Astrophysics

IRTF Future Directions Workshop
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www.nasa.gov
NASA Astrophysics

A Balanced Plan
A Strategic Vision
Why Astrophysics?

Astrophysics is humankind’s scientific endeavor to understand the universe and our place in it.

🌟 How did our universe begin and evolve?

🌀 How did galaxies, stars, and planets come to be?

💧 Are we alone?

Enduring National Strategic Drivers

- 1972
- 1982
- 1991
- 2001
- 2010
Astrophysics Strategic Planning

2016 update includes:
• Response to Midterm Assessment
• Planning for 2020 Decadal Survey

To be updated in 2018 (per GPRAMA)

https://science.nasa.gov/astrophysics/documents
Current Program: an integrated strategic plan

We are executing a balanced strategic program for Astrophysics

• Operating missions, large and small, continue to deliver paradigm changing science
• New missions are in development
• Future planning to support the next Decadal Survey is under way
Observational astrophysics is a photon starved discipline, demanding high performance from all systems and subsystems utilized for on-sky observations and detections.

The astrophysics problems of interest to NASA are difficult and demand the use of all available resources.
“Observations from these powerful ground-based electromagnetic, cosmic ray, and gravitational wave observatories will make crucial contributions to achieving the scientific goals of the Roadmap, in concert with capabilities that can be realized uniquely from space (2013).”
Role of Ground Based Astronomy for Astrophysics

• Strategic support for current flight missions to:
  – Achieve their science goals
  – Enhance their scientific output
  – Provide data for mission planning
  – Provide preparatory data for planned missions
  – Data for future mission planning

• Current NASA funded ground based facilities for astronomy
  – 50% observing time on IRTF
  – 1/6th observing time on WM Keck Observatory (two 10-m telescopes) for all NASA (Astrophysics, Planetary, etc.)
  – Large Binocular Telescope Interferometer
  – NN-EXPLORE (WYIN telescope)- precision radial velocity spectrometer
  – Other Telescopes as needed (UKIRT, Pan-STARRS, Palomar 5-m)
• **Exoplanets**
  - Characterization of exoplanet populations around giant and low mass stars
  - Atmospheric chemistry of exoplanets
  - Role of protoplanetary and planetary disks in planet formation, including disk accretion and chemistry
  - Connection between low mass stars and free-floating planets

• **Stellar and Substellar Astrophysics**
  - Determining stellar abundances
  - Characterization of low mass stars, including low mass IMFs of stellar clusters and star forming regions, physical properties, role of magnetic files
  - Stellar ages of Young Stellar Objects (YSOs)
  - Chemistry of protostellar winds
  - Evolution of late-type stars
  - Supernova physics, IR characterization of SN Ia’s
Astrophysics Science on IRTF

• Galactic
  – Composition of hot and cold molecular clouds
  – Chemical composition of the Galactic thin and thick disk
  – Determining the evolved stellar population of the Galaxy, including near the Galactic Center
  – Characterization of Galactic Cepheids in the IR

• Extragalactic
  – NIR spectroscopy of evolved stars in nearby Local Group Galaxies
  – Determining black hole masses of galaxies
  – Studying AGNs, including monitoring dusty AGNs, looking at the role of star formation in AGNs, and determining the IR Spectral Energy Distribution (SEDs) of AGN
  – Using dusty quasars to feedback and galaxy evolution
Currently, facility instruments iSHELL and SpeX are used the most by astronomers

- SpeX (R\~50 - 2000 and 1-5um imaging, depending on program) gets about 60% of the time
- iSHELL (R\~20,000-75,000) gets about 30% of the time
- remainder \~10% of time goes to visitor instruments (mostly TEXES R\~10,000-100,000 MIR)

SpeX is the workhorse instrument and iSHELL more specialized (comets, planetary atmospheres, star and planet forming disks, stars)
Science Examples
• Tabby’s Star or Boyajian’s Star (KIC 8462852) was observed at IRTF by Casey Lisse, Massimo Marengo, and Michael Sitko, and they were one of the teams suggesting comet swarms to account for the brightness variations. No alien megastructure was needed. This paper was published Dec. 20, 2015 in ApJL, only 50 days after the observations were made. This paper was published even before Boyajian's discovery paper was published.
Dust Formation in V2362 Cygni:
Coordinated IRTF/Spex, VNIRIS, BASS, SPITZER and SWIFT Observations

David K. Lynch, Ray W. Russell, Richard J. Rudy (The Aerospace Corp.), Charles E. Woodward (U. Minnesota), Mike Sitko (U. Cincinnati) and J. Rayner (U. Hawaii)
IRTF Spectral Library: Cool Stars
(Rayner, Cushing & Vacca 2009)
http://irtfweb.ifa.hawaii.edu/~spex/IRTF_Spectral_Library/

