VENUS FLAGSHIP MISSION PLANETARY DECADAL STUDY, A MISSION TO THE CLOSEST EXOPLANET

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STEPHEN KANE, UC RIVERSIDE

AND THE VENUS FLAGSHIP MISSION STUDY TEAM

Exoplanets in Our Backyard
February 5-7, 2020

UC RIVERSIDE UNIVERSITY OF CALIFORNIA

Wesleyan University

NASA Jet Propulsion Laboratory
California Institute of Technology

VENUS FLAGSHIP MISSION CONCEPT SCIENCE TEAM

Name	Institution	Expertise
Sushil Atreya	Univ. of Michigan	Interior-surface-atmosphere interaction
Patricia Beauchamp	JPL-Caltech	Technology, Instrumentation, Chemistry
Penelope Boston	Ames Research Center	Astrobiology
Mark Bullock	Science & Technology Corp	Chemistry of Atmospheres and Surfaces
Shannon Curry	U.C. Berkeley	Solar wind interactions with Venus
Martha Gilmore	Wesleyan University	Surface processes, spectroscopy
Robbie Herrick	Univ. of Alaska	Geology and Geophysics
Jennifer Jackson	Caltech	Mineral Physics
Stephen Kane	U.C. Riverside	Exoplanet Science
Alison Santos	GRC	Petrology
David Stevenson	Caltech	Geophysics
Colin Wilson	Oxford University	Atmospheric Physics
Janet Luhmann	UC Berkeley	Venus escape processes
Robert Lillis	UC Berkeley	Modeling of plasma and magnetic processes
Joshua Knicely (student)	Univ. of Alaska	Venusian Volcanoes

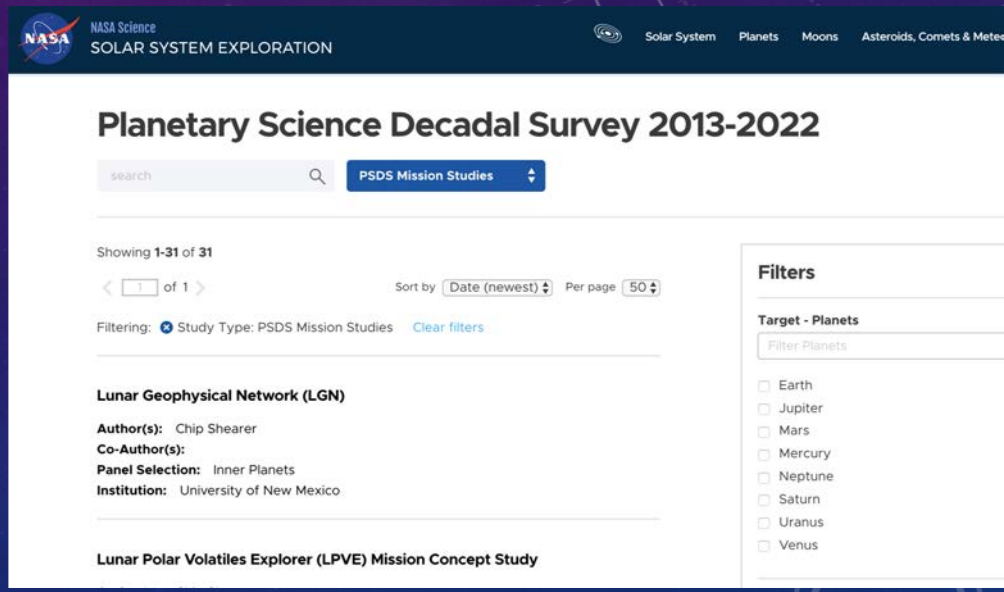
Mission Design at GSFC, M. Amato Lead

Host of generous colleagues sharing science and instrument expertise – THANK YOU!

PLANETARY DECADAL STUDY PROCESS

- Mission studies recommended by the Decadal Midterm report to feed into the next Planetary Decadal Survey (2023-2032)
- NASA Call for Planetary Mission Concept study proposals submitted April 2019
- Selected studies (n =11) are performed by science teams with NASA centers. Each will be costed.
- Final reports due to Decadal Survey by June 30, 2020 for consideration.

32 studies commissioned during last Decadal



Venus Flagship is an opportunity to input exoplanet science into the decadal

VFM SCHEDULE AND REPORT

Oct 2019 – Study Initiated

Nov/Dec 2019 - Input from community, refinement of STM

February 25 – 26, 2020 – Engineering Run I at GSFC Lander focus

March 15, 2020 – Decadal Studies Interim Reports at LPSC

Week of March 30, 2020 – Engineering Run II at GSFC, Mission Architecture

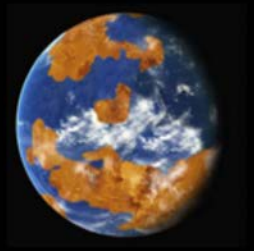
June 30, 2020 – Final Report Due

July 2020 - Deadline for submission of white papers (199 submitted last time), Survey committee and panel meetings begin

VENUS FLAGSHIP
A MISSION TO ASSESS THE HABITABILITY OF VENUS
GOALS

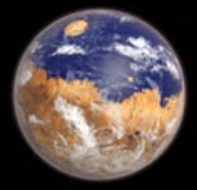
1. History of volatiles and liquid water on Venus and determine if Venus was habitable.
2. Composition and climatological history of the surface of Venus and the present-day couplings between the surface and atmosphere.
3. The geologic history of Venus and whether Venus is active today.

Our neighborhood 4 billion years ago
3 habitable planets?

