Using ancient observations to classify stars

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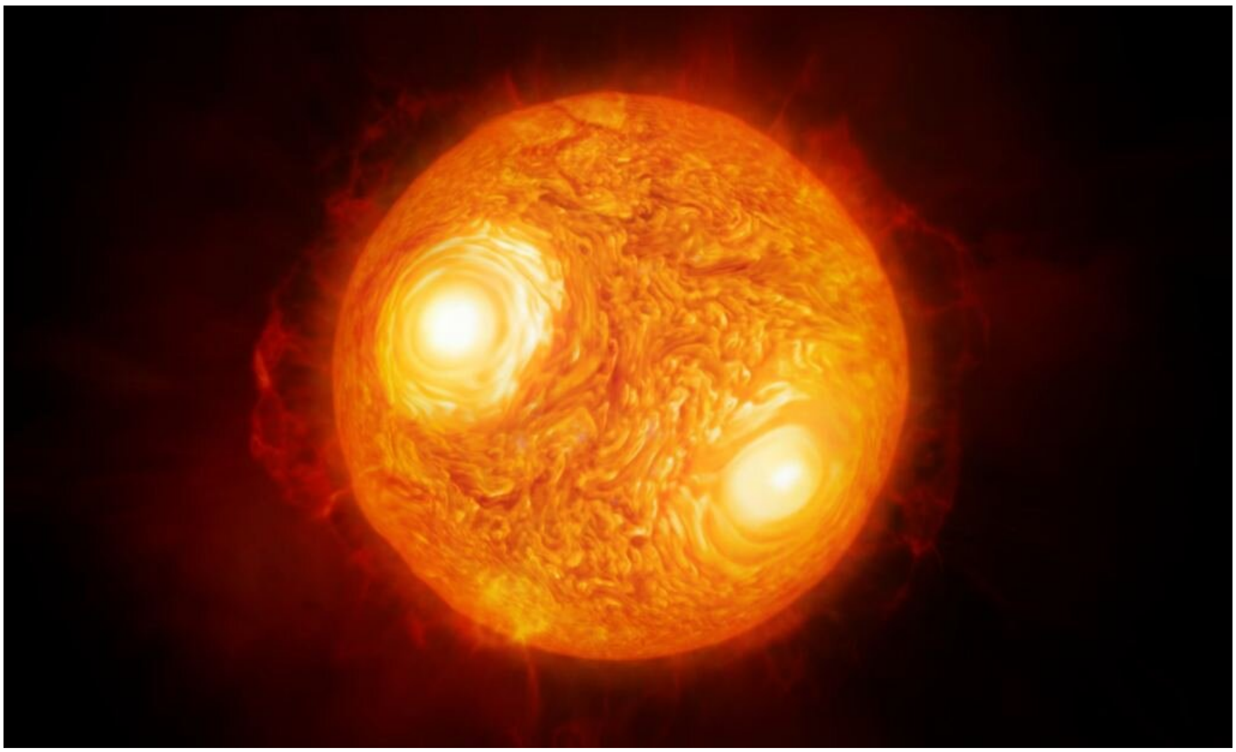


Artist's Impression of Antares. Credit: M. Kornmesser / ESO

Stars don't usually evolve fast enough for humans to notice them change within one lifetime. Even a hundred lifetimes won't do—astronomical processes are just too slow. But not always. There are some phases of stellar evolution that happen quickly, and when they do, they can be tracked. A new paper posted to ArXiv last week uses astronomical observations found in ancient Roman texts, medieval astronomical logs, and manuscripts from China's Han Dynasty to trace the recent evolution of several bright stars, including red supergiant Antares, and Betelgeuse: one of the most dynamic stars in our sky. With observations from across the historical record, the paper suggests that Betelgeuse may have just recently passed through the Hertzsprung gap, the transitional phase between a main sequence star and its current classification as a red supergiant.

