SIG 3 ExoSS Synergies

Victoria Meadows (UW/NExSS/ExoPAG), Kathy Mandt (JHU/APL/OPAG)

Presentation by L. Mayorga (JHU/APL)
SIG 3 ExoSS Overview

• Chairs:
  • Victoria Meadows (UW/NExSS/ExoPAG)
  • Kathy Mandt (JHU/APL/OPAG)

• Founding Members:
  Giada Arney (GSFC/VExAG EC, ExoPAG)  Tiffany Kataria (JPL/Caltech, ExoPAG EC)
  Chuanfei Dong (Princeton)              Mark Marley (Ames)
  Tony Del Genio (GISS/retired)          Niki Parenteau (Ames)
  Shawn Domagal-Goldman (GSFC)           Abi Rymer (JHUAPL, OPAG EC)
  Noam Izenberg (JHUAPL, VExAG Deputy Chair)  Karl Stapelfeldt (JPL)
  Stephen Kane (UCR, VExAG, ExoPAG)
SIG 3 ExoSS Overview

• **Goal:** To provide a forum for interaction between the Solar System and exoplanet communities on topics of mutual interest, and to work to identify ways in which NASA and the scientific community could enhance these interactions.

• SIG3 is a mechanism to continue the community dialog started with the cross-P/AG organized Exoplanets in our Backyard Conference (Feb 5-7, 2020, Houston).
  • Findings: [https://www.hou.usra.edu/meetings/exoplanets2020/EioB-Findings.pdf](https://www.hou.usra.edu/meetings/exoplanets2020/EioB-Findings.pdf)

• SIG3 approved on March 26, 2020. Held its inaugural meeting on July 14.

• SIG3 is now open to all interested scientific community members (please contact meadows@uw.edu or Kathleen.Mandt@jhuapl.edu to join)
SIG 3 ExoSS Activities

• ExoSS Slack Channel
  • news updates, paper-sharing, collaborations, all are welcome!
  • 193 members (If you would like to join: meadows@uw.edu or slack link at the end)
SIG 3 ExoSS Activities

• Gathering community input on key ExoSS synergies: https://tinyurl.com/yxbnyfwu
  • This document started as notes from the unconference session at EioB and is now being used as a resource for new initiatives.

• Promoted community-led Planetary Decadal activities:
Exoplanets in Our Backyard

Solar System and Exoplanet Synergies on Planetary Formation, Evolution, and Habitability

Feb 5–7 2020 Houston, Texas

A joint Assessment Group meeting by VEXAG, OPAG, and ExoPAG
• EioB 1.5 organized and held at 2020 Winter AGU.

• This session focused on lab/field/Solar System observations and what they could bring to exoplanetary science (and vice versa!)

• 40 participants
Exoplanets in Our Backyard 2

Nov 2–4
2022  Pasadena, California/Virtual
A joint Assessment Group meeting by VEXAG, OPAG, ExoPAG, MEPAG, and MExAG

Conveners: Ravi Kopparapu and Stephen Kane
Abstracts: August 19, 2022

https://www.hou.usra.edu/meetings/exoplanets2022/
SIG 3 ExoSS Activities

• Input to ExoPAG Science Gap List (also input to VEXAG GOI by SIG3 members)
• Helped coordinate speakers for the ExoPAG23 ExoSS Science Symposium
SIG3 ExoSS Tutorial Talks

Exoplanet Solar System Synergies
This webpage is provided to help promote community efforts on breaking down traditional barriers to collaboration between the exoplanet and Solar System communities. Recent and current efforts include tutorial talks to help demystify key aspects of Solar System and exoplanet science, and dedicated workshops to help identify productive avenues for future collaboration between the exoplanet, Solar System, heliophysics, and Earth science communities.

ExoPAG Science Interest Group 3 Tutorial Talks

The ExoPAG Science Interest Group 3 on Exoplanet Solar System synergies is supporting and organizing Tutorial Talks aimed at introducing field newcomers to important topics or methods in planetary and exoplanetary science. The talks include a 30-minute tutorial from an expert to introduce the topic, followed by a 30-minute group discussion of a recent paper in which the topic/method features.

