NASA Program Plans for Sub-millimeter Wave Astronomy

Mike Kaplan
Chief, Advanced Programs Branch
Astrophysics Division
Office of Space Science and Applications
NASA Headquarters

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Outline of Presentation

- NASA's Astrophysics Program
- Planned Missions
- Technology Requirements for Future Missions
- Comments and Summary
Program Goal

Conduct a comprehensive exploration of the universe

Themes:
- Astronomy: What is the nature of planets, stars and galaxies?
- Cosmology: What is the origin and fate of the universe?
- Physics: What are the laws of physics in the extreme conditions of astrophysical objects?
Program Strategy

- Contemporaneous observations across the electromagnetic spectrum with high sensitivity, high angular resolution and high spectral resolution
  - Implemented through the Great Observatories
- Fill in crucial gaps in "wavelength" or "spectroscopy" space
  - Implemented through Explorers and moderate missions
- Maintain National science and technology capability
  - Implemented through grants, sub-orbital program and technology development
- Analyze and publish results
  - Implemented through Mission Operations and Data Analysis program
Science Planning Process

- Strong grass roots community involvement in our program
  - Four Management Operations Working Groups (MOWGs) plus "Astrophysics Council"
- National Academy of Sciences
  - Committee on "Space Astronomy and Astrophysics"
    - 10 year strategy from "Bahcall report" to be released March 19, 1991
      - Prioritizes all National astronomy programs
- Integrate astrophysics initiatives into OSSA program plan
Great Observatories

- Hubble Space Telescope (HST)
- Gamma Ray Observatory (GRO)
- Advanced X-ray Astrophysics Facility (AXAF)
- Space Infrared Telescope Facility (SIRTF)
Sub-millimeter Astronomy Missions

- Kuiper Airborne Observatory (KAO)
- Sub-millimeter Wave Astronomy Satellite (SWAS)
- Stratospheric Observatory for Infrared Astronomy (SOFIA)
- Sub-millimeter Moderate Mission (SMMM)
- Large Deployable Reflector (LDR)
- Sub-millimeter Interferometer
**Science Strategy:** SWAS will perform both pointed and survey observations in 4 lines crucial to the study of interstellar cloud chemistry, energy balance and structure: 487, 557, 492 and 551 GHz

**Description:**
- 3 axis stabilized, stellar-pointing "Small Explorer" spacecraft (Scout-class)
- 530 km altitude, 3 degree inclination angle orbit
- 55 cm off-axis Cassegrain antenna, passively cooled heterodyne receivers and acousto-optical spectrometer

**Launch Date:** 1995

**Principal Investigator/Payload List:**
- PI -- Dr. Gary Melnick, SAO
- Antenna, Star Tracker, Instrument Integration -- Ball Aerospace
- Sub-millimeter Heterodyne Receiver -- Millitech
- Acousto-optical Spectrometer -- University of Cologne

**NASA Program Manager:** Dr. David Gilman, NASA HQ
Stratospheric Observatory for Infrared Astronomy (SOFIA)

- **Science Strategy:** SOFIA will provide frequent, high-quality access to the IR/sub-mm spectral region

- **Description:**
  - 2.5 m Nasmyth IR telescope housed in a modified Boeing 747 SP aircraft
  - Operates from 0.3 to 1600 microns
  - Sensitivity ~ $10^{-19}$ W/cm$^2$/SR
  - Angular Resolution: 2 arcsec in near IR and diffraction limited at wavelengths > 30 microns
  - 120 flights/year with 30 - 40 research teams/year

- **Launch Date:** 1998

- **Technology Development Requirements:**
  - Lightweight f/1 primary mirror (Zeiss)
  - Shear layer control
  - Large air bearing

- **NASA Program/Project Manager:** Mike Kaplan, NASA-HQ / Dr. Gary Thorley, NASA-ARC
Sub-millimeter Moderate Mission (SMMM)