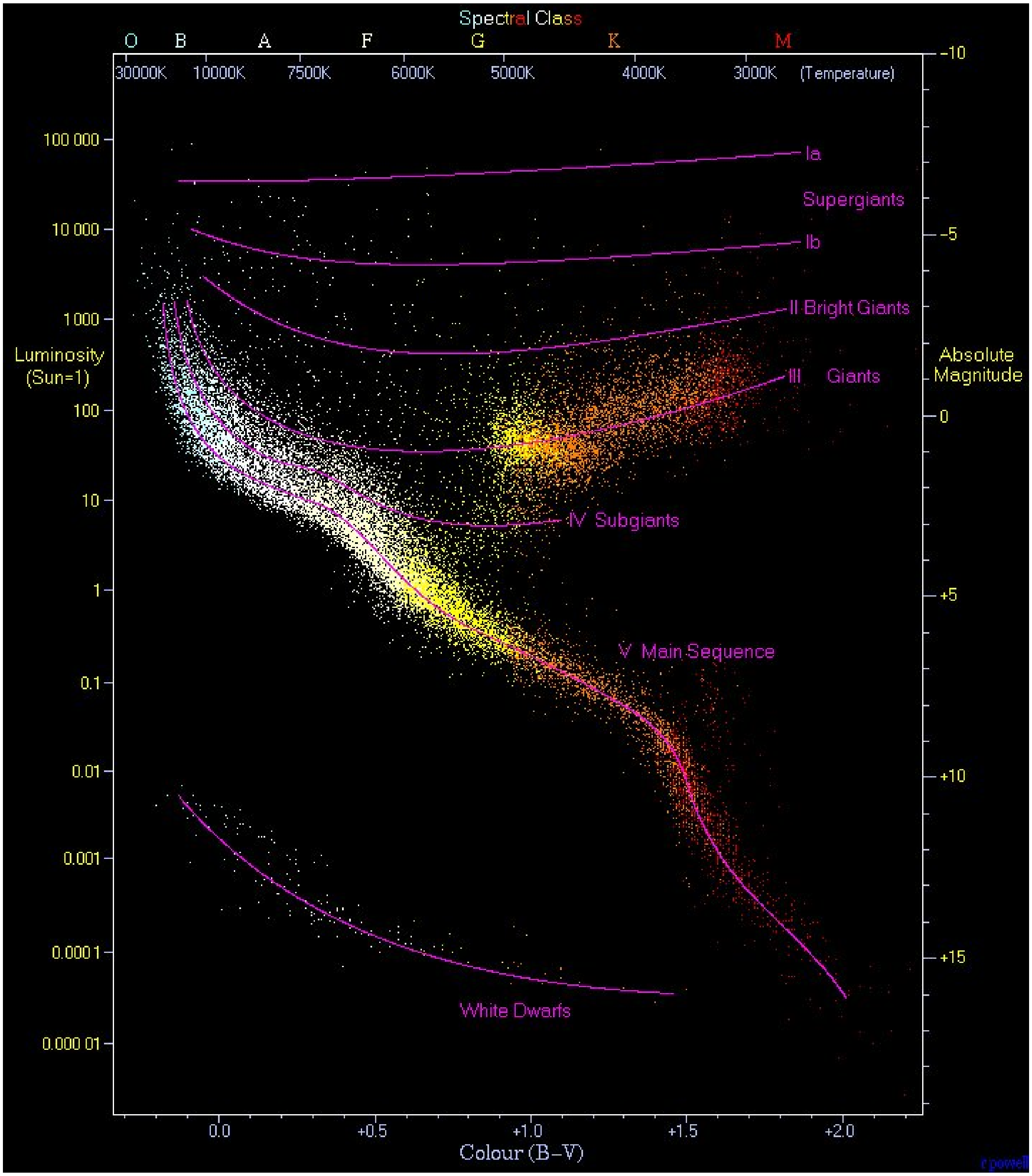
If you were to survey all the stars in the night sky for their color and luminosity, you would see that most stars fall within a distinct pattern known as the main sequence (the hydrogen-burning phase of a star's life), with a smaller number of stars falling within a second category of giants (dying stars that have used up all the hydrogen in their cores). Surveying stars this way and plotting them on a graph is called a Hertzsprung-Russell diagram, and it is a useful tool for understanding stellar evolution. One of the key features of the diagram is a distinct gap between the main sequence and giant stars, known as the Hertzsprung gap. This gap doesn't really mean that stars don't exist within that gap—but rather that stars don't stay there very long. It is a transitional phase, which can be crossed in a few thousand years, meaning that catching a star in the middle of the phase is rare—hence the gap in the diagram.

With luck, this short-lived transitional phase could theoretically be observed within humanity's written historical record, for any number of stars.

The key candidates for such a study are bright, nearby red supergiant stars visible to the naked eye—meaning they could have been observed and studied before modern telescopic lenses. Some ideal examples include Antares, a variable red supergiant in the constellation of Scorpius, and Betelgeuse (the right shoulder of Orion), a roughly 10-million-year-old star that is no longer burning hydrogen in its core.

Nearing the end of its life, Betelgeuse is expected to explode in a dramatic supernova sometime in the next 100,000 years (astronomically speaking, that is not very long).

Most of our knowledge about these stars comes from modern observations. However, modern remote sensing techniques are not perfect, and it is valuable to have multiple redundant methodologies for calculating phases of stellar evolution. The historical record can therefore help corroborate, or constrain, the predictions of modern astrophysics.



A Hertzsprung-Russell diagram, with the Hertzsprung gap between main sequence stars and red giants. This gap indicates a life stage of stars that doesn't last long, making observations of stars with that luminosity and color rare. Credit: Richard Powell (Wikimedia Commons)

The historical evidence: Betelgeuse in transition, and an unchanging Antares

A key marker of the transition across the Hertzsprung gap is a change in color toward the reddish end of the spectrum. As such, historical descriptions of Betelgeuse or Antares denoting anything other than red would hint at a recent transition.

