Sample Science Facilities

Committee on Astrobiology and Planetary Science

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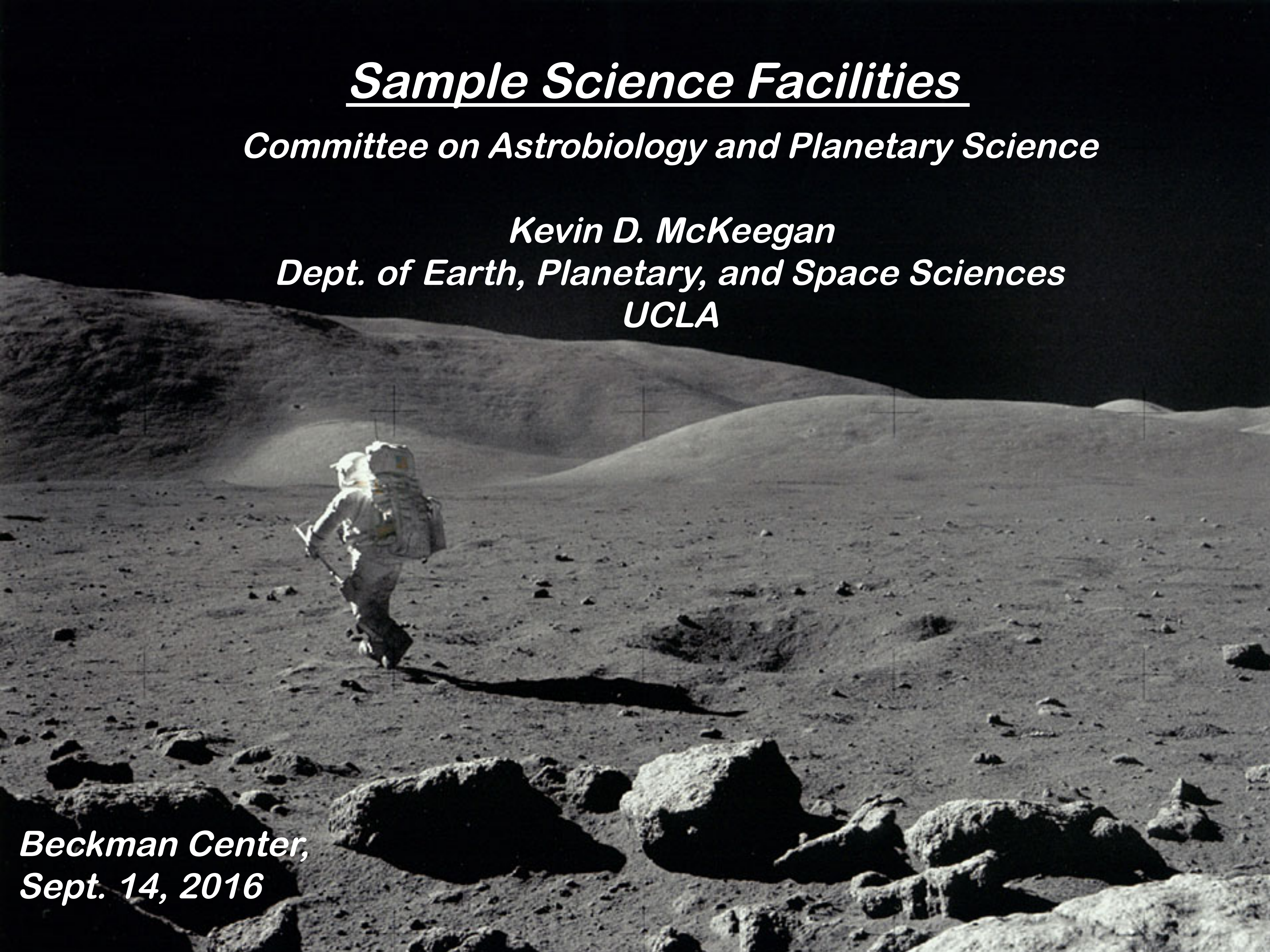


Beckman Center,
Sept. 14, 2016

Importance of sample analysis

- ***Large science return***
  - *planetary materials can retain a record of their origin and evolution*
- ***Advanced instrumentation available***
  - *Not limited by engineering/cost constraints of spaceflight*
  - *New instruments used on curated samples*
- ***Very high quality data***
  - *Important results replicated; variety of techniques used*
  - *Anomalous results weeded out; normal scientific process*
  - *New questions arise over time; iterative scientific process*
- ***Participation by large scientific community***
  - *Training opportunities for young investigators*

