# Steven D. Penn

Associate Professor, Physics Department

Hobart and William Smith Colleges
300 Pulteney Street, Geneva, NY 14456
315-383-0069 • penn@hws.edu

**Employment:**

2009 – present: Associate Professor, Hobart & William Smith Colleges
2002 – 2008: Assistant Professor, Hobart & William Smith Colleges
2002 – present: Adjunct Research Professor, Syracuse University
1997 – 2002: Post-Doctoral Fellow, Syracuse University
1994 – 1997: Post-Doctoral Fellow, University of Washington

**Education:**

Massachusetts Institute of Technology — Cambridge, MA
Doctor of Philosophy in Physics, September 1993
Thesis: "An Examination of Two-Nucleon Correlations in $^{12}C$ via (e,e´p) and (e,e´d) at $X$ = 2 and q = 913 MeV/c."
Thesis Supervisor: Professor William Bertozzi

Massachusetts Institute of Technology — Cambridge, MA
Bachelor of Science in Physics, June 1985

**Awards:**

Special Breakthrough Prize in Physics for LIGO Scientific Collaboration, 2016
Princess of Asturias Award for Technical & Scientific Research for LSC, 2017
The Karl Taylor Compton Award for Overall Excellence, MIT 1992

**Research Committees:**

LIGO Scientific Collaboration Council Chair, 2019–present
LIGO Scientific Collaboration Coatings Working Group Chair, 2011–2018

**Publications:**
*Selected*

**Observation of gravitational waves from a binary black hole merger.**
Abbott, B. P., et al. (LIGO and Virgo Collaborations including S Penn)
*Phys. Rev. Lett.* 116.6 (2016): 061102. (Front cover article)

**Mechanical Ringdown Studies of Large-Area Substrate-Transferred GaAs/AlGaAs Crystalline Coatings**
S D Penn, M M Kinley-Hanlon, Ian A. O. MacMillan, *et al.*
*Journal Opt. Soc. Am. B,* ***36****,* (2019) C15

**Frequency and surface dependence of the mechanical loss in fused silica**
Steven D Penn, *et al.*, *Phys. Lett. A* **352** No 1-2 (2006) 3-6

**Gravitational Wave Detection and Coating Thermal Noise**
S. Penn and D Ottaway, in *Optical Coatings for Precision Measurements*, Ed. by G. Harry, T. Bodiya, R. deSalvo, 2010, Cambridge University Press

**Mechanical Loss in Silica/Tantala Dielectric Mirror Coatings**
S D Penn, Sheila Rowan, *et al.*, *Class. Quantum Grav.* **20** (2003) 2917-2928

**Mirror Coating Solution for the Cryogenic Einstein Telescope**
Kieran Craig, Jessica Steinlechner, Peter G. Murray, Angus S. Bell, Ross Birney, Karen Haughian, Jim Hough, Ian MacLaren, Steve Penn, Stuart Reid, Raymond Robie, Sheila Rowan, and Iain W. Martin
*Phys. Rev. Lett.* **122**, 231102 (Front cover article)

**TEACHING EXPERIENCE:**

PROFESSOR, Hobart and William Smith Colleges, 2002-present

- General Relativity (400-level)
- Advanced Physics Laboratory (300-level Lab) ☆
- Electricity & Magnetism (300-level)
- Classical Mechanics (300-level, Lagrangian & Hamiltonian Mechanics)
- Modern Physics & Laboratory (200-level Lab) ☆
- Waves and Optics (200-level) ☆
- Mathematical Methods & Laboratory (200-level)
- Computational Methods / Scientific Computing ☆
- Introduction to Astrophysics (200-level) ☆
- Introduction to Astronomy (100-level, cosmology focus)
- Green Energy, (200-level, Physics & Environmental Studies) ☆
- Energy (100-level, Environmental Studies)
- Principles of Physics, (100-level, physics for nonmajors)
- PhysX (100-level Seminar) ☆
- How Things Work (100-level Seminar) ☆

☆ = New HWS Course developed by me

INSTRUCTOR, Syracuse University, 1998–1999

- Recitation instructor for First year physics (mechanics).
- Laboratory instructor for introductory astronomy.

