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An Autarkic Science: Physics, Culture, and Power in Franco's Spain

ABSTRACT

We discuss the rise of modern physics in Spain during Francoism (1939–1975) within the context of culture, power, and the ongoing historical assessment of science during the dictatorship. Contrary to the idea that Francoist policy was indifferent if not hostile to modern science, and that ideology did not go deeper than the rhetorical surface, we discuss the ways in which the physical sciences took advantage of, and in turn were used by, the regime to promote international relations, further the autarkic economy, and ultimately generate power. In order to understand what physics meant within the National Catholic political order, we contrast the situation in the post–Civil War decades with the situation before the war. First we discuss how the war transformed the physicists' community, molding it around certain key fields. We then turn to the work of right-wing ideologues and conservative scientists and philosophers, who stressed the spiritual dimension of the discipline and argued for the integration of science into the Christian scheme of the world. The cultural realignment of the discipline coincided with the institutional changes that harnessed physics to the military and economic needs of the autarkic state, which we discuss in the final section. To conclude, we reflect upon the demise of autarkic physics in the late 1960s and the overall implications of our argument with regard to the development of physics in Spain.

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The following abbreviations and acronyms have been used: CSIC, National Research Council (Consejo Superior de Investigaciones Científicas); INFQ, National Institute for Physics and Chemistry (Instituto Nacional de Física y Química); INTA, National Institute of Aeronautical Technology (Instituto Nacional de Técnica Aeronáutica); JAE, Board for the Promotion of Studies and Scientific Research (Junta para Ampliación de Estudios e Investigaciones Científicas); JEN, Nuclear Energy Board (Junta de Energía Nuclear).

Historical Studies in the Natural Sciences, Vol. 43, Number 2, pps. 202–235. ISSN 1939-1811, electronic ISSN 1939-182X. DOI: 10.1525/hsns.2013.43.2.202.

KEY WORDS: history of physics, Spain, twentieth century, international relations, science and ideology, science and politics, science and culture, Francoism

In 2002, the journal *Physics Today* was witness to a pointed exchange over science and power during General Francisco Franco's regime (1939–1975). In response to a feature article on the vigorous development of Spanish physics after the dictatorship had ended, a physicist at the Universidad Autónoma de Madrid protested that "the initial impetus was already quite visible in 1976," and that it was thus "a little unfair [to suggest] that Franco's government was doing nothing to promote physics in Spain." He also claimed that "Franco's image in his final years was more one of a benign elder statesman than a fascist dictator. Perhaps Franco's unforgivable sin was that he won a decisive victory over communism." Outraged physicists in Spain and elsewhere countered that science in Spain had "really progressed only after the establishment of a democratic regime," that in the aftermath of the Civil War (1936–1939) many scientists had suffered repression and exile and been "replaced by incompetent ones whose only scientific value was to be Franco's henchmen," and that "political pressure and an atmosphere hostile to science" had forced others to leave the country even into the late 1960s and early 1970s.[1]

The exchange was extraordinary because it brought before an international audience issues that had lain dormant since Franco's death, when physicists joined in a broad political consensus not to settle accounts with the dictatorship. A comprehensive official report on the discipline, gathering data from the late 1970s and published in 1982, provides a clear instance. A preliminary account, by prominent condensed matter physicist Federico García Moliner, granted that the creation of the National Research Council (Consejo Superior de Investigaciones Científicas, CSIC) immediately after the Civil War had been "a much debated question," hastily adding that he wished to make it "absolutely clear that there is no attempt whatsoever to make a judgment on this issue here." The full report, by six leading physicists, did not once mention Francoism and exile, referring instead "to the new stage that opened up after

1. Julio Gonzalo, "Science in Franco's Spain," *Physics Today* 55, no. 3 (2002): 14, and answers by Enrique Álvarez, José M. Calleja, Cayetano López; Alexander Tenenbaum; and Cristóbal Fernández-Pineda, José M. Guerra, Julio Serna, grouped under the heading "Another Look at Science in Spain under Franco," *Physics Today* 55, no. 7 (2002): 84 (no more than three people may sign letters to *Physics Today*). The article prompting this response was Toni Feder, "Spanish Physicists Hungry for Fresh Infusion of Jobs, Money," *Physics Today* 54, no. 8 (2001): 20–21.

the Civil War" and regretting that "unfortunately, and for reasons we are not in a position to judge here, most of the leading physicists joined research teams abroad." Renewing their claims for political attention during the transition to democracy, physicists who had come of age during the dictatorship portrayed the discipline as irrelevant to the regime, and themselves as "conspicuously absent from power in Spain."[2]

Also extraordinary were those references to the relation between physics and politics, to the links between political allegiance and scientific competence, and to an intellectual environment hostile to science—central themes in the historiography of twentieth-century science. The moral and political issues underlying research in fascist and totalitarian regimes have been amply discussed, along with the cultural relations of modern physics.[3] Yet this literature has, until very recently, neglected the Spanish case.[4] Conversely, the literature on science and ideology, including Paul Forman's classic paper on physics and Weimar culture (translated into Spanish earlier than into German), has elicited little response in Spain.[5] Extensive research has been conducted on the

2. Federico García Moliner, "Physics in Spain," *Contemporary Physics* 20, no. 5 (1979): 505–13, on 504; and J. L. Segovia, E. Bernabeu, A. Fernández-Rañada, F. Flores-Sintas, M. García-Velarde, and F. Verdaguer, *La física en España* (Madrid: Ministerio de Educación y Ciencia, 1982), 16. The English version of the report did not include the historical introduction: J. L. Segovia, E. Bernabeu, A. Fernández-Rañada, F. Flores-Sintas, M. García-Velarde, and F. Verdaguer, "The State of Physics in Spain," *Anales de Física* 77 (1981): 168–75. García Moliner acknowledged that physics was one of fields most damaged by the war.

3. Susanne Heim, Carola Sachse, and Mark Walker, eds., *The Kaiser Wilhelm Society under National Socialism* (Cambridge: Cambridge University Press, 2009); Helmuth Trischler and Mark Walker, eds., *Physics and Politics: Research and Research Support in Twentieth-Century Germany in International Perspective* (Stuttgart: Franz Steiner Verlag, 2010); "Physicists in the Postwar Political Arena: Comparative Perspectives," special issue of *HSPS* 30, no. 1 (1999); Mark Walker, ed., *Science and Ideology: A Comparative History* (London: Routledge, 2003).

4. "Franco" and "Spain," for instance, do not make it into Paul R. Josephson, *Totalitarian Science and Technology: Control of Nature* (Amherst, NY: Humanity Books, 2005), which has a chapter, "The Physical Sciences under Totalitarian Regimes" (71–116), that includes a section on "Nuclear Knowledge and Authoritarian Power: Argentina, Cuba, and North Korea." Exceptions include Roy MacLeod, ed., "Science in the European Periphery during the Cold War," special issue of *Minerva* 43, no. 2 (2005): 119–218, gathering papers on science in Spain, particularly during Francoism; Tiago Saraiva and M. Norton Wise, "Autarky/Autarchy: Genetics, Food Production, and the Building of Fascism," *HSNS* 40, no. 4 (2010): 419–28, introduction to an issue on fascism and science that compares the experience of Germany, Italy, Portugal, France, and Spain; and the special issue on "The Fascistization of Science," ed. Tiago Saraiva, *Journal of History of Science and Technology* 3 (2009), http://johost.eu/?ri=2&sh= (accessed 2 Feb 2012).

5. Paul Forman, "Weimar Culture, Causality, and Quantum Theory, 1918–1927: Adaptation by German Physicists and Mathematicians to a Hostile Intellectual Environment," *HSPS* 3

scientific and technological policies of the Francoist regime and its key scientific institutions, including the CSIC, the National Institute of Aeronautical Technology (Instituto Nacional de Técnica Aeronáutica [INTA], established in 1942), and the Nuclear Energy Board (Junta de Energía Nuclear [JEN], established in 1951).[6] However, these works have struck an uneasy balance between praising the purported modernity of these institutions and dismissing the reactionary regime that promoted them. Indeed, the ideological meaning of the physical sciences has been shrugged off by opposing viewpoints. Noted physicists retrospectively claimed that the ideology made little difference. To Carlos Sánchez del Río (b. 1924), pioneer nuclear physicist in the 1950s and president of the CSIC in the late 1970s, this organization effectively promoted research after the war in keeping with prewar practices, even if "it expressed its aims in the imperial phraseology common at the time."[7] Historians, on the other hand, have emphasized the antagonism between modern science and National Catholicism and have rhetorically asked whether science was at all possible in ruined post–Civil War Spain: "Vain talk, pure retrograde ideology . . . . What science could be done with such a spirit?"[8]

(1971): 1–115; Spanish edition by José Manuel Sánchez Ron, *Cultura en Weimar, causalidad y teoría cuántica, 1918–1927: Adaptación de los físicos y matemáticos alemanes a un ambiente intelectual hostil* (Madrid: Alianza 1984); German edition, by Karl von Meyenn, *Quantenmechanik und Weimarer Republik* (Braunschweig: Vieweg, 1994). Cf. Helmuth Trischler, Cathryn Carson, and Alexei Kojevnikov, "Beyond Weimar Culture: The Significance of the Forman Thesis for a Cultural Approach to the History of Science," *Berichte zur Wissenschaftsgeschichte* 31, no. 4 (2008): 305–10.

6. General works include Rafael Huertas and Carmen Ortiz, eds., *Ciencia y fascismo* (Aranjuez: Doce Calles, 1997); Luis Sanz Menéndez, *Estado, ciencia y tecnología en España, 1939–1997* (Madrid: Alianza, 1997); Amparo Gómez and Antonio F. Canales, eds., *Ciencia y fascismos: La ciencia española de posguerra* (Barcelona: Laertes, 2009); Miguel Ángel Puig-Samper, ed., *Tiempos de investigación: JAE-CSIC cien años de ciencia en España* (Madrid: CSIC, 2007); Ana Romero de Pablos and María Jesús Santesmases, *Cien años de política científica en España* (Bilbao: Fundación BBVA, 2008); José Manuel Sánchez Ron, *INTA: 50 años de ciencia y técnica aeroespacial* (Madrid: INTA, 1997); Ana Romero de Pablos and José Manuel Sánchez Ron, *Energía nuclear en España: De la JEN al CIEMAT* (Madrid: CIEMAT, 2001).

7. Carlos Sánchez del Río, "La investigación científica en España," in C. Sánchez del Río, *Escritos varios: Libro homenaje de la Universidad Complutense de Madrid* (Madrid: Editorial Complutense, 1995), 203–14, on 207: "los objetivos [del Consejo Superior de Investigaciones Científicas] eran esencialmente idénticos a los de la extinguida Junta, aunque vinieran expresados en la fraseología imperial propia de aquellos años."

8. José Manuel Sánchez Ron, "La europeización científica de España," in *Historia de España,* vol. 11, *España y Europa*, ed. Josep Fontana and Ramón Villares (Barcelona: Crítica; Madrid: Marcial Pons, 2008), 289–535, on 504: "Palabrería vana, pura ideología retrógrada . . . ¿Qué ciencia se podía hacer bajo semejante espíritu?"

In this paper we propose an interpretation of the rise of physics in Francoist Spain that brings together the historiography of totalitarian science and that of science during Francoism.[9] Increasingly, research on science in the dictatorship is moving away from the presumed dichotomy between modern science and totalitarian power.[10] Historians have recently explored the coproduction of science and the state of fields such as engineering, geophysics, mathematics, molecular biology, and agriculture, and have critically revised the scientific culture of early Francoism.[11] They have also advanced nuanced views on the survival of Republican research traditions and practices in Francoist labs, and have addressed issues of continuity and genealogy.[12]

9. Historians have long debated the nature and character of the Francoist dictatorship. The problem is compounded by the duration of the regime, which allowed for many changes and adaptations. The regime asserted its fascist character until 1945 even though, unlike contemporary fascist regimes, it was born out of a civil war. The power of the single Party (Falange Española) was seriously challenged by the military and the Catholic church, and the regime adopted National Catholicism, which posed the Catholic essence of the Spanish nation, as its official ideology. For a thorough recent synthesis of the vast literature on Francoism, see Borja de Riquer, *Historia de España,* vol. 9, *La dictadura de Franco* (Barcelona: Crítica; Madrid: Marcial Pons, 2010).

