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**Facing the Sun**

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WINTER SOLSTICE ALIGNMENTS
‘FACING THE SUN’

Frank Prendergast, Muiris O’Sullivan, Ken Williams and Gabriel Cooney discuss an extraordinary seasonal phenomenon.
Introduction
At this time of year, attention focuses on the orientation of Newgrange towards sunrise at the midwinter solstice. For many people this prehistoric phenomenon, dating back over 5,000 years, has become linked with the celebration of Christmas and the turning of the year. In 2016 there was media coverage of the suggestion by Michael Gibbons that the alignment of the roof-box at Newgrange, through which the sun shines to illuminate the passage and chamber at winter solstice sunrise, was the result of the reconstruction of this feature by the late Professor M.J. O’Kelly, who excavated and restored the monument.

While there are aspects of the Newgrange reconstruction that are open to debate, notably the quartz wall flanking the entrance, there is widespread agreement, as first scientifically described by Jon Patrick and Tom Ray, and argued by Geraldine Stout, that the original and authentic purpose of the roof-box was to capture the beam of winter solstice sunlight and direct it to the back of the chamber. Equally important in understanding the wider significance of the Newgrange alignment is that it is not unique. Deliberate solar orientation is a recurring element of the passage tomb tradition, in Ireland and further afield. In the Boyne Valley the sun illuminates the southern tomb at Dowth at winter solstice sunset and Townley Hall passage tomb at summer solstice sunrise. Cairn T, the central tomb in the Loughcrew passage cemetery complex, is orientated towards sunrise around the time of the spring and autumn equinoxes. Further afield, the passage tomb of Maes Howe in Orkney is illuminated at sunset at the winter solstice, and the passage tomb at Bryn Celli Ddu in Wales is aligned towards summer solstice sunrise.

It seems timely to focus on this important element of the cultural practices surrounding the construction and use of these monuments during the Neolithic period and to ask the specific question of why solstitial and, in a few cases, orientations close to sunrise and sunset near the equinoxes were incorporated into passage tomb architecture.

Positional astronomy and solar alignments
Solstices and equinoxes are four events that predictably recur as the earth makes one revolution of the sun in 365.2422 days, a period known as the tropical year (Fig. 1). Winter and summer solstices can happen at any time within 21–22 December and 20–22 June respectively, while the vernal and autumnal equinoxes can similarly fall within 19–21 March and 22–23 September respectively. Relatedly, the next winter solstice will occur on 21 December at 16:28 UTC (Coordinated Universal Time, the time-scale available from broadcast time signals). The solstices and equinoxes also conveniently divide the year into quarters, each with an average duration of c. 91 days.

When thinking about the observed sky in prehistoric times, we first need to consider briefly the aspect and motion of earth’s axis in space. It is currently tilted at 23°.4 and this creates the four seasons, giving associated weather patterns and diurnal and seasonal differences in light levels. Crucially, axis tilt also causes very noticeable changes in the direction of sunrise and sunset throughout the year. These reach a limit in the south-east and south-west in late December, and in the north-east and north-west in late June, on what are known as ‘solstice days’. On those, and for a period lasting for about five days on either side, the naked eye cannot perceive significant changes in the rising and setting positions of the sun.

Fig. 1—Earth’s cycles and seasons.
change in the rising or setting position of the sun when referenced against horizon markers. This explains ‘solstice’, a term derived from the Latin words for ‘sun’ (sol) and ‘to stop’ (sistere). In Ireland, the apparent angular movement of the sun from solstice to solstice is about 84°, thus making our nearest star an obvious and practical target for tracking time, anticipating seasonal changes and planning festivals. Since the Neolithic, when the tilt of the axis was about 24°, the limiting directions of the sun on the horizon at the solstices have contracted and will continue to do so for many millennia (see Fig. 9).

The distances between the earth and the sun in June and December also differ by about 3%, with the earth being closer to the sun in December owing to the elliptical rather than circular nature of its orbital path. That difference causes the solar disc to seem fractionally larger in midwinter and explains why the phenomena of sunrise and sunset at that time can seem noticeably brighter and more spectacular.

Below: Fig. 2—Annual apparent motion of the sun on the horizon.

The changing skyscape through the year
Those who regularly watch the sky can hardly fail to notice the changing directions of sunrise and sunset—if not from day to day, then certainly from week to week. It would also be apparent that the rate of change is variable from month to month—greatest around the equinoxes in March and September and least around the solstices in June and December. The cyclical phenomenon of reversal, or turning, would be obvious too—a dazzling example of nature’s greatest U-turn (Fig. 2). Immediately afterwards, the sun appears to move northwards after the winter solstice and southwards after the summer solstice. Less obvious would be the dates of sunrise and sunset midway through this cycle. These are the equinoxes, when the hours of daylight and darkness are approximately equal and sunrise and sunset are diametrically opposed due east and west, provided that the horizons have the same level. Solstices, by comparison, are those days when the differences between the hours of daylight and darkness are at their most extreme. Practically and intuitively, the limiting direction of the sun at solstice is easily determined by simple observation. That is not the case for the equinoxes.

The sun at solstice
Solstices have profound temporal significance and associated ritual meaning across many cultures and chronologies. The reasons are not hard to find. For an observer located in either hemisphere of the globe, it will be obvious that the daily change in the apparent direction of sunrise and sunset after the time of solstice begins to slow down. The effect is more pronounced the further one is north or south of the equator. As an example, we show the changes for repeated five-day intervals at sunrise shortly before and after the winter solstice (Fig. 3). Notice how the width of the angular gap between any pair of adjacent solar discs reduces as the solstice is neared, even though the number of days remains a constant. Also, for a period of about five days on either side of the solstice itself, there is little perceptible change to the naked eye in the direction of sunrise. If the azimuth scale (true bearings) is disregarded, Fig. 3 is also valid for...
summer solstice sunset and, if reversed, for summer solstice sunrise and winter solstice sunset.