INSTRUCTOR, University of Washington, 1995-1997

- Tutorial instructor for First-year physics (mechanics, E&M)

**SERVICE COMMITTEES:**

LIGO Scientific Collaboration Council Chair, 2019–present

LIGO Scientific Collaboration Bylaws Committee, 2012 (Chair), 2018

LIGO Scientific Collaboration Publication & Presentation Committee, 2008-13

APS Topical Group on Gravitation, Executive Board, Jan 2005–2008

NSF Grant Review Panel, Nov 2009

NSF Grant Review Panel for Experimental Gravity, Jan 2006

HWS Faculty Information Technology Committee, 2003–2005

HWS Committee on Standards (Chair), 2015–2019

**CONFERENCE ORGANIZED:**

First LIGO-Virgo Thermal Noise Meeting, Virgo Observatory, Pisa, Italy 2006

**GRANT AWARDS:**

NSF/Moore Foundation, "Center for Coating Research" grant award. $3M for 10 institutions, (Proposal co-authored by me, M. Fejer, and R. Bassiri). Awards for HWS: $107,738 (2017) and $107,464 (2020)

NSF, MPS Division, 7 grants from 2002-2022 totaling $1,605,103

NSF MRI Grant (Jan 2003): Award: $80,000.

NSF MRI Grant (July 2019): Award: $155,000 with Prof. Ballmer, Syracuse

**Invited Talks:**
*Conferences*

**From Thin Films to Black Holes: the impact of Thermal Noise in Gravitational Wave Astronomy**
• 117th Topical Symposium of the NY State section of APS/AAS Joint Meeting, Union College, Nov 2017

**How black holes relate to relaxation phenomena in amorphous oxide thin films**
• 8th Symposium on Functional Coatings and Surface Engineering, June 2017

**Developing Mirror Coatings for Future Gravitational Wave Detectors**
• OSA Optical Interference Coatings Conference, June 2016

**Prospects for Better Coatings**
• Gravitational Wave Advanced Detector Workshop, May 2015

**Wave of the Future: The Status of the LIGO and the Advanced LIGO Detectors**
• Miami 2010 Conference, 18 Dec 2010

**Status of LIGO and Advanced LIGO**
• CHIPP Workshop on Space Time and Gravitation, Swiss Institute of Particle Physics, Lausanne, Switzerland, April 2006

**Invited Talks:**
*Seminars & Colloquia*

**Gravitational Wave Detectors and the Challenge of Coating Thermal Noise**
• CCRG/Astronomy Lunch Talk • RIT • 25 May 2016

**How LIGO Detects Gravitational Waves and the Challenge of Coating Thermal Noise**
• Ithaca College Physics & Astronomy Research Seminar , 13 Sept 2016

**On Further Reflection: The structure of Fused Silica and the design of low loss, high index coatings.**
• Stanford University Byer-Fejer Group Seminar, 5 March 2014

**Avenues for Reducing Coating Thermal Noise**
• Institute for Gravitational Research, University of Glasgow, Dec 2013

**Amorphous Coatings: Current Status — Future Plans**
• Gravitational Wave Advanced Detector Workshop, May 2012

**Gravity and Glass: Advanced LIGO, Thermal Noise and the Curious Physics of Fused Silica**
• American University Physics Seminar, 20 April 2012

**Wave of the Future: Advanced LIGO and the Next Generation of Gravitational Wave Detectors**
• Old Dominion University Physics Colloquium, 16 Nov 2010

**Mechanical Loss in Fused Silica Substrates**, and **Suspension Thermal Noise in Initial LIGO**
• LIGO-Virgo Thermal Noise Meeting, Virgo Observatory, Pisa, Oct. 2006

