

MPS Research Update

July and August 2019

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Staff mentions in the press, public engagement

University of Sussex

Kathy Romer held a school outreach session on 11th July 2019.

Jodrell Bank Observatory

Stephen Wilkins, PhD student Cairan F, and several other PhD students attended BlueDot Festival.

Stephen Wilkins also ran GuideStars (July 30th 2019).

Royal Society Science Book Prize

John Gribbin's has been shortlisted for the award.

University of Sussex

Anastasia Fialkov is working on a press release related to a new paper.

4MOST Press Release

Physicists at the University of Sussex will be part of a global team of scientists creating a three-dimensional map of ten million galaxies neighbouring our own. The Sussex team includes Dr Jon Loveday, Prof Seb Oliver, Prof Kathy Romer and Dr Robert Smith as well as numerous students and other researchers. (<https://www.sussex.ac.uk/news/all?id=49321>).

University of Sussex

Stephen Wilkins has announced his new charity Curiosity Sussex, with its first event "Wonderfest" being held in October.

Awards & Recognitions

No news reported in this area.

Areas of Knowledge Exchange

Seb Oliver organised the national STFC Data Intensive Science summer school.

Robert Smith and PhD student RS Chis Lovell taught the course "*Introduction to MPI*" at the DIS Summer School.

Talks Delivered

Iacopo Vivarelli delivered a 4.5 hour lecture at WHEPS (The 2019 Weihai High-Energy Physics School which was held in Weihai, China). WHEPS is a series of advanced schools organised by the CCEPP, inviting world-leading researchers to discuss current research advances.

Bertram Duering was invited to a mini-symposium talk at the 3rd International Conference on Computational Finance 2019 (ICCF2019), A Coruña, Spain (11th July 2019).

Bertram was also invited to a mini-symposium talk at the 9th International Congress on Industrial and Applied Mathematics (ICIAM 2019), Valencia, Spain (15th July 2019).

Whilst attending the 9th International Congress, Bertram was also the organiser of a mini-symposium on "*Anisotropic variational models and partial differential equations*".

Manoj Tripathi was an invited speaker at the '*2D Materials: Student Conference Series*' held at Cambridge from the 1st – 4th of July 2019.

<https://www.2dconference.co.uk/speakers.html>

Manoj also attended the *Nanotec19 Conference* in Zaragoza, Spain (27th – 30th August 2019).

<https://nanotec19.icb.csic.es/>

Nicos Georgiou organised the conference "*Advances in Last passage percolation*", held from the 24th -27th June (apologies that this was not included in the previous May-June report). The conference had invited speakers from all over the world who inform that it was "a great success!"

Enrico Scalas presented the PhD research seminar: "*From Markov chains to semi-Markov processes: The consequences of time change*", whilst being a visiting professor at the Department of Mathematics, University of Salerno, Italy (1-15th July 2019).

Enrico also held a seminar on: "*The Mathematics of Human Contact*", Department of Mathematics and Applications, University of Naples, Italy (10th July 2019).

On the 22nd August 2019, **Enrico** acted as co-organiser and co-chair of the special session on *The Mathematics and Statistics of Wealth and Income Distributions* at AMMCS 2019, Wilfrid Laurier University, Waterloo, ON, Canada. Whilst in attendance, Enrico held two talks:

1. "*Functional and Thermodynamic Limits of a Simple Stylized Model*"
2. "*Approximate Bayesian Computation*"

(**Enrico** attended AMMCS as a member of the Scientific Committee, 18th-23rd August 2019).

Stephen Wilkins and PhD students **Chris Lovell**, **Reese Wilkinson** and **David Turner** spoke at the National Astronomy Meeting.

Robert Smith gave an MIAPP invited talk in Munich.

PDRA Paul Giles, PhD student **David Turner**, and UG student **Lauren Conway** gave talks at the UK X-ray Astronomy meeting.

Christian Byrnes gave an invited plenary talk at Cosmo19 in Aachen (270 participants)

<https://indico.cern.ch/event/782784/timetable/#20190902>.

