VENUS EXPLORATION ANALYSIS GROUP

EXOPAG 30

5 MAY, 2024

NOAM IZENBERG, VEXAG CHAIR

PAC meeting
March 5, 2024

VEXAG

2023 Findings
Inter-AG findings doc
Upcoming Activities

Noam Izenberg	Applied Physics Laboratory, Chair
Debra Buczkowski	Applied Physics Laboratory, Dpty Chair
Siddharth Krishnamoorthy**	Jet Propulsion Laboratory, ECR
Sara Port**	Glenn Research Center, ECR
Chuanfei Dong	Boston University, ECR
Erika Kohler	Goddard Space Flight Center, ECR
Eric Grosfils	Pomona College
Daniel Nunes	Jet Propulsion Laboratory
Anna Gulcher	California Institute of Technology, ECR
Michael Way	Goddard Institute for Space Studies
Tracy Gregg	University of Buffalo
Alexander Akins	Jet Propulsion Laboratory, ECR
Kelsey Crane	Mississippi State University, ECR
Jacob Izraelevitz	Jet Propulsion Laboratory
Piero D'Incecco	National Institute for Astrophysics, Italy, ECR
Robbie Herrick	University of Alaska, Fairbanks
Ri Cao	Scribe
Nathan McGregor	Scribe
Darby Dyar	PSI, Mount Holyoke College, Emeritus
Nick Lang	NASA HQ, ex officio

VEXAG Three-Year Goals 2023-2025

WWW.LPI.USRA.EDU/VEXAG/

Develop Venus Exploration Strategy for the next decade with NASA

Work with missions and the international Venus community

Nurture the next generation of Venus scientists and engineers

Improve communication within Venus community and among the general public

Open meetings and public forums

FINDINGS
ENDORSEMENTS
QUESTIONS 2023

VEXAG

https://tinyurl.com/dkxxsswt

Cross-AG Findings document

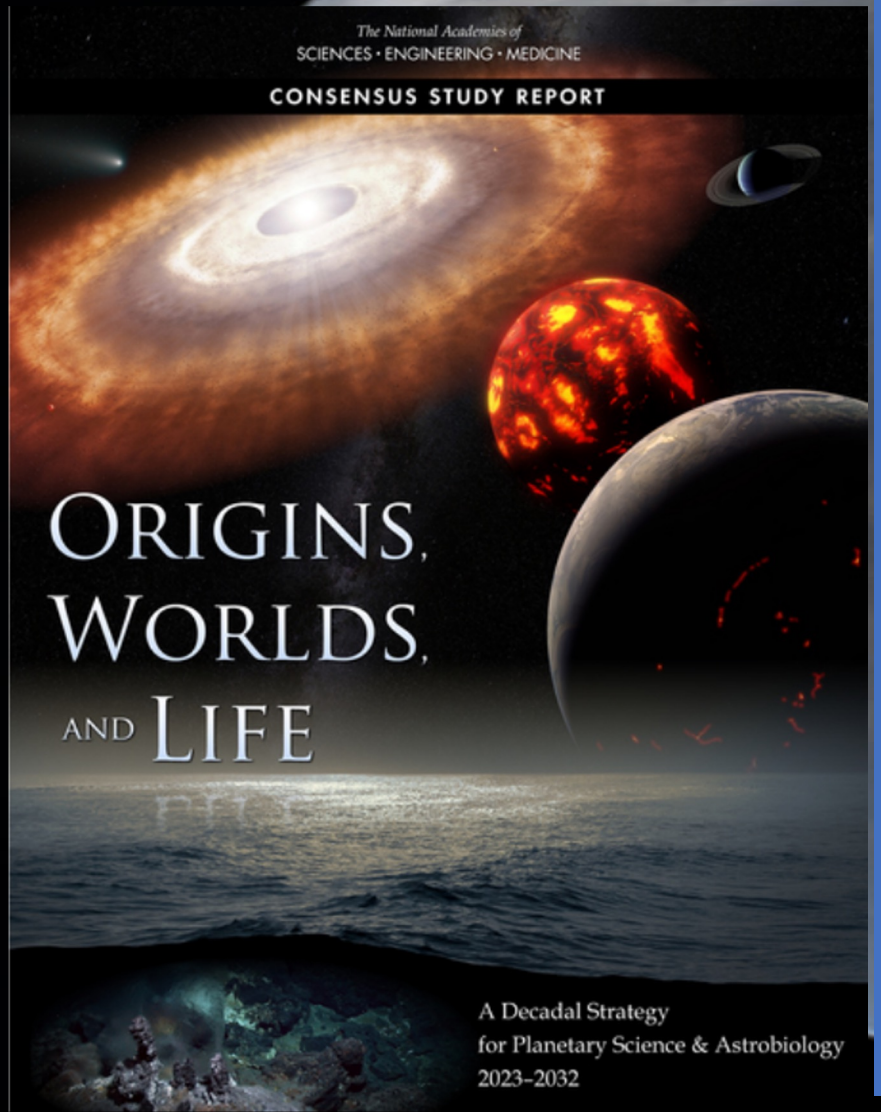
Intended as a reference for NASA Assessment Group [AG] leadership, HQ, and potentially other parties, so that latest findings can be accessed, referred to, and potentially commented upon and discussed with individual AGs and the Cross-AG leadership.