**INVITED TALKS:**
*Seminars & Colloquia (continued)*

**LIGO: The Next Wave in Astronomy**
- SUNY Geneseo, Geneseo, NY, February 2006

**Gravity Waves: The Missing Piece in Einstein's Theory of Relativity is a Window on the Universe**
- Hamilton College, Clinton, NY, April 2005
- Ithaca College, Ithaca, NY, April 2005
- Hobart and William Smith Colleges, Geneva, NY, February 2005

**Minimizing the Mechanical Loss in Fused Silica & Lowering the Thermal Noise in Advanced LIGO**
- APS Spring Meeting, Tampa, FL, April 2005

**Gravity Waves and the Wonders of Glass**
- University of Glasgow, Glasgow, Scotland, UK, April 2003

**Listening for the Ringing of Black Holes and Neutron Stars**
- Hobart and William Smith Colleges, Geneva, NY March 2001

**Vibrations in Space-Time. Vibrations in Glass: Thermal Noise in Advanced LIGO**
- Hofstra University Physics Department, Hempstead, NY March 2000

**Parting the Thermal Sea: Taming Thermal Noise for Advanced LIGO**
- MIT Physics Department Seminar, Cambridge, MA June 1999

**What?! That's Not Relativity! The Work of the Syracuse Experimental Relativity Group**
- Syracuse University Relativity Seminar, Syracuse, NY April 1999

**New Techniques in Anelastic Aftereffect Measurements for High Q Mirror Materials**
- APS Centennial meeting, Atlanta, GA March 1999

**New Developments in Measuring Test Mass Thermal Noise Using the Anelastic Aftereffect**
- Eastern Gravity Meeting, Syracuse, NY March 1998
- APS meeting, Columbus, OH April 1998

**INVITED TALKS:**
*Nuclear Physics*

**An Initial Measurement of the PNC Spin Rotation of Cold Neutrons in LHe**
- Syracuse University Physics Department Seminar, Syracuse, NY Aug. 1997

**The Eötwash Experiments: Tests of Gravity and the Search for Gravity-like Forces**
- Syracuse University Physics Department Seminar, Syracuse, NY Aug. 1997

**Apparatus to Measure the PNC Spin Rotation of Cold Neutrons in a LHe Target**
- APS meeting, Indianapolis, IN April 1996

**Exploring Two-Nucleon Correlations with 12C(e,e′d)**
- University of New Hampshire, Durham, NH February 1995
- Argonne National Laboratory, Argonne, IL August 1994
- Nuclear Physics Lab., University of Washington, Seattle, WA Aug. 1994
- Saskatchewan Accelerator Lab, Saskatoon SK June 1994
- New Mexico State University, Las Cruces, NM May 1994

**PUBLICATIONS:**
Advanced LIGO:
*Fused Silica Thermal Noise*

**Low temperature mechanical dissipation of an ion-beam sputtered silica film**
I W Martin, R Nawrodt, K Craig, C Schwarz, R Bassiri, G Harry, J Hough, S Penn, S Reid, R Robie and S Rowan
*Classical and Quantum Gravity* **31.3** (2014): 035019.

**Frequency and surface dependence of the mechanical loss in fused silica**
Steven D Penn, Alexander Ageev, Dan Busby, Gregory M Harry, Andri M Gretarsson, Kenji Numata, and Phil Willems
*Phys. Lett. A* **352** No 1-2 (20 March 2006) 3-6

**Very high quality factor measured in annealed fused silica**
A Ageev, B C Palmer, A De Felice, S D Penn, & P R Saulson
*Class. Quantum Grav.* **21** No 16 (21 August 2004) 3887-3892

**High Quality Factor Measured in Fused Silica**
S.D. Penn, G.M. Harry, A.M. Gretarsson, S.E. Kittelberger, P.R. Saulson, J.J. Schiller, J.R. Smith, and S.O. Swords
*Review of Scientific Instruments* **72** (2001) 3670-3673.