Samples

- **Earth, Moon, Itokawa, Mars (most likely), Vesta (probably), Ryugu (Hayabusa-2), Bennu (Osiris-rex)**
- **Meteorites (other unknown asteroids) and interplanetary dust (comet and asteroid dust)**
- **dust from coma of Comet Wild2 (Stardust)**
- **Solar wind (Apollo, Genesis missions)**
- **small amount of presolar and extrasolar materials**
- **Early Earth minerals and rocklets**

No ices; limited volatiles. Pristinity/completeness of organic matter sampling is uncertain.

Hubble Heritage

Outline

- Introduction
- “Facilities” and “capabilities”
- Non-NASA Facilities (relevant to samples)
- U.S. competitiveness
- Future opportunities & concerns

Introduction

- Task (as understood by me)

… perception that current U.S. facilities for sample science may be falling behind compared to facilities overseas.
… what are current state of the art facilities for sample science in the U.S. and what sort of investments and initiatives need to be undertaken to bring U.S. facilities up to the world standard?

- Why me?

- *experience with analysis of most of the types of samples listed. (co-I on Stardust, Genesis. Apollo investigator. Meteorites and IDPs; some Mars & early Earth investigations.)*
- *Running NSF National Ion Probe Facility (w/ Harrison; 21 yrs.)*
- *Incoming CAPTEM Chair*

- disclaimers

- *Not speaking for CAPTEM or any other body!*
- *No real expertise in programmatic matters*

Facilities and/or capabilities

- Facilities for sample science
- *Astromaterials sample curation*
    - *missions & collections; clean rooms @ JSC*
    - *preservation, archiving, characterization*
    - *interagency cooperation for some collections (e.g., Antarctic meteorites)*
- *Sample allocation and preparation (facilitation of investigations); research on methods for maximizing sample science return (e.g., CAT scan; specialized sample prep, etc.)*
- *Earth samples archived by NSF for "recent" environments. Hadean samples not included but could be by NASA (and may require some coordinated protection in future)*

- sample facilities largely in NASA centers
- *Some inclusion of universities, facilities supported by other agencies*

Facilities and/or capabilities

NASA facilities to enhance understanding of sample science

- *Generally not multi-user for independent investigations related to sample*
- *Purpose is for unique experimental capability and/or coordinating data for comparison of remote sensing and sample investigations. Some examples:*
  - *RELAB*
  - *Ames Vertical Gun*
  - *environmental chambers (GEER)*
  - *dust accelerator (U. Colorado)*

Distinct from "sample analysis"

- *multi-user facilities for sample analysis are typically collaborative for NASA-sponsored work; not always the case for other agencies (NSF, DOE, etc.)*

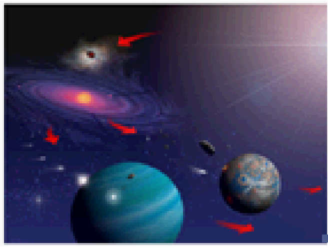
"Facilities" not same as "capabilities"