10. Mitchell Ash's concept of science and power as resources for one another has proved rather inspiring in this connection; see his "Wissenschaft und Politik als Ressourcen für einander," in *Wissenschaften und Wissenschaftspolitik: Bestandsaufnahmen zu Formationen, Brüchen und Kontinuitäten im Deutschland des 20. Jahrhunderts*, ed. Rüdiger vom Bruch and Brigitte Kaderas (Stuttgart: Franz Steiner, 2002), 32–51. See also Bruno Strasser, "The Coproduction of Neutral Science and Neutral State in Cold War Europe: Switzerland and International Scientific Cooperation, 1951–69," *Osiris* 24 (2009): 165–87.

11. Aitor Anduaga, *Geofísica, economía y sociedad en la España contemporánea* (Madrid: CSIC: 2009); Lino Camprubí, "Los estándares como instrumentos políticos: Ciencia y Estado franquista a finales de los años cincuenta," *Empiria* 18 (2009): 85–114; Lino Camprubí, "One Grain, One Nation: Rice Genetics and the Corporate State in Early Francoist Spain (1939–1952)," *HSNS* 40, no. 4 (2010): 499–531; Lino Camprubí, "Political Engineering: Science, Technology, and the Francoist Landscape (1939–1959)," (PhD dissertation, University of California Los Angeles, 2011); Antonio Canales Serrano and Amparo Gómez Rodríguez, "The Rebels and the New Spanish Scientific Culture," *Journal of War and Culture Studies* 2, no. 3 (2009): 321–33; Antoni Malet, *Ferran Sunyer i Balaguer (1912–1967)* (Barcelona: IEC, 1995); Antoni Malet, "Las primeras décadas del CSIC: Investigación y ciencia para el franquismo," in Romero and Santesmases, *Cien años de política científica* (ref. 6), 211–56; Antoni Malet, "José María Albareda (1902–1966) and the Formation of the Spanish Consejo Superior de Investigaciones Científicas," *Annals of Science* 66, no. 3 (2009): 307–32; María Jesús Santesmases, "Severo Ochoa and the Biomedical Sciences in Spain under Franco, 1959–1975," *Isis* 91, no. 4 (2000): 706–34; María Jesús Santesmases, "Peace Propaganda and Biomedical Experimentation: Influential Uses of Radioisotopes in Endocrinology and Molecular Genetics in Spain (1947–1971)," *Journal of the History of Biology* 39, no. 4 (2006): 765–94.

12. María Jesús Santesmases, "Neutralidades y atrasos: Ciencias y tecnicismo en la España de Franco," in *Actes de la VII Trobada d'Història de la Ciència i de la Tècnica*, ed. Josep Batlló Ortiz, Roser Puig Aguilar, and Pasqual Bernat López (Barcelona: SCHCT, 2003), 63–78; María Jesús

Here we focus on the physicists who, after the war, "came to stand for science's connection to politics via the instrumentality of technical power."[13] We discuss the ways in which they found accommodation in the regime—both taking advantage of it and being used by it—to further industry, legitimate international relations, and ultimately generate power.[14]

The argument is in three parts. First, we discuss how the regime's science policy makers used war, exile, and purging to mold the physicists' community around military-related and applied fields such as optics and the material and nuclear sciences—changes to which physicists actively contributed.[15] We then turn to obscure yet significant work by ideologues on the extreme right and noted conservative physicists and philosophers, who sought to replace the progressive modernist reading of physics that had prevailed in the country before the war with a reactionary modernist reading that stressed the spiritual rather than the material dimensions of the discipline, and argued for its integration into the Christian scheme of the world. Both the cultural realignment of the discipline and the adaptation of physicists to a not-so-hostile intellectual environment were of a piece with the institutional changes that harnessed physics to the military and economic needs of the autarkic state, as we argue in the final section. This process resulted in a form of physics that was most obviously autarkic in its relation to the economy and power, but also autarkic because national norms of excellence and cultures of research prevailed over international ones. In the conclusion we reflect on the demise of autarkic physics in the late 1960s, and the implications of our argument with regard to an understanding of the development of physics in Spain.

Santesmases, "Viajes y memoria: Las ciencias en España antes y después de la Guerra Civil," *Asclepio* 59, no. 2 (2007): 213–30; María Jesús Santesmases, "Genealogía: Las investigaciones biológicas en España, 1940–1956," in Gómez and Canales, eds., *Ciencia y fascismos* (ref. 6), 269–300.

13. Cathryn Carson, *Heisenberg in the Atomic Age: Science and the Public Sphere* (Cambridge: Cambridge University Press, 2010), 161.

14. Cf. Camprubí, "One Grain, One Nation" (ref. 11), 501: "I'm interested in how agricultural scientists participated in the regime rather than in how they came to work 'under' it or 'despite' its official policies and rhetoric . . . . The authoritarian and hierarchical nature of Francoism made room for various people to utilize their knowledge and skills to shape its organization and to foster their own plans."

15. Cf. Paul Forman, "Behind Quantum Electrodynamics: National Security as Basis for Physical Research in the United States, 1940–1960," *HSPS* 18, no. 1 (1987): 149–229.

MOLDING THE COMMUNITY

In the first months of 1939, as Barcelona and then Madrid were seized by the rebel army that had risen against the elected Republican government in July 1936, Blas Cabrera (1878–1945) thought that the Civil War and his exile in Paris were coming to an end. Being the leading Spanish physicist of his generation, and an experimental researcher of international reputation in the field of magnetism, he looked forward to returning to his research institute and university chair in Madrid.[16] Since the turn of the century there had been several attempts in Spain, public and private, in the capital and the industrialized peripheries of the country, to create a supportive environment for science and technology.[17] The Board for the Promotion of Studies and Scientific Research (Junta para Ampliación de Estudios e Investigaciones Científicas, JAE), established in 1907, is the most significant and certainly the best documented of such initiatives.[18] Cabrera directed the JAE's Laboratory of Physical Research (Laboratorio de Investigaciones Físicas) from its creation in 1910, and led its transformation, two decades later, into a grand National Institute of Physics and Chemistry (Instituto Nacional de Física y Química, INFQ).[19] The laboratory drew on the JAE's fellowship program, which allowed twenty-one Spanish physicists between 1910 and 1936 to train and do research

16. José Manuel Sánchez Ron, "International Relations in Spanish Physics from 1900 to the Cold War," *HSPS* 33, no. 1 (2002): 3–31, on 16–17. On Cabrera, see *En el centenario de Blas Cabrera* (Las Palmas: Universidad Internacional de Canarias Pérez Galdós, 1979); Francisco González de Posada, ed., *Blas Cabrera ante Einstein y la relatividad: Con 8 artículos de Blas Cabrera* (Madrid: Amigos de la Cultura Científica, 1995); Rosario E. Fernández Terán and Francisco A. González Redondo, "Blas Cabrera y la física en España durante la segunda República," *Llull* 30, no. 65 (2007): 65–104.

17. General works include Leoncio López-Ocón, *Breve historia de la ciencia española* (Madrid: Alianza Editorial, 2003); José Manuel Sánchez Ron, *Cincel, martillo y piedra: Historia de la ciencia en España (siglos XIX y XX)* (Madrid: Taurus, 1999); Sánchez Ron, "La europeización científica" (ref. 8) and Romero and Santesmases, *Cien años de política científica* (ref. 6).

18. José Manuel Sánchez Ron, ed., *La Junta para Ampliación de Estudios e Investigaciones Científicas 80 años después, 1907–1987* (Madrid: CSIC, 1988); José Manuel Sánchez Ron, Antonio Lafuente, Ana Romero de Pablos, and L. Sánchez de Andrés, eds., *El laboratorio de España: La Junta para Ampliación de Estudios e Investigaciones Científicas, 1907–1939* (Madrid: Sociedad Estatal de Conmemoraciones Culturales; Residencia de Estudiantes, 2007). The Board's extensive archive, launched online in 2007, has secured the institution's historiographical prominence.

19. Thomas F. Glick, "Dictating to the Dictator: Augustus Trowbridge, the Rockefeller Foundation, and the Support of Physics in Spain, 1923–1927," *Minerva* 43, no. 2 (2005): 121–45; José Manuel Sánchez Ron and Antoni Roca-Rosell, "Spain's First School of Physics: Blas Cabrera's Laboratorio de Investigaciones Físicas," *Osiris* 8 (1993): 127–55.

abroad.[20] Recipients included Cabrera, Esteban Terradas (1883–1950), and Miguel A. Catalán (1894–1957), the core members of the first group of modern physicists in Spain.[21]

The end of the Civil War in April 1939, however, brought anything but peace. It unleashed a fierce, long-lasting repression and prompted the exile or purging of staff at universities and public institutions. By 1940, nearly half of the 580 university professors active before the war had died, gone into exile, or been purged, a higher proportion than in Germany, Portugal, or Italy.[22] Harassed by the victors, who deprived him of his chair in Madrid, Cabrera sailed to Mexico in 1941, and taught at the Universidad Nacional Autónoma de México until his death in 1945; half of the other physics professors at the University of Madrid (four of eight), most of them politically engaged, joined him in exile.[23] M. Catalán returned to the INFQ barely two weeks after the

20. Figures drawn from the Board's online archive, http://archivojae.edaddeplata.org/jae_app/ (accessed 2 Feb 2012). Chemistry and Physics received 6.3 percent and 2.4 percent of the grants, respectively, a ratio strikingly similar to that of publishing authors in these disciplines during the same period, as reckoned by Yves Gingras, "The Transformation of Physics from 1900 to 1945," *Physics in Perspective* 12, no. 3 (2010): 248–65.

21. There are book-length biographies of Terradas and Catalán, both based on extensive personal archives: Antoni Roca-Rosell and José Manuel Sánchez Ron, *Esteban Terradas Illa (1883–1950): Ciencia y Técnica en la España contemporánea* (Barcelona: INTA/El Serbal, 1990); Antoni Roca-Rosell, *Esteban Terradas* (Madrid: Fundación Banco Exterior, 1991); Antoni Roca-Rosell, ed., *Esteve Terradas Illa (1883–1950): Enginyeria, arquitectura i ciència al segle XX* (Barcelona: La Salle, 2004). Catalán's reputation was based on his discovery of multiplets in the manganese spectrum; see José Manuel Sánchez Ron, *Miguel Catalán: Su obra y su mundo* (Madrid: CSIC; Fundación Ramón Menéndez Pidal, 1994).

22. Jaume Claret Miranda, *El atroz desmoche: La destrucción de la universidad española por el franquismo, 1936–1945* (Barcelona: Crítica, 2006), 350–53, and 80–84 for a comparison with professional purges in the countries mentioned. The Spanish and Italian cases are further compared in Francisco Morente Valero, "La universitat feixista i la universitat franquista en perspectiva comparada," in *Nou Estat, nova política, nou ordre social: Feixime i franquisme en una perspectiva comparada*, ed. Giuliana di Febo and Carme Molinero (Barcelona: Fundació Carles Pi i Sunyer; CEFID, UAB, 2005), 117–60, Spanish version in *Cuadernos del Instituto Antonio de Nebrija* 8 (2005): 179–214. On the University of Madrid, see also Luis E. Otero Carvajal, *La destrucción de la ciencia en España: Depuración universitaria y franquismo* (Madrid: Editorial Complutense, 2006). See Riquer, *La dictadura de Franco* (ref. 9), 144–50 on figures for the purge of civil servants.

