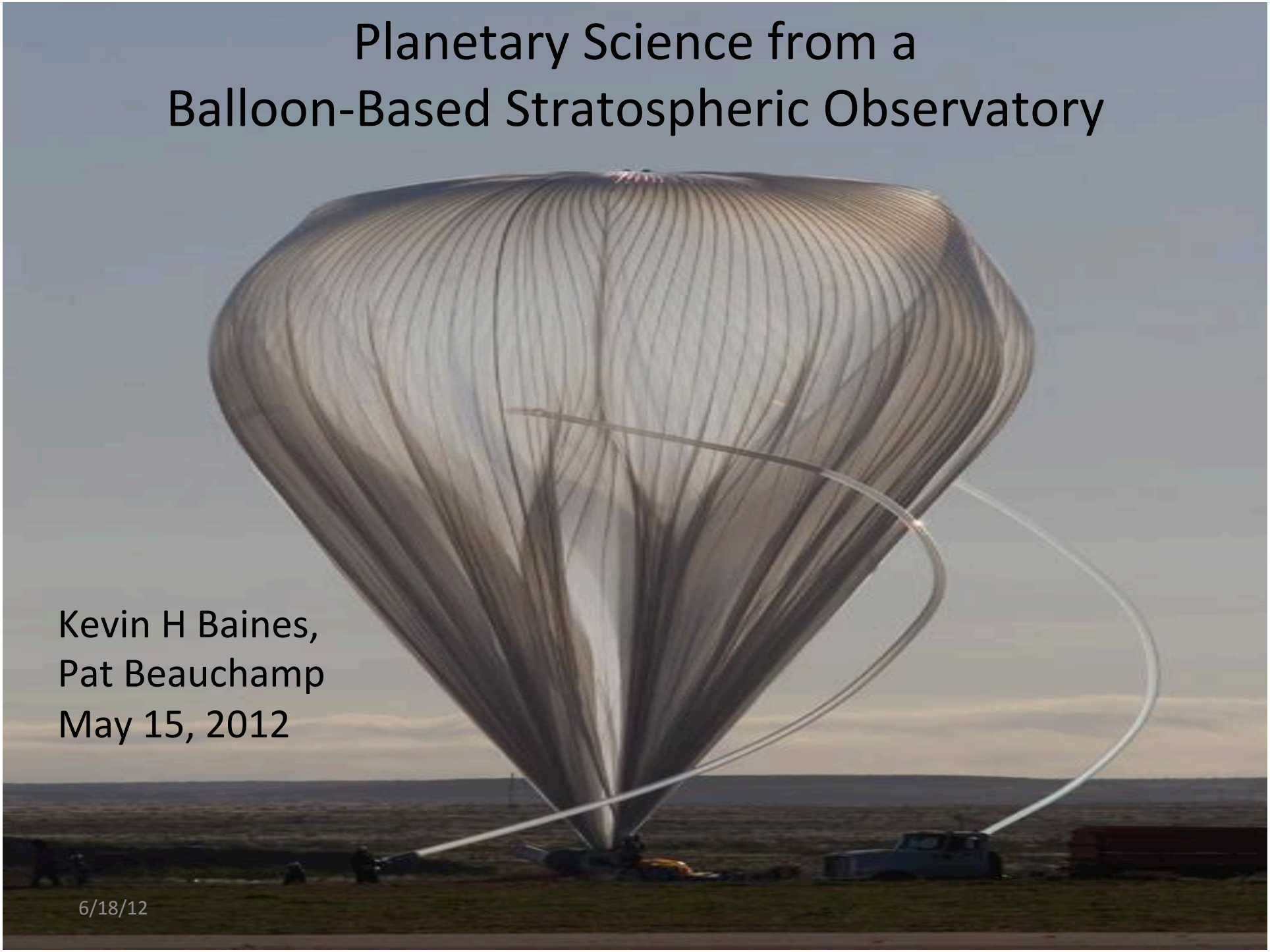
Planetary Science from a Balloon-Based Stratospheric Observatory



Kevin H Baines,
Pat Beauchamp
May 15, 2012

National Aeronautics and Space Administration

Exploring the Planetary Science Achievable from a Balloon-Based Observatory

January 25 and 26, 2012 • Workshop — Agenda — Registration

November 16, 2011 • Pre-Workshop Virtual Meeting — Agenda

Sponsored by

NASA Glenn Research Center

Cleveland, Ohio • at the Ohio Aerospace Institute

The primary purpose of the workshop is to determine the level of planetary science support for a balloon-based planetary observatory.

