OBSERVING THE CYCLING OF MATTER IN THE INFRARED

MAKING Worlds

MAKING Stars

MAKING Dust

Presented by: SOFIA Project Scientist
Kimberly Ennico Smith

Presented to: Spectroscopy with SOFIA Ringberg
Dr. Kimberly Ennico Smith

- Started as SOFIA Project Scientist, December 1, 2016
- Based at NASA Ames Research Center, Moffett Field, California

Kimberly.Ennico@nasa.gov <- Love to capture all that’s happening with SOFIA today

Commissioning FORCAST Grisms 2013

New Horizons Pluto Fly-By 2015
Completed Science Cycle 4 on February 3, 2017

- Satisfied Level 1 Requirement to provide 80% of planned research hours
- **Completed 646 research hours:** 386 General Observer, 106 GTO, 20 DDT, 134 Calibration
- Completed commissioning and initiated observations with new science capability
  - upGREAT High Frequency Array (HFA): October 3, 2016
  - HAWC+ science instrument: December 15, 2016
- Completed planned Observatory Maintenance/Upgrades
  - Observatory System Software updates, including Telescope Systems
  - Avionics Communication System Upgrade – required for international operations
First Images Demonstrate the Capabilities of SOFIA’s New Instrument, HAWC+

This image shows how dust grains are aligned in the W3 star-forming region, a giant molecular cloud in the constellation Cassiopeia approximately 6,200 light years from Earth. Researchers are now comparing data from these observations with models that predict how stars form.

*Credit: NASA / SOFIA / Caltech / Darren Dowell*
Initiated Science Cycle 5 on February 7, 2017

Science Cycle 5 Attributes

- 116 total flights: 102 science, 2 commissioning, 12 engineering/ferry, and increased contingency flight opportunities (22%)

- **758 Research Hours**: 505 General Observer, 100 GTO, 45 DDT, 108 Calibration

- Southern Hemisphere Deployment in Christchurch, New Zealand
  - June 21 – August 13, 2017
  - 3 Science Instruments (upGREAT, FIFI-LS, and FORCAST)
  - NASA HQ-directed Kuiper Belt Object (MU69) on July 10, 2017 in support of New Horizons Mission, provided path is within operational range for return-to-base to Christchurch, New Zealand
Cycle 5 (cont.)

- Planned Observatory Maintenance/Upgrades
  - 2 Channel Cryo-cooler upgrade to be installed during March/April Maintenance/Upgrade Period #13 to support upGREAT/4GREAT commissioning and New Zealand operations
  - HAWC+ ADR vibration heating issue to be repaired during May 19 - Sept 11, 2017
  - Aircraft C-Check planned for November 18 – December 30, 2017

- Science Community / Public Engagement Opportunities
  - Tours in support of AA Education request for Great American Eclipse, August 21, 2017
  - Deployment to American Astronomical Society (AAS) Meeting in Washington D.C. area, January 6-12, 2018
Cycle 5 (cont.)

- High Priority, High Impact Science Observations
  - upGREAT Galactic Center C+ Mapping and [O I] Mapping
  - Time-critical Europa observations on March 15th and May 26th, 2017
  - Triton Occultation from Daytona Beach, Florida on October 5, 2017
  - High-Resolution Molecular Line Survey towards Orion IRc2
  - Joint SOFIA HAWC+/ALMA study of magnetic fields
Cycle 6 – February 1, 2018 – January 31, 2019

Proposal Schedule
– Call issue: May 1, 2017
– Call update: June 5, 2017
– US Proposal deadline: June 30, 2017
– German TAC deadline: ~July 8, 2017
– US TAC: week of 14 August 2017
– German TAC: early September
– Selections announced: October 2017

Program Allocations
– 104 Science Flights, 560 Call for Proposal (CfP) Hours
– US: 476 CfP Hours (Assumes 50 US GTO hours)
– German: 84 CfP Hours (Assumes 55 DE GTO hours)
– Southern Hemisphere Deployment in June-July (two instrument baseline)

Program Manager considering changes to series and flight cadences
Science Capabilities Updates

- **upGREAT 4GREAT and LFA/HFA configurations** – commissioning Summer 2017
  - Enabled by the cryo-cooler upgrade
  - 4 GREAT (0.492–0.635, 0.892–1.1, 1.2–1.5, 1.81–1.91 THz)
  - LFA 1.9 – 2.5 THz (14 pixels) OH lines, [CII], CO series, [OI]
  - HFA 4.7 THz (7 pixels) [OI]

- **HIRMES**
  - Delta-PDR Mar 8 & 9, 2017
  - CDR Aug 14, 2017
  - Commissioning Spring 2019
  - $R = 600-100,000$ over 25-122 $\mu$m
  - Characterize mass of gas, water vapor, water ice, measure ice to rock mass in protoplanetary disks, H/D ratios in stellar outflows, high states in the CO ladder to probe structure & kinematics of AGB stars, ...
If you were awarded 200 hrs on SOFIA or a series of many balloon campaigns what would you do with that time? 
What science areas are not being addressed by our current far-IR (20-600 micron) platforms? 
Where are our critical technology gaps?