Recordings of Past Presentations:

- August 2020 – Volatile Solubilities in Rocks – Laura Schaefer
- September 2020 – How to Leverage NASA’s Planetary Data System Atmospheres Node for Exoplanet Science – Nancy Chanover
- October 2020 – The advantages and Challenges of M Dwarfs as Planet Hosts – Elisabeth Newton
- February 2021 – How to “See” the Atmosphere of a Transiting Exoplanet – Laura Kreidberg
- April 2021 – What We Learn from the Clouds on Giant Planets – Amy Simon / Clouds and Hazes in the Atmospheres of Terrestrial Exoplanets – David Crisp
- May 2021 – Round-up of Exoplanets and Disks – JWST Cycle 1 GO Programs – Johanna Teske
- June 2021 – Titan and Solar System Science with the James Webb Space Telescope – Conor Nixon
- NEW December 9, 2021 – Convective Cooling of Planetary Interiors – Johnny Seales
- NEW March 17, 2022 – Solar System Studies of Atmospheric Escape – Shannon Curry

- Initiated monthly SIG3 Tutorial/Journal Club to explain key concepts within our different scientific communities
- All talks recorded and available here: https://nexss.info/exoss-synergy/
- Organized by: Laura Schaefer, Vikki Meadows, Kathy Mandt, and Mark Marley
Decadal Synergies

Astrophysics

Pathways to Discovery in Astronomy and Astrophysics for the 2020s

Planetary

Origins, Worlds, and Life

A Decadal Strategy for Planetary Sciences and Astrobiology 2023-2028
Exoplanet/Solar System Synergy, Decadal Edition

Pathways to Discovery in Astronomy and Astrophysics for the 2020s
Steering Committee “friends of exoplanets”:
Jonathan Fortney, Bruce MacIntosh, Keivan Stassun, Rachel Osten

Panel on Exoplanets, Astrobiology, and the Solar System

The Panel on Exoplanets, Astrobiology, and the Solar System will identify and articulate the scientific themes that will define the frontier in research of exoplanets, astrobiology, and the solar system in the 2022-2032 decade. Its scope will include the detection, demographics, and physical characteristics of exoplanets, solar system observations relevant to Astro2020, astrobiology, stellar phenomena and activity that impact detectability and characterization of exoplanets, and effects of stellar activity on the evolution and habitability of planets. The panel will consider as inputs the congressionally mandated reports Exoplanet Science Strategy and An Astrobiology Strategy for the Search for Life in the Universe.

EASS Panel Members: Victoria Meadows, David Brain, Ian Crossfield, Courtney Dressing, Jonathan Fortney, Tiffany Kataria, Kathy Mandt, Mark Marley, Britney Schmidt, Chris Stark.

And THIS panel was informed by white papers, and the 2018 Exoplanet (Charbonneau, Gaudi) and Astrobiology (Sherwood-Lollar) Strategies....
Highlights on the Planetary Decadal