The state of the art in balloon platform capabilities will be presented to provide a basis to explore, discuss, and articulate potential science opportunities that can be realized with balloon-based observations. After considering science benefits and exploring recent examples of balloon missions, the focus will turn to identifying driving architecture requirements and technology challenges for a reusable, high-altitude balloon platform for planetary science missions. For more information about this exciting event, visit

http://spaceflightsystems.grc.nasa.gov/SSPO/SP/Balloon_Platform/

Link: Achieve Planetary Science Using Earth-Based Balloons Blog

www.nasa.gov

PS-00635-1011

Planetary Science from a Balloon-based Observatory – An Update

March 30, 2012

Tibor Kremic
NASA/Glenn Research Center

Outline

- Refresh on what we're doing and why
- Workshop results
- Summary of ideas to date
- Next Steps

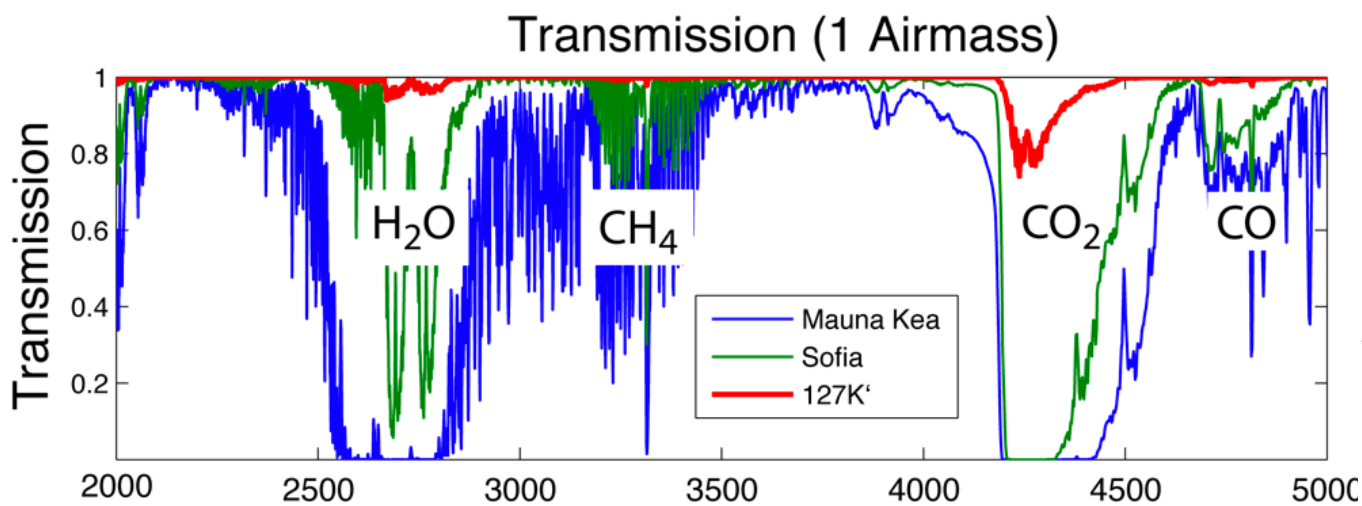
BLAST mission – Astrophysics

Not your Grandfather's Balloons

- Balloons today can operate at over 120,000 ft (above 99.5% of the atmosphere)*
- Carry payloads in excess of 6,000lbs*
- Operate at altitude for over 50 days*
- Are relatively inexpensive to develop, launch, operate and can be done so quickly
- Recently demonstrated sub-arc second pointing for ten's of minutes