Max Jensen delivered two talks at ICIAM 2019 in Valencia:

1. “*Semi-Lagrangian methods for Monge--Ampère equations*” (17th July 2019 - Authors: Max Jensen, Sussex University; Xiaobing Feng, University Of Tennessee).
2. “*Dynamic Programming for Finite Ensembles of Nanomagnetic Particles*” (19th July 2019 - Authors: Max Jensen, Sussex University; Ananta Majee, IIT Delhi; Andreas Prohl, Universität Tübingen; Christian Schellnegger, Universität Tübingen).

Marco Peccianti was the General Chair at the *Integrated Photonics Research 2019* conference (29th July – 3rd August; Optical Society of America).

Impact

No news reported in this area.

Significant Research Outcomes

Iacopo Vivarelli Public result on Soft b-tagging in ATLAS

<https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2019-027/>

Anastasia Fialkov has an exciting new result related to a first of the kind hydrodynamical simulation with ultralight dark matter.

Other news

Bertram Duering is an invited participant to attend the "*Geometry, compatibility and structure preservation in computational differential equations*" programme, held at the Isaac Newton Institute for Mathematical Sciences, Cambridge, from the 3rd July – 19th December 2019.

Nicos Georgiou attended the Technical University of Munich, Germany for a research collaboration and conference.

PDRA Paul Giles organised a successful X-ray cluster session at NAM.

Paul Giles also attended the LSST-DESC meeting in Paris.

Antony Lewis and Christian Byrnes organised the Benasque cosmology meeting.

Mark Sargent attended SKA headquarters opening ceremony (10th July 2019).

Kathy Romer led a discussion session at Athena UK meeting.

Stephen Wilkins is CoI of the 135 orbit COS Legacy Archive Spectroscopic Survey (CLASSY) on the Hubble Space Telescope.

Marco Peccianti's ERC-Proof of Concept has started (1st August 2019).

Grant Report

Submitted

Byrnes, Christian	UKRI	UKRI Stephen Hawking Fellowship	Quantum diffusion in the early universe [External]	404,810
Fabbian, Giulio	Royal Society	RSOC University Research Fellowship	Precision cosmology with CMB polarization and galaxy surveys	624,099
Hartnell, Jeff	Royal Society	RSOC University Research Fellowship	Precision Neutrino Physics (Fellow: External Applicant)	626,363
Hensinger, Winfried	EPSRC	Oxford Hub	EPSRC Hub for Quantum Computing and Simulation - Hensinger	281,515
Huber, Stephan	Royal Society	RSOC University Research Fellowship	Maximising the new physics reach of the LHC through effective field theories (Fellow: External)	596,199
Jaeger, Sebastian	Royal Society	RSOC University Research Fellowship	Searching for New Physics Effectively (Fellow: External Applicant)	625,913
Lakkis, Omar	Ambiental Technical Solutions Ltd	Case Studentship	Two-dimensional stochastically perturbed shallow water equations	25,200
Lewis, Antony	European Union	H2020 - ERC Advanced Grant	NewCMB: New Physics from Cosmic Microwave Background observations	1,492,739
Litim, Daniel	Leverhulme Trust	Leverhulme Trust Visiting Professorship	Visiting Professorship - Gudrun Hiller	14,955
Madzvamuse, Anotida	EPSRC	EPSRC Hubs for Mathematical Sciences in Healthcare	EPSRC Hub for Bridging Scales for Optimal Healthcare: From cells to patients	1,388,353
Oliver, Seb	AGRICULTURE AND HORTICULTURE DEVELOPMENT BOARD	Studentship	An empirical, data-driven, model for wheat cultivars and optimisation for future climate scenarios	74,100
Peeters, Simon	STFC	Research Grant	Proposal for UK Participation in the DarkSide Experiment	177,359

Salvatore, Fabrizio	STFC	STFC Innovation Partnership Scheme	Deception detection for insurance fraud cases using algorithms developed from particle physics applications	328,909
Sanz, Veronica	UKRI	UKRI Stephen Hawking Fellowship	Maximising new physics reach at the LHC through Effective Field Theories (External)	436,359
Scalas, Enrico	European Union	H2020 - Marie Curie Individual Fellowships: European Fellowship	SNNSPDEs – Spiking Neural Networks and (Stochastic) Partial Differential Equations [External]	178,518
Thomas, Peter	Royal Society	RSOC University Research Fellowship	Rousing the monsters: elucidating the critical role of AGN in cluster cosmology (Fellow:External)	623,199
Thomas, Peter	Royal Society	RSOC University Research Fellowship	Unveiling the true chemical evolution of the Universe (Fellow: External Applicant)	623,199
Tripathi, Manoj	Royal Society	RSOC University Research Fellowship	2D-HSAct (2-Dimensional Hetero-System Actuators)	612,899