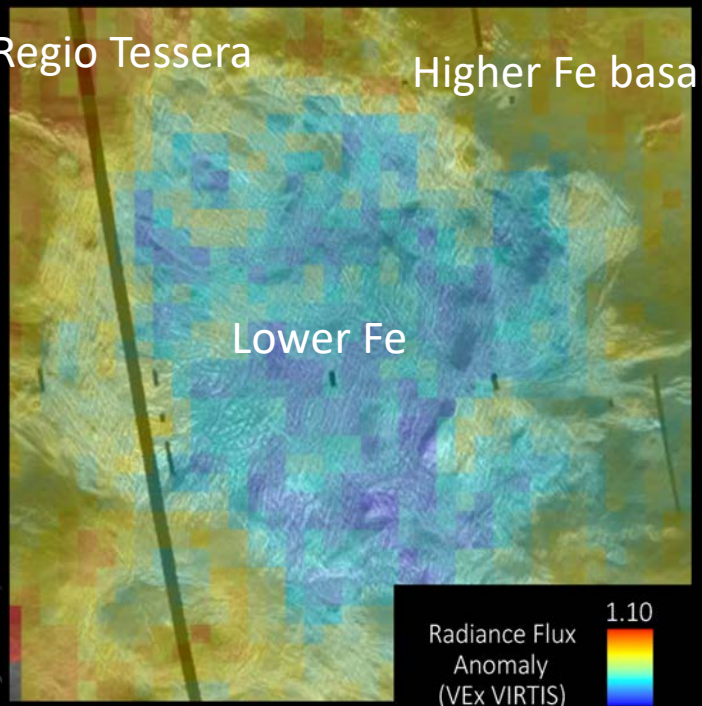


Venus

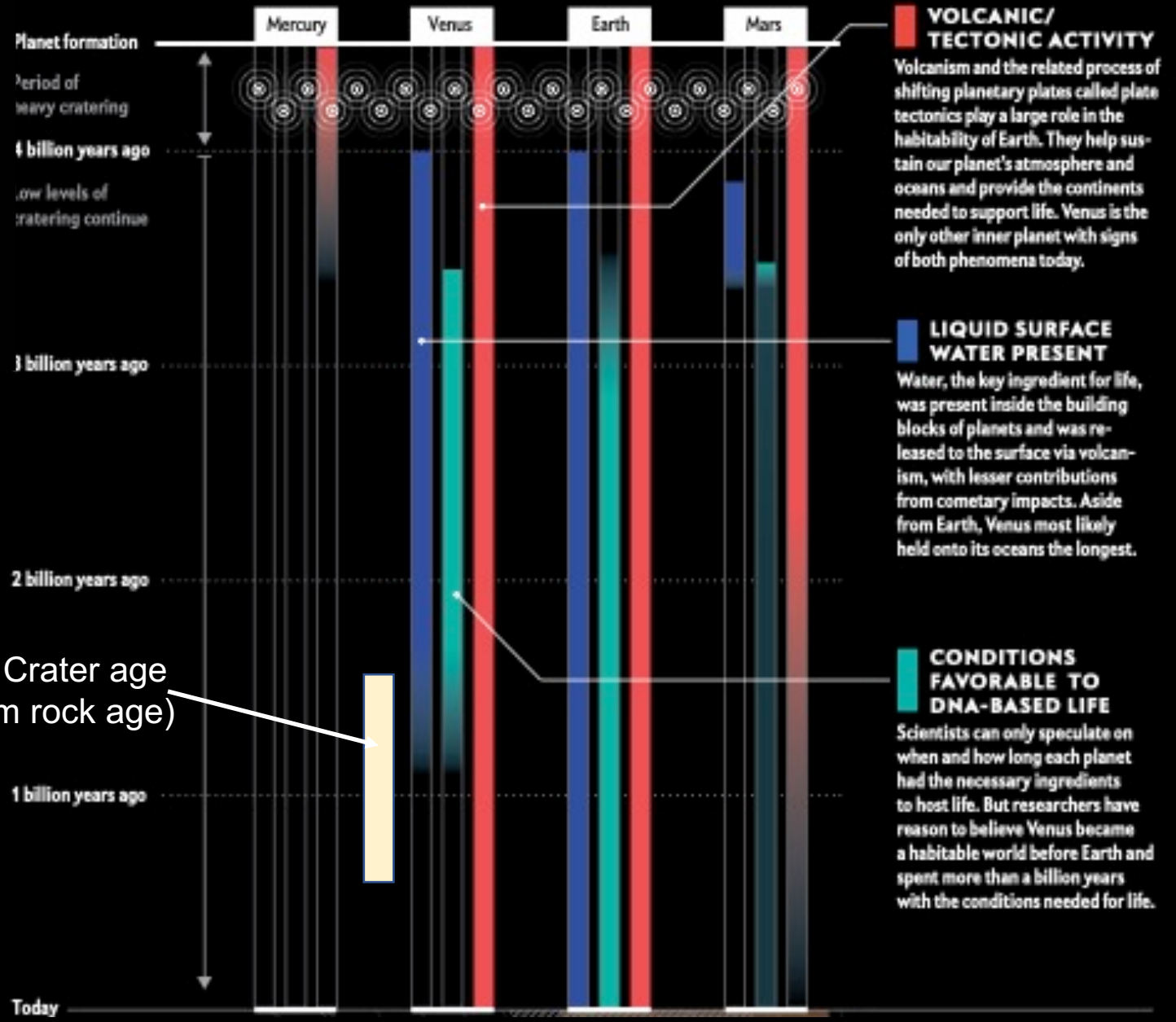
Earth



Mars

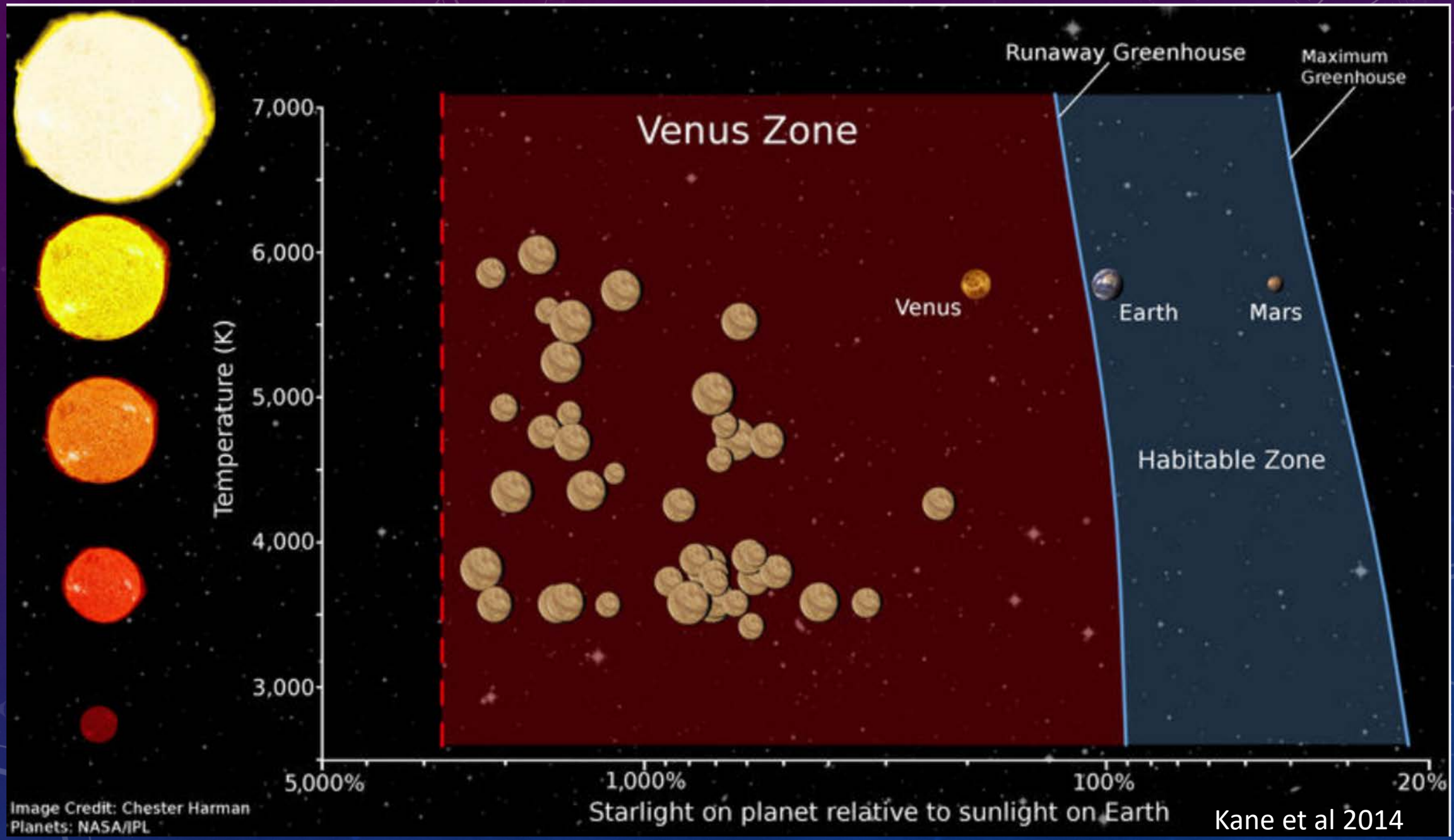


Gilmore et al., 2015

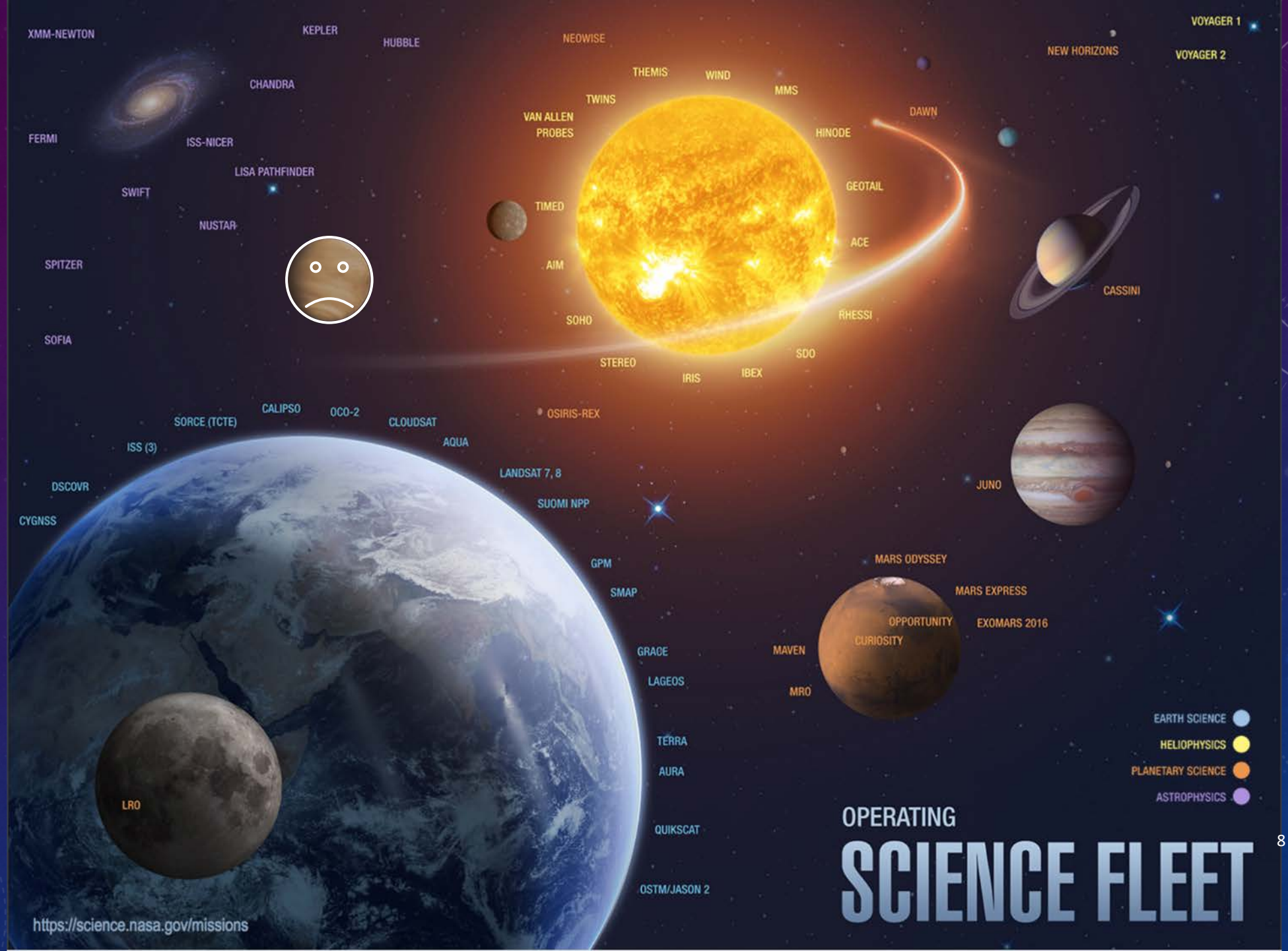


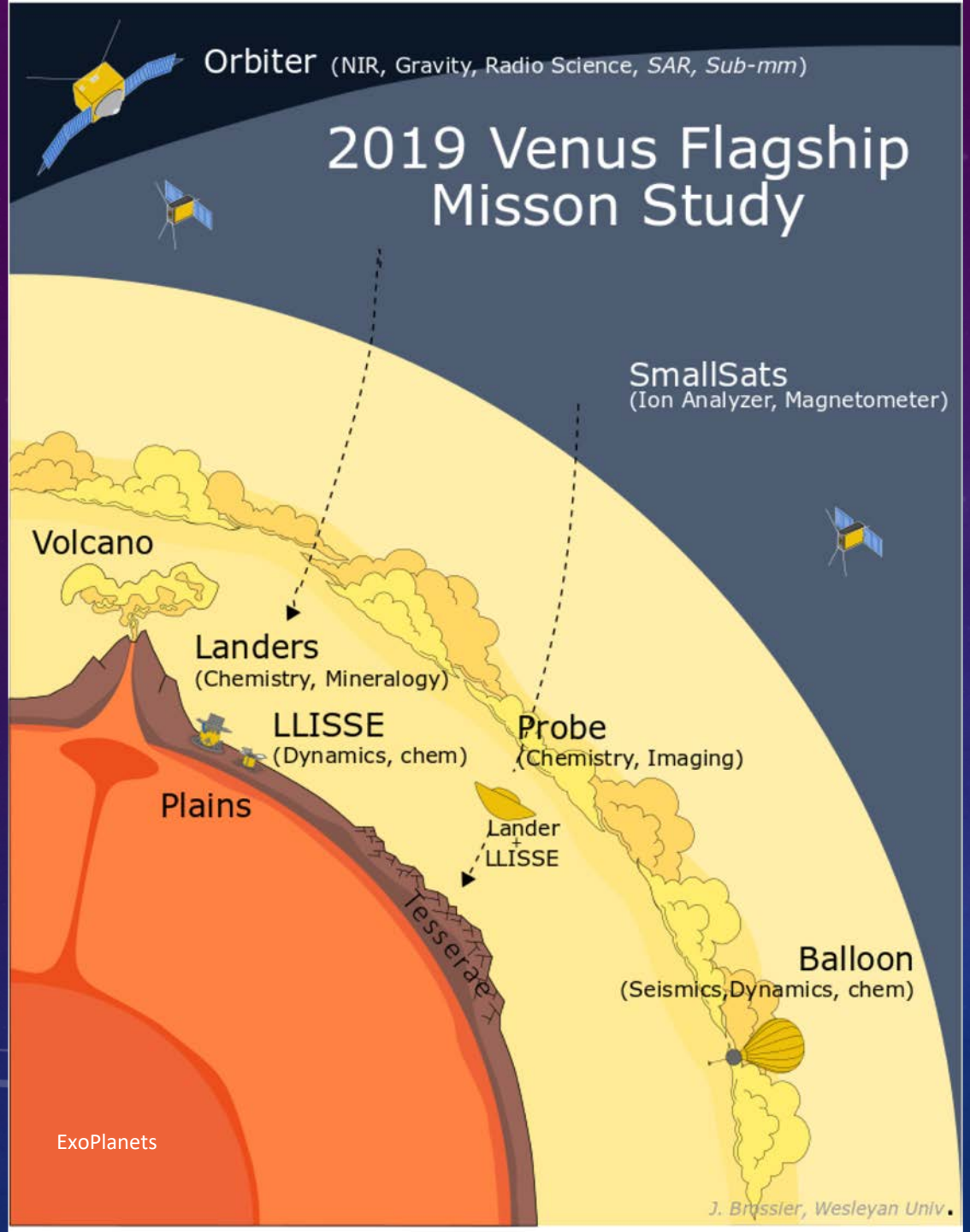
Tessera Crater age
(minimum rock age)

Graphic by Tiffany Farrant-Gonzalez, Dyar et al. Sci. Am. Feb 2019



Kane et al 2014


XMM-NEWTON
KEPLER
HUBBLE
NEOWISE
VOYAGER 1
NEW HORIZONS
VOYAGER 2
CHANDRA
THEMIS
WIND
MMS
TWINS
DAWN
VAN ALLEN PROBES
HINODE
FERMI
ISS-NICER
LISA PATHFINDER
GEOTAIL
SWIFT
TIMED
NUSTAR
ACE
SPITZER
AIM
CASSINI
SOHO
RHESSI
SOFIA
SDO
STEREO
IBEX
IRIS
CALIPSO
OCO-2
OSIRIS-REX
SORCE (TCTE)
CLOUDSAT
AQUA
ISS (3)
LANDSAT 7, 8
JUNO
DSCOVR
SUOMI NPP
CYGNSS
GPM
MARS ODYSSEY
SMAP
MARS EXPRESS
OPPORTUNITY
EXOMARS 2016
CURIOSITY
GRACE
MAVEN
LAGEOS
MRO
TERRA
AURA
LRO
QUIKSCAT
OSTM/JASON 2
EARTH SCIENCE
HELIOPHYSICS
PLANETARY SCIENCE
ASTROPHYSICS
OPERATING
SCIENCE FLEET
https://science.nasa.gov/missions