23. Arturo Duperier (1896–1959), professor of geophysics, left for the United Kingdom, where he managed to work with P. M. S. Blackett at the University of Manchester and Imperial College, London, until his return to Spain in 1953. Manuel Martínez-Risco (1888–1954), who held the chair of Optics and Acoustics and was a Member of Parliament for Orense, left for France, eventually joining the Centre National de la Recherche Scientifique (CNRS). The astronomers Pedro Carrasco Garrorena (1883–1966) and Honorato de Castro (1885–1962) settled in Mexico. On the

end of the war, finding it had suffered little damage and intending to resume work on spectroscopy; yet he was barred from the institute and remained in bureaucratic limbo, forced to make a living in the chemical and pharmaceutical industry before being readmitted to his chair in 1945.[24] Other physicists were deprived of their chairs or reassigned, a technique devised to break the social and family ties of public servants. Salvador Velayos (1908–1997), a disciple of Cabrera, was forced to leave the University of Valencia for the University of Valladolid, and Luis Bru (1909–1997), likewise a former member of the INFQ, had to leave the University of La Laguna for the University of Seville.[25] Repression was harsh and often arbitrary: the flimsiest connection with Republican polity could mean punishment. But this practice was uneven and, together with the uncertainty of exile, it meant that purged scientists occasionally managed to return or remain in Spain, however damaged their careers.

The void left by those who suffered exile and purging has long been recognized. Not so the chances it provided: "Every vacancy of a defeated created an opportunity for a victor." J. Claret's forensic study of the destruction of the university has led him to conclude that "when we speak of the Francoist wasteland, we always have in mind all those lecturers lost to the country; but we forget that the true, lasting wasteland was created, above all, by those professors who remained in Spain and filled the vacant positions."[26] Indeed the number of professors soon reached pre–Civil War levels, and in the five years after the war, 155 new chairs were provided, most of them going to

scientific exile, see Josep Lluís Barona, ed., *El exilio científico republicano: Un balance histórico 70 años después* (València: Servei de Publicacions de la Universitat de València, 2010). Francisco Giral, *La ciencia española en el exilio: El exilio de los científicos españoles (1939–1989)* (Barcelona: Anthropos, 1994), contains valuable prosopographical information.

24. M. Á. Catalán to A. Sommerfeld, 12 Apr 1939, cited in José Manuel Sánchez Ron, "Documentos para una historia de la física moderna en España: Arnold Sommerfeld, Miguel Ángel Catalán, Ángel del Campo y Blas Cabrera," *Llull* 5 (1983): 97–109, on 107; Sánchez Ron, *Miguel Catalán* (ref. 21), 329; Claret, *El atroz desmoche* (ref. 22), 312–13.

25. Sánchez Ron, *Miguel Catalán* (ref. 21), chs. 7 and 8; Sánchez Ron, "La europeización científica" (ref. 8), 469–70; J. M. Sánchez Ron, "Cien años de física. La física en España. III: La Guerra Civil y sus consecuencias," *Revista Española de Física* 17, no. 3 (2003): 9–15, on 10; Claret, *El atroz desmoche* (ref. 22), 341, on Velayos's move on 7 Mar 1940.

26. Claret, *El atroz desmoche* (ref. 22), 2: "Cada vacante de un vencido generaba una oportunidad para un vencedor," and 360, respectively: "Cuando nos referimos al yermo franquista siempre tenemos en mente a todos aquellos docentes que se perdieron, pero olvidamos que el yermo real y duradero lo crearon sobre todo aquellos profesores que permanecieron en España y ocuparon las vacantes."

members of Catholic organizations such as the Asociación Católica Nacional de Propagandistas, Acción Católica, and Opus Dei.[27] Having demonstrated the necessary political allegiances, some physicists returned to their chairs after the war. Terradas and Julio Palacios (1891–1970) are clear examples.[28] Reappointed to a chair at the University of Madrid, Terradas led high-profile institutional ventures such as the National Institute of Aeronautical Technology (Instituto Nacional de Técnica Aeronáutica, INTA), vigorously pursuing a program of research and industrialization for the regime regardless of his mounting private unease.[29] Palacios, who was among the physicists at the University of Madrid who did not lose their chairs, was appointed vice rector of the university and vice president of the Instituto de España, an attempt to establish a politically autonomous national research council, with responsibilities over all research centers in the natural and physical sciences.[30] Yet he fell from grace because of his monarchism and lack of belligerence with regard to the legacy of the JAE, the *bête noire* of Francoist policy makers. The Instituto de España was promptly quashed by the promoters of the CSIC, and from 1947 Palacios took shelter in Lisbon, teaching at the university and directing the physics laboratory at the Lisbon Cancer Hospital.[31]

Yet no career in the physical sciences provides a clearer instance of the links between political obedience, religious observance, and professional advancement in Franco's Spain than that of Navy engineer José María Otero

27. Claret, *El atroz desmoche* (ref. 22), 354; Alicia Alted Vigil, "Bases político-ideológicas y jurídicas de la universidad franquista durante los ministerios de Sainz Rodríguez y primera época de Ibáñez Martín (1938–1945)," in *La universidad española bajo el régimen de Franco* (1939–1975), ed. Juan José Carreras and Miguel Ángel Ruiz Carnicer (Zaragoza: Institución Fernando el Católico, 1991), 95–124, on 117.

28. Other instances are José Baltá Elías (theoretical and experimental physics, University of Salamanca) and Rafael Salvia Hernández (physics, attached to the University of Seville). See Claret, *El atroz desmoche* (ref. 22), 108 and 227, n. 39.

29. Antoni Roca-Rosell, "Professionalism and Technocracy: Esteve Terradas and Science Policy in the Early Years of the Franco Regime," *Minerva: Review of Science, Learning and Policy* 43, no. 2 (2005): 147–62; Sánchez Ron, *INTA* (ref. 6), chs. II and III.

30. Malet, "Albareda" (ref. 11), 317, quoting a copy of the official appointment (1 May 1939) in the archives of the Residencia de Estudiantes. On Palacios, see also Antonio Moreno González, "Julio Palacios: Entre el aula, el laboratorio y otras dedicaciones," *Revista Española de Física* 5, no. 4 (1991): 58–63, and José Aguilar Peris, "Julio Palacios, la Real Sociedad Española de Física y Química y su legado científico," *Revista Española de Física* 17, no. 5 (2003): 11–12.

31. On Palacios and science policy in the aftermath of the Civil War, see Malet, "Albareda" (ref. 11), 317–18, and Malet, "Primeras décadas del CSIC" (ref. 11), 217–29; cf. Antonio F. Canales, "La política científica de posguerra," in Gómez and Canales, eds., *Ciencia y fascismos* (ref. 6), 105–36.

Navascués (1907–1983). A former student of Palacios at the INFQ, Otero trained in optics in Germany in the early 1930s, at the Technische Hochschule in Berlin, the Zeiss's works in Jena, and the Zeiss's military subsidiary, Nedinsco.[32] He was not breaking new ground, but rather benefitting from the network of personal and institutional relations that the Spanish and German military had built since the end of the Great War.[33] These involved the development and production of weaponry, including poison gas and explosives, and the construction of aircraft and vessels. In many instances, Otero's ties with German academics, engineers, and military men survived both the Civil War and World War II.

The Civil War cleared the way for Otero, a devout Catholic and loyal member of the rebel army. His foremost scientific contribution concerned an optical topic of direct autarkic (i.e., military and economic) relevance: nocturnal myopia. Together with A. Durán, Otero devised a method for quantifying the phenomenon sometimes mistaken in the literature for the discovery of nocturnal myopia itself.[34] He also published on optical instrumentation and the physiology of sight. Most importantly, he was able to deploy his institutional vision, playing a leading role in the configuration of

32. Sánchez Ron, "International Relations" (ref. 16), 13; Romero and Sánchez Ron, *Energía nuclear en España* (ref. 6), 83–84. See also the hagiographical memoirs by Leonardo Villena, "José María Otero Navascués (1907–1983)," *Óptica Pura y Aplicada* 17 (1984): 1–12, and "Otero, José María: An international scientist," *Arbor* 115, no. 450 (1983): 95–108. Also, J. R. de Andrés Martín, *José María Otero de Navascués Enríquez de la Sota, Marqués de Hermosilla: La baza nuclear y científica del mundo hispánico durante la Guerra Fría* (Barcelona: Plaza Valdés, 2005). It is not clear whether Otero had degrees or a PhD in physics or chemistry. In a letter to P. M. S. Blackett, he described his career as that of a "Naval Officer (Engineer), and then Physicist" (Otero to Blackett, 16 Oct 1969, Royal Society Archives, PB/7/2/4/18).

33. Albert Presas, "Technological Transfer as a Political Weapon: Technological Relations between Germany and Spain from 1918 to the early 1950s," *Journal of Modern European History* 6, no. 2 (2008): 218–35; Albert Presas, "Technoscientific Synergies between Germany and Spain in the Twentieth Century: Continuity amid Radical Change," *Technology and Culture* 51, no. 1 (2010): 80–98; Albert Presas Puig, "La correspondencia entre José M. Otero Navascués y Karl Wirtz, un episodio de las relaciones internacionales de la Junta de Energía Nuclear," *Arbor* 164, nos. 659–60 (2000): 527–602.

34. M. Otero and A. Durán, "Rendimiento fotométrico de sistemas ópticos a bajas luminosidades," *Anales de Física y Química* 37, no. 1 (1941): 459–77. See María Luisa Calvo and Carlos Gómez-Reino, "In Memoriam: Armando Durán Miranda (1913–2001)," *Óptica Pura y Aplicada* 33, no. 1 (2000): 3–16, esp. 7–12. For precedents going back to the eighteenth century and an explicit rebuttal of the discovery claim, see John R. Levene, "Nevil Maskelyne, F. R. S., and the Discovery of Night Myopia," *Notes and Records of the Royal Society of London* 20, no. 1 (1965): 100–08.

physics during the first two decades of Francoism. He presided over the National Council for Physics (Consejo Nacional de Física), an umbrella organization for the CSIC's physics institutes, from 1950 until its dissolution in 1966.[35] All along he enjoyed international recognition as a national representative of Spain in organizations such as the International Union of Pure and Applied Physics, the International Committee on Weights and Measures (over which he presided from 1968–1976), and the International Atomic Energy Agency (the General Conference of which he chaired in 1971).

Terradas, Otero, and Palacios's PhD graduates found positions in the depleted university. Joaquín Catalá (1911–2009), who had visited Franz Weidert's Optisches Institut in Berlin in 1942 and completed his PhD on optics with Otero in 1943, was appointed in 1944 to the chair of Theoretical and Experimental Physics at the University of Valencia. After learning to use nuclear research emulsions with C. F. Powell in Bristol, in 1950 he set up an experimental group that pioneered research on cosmic ray and high-energy physics.[36] Armando Durán (1913–2001), Palacios's assistant at the INFQ before the Civil War, spent the years between 1941 and 1943 at Weidert's institute and completed his PhD on optics, under Palacios's supervision, in 1943. Two years later he was appointed to the chair of Optics and Acoustics at the University of Madrid. As an active physicist in the field of optics until 1953, and a science administrator and policy maker afterwards, he may have helped to lay "a firm basis allowing for the exponential growth of physics and chemistry in Spain,"

35. "Agrupación de los Centros de Investigación de Física en un Instituto Nacional como Organismo Coordinador," cited in Miquel Terreu, "El CSIC durant l'autarquia: El procés d'adquisició del primer microscopi electrònic" (MPhil dissertation, Universitat Autònoma de Barcelona, 2008), on 10. See also Romero and Sánchez Ron, *Energía nuclear en España* (ref. 6), 38, and Villena, "José María Otero" (ref. 32), 8: "Otero se había interesado repetidamente por la coordinación, tan difícil entre los españoles, de las distintas escuelas de Investigación Física. Por fin se crea, en 1949, dentro del CSIC, el Consejo Nacional de Física . . . . Esta intensa labor de coordinación dura hasta 1966. Se hace el elenco de aparatos disponibles y de los demás temas a investigar. Hay que evitar duplicaciones y cubrir huecos. Es una tarea muy importante que no sale adelante porque nadie se deja aconsejar ni coordinar."