- **Science Strategy**: SMMM will be a spectral survey of selected objects from 100 - 750 microns and imaging in the 100 - 300 micron range
- **Description**:
  - 2.5 to 4 m segmented, ambient temperature aperture
  - High orbit, 2 year lifetime
  - Liquid He-cooled focal plane
    -- Fabry-Perot spectrometer with 0.1 deg K bolometers
    -- IR camera with 0.3 deg K bolometers
    -- Ten-band heterodyne radiometer operating at 2 deg K
- **Mission Options**: Explorer-class (2.5 m aperture, spectroscopy only), CNES and/or ESA collaboration
- **Launch Date**: 2001?
- **Technology Development Requirements**:
  - SIS mixers, heterodyne receivers with sensitivities within a factor of 5 of the quantum limit and local oscillators with increased conversion efficiency
  - Far IR integrating arrays (impurity band conduction technology)
  - Bolometers
  - Lightweight precision aperture
- **Science Working Group Chairman**: Dr. Tom Phillips, Caltech
Large Deployable Reflector (LDR)

Science Strategy: LDR will view sources in the wavelength region between 30 and 3000 microns.

- 20 m class diameter antenna for imaging spectroscopy and photometry
- Composed of 90 lightweight, hexagonal panels, 4 mirror, two-stage optical system
- Diffraction limit < 50 microns
- Spectral resolving limit from 10 to 10^5
- Angular resolution of 1 arcsec at 100 microns
- Sensitivity > 2 x 10^{-14} W/cm^2/SR

Launch Date: 2009 ??

Technology Development Requirements:
- Lightweight mirror segments
- Active figure control
- Heterodyne receivers with SIS mixers
- Long lifetime cryogenics

NASA POC: Dr. Larry Caroff, NASA-HQ
Sub-millimeter Interferometer (SMMI)

- **Science Strategy:** SMMI will view sources in the wavelength region between 30 and 1000 microns with 100x better resolution than any other existing or proposed instrument. Based at lunar outpost

- **Description:**
  - Two-dimensional array of 5-meter antennas distributed on baselines from 50 m to several km
  - Actively-cooled, superheterodyne receivers
  - Spectral resolving limit from 10 to $10^6$ over the entire spectrum 10 GHz BW
  - Angular resolution of 10 milliarcsec at 100 microns

- **Launch Date:** 2013 ??

- **Technology Development Requirements:**
  - High throughput correlators
  - Lightweight materials that operate at 100 deg K and cycle to 385 deg K
  - Fiber-optics
  - Telerobotic operation

- **NASA POC:** Mike Kaplan, NASA-HQ
Sample Mission Schedule for Major Astrophysics Space Observatory

Mission Phase

Pre-Phase A  Phase A  Phase B  Phase C/D  Operations

Science Req'ts.
Definition
Mission / System
Definition
Critical Technologies
Identification
Technology Development
Optics
Instruments
(Detectors/Sensors)
Spacecraft Systems
Full-Scale Development,
Fabrication & Test
Mission Operations &
Data Analysis

Funding Profile


Δ 10%
Technology Requirements for Sub-millimeter Astronomy Missions

- **Sub-millimeter Heterodyne Receivers**: Develop robust, space-qualifiable heterodyne technology for extension into the terahertz regime, increased sensitivity and array applications
  
  - Local oscillator power of 50 microwatts to 20 mW for 200 GHz to 1 THz
  
  - Mixers with noise performance $< 10$ x quantum limit @ $> 600$ GHz to 3 THz
  
  - Low power, smaller size, larger bandwidth spectrometer concepts for space
  
  - Focal plane arrays covering 100 GHz to 2 THz

- **Sub-millimeter Apertures**: Develop large, precise lightweight segmented apertures up to 30 m in diameter with excellent thermal characteristics - NASA OAET Precision Segmented Reflector (PSR) program

- **Others**:

  - Space cooler and cryogenic technology - to support long duration missions
• Release of Augustine report has caused new emphasis on space science within NASA

• We will see a revolution in space astronomy over the next decade

• NASA has ambitious plans to explore the universe in sub-millimeter portion of the electromagnetic spectrum

• These missions are enabled with the development of new sub-millimeter wave technology

• Exciting times for sub-millimeter wave astronomy are around the corner!!