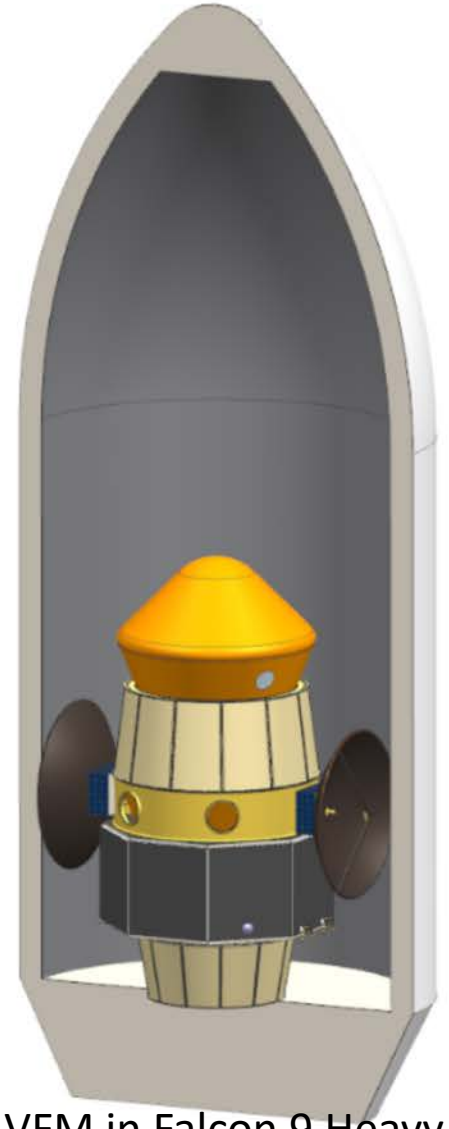


OVERVIEW

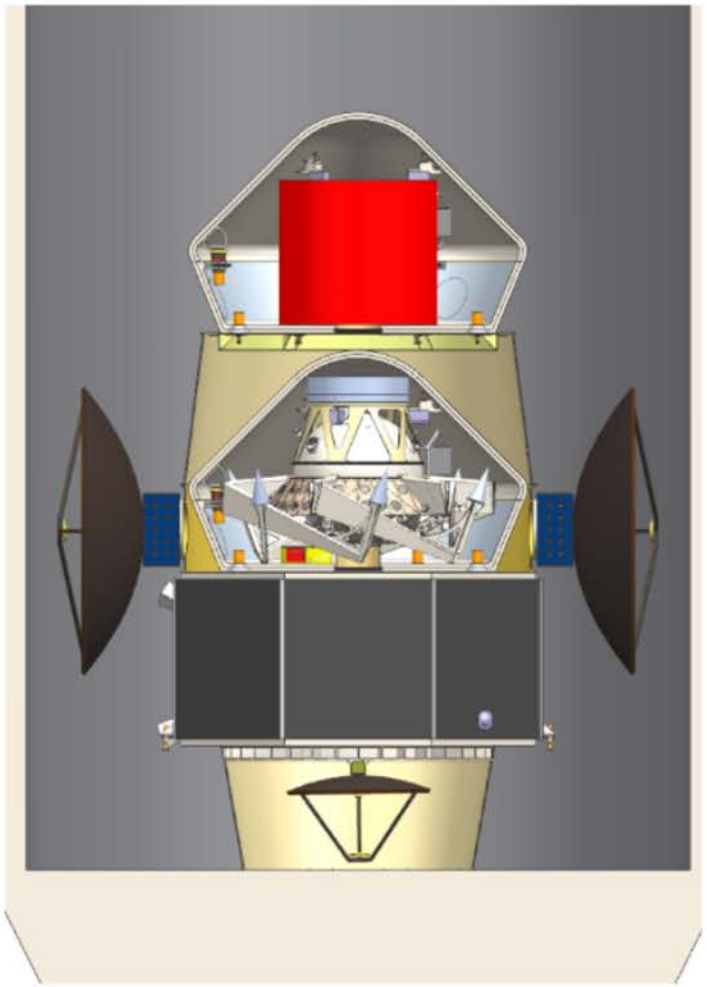
Launch ~2029-2032
Synergistic measurements

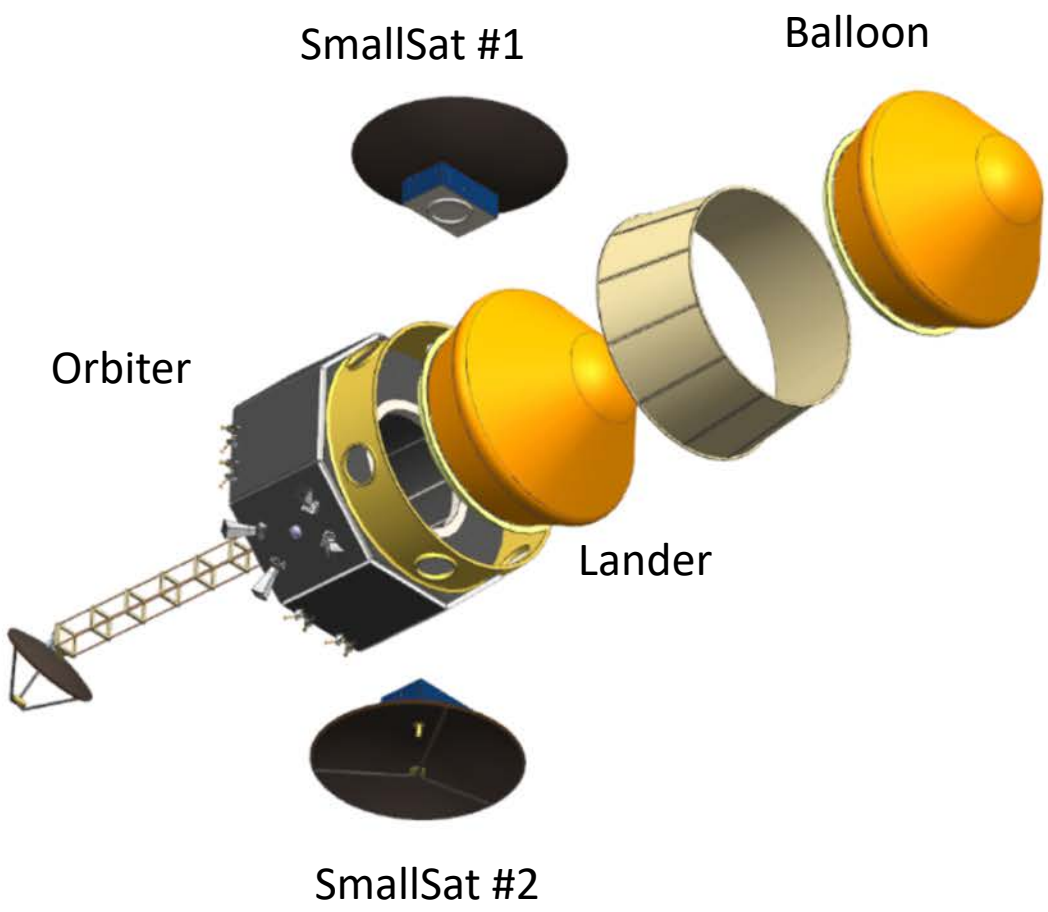
1 Orbiter
2 Orbiting SmallSats
1 Short-lived landers/Probes
1 Balloon
1 Long-lived lander (LLISSE)