36. Agustín Ceba Herrero, Víctor Navarro, and Jorge Velasco, "Los orígenes de la investigación experimental en Física Nuclear y de Partículas en España," *Revista Española de Física* 25, no. 2 (2011): 54–61; Víctor Navarro-Brotóns, Jorge Velasco González, and José Doménech Torres, "The Birth of Particle Physics in Spain," *Minerva* 43, no. 2 (2005): 183–96; Agustín Ceba, "Joaquín Catalá y la investigación en física nuclear y de partículas en Valencia," in *La física en la dictadura: Físicos, cultura y poder en España (1939–1975)*, ed. Néstor Herran and Xavier Roqué (Bellaterra: Servei de Publicacions de la UAB, 2012).

but he can hardly be portrayed as a pioneer who had to make do without resources or social recognition.[37]

Prominent among the Spanish physicists who came of age in the 1940s was Carlos Sánchez del Río y Sierra (b. 1924), who submitted a PhD in optics in 1948.[38] As Durán recalled, "man proposes but God disposes": The Spanish nuclear project had just secretly been launched, and Sánchez del Río was co-opted by Otero and his thesis advisor, Durán, to whom Otero had introduced Sánchez del Río as "a clever relative of his."[39] As professor of atomic and nuclear physics at the University of Madrid from 1953 and member of the JEN board, Sánchez del Río played a key role in the rise of theoretical and nuclear physics in Spain. He also held various technical and political roles: president of the Spanish Royal Society of Physics and Chemistry (Real Sociedad Española de Física y Química, RSEFQ), president of the Nuclear Spanish Society (Sociedad Nuclear Española), National Education Councilor (Consejero Nacional de Educación), and president of the CSIC.

The key physicists for the reconstruction of the discipline after the Civil War had close personal and professional relations, often verging on clientelism.[40]

37. Calvo and Gómez-Reino, "Armando Durán Miranda" (ref. 34), 5: "En la cátedra, Durán inicia una vida académica y profesional muy intensa. Algunos de los antiguos alumnos de D. Blas Cabrera son los que en esos momentos tienen la responsabilidad de sacar a la ciencia española de la situación tan precaria en la que se encontraba. Profesores e investigadores cuya actividad pionera, oscura, carente de recursos y sin reconocimiento social, hizo posible que más tarde se creara una base firme y sólida que permitió el crecimiento exponencial de la física y la química en España." Calvo and Gómez-Reino list Durán's papers and his administrative and political roles: he directed the CSIC institute Leonardo Torres Quevedo, was from the outset involved in the Spanish nuclear project, and became Director General of Technical Education at the Ministry of National Education.

38. Sánchez del Río was the son of Carlos Sánchez del Río Peguero, professor of Roman Law at the University of Zaragoza, member of the provincial delegation of the government (Gobierno Civil) established by the insurgents right at the beginning of the war, and Secretary of the Board of the Ciudad Universitaria in Madrid after it; Claret, *El atroz desmoche* (ref. 22), 144.

39. "Un pariente suyo muy inteligente," A. Durán, "Carlos Sánchez del Río y la Física," in Sánchez del Río, *Escritos varios* (ref. 7), 19; "El hombre propone y Dios dispone," 20.

40. A telling instance is Catalá to Otero, 20 Set 1945, quoted in Ceba, Navarro, and Velasco, "Orígenes de la investigación experimental" (ref. 36), 55: "I beg you not to forget me in your projects! This monotonous life, which has nothing to do with science, makes me despair, and if I do not get some fresh air I am lost. You know that I am a wholehearted member of the optics section you have created, and that I should like to work on its behalf wherever I can" ("Le ruego que no me olvide en sus proyectos . . . ! Estoy desesperado con esta monótona vida que nada tiene de científica y si no me aireo un poco me veo perdido! Ya sabe Vd. que estoy de corazón en esa sección de Óptica que Vd. ha creado y desearía trabajar, dónde sea, por ella").

As we shall presently see, they also shared a pronounced outlook on the meaning and value of contemporary physics.

ALIGNING THE DISCIPLINE

Given the nature of Franco's regime, we may expect the pursuit of modern physics to have taken a political, ideological, and religious turn. Yet this posed a problem. For three decades before the onset of war, science had thrived in Spain under the auspices of the JAE, which had deployed it as a progressive, modernizing force. Throughout this period the physical sciences were featured in the press, in scientific lectures, and in books, popular journals and exhibitions. Disputes were often public. Radium, for instance, was dismissed by politically conservative scientists as "a revolutionary metal . . . an anarchist that comes to disturb the established order and destroy . . . the laws of classical science" and hailed by socialist popularizers as "an inflexible fact that doesn't honor beliefs, traditions or theories."[41] Nonetheless, a broad consensus appears to have been reached about the value of science, as shown by the public reaction to Einstein's visit to Spain in February–March 1923, which led T. F. Glick to introduce the notion of "civil discourse . . . a tacit, unwritten agreement to suspend ideological warfare in scientific debate and to encourage open discourse in matters of science."[42] Writers, journalists, philosophers,

41. Néstor Herran, "'A Subversive Element': Science, Politics and the Early Appropriation of Radioactivity in Spain," in *Neighbours and Territories: The Evolving Identity of Chemistry*, ed. José Ramón Bertomeu Sánchez, Brigitte van Tiggelen, and Duncan Thorburn Burns (Louvain-la-Neuve, Belgium: Mémosciences, 2008), 176–86; see also Matiana González-Silva and Néstor Herran, "Ideology, Elitism and Social Commitment: Alternative Images of Science in Two fin de siècle Barcelona Newspapers," *Centaurus* 51, no. 2 (2009): 97–115; Néstor Herran, "'Science to the Glory of God': The Popular Science Magazine *Ibérica* and its Coverage of Radioactivity, 1914–1936," *Science and Education* 21, no. 3 (2012): 335–53; Agustí Nieto-Galan, "'not fundamental in a state of full civilization': The Sociedad Astronómica de Barcelona (1910–1921) and Its Popularization Programme," *Annals of Science* 66, no. 4 (2009): 497–528.

42. Thomas F. Glick and José Manuel Sánchez Ron, "Science Frustrated: The 'Einstein Institute' in Madrid," *Minerva* 44, no. 4 (2006): 355–78, "civil discourse" on 358. The full account of Einstein's visit is in Thomas F. Glick, *Einstein in Spain: Relativity and the Recovery of Science* (Princeton, NJ: Princeton University Press, 1988), and Spanish translation, Víctor Navarro-Brotóns, trans., *Einstein y los españoles: Ciencia y sociedad en la España de entreguerras* (Madrid: Alianza, 1986; rev. ed. Madrid: CSIC, 2005). See also J. M. Sánchez Ron and Ana Romero de Pablos, *Einstein en España* (Madrid: Publicaciones de la Residencia de Estudiantes, 2005), and Pablo Soler-Ferran, "La teoría de la relatividad en la física y matemática españolas: Un capítulo de la historia de la ciencia en España" (PhD dissertation, Universidad Complutense de Madrid, 2008).

scientists, and politicians were able to discuss relativity without compromising their various ideological positions. In the postwar polity, however, science was subservient to politics and religion. For physics to be of use, its links with the political culture that the war had set out to destroy needed to be severed, and not only its practitioners but the discipline itself had to be purged and realigned with the regime's views on the essence and future of Spain. How was this achieved?

When civil discourse began to deteriorate in the early 1930s, physics was not spared. In 1923, Einstein had been viewed as a German scientist by liberal and conservative newspapers alike. Ten years later, when he was granted an extraordinary chair at the University of Madrid, the press clashed over his Jewishness.[43] This change was related to the spread of anti-universalist, anti-rationalist world-historical visions, notably of course those of Oswald Spengler, whose *Decline of the West* was translated into Spanish in 1927, to be followed by *Decisive Years* in 1934. There were explicit links with physics. Spengler's editor, the philosopher, newspaper editor, and publisher José Ortega y Gasset, was best known as the author of *The Revolt of the Masses* (1930, translated into English in 1932) and a disenchanted manifesto of his own, *El tema de nuestro tiempo* (1923, translated as *The Modern Theme*, London, 1931); but he also kept a keen eye on physics, which he deemed "the pinnacle" of Western culture and to which he devoted a number of essays, on Galileo, relativity, and the meaning of contemporary physics for philosophy.[44] Spengler's translator, the noted philosopher Manuel García Morente (1886–1942), had previously translated Moritz Schlick's *Raum und Zeit in der gegenwärtigen Physik* (1919) and Max Born's *Die Relativitätstheorie Einstein* (1920).[45]

43. Glick and Sánchez Ron, "Science Frustrated" (ref. 42).

44. See Robert Wohl, *The Generation of 1914* (Cambridge, MA: Harvard University Press, 1979). Wohl's chapter 4, "Spain: The Theme of Our Time," is entirely devoted to Ortega y Gasset, who complained about "a country . . . without physicists or mathematicians, without ideas or ideologues, without libraries of science" (on 122). Wohl points out that *The Modern Theme* is a misleading translation, "since Ortega's central point is that the modern period is coming to an end and giving way to a new organization of thought and feeling" (on 138). On Spengler, science, and culture, see the landmark study by Forman, "Weimar Culture" (ref. 5).

45. M. Schlick, *Raum und Zeit in der gegenwärtigen Physik: Zur Einführung in das Verständnis der Relativitäts- und Gravitationstheorie* (Berlin: Springer, 1919), translated as *Teoría de la relatividad: Espacio y tiempo en la física actual* (Madrid, Calpe, 1921); Max Born, *Die Relativitätstheorie Einsteins und ihre physikalischen Grundlagen: Gemeinverständlich dargestellt* (Berlin: Springer, 1920), translated as *La teoría de la relatividad de Einstein y sus fundamentos físicos: exposición elemental* (Madrid: Calpe, 1922). On Morente and relativity, see Glick, *Einstein in*

Spengler's cultural pessimism also appealed to right-wing ideologues, who echoed it while replaying German debates on technology and culture.[46] This may be regarded as the intellectual counterpart to the personal relations discussed in the previous section, and the material connections to be discussed in the following section. The main venue for Spanish reactionary modernists was *Acción Española*, a major, well-funded anti-Republican publication whose patrons and authors eventually joined the Francoist establishment. In 1932, the journal carried a remarkable series of articles on "Physics and the Spirit" by one such ideologue, José Pemartín (1888–1956), a Parisian-trained engineer and member of the wealthy wine-making gentry of Jerez.[47] Pemartín argued that in the last decades of the nineteenth century sensational inventions such as the electric light and the telephone, together with theories such as evolution, had created "the superstition of Science." The anticlerical, bourgeois elites had knelt before science, the "naturalistic idol." This had allowed them to enjoy the wealth acquired by "exploiting the workers with industrial Taylorism and deceiving them with democratic liberalism." Pemartín shared in the German right's fascination with and horror of the United States and Russia. Technology was a fetish and a superstition too, if a lesser one, and he lectured at length on the error of reducing physics to technology, summoning mysticism to the rescue. Technology's fulfillment required "a proper spiritual action, in which the spirit gets infinitely concentrated and compressed, sticking into its own substance the sharp needle that penetrates to the synthesis of pure Science, the unspeakable joy of Art, the pure love of Mysticism."[48]

Spain, trans. Navarro-Brotóns, *Einstein y los españoles* (ref. 42), 189 and 240–42. Morente's appendices to Schlick's booklet show his command of mathematical physics.