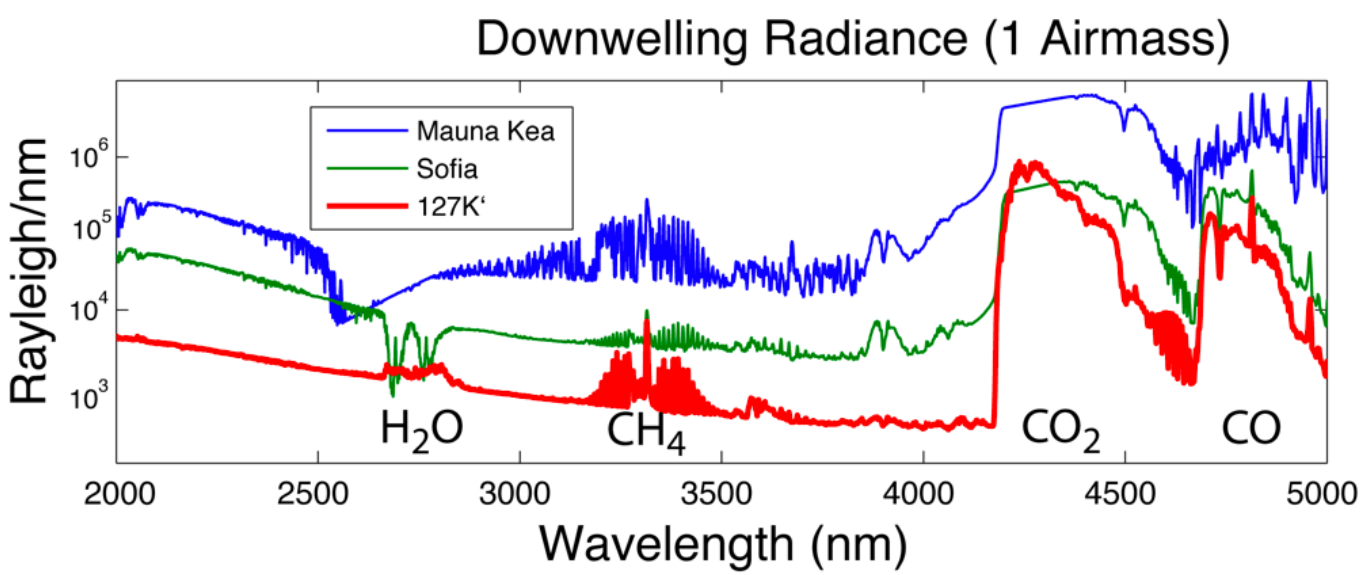
* Currently all these are not doable on the **same** mission. Near term goal is to fly 2000lbs at 120K ft for 100 days.

NIR-Mid-IR Observing Conditions.