capabilities for NASA sample science

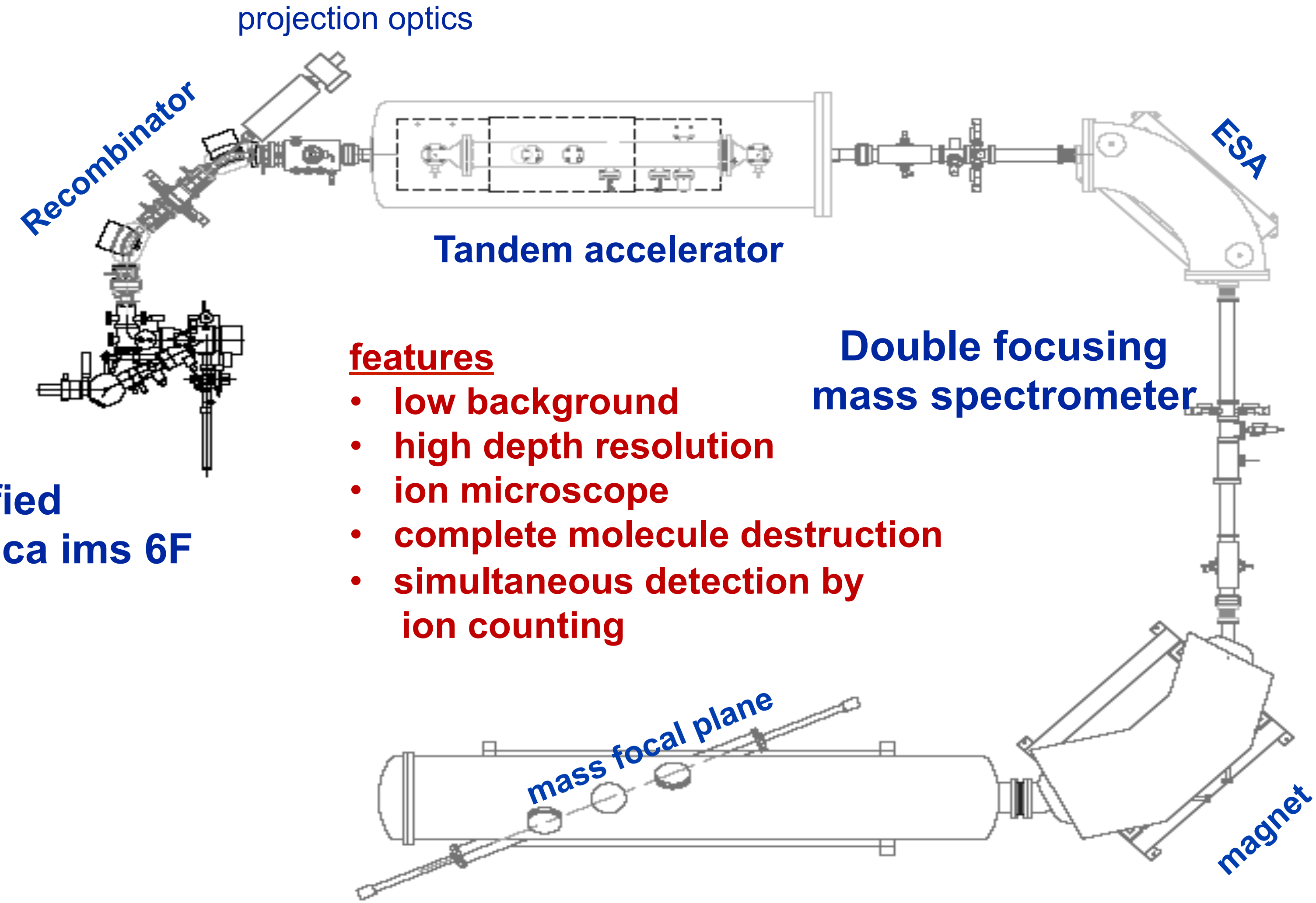
- *historically NASA Center and University based laboratories*
  - *development of new analytical instrumentation/methods*
  - *largely independent PI driven science*
  - *mission science has supported "capabilities" to varying degrees (different models; Genesis vs. Stardust)*
  - *R&A programs (e.g, cosmochemistry, PME, LARS) have supported individual laboratory capabilities for sample analyses that enhance mission science; investments made in capabilities (incl. people) that then must be sustained.*

Example: focus on mass spectrometry

- *Development of mass spectrometry for high precision (e.g., TIMS), high spatial resolution (e.g., SIMS, RIMS), and/or high sensitivity (AMS, RIMS, SIMS, noble gases)*