46. On the relationship between *Technik* and *Kultur*, see J. Herf, *Reactionary Modernism: Technology, Culture, and Politics in Weimar and the Third Reich* (Cambridge: Cambridge University Press, 1986).

47. See Raul Morodo, *Los orígenes ideológicos del franquismo:* Acción Española (Madrid: Alianza, 1985). According to Morodo, Pemartín was "the most characteristic and radical ideologist and theorist of Primo de Rivera's dictatorship [1923–1930]" (on 31). His brother, Julián Pemartín (1901–1966), was a prominent Falangist author. After the Civil War Pemartín directed the Instituto Nacional del Libro and wrote scripts for epic, propagandistic films.

48. José Pemartín, "La física y el espíritu (I)," *Acción Española* 3, no. 18 (1932): 595–604; "La física y el espíritu (II)," *Acción Española* 4, no. 19 (1932): 27–37; "La física y el espíritu (III)," *Acción Española* 4, no. 20 (1933): 131–46; "La física y el espíritu (IV)," *Acción Española* 4, no. 21 (1933): 248–56; "La física y el espíritu (V)," *Acción Española* 4, no. 22 (1933): 347–56; "La física y el espíritu (VI)," *Acción Española* 4, no. 23 (1933): 449–58. Quotes from "La física y el espíritu (II)," 34: "Se nos quiere . . . agobiar . . . con esa superstición de la técnica que es el último fetiche de la barbarie

Given the relation of physics to modern technology, only the spirit could stop it from being reduced to mechanism and positivism. Like Ulrich Wendt in *Die Technik als Kulturmacht* (1906), yet substituting physics for technology, Pemartín argued that physics should become more, rather than less, spiritual; like Eugen Diesel in *Der Weg durch das Wirrsaal* (1926), Pemartín thought that "despiritualization" (Entgeistung) was the illness of the current era. The spiritualization of physics advocated by Pemartín did not entail the creation of an alternative form of physics, but rather, as we shall presently see, the embracement of indeterminism and acausality. Later, in a much-quoted speech to university students during the Civil War, a notorious psychiatrist denounced, in much the same terms, the dream of transplanting to Spain "laboratories, seminars and libraries with plated tubes and polished floors. Campus of Madrid, so modern and so devoid of spirit!"[49]

During the war Pemartín became Director of Secondary and Higher Education for the rebel Ministry of National Education and published a programmatic book on the foundations of Spanish fascism, *Qué es 'Lo Nuevo'... Consideraciones sobre el momento español presente,* described in 1939 by the Spanish Information Bureau in New York as Franco's *Mein Kampf.*[50] Pemartín encompassed "the Spanish present moment" within three axes: Idealist-Catholic, Historical-Providentialist, and Realist-Scientific.[51] This was a clear instance of the metaphysics of science and power that the regime was set to implement, a reincarnation of the early modern trinity of higher knowledge: religion, politics, and science.[52]

This cultural take on physics proved relevant after the Civil War, when Francoist policy makers sought to enlist physics in their totalitarian designs and physicists strove to adapt to the new order. According to its often-quoted

que avanza por el Oriente." See also Miguel García de la Herran, "Cultura y técnica," *Acción Española* 7, no. 41 (1933): 494–505.

49. Juan José López Ibor, *Discurso a los universitarios españoles* (Santander: Cultura Española, 1938), ch. I: "Se soñaba, con cierta estolidez, en un desfile de laboratorios, de seminarios y de bibliotecas con tubos de níquel y suelos charolados. ¡Ciudad Universitaria de Madrid, tan moderna y tan sin espíritu!"

50. *Franco's "Mein Kampf": The Fascist State in Rebel Spain* (New York: Spanish Information Bureau, 1939), quoted in Claret, *El atroz desmoche* (ref. 22), 46.

51. J. Pemartín, *Qué es 'Lo Nuevo'... Consideraciones sobre el momento español presente* (Santander: Cultura Española, 1938), on 30. During the war he also published *Introducción a una filosofía de lo temporal: doce lecciones sobre espacio, tiempo, causalidad* (Seville: Álvarez y Zambrano, 1937).

52. Alexei Kojevnikov, "Dialogues about Knowledge and Power in Totalitarian Political Culture," *HSPS* 30, no. 1 (1999): 227–47.

foundational decree, the CSIC aimed at "restoring the classical and Christian unity of the sciences, destroyed in the eighteenth century." To this end, the Spanish "universal and Catholic tradition" was to be combined with the demands of modernity. In an influential science policy manifesto, the all-powerful General Secretary of the CSIC, soil chemist and Opus Dei member José María Albareda (1902–1966), argued that science needed guidance, because scientists had disregarded their duties towards God and mankind, setting up an "atheistic pseudo-science."[53]

Albareda did not need to elaborate on this notion, because his readers were thoroughly familiar with it. This reactionary view of science built on previous attempts—dating back to the last decades of the nineteenth century and first deployed in relation to thermodynamics—to revive Thomist science. In 1877, professor of physics Bartolomé Feliú had already subscribed to a Thomistic science and warned against the rising social authority of natural science. His remarks fit into a broader attempt to neutralize the menace posed by a materialistic and atheistic science, as reflected upon in Pope Leon XIII's encyclical *Aeterni Patris* (1879) and discussed most recently for the Spanish case by Stefan Pohl.[54] Throughout the first decades of the twentieth century, and as a reaction against liberal and socialist discourses that associated religion with superstition and backwardness, conservative intellectuals urged like-minded individuals to "respond to science with science." Catholicism had to be reconciled with science if it was to remain in step with the modern world.[55]

Otero provides a prime example of the kind of paradoxes a Catholic physicist faced in Franco's Spain. According to his hagiographer, he was "severely critical of the modern world that surrounded Franco's Catholic Spain [and] perfectly deciphered the origin of the 'mechanical age' and the 'apostate, paganized society' that surrounded and harassed it."[56] Fortunately physics

53. Malet, "Albareda" (ref. 11), 320.

54. Stefan Pohl-Valero, "The Circulation of Energy: Thermodynamics, National Culture and Social Progress in Spain, 1868–1890," in *Popularizing Science and Technology in the European Periphery, 1800–2000*, ed. F. Papanelopoulou, Agustí Nieto-Galan, and Enrique Perdiguero (Aldershot, UK: Ashgate, 2005), 115–34; the extended argument is to be found in S. Pohl-Valero, *Energía y cultura: Historia de la termodinámica en la España de la segunda mitad del siglo XIX* (Bogotá: Editorial Pontificia Universidad Javeriana, Editorial Universidad del Rosario, 2011); Harry W. Paul, *The Edge of Contingency: French Catholic Reaction to Scientific Change from Darwin to Duhem* (Gainesville: University Press of Florida, 1979).

55. Herran, "'Glory of God'" (ref. 41).

56. de Andrés, *José María Otero* (ref. 32), 21: "Otero fue severamente crítico con el mundo moderno que rodeaba por entonces a la España católica de Franco . . . . Descifró perfectamente el

itself, which had contributed to the mystification of materialism and mechanism, now provided a way out of these dilemmas. The demise of classical physics had made the scientist more humble:

> Gone forever are the times when Science was drawn apart from Religion, an epoch that culminated at the turn of the century, when a Physics imbued with a mechanical philosophy believed that the discovery of natural laws made superfluous the existence of a Divine Being . . . . Today Science more than anything else brings us nearer to God. Thus, while in the last century the vanity of their discoveries led scientists to atheism, today, on the contrary, few among the leading figures of Universal Science are nonbelievers.

In revealing the limits of human understanding, quantum mechanics eased the integration of physics into the "scheme of creation."[57]

Spengler's translator exemplifies the ascendancy of these views immediately after the war. In 1940, García Morente was ordained and began preaching the essential compatibility between science and faith, portraying Saint Thomas as "the most modern philosopher of our generation." Physical science, he argued, was not able to cope with spiritual and metaphysical beings, "and when it has tried to administer them, as it has since the nineteenth century, it has reached monstrous conclusions."[58] According to a young physicist-philosopher, recent scientific progress showed "the expiration of certain philosophies and the enormous explicative potential of scholastic philosophy, formerly despised in the name of science." It was "the revenge of truth."[59] A rising geophysicist

origen de la 'era mecanicista' y la 'sociedad en buena part apóstata y paganizada' que les rodeaba y acosaba."

57. J. M. Otero, "Universitarias católicas cultivadoras de las ciencias" (1948), quoted in de Andrés, *José María Otero* (ref. 32), 22: "Se han ido para siempre los tiempos en que se pretendía que la Ciencia se separara de la Religión, época que tenía su ápice en el cambio de siglo, cuando la Física imbuida de una filosofía mecanicista, creía que con el descubrimiento de las leyes que rigen los fenómenos naturales era superfluo un Ser Divino que ordenase y hubiese fijado de antemano todas estas leyes que, en su armonía, no son sino el reflejo de la Sabiduría Divina . . . . Hoy, la Ciencia más que nada nos acerca a Dios y, así, ocurre que, mientras en el siglo pasado abundaban los científicos que la soberbia de sus descubrimientos les había llevado al ateísmo, hoy, por el contrario, son raras la figuras cumbres del la Ciencia Universal no creyentes."

58. Manuel García Morente, "La razón y la fe en Santo Tomás de Aquino" (Valladolid: Universidad de Valladolid, 1940), and "El espíritu científico y la fe religiosa" (lecture in Pamplona, 12 Oct 1941, published in *El Pensamiento Navarro* between 14 and 23 Oct 1941), in M. García Morente, *Obras Completas. II (1937–1942)*, vol. 2 (Madrid/Barcelona: Fundación Caja de Madrid/Anthropos, 1996), on 71 and 184, resp.

59. Raimundo Pániker, "El indeterminismo científico," *Anales de Física y Química* 41 (1945): 573–605, on 575: "Una de las mayores lecciones de los progresos científicos consiste en mostrar la

wrote in 1941 an account of the *Relation between Days of the Genesis, Geological Age, and Years*, the first publication of the CSIC's National Institute of Geophysics (Instituto Nacional de Geofísica) after the war.[60] And the philosopher Xavier Zubiri (1898–1983), who had met García Morente in Ortega's *tertulias*, published *Nature, History, God* in 1944, a collection of essays that included "The Idea of Nature: The New Physics." In this paper Zubiri reflected on "the fundamental problem" of contemporary physical science, uncertainty or indetermination, and reveled in the constraints it set upon science's claims to truth:

> The fact that this physics is provisional is not a reproach, but a eulogy. A science which finds itself in the situation of being unable to advance without going back and revamping its principles, is a science which *lives* from them at every moment. It is a science that is alive, and not simply an occupation. That is, it is science with *spirit*. And when a science lives, i.e. it has spirit, the scientist and the philosopher meet in it, as we have seen, because philosophy is nothing but intellectual life and spirit.[61]

These views were impressed upon the scientists and engineers who came of age after the Civil War. Students of electrical engineering at the Catholic Institute of Industrial Arts in Madrid faced exam questions such as "to prove theologically that God's existence can be demonstrated through the light of reason," and were asked to discuss the meaning of acausality in John von Neumann's *Mathematische Grundlagen der Quantenmechanik* (1932), translated into

caducidad de algunas filosofías, y la enorme potencialidad explicativa de la filosofía escolástica, despreciada precisamente en otro tiempo en nombre mismo de la ciencia. Es la venganza de la verdad." Pániker's "Filosofía cristiana: El concepto de la Naturaleza" (PhD dissertation, University of Madrid, 1946) was published by the CSIC in Madrid in 1951. The final destination of this sweeping review of the concept of "nature" was modern physics and Christian culture (*Sumarios y extractos de las Tesis Doctorales leídas desde 1940 a 1950 en las secciones de Filosofía y Pedagogía, Facultad de Filosofía y Letras*, Universidad de Madrid, on 71–74.

