

Muslim Science as the Source of the Portuguese Age of Discoveries

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**Joseph Abraham Levi,**  
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**Abstract:** In his article "Muslim Science as the Source of the Portuguese Age of Discoveries" Joseph Abraham Levi analyses the Jewish, mostly Sephardic, and Islamic contributions to science and their legacy in Iberia, particularly present-day Portugal. Using as a springboard the countless contributions to the sciences brought by Muslims to the Iberian Peninsula, southern France (mainly Provence), Sardinia, Sicily, and the rest of southern Italy, as well as other parts of the Mediterranean, Levi concentrates on the key role that Muslim scholars had, oftentimes assisted by their Sephardic Jewish counterparts, in training the scientific researchers of the then-burgeoning young Portuguese nation, thus opening the door to the Portuguese Age of Discoveries and Expansion Overseas, as well as paving the way to the modern era.

## Joseph Abraham LEVI

### Muslim Science as the Source of the Portuguese Age of Discoveries

The contributions to the sciences brought by Muslims to areas of the world once part of or heavily influenced by the Islamic empire of the West, that is, the Iberian Peninsula — present-day Portugal and Spain — southern France (mainly Provence), Sardinia, Sicily, and the rest of southern Italy, as well as other parts of the Mediterranean were countless. In a sense, Islam was the door through which Europeans were able to gradually emerge from the deep cloud of ignorance of the middle ages and venture out into a different world, one that would propel them into the modern age. As a whole, the millennium that goes from the fall of the Western Roman Empire to the Renaissance was a revival of classical art, architecture, literature, science, and learning which eventually marked the transition from medieval to modern times. Of all places in Europe, this gradual but active social ferment originated in Italy during the fourteenth century. Also in Italy, the presence of Jewish and Muslim scholars and of their works was instrumental for the passage from the medieval to the modern eras. Yet, given that Italy was not a unified nation with a royal crown functioning as a catalyst when it came to matters like science and technology, it could not function as a country with expansionist goals. For instance, rulers and citizens of the Maritime republics — e.g., Venice (697-1797), Amalfi (958-1037), Genoa (1005-1815), Pisa (11th century-1406), and Ancona (774-1532) — acted on their own, on behalf of their respective city-state/republic, and/or at the service of other nations, as in the case of Portugal, one of the first unified countries in Europe and a nation that, because of its small size and relative small population (a little over one million people at the time), had a considerable Jewish and Muslim presence.

Iberian Muslim and Jewish scholars were to play a key role in training the scientific researchers of the then-burgeoning young Portuguese nation (1143), thus opening the door to the Portuguese Age of Discoveries and Expansion Overseas (1415), as well as to the modern era (1453-1789). Although the Portuguese Age of Discoveries officially began in 1415 with the seizure of Ceuta (1415-1640), the first Portuguese enclave in Africa, Portuguese navigators, with the aid of Genoese and Pisan sailors, actually began exploring the seas towards the end of the twelfth century of the common era. It is no surprise then, that "it was the small kingdom of Portugal that was the first power to harness Europe's advances in cartography, navigation, finance, and shipbuilding and launch the Age of Discovery" (Ames 24). By 1460, "Portugal was poised to build on an already impressive record of discovery it had achieved along the west coast of Africa" (Ames 24). Almost forty years later, in 1498 the Portuguese conquered the Cape of Storms, soon renamed Cape of Good Hope and reached Goa in the same year. In 1517 the Portuguese had their first recorded encounter with the Hong Kong and Macau area. During three centuries Portuguese presence in Africa, Asia, and the Americas was a key factor in the establishing trade links among peoples and nations.