Cost $2B



VFM in Falcon 9 Heavy





ENROUTE – DEPLOY 2 SMALLSATS WITH ESPA RING
S. CURRY, LEAD

Fluxgate magnetometer (including boom)
Electron electrostatic analyzer
Ion Electron Static Analyzer
Solar Energetic Particle Detector
Electric Fields Detector
Neutral Mass Spectrometer
Langmuir Probe (including boom)
EUV

Science: Understand evolution of Venus atmosphere via measurements of the interaction the atmosphere with solar wind

- Elliptical orbits on two sides of the planet during solar cycle 25
- Significantly aid in tracking of and comm with in situ elements

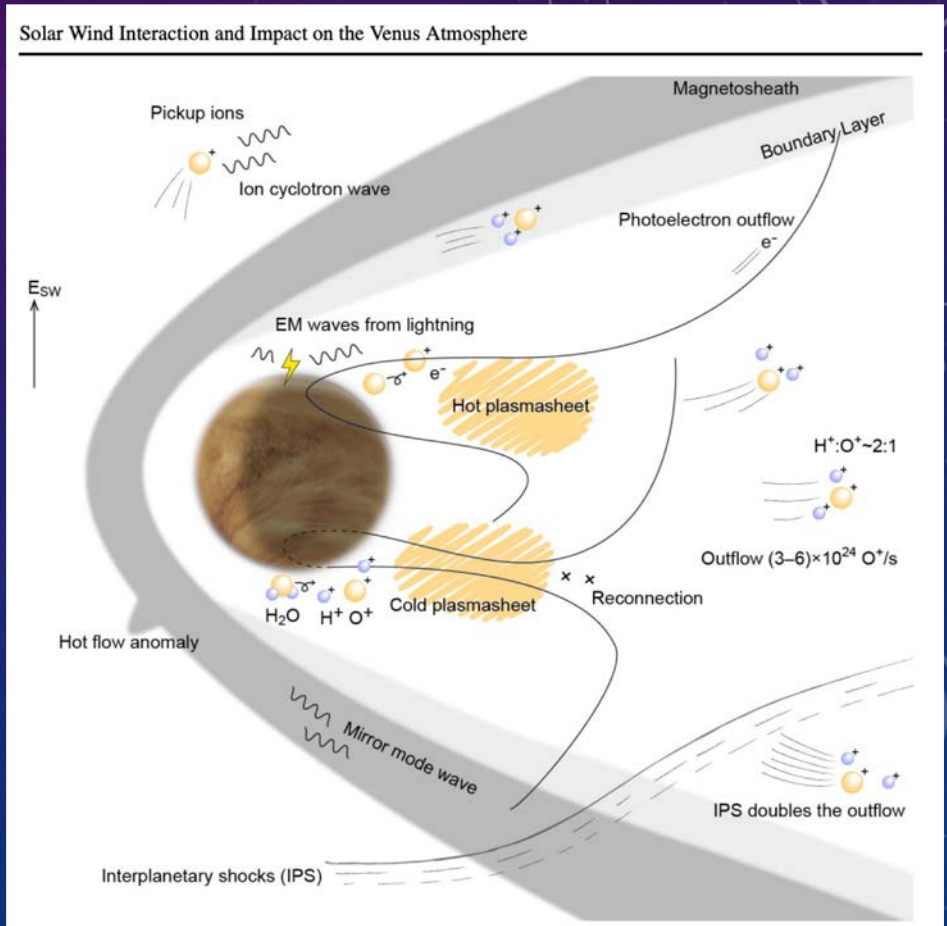


Fig. 1 An illustration summarizing the Venus Express findings on the space environment of Venus

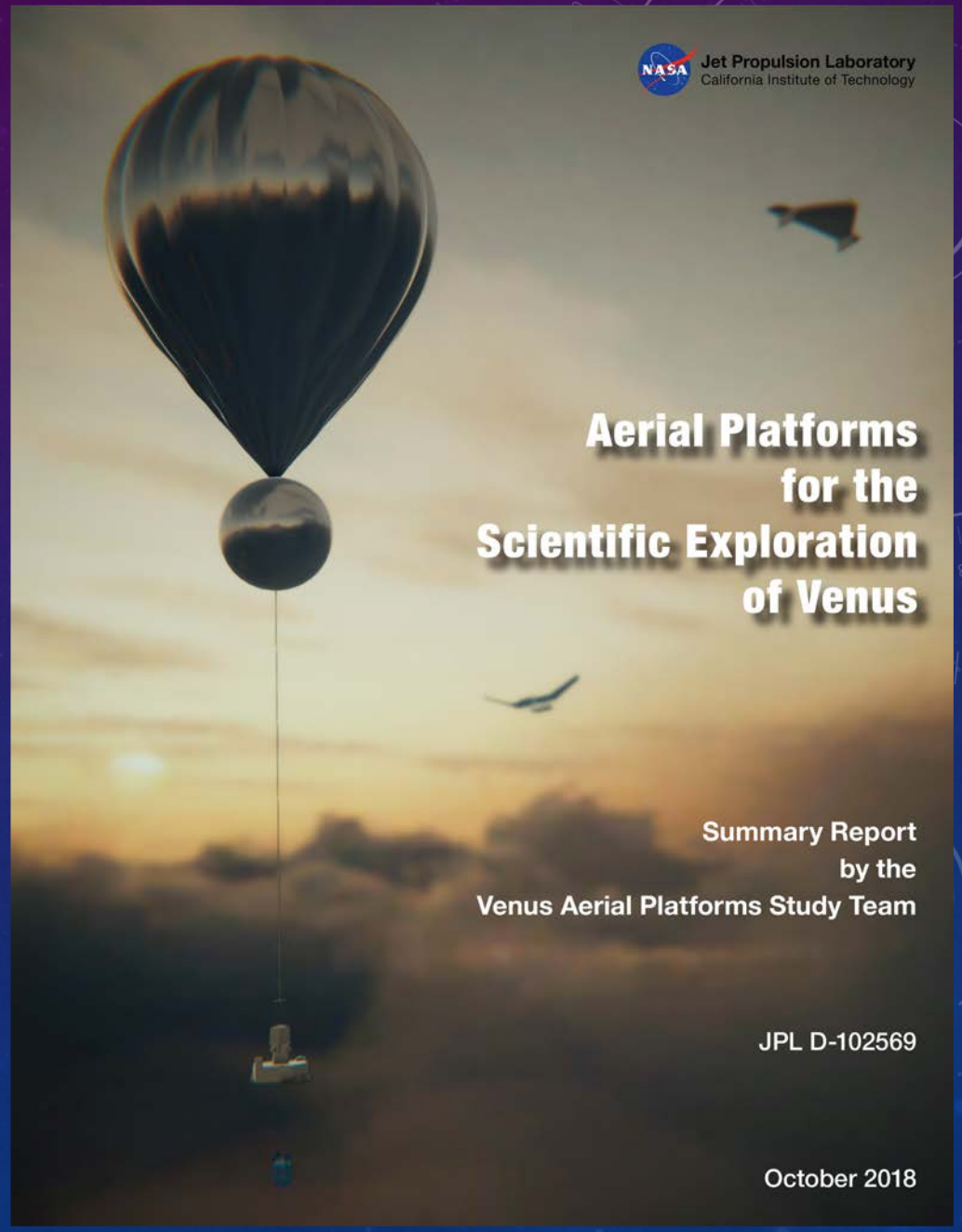
Futaana et al., 2017

VENUS ARRIVAL – BALLOON
C. WILSON, LEAD

Aerosol Mass Spec
Pressure Sensors
Temperature Sensors
Infrasound
Polarizing Nephelometer
Magnetometer
Fluorometer
Electric Fields
Cloud XRF

Science: Measure composition and nature of cloud particles, cloud environment, dynamics. Try to look for chemistry necessary for biology, seismicity and magnetic field.