Forecasted

Vivarelli, Iacopo	European Union	H2020 - Marie Curie Research and Innovation Staff Exchange (RISE)	Future Experiments seek Smart Technologies (FEST)	16,355
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Awarded

Dahlqvist, Antoine	London Mathematical Society	LMS - Celebrating New Appointments	Randomness, Symmetry and Free Probability	600
Hensinger, Winfried	US Department of Defence (US Army)	Research Grant	Grant extension proposal - Development of microwave ion chip entanglement	213,108

			architectures for quantum technologies	
Hensinger, Winfried	US Office of Naval Research	Research Grant	Voltage controlled quantum logic with trapped ions	306,166
Oliver, Seb	STFC	STFC Food Innovation Network+	SIM Farm 2030	6,470
Oliver, Seb	STFC	STFC Impact Acceleration Account	STFC Impact Acceleration Account	70,000
Simm, Nicholas	London Mathematical Society	LMS - Celebrating New Appointments	Random Matrices and Applications	940
Wang, Minmin	London Mathematical Society	LMS - Celebrating New Appointments	Branching Processes and Their Applications	600
Wilkins, Stephen	Royal Astronomical Society	Research Grant	Preparing for Webb	1,200
Wilkins, Stephen	Royal Astronomical Society	Research Grant	Numerical Simulations for Inflationary Model Analysis	1,200

Department of Mathematics. Publications deposited in SRO during July and August 2019					
To view the publication, enter the five-digit SRO ID number as http://sro.sussex.ac.uk/nnnnn					
Sussex Author	SRO ID	Status	Author(s)	Output Title	Volume Title
Cole, Philippa S	84698	Published	Byrnes, Christian T; Cole, Philippa S; Patil, Subodh P	Steepest growth of the power spectrum and primordial black holes	Journal of Cosmology and Astroparticle Physics
Duering, Bertram	85577	Accepted	Carrilo, José A; Düring, Bertram; Kreusser, Lisa Maria; Schönlieb, Carola-Bibiane	Stability analysis of line patterns Of an anisotropic interaction model	SIAM Journal on Applied Dynamical Systems
Giesl, Peter A	84768	Accepted	Giesl, Peter	Computation of a contraction metric for a periodic orbit using meshfree collocation	SIAM Journal on Applied Dynamical Systems
Kiplangat, Benard Kipchumba K	83856	Published	Kiplangat, Benard Kipchumba	Modelling and simulations of a viscous model for cell migration	
Kiss, Istvan Z	85244	Published	Vizi, Zsolt; Kiss, István Z; Miller, Joel; Röst, Gergely	A monotonic relationship between the variability of the infectious period and final size in pairwise epidemic modelling	Journal of Mathematics in Industry
Kiss, Istvan Z	85312	Published	Messenger, Antoine; Parisis, Georgios; Kiss, Istvan Z; Harper, Robert; Tee, Philip; Berthouze, Luc	Inferring functional connectivity from time-series of events in large scale network deployments	IEEE Transactions on Network and Service Management

Venkataraman, Chandrasekhar	84688	Published	Chaplain, Mark A J; Lorenzi, Tommaso; Lorz, Alexander; Venkataraman, Chandrasekhar	Mathematical modelling of phenotypic selection with solid tumours	Lecture Notes in Computational Science and Engineering
Venkataraman, Chandrasekhar	85222	Published	Lorenzi, Tommaso; Venkataraman, Chandrasekhar; Lorz, Alexander; Chaplain, Mark	The role of spatial variations of abiotic factors in mediating intratumour phenotypic heterogeneity	Journal of Theoretical Biology