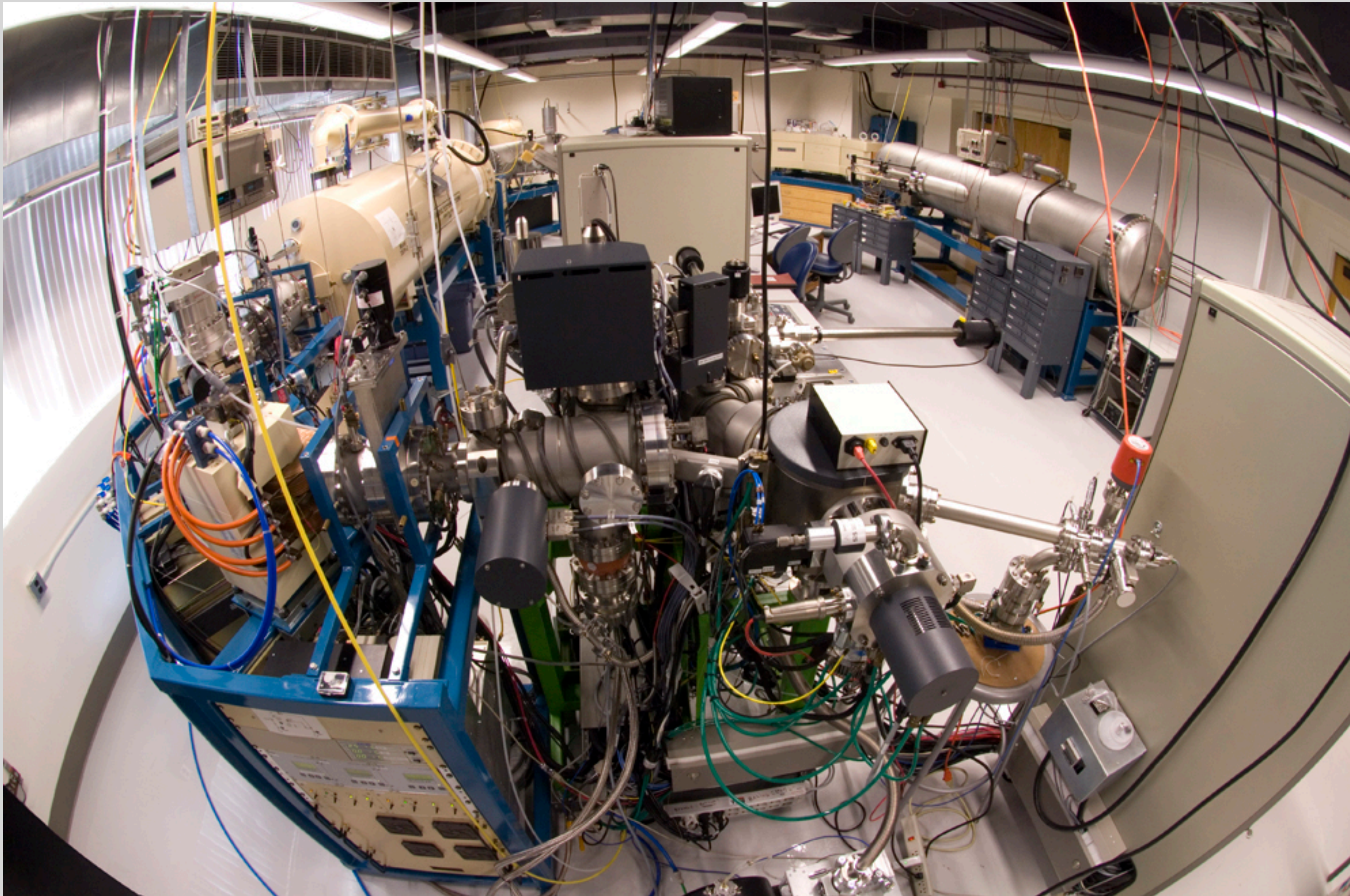
UCLA MegaSIMS



features

- low background
- high depth resolution
- ion microscope
- complete molecule destruction
- simultaneous detection by ion counting

the UCLA MegaSIMS



GENESIS

Prioritized Measurement Objectives

- [x] (1) O isotopes.
- [x] (2) N isotopes in bulk solar wind.
- [x] (3) Noble gas elements and isotopes.
- [x] (4) Noble gas elements and isotopes; regimes.

(5) C isotopes.
(6) C isotopes in different solar wind regimes.
(7) Mg,Ca,Ti,Cr,Ba isotopes.
(8) Key First Ionization Potential Elements
(9) Mass 80-100 and 120-140 elemental abundance patterns.
(10) Survey of solar-terrestrial isotopic differences.
(11) Noble gas and N, elements and isotopes for higher energy solar particles.
(12) Li/Be/B elemental and isotopic abundances.
(13) Radioactive nuclei in the solar wind.
(14) F abundance.
(15) Pt-group elemental abundances.
(16) Key s-process heavy elements.
(17) Heavy-light element comparisons.
(18) Solar rare earth elements abundance pattern.
(19) Comparison of solar and chondritic elemental abundances.