As of 5/4/2024: VEXAG, XAG EDIA WG, and SBAG have findings/draft findings on doc

VENUS AND EXOPLANETS

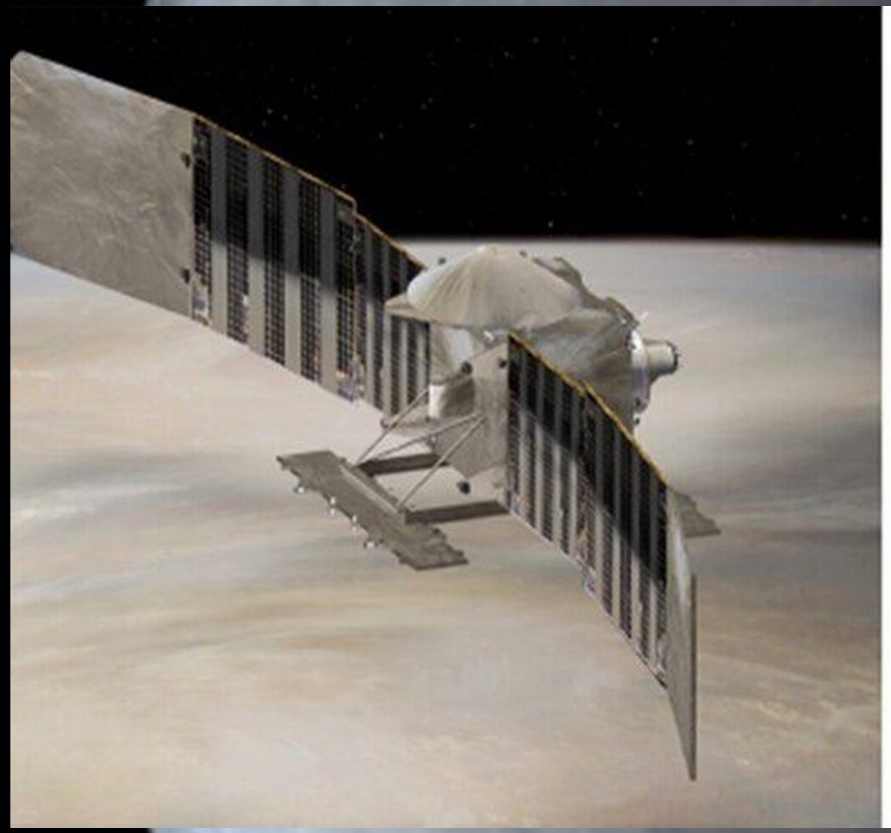
- LPSC had a number of talks with Venus Exoplanet Synergies:
  - Kane: Venus as an anchor point for planetary habitability
  - Kohler: Hot Environments Lab for Venus and Exoplanet Investigations
  - Weller: Venus' Climatic and Atmospheric Evolution from Geodynamic and Global Circulation Models
  - White: Thermodynamic Modeling of Alterations During Climate Transition Reveals Evidence of Past Temperate Conditions on Venus
- Exoplanets in our Backyard 2 was companion meeting to 20th VEXAG
- Exoplanets in our Backyard 3 is planned as companion meeting to 22nd VEXAG – Nov. 2024, Louisville KY
  - EioB 3: Nov 13-15; VEXAG Nov 18-19*
- Additional meetings and synergies (AbSciCon)
- Science Analysis Workgroups
  - Strategic documents
- Venus Exploration Strategy