Department of Physics. Publications deposited in SRO during July and August 2019					
To view the publication, enter the five-digit SRO ID number as http://sro.sussex.ac.uk/nnnnn					
Sussex Author	SRO ID	Status	Author(s)	Output Title	Volume Title
Abraham, Nicola L	85600	Published	Aaboud, M; Abbott, B; Aad, G; Abraham, N L; Allbrooke, B; Asquith, L; Cerri, A; Safarzadeh Samani, B; De Santo, A; Salvatore, F; and 4 other(s)	Search for pair production of Higgs bosons in the bb bb final state using proton-proton collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector	Journal of High Energy Physics
Abraham, Nicola L	85602	Published	Aaboud, M; Aad, G; Abraham, N L; Allbrooke, B; Asquith, L; Cerri, A; Safarzadeh Samani, B; De Santo, A; Salvatore, F; Shaw, K; and 5 other(s)	Operation and performance of the ATLAS Tile Calorimeter in Run 1	European Physical Journal C: Particles and Fields
Abraham, Nicola L	85603	Published	De Santo, A; Aad, G; Abidinov, O; Abraham, Nicola Louise; Allbrooke, Benedict; Asquith, Lily; Cerri, Alessandro; Safarzadeh Samani, Batool; Salvatore, Fabrizio; Shaw, Kate; and 6 other(s)	In situ calibration of large-radius jet energy and mass in 13 TeV proton–proton collisions with the ATLAS detector	European Physical Journal C: Particles and Fields
Abraham, Nicola L	85617	Published	Abraham, N L; Allbrooke, B M M; Asquith, L; Cerri, A; De Santo, A; Salvatore, F; Shaw, K; Stevenson, T J; Suruliz, K; Sutton, M R; and 2 other(s)	Search for resonant WZ production in the fully leptonic final state in proton–proton collisions at $\sqrt{s}=13$ TeV with the ATLAS detector	Physics Letters B
Abraham, Nicola L	85618	Published	Abraham, N L; Allbrooke, B; Asquith, L; Cerri, A; Safarzadeh Samani, B; DeSanto, A; Salvatore, F; Shaw, K; Stevenson, T; Suruliz, K; and 3 other(s)	Cross-section measurements of the Higgs boson decaying into a pair of t-leptons in proton-proton collisions at $\sqrt{s}=13$ TeV with the ATLAS detector	Physical Review D

Abraham, Nicola L	85619	Published	Abraham, N L; Allbrooke, B; Asquith, L; Cerri, A; Safarzadeh Samani, B; DeSanto, A; Salvatore, F; Shaw, K; Stevenson, T; Suruliz, K; and 3 other(s)	Search for heavy particles decaying into top-quark pairs using lepton-plus-jets events in proton–proton collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector	European Physical Journal C: Particles and Fields
Abraham, Nicola L	85621	Published	Abraham, N L; Allbrooke, B; Asquith, L; Cerri, A; Safarzadeh Samani, B; DeSanto, A; Salvatore, F; Shaw, K; Stevenson, T; Suruliz, K; and 3 other(s)	Study of the hard double-parton scattering contribution to inclusive four-lepton production in pp collisions at $\sqrt{s}=8$ TeV with the ATLAS detector	Physics Letters B
Abraham, Nicola L	85627	Published	Abraham, N L; Allbrooke, B; Asquith, L; Cerri, A; Safarzadeh Samani, B; DeSanto, A; Salvatore, F; Shaw, K; Stevenson, T; Suruliz, K; and 3 other(s)	Observation of electroweak $W\pm Z$ boson pair production in association with two jets in pp collisions at $\sqrt{s}=13$ TeV with the ATLAS detector Physics Letters B , 793 pp. 469-492. ISSN 0370-2693	Physics Letters B
Abraham, Nicola L	85634	Published	Abraham, N L; Allbrooke, B; Asquith, L; Cerri, A; Safarzadeh Samani, B; DeSanto, A; Salvatore, F; Shaw, K; Stevenson, T; Suruliz, K; and 3 other(s)	Search for top-quark decays $t \rightarrow Hq$ with 36 fb ⁻¹ of pp collision data at $\sqrt{s} = 13$ TeV with the ATLAS detector	Journal of High Energy Physics
Allbrooke, Benedict MM	85621	Published	Abraham, N L; Allbrooke, B; Asquith, L; Cerri, A; Safarzadeh Samani, B; DeSanto, A; Salvatore, F; Shaw, K; Stevenson, T; Suruliz, K; and 3 other(s)	Study of the hard double-parton scattering contribution to inclusive four-lepton production in pp collisions at $\sqrt{s}=8$ TeV with the ATLAS detector	Physics Letters B
Amorim Graf, Aline	85326	Published	Amorim Graf, Aline; Large, Matthew; Ogilvie, Sean Paul; Rong, Yuanyang; Lynch, Peter; Fratta, Giuseppe; Ray, Santanu; Shmeliov, Aleksey; Nicolosi, Valeria; Arenal, Raul; and 1 other(s)	Sonochemical edge functionalisation of molybdenum disulfide	Nanoscale

