Large TeraHertz Arrays for SOFIA
SOFIA Focal Plane
~8 arcminutes

SOFIA Needs Large Heterodyne Arrays!
SOFIA Focal Plane can support Kilo-Pixel Heterodyne Arrays: Increasing Science Return >10x
Spectral Resolution is Key to Disentangling Complex Lines of Sight
THz Arrays: Why Now?
A Confluence of Technologies:

- Mixer technology
- LO technology
- Microfabrication
- IF amplifiers
- Digital signal processing
THz Mixer Evolution
(from 2010 SOFIA Asilomar)

CSO Mixer @ 492GHz
c.a. 1990

4 pixel AST/RO array @ 810GHz
c.a. 2000

Prototype: 2 THz Stacked Linear Arrays

SuperCam 8x8 Array
@ 350 GHz
c.a. 2010
GUSTO Observational Objectives: [CII], [OI], & [NII] Surveys of MW and LMC

124 sq. degree Milky Way Survey

Herschel CII line of sight (LOS): GUSTO will observe 540,000 LOS’s

25 sq. degree LMC Survey
GUSTO Quasioptical Mixer Arrays

- 2x4 [NII] 1.46 THz
- 2x4 [CII] 1.9 THz

Silicon Lenses
2x4 [OI] HEB Array Assembly at SRON
4.7 THz

Back of Array
SRON-TU Delft HEB detector array

- NbN HEBs on 2x2 mm Si chip fabricated at TU-Delft.
- SiO$_2$ passivation layer to prevent oxidation.
- Spiral Antenna
  - Same mixer works from 1 to 6 THz!

2 THz Performance

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<th>Temperature (K)</th>
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$T_{\text{mix}} < 450K$

4.7 THz Performance

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$T_{\text{mix}} < 725K$

See cover page re. ECCN
LO Sources: Frequency Multipliers

**GUSTO Band 1/2**

LO Array

\[ P_{\text{out}} \sim 15 \mu\text{W/pixel} \]
LO Sources: 4.7 THz Quantum Cascade Laser

- D0 7
- D0 8
- D0 9
- D1 0
- D1 2
- D1 3

10 mm

~2 GHz

QCL Chip

~5 mW
Phase Grating for GUSTO
Designed, Modelled and Tested-Verified in TUDelft

Manufactured by Arizona State University
Phase grating to produce uniform square flat beam LO illumination for 32x32 pixels

Y. Gan, B. Mirzaei, et al., Opt. Express, 2019
GUSTO 1x8 Cryogenic LNA block

Noise @ constant Bias @ different temperatures

GUSTO Cryogenic LNA Prototype (LNA#342)
Noise and Gain at Tambiant – 10K and 20K
Bias: 1.25V @ 4.2mA
04/19/2019
Flexible 0.3-4 GHz RF line: No more Cryo Coax!

Smooth bore SMP conn.

Heat sink

Flight hardware

Measured prototype flex data

8 IF Lines

Prototype

See cover page re. ECCN
GUSTO Autocorrelator System

- 24 X 5 GHz
  (Total 120 GHz)
- 24,576 Channels
- 75 W
- 2.5 kg
- 160 x 160 x 160 mm
Realizing a 1024 Heterodyne Array with GUSTO Technology

Incoherent Quasioptical Approach

Microlens array technology is well developed

AMKID (KID) detector arrays (APEX)
Kilo-pixel TES for XIFU-Athena developed @ SRON using microstrip wiring structures for k-pixles
Cost/ Pixel \(\sim 1/n^{1/2}\)

- Single Pixel
- Desert STAR
- Pole STAR
- SuperCAM 1-D
- 2-D Arrays

Walker et al. 2008
**SOFIA Kilopixel Coherent Camera (KCAM)**

<table>
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<tr>
<th>Strawman Budget</th>
<th>Time Line</th>
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<tr>
<td>Mixers</td>
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**TOTAL COST** $23M  

Leverages off GUSTO/STO NRE
Summary

• Technological advancements now make it possible to construct a Kilopixel Heterodyne Camera capable of operation from ~1 to 6 THz.

• Such a camera would increase the science return of SOFIA by *more than an order of magnitude per flight and could be constructed within 5 years.*