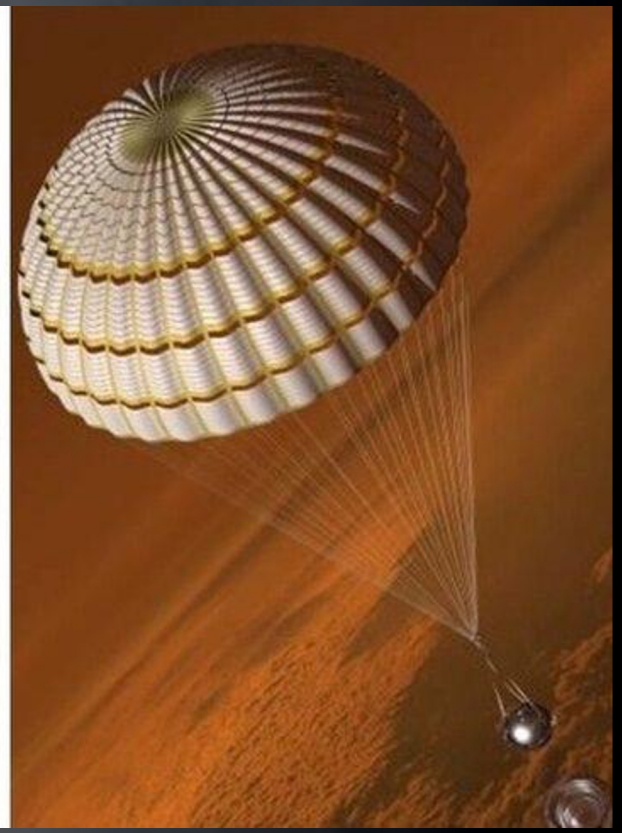
Venus in the Decadal Survey



Q #	OWL Theme with Venus Relevance
1.1	What Were the Initial Conditions in the Solar System?
1.2	How Did Distinct Reservoirs of Gas and Solids Form and Evolve in the Protoplanetary Disk?
1.3	What Processes Led to the Production of Planetary Building Blocks?
3.1	How and When Did Asteroids and Inner Solar System Protoplanets Form?
3.3	How Did the Earth-Moon System Form?
3.4	What Processes Yielded Mars, Venus, and Mercury and Their Varied Initial States?
3.5	How and When Did the Terrestrial Planets and Moon Differentiate?
3.6	What Established the Primordial Inventories of Volatile Elements and Compounds in the Inner Solar System?
4.2	How Did Impact Bombardment Vary with Time and Location in the Solar System?
4.4	How Do the Physics and Mechanics of Impacts Produce Disruption of and Cratering on Planetary Bodies?
5.1	How Diverse Are the Compositions and Internal Structures Within and Among Solid Bodies?
5.2	How Have the Interiors of Solid Bodies Evolved?
5.3	How Have Surface/Near-Surface Characteristics and Compositions of Solid Bodies Been Modified by, and Recorded, Interior Processes?
5.4	How Have Surface Characteristics and Compositions of Solid Bodies Been Modified by, and Recorded, Surface Processes and Atmospheric Interactions?
5.6	What Drives Active Processes Occurring in the Interiors and on the Surfaces of Solid Bodies?
6.1	How Do Solid-Body Atmospheres Form and What Was Their State During and Shortly after Accretion?
6.2	What Processes Govern the Evolution of Planetary Atmospheres and Climates Over Geologic Timescales?
6.3	What Processes Drive the Dynamics and Energetics of Atmospheres on Solid Bodies?
6.4	**How Do Planetary Surfaces and Interiors Influence and Interact with Their Host Atmospheres?**
6.5	What Processes Govern Atmospheric Loss to Space?
6.6	What Chemical and Microphysical Processes Govern the Clouds, Hazes, Chemistry and Trace Gas Composition of Solid Body Atmospheres?
10.1	**What Is "Habitability"?**
10.3	Water Availability: What Controls the Amount of Available Water on a Body Over Time?
10.5	What Is the Availability of Nutrients and Other Inorganic Ingredients to Support Life?
11.3	Life Detection: Is or Was There Life Elsewhere in the Solar System?
11.4	Life Characterization: What Is the Nature of Life Elsewhere, If It Exists?
12.1	Evolution of the Protoplanetary Disk
12.2	Accretion in the Outer Solar System
12.3	**Origin of Earth and Inner Solar System Bodies**
12.6	**Atmosphere and Climate Evolution on Solid Bodies**
12.10	**Dynamic Habitability**
12.11	**Search for Life Elsewhere**