We want to hear from you! Please bring your answers to those questions, and share your ideas to shape how we collect future Far-IR data at the Far Infrared Next Generation Instrumentation Community Workshop, at Caltech, on Thursday March 23, 2017, 8:30am-5pm PST.
Instrumentation Updates (cont.)

NASA Next Generation Instrument Call
- Far Infrared Community Workshop, Caltech, Pasadena, CA: March 23, 2017
- Details https://www.cfa.harvard.edu/~mmacgreg/FIR_SIG/workshop.html

- Call for new SOFIA Instruments in ROSES-2017
The 2018 Senior Review is a new opportunity to describe SOFIA's scientific future.

- The Senior Review is part of the normal review process for all NASA missions in operations.
- Presents a unique opportunity to propose SOFIA for continued extended mission operations; i.e. post-prime mission.
- Central to the proposal must be a unified, integrated science proposal that will serve as the new science vision for the future.
2017 is key for Senior Review – Must Publish!!!!!

- As of Feb 28, 2017
- Not counting SPIE, AAS Abstracts.
SOFIA Today

- SOFIA is now the world’s prime access to 30-300 $\mu$m part of the spectrum.
- SOFIA provides for high-resolution mid-far IR spectroscopy (no other space mission can do that)
- SOFIA provides FIR polarimetry

- **Future instrumentation** could get us a factor of 3 in sensitivity. That is huge!
- We can be in the science regime Herschel opened up for us.

- How can we use SOFIA as that bridge between JWST & ALMA?
- How can we use SOFIA to fill in the gaps left by Herschel & Spitzer?

- Let’s fill in vital missing information (FIR structure lines, energetics, thermal emission, **eager to hear results from this conference**) in this “era of complicated datasets.”
As we direct the Observatory to a Shared Vision, to be summarized in our upcoming Senior Review Proposal to NASA.

- What are the questions?
- What specific questions will we tackle in the next 5 years? Where will we fill the gaps explicitly? How will we do it?
- Then looking back at those 5 years, did we achieve what we set out to do?
- Can SOFIA continue to answer those specific questions? How then can we push forward for the next, next 5 years?

I look forward to getting to know this community and listen for those questions to shape the Shared Vision.

Kimberly.Ennico@nasa.gov
Die fliegende Sternwarte SOFIA

https://www.youtube.com/watch?v=km2c79_Pqwg
### Cycle 5 Daily Overview – Page 1 of 2

#### Cycle Start
- **Cycle 5 Start**

#### Cryo Decision Gate
- **February – 2017**

#### Europa

#### Cryo Decision Gate
- **March – 2017**

#### Cycle 5 F (EXES)
- **April – 2017**

#### Cycle 5 G (upGREAT NHALFA)
- **May – 2017**

#### Cycle 5 H (upGREAT)
- **June – 2017**

#### Key
- **Observing Cycle: 5**
- **Baseline Science Flights: 102**
- **Baseline RHs: 758**
- **Planned Science Flights: 104**
- **Estimated RHs*: 766**
- **(Year to date + Estimate)**

#### Eng LO
- **Safety**
- **Seek Flt**
- **OC#4 (upGREAT) 7 Flights**
- **OC#5 (upGREAT) N (upGREAT) 6 Flights**

#### Cycle 5 Daily Overview – Page 1 of 2

#### Key
- **Weekend day**
- **Work day**
- **AFRC Regular Day Off**
- **FDA**
- **M**
- **P**
- **Weekend day**
- **Work day**
- **AFRC Regular Day Off**
- **FDA**
- **M**
- **P**

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#### Key
- **Observing Flight**
- **Instr. Commissioning Flight**
- **Line Operations**
- **Deployment Observing Flights**

#### Key
- **S**
- **T**
- **M**
- **W**
- **T**
- **F**
- **S**

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# Cycle 5 Daily Overview – Page 2 of 2

## Key Observing Cycle: 5

<table>
<thead>
<tr>
<th>Observation Cycle: 5</th>
<th>Baseline Science Flights: 102</th>
<th>Baseline R.Hs: 758</th>
<th>Planned Science Flights: 104</th>
<th>Estimated R.Hs*: 766</th>
<th>PMB sequence approval: 2/13/17</th>
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## Tour Eclipse

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<th>Maintenance / Upgrades #14</th>
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## Cycle 6 Start

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<tr>
<th>OC#5 J (FORCAST)</th>
<th>Prep</th>
<th>Ferry PMD</th>
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## Tributes / Occurs

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## Maintenance / Upgrades #15 w/ 'C' Check

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<td>20 21 22 23 24</td>
<td>25 26 27 28 29</td>
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## Cycle 5 Baseline Science Flights: 102