60. J. M. López de Azcona and J. Leal Luna, *Relación entre días del Génesis, edad geológica y años* (Madrid: Instituto Nacional de Geofísica, 1941).

61. X. Zubiri, *Naturaleza, Historia, Dios*, 6th ed. (Madrid: Editora Nacional, 1974), 303: "El que esta física sea provisional no es un reproche, sino un elogio. Una ciencia que se halla en la situación de no poder avanzar, sin tener que retrotraerse a sus principios, es una ciencia que *vive* en todo instante de ellos. Es ciencia viva, y no simplemente oficio. Esto es, es ciencia con *espíritu.* Y cuando una ciencia vive, es decir, tiene espíritu, se encuentran en ella, ya lo hemos visto, el científico y el filósofo. Como que filosofía no es sino espíritu, vida intelectual"; translated by Thomas B. Fowler, Jr., as *Nature, History, God* (Washington, DC: University Press of America, 1981), on 267. See Francisco González de Posada, *La física del siglo XX en la metafísica de Zubiri* (Madrid: Instituto de España, 2001).

Spanish by Ramón Ortiz Fornaguera, a disciple of Terradas.[62] In 1956, a plenary speaker at the National Ignatian Conference denounced the obfuscation of modern technology and the blind faith in scientific progress. He rejected dialectic materialism and the mechanical view of the universe, for they had dissolved ethical questions on the relation between men and society into a "social mysticism." The solution to these maladies lay in scientific humanism:

> There is, fortunately, a third point of view, that represented by the perennial healthy philosophy, and one even more broad and sure, that represented by the Christian conception of the world . . . . The creation of a true scientific humanism will only be achieved through the integration of science in the Christian scheme of the world, in the same way as Saint Ignatius integrated Renaissance humanism in the Christian order.

These were not the words of a radical ideologue or a political agitator, but those of a leading Spanish nuclear physicist, here rehearsing reactionary modernist themes in an address on "The Creation of a True Scientific Humanism" almost two decades after the end of the war (1956).[63]

Physicists such as Otero and Sánchez del Río appear to have actively contributed to the development and spread of spiritual physics. Following the approach advocated by Pemartín before the Civil War, they took indeterminism and acausality as epistemological limitations that justified religious guidance, relativity being occasionally summoned: "Through its findings on the ultimate facts and the physical laws of relativity and indetermination . . . the new Physics has left the door open to God." Julio Palacios's anti-relativistic stance may be considered, in this context, as an exception.[64]

62. "Ingenieros: Exámenes trimestrales de diciembre de 1949: Religión," in R. Ortiz Fornaguera's copy of John von Neumann, *Fundamentos Matemáticos de la Mecánica Cuántica* (Madrid: CSIC, 1949). See Marià Baig, Gonzalo Gimeno, and Mercè Xipell, "Von Neumann traducido por Ortiz: una obra pionera en la enseñanza de la cuántica," in Herran and Roqué, *La física en la dictadura* (ref. 36), 177–92. We thank Gonzalo Gimeno and Mercè Xipell for pointing our attention to this examination.

63. Carlos Sánchez del Río, "Creación de un verdadero humanismo científico," in Sánchez del Río, *Escritos varios* (ref. 7): "mística social" (on 131); "afortunadamente, todavía queda un tercer punto de vista, el representado por la filosofía sana perenne, y más amplio y seguro todavía el representado por la concepción cristiana del mundo y del hombre que lo asume y completa . . . . La creación de un verdadero humanismo científico sólo podrá llevarse a cabo por medio de la integración de las actividades científicas dentro de un esquema cristiano del mundo, de un modo paralelo a la integración del humanismo renacentista dentro del orden cristiano llevado a cabo por San Ignacio" (on 132).

64. José María Pemán, "Caminos de conversión," *La Vanguardia Española*, 9 May 1950: "Por sus hallazgos en el fondo último de los hechos y las leyes físicas de la relatividad y la indeter-

SEIZING THE INSTITUTIONS: AUTARKIC PHYSICS

In much the same way that the regime worked with physicists to mold the community and realign the discipline, it also took over the institutions of science, from universities to research laboratories to professional societies, endowing them with new political meanings. As the main scientific institution in Francoist Spain, the CSIC has long been recognized as both an instrument of the regime's policies and a key component of such policies. We have already referred to the ideology that informed the Council's "defense of God and Hispanic culture" and to its relevance for physics. Equally important was the promotion of "research for the development and independence of the national economy" in the CSIC's charter, which included new research and development institutions devoted to aeronautics, optics, and the nuclear sciences.[65] Together with the Council's institutes, these provided the institutional setting for *autarkic physics*, the form of physics that prevailed in Spain between the end of the war and the mid-1960s. We propose this label for three reasons. Physics throughout this period was most obviously autarkic because it was tuned to the development of technologies fostering the economic self-sufficiency of the state. It was autarkic too, because physicists engaged in the process of state building. And finally, it was autarkic in the sense of self-rule, because national norms of excellence and cultures of research prevailed over international ones, as reflected in publication patterns and scientific careers. The fact that economic autarky was never attained does not detract from our argument but rather supports it, because the notion of autarkic physics also needs to be presented in a nuanced manner. Moreover, the long-term failure of autarky as an economic policy does not preclude it from playing a role in the historical dynamics of the processes of regime building: "The

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minación,[la nueva Física] ha dejado la puerta abierta a Dios." On Palacios and relativity, see Soler Ferran, "Teoría de la relatividad" (ref. 42), esp. 273–391; cf. Glick, *Einstein in Spain*, trans. Navarro-Brotóns, *Einstein y los españoles* (ref. 42), 296–97.

65. Luis Sanz Menéndez and Santiago López García, "Continuidad y cambio en las políticas de ciencia y tecnología durante la autarquía y los inicios del desarrollismo," *Quaderns d'Història de l'Enginyeria* 2 (1997): 70–98, on 80. See also Santiago López García, "El saber tecnológico en la política industrial del primer franquismo" (PhD dissertation, Universidad Complutense de Madrid, 1994), esp. chs. 3–4; Sanz Menéndez, *Estado, ciencia y tecnología* (ref. 6), ch. 4. On the history of the CSIC, see Puig-Samper, ed., *Tiempos de investigación* (ref. 6), Malet, "Albareda" (ref. 11), and Canales, "La política científica" (ref. 31).

fact that internal self-sufficiency can never be complete is no reason to underemphasize autarky."[66]

Immediately after the war, the JAE laboratories were incorporated into the Council. In 1940 the INFQ was split into a physics institute (Instituto Alonso de Santa Cruz) and a chemistry institute (Institute Alonso Barba), named, respectively, after an astronomer and a metallurgist of the Spanish Golden Age. They were both under the direction of the aging and retired, yet ideologically safe professor of pharmacy, José Casares Gil (1866–1961), a member of the new Governing Body of the University of Madrid.[67] While the INFQ had been organized into five sections (electricity and magnetism, X-rays, spectroscopy, physical chemistry, and electrochemistry), the new Institute of Physics was organized into three: optics (under Otero Navascués), X-rays (directed by Palacios), and electricity. In 1946, the optics section became an independent institute, the Instituto Daza de Valdés, which was also named after a natural philosopher of Imperial Spain.

By 1949, the CSIC had seven institutes related to physics, and a National Council of Physics (Consejo Nacional de Física) was established to coordinate their activities.[68] Some of them belonged to the Department of Applied Research the most important of the CSIC's five departments. It secured more than half the staff and resources of the Council in the 1940s, and it had close ties with the National Institute of Industry (Instituto Nacional de Industria, INI, established 1941), the major tool of autarkic policy. In 1947, the Applied Physics Commission of the Department of Applied Research issued a report recommending work in three basic areas: nuclear physics, electronics, and

66. Saraiva and Wise, "Autarky/Autarchy" (ref. 4), 424. On the constraints on Spanish autarkic policy and the continuity of international exchange, see Fernando Guirao, *Spain and the Reconstruction of Western Europe, 1945–1957: Challenge and Response* (London: Macmillan/St. Martin's Press, 1998). See also Aitor Anduaga, "Autarchy, Ideology, and Technology Transfer in the Spanish Oil Industry, 1939–1960," *Comparative Technology Transfer and Society* 7, no. 2 (2009): 172–200; María Jesús Santesmases, *Antibióticos en la autarquía: Banca privada, industria farmacéutica, investigación científica y cultura liberal en España, 1940–1960* (Madrid: Fundación Empresa Pública, 1999); David Edgerton, *The Shock of the Old: Technology and Global History since 1900* (Oxford: Oxford University Press, 2006), esp. ch. 5, "Nations;" and Camprubí, "Political Engineering" (ref. 11).

67. Claret, *El atroz desmoche* (ref. 22), 297.

68. By 1955, its members were José M. Otero and Leonardo Villena (Institute of Optics "Daza Valdés"), José Baltá (Institute of Physics "Alonso de Santa Cruz"), Armando Durán (Institute of Mechanics "Torres Quevedo"), Francisco Morán (National Institute of Geophysics), Octavio R. Foz (Institute of Physical Chemistry "A. G. Rocasolano"), Manuel Espinosa (National Institute of Electronics), and José García Santesmases (Institute of Electricity).

self-propelled projectiles.[69] Beyond such topics of major industrial and military interest, research also concerned the design of optical instruments, the measurement of physiological optical constants, the spectroscopic study of rare earth elements, the crystallographic analysis of metals, and the determination of electric proprieties of materials, such as ferro-resonance, which seemed relevant for the designing of electronic circuits.

Physicists do not appear to have flocked to the CSIC: in 1940–1955, they amounted to two percent of the staff, compared with chemists at forty-two percent.[70] Yet these often-quoted figures may be misleading, because research institutions not related to the CSIC were created in strategic areas linked to the physical sciences. We have already referred to the INTA, established in 1942 as a department of the Spanish Ministry of the Air Force with the aim of supporting a national aeronautical industry through research on material sciences and fluid dynamics. From 1944, the Navy's Research Laboratory and Workshop (Laboratorio y Taller de lnvestigaciones del Estado Mayor de la Armada) did research in optics under Otero's direction, providing optical glass and developing military equipment under Zeiss's license, which would later be manufactured by the public company ENOSA (Empresa Nacional de Óptica). These institutes were directed by a close-knit elite of high-ranking officers and navy engineers, including Juan Vigón Suerodíaz (1880–1955), Franco's head of general staff and Minister of the Air Force; Juan Antonio Suanzes (1891–1977), a Navy engineer who headed the National Institute of Industry; and Luis Carrero Blanco (1904–1973), minister of Presidential Affairs (Presidencia del Gobierno). Like Otero, they had pre–Civil War experience in the direction of Army and Navy laboratories, and personal and professional ties with their German counterparts.[71] Combining substantial state funding and artifact-oriented research, these institutions meant Big Science to a totalitarian,

69. Romero and Sánchez Ron, *Energía nuclear en España* (ref. 6), 13.

70. Pedro González Blasco and José Jiménez Blanco, "La investigación en el Consejo Superior de Investigaciones Científicas: Estudio de un grupo significativo durante el período 1940–1955," in *Historia y sociología de la ciencia en España* (Madrid: Alianza, 1979), 126–62, on 155; cf. Malet, "Primeras décadas del CSIC" (ref. 11), 239–40. On the INFQ, see José Miguel Gamboa, *50 años de investigación en Física y Química en el edificio Rockefeller de Madrid, 1932–82* (Madrid: CSIC, 1982).