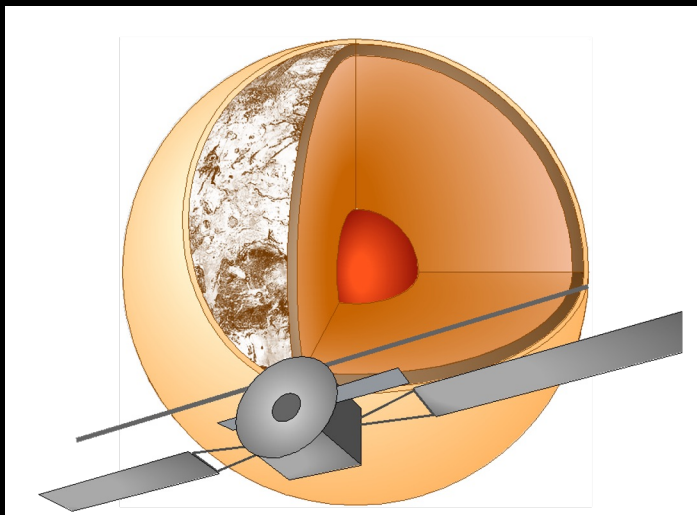
V3NUS = VERITAS, DAVINCI, EnVision





VERITAS

DAVINCI



EnVision

Understanding why our closest neighbour is so different

V3NUS and the GOI

(Goals Objectives and Investigations VEXAG Strategic document)

Dark blue - "Substantially Addressed"

The Investigation can to be substantially incremented/revised after V3NUS completion.

Medium Blue– "Partially Addressed"

The Investigation might need to be incremented/revised after V3NUS completion.

White – "Not substantially addressed"

The V3NUS missions won't affect these Investigations.

GOI under revision, 2024

Goal	Objective	Investigation	Achieved by end of V3NUS	Future Achievement
I. Understand Venus' early evolution and potential habitability to constrain the evolution of Venus-size (exo)planets.	A. Did Venus have temperate surface conditions and liquid water at early times?	**HO. Hydrous Origins**	Near-IR emissivity maps, searching for widespread felsic crust.	Measurement of surface rock composition in situ (e.g. XRF, GRS, LIBS), particularly in tesserae.
		RE. Recycling	Radar maps, subsurface sounding, Near-IR emissivity maps.	Measurement of surface rock composition in situ (e.g. XRF, GRS, LIBS). Follow-up high-res radar & high res NIR surface imaging.
		A**L. Atmospheric Losses**	-	Orbital measurements of ionosphere & solar wind interaction; sub-mm sounder to measure winds and transport through lower thermosphere.
		MA. Magnetism	-	Magnetic fields measured from orbit and/or balloon
	B. How does Venus elucidate possible pathways for planetary evolution in general?	**IS. Isotopes**	Comprehensively addressed by DAVINCI+.	Next generation MS instruments on long-lived cloud platform may be able to achieve even higher sensitivity
		LI. Lithosphere	Comprehensively addressed by VERITAS & EnVision's SAR & gravity.	Seismometry; Magnetotelluric sounding; In situ measurements of surface material composition. Follow-up high-res radar & high res NIR surface imaging.
		HF. Heat flow	Constraints from gravity/ topography calcs; also from detection & characterization of volcanism & tectonism.	Seismometry; *[in situ heat flow in different provinces].*
		CO. Core	Strongly constrained by gravity measurements & spin vector variation monitoring.	Seismometry. [*Higher accuracy gravity from e.g. gradiometry*] Magnetic field measurements from orbit and/or aerobot.