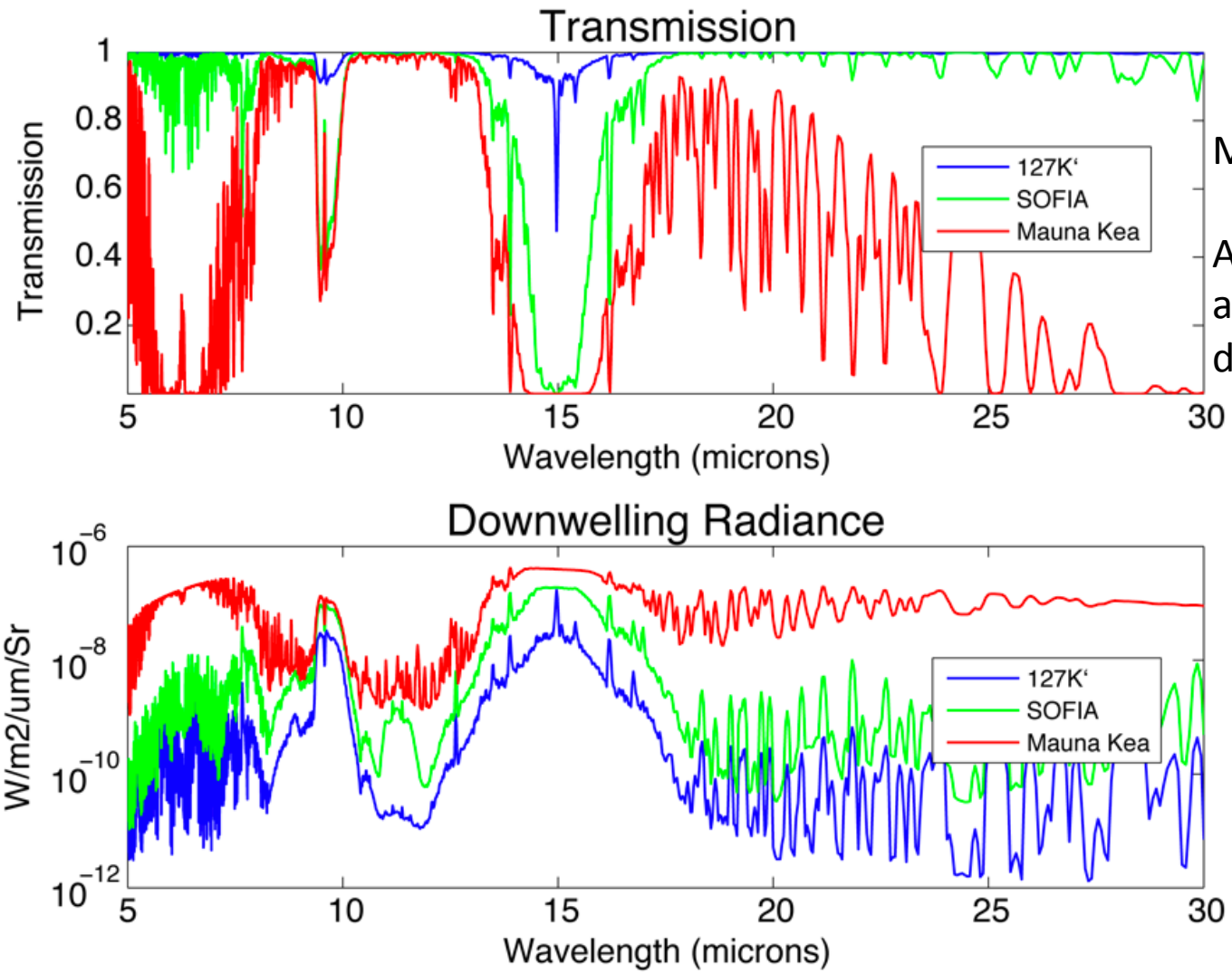


ModTran results.

At 120K', spectrum fully available with low downwelling radiance



TIR Observing Conditions



ModTran results.

At 120K', spectrum fully available with low downwelling radiance

SPATIAL RESOLUTION in DETAIL

Atmospheric seeing at 120,000 ft is insignificant (evidence: the SUNRISE mission's wavefront sensor). Balloon-borne telescopes can operate at the diffraction limit, *even in the visible*.

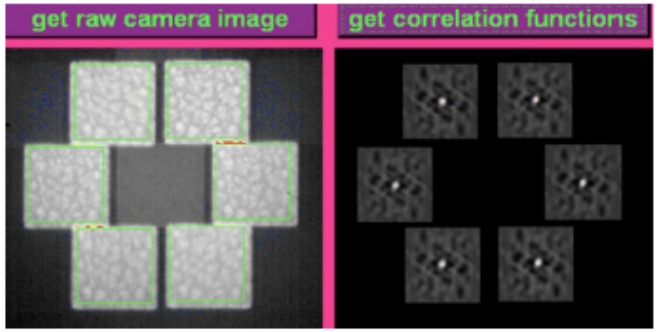
Solar Phys (2011) 268: 103–123
DOI 10.1007/s11207-010-9676-3

THE SUNRISE BALLOON-BORNE OBSERVATORY

The Wave-Front Correction System for the *Sunrise* Balloon-Borne Solar Observatory

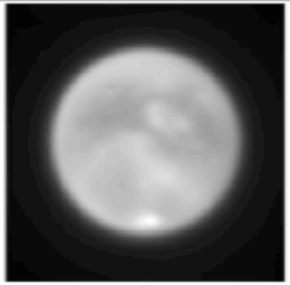
T. Berkefeld · W. Schmidt · D. Soltau · A. Bell · H.P. Doerr · B. Feger · R. Friedlein · K. Gerber · F. Heidecke · T. Kentischer · O. v. d. Lühe · M. Sigwarth · E. Wälde · P. Barthol · W. Deutsch · A. Gandorfer · D. Germerott · B. Grauf · R. Meller · A. Álvarez-Herrero · M. Knölker · V. Martínez Pillet · S.K. Solanki · A.M. Title

Received: 8 June 2010 / Accepted: 4 November 2010 / Published online: 8 December 2010