- Variable altitude balloon@ 52-62 km
- Minimum lifetime of 30 days



VENUS ORBITER INSERTION
R. HERRICK, LEAD

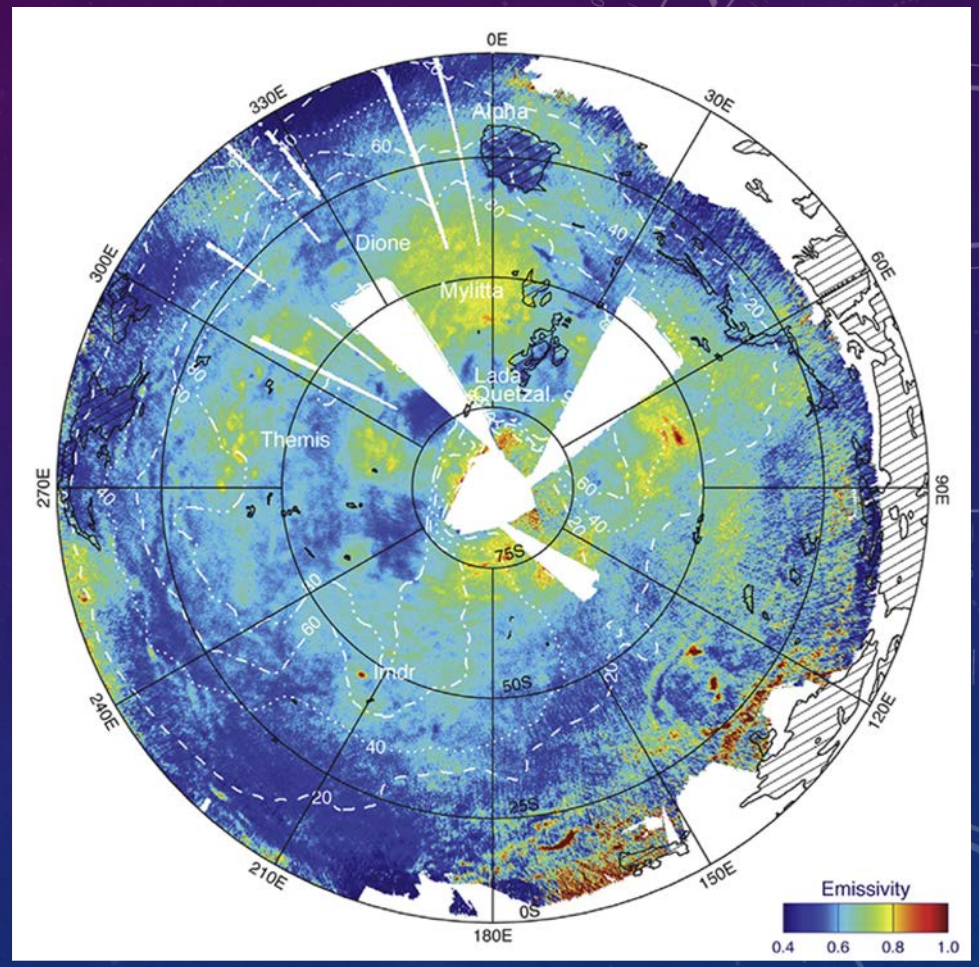
SAR
NIR imager
Electrostatic Analyzer
Magnetometer
Sub-mm sounder
Radio Occultation
Gravity

Science: Morphology and composition of Venus surface, gravity field, particles and fields, upper atmosphere composition

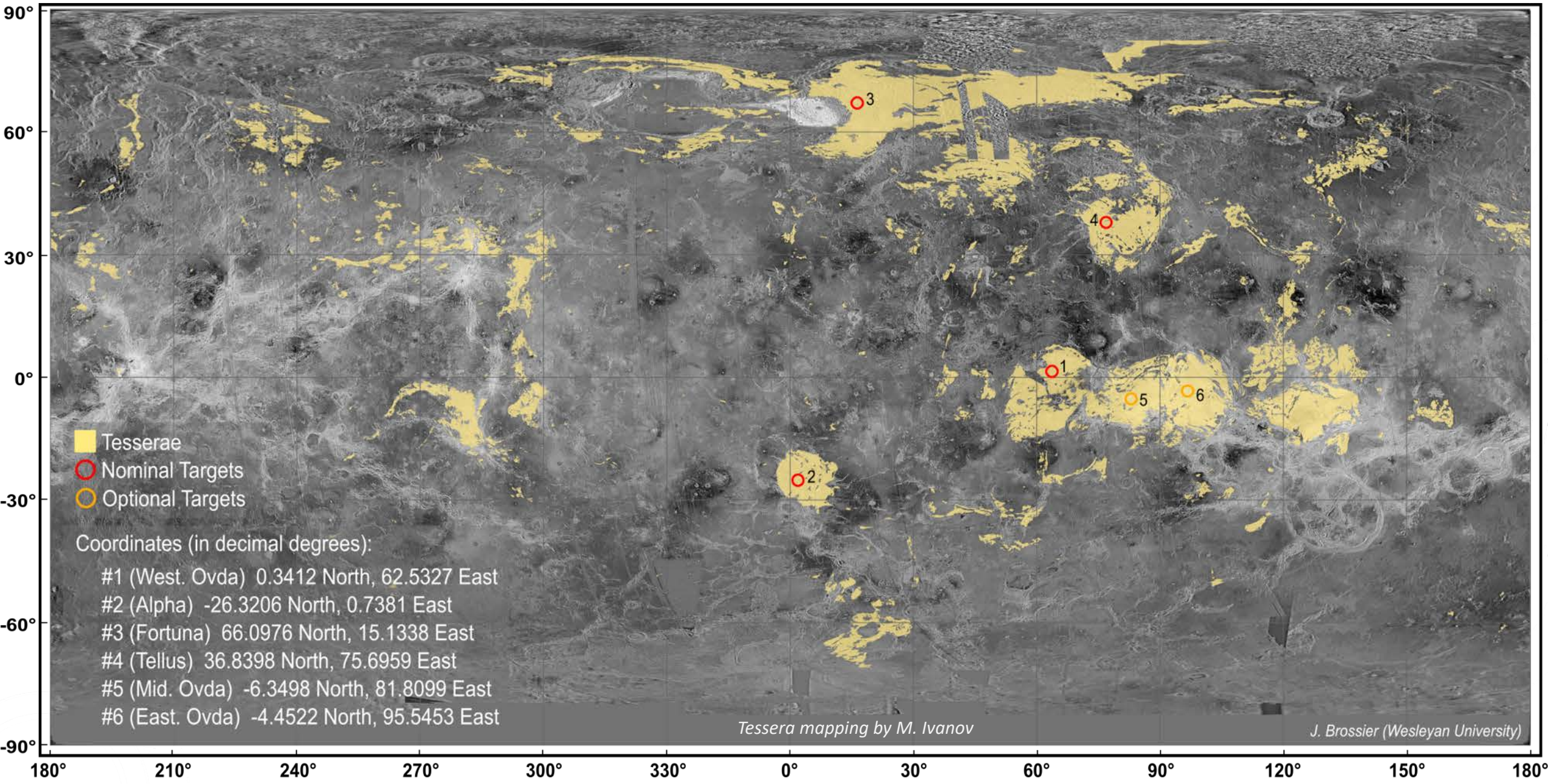
LANDING SITE CAMPAIGN
High resolution imaging and topography of potential landing sites

MAPPING CAMPAIGN
After lander release, reorient and aerobrake to mapping orbit to provide SAR and NIR of Venus.

VIRTIS 1 µm map Smrekar et al., 2014



Specifics of mapping campaign will consider status of Venus missions currently in consideration in Discovery and by ESA.