**Pendulum Mode Thermal Noise in Advanced Interferometers: A comparison of Fused Silica Fibers and Ribbons in the Presence of Surface Loss**
A.M. Gretarsson, G.M. Harry, P.R. Saulson, S.D. Penn, W.J. Startin, S. Rowan, G. Cagnoli, J. Hough
*Physics Letters **A*** **270** (2000) 108-114

**PUBLICATIONS:**
Advanced LIGO:
*Silica Suspension Thermal Noise*

**Intrinsic mechanical loss of laser-welded fused silica fibers**
Gregory Harry, Thomas Corbitt, Marat Freytsis, David Ottaway, Nergis Mavalvala, Steven Penn
*Rev. Sci. Instrum.* **77** 023906 (2006)

**Silica suspension and coating developments for Advanced LIGO**
Cagnoli G, Armandula H, Cantley C A, Crooks D R M, Cumming A, Elliffe E, Fejer M M, Gretarsson A M, Harry G M, Heptonstall A, Hough J, Jones R, Mackowski J-M, Martin I, Murray P, Penn S D, Perreur-Lloyd M, Reid S, Route R, Rowan S, Robertson N A, Sneddon P H and Strain K A
*J. Phys.: Conf. Ser.* **32** (2006) 386-392

**Mechanical Loss Associated with Silicate Bonding of Fused Silica**
Joshua R. Smith, Peter R.Saulson, Steven D. Penn, Andri M.Gretarsson, Scott E. Kittelberger, Dave Guild, Gregory M. Harry, Joe C. Betzwieser, Michael J. Mortonson, Sheila Rowan, Jim Hough, D. R. M. Crooks
*Class. Quantum Grav.* **20** (2003) 5039-5047

**Exploration of Co-Sputtered Ta2O5–ZrO2 Thin Films for Gravitational-Wave Detectors**
M Abernathy, a Amato, a Ananyeva, S Angelova, B Baloukas, R Bassiri, G Billingsley, R Birney, G Cagnoli, M Canepa, M Coulon, J Degallaix, a Di Michele, M A Fazio, M M Fejer, D Forest, C Gier, M Granata, a M Gretarsson, e M Gretarsson, e Gustafson, e J Hough, M Irving, É Lalande, C Lévesque, a W Lussier, a Markosyan, i W Martin, L Martinu, B Maynard, C S Menoni, C Michel, P G Murray, C Osthelder, S Penn, L Pinard, K Prasai, S Reid, R Robie, S Rowan, B Sassolas, F Schiettekatte, R Shink, S Tait, J Teillon, G Vajente, M Ward And L Yang
*Class. Quantum Grav*. **38 (**2021**)** 195021

**PUBLICATIONS:**
Advanced LIGO:
*Mirror Coating Thermal Noise*

**PUBLICATIONS:**
Advanced LIGO:
*Mirror Coating Thermal Noise*

**Effect of Elevated Substrate Temperature Deposition on the Mechanical Losses in Tantala Thin Film Coatings**
G Vajente, R Birney, A Ananyeva, S Angelova, R Asselin, B Baloukas, R Bassiri, G Billingsley, M M Fejer, D Gibson, L J Godbout, E Gustafson, A Heptonstall, J Hough, S MacFoy, A Markosyan, I W Martin, L Martinu, P G Murray, S Penn, S Roorda, S Rowan, F Schiettekatte, R Shink, C Torrie, D Vine, S Reid and R X Adhikari
*Class. Quantum Grav.* **35** (2018 ) 075001

**High Precision Detection of Change in Intermediate Range Order of Amorphous Zirconia-Doped Tantala Thin Films Due to Annealing**
Prasai, K., Jiang, J., Mishkin, A., Shyam, B., Angelova, S., Birney, R., Drabold, D. A., Fazio, M., Gustafson, E. K., Harry, G., Hoback, S., Hough, J., Lévesque, C., MacLaren, I., Markosyan, A., Martin, I. W., Menoni, C. S., Murray, P. G., Penn, S., Reid, S., Robie, R., Rowan, S., Schiettekatte, F., Shink, R., Turner, A., Vajente, G., Cheng, H-P., Fejer, M. M., Mehta, A., Bassiri, R.
*Phys. Rev. Lett.* **123** (2019) 045501