A STRATEGY FOR THE EXPLORATION OF VENUS

A VEXAG-led, community-driven strategy for the sustainable, integrated exploration of Venus

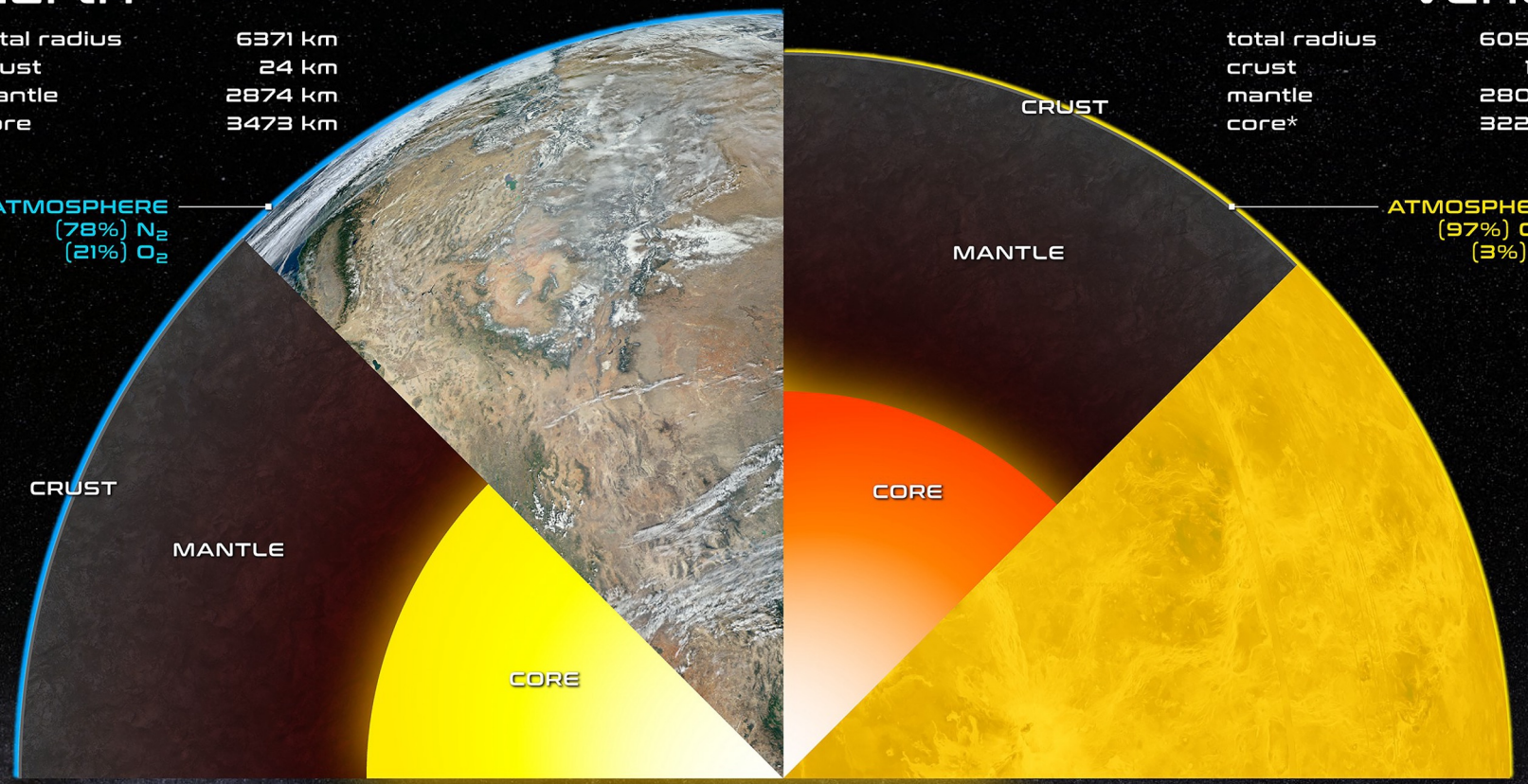
Lunar and Planetary Science Conference 55 | 2024.03.14