Following Muhammad's death in 632, the *Khulafā' al-Rashīdūna*, or rather, four rightly-guided caliphs (632-661), were chosen among the close companions of the Prophet to lead the newly born religion, Islam, and community of believers (*ummah*). Islam was able to spread and conquer militarily the entire Arabian Peninsula, Southern Mesopotamia, Palestine, Syria, the Sassanid Empire, Jerusalem, Egypt, parts of Libya, and Cyprus, as well as it challenged the Byzantine Empire and its possessions along the Mediterranean, particularly the Arab army of the Byzantine emperor Heraclius (610-641). Although obviously engaged in the political expansion of Islam within and outside the Arabian Peninsula, the first four caliphs were still spiritual leaders; hence, their epithet "Rightly-Guided" in contrast with the subsequent Islamic dynasties and empires more centered on the secular aspect of Islam. In fact, it was during the reign of the third caliph 'Uthmān (644-656) that the Qur'ān was finally organized in its final form (650), followed by the 700 edition of Caliph 'Abd al-Mālik (685-ca. 705) of the 'Umayyad Dynasty (661-750). During the 'Umayyad Dynasty Islam reached the West (*al-Garb*), that is, the Maghreb, the Iberian Peninsula (*al-Andalus*) (711), southern France (defeated by Charles Martel in 732), Central Asia, and the Indian sub-continent to the Indus Valley. Although not occupying Asia Minor, Muslims carried out frequent raids to the area (for example, the 670-677 and the 717-718 sieges of Constantinople). In 711, Islam also reached *al-Sind* (India), the bulk of its presence being mainly composed of Muslim, mercantile colonies and it was not until 1190, with the

establishment of the Sultanate of Delhi (1210-1526), that Islam became dominant in the Indian sub-continent and adjacent areas. The 'Umayyad Dynasty adopted a military and political expansion strategy: since conversion to Islam would have reduced the state's coffers given that taxes levied on non-Muslims were obviously higher. Arab descendants of one of Muhammad's uncles, al-Abbās, at the Battle of the Great Zab (750), defeated and killed the last 'Umayyad Caliph, Marwān II (744-750), thus ending the 'Umayyad Dynasty. After more than a century of political conquest the Arabization/Islamization of the Middle East and Central Asia began. Being overextended, the 'Umayyads could thus not rely solely on Arab soldiers and hence the need to enlist other ethnic groups — Muslim, semi-Islamized, or otherwise religiously affiliated. Non-Muslims subjects paid the *jizyah* (tax) and in return Muslim rulers did not interfere with their religious and secular customs provided they were not in contrast with the monotheistic faith of Islam. Gradually, however, conversions to Islam of non-Arab increased and the Arabic aristocracy, tracing an alleged direct link with the Prophet Muhammad, began mixing with other ethnic groups who, although not Arabic, were Muslim nevertheless, as in the case of Berber, Persian, and Turkic peoples.

With the 'Abbāsīd dynasty (749-1258), Persian influences were prevailing, later added by Turkic presence. The caliph was now an absolute sovereign and the vizier (*wazīr*), originally a personal aide to the caliph, became the chief deputy, minister, and adviser acting on behalf of the caliph militarily, as well as in other civil matters. The capital of the Islamic empire was also moved from Damascus to Baghdad and thus the axis of the Muslim world moved from the Mediterranean to the East: Central Asia, India, China, and Southeast Asia. The new Islamic capital was thus central to most of the west and the Asian empire, as well as Mesopotamia. Thus, the first two centuries of 'Abbāsīd rule were characterized by a great cultural and scientific growth. The practice of hiring mercenaries and armies from peripheral regions, mainly of Turkic origin, eventually proved fatal to the 'Abbāsīds, as in the case of the Aghālibs, Būyids, and Tūlūnids. The Islamic empire of the 'Abbāsīds eventually fell when the Mongols invaded Baghdad in 1258.

In the Muslim world, as well as elsewhere, Islamic Iberia was then known as *al-Andalus* (711-1492). There is much controversy over the origin of the Arabic word *Andalus*, given that not all scholars are happy with the idea that it came from *Wandalusiyyah*, a Berber corruption of the expression "Land of the Vandals," the latter being one of the Germanic tribes that in 409 invaded the Iberian Peninsula. In modern, standard Arabic the word for Vandals is *al-Wandalu*. As for its synonym, *Isbāniyāh*, it is a clear calque from the Latin *Hispania*, in itself a calque from the Phoenician quadrilateral root HSPM (*Hispamia*), which meant "land of rabbits." These are the terms used to denote the Iberian Peninsula during the Muslim occupation, as well as present-day Spain. Whereas *Burtuqāl* was used and is used today to denote Portugal and the city of Porto, since the latter country became an independent nation in 1139, although only in 1249 were the Portuguese able to "reconquer" the southernmost region of the country, known as the Algarve, until then still in Muslim hands. The first name of the future, independent nation of Portugal was *Condado de Portu Cale*, that is, County of Porto (formed in 1093; independent in 1139; recognized as a sovereign nation in 1143).

