Women in Astronomy:  
The Past Inspires the Future
Outline of this Science Briefing

1. Dr. Gabriela Gonzalez (LIGO, Louisiana State University)
   Music of the Universe: Einstein’s gravitational waves

2. Dr. Elizabeth Hays (Goddard Space Flight Center)
   Gamma-ray Pulsars, Lighthouses in the Galaxy

3. Dr. Farisa Morales (NASA Jet Propulsion Laboratory)
   Formation of Planetary Systems

4. Q&A

5. Dr. Quyen Hart (Space Telescope Science Institute)
   [title]

6. Q&A
Music of the Universe:
Einstein’s gravitational waves

Gabriela González
Louisiana State University
Gravitational waves: a long history

- Predicted by Einstein in 1916: “ripples in space time”
- First observation announced in 2016 (100 years later!)
- Signal “heard” by two LIGO observatories, from the dance and merger of two black holes.

Interferometers to measure space(-time)

- LIGO = Laser Interferometer Gravitational-wave Observatory

Strain detected: 1 part in $10^{21}$

Interferometer is 4km long.

Change in distance measured: 4/1000 of a proton diameter!

Credit: Johan Jarnestad/
The Royal Swedish Academy of Sciences
LIGO detectors are not alone
Ten black hole mergers and...

... a neutron star merger with fireworks that followed!
More (public) music notes in 2019-20

Gracedb.ligo.org

LIGO/Virgo O3 Public Alerts
Detection candidates: 53

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Phone apps!
The next few years
And more instruments for different notes
The past inspires the future

Einstein, 1904

Choquet-Bruhat, 1974

DeWitt-Morette, ca. 1955

Weiss, ca. 1970

Thorne, ca. 1970

Gonzalez, Saulson, 1995

Weiss, Cordova, Reitze, Gonzalez, Thorne, 2016
More resources

• Information: www.ligo.org (at many different levels, with links to documentaries, articles, books, activities, multimedia, student/teacher activities, LIGO magazine, ...)

• Images/Movies: https://www.ligo.caltech.edu/gallery

• 1-hr public talk: https://insidetheperimeter.ca/music-of-the-universe-gabriela-gonzalez-public-lecture-webcast/

• Many TED, TEDx talks (search for LIGO TED)
Gamma-ray Pulsars, Lighthouses in the Galaxy

Credit: NASA/Fermi/Cruz de Wilde

Liz Hays
Goddard Space Flight Center
What is a pulsar?

- **Pulsars pulse.** Regularly repeating radio signals were co-discovered by Jocelyn Bell Burnell in 1967.

- A pulsar is a rotating neutron star with a very strong magnetic field.
  - A star stops burning fuel and collapses into extremely dense, rapidly spinning ball of neutrons.
  - **Small!** Size of a large city, ~12 miles across.
  - **Fast!** A few times a second up to a few hundred times a second.

- 1000s of pulsars have been found in our Galaxy using radio telescopes.
Pulsars are gamma-ray power houses

The first seven gamma-ray pulsars and their pulse shapes at different wavelengths
Fermi maps the entire sky in gamma rays
Fermi has found more than 250 gamma-ray pulsars

Credit: Fermi/LAT
Scientists at NASA use supercomputers to trace the paths of particles caught in a pulsar’s electric and magnetic fields. Their fate in these models helps explain the observed gamma-ray emission.
The Fermi pulsars have changed the simple picture of a pulsar dramatically.

The gamma rays can come from a different part of the pulsars magnetic field and make a broad lighthouse beam.
Pulsars appear prominently in the informal gamma-ray constellations.

The brightest steady source in the Fermi sky, the Vela pulsar, marks the beacon of Pharos, the lighthouse of Alexandria.

The black widow spider represents a pulsar that is destroying a small companion star with its radiation.

The radio telescope dish symbolizes close partnerships between gamma-ray and radio astronomy.
Formation of Planetary Systems

Farisa Y. Morales, PhD

Exoplanet Observations

Debris Disk Observations

NASA'S UNIVERSE OF LEARNING
Proto-planetary disks $\rightarrow$ Planet perturbations of planetesimals

Stars Form with Proto-Planetary Disks building Planetesimals

Planet Perturbations Induce Dust Production

Formation of Rubble Bands


http://www.spitzer.caltech.edu/video-audio/724-ssc2004-17v2-Swirling-Rings-of-Dust
Clues to Planetary System Architecture
Clues to Planetary System Architecture
Clues to Planetary System Architecture

![Brightness vs Wavelength](image1)

![Brightness vs Wavelength](image2)

![Graph of F_ν vs λ](image3)
Clues to Planetary System Architecture

[Graphs and diagrams showing brightness versus wavelength for different systems, labeled IRS and MIPS.]
Clues to Planetary System Architecture

Figure 1
Morales et al. (2011)
Clues to Planetary System Architecture

Figure 1
Morales et al. (2011)
Dust production is clearly favored at the same characteristic $T_{\text{dust}}$ horizon — across the large stellar spectral range (B8-K0) — slightly above the ice evaporation temperature for inner belts!

Note the relative void in $T_{\text{dust}} \sim 100$ K
Two Belt Temperature

Figure 2
Morales et al. (2011)

• Dust production is clearly favored at the same characteristic $T_{dust}$ horizon
  — across the large stellar spectral range (B8-K0)
  — slightly above the ice evaporation temperature for inner belts!

• Note the relative void in $T_{dust} \sim 100$ K
Herschel Resolved Outer/Cold Rings!