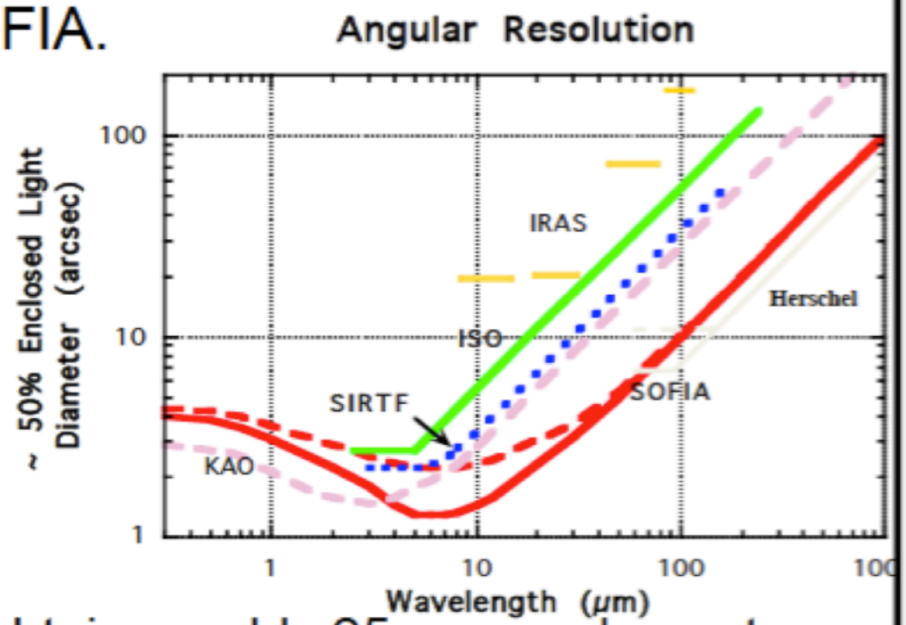
Adaptive optics systems on the Keck, Subaru, Gemini, VLT (and other) telescopes work well in IR wavelengths longer than 1.2 μm, with Strehl ratios up to 60 - 70% in K-band. However, these AO systems do not work in visible wavelengths.

SPATIAL RESOLUTION in DETAIL



From SOFIA, the spatial resolution is several arcseconds. Titan (at left) subtends 1" - it would not be resolved by SOFIA.

In contrast, a one-meter balloon-borne telescope can resolve Titan into 75 resolution elements.



Conclusions:

1) 1-m balloon-borne telescopes obtain roughly 25x more elements than KECK in visible wavelengths ($\lambda < 1.0$ μm).
2) 1-m balloon-borne telescopes obtain more than 1000x more areal elements than SOFIA.
3) 1-m balloon-borne telescopes cannot compete with Keck at $\lambda > 1.2$ μm (unless you consider 4-m telescopes and larger).

Summary of SOFIA Characteristics

Spatial Resolution

Current performance: ~4" at 0.6 μm.
Eventual spec: 1.6" at 0.6 μm.

Telluric Absorption

Virtually NO telluric water absorption, but CO, CO_2, CH_4 are still factors.

Access

Eventual goal: 960 hr per year (6 hr at 41,000 per flight, 40 PI/GI teams/yr). Can be deployed from any airport that supports 747s. Not subject to clouds.

Cost

$78M per year.

Summary of BALLOON Characteristics

Spatial Resolution

Diffraction limited. At 0.5 μm, a one meter telescope has 0.12" resolution; a 2-m telescope has 0.06" resolution.

Telluric Absorption

Above 99.5% of the atmosphere. Virtually no telluric absorptions from 0.3 to 5 μm (even 4.3 μm is workable).

Access

Not subject to clouds. Flight durations up to 40 days (100 days being considered). Launches are affected by weather.

Cost

Launches from $100K to $1M. Payloads at the $5M+ level (typical in APRA).

Potential Advantages of a Balloon-Based Facility

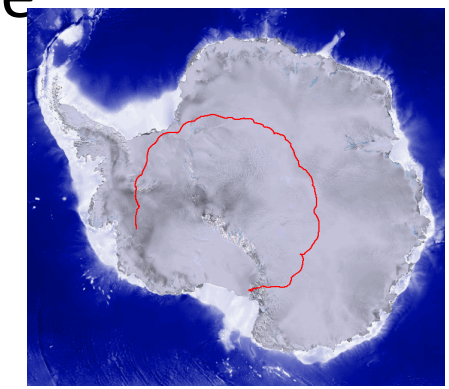
- Low-cost planetary science
- Hubble-like performance at greatly reduced cost
- Clear access to wavelengths obscured by Earth's atmosphere
- Very stable photometry
- Ability to observe targets close to sun
- Long observation periods (enables some atmospheric science)
- Low-cost enables the facility to be dedicated for planetary science – eases operations
- Large payload capacity – offers piggyback science, student projects, technology demonstrations
- Broadens flight opportunities for planetary PI's
- Fast development cycles and science return

What are we doing?

- Determine if there is high-value planetary science that can be achieved from a stratospheric balloon based platform
  - Is there community support to explore this potential

- What might that science be
  - Disciplines, Targets, Quantity

- What would it take to achieve that science
  - Mission and platform concepts
  - Costs and risks



Why?