**Mirror coating solution for the cryogenic Einstein telescope**
Craig, Kieran, Steinlechner, Jessica, Murray, Peter G., Bell, Angus S., Birney, Ross, Haughian, Karen, Hough, Jim, MacLaren, Ian, Penn, Steve, Reid, Stuart, Robie, Raymond, Rowan, Sheila, Martin, Iain W
*Phys. Rev. Lett.* **122** (2019) 231102 (Front cover article)

**Mechanical Ringdown Studies of Large-Area Substrate-Transferred GaAs/AlGaAs Crystalline Coatings**
Steven D. Penn, Maya M. Kinley-Hanlon, Ian A. O. MacMillan, Paula Heu, David Follman, Christoph Deutsch, Garrett D. Cole, Gregory M. Harry
*Journal Opt. Soc. Am. B,* ***36,*** (2019) C15

**Effect of elevated substrate temperature deposition on the mechanical losses in tantala thin film coatings**
G Vajente, R Birney, A Ananyeva, S Angelova, R Asselin, B Baloukas, R Bassiri, G Billingsley, M M Fejer, D Gibson, L J Godbout, E Gustafson, A Heptonstall, J Hough, S MacFoy, A Markosyan, I W Martin, L Martinu, P G Murray, S Penn, S Roorda, S Rowan, F Schiettekatte, R Shink, C Torrie, D Vine, S Reid, and R X Adhikari
*Class. Quantum Grav.* **35** (2018) 075001

**Bulk and shear mechanical loss of titania-doped tantala**
Matthew Abernathy, Gregory Harry, Jonathan Newport, Hannah Fair, Maya Kinley-Hanlon, Samuel Hickey, Isaac Jiffar, Andri Gretarsson, Steve Penn, Riccardo Bassiri, Eric Gustafson, Iain Martin, Sheila Rowan, Jim Hough
*Physics Letters A* (2017) https://doi.org/10.1016/j.physleta.2017.08.007

**The effect of time on optical coating mechanical loss and implications for LIGO-India**
Kinley-Hanlon, Maya, Hannah M. Fair, Isaac Jiffar, Jonathan Newport, Louis Gitelman, Gregory Harry, Garilynn Billingsley, and Steve Penn.
*Classical and Quantum Gravity* 33.14 (2016): 147001.

**PUBLICATIONS:**
Advanced LIGO:
*Mirror Coating Thermal Noise*

**Al-doped ZnO amorphous films as conductive layers in ultra-low absorptive optical coatings**
Ashot Markosyan and Riccardo Bassiri and Robert Faris and Valery Mitrofanov and Leonid Prokhorov and Steven Penn and Brian Lantz and Roger Route and Ric Shimshock and Martin M. Fejer
*Optical Interference Coatings 2016,* http://www.osapublishing.org/abstract.cfm?URI=OIC-2016-MB.4

**Mapping the optical absorption of a substrate-transferred crystalline AlGaAs coating at 1.5 μm**
Jessica Steinlechner, Iain W Martin, Angus Bell, Garrett Cole, Jim Hough, Steven Penn, Sheila Rowan and Sebastian Steinlechner
*Classical and Quantum Gravity* **32.10** (2015): 105008.

**Ion-beam sputtered amorphous silicon films for cryogenic precision measurement systems**
Peter G. Murray, Iain W. Martin, Kieran Craig, James Hough, Raymond Robie, Sheila Rowan, Matt R. Abernathy, Teal Pershing, and Steven Penn
*Physical Review D* **92.6** (2015): 062001.