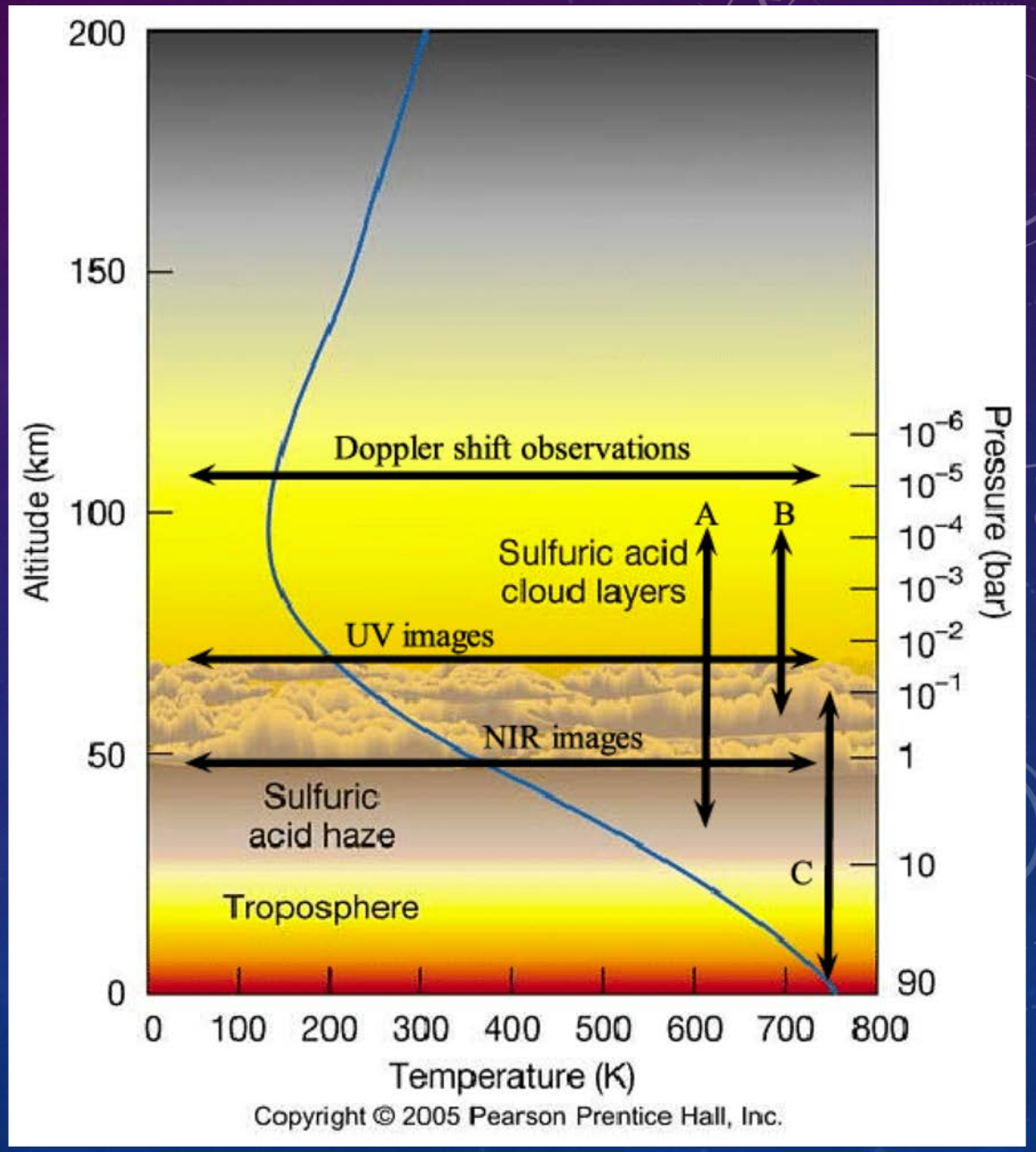

90°
60°
30°
0°
-30°
-60°
-90°
180°
210°
240°
270°
300°
330°
0°
30°
60°
90°
120°
150°
180°
1
2
3
4
5
6
Tesserae
Nominal Targets
Optional Targets
Coordinates (in decimal degrees):
#1 (West. Ovda) 0.3412 North, 62.5327 East
#2 (Alpha) -26.3206 North, 0.7381 East
#3 (Fortuna) 66.0976 North, 15.1338 East
#4 (Tellus) 36.8398 North, 75.6959 East
#5 (Mid. Ovda) -6.3498 North, 81.8099 East
#6 (East. Ovda) -4.4522 North, 95.5453 East
Tessera mapping by M. Ivanov
J. Brossier (Wesleyan University)

LANDER DESCENT SCIENCE
S. ATREYA, LEAD

Mass Spec
Tunable Laser Spectrometer
NIR Imager
Pressure
Temperature

Science: Composition, environment of the atmosphere to the surface. Landing site characterization

"We don't know anything about the lower atmosphere."
– unnamed famous Venus atmospheric scientist whom I trust.



LANDER SCIENCE
A. SANTOS, LEAD

Venera 13 Image Credit: NASA National Space Science Data Center/Harvard Micro Observatory/Don P. Mitchell

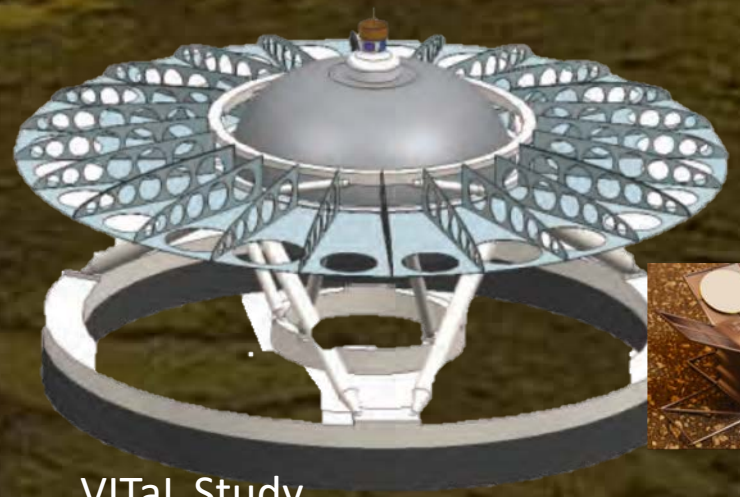
CheMin-V
PIXL
BECA
VEMCam
Panoramic Camera
MAHLI equivalent camera

Science: Mineralogy, geochemistry and morphology of Venus tessera terrain, constrain surface-atmosphere interactions

- Ingestion of samples into the lander for elemental chemistry and mineralogy
- "Mobility" achieved by multiple targets with Raman/LIBS for chemistry and mineralogy

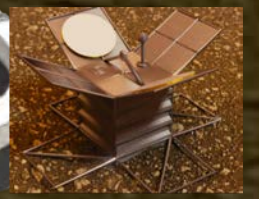
LLISSE – Long-Lived In Situ Solar System Explorer, T. Kremic, Glenn – 60—120 days