### Observations

- **Ferry PMD**: (black text with no fill)
- **Instr. Commissioning Flight**: (black/white text, purple fill, bold border)
- **Observing Flight**: (black/white text, light blue fill, bold border)
- **Ferry Maint./Non-Sci Flight**: (black/white text, green fill, bold border)
- **Short Flight**: (colored fill only lower half, bold bdr.)
- **Half Sci. & Half Ferry Maint./Non-Sci Flight**: (two colored fill)
- **Media/VIP Flight**: (black/white text, yellow fill)
- **Communications Flight**: (black/white text, green fill, bold border)
- **Strategic Capacity Flight**: (orange fill on day of week)

### Observations (cont.)

- **Educator on Flight**: (white/gray text, black fill)
- **C-Check / Warranty CPCP / Deferred Items**: (black/white text, gray fill)
- **C-Check / Warranty CPCP / Deferred Items (planned)**: (black/white text, gray fill)
- **C-Check / Warranty CPCP / Deferred Items (actual)**: (black/white text, gray fill)
- **PMB Approved**: (black/white text, green fill, bold border)

## Cycle 6 Start 6 Flights

### Observations

- **Ferry PMD**: (black text with no fill)
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- **Communications Flight**: (black/white text, green fill, bold border)
- **Strategic Capacity Flight**: (orange fill on day of week)

## Cycle 6 End

### Observations

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- **PMB Approved**: (black/white text, green fill, bold border)
Cycle 5

- 7 Instruments in Use
- 3 New Capabilities (HAWC+, upGREAT 4G/HFA and LFA/HFA)
- 3 Instrument Southern Deployment (upGREAT, FIFI-LS, FORCAST)
Cycle 5 Highlight – Galactic Center

Four very highly rated proposals were selected to investigate the Galactic Center with upGREAT

- **[CII] Mapping**
  - 05_0076  Bally – “Impact Program: The Outer CMZ C+ Survey”
  - 05_0022  Harris & 05_0033 Guesten – “Joint Impact Proposal: Mapping C+ Across the Galaxy's Central Molecular Zone”

- **[O I] Mapping**
  - 05_0021  Ragan – “Cooling and kinematics in the Central Molecular Zone”
  - 05_0102  Morris – “Characterizing Neutral Gas in the Central Parsec of the Galaxy”
Comparison of Mapped Regions

Yellow: 05_0076 Bally
White: 05_0022/0033 Harris-Güsten
Ragan and Morris Fields

White Boxes: 05_0022 Ragan
Yellow Box: 05_0102 Morris
Cycle 5 Highlight – Water on Europa

• 05_0153 Sparks “Confirmation of Water Plumes on Europa”
• Observations with EXES at 6.27 μm (H₂O vibrational band) to confirm HST observations of water plumes on the moon of Jupiter.
  • SOFIA observations Mar 15 & May 26
  • HST observations Mar 12 & 23
• These observations would provide input to a future Europa probe mission.
Cycle 5 Highlight - Occultation of Triton

• **05_0125 Person – “A New Look at Triton's Atmosphere”**
• To characterize the atmosphere of Neptune’s moon Triton. Monitoring of Triton’s expanding atmosphere has not been re-examined since 2001.
• **FLITECAM/HIPO** observations of Trion occulting a R=12 mag star Oct 6, 2017.
• Will be conducted using GTO time.
• Requires a mini-deployment to the US East Coast.
Cycle 5 Highlight - High Resolution Spectral Survey

- 05_0043 Naseem Rangwala
  An EXES High-Resolution Molecular Line Survey towards Orion IRc2, a prototypical hot-core source.
- Unprecedented resolving power ($R = 50,000$) will be 5 to 50 times more powerful than ISO in identifying narrow lines.
- Study will provide a wealth of information on hot core chemistry.

![SOFIA Cycle 5 Highlight - High Resolution Spectral Survey Diagram]

- Spectrum from Cycle 3 pilot program toward IRc2
- Likely molecules from hot core models
Cycle 5 Highlight - Studying Magnetic Fields

- 05_0133 Novak - “Joint HAWC+/ALMA study of magnetic fields in Ophiuchus”
- HAWC+ will have 35x better angular resolution than the Planck polarimeter and provides a bridge to the very much higher resolution observations of ALMA

Large scale B-field directions from Planck 850 µm polarimetry superposed on Herschel 160 µm dust emission. Individual targets are being studied using ALMA.
State of the Observatory

Program Completed Science Cycle 4 on February 3, 2017
– Satisfied Level 1 Req to provide 80% of planned research hours (646 RHs)
<table>
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<tr>
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<th>Cycle 1</th>
<th>Cycle 2</th>
<th>Cycle 3</th>
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<td><strong>Hours Executed</strong></td>
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* Does not include "Do If Time"  

As of 1 Oct 2016