- Increasing cost pressures will require novel approaches for getting more planetary science with less resources
- Recent technical advances
  - E.g. pointing
- Opportunity to leverage progress made by other SMD divisions for the platform
- Engage a broader planetary community in missions, other…

STO hardware

Workshop Results

- The primary goals of the workshop were to determine the level of support from the planetary community and to get an idea of the science
- Very positive response from attendees and others in the planetary community
- URL for workshop, presentations, and other information is http://spaceflightsystems.grc.nasa.gov/SSPO/SP/Balloon_Platform/

Workshop Results

- Good array of ideas and discussion of science - (40) science concepts captured with an emphasis on why this platform would be preferred/necessary
  - Main discriminators of platform tended to be
    - View location: Above most atmospheric effects
    - Opportunity for long flights and observations (weeks and moving to months)
    - Payload capability (large and heavy payloads) as compared to spacecraft

- Cost not directly factored in yet but that is expected to be a significant benefit as well

Science Idea Summary

Target	Idea Title
Major Planets	Ammonia Storm Cloud Evolution on Jupiter and Saturn
	Methane Cloud Evolution on Uranus/Neptune
	Auroral Observations
	Exogenic Water in the Atmospheres of Major Planets
	Mapping Waves and Dynamics on the Giant Planets
	Saturn Rings Observations (??)
Icy Satellites	Methane Storm Cloud Evolution on Titan
	Red Absorber and Hydrocarbon Ices on Satellites
	Spectroscopy of Surface Ices on Triton, Pluto, and Large TNOs
	Secular Volcanism on Io
	Discovery and Characterization of CO_2 on Airless Bodies
	Light Curves of Absorbing Materials on Titan, Triton and Others
	Near Surface Methane on Titan

List of ideas generated – community review and comments will establish merits. Further study will address technical risk

Major Planets and Icy Satellites

Break-out: Major Planets and Icy Satellites

Form completed by: Kevin Baines

Concept title (ID): Aurorae Observations *(38)*

Description of the potential science / science goals:

Mapping aurorae in the polar regions for the Major Planets. UV, visible, and near-IR maps obtained continuously (every 15 minutes) for 20 hrs, several times per week over a month, to obtain short-term and long-term timescales.

Relevance of the science (Why is this important?) What are the specific Decadal ties?

Chemistry, dynamics of planetary atmospheres and interaction with the magnetophere and solar wind. Answering Priority Questions 2, 7, 8, 9, & 10 of The Decadal Survey; see Decadal Survey p. 88 TABLE 3.1 "The Key Questions and Planetary Destinations to Address Them"

What measurements are required to achieve the science?

Maps of the polar regions obtained every 15 minutes for 20 hrs. Done several times per week over a month. Assorted diagnostic wavelengths in the UV, visible and near-IR, In particular, 3.4-3.7 um observations of H3+ emissions.

What are the driving requirements to achieve the measurements? (E.g. time on target, frequency of observations, aperture, focal length, wavelengths, pointing precision and stability, specific observing location(s), critical observation time(s), are repeat flights required? or whatever else that may drive the hardware or mission design/architecture).

Minimum Telescope aperture: Telescope focal length:

Wavelengths: UV visible, and 3.4-3.7 um spectral resolution

Pointing Stability: 0.05 arc sec desired

Required time on target: Approx 30 days, semi-continuous. Approximately 12 times, each for 20 hrs

Are there other ways to achieve this science, and if so, why would a balloon platform be preferable?

Continuous observations over 20 hrs only possible from this platform, other than from spacecraft

What are the potential observation targets? Jupiter, Saturn, Uranus, and Neptune

What planetary science disciplines would this involve?

Planetary atmospheres, Space Physics, Magnetospheric physics

Point of contact for follow-on questions (Name and contact info)

Kevin Baines, blueskies4321@yahoo.com

Science Idea Summary

Target	Idea Title
Small Bodies	Survey and characterization of organics and volatiles on asteroids
	Physical properties of asteroids
	CO_2 on asteroids
	Monitoring Comet & Transition Object Behavior
	Population Compositional Characterization of Primitive Asteroids
	Understand UV variability in C-type asteroids
	Space Weathering on S-Type Asteroids
	Characterize Volatile Ice on TNOs (Trans Neptunian Objects)
	Small Body Targets-of-Opportunity
	Searching for OH emission around Ceres and other asteroids
	Observations of faint moving objects
	Interplanetary Dust Particles (IDP)