In 755, an exiled 'Umayyad, 'Abd al-Rahmām ibn Mu'āwiya, later known as al-Dākhil (the Incomer), reached *al-Andalus*, soon starting the al-Andalusian 'Umayyad Dynasty (756-1031) at Córdoba, the capital. In 1031, the 'Umayyad Caliphate was abolished and *al-Andalus* fragmented into numerous small kingdoms, known as the *Tā'ifah* or *mulūk al-Tawā'if*, Taifa kingdoms, or better yet, party realms (1031-1086), gradually losing power and land to the Christian reconquest(s). Although divided into several fragmented Muslim kingdoms — with their own capitals throughout most of southern, present-day Portugal and Spain — these small Muslim kingdoms "became centers of literature and of culture, and their rulers, ministers, or rich inhabitants, sponsored major works of art" (**Grabar** 6). The Almoravids (1040-1147), and the Almohads (1121-1269) after them, also occupied parts of the southern half of the Iberian Peninsula. The Emirate of Granada, *Imārat Gharnātah* (1228-1492), was the last Islamic presence in the Iberian Peninsula until it was defeated by and annexed to the newly-born Kingdom of Spain (1469).

*al-Andalus* is where the coming together of Islam, Sephardic Judaism, and Christianity produced a unique body of cultural and scientific works unequalled in human history. Although oftentimes idealized, this peaceful and (almost always) tolerant, cooperation among the *Ahl al-Kitāb* (People of

the Book) (711-11th century), was able to foster the flourishing of the arts and sciences including agriculture, architecture, arithmetic, arts, chemistry, cosmography, geography, mathematics, medicine, music, philosophy, etc., thus opening the doors to the Portuguese Age of Exploration. From this time onward, Africa, Asia, South East Asia, and surrounding areas in Oceania, as well as the Americas, were now within reach of the Portuguese. Although officially begun in 1415 with the siege of Ceuta, in present-day Morocco, the Portuguese Age of Exploration was preceded by centuries of timid explorations of the Atlantic sea (north and south): between 1307-1312 King Dinis (1279-1325), promoted the organization of the Portuguese navy and in 1317 he appointed the Genoese Emmanuele di Pezagna — also spelled Passagna or Pessagno, corresponding to the Italianized form Passano — known in Portugal as Manoel (de) Peçanha, as Admiral of Portugal. During the reign of King Afonso IV (1325-1357), the Portuguese undertook their first expedition to the Canary Islands (1335-1341) and King Fernando (1367-1383) founded the Grower of Ships Company in Lisboa and Porto. In 1413, a Prior of the Knights Hospitaller advised King João I (1385-1433) to capture Ceuta. Two years later, in 1415, King João I and his sons, Duarte (1391-1438), and Henrique (1394-1460), seized the North African city of Ceuta, thus officially starting the Portuguese Era of Discoveries and Expansion. King João I had nine children with his wife, Filipa de Lencastre (1359-1415), and two children with his mistress, Inês Pires. A poet and a writer, Prince Duarte succeeded his father as King Duarte I. His son Henrique, Duke of Viseu, also known as Prince Henry the Navigator, dedicated his entire life and fortune investigating the nautical sciences that would have allowed the Portuguese to eventually circumnavigate the African continent and reach the much sought after spices of India and the rest of the Orient. At his death in 1460 the Portuguese had reached as far south as present-day Sierra Leone in West Africa.