**Effect of heat treatment on mechanical dissipation in $Ta_2O_5$ coatings**
Martin, IW; Bassiri, R; Nawrodt, R; Fejer, MM; Gretarsson, A; Gustafson, E; Harry, G; Hough, J; MacLaren, I; Penn, S; Reid, S; Route, R; Rowan, S; Schwarz, C; Seidel, P; Scott, J; Woodcraft, AL,
*Class. Quantum Grav.* **27**, 22502 (2010)

**Cryogenic mechanical loss measurements of heat-treated hafnium dioxide**
Abernathy, MR; Reid, S; Chalkley, E; Bassiri, R; Martin, IW; Evans, K; Fejer, MM; Gretarsson, A; Harry, GM; Hough, J; MacLaren, I; Markosyan, A; Murray, P; Nawrodt, R; Penn, S; Route, R; Rowan, S; Seidel, P,
*Class. Quantum Grav.* **28**, 19501 (2011)

**Comparison of the temperature dependence of the mechanical dissipation in thin films of $Ta_2O_5$ and $Ta_2O_5$ doped with $TiO_2$**
I Martin, E Chalkley, R Nawrodt, H Armandula, R Bassiri, C Comtet, M M Fejer, A Gretarsson, G Harry, J Hough,I MacLaren, C Michel, J-L Montorio, N Morgado, S Penn, S Reid, R Route, S Rowan, C Schwarz, P Seidel, W Vodel and A Zimmer
*Class. Quantum Grav.* **26**, 15501 (2009)

**Measurements of a low-temperature mechanical dissipation peak in a single layer of $Ta_2O_5$ doped with $TiO_2$**
I Martin, H Armandula, C Comtet, M M Fejer, A Gretarsson, G Harry, J Hough, J-M M Mackowski, I MacLaren, C Michel, J-L Montorio, N Morgado, R Nawrodt, S Penn, S Reid, A Remillieux, R Route, S Rowan, C Schwarz, P Seidel, W Vodel and A Zimmer
*Class. Quantum Grav.* **25** (2008) 055005

**The effects of heating on mechanical loss in tantala/silica optical coatings**
Matthew R. Abernathy, Gregory M. Harry, Flavio Travasso, Iain Martin, Stuart Reid, Sheila Rowan, Jim Hough, Martin M. Fejer, Roger Route, Steve Penn, Helena Armandula, Andri Gretarsson
*Physics Letters A.* **372** (2008) 87-90

**PUBLICATIONS:**
Advanced LIGO:
*Mirror Coating Thermal Noise*

**Titania-doped tantala/silica coatings for gravitational-wave detection**
Gregory M Harry, Matthew R Abernathy, Andres E Becerra Toledo, Helena Armandula, D R M Crooks, Gianpietro Cagnoli, Jim Hough, Peter Murray, Stuart Reid, Sheila Rowan, Peter H Sneddon, Martin M Fejer, Roger Route, Steven D Penn, Jean-Marie Mackowski, Laurent Pinard, Alban Remillieux
*Class. Quantum Grav.* **24** No 2 (21 January 2007) 405-415

**Experimental measurements of mechanical dissipation associated with dielectric coatings formed using $SiO_2$, $Ta_2O_5$ and $Al_2O_3$**
D R M Crooks, G Cagnoli, M M Fejer, G Harry, J Hough, B T Khuri-Yakub, S Penn, R Route, S Rowan, P H Sneddon, I O Wygant and G G Yaralioglu
*Class. Quantum Grav.* **23** No 15 (7 August 2006) 4953-4965

**Thermal noise from optical coatings in gravitational-wave detectors**
Gregory M Harry, Helena Armandula, Eric Black, D R M Crooks, Gianpietro Cagnoli, Jim Hough, Peter Murray, Stuart Reid, Sheila Rowan, Peter Sneddon, Martin M Fejer, Roger Route, Steven D Penn
*Applied Optics* **45** No 7 (1 March 2006) 1569-1574

**Thermoelastic dissipation in inhomogeneous media: loss measurements and displacement noise in coated test masses for interferometric gravitational wave detectors**
M. M. Fejer, S. Rowan, G. Cagnoli, D. R. M. Crooks, A. Gretarsson, G. M. Harry, J. Hough, S. D. Penn, P. H. Sneddon, and S. P. Vyatchanin
*Phys. Rev. D* **70**, 082003 (2004)