PROPERTIES
- 212 stars with optical MK classification (FGKM-SC stars)
- Mostly near-solar metallicities
- 0.8-2.4 \( \mu \text{m} \) all stars, most 0.8-5 \( \mu \text{m} \)
- \( R \sim 2000 \), \( S/N \geq 100 \) typical
- Continuum shape is preserved
- Spectra are absolute flux calibrated (2MASS)

APPLICATIONS
- Physics of cool stellar and sub-stellar atmospheres
- IR classification of optically embedded and cool stars
- IR evolutionary population synthesis studies
- Synthetic photometry
Extended IRTF Spectral Library  
(Villaume et al. 2016)

**PROPERTIES**

- 284 stars OBAFKM SpT
- Non-solar metallicities, -1.7 < [Fe/H] < 0.6
- 0.7-2.5 μm, supplemented with optical spectroscopy
- R ~ 2000, S/N ≥ 100 typical
- Continuum shape is preserved

**EXTENDED APPLICATIONS**

- Physics of hot stellar atmospheres
- Improved IR evolutionary pop. synthesis studies (non-solar metallicities)
Examples of Application of IRTF Spectral Library

- Substantial population of low mass stars found in luminous elliptical galaxies using *IRTF Spectral Library* to construct stellar population synthesis model of the observed spectra. (Pieter G. Van Dokkum & Charlie Conroy *Nature 16 Dec 2010, 468, 940*).

- A gapped primordial disk around LkCa15 was discovered using *IRTF Spectral Library* data which showed that the excess infrared emission above the photosphere of LkCa15 is a black body continuum which can only be due to optically thick material in an inner disk around the star (Espaillat et al. *2008, ApJ 682, L125*).
A thermometer for Goldilocks:
improved parameters for *Kepler* M dwarfs and their planets

Andrew Mann & Eric Gaidos

angular radius + bolometric flux $\rightarrow$ effective temperature

parallax + bolometric flux $\rightarrow$ luminosity

angular radius + parallax $\rightarrow$ stellar radius

Bolometric fluxes of cool (<4700K) calibrator stars (Boyajian et al.) were recalculated using Spex + visible spectra instead of template SpeX
Astrophysics Charge to Workshop

In the context of current and upcoming ground based facilities and NASA Astrophysics missions what unique capabilities can IRTF and new science instruments offer to strategically support Astrophysics missions?

Some possible areas to consider

- **Exoplanets**
  - The new iShell instrument will be very powerful for characterizing M star host stars and with Plavchan's gas cell for enabling PRV for bright targets.
  - Robo-AO at IRTF which would enable rapid, diffraction limited imaging to validate TESS exoplanet candidates

- **Stellar and Substellar Astrophysics/Extragalactic**
  - iShell will be a valuable tool for Galactic sources, e.g. star forming regions and bright brown dwarfs

- **Time Domain Astronomy**
  - As we get more ToO targets from Gravitational Wave targets from LIGO+Space missions, IRTF could play a role.
Revised December 1, 2017

+ MIDEH/MO (2023), SMEX/MO (2025), etc.

WFIRST
Mid 2020s

Chandra
7/23/1999

Swift
11/20/2004

XARM (JAXA)
2021

Spitzer
8/25/2003

Kepler
3/7/2009

Fermi
6/11/2008

NuSTAR
6/13/2012

XMM-Newton (ESA)
12/10/1999

Euclid (ESA)
2020

Hubble
4/24/1990

IXPE
2021

ISS-NICER
6/3/2017

ISS-CREAM
8/14/2017

WFIRST
Mid 2020s

GUSTO
2021

SOFIA
Full Ops 5/2014

+ Athena (late 2020s), LISA (mid 2030s)
NASA Astrophysics

Backup
A nova is thermonuclear runaway on the surface of a white dwarf that has accreted material from a secondary star through its inner Lagrange point in a close binary system.

- Novae are important to study because:
  - They produce heavy elements and inject them into the interstellar medium.
  - They involve exotic nuclear reactions that cannot be reproduced on Earth.
  - Some novae are thought to be progenitors of Type Ia supernovae, important for cosmological reasons.
  - All novae are different: White dwarf mass and composition, secondary composition, accretion rate, etc.
V2362 Cyg is very unusual. It faded for about 4 months while its spectrum hardened as novae usually do, then unexpectedly brightened again as the themonuclear runaway turned on (based on collaborators’ X-Ray data), then formed dust and is now rapidly fading.
Dust formation was dramatic. Sometime between the SpeX observations on Nov 30 and the BASS/IRTF observations on Dec 12, dust formation caused the spectrum to change enormously.

At $\approx 1410 \pm 15$ K, the observed dust was some of the hottest ever observed.