You might be inclined to dismiss historical texts as potentially misleading or inaccurate—besides, a vague description of a star as 'reddish' isn't very scientifically helpful by today's standards. But the real value of historical documents occurs when ancient writers make comparisons between distinct astronomical objects: Betelgeuse to Saturn, or Antares to Mars, for example. Those kinds of statements give us a much more measurable, if still approximate, dataset to work with, because we can make the same comparisons in today's sky with modern equipment.

This is exactly the kind of data the paper's authors, led by Ralph Neuhäuser (AIU Jena), were able to find. Digging into a variety of historical records, they uncovered several early descriptions of bright supergiants like Betelgeuse and Antares. One of the key sources for Betelgeuse was "De Astronomica," a Roman text attributed to Gaius Julius Hyginus (64 BC-AD 17), the keeper of the Palatine library during the reign of Augustus Caesar. "De Astronomica" states, in a literal translation, that "The sun's star…body is large [i.e. bright], and color/coloration fiery/burning; similar to that star which is in the right shoulder of Orion [i.e. Betelgeuse]…Many have said that this star is [the star] of Saturn."

As an aside, the tradition of calling Saturn "the sun's star," as Hyginus does, can be traced as far back as early Babylonian texts, and may have originated because Saturn's movement in the sky is the steadiest of all the planets, and its synodic period (its apparent movement in the sky) closely matches the length of the solar year. Hyginus describes Betelgeuse's color as Saturn-like, which is distinctly not red (Mars would be the obvious comparison for a red star). This suggests that nearly two thousand years ago, Betelgeuse may not yet have entered its current life stage as a red supergiant.

A second Roman source from a century later, the Almagest, lists the brightest red stars in the sky—including Antares—but Betelgeuse is conspicuously missing from the list.

Meanwhile, across the globe, Sima Qian (BC 145–87), a "Senior Archivist" in the Western Chinese Han Dynasty, wrote a treatise on celestial bodies called the Tianguan shu. In this manuscript, Sima Qian describes Betelgeuse as yellow, while Antares was red. This corroborating account from an entirely different culture strengthens the case for a color shift in Betelgeuse during the last 2,000 years.

An illustrated page of De Astronomica, showing Betelgeuse on the right shoulder of Orion (red dots indicate constellation stars). Credit: Bavarian State Library, World Digital Library

Nearly 1,000 years later, Ibn Qutayba (AD 828–889), an Islamic scholar of the Abbasid Caliphate, described Betegeuse as reddish, as did Astronomer Tycho Brahe (AD 1546–1601) a few centuries later still. Oral tradition from Indigenous Hawaiians also describes Betelgeuse as red. These three examples clearly characterize the star differently from their more ancient peers, and more in line with modern observations.

Over the course of recorded history, if these accounts are to be believed, Antares appears to have remained consistently bright red, which Betelgeuse has transitioned from yellow to red.

Drawing conclusions: the challenges of historical astronomy

Combining history with astronomy can provide valuable insights into the recent (astronomically speaking) evolution of the night sky, but it isn't a perfect science and must be done carefully. One of the challenges of this methodology is the difficulty in accurately dating ancient texts. Most ancient manuscripts don't survive in the original, but rather as copies transcribed over the centuries in monasteries, libraries, and scriptoriums. As such, the exact dates can be uncertain, and works can be attributed to authors incorrectly. There is a chance, for example, that "De Astronomica" is falsely attributed to Hyginus, and is actually a 2nd-century document, not a 1st, because it seems to borrow some of its structure from the 2nd-century Almagest. The good news is, on astronomical scales, a century or two, give or take, doesn't matter much.

A second thing that might trip up modern researchers involves the cultural influences that shape the language of ancient authors. The Tianguan Shu, for example, groups star colors into five categories: red, blue, yellow, black and white. These colors don't actually match visual descriptions ("black" stars don't make much sense literally, though it could mean "dim" or "dark"). Instead, the five colors come from Chinese Wuxing philosophy, in which the colors align with five elements (Earth, Wood, Metal, Fire, and Water) that underscore cyclical changes in nature, politics, and human physiology. Wuxing color groupings are not reliable markers of objective observational hues. Nonetheless, they represent distinct categories that can be used for comparison—red stars are clearly different from blue stars, for example. This means that Betelgeuse's placement in a different category from Antares probably reflects a real observed difference, even if the exact hue of each category is unknown.

Comparing ancient text to modern observations: what do we know?

Modern estimates suggest that Betelgeuse has been in the red supergiant phase of its life cycle for at least a few thousand years, and could have been for as long as 140,000 years (best estimates put it at about 40,000 years). The historical data suggests the truth might lie in the more recent end of that range. While it isn't conclusive evidence, the historical record shouldn't be lightly discarded either.

After all, modern astronomical knowledge, to paraphrase Isaac Newton, "stands on the shoulders of giants:" our current understanding is only possible because of the insights made by generations before us. From the writings and oral histories they left behind, our ancestors may have something to teach us yet.

More information: Ralph Neuhäuser et al, Colour evolution of Betelgeuse and Antares over two millennia, derived from historical records, as a new constraint on mass and age. arXiv:2207.04702v1 [astro-ph.SR], arxiv.org/abs/2207.04702

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