Measurement of bulk solar wind except when noted.
First 4 objectives are required.

Genesis key science objectives required development of capabilities with strong international participation

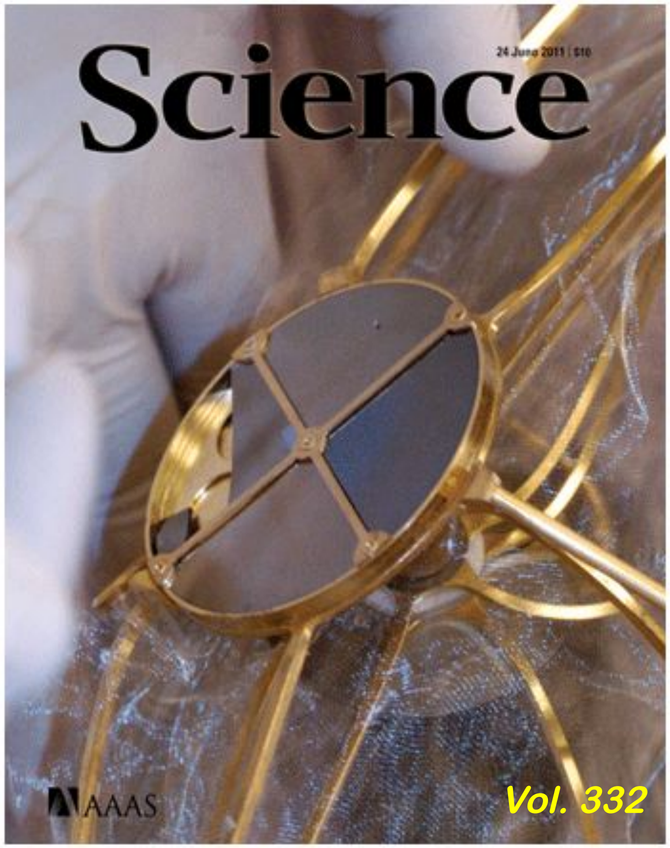


Image: NASA Genesis Team

The Oxygen Isotopic Composition of the Sun Inferred from Captured Solar Wind

K. D. McKeegan,[1*] A. P. A. Kallio,[1] V. S. Heber,[1] G. Jarzebinski,[1] P. H. Mao,[1,2] C. D. Coath, T. Kunihiro,[1,4] R. C. Wiens,[5] J. E. Nordholt,[5] R. W. Moses Jr.,[5] D. B. Reisenfeld,[6] A. J. G. Jurewicz,[7] D. S. Burnett[8]

A ^{15}N-Poor Isotopic Composition for the Solar System As Shown by Genesis Solar Wind Samples

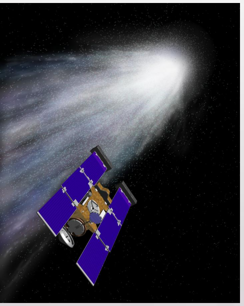
B. Marty,[1*] M. Chaussidon,[1] R. C. Wiens,[2] A. J. G. Jurewicz,[3] D. S. Burnett[4]

Isotopic and elemental fractionation of solar wind implanted in the Genesis concentrator target characterized and quantified by noble gases

Veronika S. HEBER[1,2*], Roger C. WIENS[3], Amy J. G. JUREWICZ[4], Nadia VOGEL[1], Daniel B. REISENFELD[5], Heinrich BAUR[1], Kevin D. McKEEGAN[2], Rainer WIELER[1], and Donald S. BURNETT[6]

Meteoritics & Planetary Science, 46, 493–512 (2011)

Stardust relied on existing instrumentation infrastructure



Probing Comets

resolution & composition
at very fine scale

“Facilities” not same as “capabilities”