List of ideas generated – community review and comments will establish merits. Further study will address technical risk

Science Idea Summary

Target	Idea Title
Venus	Venus Surface Thermal Emissivity
	Lightning detection on Venus
	Venus Day side cloud circulation
	Venus clouds circulation (night)
Mars	Water cycle of Mars
	Dust cycle of Mars
	Mars – trace gas observations
Moon	Moon and Mercury non-mafic silicate composition
	Temporal and Spacial Variance of chemical species in the exospheres Mercury and secondarily the Moon
	Water Cycle on the Moon
	Moon Dust
Other	Secondary Support for Primary Missions
	Balloons and Instrument validation
	Exoplanet transit and transit spectroscopy
	Planetary Surprises requiring quick response
	Observations of faint moving objects: KBOs, asteroids, NEOs
	Multi Instrument Campaigns

List of ideas generated – community review and comments will establish merits. Further study will address technical risk

Next Steps

- Share what has been done to date and solicit broad community input. **Look for notices from PEN and AGs**
  - Site established through LPI http://www.lpi.usra.edu/balloon_science/

- **Please comment on the current concepts and related documents and add any new ideas you may have**
  - Comments/inputs will be accepted through April

- Leverage OCT selection of balloon mission demonstrating a hardware/ technique for precise pointing. Will fold results into future PSD efforts

- Ideas will then be clustered around similar platform requirements with the intent to further study 1 or more of the most promising platforms to better understand science, technical challenges, cost, etc…

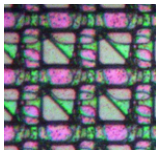
We need you inputs!

What is NASA's Flight Opportunities Program?

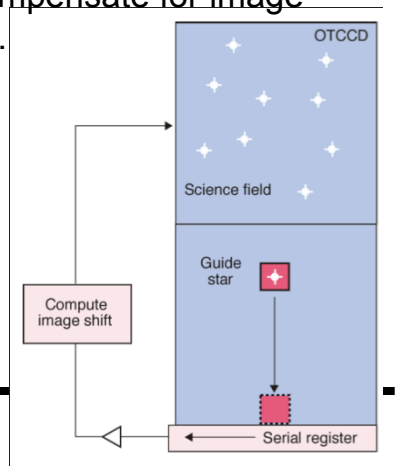
http://www.nasa.gov/offices/oct/crosscutting_capability/flight_opportunities/index.html

- A chance to apply for a parabolic, suborbital or balloon flight.
- Balloon flights to 120,000 ft: a good way to test new technologies.
- Example: demonstrate an image stabilization system.

Why is Image Stabilization on a Balloon Important? It allows HST resolution in visible wavelengths.



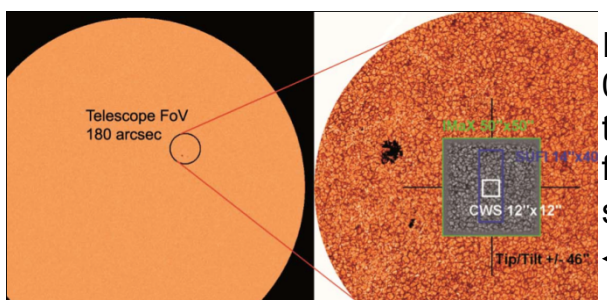
An OTCCD (left) can sense and compensate for image motion.



- Consider an Orthogonal Transfer CCD (shifts charge in 4 directions).
- Measures pointing errors and performs motion compensation.
- Will work with coarse pointing systems like WASP.

"Flight Demonstration of an Integrated Camera and Solid-State Fine Steering System" *E. Young, SwRI, Boulder, CO*

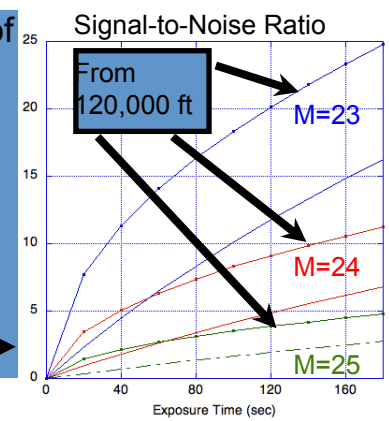
What is the Significance of Diffraction-Limited Imaging from a Balloon?