Yet, there are documents attesting to Portuguese presence in the Northern Sea as early as the last decades of the twelfth century (Parry 69; Diffie 24-25; Levi 190), oftentimes with the precious help of the Genoese and Catalans who, in their turn, were also heirs of, thus they were benefitting from, the Jewish— mainly Sephardic, *Shuadic* (*Shuadit*: Judeo-Provençal) and *Italkian* (*Italki*: Judeo-Italian) — and Islamic cultures of the Mediterranean: as People of the Book, the status and role of the Iberian Jews (Sephardim) living under Muslim rule proved to be instrumental for the transmission of scientific knowledge and advancement in technology to Portugal and the rest of the then in-the-making world. Like other geographical areas under Islamic rule, *al-Andalus* was thus considered as *Dār al-Islām* (Islamic Land). After the final Portuguese (1249) and Spanish reconquests (1492), *al-Andalus* inevitably became *Dār al-Harb* (Land of the Enemy), where the majority of its inhabitants is made of non-Muslims. In *al-Andalus* Muslims and non-Muslims spoke Mozarabic, a Latin-based language with many lexical borrowings from the Arabic language. Mozarabic was in itself divided among many different regional Iberian dialects or variants. The term Mozarabic derives from the Arabic *musta'arab*, in itself derived from the tenth verbal form *ista'araba*, or rather, "to behave/live as an Arab and/or a Muslim." Hence, by extension, it meant to be/become Arabicized/Islamized. The term was used to refer to people who, despite their Christian faith, felt more comfortable speaking, reading, and writing in Arabic, including using Muslim attire. Given that the Mozarabs knew how to read and write in Arabic — that is, they had access to the *madrasa* (Qur'ānic School) — they also developed a form of writing in their own vernacular using Arabic script, known in Portuguese and Spanish as *aljamiado*. The *Mudéjares* — a Portuguese and Spanish rendering of the Arabic *Mudajjanûn* (those who were allowed to stay; hence, those who were domesticated) — were the people who remained Muslim after their land was retaken by the Christians during the Portuguese and Spanish reconquests. *Aljamiado* literature is thus a rich corpus of writing where amidst Vulgar Latin-based words — as in the case of Portuguese, Castilian Spanish, Catalan, and Sicilian — lexical and cultural borrowings from Arabic appear. In order to compensate the lack of sounds not found in the Arabic language the Mozarabs had to create new letters and other symbols in order to accurately pronounce their language. Hence, *al-'ajamiyyah* is or was a language used in the former or present Muslim world with lexical and, at times, morpho-syntactical interferences from Arabic. All languages which had direct or indirect contact with the Islamic world thus show a varying degree of lexical borrowing from Arabic and, through Arabic, of other languages, as in the case of Farsi and *Osmanli* that, owing to their sociopolitical and cultural status, were able to influence Arabic lexically.

On the Iberian Peninsula, *Bait al-Hikma* (Islamic House of Knowledge) was also known as *al-Madrasah al-Mushatarak* (Common Teaching Establishment), a unique place in the then-Muslim world, where Sephardic Jews, Christians, and Muslims assembled to talk about different topics, religious as well as secular, among the latter philosophy and science. Yet science was the key to all sciences and through which humankind could reach all levels of knowledge. Usually, Islamic philosophy is divided into main parts of branches, namely: 1) *'Ilm al-Falsafah*, Islamic Philosophy per se, a "marginal" discipline," second to the "religious sciences," as well as the "foreign sciences"; 2) *'Ilm al-Kalām* (Science of the Word), universally known as *Kalām*: it is the philosophical, dialectical, and theological speculation within Islam, mainly based upon *'Aql* (Human Reason) and rational examination; 3) *Tasawwuf* (Islamic Mysticism) as in the case of *Sūfiyyah* (Sufism). Considered at best as "marginal sciences" (Gardet 597), the *'Ilm al-Falsafah*, *'Ilm al-Kalām*, and *Tasawwuf*, all aimed at attaining the same ultimate goal, that is, enhancing human knowledge and deep understanding *Āyāt* (God's Signs) in order to become One with Him, as in the case of (Sufi) mystics/ascetics, in addition to decoding the signs of *Khalq* (God's Creation). Given the usefulness of the *al-Madāris al-Mushatarak*, these centers "continued to function even after a number of Andalusian cities had been reconquered by Castile and Portugal. Their educational and scientific approach, which was truly unique among institutions of their kind, is described in various Arabic reference works on the history of the Peninsula" (Tazi 62).