capabilities for NASA sample science

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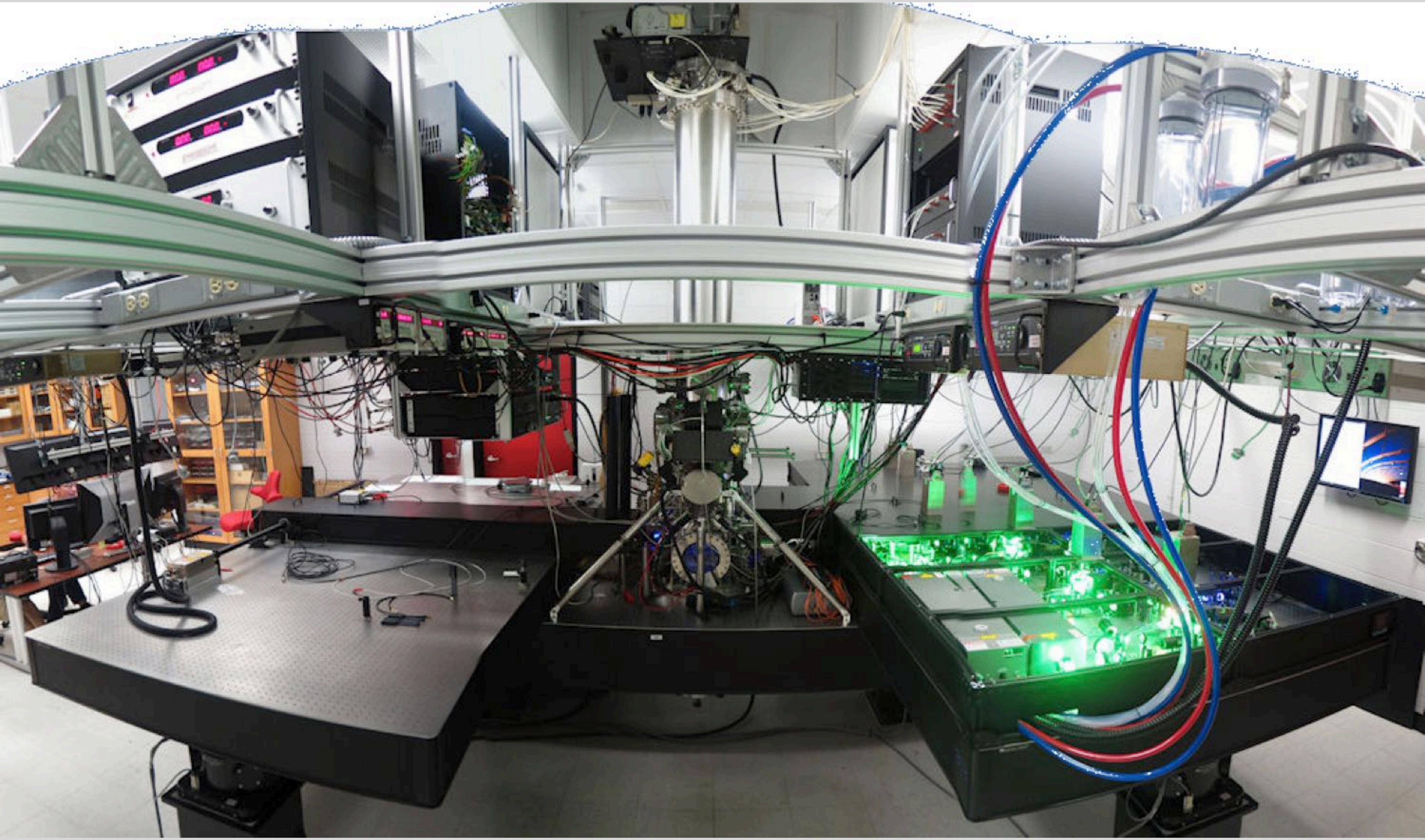
  - *R&A programs (e.g, cosmochemistry, PME, LARS) have supported individual laboratory capabilities for sample analyses that enhance mission science; investments made in capabilities (incl. people) that then must be sustained.*

Example: focus on mass spectrometry

- *Development of mass spectrometry for high precision (e.g., TIMS), high spatial resolution (e.g., SIMS, RIMS), and/or high sensitivity (AMS, RIMS, SIMS, noble gases)*
- *other agencies (NSF) led in ICPMS, gas-source mass spec*
- *Organic analyses not as well developed for ET samples*

CHILI (CHicago Instrument for Laser Ionization)



heritage from CHARISMA, SARISA (DOE + Genesis/LARS)

Ed Young's PANORAMA instrument at UCLA

Panorama is a collaboration between UCLA and the Geophysical Laboratory of the Carnegie Institution of Washington. Funding is from the Sloan Foundation, NSF, DOE, UCLA, Carnegie, and Shell.