Decadal Process

- > 500 white papers received (summer 2020)
- 153 Panel and 23 steering group meetings (fall 2020 to fall 2021)
  - > 300 presentations by external speakers in open sessions
- Key Milestones:
  - Review of white papers and Planetary Mission Concept Study reports (Fall 2020)
  - Identification of priority science questions (Fall 2020)
  - Definition of 9 additional mission concepts & new study completion (Fall 2020 – Winter 2021)
  - Prioritization of mission concepts for TRACE (Spring 2021)
  - Prioritizations and high-level recommendations (Summer – Fall 2021)
  - Draft report to Academies and external review (November – December 2021)
  - Response to 23 external reviews and final report approval (January – March 2022)
<table>
<thead>
<tr>
<th>Themes</th>
<th>Priority Science Question Topic and Scope</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A) Origins</strong></td>
<td>Q1. Evolution of the protoplanetary disk What were the initial conditions in the Solar System? What</td>
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<tr>
<td></td>
<td>processes led to the production of planetary building blocks, and what was the nature and evolution of</td>
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<td></td>
<td>these materials?</td>
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<td>Q2. Accretion in the outer solar system How and when did the giant planets and their satellite systems</td>
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<td>originate, and did their orbits migrate early in their history? How and when did dwarf planets and</td>
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<td>cometary bodies orbiting beyond the giant planets form, and how were they affected by the early evolution</td>
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<td>of the solar system?</td>
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<td></td>
<td>Q3. Origin of Earth and inner solar system bodies How and when did the terrestrial planets, their</td>
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<td></td>
<td>moons, and the asteroids accrete, and what processes determined their initial properties? To what</td>
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<td></td>
<td>extent were outer Solar System materials incorporated?</td>
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<td><strong>B) Worlds &amp; Processes</strong></td>
<td>Q4. Impacts and dynamics How has the population of Solar System bodies changed through time, and how</td>
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<td>has bombardment varied across the Solar System? How have collisions affected the evolution of</td>
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<td>planetary bodies?</td>
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<td>Q5. Solid body interiors and surfaces How do the interiors of solid bodies evolve, and how is this</td>
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<td>evolution recorded in a body’s physical and chemical properties? How are solid surfaces shaped by</td>
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<td>subsurface, surface, and external processes?</td>
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<td>Q6. Solid body atmospheres, exospheres, magnetospheres, and climate evolution What establishes the</td>
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<td>properties and dynamics of solid body atmospheres and exospheres, and what governs material loss to</td>
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<td>space and exchange between the atmosphere and the surface and interior? Why did planetary climates</td>
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<td>evolve to their current varied states?</td>
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<td>Q7. Giant planet structure and evolution What processes influence the structure, evolution, and dynamics</td>
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<td>of giant planet interiors, atmospheres, and magnetospheres?</td>
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<td>Q8. Circumplanetary systems What processes and interactions establish the diverse properties of</td>
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<td>satellite and ring systems, and how do these systems interact with the host planet and the external</td>
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<td></td>
<td>environment?</td>
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<tr>
<td><strong>C) Life &amp; Habitability</strong></td>
<td>Q9. Insights from Terrestrial Life What conditions and processes led to the emergence and evolution of</td>
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<td>life on Earth, what is the range of possible metabolisms in the surface, subsurface and/or atmosphere,</td>
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<td>and how can this inform our understanding of the likelihood of life elsewhere?</td>
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<td>Q10. Dynamic Habitability Where in the solar system do potentially habitable environments exist, what</td>
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<td>processes led to their formation, and how do planetary environments and habitable conditions co-evolve</td>
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<td>over time?</td>
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<td>Q11. Search for life elsewhere Is there evidence of past or present life in the solar system beyond</td>
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<td></td>
<td>Earth and how do we detect it?</td>
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<tr>
<td><strong>All Themes</strong></td>
<td>Q12. Exoplanets What does our planetary system and its circumplanetary systems of satellites and rings</td>
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<td>reveal about exoplanetary systems, and what can circumstellar disks and exoplanetary systems teach us</td>
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<td>about the solar system?</td>
</tr>
</tbody>
</table>
Planetary Decadal

- Long (781 pages)
- How to read table

TABLE 1.2 A Guide to Reading This Report

<table>
<thead>
<tr>
<th>Topic</th>
<th>Primary Discussion</th>
<th>Additional Discussion</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Issues Related to Nine Priority Topics Identified in the Statement of Task</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>1. Overview of planetary science, astrobiology, and planetary defense</td>
<td>Chapter 1</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>2. Broad survey of the current state of knowledge</td>
<td>Chapter 2</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>3a. Compelling questions, goals and challenges for planetary science</td>
<td>Chapters 3 to 11</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>3b. Ditto astrobiology</td>
<td>Chapters 3 and 12-14</td>
<td>Chapter 22</td>
<td>n/a</td>
</tr>
<tr>
<td>3b. Ditto planetary defense</td>
<td>Chapter 18</td>
<td>Chapter 22</td>
<td>Chapter 18 and 22</td>
</tr>
<tr>
<td>4a. Recommended research traceable to objectives and goals</td>
<td>Chapters 4 to 15</td>
<td>Chapter 22</td>
<td>n/a</td>
</tr>
<tr>
<td>4b. Recommended missions traceable to objectives and goals</td>
<td>Chapter 22</td>
<td>Appendix C</td>
<td>Chapter 22</td>
</tr>
<tr>
<td>5a. Comprehensive research strategy for planetary science, astrobiology and planetary defense</td>
<td>Chapter 22</td>
<td>n/a</td>
<td>Chapter 22</td>
</tr>
<tr>
<td>5b. Timing, cost, risk, and technical readiness of recommended missions</td>
<td>Chapter 22</td>
<td>Appendix C</td>
<td>n/a</td>
</tr>
<tr>
<td>6. Decision rules</td>
<td>Chapter 22</td>
<td>n/a</td>
<td>Chapter 22</td>
</tr>
<tr>
<td>7a. Human Exploration</td>
<td>Chapter 19</td>
<td>Chapter 22</td>
<td>Chapters 19 and 22</td>
</tr>
<tr>
<td>7b. International Cooperation</td>
<td>Chapter 1</td>
<td>n/a</td>
<td>Chapter 22</td>
</tr>
<tr>
<td>8. Intra- and inter-agency collaboration</td>
<td>Chapters 1 and 19-21</td>
<td>Chapter 22</td>
<td>Chapters 19 and 22</td>
</tr>
<tr>
<td>9. State of the Profession</td>
<td>Chapter 16</td>
<td>Chapter 22</td>
<td>Chapters 16 and 22</td>
</tr>
</tbody>
</table>

