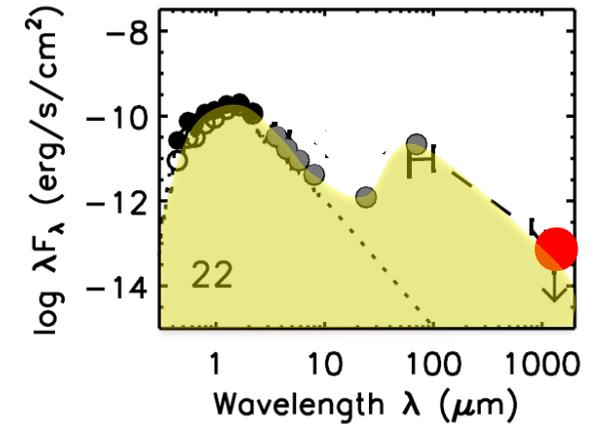
- Sz91 (Class-III)
 - large inner gap?



SMA $^{12}\text{CO}(3-2)$



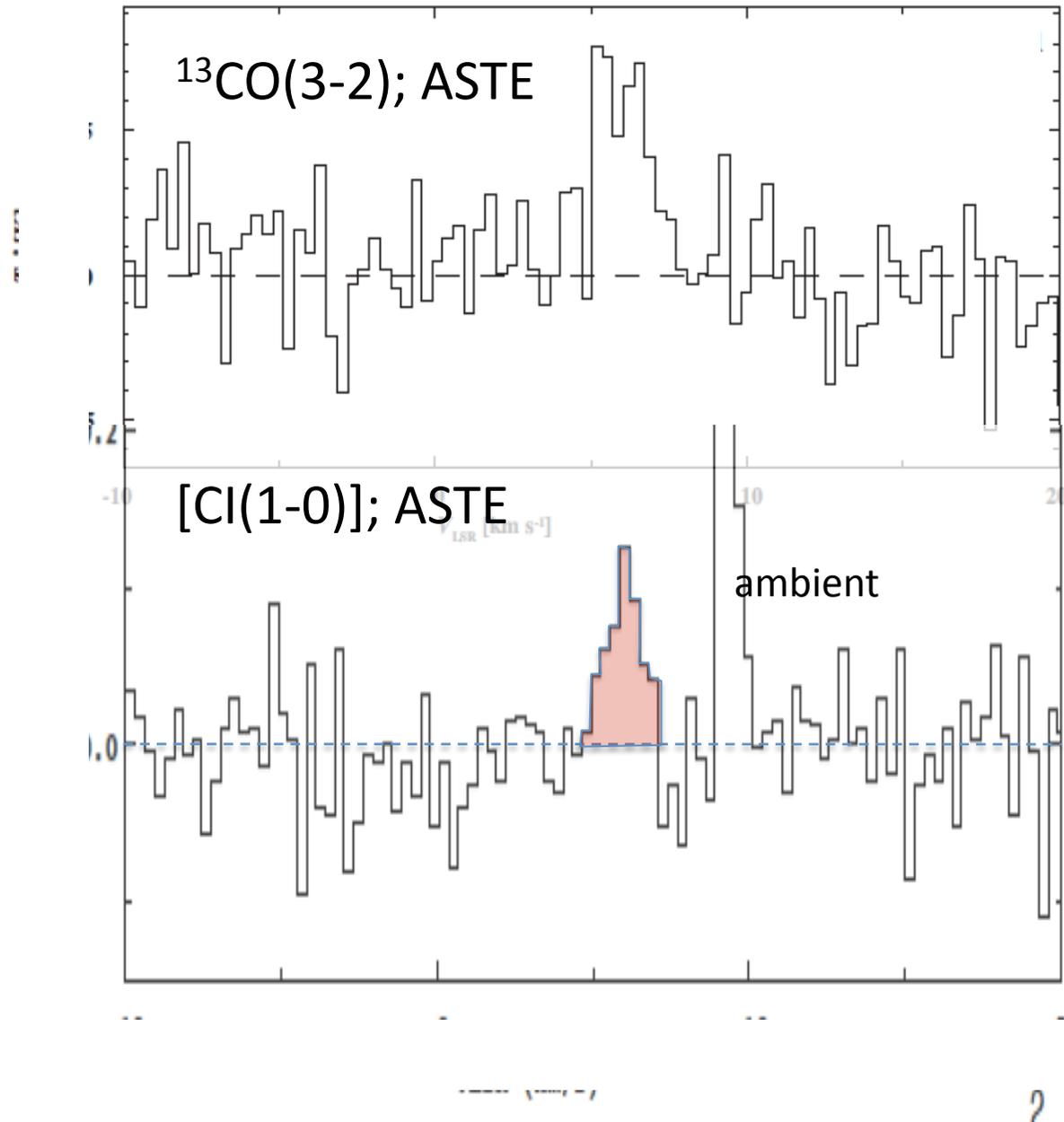
Compact Gas Disk
in Class-III !



Tsukagoshi+ ApJ 2010

Tsukagoshi+ 2011 in prep.

First [CI] detection toward disk



Tsukagoshi +
in prep.

Carbon is a
important species
controlling
Chemical Evolution
In ISM.

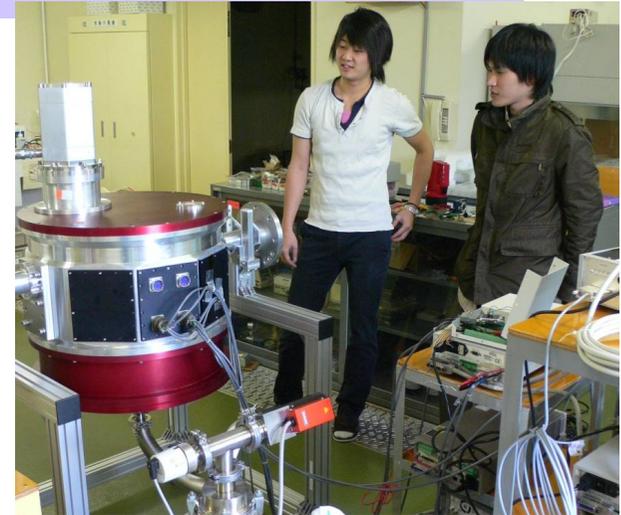
How looks in CII?

Desired Figure/Instrument of SPICA

- Spectroscopy at Mid/Far-IR will be very important; SAFARI/BLIST
 - Redshift of high-z Sub-mm Galaxies/Herschel sources, & obscured GRB
 - Large-scale structure at medium & high-z
 - Cosmic Star Formation History
 - Physics and Chemistry of ISM, Star forming regions
 - Physics and Chemistry of Proto-planetary disk; complement to mm/sub-mm spectroscopy

Multi Color TES Camera for ASTE

- Main Purposes
 - Photo-z estimate for SMGs
 - New surveys of SMGs/SF regions
- Collaboration with UC Berkely (A. Lee) Cardiff, U. Tokyo, Hokkaido U.
- Installation will be in Feb 2011
- Science Oper. From Oct 2011



| Wavelength | No. of pixs | Beam size | FOV (arcmin) |
|------------|-------------|-----------|--------------|
| 1.1 mm | 169 | 28" | 7.5 |
| 850 micron | 271 | 22" | 7.5 |
| 450 micron | 881 | 11" | 7.5 |