Sephardic Jews, Christians, and Muslims also met at the *al-Quds* (Sanctuary), where "each member of each faith" carried out "the duties that his own faith required of him" (Tazi 62). For over two centuries then, between the ninth century and the end of the eleventh century, Sephardic Jews and Muslims in present-day Portugal and Spain "had an allegiance to centers or to issues outside of" the Iberian Peninsula. In fact, Iberian Jews "consulted the rabbis and learned men of Iraq in matters of faith. Moreover, they were connected through marriage with their coreligionists in North Africa, Sicily, Egypt, and even India" (Grabar 7). Those responsible for the sociopolitical and religious welfare of the Muslim community, the *Ummah*, were the *'Ulamā'* (singular: *'Ālim*) (learned men), "those who possessed the *'Ilm*" (knowledge). Hence, the *'Ulamā'* were the (religious) teachers, the learned instructors, whereas the *Fuqahā'* were the lawmakers at the service and for the benefit of the entire Muslim community, the *Ummah*. Together, these scholars and religious learned men alike were in charge of the *Sharī'ah* (Divine Law). Given the complete absence of priesthood and the accompanying religious hierarchy in Islam, the *'Ulamāh* and *Fuqahā'* were the custodians of both the secular and religious aspects of the *Sharī'ah*. Logic, mathematics, metaphysics, and the natural sciences comprised the *'Aqlī*, the philosophical and intellectual sciences, which could be acquired naturally by any Muslim through the use of instinctive reason and intellect. However, a believer cannot learn any of these sciences by himself, since they entail deep understanding and extensive training. Conversely, the opposite can be said for the *Naqlī* (transmitted sciences) which all Muslims can acquire through transmission (simply put, via teaching), investigating the original sources, and, as for the religious sciences, studying *Wahy* (Divine Revelation) itself. The *Naqlī* comprise many sources, although their three pillars are the *Qur'ān*, the *Ahādīth* of the Prophet (*Sunnah*), and *al-Sarf*, (grammar), the grammar of the Arabic language, the language of the uncreated and eternal Holy Qur'ān, the language of God; hence, the necessity of understanding the exact meaning of all words truly which, in turn, will also help believers understand the spiritual and socio-religious messages and *Āyāt* (signs) contained in the sacred text.

As Islam was growing in numbers of believers and as Islam was physically and geopolitically progressing leaving the Arabian Peninsula behind itself and expanding from south to north, from east to west including Europe, from east to the south- and northeast Asia and beyond, Islam absorbed and forged new ideas/ideals and new models upon which to construct and reshape its sociopolitical organization, as well as its scientific and philosophical-theological discourse. Needless to say, Greek/Hellenic, Sanskrit, and Hindu, as well as Old and Middle (Pahlavi) Iranian thinking had a profound impact on the formative years of Islamic philosophy and science. Islam in former Sassanid Persia and present-day Iraq was per force influenced by Zoroastrian (Mazdaism) and Manichean trends as far as these views did not contradict the fundamental Islamic tenets. This explains the 779-786 persecution of the followers of Dualism (Manichaeism), who were eventually seen as heretics and worshippers of more than one god, practicing *shirk* (association) thus falling outside the category of

the *dhimmi* (protected people). In other words, they did not belong to the *Ahl al-Kitāb* who, by virtue of their monotheistic faith, enjoyed the *dhimma* (protection) as Jews, Christians, and Zoroastrians normally did/do. The *Ahl al-Kitāb*, which include Jews and Christians, are those who believe in a sacred book, or rather, the Bible, the Torah, (*al-Tawrah*), the New Testament (*al-Injīl*), and the Psalms (*al-Zabūr*). However, the *Ahl Al-kitabi* also includes Zoroastrians, Sabaeans, Mineans, and any other group of people with whom Islam had contact during its territorial expansion outside the Arabian Peninsula, who believe(d) in only one god and who base(d) their religion on a holy book, as in the case of Hindus. The ancient Sabean and Minean pre-Islamic religion, although containing a few polytheistic elements, were not condemned by Islam. The kingdoms of Sheba (930-115) and Mina (1200-650), the former in the south and the latter in the southeast of the Arabian Peninsula, were civilizations which were involved with the spice trade between Asia/Middle East and the Mediterranean.

One way for the newly converted and/or somewhat syncretic, non-Arab population of the former Sassanid Persia (205-641) and present-day Iraq to include their pre-Islamic customs and beliefs was to divert their heterodox and not completely accepted Muslim ways to philosophy, which at this time was well grounded in the entire region. Of obvious Greek/Hellenic origin, Western philosophy — most of the times linked with the study of astrology, astronomy, chemistry, mathematics, and medicine — had deep roots in this geographic area, being practiced and taught mostly by (heterodox) Christian and Jewish scholars. As a result, translations from ancient and not-so-ancient works from a wide spectrum of languages and fields were ordered to be made into Arabic, including philosophical treatises. As time passed, revisions were required since they had to reflect the latest scholarly improvements, discoveries, translations, and theories in the field. In *al-Andalus* works were first translated into Latin and later into the local vernacular languages including Portuguese, Castilian Spanish, Aragonese, and Catalan. Yet, Latin was the first step to introduce these new works to Europe, particularly during the twelfth century — a time in which as the Islamic sciences were declining and European interest in sciences was increasing, "when Islamic medicine and science came to a standstill, about 1100, they began to be transmitted to Europe in Latin translations" (Meyerhof 345). In Portugal and what later came to be known as the Kingdom of Spain, we thus have the birth of learning centers which were instrumental for the future awakening of Europe.