Amorim Graf, Aline	85314	Published	Rong, Yuanyang; Large, Matthew J; Tripathi, Manoj; Ogilvie, Sean P; Amorim Graf, Aline; Mao, Boyang; Tunesi, Jacob; Salvage, Jonathan P; King, Alice A K; Pasquazi, Alessia; and 4 other(s)	Charge transfer hybrids of graphene oxide and the intrinsically microporous polymer PIM-1	ACS Applied Materials & Interfaces
Bao, Hualong	84717	Published	Rowley, Maxwell; Wetzel, Benjamin; Di Lauro, Luigi; Totero Gongora, Juan S; Bao, Hualong; Silver, Jonathan; Del Bino, Leonardo; Haye, Pascal Del; Peccianti, Marco; Pasquazi, Alessia	Thermo-optical pulsing in a microresonator filtered fiber-laser: a route towards all-optical control and synchronization	Optics Express
Boland, Conor S	84703	Published	Boland, Conor S; Khan, Umar; Ryan, Gavin; Barwich, Sebastian; Charifou, Romina; Harvey, Andrew; Backes, Claudia; Li, Zheling; Ferreira, Mauro S; Möbius, Matthia E; and 1 other(s)	Sensitive electromechanical sensors using viscoelastic graphene-polymer nanocomposites	Science
Booth, Alexander C	85218	Published	Acero, M A; Adamson, P; Aliaga, L; Alion, T; Allakhverdian, V; Altakarli, S; Anfimov, N; Antoshkin, A; Aurisano, A; Baird, M; and 5 other(s)	Observation of seasonal variation of atmospheric multiple-muon events in the NOvA Near Detector	Physical Review D
Byrnes, Christian T	84698	Published	Byrnes, Christian T; Cole, Philippa S; Patil, Subodh P	Steepest growth of the power spectrum and primordial black holes	Journal of Cosmology and Astroparticle Physics
Calmet, Xavier	85335	Accepted	Calmet, Xavier	On searches for gravitational dark matter with quantum sensors	The European Physical Journal Plus

Calmet, Xavier	85336	Accepted	Calmet, Xavier; Latosh, Boris	The spectrum of quantum gravity Particles and Nuclei	Letters
Cutting, Daniel	84693	Published	Cutting, Daniel; Hindmarsh, Mark; Weir, David J	Gravitational waves from vacuum first-order phase transitions: from the envelope to the lattice	Physical Review D
Dalton, Alan B	85326	Published	Amorim Graf, Aline; Large, Matthew; Ogilvie, Sean Paul; Rong, Yuanyang; Lynch, Peter; Fratta, Giuseppe; Ray, Santanu; Shmeliov, Aleksey; Nicolosi, Valeria; Arenal, Raul; and 1 other(s)	Sonochemical edge functionalisation of molybdenum disulfide	Nanoscale
Dalton, Alan B	85578	Accepted	Martinez, Patricia; Ishteev, Arthur; Fahimi, Azin; Velten, Josef; Jurewicz, Izabela; Dalton, Alan; Collins, Steve; Baughman, Ray; Zakhidov, Anvar	Silver nanowires on carbon nanotube aerogel sheets for flexible, transparent electrodes	Applied Materials & Interfaces
Di Lauro, Luigi	84717	Published	Rowley, Maxwell; Wetzels, Benjamin; Di Lauro, Luigi; Totero Gongora, Juan S; Bao, Hualong; Silver, Jonathan; Del Bino, Leonardo; Haye, Pascal Del; Peccianti, Marco; Pasquazi, Alessia	Thermo-optical pulsing in a microresonator filtered fiber-laser: a route towards all-optical control and synchronization	Optics Express
Garraway, Barry M	85224	Published	Martin, Jean-Marc; Bade, Satyanarayana; Dubosclard, William; Khan, Murtaza Ali; Kim, Seungjin; Garraway, Barry M; Alzar, Carlos L	Pumping dynamics of cold-atom experiments in a single vacuum chamber	Physical Review Applied