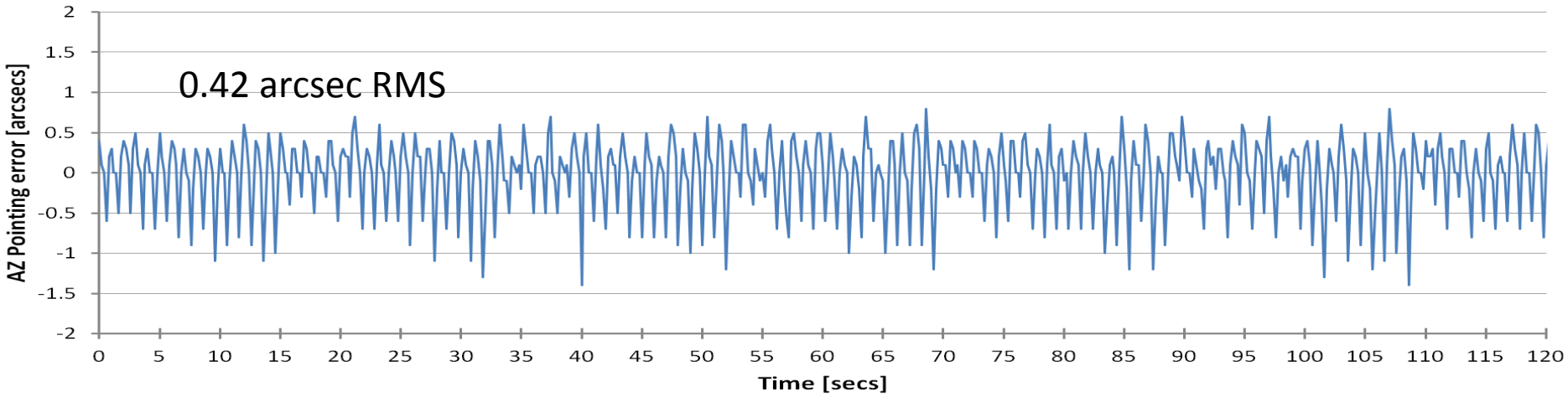
It allows visible imaging at 0.05" resolution (with a 2-m telescope), not possible from ground-based AO systems.

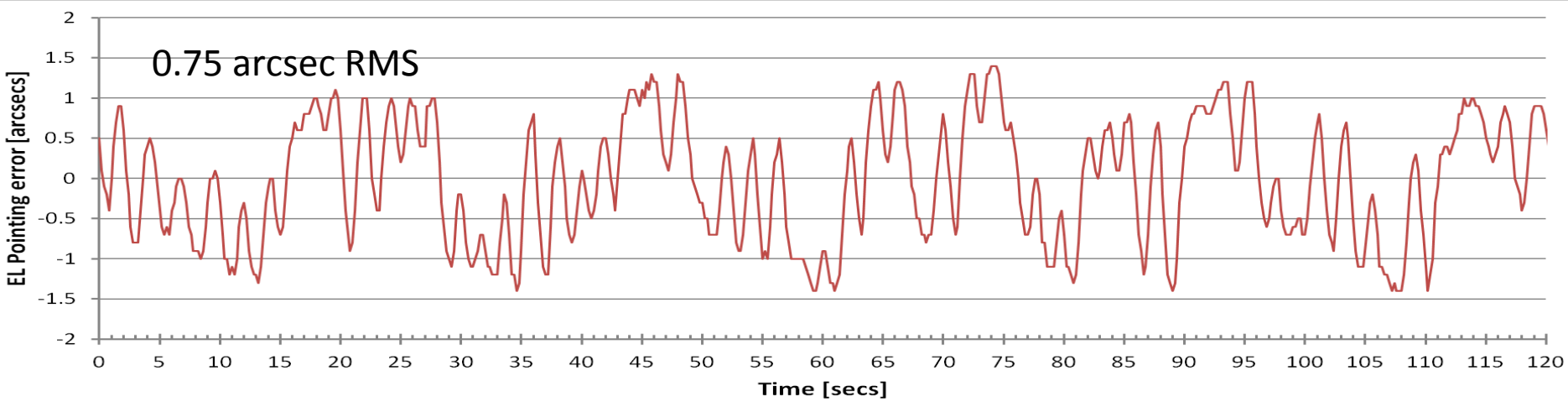
SUNRISE (2009): sharpest pics of Sun to date

It allows deeper imaging of faint objects. Example: objects would have 60% higher SNR from a 1-m telescope at 120,000 ft than from the same telescope on the ground; SNR of 5 in 180 s for a 25th-mag object



Example of Pointing Stability Demonstrated - STO





- Does not imply that this is best that could be done today