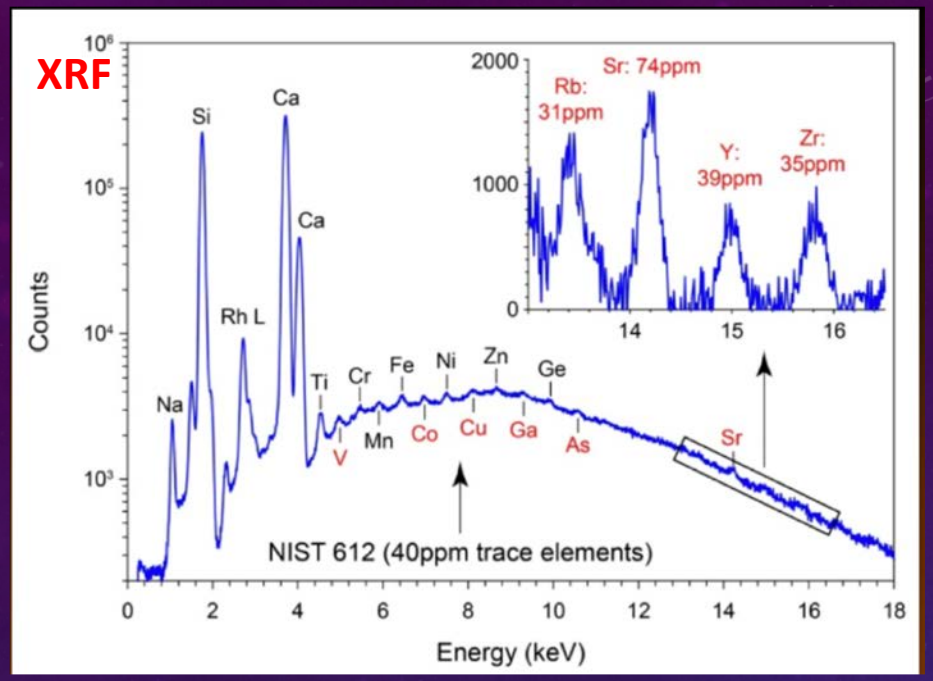
- Goal is 4 - 8 hour lander
- Pressure Vessel with robust landing for rugged terrain



VITaL Study

LLISSE





PIXL on Mars 2020 (A. Allwood)

Clegg et al., 2019

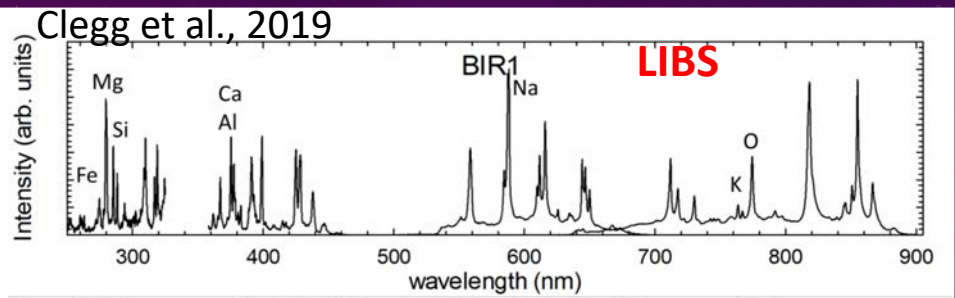


Figure 1: LIBS spectrum of the Icelandic Basalt (BIR-1) under simulated Venus atmospheric temperatures (465°C) and pressure (92 atm).

SuperCam – Raman/LIBS on Mars (R. Weins)

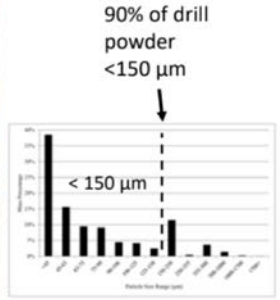
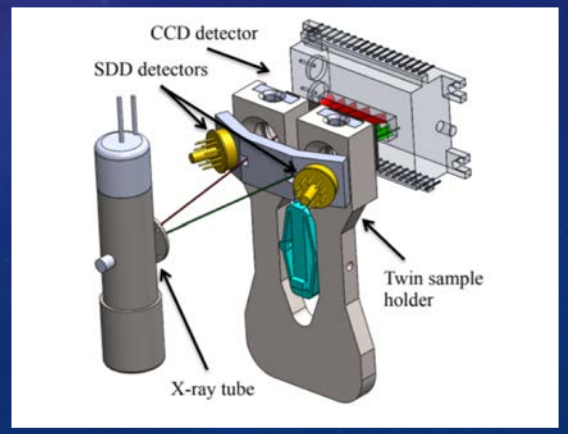


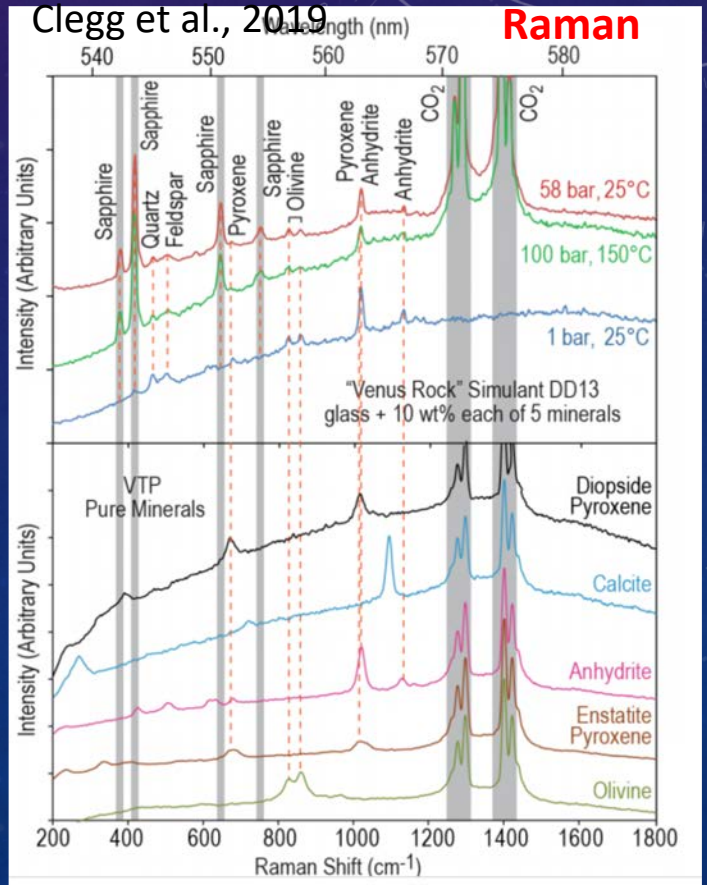
Fig. 1: The HBR Venus drill successfully drilled in JPL's Venus chamber. 90% of the retrieved powder is < 150 µm grainsize, suitable for analysis in Che-Min-V.

XRD

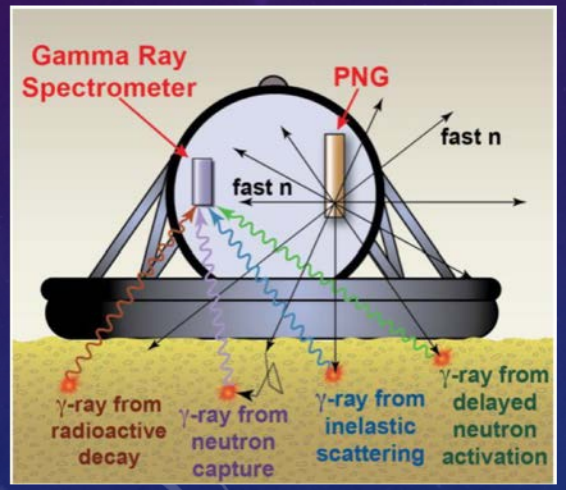
Chemin – V, (Blake et al., 2019)
Chemin is on MSL



Clegg et al., 2019



Gamma-ray



BECA on Dragonfly, A. Parsons

Table 1. Initial results between elemental concentrations from a BECA prototype instrument and an independent assay of granite.

Element	Units	Granite Assay	Granite BECA Results	Statistical Uncertainty
Al	wt%	7.4	7.41	0.09
Ca	wt%	0.63	0.74	0.07
Fe	wt%	1.14	1.23	0.01
Gd	ppm	4.55	4.72	0.07
K	wt%	4.32	5.09	0.05
Mg	wt%	0.17	0.11	0.02
Na	wt%	2.27	2.09	0.07
Si	wt%	34.23	34.65	0.20
Ti	wt%	0.14	0.18	0.01

Schweitzer et al., 2017

WHAT DO YOU WANT TO KNOW ABOUT AN EXOPLANET?

WHAT SPECIFICALLY SHOULD WE MEASURE AT VENUS?

(IT'S NOT GOING TO BE EASIER THAN THIS SAYS STEVE KANE)