Image credit: Detlev Van

Supporting Venus Science in the U.S. and Internationally

Finding: The substantial interest in Venus exploration by other national space agencies and commercial entities offers an exciting opportunity to develop and take advantage of partnerships in an unprecedented way for a planetary science destination.

Recommendation: NASA could place a greater emphasis on Venus-focused science and related technology in its R&A portfolios, supported meetings, and international collaborative activities to take advantage of the planet's unique combination of processes and phenomena that are relevant to numerous other Solar System and extrasolar bodies.



Property	Earth	Venus
Mass (% Earth)	100	82
Radius (% Earth)	100	95
Semimajor Axis (AU)	100	72
Insolation Flux (% Earth)	100	191
Moon (mass ratio moon:planet)	0.0123	n/a
Sidereal Day (Earth solar day)	0.997	243
Obliquity (°)	23.44	2.64
Magnetic Field Strength (G)	0.25–0.66	<<<
Bond Albedo	0.306	0.76
Geometric Albedo	0.434	0.689

* core state of Venus is presently uncertain

		Earth	Venus
WATER	Surface Liquid	✓	✗
WATER	Subsurface Liquid	✓	✗
WATER	Ground Ice	✓	✗
WATER	Water Vapor	✓	✓
CHEMISTRY	CHNOPS[1]	✓	
CHEMISTRY	Complex Organics	✓	
ENERGY	Solar Heating	✓	✓
ENERGY	Interior Heating[2]	✓	✓
ENERGY	Redox[3]	✓	?
BODY	Atmosphere[4]	✓	✓
BODY	Magnetic Field[5]	✓	✗
	Present Habitability	✓	?
	Past Habitability	✓	?