Other Topics Discussed in the Report

- Apollo 2029 encounter
  - Chapter 18 | n/a | n/a |
- Aresibo
  - Chapter 18 | Chapter 19 | Chapter 22 | Chapters 18 and 22 |
- Artemis Program
  - Chapter 19 | Chapter 22 | Chapters 19 and 22 |
- Budgetary projections
  - Chapter 22 | n/a | n/a |
- Deep Space Network
  - Chapter 19 | n/a | n/a |
- Discovery program
  - Chapter 22 | n/a | Chapter 22 |
- Europa Clipper
  - Chapter 22 | n/a | Chapter 22 |
- Ground-based and space-based telescopes
  - Chapter 20 | Chapter 18 and Appendix E | n/a |
- International Mars Ice Mapper
  - Chapter 22 | Chapter 19 | Chapter 22 |
- Launch vehicles
  - Chapter 20 | Chapter 22 | Chapter 22 |
- Lunar Exploration and Discovery Program
  - Chapter 22 | Chapter 19 | Chapter 22 |
- Mars Exploration Program
  - Chapter 22 | n/a | Chapter 22 |
- Mars Sample Return
  - Chapter 22 | n/a | Chapter 22 |
- Mission studies, PMCS and SDT
  - Chapter 18 | Appendix B | n/a |
- Mission studies, future
  - Appendix C | n/a | n/a |
- Mission studies, decadal survey
  - Appendix C | Appendices D and E | n/a |
- New Frontiers program
  - Chapter 22 | n/a | Chapter 22 |
- NSF facilities and programs
  - Chapter 20 | Chapter 1 | n/a |
- Planetary Data System
  - Chapter 17 | n/a | Chapter 17 |
- Planetary radar facilities
  - Chapter 18 | Chapter 22 | Chapters 18 and 22 |
- PIA193
  - Chapter 20 | Chapter 22 | Chapters 20 and 22 |
- Research and Analysis Programs
  - Chapter 17 | Chapter 22 | Chapters 17 and 22 |
- Sample receiving and curation facilities
  - Chapter 20 | Chapter 22 | Chapter 22 |
- SIMPLEX program
  - Chapter 22 | n/a | Chapter 22 |
- Technology development
  - Chapter 21 | Chapter 22 | Chapters 21 and 22 |
- Technical risk and cost evaluation
  - Appendix C | Chapter 22 | n/a |
- White papers received
  - Appendix B | n/a | n/a |
Highest priority new flagship: Uranus Orbiter and Probe

- In situ probe & multi-year orbital tour: atmosphere, interiors, magnetosphere, rings, and satellites
- First dedicated study of class of planets that may be most common in the universe
- Technically ready to start now
- Launch on Falcon Heavy Expendable
  - Optimal launch in 2031-2032 with Jupiter gravity assist to shorten cruise to 12 to 13 yrs
    - Flexible launch opportunities through 2038 with increased ~ 15 yr cruise and inner solar system gravity assists
- Strong international interest & potential for partnership (e.g., 2021 report of ESA’s Voyage 2050 Senior Committee)
Q2: Accretion in the Outer Solar System  ← Priority Science Question Topic

Q2.1 How did the giant planets form? ← Most important sub-questions
  Q2.1a. What is the formation mechanism of gas giant planets? What were the accretion rates of solids (planetesimals/pebbles) and gas during the formation process? How long did it take?
  Q2.1b. How did Uranus and Neptune form and what prevented them from becoming gas giants?
  Q2.1c. What were the primordial internal structures of giant planets?

Strategic Research Q2.1: ← Strategic research needed to address each main sub-question