During the 'Abbāsīd caliphate (750-1258) the physical place where scholars met and translated works of knowledge into Arabic was in fact called *bayt al-Hikmah* (House of Knowledge) which, of course, also included a *maktabah* (library) or a *dār kutub* (dwelling of books). This "new emphasis on learning" opened the doors to other disciplines, like science and the Arabic language, as well as "the philosophical discourse on reason and faith that had been a focus of the intellectual life of Iraq in the ninth century" (Grabar 7). It was actually from the southern area of the Iberian Peninsula that "these great accomplishments were transmitted" (Grabar 7) everywhere else in eleventh century *al-Andalus*, as well as elsewhere of the then known world. The *Qur'ān* encourages believers to travel, since this is yet another way of learning, thus opening up the heart in order to discover and appreciate new cultures, including different religions. From a state of mere translation, particularly from the late-Hellenic period, Muslim scholars passed to one of revision, amelioration, and eventually full-blown, independent thinking, and prolific production. Hence, the Greco-Hellenic tradition was very much impregnated with Eastern traditions and trying to distinguish the two was practically impossible.

Among the first translations worth mentioning are the works by cartographers and geographers Marinus of Tyre (ca. 70-130) and Claudius Ptolemy (ca. 90-168). Thus scientific, medical, mathematical, astrological, astronomical, and musical treatises produced in Greek, Syriac, Pahlavi (Middle Iranian), and Sanskrit were being translated to Arabic and, at the same time, revised and improved according to the newest theories in the field. Most often the translators also created compendia where they recapitulated the entire treatise and its main points: "In the Atlantic the Arabs came to know familiarly the Western seaboard of *al-Andalus* (the Iberian Peninsula) with the important port of *al-Ushbūna* (Lisbon) on the *Tājuh* (Tagus), and Muslim ships at least upon occasion operated at Oporto (*Burtuqāl*)" (Dunlop 160). In *al-Andalus* and Sicily (*Siqiliyyah*) (827-1091) and the Emirate of Sicily (965-1072), Muslims were thus the leaders in the field of astrology, astronomy,

arithmetic, algebra, medicine, music, pottery, faience, glassware, tapestry, and irrigation. Through *al-Andalus* thus Europeans got acquainted with the compass, the sextant, and the astrolabe.

The bulk of the translations of these texts from the pre-Islamic Middle East and East was performed during the second half of the eighth century. The oral tradition of the newly-converted Muslims of the Islamic empire(s) — as in the case of Syrians and Aramaics — also played a key role in the literary and scientific corpora then being forged by Muslim scholars (Nallino 7-8) Carlo Alfonso Nallino lists a few prominent names, among whom are Mā Shā' Allah (d. ca. 815-820), Abū 'Uthmān Sahl ibn Bishr bin Habīb ibn Hāni (Haya) (first half of the ninth century), Rabban Sahl al-Tabāri (first half of the ninth century), and Abū al-Taiyib Sanad ibn 'Aly (d. ca. 864). The presence and active participation of Jewish scholars in this transfer of knowledge is first noticeable in the Muslim east and then in the Muslim west, the latter covering the Maghreb and the Iberian Peninsula. For instance, Ptolemy's *Almagest* was first translated to Syriac and then to Arabic. The *Almagest* is a complete and detailed exposition of mathematical astronomy, one of the most important scientific treaties not only for its theories and technical and practical observations, but also for its influence in the future development of astronomy and the West and the Islamic world will both be influenced and transformed by this work. One of its Arabic translations was done by al-Hajjāj ibn Yusuf ibn Matar (Baghdad ca. 786-833), perhaps based upon a Syriac version. Most likely al-Hajjāj was the one who gave the work the title *Almagest*. Among the many translations available, perhaps the most authoritative is the translation from the Arabic into Latin made by Gherardo da Cremona, (ca. 1114-1187), which was copied in Toledo and completed in 1175.