✓ Yes/ Present

? Unknown/ Uncertain

✗ No/ Absent

Insufficient Information

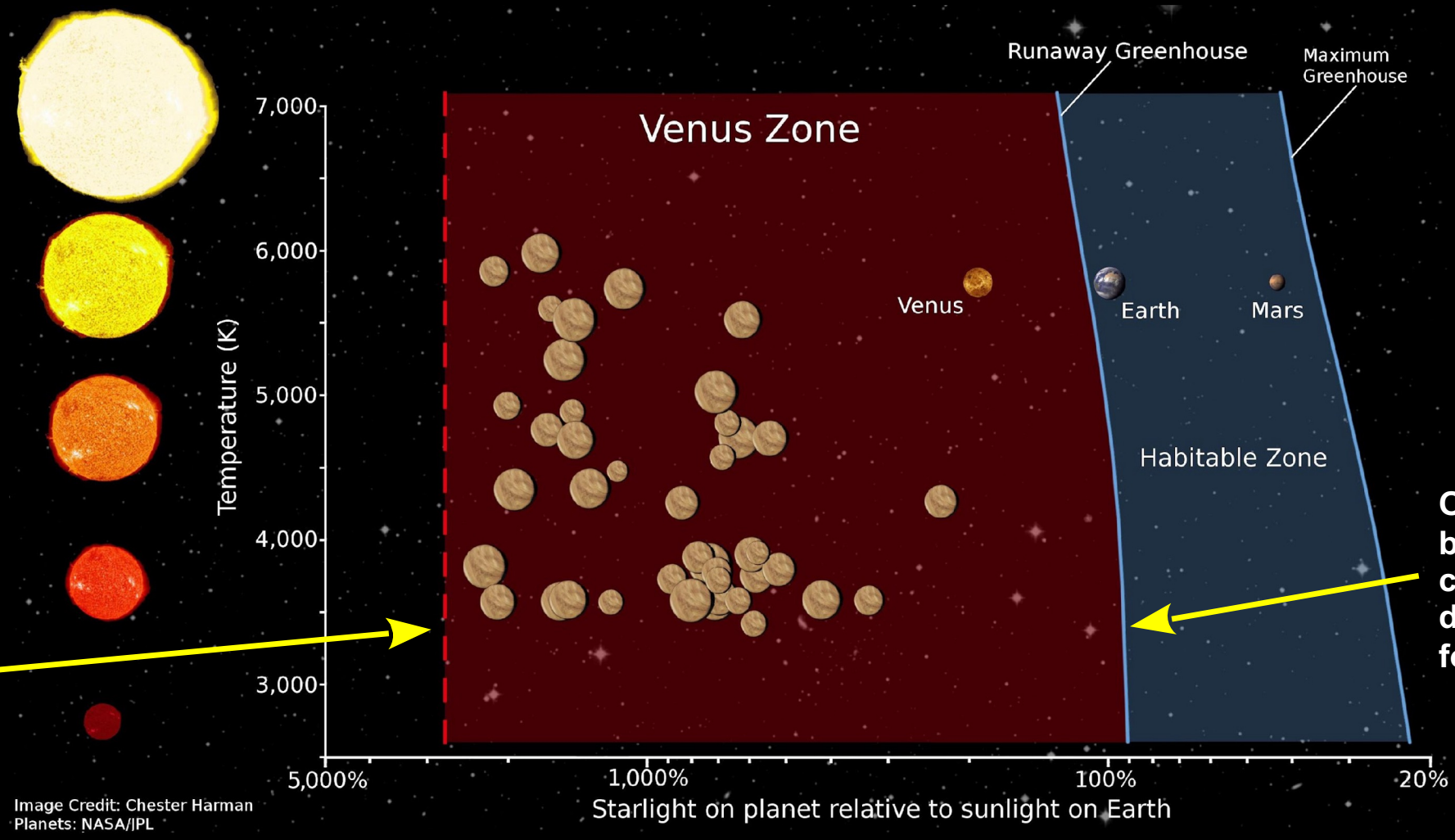
Slide from Kane & Byrne 2024

Terrestrial Exoplanet Discoveries

Fraction of stars with at least one terrestrial planet within the Venus Zone.

For M stars: 32%
For GK stars: 45%

= Potential Venus analogs are common!



Inner Venus Zone boundary = 25x stellar flux, based upon "cosmic shoreline".

Outer Venus Zone boundary is conservative and does not account for slow rotators.

Slide from Kane & Byrne 2024

Kane, Kopparapu, Domagal Goldman. 2014, ApJ, 794, L5
Ostberg & Kane, 2019, AJ, 158, 195
Ostberg et al. 2023, AJ, 165, 168

Gaps and Context

QUESTIONS / GAPS		VENUS CONTEXT
How do planets become, remain, and cease to be Habitable?	⟷	Was Venus habitable, for how long, and how did it? become uninhabitable*?
How do rocky worlds broadcast their interiors, surfaces, and atmospheres to the in-situ, orbital, and telescopic eye?	⟷	Venus represents a key subcategory of large rocky worlds – one of the precious few we can examine up close and personal.
How Common are Venus like worlds? How blurry is the line between Venus-like and Earth like?	⟷	Venus (and Earth) are the only two worlds of their kind we will ever touch.
Exoplanetary studies of Venus like worlds with JWST (and other assets) now and in the future (HWO…)	⟷	Telescopic and in situ studies of Venus with multiple assets now and in the future (DAVINCI, VERITAS, EnVision…)

VEXAG

SCIENCE & ANALYSIS WORKGROUPS (SAWS)

SAW 1: Organization Documentation
SAW 2: VEXAG 2024
SAW 3: 2nd meeting support (EioB 3, +)
SAW 4: Exploration Strategy
SAW 5: Science Nuggets
SAW 7: Technology & Laboratory Studies
SAW 9: Social Media
SAW 10: VEXAG website
SAW 11: IDEA
SAW 12: Aerial platforms
SAW 14: Venus Mapping
SAW 15: Surface platforms
SAW 16: Mentoring
SAW 17: Strategic Document Revision
SAW 18: Venus Data Resources