- **Determine the atmospheric composition of Saturn, Uranus, and Neptune** via in situ sampling of noble gas, elemental, and isotopic abundances, and remote sensing by spacecraft and ground/space-based telescopes.
- **Determine the bulk composition and internal structure of Uranus and Neptune** via gravity, magnetic field, and atmospheric profile measurements by spacecraft, as well as Doppler seismology.
- **Constrain physical properties and boundary conditions (i.e., tropospheric temperatures, shapes, rotation rates) for structure models of Uranus and Neptune** via gravity, magnetic field, and atmospheric profile measurements by spacecraft, remote sensing by spacecraft and ground/space-based telescopes.
- ........
15 QUESTION 12: EXOPLANETS
Q12.1 Evolution of the Protoplanetary Disk, 15-3
Q12.2 Accretion in the Outer Solar System, 15-5
Q12.3 Origin of Earth and Inner Solar System Bodies, 15-6
Q12.4 Impacts and Dynamics, 15-8
Q12.5 Solid Body Interiors and Surfaces, 15-9
Q12.6 Atmosphere and Climate Evolution on Solid Bodies, 15-11
Q12.7 Giant Planet Structure and Evolution, 15-14
Q12.8 Circumplanetary Systems, 15-15
Q12.9 Insights from Terrestrial Life, 15-16
Q12.10 Dynamic Habitability, 15-19
Q12.11 Search for Life Elsewhere, 15-21
Supportive Activities for Question 12, 15-22
References, 15-23
Supporting Activities for Question 12

- Observations of solar system planets and moons through transit spectroscopy and direct-imaging as analogs to exoplanet observations, including hemispherically averaged fluxes as a function of orbital phase and time; observations of particle and gas opacity in the giant planets and Venus as a function of phase angle to help determine the dependence of reflectivity and scattering on particles and clouds in exoplanet atmospheres; and ultraviolet-near-infrared-scattered light observations from the poles of the giant planets for comparison with future direct imaging of giant exoplanets.

- A census of protoplanetary disks, young planets, and mature planetary systems across a wide range of planet-star separations to determine how the initial composition and conditions in a protoplanetary disk influence the diversity of resulting planets.

- Improved spatial resolution of telescopic techniques to determine variations in the structure and composition of circumstellar disks, as well as the next-generation telescopes recommended by NASEM (2021) that will allow for observations of circumplanetary disks, detection of exomoons and ring systems, and characterization of exoplanets around sun-like stars.

- Laboratory studies to understand the relationship between the bulk composition of a planet and its atmosphere, and to determine the optical properties of clouds and hazes relevant to exoplanet atmospheres.

- Increased interactions between the astronomy and planetary science and astrobiology communities (supported under, e.g., NASA’s Planetary Science and Astrophysics divisions) are needed to maximize advances in exoplanetary science and to address the questions identified in this chapter. This point was emphasized in multiple white papers received by the committee.
2022 Planetary Mission Senior Review (PMSR22)

Missions reviewed: InSight, LRO, Mars Odyssey, MAVEN, MRO, MSL, New Horizons, and OSIRIS-REx (APEX).

- 2022 NASA Response to the Senior Review
- 2022 Final Report Package
- 2022 Call for Proposals
- 2022 Terms of Reference

Occurred prior to the decadal release!

https://science.nasa.gov/solar-system/documents/senior-review
• OSIRIS-APEX (APophis EXplorer) is arguably the most imaginative extended mission proposal of recent PMSRs, and the Review Chairs agree with the Panel scores. After the OREx Sample Return Capsule is released to Earth’s surface in 2023, the spacecraft will divert into an orbit around the Sun with remaining potential to observe other Near-Earth Objects (NEOs).

• Earth observations may even provide an opportunity for the Exoplanet community to collect data to improve their habitable world search models, however critical details of imaging “Earth as-an-analog” requires greater engagement with the exoplanet community to confirm viability.
OSIRIS-APEX - Excellent/Very Good

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Descoped
OSIRIS - APEX
Observing Plan

To observe Earth as an exoplanet analog during cruise. This goal involves repeated imaging of Earth at various wavelengths and phase angles, to expand understanding of observable discriminants for habitable environments.

Science Goals:
• Measure Earth's reflectivity throughout a continuous 24-h period over phase angles between 30° and 90°.
• Repeat the measurements during multiple Earth seasons.

Instruments:
• OCAMS
• OVIRS
• OTES

Figure D-7 Earth phase angles observed by APEX. During the cruise to Apophis, three EGA flybys present opportunities to image Earth in reflected light as an exoplanet analog and assess Earth’s rotational and seasonal variability. The points are color-coded by EGA (2025:blue, 2027:green, and 2029:red) and sized by the apparent pixel size of Earth in MapCam images.
How Can I Participate with SIG3?

• Get on the mailing list (email meadows@uw.edu)
• SIG3 tutorial recordings are here:
  • https://nexss.info/exoss-synergy/
• Exoplanets in our Backyard 2.0!
• Join the slack!
  • https://join.slack.com/t/exoss2/shared_invite/zt-1aa91dkp3-tlkfPRqF8K_xjRxIrGmB9A
  • (link good for 30 days)