largest gas-source multiple-collector mass spectrometer

Non-NASA Facilities

Multiuser facilities (DOE, NSF, others)

- *Development and operation*
- *Customized commercial instrumentation*

Operational subsidy

- *Enables access to very expensive instrumentation by a large number of scientists and students.*
- *Permits technical developments by experts in the technology.*
- *Subsidy provides some funding stability for facility operators.*
- *In exchange for subsidy, facility operators lend expertise and yield fraction of instrument time. Some (but not all) work is collaborative, synergies can result. Can "leverage" costs across several agencies (and university).*
- *User projects funded by research grants; user fees applied or proposals submitted to compete for instrument time.*

National Science Foundation
WHERE DISCOVERIES BEGIN

http://www.nsf.gov/geo/ear/if/facil.jsp

Earth Sciences: Instrumentation and Facilities Program

Consortium for Materials Properties Research in Earth Sciences (COMPRES)

GeoSoilEnviroCARS Synchrotron Radiation Beamlines: Advanced Photon Source

Purdue Rare Isotope Measurement Laboratory (PRIME Lab)

Institute for Rock Magnetism (IRM)

UCLA SIMS Laboratory (UCLA SIMS)

Arizona State University SIMS Laboratories

UT High-Resolution Computed X-Ray Tomography Facility (UTCT)

Arizona LaserChron Center (ALCC)

University of Wisconsin SIMS Lab (Wisc-SIMS)

WHOI Northeast National Ion Microprobe Facility (NENIMF)

National Science Foundation
WHERE DISCOVERIES BEGIN

Facilities with significant NASA related science programs

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U.S. competitiveness

JAXA developing curatorial facilities for Hayabusa-2, O-rex, martian asteroid exploration

- *State-of-the-art, but basic analytical capabilities*

MEXT (= Japanese NSF) has new program "Open Innovation Platform" for state-of-the-art instrumentation

- *Operational support is part of the program*
- *Good atmosphere for extraterrestrial sample analysis*
- *Several highly innovative developments in Japan (especially Yurimoto's lab: SCAPS, LIMAS)*

My non-quant assessment: Japan equal to US in most beam analyses (small samples), but not yet in highest precision work. European labs equal (or better) to U.S. but no returned samples as of yet. Commercial collab. w/ geochemists generally better overseas.

Japanese facilities for extraterrestrial sample research (courtesy H. Yurimoto):

University

Hokkaido University (Yoshi Yurimoto: SIMS, aber. corr. TEM, Orbitrap MS)
Tohoku University (Tomoki Nakamura: NanoSIMS (coming soon))
Tokyo University (Hiroko Nagahara: Laser ICP-MS, nanoSIMS)
Tokyo Tech (Tetsuya Yokoyama: ICP-MS, TIMS)
Nagoya University (Hiroshi Hidaka: SHRIMP)
Kyoto University (Akira Tsuchiyama: X-ray CT, HR-TEM)
Okayama University (Eizo Nakamura: Many instruments)
Kyushu University (Hiroshi Naraoka: DESI-Orbitrap)

Institute

SPring-8 (X-ray CT, XANES, EXAFS, STXM)
JAMSTEC (Motoo Ito: SIMS, nanoSIMS, aberration correction TEM)
NIPR (SHRIMP)
Institute for Molecular Science (STXM, NEXAFS)

JAXA will make collaborations with these facilities and some of Open Innovation Platforms and analytical divisions of Japanese companies for Hayabusa 2 sample analysis.

These facilities (except companies) are open for international collaboration

Futurism: opportunities and concerns

NASA astromaterials curatorial facilities are a strength

- *But requires continued investment, especially as primitive samples are returned with interesting volatiles, organics (contamination control, cyrogenic sample handling...)*
- *"Astrobiological infrastructure" development needed. Early Earth samples should be curated in some fashion.*
- *Mars sample return is another level entirely*

US analytical capabilities are not significantly trailing "world standards" but concerns are legitimate

- *Some areas need investment: noble gases, organics, ices...*
- *Are we investing enough in sustaining research scientists at universities? In training young scientists in instrumentation?*

Interagency cooperation good, but should be enhanced

- *"mid-size instrumentation" funding gap (>MRI, <MREFC)*
- *Enhance LARS, PME budgets to be more compatible w NSF/IF?*
- *Increase NASA contributions to technical support at facilities*