SAW 3: “Off-season Meeting”

Exoplanets in our Backyard 3

November 13-15, 2024

Louisville, KY

exoplanetsbackyard.com

Four Science Themes:

Star-Exoplanet Interactions Using Our Heliosphere as a Rosetta Stone

Leveraging the History of the Inner Solar System to Inform the Search for Habitable and Inhabited Exoplanets

Cross-Domain Machine Learning Methods for Applications to Exoplanetary Atmospheric Retrieval

Bridging Communities: Theory and Experiments Collide to Tackle Exoplanet Research Challenges

plus lots and lots of discussion!

SAW Lead – Erika Kohler

SAW 17: STRATEGIC DOCUMENTS

VEXAG

Goal(s): Revise and update the VEXAG strategic documents: Goals, Objectives, Investigations (GOI), Roadmap, and Technology Plan

Products: 2024 update of 2019 documents

Members: Editors: Noam Izenberg, Debra Buczkowski
Leads: GOI – Joe O'Rourke
Tech Plan – Siddharth Krishnamoorthy
Roadmap – Robbie Herrick

Timeline: Spring 2024 – Community input
Summer 2024 – revise documents

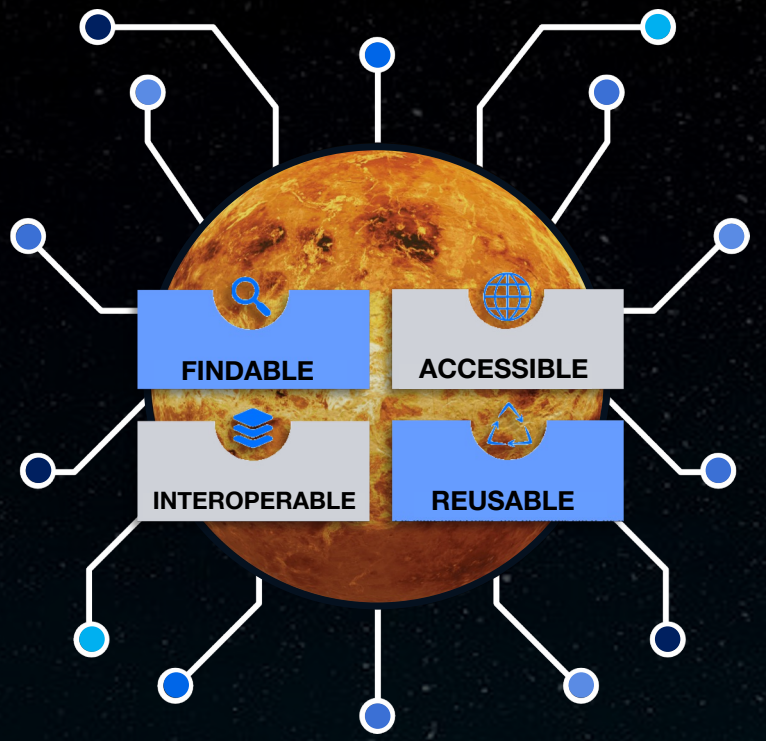
VENUS EXPLORATION VEXAG ANALYSIS GROUP

SAW 18: Venus Data Resources

- **GOAL**: **Boost efficient and fair distribution of knowledge on Venus data and resources**

- **PRODUCT**: VExAG Venus Data Resource Webpage
  - **Database products** from missions
  - **Derived products** from publications
  - **Ground-based observations and archives**
  - **Experimental facilities**
  - **Software tools**
  - **Frequently Asked Questions (FAQs)**

- **NEXT STEPS**:
  - **Resource gathering**
  - **Community engagement**
  - **Webpage design**
  - **Promotion and updating of webpage**



Anna Gülcher, Rebecca Hahn, Robbie Herrick, Gael Cascioli, Alex Akins, Trevor Austin, and Stephen Kane