**Experimental measurements of coating mechanical loss factors**
D R M Crooks, G Cagnoli, M M Fejer, A Gretarsson, G Harry, J Hough, N Nakagawa, S Penn, R Route, S Rowan and P H Sneddon
*Class. Quantum Grav.* **21** No 5 (7 March 2004) S1059-S106

**Mechanical Loss in Silica/Tantala Dielectric Mirror Coatings**
Steven D. Penn, D. R. M. Crooks, Gregory Harry, Sheila Rowan, Andri Gretarsson, Peter Saulson, Jim Hough, Scott Kittelberger, Geppo Ciagnoli, Helena Armandula, Joe C. Betzwieser
*Class. Quantum Grav.* **20** (2003) 2917-2928

**Thermal Noise in Interferometric Gravitational Wave Detectors due to Dielectric Optical Coatings**
G.M. Harry, A.M. Gretarsson, S.E. Kittelberger, S.D. Penn, P.R. Saulson, W.J. Startin, S. Rowan, D. Crooks, J. Hough
*Class. Quantum Grav.* **19** (2002) 897-918.

**Effect of Optical Coating and Surface Treatments on Mechanical Loss in Fused Silica**
Andri M Gretarsson, Gregory M Harry, Steven D Penn, Peter R Saulson, John J Schiller, William J Startin
*Proceedings of the Third Eduardo Amaldi Conference on Gravitational Waves*, July 1999

**PUBLICATIONS:**
Advanced LIGO
*Instrument Science*

**Effects of transients in LIGO suspensions on searches for gravitational waves**
M. Walker, et al. (LSC Instrument Authors, including S Penn)
*Rev Sci Instr*. **88** (2017) 124501, https://doi.org/10.1063/1.5000264

**First Demonstration of Electrostatic Damping of Parametric Instability at Advanced LIGO**
Blair, Carl and Gras, Slawek, et al. (LSC Instrument Authors, including S Penn)
*Phys Rev Lett*. 118 (2017) 151102, https://link.aps.org/doi/10.1103/PhysRevLett.118.151102

**Calibration of the Advanced LIGO detectors for the discovery of the binary black-hole merger GW150914**
Abbott, B. P., et al., (LIGO Scientific Collaboration, including S Penn)
*Phys. Rev. D,* 95 (2017) 062003, https://link.aps.org/doi/10.1103/PhysRevD.95.062003

**Quantum correlation measurements in interferometric gravitational-wave detectors**
Martynov, D. V., et al., (LSC Instrument Authors, including S Penn)
*Phys. Rev. A*, 95 (2017) 043831, *https://link.aps.org/doi/10.1103/PhysRevA.95.043831*

**First Measurement of the Hubble Constant from a Dark Standard Siren using the Dark Energy Survey Galaxies and the LIGO/Virgo Binary-Black-hole Merger GW170814**
LIGO Scientific Collaboration and Virgo Collaboration
*Astrophysical Journal Letters.*, **876** (2019)1, [L7].

**PUBLICATIONS:**
Advanced LIGO
*GW Detections and Upper Limit Results*

**Low-Latency Gravitational-Wave Alerts for Multimessenger Astronomy During the Second Advanced LIGO and Virgo Observing Run**
LIGO Scientific Collaboration and Virgo Collaboration
*The Astrophysical Journal,* **875.2** (2019): 161.

**Binary Black Hole Population Properties Inferred from the First and Second Observing Runs of Advanced LIGO and Advanced Virgo**
LIGO Scientific Collaboration and Virgo Collaboration
*Astrophysical Journal Letters*, **882**(2), [L24].

**Search for the Isotropic Stochastic Background Using Data from Advanced LIGO's Second Observing Run**
LIGO Scientific Collaboration and Virgo Collaboration
*Physical Review D,* **100.6** (2019)

**Tests of general relativity with GW170817**
LIGO Scientific Collaboration and Virgo Collaboration
*Physical Review Letters*, **123**(2019)1, 1-15. [011102].