(PSF subtracted Mosaic)

HERSCHEL-RESOLVED OUTER BELTS OF TWO-BELT DEBRIS DISKS
—EVIDENCE OF ICY GRAINS

F. Y. Morales1,2, G. Bryden1, M. W. Werner1, and K. R. Stapelfeldt1

Figure 1

Morales et al. (2016)
Water Ice Present in Kuiper-like Belts

HD 166 (K0V)
- \( \sim 456 \) Myr
- 13.7pc
- \( M_{\text{cold}} \approx 0.009 \, M_{\text{Moon}} \)
The presence of rocky grains have been recently confirmed via a spectra stacking technique.
The SED of the dust excess from HR8799 (below) is compared with those of other systems. Angular Separations range from ~0.5 to 4.7 arcsec (~10 to 280 AU, median 95 AU).
Planet Hunting—Ongoing Effort, Palomar
Planet Hunting—Ongoing Effort, Palomar
• **Spitzer Space Telescope** sees both warm and cold excess emission of debris around mature stars

• **Herschel Space Observatory** confirmed the presence of cold-Kuiper belt like dust, measured the size of the outer cold belt, and **revealed the presence of ice**

• Exopalent candidates have been identified using Keck and Palomar Observatories

• For more info on Spitzer Space Telescope, its Legacy, images and animations
  - [www.nasa.gov/spitzer](http://www.nasa.gov/spitzer)
  - [www.spitzer.caltech.edu](http://www.spitzer.caltech.edu)
Inspiration

- **Cecilia Helena Payne-Gaposchkin** was (1900-1979) was a British-born American astronomer and astrophysicist who proposed in her 1925 doctoral thesis that stars were composed primarily of hydrogen and helium.

- Harvard University (1923–1925)
Website to find out about the most recent gravitational wave detections.

One hour public lecture on LIGO by Dr. Gabriela Gonzalez

http://epo.sonoma.edu/ligo
This includes an Educator's guide, and 2 online courses. The online course from 2016 has a huge amount of useful information.
Science Background Resources – Fermi and Pulsars

More information on Fermi, a Gamma-ray Space Telescope
https://fermi.gsfc.nasa.gov/

Supernova Educators Guide, including information and activities around pulsars.

NASA Visualizations of Pulsars:
https://svs.gsfc.nasa.gov/vis/a01000/a010100/a010144/index.html

NASA Goddard Media Studios – Videos about Fermi and Pulsars
https://svs.gsfc.nasa.gov/Gallery/Fermi--Pulsar.html
3D Multiwavelength representation of the Crab Nebula, a Pulsar Wind Nebula

https://hubblesite.org/video/1271/category/139-hd-video

Animation of rotating neutron stars and sonification of their pulse frequency.

https://www.astron.nl/pulsars/animations/
Science Background Resources – Protoplanetary Disks

Videos related to protoplanetary disks

- The Evolution of a Planet-Forming Disk: [Link](http://www.spitzer.caltech.edu/video-audio/730-ssc2004-22v2-The-Evolution-of-a-Planet-Forming-Disk)
- Band of Rubble: [Link](http://www.spitzer.caltech.edu/video-audio/749-ssc2005-10v1-Band-of-Rubble)
- Swirling Rings of Dust: [Link](http://www.spitzer.caltech.edu/video-audio/724-ssc2004-17v2-Swirling-Rings-of-Dust)
Resources to Celebrate Women’s History Month

Women in STEM poster series and other printable resources

Women of Color: Pioneers and Innovators, two sided poster

Lithograph highlighting women who have contributed to high-energy astrophysics

https://women.nasa.gov/
Resources for engaging girls in astronomy and other STEM fields

National Girls Collaborative Project – Engaging girls in STEM and exemplary models.

https://ngcproject.org/engaging-girls-in-stem

SciGirls Strategies: How to Engage Girls in STEM Resource page, including a guide book, framework, tips, and strategies to rework current activities,

http://www.scigirlsconnect.org/scigirls-strategies-engage-girls-stem/

Creating Connections with Role Models: The Power of Collaboration - Techbridge developed this role model guide for the National Girls Collaborative Project.

This montage VIDEO of more than 600 images from the Hubble Space Telescope celebrates the telescope’s 30 years of discovery. 

https://hubblesite.org/contents/media/videos/1273-Video

Resources page, including links to exhibit materials, lithographs, posters, and activities

https://hubblesite.org/hubble-30th-anniversary/resources

30th Anniversary Image Unveiling in all 50 states

https://hubblesite.org/hubble-30th-anniversary/events
Hubble 30th Anniversary – https://hubblesite.org/30

Space Telescope Science Institute
Public Lecture Series

April 7, 2020 8pm EST
30 Years of the Hubble Space Telescope: An All-Star Cast,
Space Telescope Science Institute

Lecture will be streaming live
OR you can watch the recorded lecture.

http://www.stsci.edu/public-lectures
Additional NASA’s UoL Resources

NASA’s UoL Viewspace video on multi-messenger astronomy, including gravitational waves.

NASA’s UoL Viewspace video - discover infrared, the invisible light beyond the red end of the rainbow and what it reveals to use about the universe.

August 2017 NASA’s UoL Science Briefing on Pulsars (PPT, PDF, audio recording)

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If you prefer not to participate in the evaluation process, you can opt out by contacting Kay Ferrari <kay.a.ferrari@jpl.nasa.gov>.

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