71. Albert Presas Puig, "Technological Transfer as a Political Weapon: Technological Relations between Germany and Spain from 1918 to the Early 1950s," *Journal of Modern European History* 6, no. 2 (2008): 218–36; Albert Presas, "La inmediata posguerra y la relación científica y técnica con Alemania," in Romero and Santesmases, *Cien años de política científica* (ref. 6), 173–209.

impoverished regime that hoped to take advantage of the Cold War, and bear witness to the ascendancy of the military in the configuration of the Spanish research and development system.[72]

As elsewhere, the nuclear sciences stood apart. Their promoters in Spain could easily argue that building an experimental nuclear reactor and securing uranium demanded investments "of the order of the great state expenses, such as the Army and the Navy, and to be judged according to the future importance of nuclear physics as applied to industry and economy."[73] In 1948 a company unimaginatively called Studies and Patents for Special Alloys (Estudios y Patentes de Aleaciones Especiales, EPALE), referred to in the confidential decree that incorporated it as the Board of Nuclear Investigations (Junta de Investigaciones Atómicas), began work on a national nuclear program, involving training and research, prospection and mining of uranium, and international exchanges.[74] This was the seed of the Nuclear Energy Board (JEN), established in 1951 within the Ministry of Industry. Between 1946 and 1951 the JEN received some 12 million pesetas. Considering that work only began in 1948, this was a substantial amount: in 1946, the CSIC's Department of Applied Research received some 16 million pesetas, which was about half the entire budget of the Council. By 1960 the JEN had become the single most important scientific institution in Spain.[75] According to figures provided by

72. Cf. David Edgerton, *Warfare State: Britain, 1920–1970* (Cambridge: Cambridge University Press, 2006); Paul Forman and José M. Sánchez Ron, eds., *National Military Establishments and the Advancement of Science and Technology* (Boston: Kluwer Academic Publishers, 1996), including Javier Ordóñez and José Manuel Sánchez Ron, "Nuclear Energy in Spain: From Hiroshima to the Sixties," 173–90.

73. Romero and Sánchez Ron, *Energía nuclear en España* (ref. 6), 25, citing an anonymous undated document in the Archivo de Presidencia del Gobierno: "del orden de los grandes gastos de un Estado, tales como los del Ejército y la Marina, y que deben juzgarse de acuerdo con la futura importancia de la física nuclear aplicada para la industria y la economía."

74. Staff and resources from the National Institute of Geophysics (Instituto Nacional de Geofísica), which absorbed the by-then derelict Instituto de Radioactividad de la Universidad de Madrid after the Civil War, joined in this effort. Between 1946 and 1952 the radioactivity section of the Institute of Geophysics multiplied its staff by five and accounted for more than half of the institute personnel. See Néstor Herran, *Aguas, semillas y radiaciones: El Laboratorio de Radioactividad de la Universidad de Madrid, 1904–1929* (Madrid: Consejo Superior de Investigaciones Científicas, 2008), 201; for an abridged argument in English see Néstor Herran, "Waters, Seeds and Radiation: Radioactivity Research in Early Twentieth-Century Spain," in *Beyond Borders: Fresh Perspectives in History of Science*, ed. Josep Simon-Castel and Néstor Herran (Newcastle, UK: Cambridge Scholars Publishing, 2008), 325–44.

75. Romero and Sánchez Ron, *Energía nuclear en España* (ref. 6), 41; López García, "Saber tecnológico" (ref. 65), 69.

the Spanish government in 1963, when the first comprehensive study was undertaken, the expenditure on research and development was 1,513.8 million pesetas, which was very unevenly distributed among basic research (164 million, 10.8%), applied research (719 million, 47.5%), and development (630.8 million, 41.7%). The distribution by scientific and economic sectors showed the importance accorded to Nuclear Energy, Biological and Agricultural Research, and Geology and Mining, which combined received 712 out of 1,194 million pesetas (two thirds of the total expenditure).[76]

Together with the replenishment of university chairs, these institutional developments help explain why productivity in physics, regardless of quality, did not decline but resumed growth soon after the Civil War. The *Anales de Física y Química*, the organ of the Spanish Society for Physics and Chemistry (established in 1903), remained the journal of choice for Spanish physicists well into the 1960s.[77] Valera Candel and López Fernández have made an exhaustive study of the journal and tracked changes in publication patterns through the period 1903–1965. The war did not change the proportion of physics papers in the journal, a steady twenty-five percent, but continuity did not extend to authors and subjects. Just two of the most prolific authors for the periods 1931–1937 and 1940–1949 (Palacios and Bru) kept publishing at the same rate, their work on crystallography providing "the one significant link between pre-war and post-war physics."[78] When data from *Anales* are crossed with the information provided by ISI's Web of Science, a stark contrast between publication patterns before and after the war is more readily apparent. Notwithstanding Palacios and Bru, five of the physicists listed in the period 1931–1937 (Cabrera, Catalán, Duperier, Velayos, and Julio Garrido) published a total of sixty-three papers in international journals; the corresponding figures for 1940–1949 are three physicists (Durán, Otero, and Leonardo Villena) and sixteen papers. The trend continued unchecked in the 1950s: Catalá's group in Valencia published fifty-seven papers in 1950–1958, but most of them appeared in the *Anales* and just two of them in international

76. 55th Meeting of the Finance Committee, 13 Nov 1963 (CERN-FC-639-Rev), 4.

77. As Yves Gingras points out regarding the physics papers published in national physics journals, "the vast majority, more than 90%, were published by national authors from 1900 to 1944." Gingras, "Transformation of Physics" (ref. 20), 244.

78. Manuel Valera Candel and Carlos López Fernández, *La física en España a través de los Anales de la Sociedad Española de Física y Química, 1903–1965* (Murcia: Servicio de Publicaciones de la Universidad de Murcia, 2001), 205, "Tabla 9: Comparación de los autores más prolíficos correspondientes a los periodos 1931–37 y 1940–49."

journals.[79] These results match the conclusions of A. Malet, who has described the inflationist publication policy of the CSIC and noted the existence of "autarkic authors," i.e., "highly productive authors . . . when it comes to publishing in Spanish journals or in Spanish, but who barely published or did not publish in international journals."[80]

The distribution according to subject also shows the impact of the Civil War. The fields most represented in the *Anales* before 1936 were magnetism, physical chemistry, electrochemistry, spectroscopy, and X-ray diffraction, closely matching the sections of the INFQ. Together with astronomy and meteorology, these fields fell sharply from 1940, as optics and nuclear physics rose to prominence. In 1940–1949, papers in optics (36.5%) outnumbered those in other fields, and by the mid-1960s nuclear physics (33.7%) had taken an easy lead (the aggregate totals for 1940–1965 are 25.4% and 16.1%, respectively). The rise of optics alongside the mighty nuclear sciences was "puzzling" to Valera Candel and López Fernández, but it is clear from what has been said that it need not be.[81] Together with disciplinary trends that applied to other countries, most apparently in nuclear matters, there were powerful local reasons for this balance of subfields, which was also reflected in the institutional layout of scientific research in Franco's Spain.

This layout extended to instruments and metrologies.[82] Before the war, the Republican government had launched initiatives in the domain of applied science such as the National Foundation for Scientific Research and Technical Essays (Fundación Nacional para Investigaciones Científicas y Ensayos de Reformas, established in 1931), which aimed to promote technological

79. Ceba, Navarro, and Velasco, "Orígenes" (ref. 36), 58.

80. Malet, "Primeras décadas del CSIC" (ref. 11), 241–46. M. J. Santesmases, "Neutralidades y atrasos" (ref. 12), 66, has also warned against giving much weight to the number of publications: "Si en las sesiones plenarias del CSIC presididas por Franco las publicaciones, como dijo el fisiólogo Antonio Gallego, 'se valoraban al peso', no parece pertinente hacer ahora lo mismo."

81. Valera Candel and López Fernández, *La física en España* (ref. 78), 255–364, "puzzling" on 266.

82. The work of A. Romero, S. López García, and L. Camprubí is essential here. See Ana Romero de Pablos, "Políticas e instrumentos: De la Junta para Ampliación de Estudios al Consejo Superior de Investigaciones Científicas," in Romero and Santesmases, *Cien años de política científica* (ref. 6), 107–39; Ana Romero de Pablos, "Educación, investigación e instrumentación científica en la España del primer tercio del siglo XX: La intervención del estado" (PhD dissertation, Universidad Autónoma de Madrid, 2000); Santiago López García, "Las ciencias aplicadas y las técnicas: La Fundación Nacional de Investigaciones Científicas y Ensayos de Reformas y el Patronato Juan de la Cierva del CSIC (1931–1961)," in Romero and Santesmases, *Cien año de política científica s* (ref. 6), 79–106; Camprubí, "Political Engineering" (ref. 11).

development together with social reform. In the physical sciences, however, research was oriented toward fundamental problems related to international research programs. The know-how acquired by physicists abroad, thanks to the JAE's fellowship program, often became the backbone of their research: Cabrera's work on magnetism and his commitment to Weiss's magneton as the natural unit of magnetism bear the imprint of his stay at Pierre Weiss's laboratory at the Swiss Federal Institute of Technology in Zurich, while Catalán's spectroscopical research was indebted to his stay at Alfred Fowler's laboratory at Imperial College London. Upon their return, the physicists readapted to an experimental "culture of scarcity" (Glick's term), meaning they either strove to get a piece of equipment to last them through their career (Catalán favored a purpose-made twenty-one-foot concave grating over a ready-made ten-foot one, even if the former took much longer to get), or changed subjects (back from Heike Kamerlingh Onnes's low-temperature physics laboratory in Leiden, Palacios switched to low-cost x-ray diffraction physics).[83] The JAE's Laboratory of Industrial Mechanics and Automatics (Laboratorio de Mecánica Industrial y Automática), established in 1911, alleviated the material poverty of Spanish laboratories by designing, adapting, producing, and certifying instruments. However, it could hardly be considered a national physical laboratory, and advanced equipment continued to be imported.[84]

After the Civil War, a Centre of Physical Metrology (Centro Metro-Físico) was created in 1954, yet the INTA unofficially acted as a national metrological laboratory.[85] Restriction on investments, together with the autarkic policy of privileging instruments produced in Spain, prevented the acquisition of advanced equipment. Autarkic physicists had to make do with Spanish instruments, and extant ones bear witness to the scarcity of material.[86] There were exceptions. Otero's Institute of Optics received the first electron microscope brought to Spain, a Radio Corporation of America EMU-2A that Franco

83. Glick, "Dictating to the Dictator" (ref. 19), 127. Examples are also drawn from Sánchez Ron, "International Relations" (ref. 16), esp. 7–9; and Sánchez Ron and Roca-Rosell, "Spain's First School" (ref. 19), 142.

84. M. Ángeles del Egido, *Instrumentos científicos para la enseñanza de la física* (Madrid: Museo Nacional de Ciencia y Tecnología, 2000); José Ramón Bertomeu Sánchez and Antonio García Belmar, *Abriendo las cajas negras* (Valencia: University of Valencia, 2002); Pedro Ruiz Castell, "Scientific Instruments for Education in Early Twentieth-Century Spain," *Annals of Science* 65, no. 4 (2008): 519–27.

85. Sánchez Ron, *INTA* (ref. 6), 64.

86. Romero, "Políticas e instrumentos" (ref. 82), 134: "Lo que sí transmiten estos instrumentos sólo observando los materiales utilizados es la pobreza de medios de los años de la posguerra."

himself inaugurated on January 31, 1948.[87] And there were also ambitious autochthonous technical developments that ultimately did not succeed, such as the project to build a Spanish digital computer, undertaken by José María Santesmases (1907–1989).[88] The strengthening of political and economic relations with the United States from 1953 facilitated imports and signaled a shift in these developments, as shown most clearly in the case of the JEN. The Board's original nuclear program included the mining and treatment of uranium, the design and construction of reactors, the training of nuclear engineers, and the establishment of facilities for the production of radioactive isotopes. Yet in order to acquire technological know-how, the JEN maintained extended international relations, with Italy and Germany first, and later with the United States, Britain, and France. The JEN's ambitious development program was ultimately limited to the role of adapting U.S. reactor technology provided by the U.S. Atoms for Peace program.[89]

On the other hand, breaking international isolation was a powerful stimulus for the physical sciences. The Spanish government established in 1945 a loan of 40 million pesetas to intensify foreign cultural exchanges. The CSIC played a central role in this strategy, receiving funding to provide research grants for study and work abroad—340 grants were allocated between 1945 and 1948, one third to the United States—and to invite foreign researchers to lecture in Spain—692 visits between 1944 and 1953.[90] The physical sciences were among the most privileged areas of the exchange programs, together with mathematics, chemistry, and medicine.