In *al-Andalus* astronomy reached its peak during the second half of the tenth century. Abū al-Qāsim Maslamah ibn Ahmād al-Majriti (d. ca. 1007), a philosopher and mathematician, after having studied in the Muslim east for a while, was able to reedit and ameliorate the Arabic translation of Ptolemy's *Planisphaerium*. Al-Majriti is also famous for his edition of the *Astrological Tables* of Abū 'Abdallah Muhammad ibn Mūsa al-Khwarizmi (d. ca. 850) and al-Battāni (ca. 858-929) substituted ancient Persian chronology with its Arabic/Muslim counterpart. Another prominent scholar was Ibn al-Samh from Granada (d. 1035), who composed astronomical tables. And Ibn al-Samh's most important work is a small treatise where he describes an astronomical instrument with seven blades, useful for calculating the movements of the sun, the moon, and the five planets. Towards the end of the tenth century and the beginning of the eleventh century, Abū 'Abd Allah Muhammad ibn Yūsuf ibn Ahmad Mu'adh al-Jaihāni compiled astronomical tables for the city of Xaén in Andalusia. The aforementioned Gherardo de Cremona translated this work into Latin with the title *Liber tabularum iahen cum regulis suis*. The most important Andalusian astronomer was Abū Ishāq Ibrahim ibn Yahya al-Naqqash ibn al-Zarqalah, also spelled al-Zarkālī (ca. 1029-1087), (Auzarchel in medieval Latin and Azarquiel de Toledo in Portuguese and Spanish). For the Emir of Seville al-Mu'tamid ibn 'Abbad (1068-1091), al-Zarqalah invented the universal astrolabe, adaptable to any latitude.

Rediscovered by the Muslims, the Greek astrolabe thus became an instrument of great impact in nautical exploration. Further, al-Zarkālī devised a different kind of astrolabe, the *safiha*, eventually composing a useful treatise that soon became the archetype of many other works composed in the Islamic world. Al-Zarkālī's work was eventually translated into Latin by Jacob ben Makhir ibn Tibbon (1236-1304), a *Shuadic* Jew, most likely from Marseille. King Alfonso X of Castile the Wise (1252-1284) ordered that two translations be made into Castilian Spanish. Based on Arabic texts, German astronomer and mathematician Johannes Müller von Königsberg (Johannes de Monte Regio, Regiomontanus) (1436-1476) composed works related to the *safiha* as the famous *De triangulis planis et sphaericis libris quinque*, published posthumously in 1533 by the Dutch astronomer and mathematician Daniel Santbech. Among its many functions, al-Zarkālī's universal astrolabe was based upon stereographic projections and he described the instrument, its construction, and its use in the *safiha*. Given its great utility, his work was translated into many languages including Hebrew, Latin, Castilian Spanish, and Italian. al-Zarkālī performed almost all of his scientific research in Toledo under the aegis of Emir Yahya al-Ma'mūn. His observations were recorded in the *Toledan Tables*, translated into Latin by Gherardo da Cremona as *Tabulae toletanae iahen cum regulis suis*.

Despite their religious and sociopolitical differences, in the newly-formed Portuguese kingdom Muslim scholars were an indispensable element in setting the ground for not only science, but



particularly for navigation that changed the course of humankind: the encounter of other peoples and lands. Without the knowledge of Islamic sciences and the assistance of Muslim, Sephardic Jews, and Christian scholars trained in the field, Portugal and, through it, the rest of Europe, would never have had the information and the technology that would have allowed them in a little over one hundred years to navigate and encompass the entire world, thus reaching their economic goals: "The Jewish communities preserved the heritage of the Muslim-Mozarab-Jewish culture, and some of their members took part in the navigational experiments of João II's time" (Coelho 93). There are documents attesting to Muslim familiarity with or at least knowledge of the Madeira Archipelago and the Cape Verde Archipelago, right before or during the Portuguese first explorations in the area (Disney 84). Although the Portuguese were the first Europeans who accomplished the unachievable, it was thanks to their Islamic legacy, with a solid background in sciences and navigational sciences, that they were able to reach Greenland (ca. 1479), Labrador (1500), Newfoundland (1501), and Brazil (1500), as well as circumnavigate the African continent (1415-1498), and thence travel to India (1498), China (ca. 1507), Japan (1543), Southeast Asia (ca. 1510), northern Australia (ca. 1512), and many of the present-day Pacific Islands nations and territories (ca. 1512).

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