Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *Cheap Astronomy – Live in Andalucia.*

If you tuned in to last episode, you'll know Cheap Astronomy is currently touring Spain. I passed through Madrid, but didn't manage to connect up with the Deep Space Network folks. And so I had to stop and think hmmm astronomy, Spain... astronomy, Spain. Of course Cordoba! – capital of Al-Alandus, a major cultural and economic influence on the Mediterranean world for over 700 years; heart of what's considered the pre-renaissance renaissance of science (and astronomy of course) that helped bring the rest of Europe out of the dark ages and into the Renaissance. Entonces – vamos a Cordoba!

Al-Alandus persisted from around 700 AD to nearly 1500 AD – after which it became the south of Spain and the name morphed into what is now known as the Spanish region of Andalucia – which includes Cordoba – though Seville is now considered the capital of Andalucia.

There is some debate about what aspects of astronomical development should be ascribed to the Islamic Andalusian scientists versus the more familiar renaissance figures of Copernicus, Kepler and others. Around 1000 AD, al-Zarqual is credited with determining that the planets moved in elliptical orbits a good five hundred years before Kepler deduced this himself. In the 1100s Averroes began attacking the Ptolemaic model established way back in the 100s, which put the Earth at the centre of the universe with everything orbiting about it on the surface of heavenly spheres. Averroes was particularly unhappy with the somewhat incomprehensible epicycles required by the Ptolemeic model (as described in the *Algamest*) to explain why planets seem to initially move across the sky and then kind of double back for a while before continuing on again. Averroes is quoted as saying 'The astronomy of our time offers no truth, it only agrees with calculations and not with what exists'.

This refutation of Ptolemy's astronomy, that had stood unchallenged for nearly a thousand years, became known as the Andalusian revolt. The Andalusians were adamant that (cosmologically speaking) heavenly bodies and celestial spheres were subject to the same physical laws that operated on Earth.

What isn't so clear is whether the Andalucians where all agreed that the Earth orbited the Sun and those that apparently did were still fixated on another ancient Greek's world view – that of Aristotle who had proposed that heavenly bodies should move in circular orbits at uniform velocities – largely because this just fit with the Pythagorean tradition that everything of a fundamental nature should conform to integer-based mathematical neatness. It was the Aristotelian view that underlay the Ptolemaic concept of heavenly spheres.

So, even though the Andalucians had the right ideas about the planets, including Earth - being freely moving bodies and not fixed to rotating spheres - Aristotle's requirement that things move in perfect circles meant the Andalucians calculated predictions of the future positions of planets in the sky were consistently wrong – indeed even more so that Ptolemy's occasionally dodgy calculations.

al-Zarqual's earlier finding that the planets followed elliptical orbits just didn't seem to get picked up in the mainstream thinking of the day – and so the discovery of the heliocentric model of the solar system remained to be fully fleshed out by Nicolaus Copernicus.

Now I might just break off here to note that here I am a southern hemispherite in the northern hemisphere. Having carefully printed off a star chart on my first day in Cordoba, I spent a fruitless 5 am walk around the next pre-dawn morning, peering through some heavily light polluted skies to try and find Polaris. I could see a curvy bit that looked a bit like the handle of the Big Dipper, but it seemed to be in the wrong place. The next day and with some jet lag wearing off, I realised I had made the fatal star chart error, by assuming East was to the right of North like a street map that you look down on – whereas it should be to the left. Or in other words, if I correctly held the star chart up over my head, what I had assumed was north was actually south and that curvy bit I had seen the previous morning was just Scorpio.

It suddenly dawned on me – and fortunately before dawn on the second day – that I could just stick my head out of the hotel room's window and there straight in front of me was the Big Dipper – and surprisingly big it is too. Once you've found the Big Dipper, you just follow a line through the two stars which represent the front of the ladle/spoon thingy because these more or less point at a bright star at the tip of the handle of another littler dipper – or Ursa Minor if you prefer – that bright star of course being Polaris. Fabulous.

Anyhow, back to the story. Even if they never quite got the heliocentric model, the Andalucians and other astronomers of the so-called Islamic Golden Age made a number of clever deductions about the universe outside the solar system. Ibn al-Haytham did take a shot at Aristotle's view that the Milky Way was a relatively close object affixed to one of his celestial spheres by showing that it had no detectable parallax.

Al-Haytham also deduced the existence of space, at least to the extent that he refuted the whole idea of the Ptolomeic solid spheres and proposed that the atmosphere of Earth did not extend out into the deeper heavens - which he suggested must be a much less dense medium - like a vacuum. Another Islamic astronomer, Ibn Bajjah, even proposed the Milky Way was made up of many stars and that it just appears to be a continuous 'milky' image due to the effect of refraction in the Earth's atmosphere.

The Muslims of the period were also very good at constructing astrolabes which could be used by astronomers, navigators, and astrologers to locate and predict the positions of the Sun, Moon, planets, and stars; and could even determine local time if they knew the local latitude - or if they knew the local latitude, they could determine the local time. Astrolabes became the basis of navigational sextants, as well as the planispheres that we still use for backyard astronomy today.

It was al-Zarqālī of Al-Andalus, who constructed the first universal astrolabe which, unlike its predecessors, was not limited to working in just one latitude, but instead could be used anywhere on Earth. After the fall of Al-Alandus, the astrolabe was introduced across other parts of Western Europe and probably helped in the development of the sextant and other navigational aids later used by Christopher Columbus.

Furthermore, part of the mathematics behind the universal astrolabe is what's called a Tusi-couple – which describes the geometry of a small circle within a bigger circle where that little circle does one complete revolution when rolling once around the circumference of the bigger circle. There is broad agreement that Copernicus used the Tusi-couple as a vital component in building the mathematics of his heliocentric model. So we can say the Andalusians were in there somewhere – and probably deserve a lot more astronomical credits than they generally get.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website where for the sake of copyright, I'll just end with (sings Andalucia). No ads, no profit, just good science. Bye.