International conferences and institutional commemorations, such as the tenth anniversary of the CSIC in 1949, were important legitimating devices for the regime.[91] Electing prestigious scientists as corresponding members of scientific academies projected an image of institutional normality, and membership in foreign institutions was correspondingly prized.[92] International

87. The lack of technical skills, an inadequate location, and problems with components, much limited the uses of this instrument; see Terreu, "El CSIC durant l'autarquia" (ref. 35).

88. López García, "Saber tecnológico" (ref. 65), 321–32.

89. Albert Presas Puig, "Science on the Periphery—The Spanish Reception of Nuclear Energy: An Attempt at Modernity?" *Minerva* 43, no. 2 (2005): 197–218.

90. Lorenzo Delgado-Gómez-Escalonilla, "Dimensión internacional del CSIC," in Puig-Samper, ed., *Tiempos de investigación* (ref. 6), 269–77. The total budget allocated to universities at the time, including the salaries of the CSIC staff, was 71 million pesetas.

91. Malet, "Primeras décadas del CSIC" (ref. 11), 248.

92. F. Weidert, Otero's mentor during his stay in Germany, was elected honorary member of the Spanish Royal Society of Physics and Chemistry (Real Sociedad Española de Física y

legitimation and recognition, however, was achieved only insofar as Spanish interests matched the interests of such institutions. As a significant example, shortly after the end of the Civil War, the British Council resumed its activities in Spain, with "two main objectives—the maintenance and extension of contact with leading men in the intellectual, artistic, medical, scientific and technical fields (many of them men of international distinction) and the promotion of a wider understanding of British life among the great body of Spanish students and the Spanish middle class."[93] A report in March 1943 registered the ambivalent attitudes of both British officials and the Spanish scientists and physicians they contacted: "There seems to have been a great change of attitude to the British Cause since the advance of the 8th Army from Alamein," reported Robert A. McCance, Reader in Medicine at Cambridge. "The Spaniards have decided in their own (individual) minds that the Allies are likely to win the war and are making provision accordingly."[94] As the Allied victory materialized, Spain was isolated on account of its Axis sympathies, but these relations persisted: "It might in fact be said that the Council's work is nowhere of greater service to British interests than it is in the maintenance of friendly contact on a non-political level with countries whose political relations with our own are cool or even hostile."[95]

The Institut Français operated on similar terms. Beginning in 1946, successive *attachés scientifiques* to the French Embassy (Marie-Louise Josien, Marguerite Cordier, and above all Claude Colin) dynamized knowledge about physics at the Barcelona site of the Institut through a *cercle d'études* on science. Between 1955 and 1965 Colin lectured on quantum mechanics at the University of Barcelona, and he was chiefly responsible for the fact that in peak years nearly half the physics graduates of the University of Barcelona received grants

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Química, RSEFQ) in 1942, and from 1949 directed the department of Technical Optics at the Institute of Optics of the CSIC in Madrid; he was thus one of a number of German scientists and engineers who were hired by the Council in the aftermath of the war. Cf. Carson, *Heisenberg in the Atomic Age* (ref. 13), 226, n. 34, on the foreign connections of German nuclear scientists: "A Spanish invitation to visit in 1950 turned into a program of exchanges that raised some eyebrows . . . . One of the physicists at work in Göttingen was the daughter of the head of Franco's general staff [María Aranzazu Vigón]."

93. K. R. Johnstone, "The British Council: Report on a Visit to Spain and Portugal, 17 Nov – 22 Dec 1947," n.d., Royal Society Archives, HD/8/4/67, on 2.

94. R. A. McCance, "Visit to Iberian Peninsula, 1 Feb – Mar 1943," n.d., Royal Society Archives, HD/8/4/7, on 2.

95. K. R. Johnstone, "The British Council: Report on a Visit to Spain and Portugal, 17 Nov – 22 Dec 1947," n.d., Royal Society Archives, HD/8/4/67, on 2.

to pursue their studies in France.[96] This had the intended effect of enhancing French influence on the Spanish research system. Yet above all it was the Cold War that helped to end the ostracism of Franco's regime, as Spain became a strategic ally of the United States in Southern Europe.

CONCLUSION

We have sought to unveil the relation among physics, culture, and power in Spain during Francoism, especially in the first decades after the Civil War. Our interpretation of the rise of physics during the dictatorship eschews both wholesale condemnation and uncritical recognition, seeking rather to locate the discipline and its practitioners within the Francoist political economy and political order. We have described three important ways in which physics and the regime helped each other through this period: molding the community, aligning the discipline, and seizing the institutions. Some of the elements in our account, including the assault on university chairs, the impact of purges and exile, and the priority of applied research, have more readily been recognized. Yet we have incorporated them into a broader picture, alongside neglected or overlooked aspects such as the chances afforded by purging, the ideological justification of the pursuit of modern physics, and the way an autarkic scientific community prized international exchanges. We expect our argument to be extended, but we think it will no longer be possible to assume that the physicists remained aloof, or that the discipline was unaffected throughout the dictatorship.

We have characterized the scientific mode of production typical of post-Civil War Spain as "autarkic," a salient term in Spanish historiography that was also a category frequently used by the relevant historical actors. The notion is also intended to make our story sensitive to current understandings of totalitarian science, with which it shares relevant features: the preeminence of hierarchical chains of decision making, the appropriation of ideological arguments to advance and further careers, or the emphasis on the utility of science for economic (and "moral") development. The Spanish case, however, shows interesting specificities, derived from the explicitly religious predicament of the regime's ideology, National Catholicism. The clerical, reactionary support for

96. Alfonso Carpio, *Ciència i política exterior francesa a l'Espanya de Franco: El cas dels físics catalans* (Barcelona: Institut d'Estudis Catalans, 2010).

contemporary physics by a totalitarian regime in the Cold War years provides an intriguing departure from the existing literature. The effect of autarkic science on the practice of physics nevertheless remains to be assessed. One of us has elsewhere argued that, beyond the lack of political will and the economic burden that are usually blamed for Spain's withdrawal from CERN in 1968 (it had joined the organization in 1961, and would reenter in 1983), there were "failures of communication" between CERN and Spain, which reflect the research outlook of scientists and policy makers such as Otero, Sánchez del Río, and Catalá. The failure of Spain's first involvement at CERN may have been a failure of autarkic physics.[97]

This form of physics waned through the 1960s, along with the scientists and policy makers who had held leadership roles since the end of the war. Albareda died in 1966, the same year that Otero's National Council of Physics was dismantled. Palacios died in 1970, but his influence had long been diminished due to his anti-relativistic stance, which found no audience.[98] "The force of the modernizing military" at the CSIC had steadily weakened from the mid-1950s.[99] The creation of new state agencies for research, following the Organization for Economic Co-operation and Development (OECD) recommendations, and the growth of the university system, allowed a new generation of university lecturers to challenge the hegemony of the CSIC, exposing the conflation between research and the Council. In 1968 CSIC officials still assumed that the Royal Society's Exchange Programme with Spain "was intended for scientists from the CSIC exclusively and did not include those at the university who were not connected with the CSIC."[100] By the early 1970s, however, university scientists were providing more than half of the papers in the *Anales de Física y Química*, up from a mere ten percent two decades before.[101] Demography partly accounts for these changes. According to the 1982 survey, there were about a thousand research physicists in Spain, or 26.8 physicists per million of population. In absolute terms, the physicist population had grown forty-fold from 1900, or twenty-fold in terms of physicists per

97. S. A. Dakin to Otero, 3 Oct 1962 (CERN archives, DIR-ADM-PERS-02), quoted in X. Roqué, "España en el CERN (1961–1969), o el fracaso de la física autárquica," in Herran and Roqué, eds., *La física en la dictadura* (ref. 36), 239–58.

98. Soler-Ferran, "Teoría de la relatividad" (ref. 42), 29.

99. Sanz Menéndez and López García, "Continuidad y cambio" (ref. 65), on 80.

100. Robert T. Taylor (Science Officer of the British Council in Spain) to H. W. Thompson, 20 Feb 1968, Royal Society Archives, HWT/20/32.

101. Valera Candel and López Fernández, *La física en España* (ref. 78), 263.

million of population.[102] Of these, seventy percent worked in universities, seventeen percent at the CSIC, eleven percent at other public organizations, and a mere one percent in industry.[103]

The assessment of physics during Francoism, like so many issues in contemporary Spanish history, is contested. The new physics that began to take shape in the last years of the regime was in many ways the reverse of autarkic physics. Publishing in international journals became the norm, rather than the exception; international collaboration increasingly reflected shared practices; and pure physics was prized over immediate practical application to the extent that, by the 1990s, claims for strengthening the links between university and industry were often accompanied by the related historical claim that these links had never been strong in Spain. Autarkic physics receded further, and with it the memory of the intensely ideological, applied, militarized form of physics that had prevailed in the aftermath of the Civil War.

ACKNOWLEDGMENTS

We acknowledge the support of the Spanish Ministry of Science and Innovation through the following research projects: "Bases para una historia de la física en España en el siglo XX" (HAR2008-05039/HIST) and "Física, cultura y política en España" (HAR2011-27308); Néstor Herran has also received support from the 7th Framework Programme of the European Commission (PIEF-GA-2009-235012). We acknowledge permission of the Royal Society Archives, London, and the CERN Archives, Geneva (Switzerland), to quote from their archives. We thank Alexei Kojevnikov, Mark Walker, and one anonymous referee for their comments and suggestions. Simon Schaffer provided essential support and key insights during X. Roqué's sabbatical at Cambridge. This paper has long been in the making and we have benefitted from discussion with several audiences, at the universities of Strasbourg (conference

102. In 1901 there were thirteen physics professors at Spanish universities and about the same number of assistants, or 1.4 physicists per million of population. See Ministerio de Instrucción Pública y Bellas Artes, *Escalafón de antigüedad de los catedráticos numerarios de las Universidades del Reino en 1° de enero de 1902* (Toledo: Sección de Estadística del MIPBA, 1902); we have estimated the number of assistants from the "Escalafón de Profesores Auxiliares de Universidad," *La Gaceta de Madrid*, 14 Apr 1908, which includes sixteen PhDs in Physics, Physics and Chemistry, and Physics and Mathematics, plus five graduates working as assistants (*auxiliares*) at Science Schools. The Spanish population in 1900 was 18.6 million (Juan Pablo Fusi, "España, variable europea," in *Historia de España*, vol. 11 of *España y Europa,* ed. Josep Fontana and Ramón Villares [Barcelona: Crítica; Madrid: Marcial Pons, 2008], 3–171, on 55).

103. Segovia et al., "State of Physics" (ref. 2), 169.

"'Writing the history' of the Physical sciences after 1945: state of the art, questions, and perspectives," June 7, 2007); Budapest (XXIII International Congress of History of Science and Technology, Budapest, July 28–August 2, 2009); Barcelona (4th International Conference of the European Society for the History of Science, November 19, 2010); Manchester (departmental seminar, Centre for the History of Science, Technology and Medicine, March 8, 2011; Exeter (British Society for the History of Science Annual Conference, July 17, 2011); and Cambridge (departmental seminar, Department of History and Philosophy of Science, October 27, 2011). We also thank the participants in the workshop "La física en España en el siglo XX: balance y perspectivas" (Barcelona, December 1-2, 2011).