Garraway, Barry M	85591	Published	Martin, Jean-Marc; Bade, Satyanarayana; Dubosclard, William; Ali Khan, Murtaza; Kim, Seungjin; Garraway, Barry M; Garrido Alzar, Carlos	Pumping Dynamics of Cold-Atom Experiments in a Single Vacuum Chamber	Physical Review A
Hindmarsh, Mark B	84689	Published	Hindmarsh, Mark; Lizarraga, Joanes; Urrestilla, Jon; Daverio, David; Kunz, Martin	Type I Abelian Higgs strings: evolution and cosmic microwave background constraints	Physical Review D
Hindmarsh, Mark B	84691	Published	Hindmarsh, Mark; Kormu, Anna; Lopez-Eiguren, Asier; Weir, David J	Scaling in necklaces of monopoles and semipoles	Physical Review D
King, Alice AK	85326	Published	Amorim Graf, Aline; Large, Matthew; Ogilvie, Sean Paul; Rong, Yuanyang; Lynch, Peter; Fratta, Giuseppe; Ray, Santanu; Shmeliov, Aleksey; Nicolosi, Valeria; Arenal, Raul; and 1 other(s)	Sonochemical edge functionalisation of molybdenum disulfide	Nanoscale
Lacy, John H	84731	Published	Lacy, John	Development of a planar magnetic field source for the Geonium Chip Penning Trap	
Lewis, Antony M	85580	Published	Bartolo, N; De Luca, V; Franciolini, G; Lewis, A; Peloso, M; Riotto, A	Primordial black hole dark matter: LISA serendipity	Physical Review Letters

Litim, Daniel F	84702	Published	Falls, Kevin; King, Callum R; Litim, Daniel F; Nikolakopoulos, Konstas; Rahmede, Christoph	Asymptotic safety of quantum gravity beyond Ricci scalars	Physical Review D
Ogilvie, Sean P	84882	Published	Ogilvie, Sean	Liquid phase exfoliation and interfacial assembly of two-dimensional nanomaterials	
Peccianti, Marco	85781	Published	Clerici, M; Bruhács, A; Faccio, D; Peccianti, M; Spanner, M; Markov, A; Schmidt, B E; Ozaki, T; Légaré, F; Vidal, F; and 0 other(s)	Terahertz control of air lasing	Physical Review A
Peeters, Simon JM	85219	Published	Ajaj, R; Amaudruz, P-A; Araujo, G R; Baldwin, M; Batygov, M; Beltran, B; Bina, C E; Bonatt, J; Boulay, M G; Broerman, B; and 7 other(s)	Search for dark matter with a 231-day exposure of liquid argon using DEAP-3600 at SNOLAB	Physical Review D
Romer, Kathy K	85593	Published	Shin, T; Adhikari, S; Baxter, E J; Chang, C; Jain, B; Battaglia, N; Bleem, L; Bocquet, S; DeRose, J; Gruen, D; and 10 other(s)	Measurement of the splashback feature around SZ-selected Galaxy clusters with DES, SPT, and ACT	Monthly Notices of the Royal Astronomical Society
Smith, Robert E E	85223	Published	Reed, Darren S; Schneider, Aurel; Potter, Doug; Stadel, Joachim; Moore, Ben; Smith, Robert E	The cosmic web of dwarf galaxies in a warm versus cold dark matter universe: mock galaxies in CDM and WDM simulations	World Scientific

Thomas, Peter A	85581	Accepted	Vijayan, Aswin P; Clay, Scott J; Thomas, Peter A; Yates, Robert M; Wilkins, Stephen M; Henriques, Bruno M	Detailed dust modelling in the L-Galaxies semi-analytic model of galaxy formation	Monthly Notices Of The Royal Astronomical Society
	85221	Published	Boland, Conor S; Ó Coileáin, Cormac; Wagner, Stefan; McManus, John B; Cullen, Conor P; Lemme, M C; Duesberg, Georg S; McEvoy, Niall	PtSe2 grown directly on polymer foil for use as a robust piezoresistive sensor	2D Materials