**Directional Limits on Persistent Gravitational Waves Using Data from Advanced LIGO's First Two Observing Runs**
LIGO Scientific Collaboration and Virgo Collaboration
*Physical Review D* **100.6** (2019)

**Search for Intermediate Mass Black Hole Binaries in the First and Second Observing Runs of the Advanced LIGO and Virgo Network**
LIGO Scientific Collaboration and Virgo Collaboration
*Physical Review D* **100.6** (2019)

**Constraining the p-Mode–g-Mode Tidal Instability with GW170817**

**PUBLICATIONS:**
Advanced LIGO
*GW Detections and Upper Limit Results*

LIGO Scientific Collaboration and Virgo Collaboration
*Physical Review Letters* **122.6** (2019)

**GW170817: Implications for the Stochastic Gravitational-Wave Background from Compact Binary Coalescences**
LIGO Scientific Collaboration and Virgo Collaboration
*Physical Review Letters*, **120** (2019), 1-12. [091101].

**Search for Tensor, Vector, and Scalar Polarizations in the Stochastic Gravitational-Wave Background**
LIGO Scientific Collaboration and Virgo Collaboration
*Physical Review Letters,* **120.20** (2018)

**Prospects for observing and localizing gravitational-wave transients with Advanced LIGO, Advanced Virgo and KAGRA**
KAGRA Collaboration, LIGO Scientific Collaboration and Virgo Collaboration
*Living Reviews in Relativity*, 21(2018)1, [3].
**Full band all-sky search for periodic gravitational waves in the O1 LIGO data**
LIGO Scientific Collaboration and Virgo Collaboration
*Physical Review D,* **97**, 102003 (2018)

**GW170817: Observation of Gravitational Waves from a Binary Neutron Star Inspiral**
Abbott, B. P., et al., (LIGO Scientific & Virgo Collaborations, including S. Penn)
*Phys., Rev. Lett.*, 119 (2017) 161101

**Multi-messenger Observations of a Binary Neutron Star Merger**
Abbott, B. P., et al., (LIGO Scientific & Virgo Collaborations, including S. Penn)
*Astrophysical Journal Letters*, 848 (2017) L12

**Gravitational Waves and Gamma-Rays from a Binary Neutron Star Merger: GW170817 and GRB 170817A**
Abbott, B. P., et al., (LIGO Scientific & Virgo Collaborations, including S. Penn)
*Astrophysical Journal Letters*, 848 (2017) L13

**GW170814: A Three-Detector Observation of Gravitational Waves from a Binary Black Hole Coalescence**
Abbott, B. P., et al., (LIGO Scientific & Virgo Collaborations, including S. Penn)
*Phys., Rev. Lett.*, 119 (2017) 141101

**Search for continuous gravitational waves from neutron stars in globular cluster NGC 6544**
Abbott, B. P., et al., (LIGO Scientific & Virgo Collaboration, including S Penn)
*Phys. Rev. D*, 95 (2017) 082005

**GW170104: Observation of a 50-Solar-Mass Binary Black Hole Coalescence at Redshift 0.2**
Abbott, B. P., et al., (LIGO Scientific & Virgo Collaboration, including S. Penn)
*Phys. Rev. Lett.*, 118 (2017) 221101

**Observation of gravitational waves from a binary black hole merger.**
Abbott, B. P., et al. (LIGO Scientific & Virgo Collaboration including S Penn)
*Physical Review Letters* 116.6 (2016) 061102.

**PUBLICATIONS:**
Advanced LIGO
*GW Detections and Upper Limit Results*

**Prospects for localization of gravitational wave transients by the advanced LIGO and advanced Virgo observatories.**
Aasi, J., et al. (LIGO Scientific & Virgo Collaborations, including S Penn)
*Living Reviews in Relativity* 19 (2016).

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