Direct and indirect empirical statuses (DES and IES)
of theoretical symmetries in physics

A Reference List *by Valeriya Chasova*

Below is a list of some helpful references on symmetries, DES and IES in the narrow sense (except for one work which also addresses a wider sense), organised thematically and somewhat chronologically, not necessarily exhaustive or subject to completion.

Some classic symmetry works

Clarke S. (1717), *A Collection of Papers, Which passed between the late Learned Mr. Leibnitz, and Dr. Clarke, in the years 1715 and 1716.* Available at http://www.newtonproject.ox.ac.uk/view/texts/normalized/THEM00224

Wigner E. (1967), *Symmetries and Reflections*, Indiana University Press.

Earman J., Norton J. (1987), "What price spacetime substantivalism? The hole story", *The British Journal for the Philosophy of Science*, Vol. 38, No. 4, pp. 515-525.

Brading K., Castellani E. (eds.) (2003), *Symmetries in Physics: Philosophical Reflections*, Cambridge University Press.

The work where DES and IES are first introduced

Kosso P. (2000), "The empirical status of symmetries in physics", *The British Journal for the Philosophy of Science*, Vol. 51, No. 1, pp. 81-98.

Some further works on DES

Brading K., Brown H. (2004), "Are gauge symmetry transformations observable?", *The British Journal for the Philosophy of Science*, Vol. 55, No. 4, pp. 645-665.

Healey R. (2009), "Perfect symmetries", *The British Journal for the Philosophy of Science*, Vol. 60, pp. 697-720.

Greaves H., Wallace D. (2014), "Empirical consequences of symmetries", *The British Journal for the Philosophy of Science*, Vol. 65, pp. 59-89.

Teh N. (2016), "Galileo's gauge: Understanding the empirical significance of gauge symmetry", *Philosophy of Science*, Vol. 83, pp. 93-118.

Friederich S. (2015), "Symmetry, empirical equivalence, and identity", *The British Journal for the Philosophy of Science*, Vol. 66, pp. 537-559.

Friederich S. (2017), "Symmetries and the identity of physical states", pp. 153-165 in Massimi M., Romeijn J.-W., Schurz G. (eds.), *EPSA15 Selected Papers*, Springer, 2017.

Chasova V. (2018), “Local symmetries with direct empirical status, gauge symmetries, and the empirical approach”. Available at http://philsci-archive.pitt.edu/17470/

Chasova V. (2019a), *Direct Empirical Status of Theoretical Symmetries in Physics*. PhD thesis under the supervision of Alexandre Guay, defended at the Université catholique de Louvain on 27 May 2019. Available at http://hdl.handle.net/2078.1/216833

Murgueitio Ramírez S., Teh N. (forthcoming), “Abandoning Galileo's ship: The quest for non-relational empirical significance”, *The British Journal for the Philosophy of Science*, forthcoming.

Murgueitio Ramírez S. (forthcoming), “A puzzle concerning local symmetries and their empirical significance”, *The British Journal for the Philosophy of Science*, forthcoming.

Wallace D. (2022a), “Isolated systems and their symmetries, Part I: General framework and particle-mechanics examples”, *Studies in History and Philosophy of Science*, Vol. 92, pp. 239-248.

Wallace D. (2022b), “Isolated systems and their symmetries, Part II: Local and global symmetries of field theories”, *Studies in History and Philosophy of Science*, Vol. 92, pp. 249-259.

Classic descriptions of empirical symmetries

Galileo's ship: Galilei G. (1632), *Dialogo sopra i due massimi sistemi del mondo*, Florence. Translated by Drake S., with foreword by Einstein A., as Galilei G. (1967), *Dialogue Concerning the Two Chief World Systems – Ptolemaic & Copernican*, University of California Press, Berkeley and Los Angeles, 2nd edition, pp. 186-187.

Faraday's cage: Maxwell J. C. (1881), *An Elementary Treatise on Electricity*, Oxford, Clarendon Press, §§ 66-67, pp. 53-54.

Einstein's elevator: Einstein A. (1917), *Über die spezielle und die allgemeine Relativitätstheorie (Gemeinverständlich)*, Braunschweig, Vieweg, Sammlung Vieweg, Heft 38. Available at http://echo.mpiwg-berlin.mpg.de/MPIWG:M83MS9G3 Translated by Lawson R. W. as Einstein A. (1921), *Relativity: The Special and the General Theory*, New York, Henry Holt and Company, 3rd edition (or any other), Ch. XX.

't Hooft's beam-splitter: 't Hooft G. (1980), “Gauge theories of the forces between elementary particles”, *Scientific American*, Vol. 242, No. 6, pp. 104-138 (in a version with less advertisements, pp. 90-116).

Some works implicitly relevant to IES

Historical sources

Noether E. (1918), “Invariante Variationsprobleme”, *Nachrichten von der Gesellschaft der Wissenschaften zu Göttingen, Mathematisch-Physikalische Klasse*, 1918, pp. 235-257. Translated as “Invariant variation problems” in Tavel M. (1971), *Transport Theory and Statistical Physics*, Vol. 1, No. 3, pp. 183-207 (available at https://arxiv.org/abs/physics/0503066v3) and in Kosmann-

Schwarzbach Y. (2011), *The Noether's Theorems: Invariance and Conservation Laws in the Twentieth Century*, Springer, pp. 3-22.

Klein F. (1918), "Über die Differentialgesetze für Erhaltung von Impuls und Energie in der Einsteinschen Gravitationstheorie", *Nachrichten von der Gesellschaft der Wissenschaften zu Göttingen, Mathematisch-Physikalische Klasse*, pp. 171-189. Reprinted with additions in Klein F. (1921), *Gesammelte mathematische Abhandlungen*, Springer, Band 1, Ch. XXXII, pp. 567-585. Translated by Chen C.-M., Nester J. M., Vogel W (2019). Available at https://arxiv.org/abs/1912.12161v1

Books in history and philosophy

Kosmann-Schwarzbach Y. (2011), *The Noether's Theorems: Invariance and Conservation Laws in the Twentieth Century*, Springer.

Read J., Teh N. J. (eds.) (2022), *The Philosophy and Physics of Noether's Theorems: A Centenary Volume*, Cambridge University Press.

Research articles

Pitts J. B. (2010), "Gauge-invariant localization of infinitely many gravitational energies from all possible auxiliary structures", *General Relativity and Gravitation*, Vol. 42, pp. 601-622.

Brading K., Brown H. (2000), "Noether's theorems and gauge symmetries". Available at https://arxiv.org/abs/hep-th/0009058

Lange M. (2007), "Laws and meta-laws of nature: Conservation laws and symmetries", *Studies in History and Philosophy of Modern Physics*, Vol. 38, pp. 457-481.

Romero-Maltrana D. (2015), "Symmetries as by-products of conserved quantities", *Studies in History and Philosophy of Modern Physics*, Vol. 52, pp. 358-368.

A work where DES and IES are compared with a classic symmetry topic and are generalised

Chasova V. (2019b), "Direct and indirect empirical statuses compared to the Newtonian and Leibnizian interpretations of theoretical symmetries in physics". Available at http://philsci-archive.pitt.edu/16245/