Important inferences and conclusions can be drawn from Fig. 3. Solar risings and settings at the solstices are unique, predictable and discernible. Interestingly, the actual day of solstice can be inferred by halving the number of observed days that elapse from the sun transiting and next returning to a fixed horizon marker positioned well away from the actual reversal point. It can be further shown by experimentation that distinctive topographical features on any horizon are easily memorised and serve as natural reference markers to predict an approaching solstice and turning point of the sun. In other words, there is no need for any artificial or technological aid in this task.

**Solstitial alignment in Irish passage tombs**

National archaeological records list 220 extant passage tombs on this island, with 136 of these having passages in sufficiently good condition to allow the character of their orientation to be measured and analysed. Interpreting these is fraught with difficulty, since we do not know the intentions of the builders. Nevertheless, if orientation data are considered from the broadest range of landscape, anthropological and cultural perspectives, meaningful interpretations compatible with the material culture of the tombs can be hypothesised (Fig. 4). It is prudent to consider astronomical hypotheses only after other alignment alternatives have been examined.

There are 22 Irish passage tombs with extant passages and chambers indicative of intentional alignment on the sun at seasonally important dates in the solar cycle (Fig. 5). Their occurrence is well distributed throughout the island but is only a relatively small sample (16%) of the 136 measured orientations. The list includes seventeen examples of alignment on solstices, with little significant difference between those facing the sun at summer solstice (seven) and winter solstice (ten). The remaining five cases indicate an
media presence at Knockroe later in the day—and a disappointing blanket of cloud.

In 2016 it was another fine day, and as the solar spectacle played out at Knockroe the evening star was already visible just above the setting sun like an observing sentinel.

A notable double

Knockroe has a unique solstice distinction. It is the only known passage tomb with two solar alignments on midwinter days. In the morning, as a large crowd assembles at Newgrange, a few hardy souls gather at Knockroe to watch the sun rise from behind the hills beyond Tullaghought in line with the eastern tomb. It is more an event than a

Knockroe passage tomb

In search of the sun

Unpredictable weather was surely just as much a part of the midwinter experience in Ireland around 3000 BC as it is today, making every solstice a unique occasion in terms of weather, solar visibility, cloud patterns and the location of the moon and various stars. The constant was the movement of the sun, visible or not, as it travelled its predictable route.

On the morning of 21 December 2015 heavy rain was falling at Newgrange, which meant that the solstice festivities took place without the famous solar beam—*Hamlet* without the prince! Several hours later and some 140km to the south, Knockroe passage tomb, Co. Kilkenny (SMR KK034-019001), was bathed in winter sunshine and a large crowd stood spellbound as the setting sun descended to the horizon and sank out of sight in line with the western tomb. Conversely, on another midwinter day a few years earlier, an obliging morning at Newgrange had been followed by a strong media presence at Knockroe later in the day—and a disappointing blanket of cloud. In 2016 it was another fine day, and as the solar spectacle played out at Knockroe the evening star was already visible just above the setting sun like an observing sentinel.

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spectacle: not only is the entrance to the tomb set back almost 2m from the kerb but also there is only a relatively short passage to provide a sight line. And yet, standing behind this tomb today, we can see that it opens to the spot on the horizon where the midwinter sun rises (Fig. 8).

The setting sun at Knockroe is easier to appreciate and the solstice spectacle currently attracts a crowd in the region of 100–200 people. There is no roof-box, not even a roof, and the chamber could hold no more than one or two people at most. Perhaps by way of compensation, however, the denuded cairn allows the entire crowd to stand in an arc behind the tomb and marvel at the spectacle, as the evening sun sinks behind the high ground of Clashnasmuit on the opposite side of the valley.

**Newgrange roof-box**
The illumination of Newgrange passage tomb (SMR ME019-045) at winter solstice sunrise is widely known and well documented. But a recent high-accuracy survey of the chamber and roof-box undertaken by one of the authors reveals that, contrary to popular belief and published imagery, only a portion of the sun’s disc is now visible from the chamber. This is due to the combination of inward-leaning orthostats in the passage close to the chamber and a change in the tilt of the earth’s axis since the monument was constructed. In Fig. 9 we show that, from a viewpoint taken in the centre of the burial chamber at floor level, the disc of the risen sun at winter solstice was central in the roof-box during the Neolithic and very likely lit the chamber more brightly and for more days than is now the case. The direction of sunrise has already moved northwards by about two solar diameters since that time. This unstoppable drift will continue in the millennia ahead and will result in the onset of permanent darkness inside Newgrange beyond c. AD 5000. This cycle (obliquity) will reverse in c. AD 12,000 but the chamber will remain darkened until c. AD 19,000. Thereafter, the sun will again illuminate the interior of the tomb with direct sunlight. A cosmic catastrophe for Brú na Bóinne and future generations? Perhaps!

**Waiting for the light**
Other than at winter solstice, the climactic moment of each tour within the chamber of Newgrange begins when the lighting is dialled down and the orange glow of an electric lightbulb shines a streak of golden light on the floor of the chamber, in a manner similar to the solstice dawn. It is a
poor substitute for the real thing, the guides remind the visitors, and this is hardly an understatement. For those lucky enough to witness the blazing sun enter the dark chamber of a passage tomb, the experience is far more dramatic, and sometimes intensely emotional. Waiting in the dark, eyes become accustomed to the gloom, and then the first dagger of light burns through the dark, almost laser-like in its intensity. The simulation cannot convey how the widening beam of light animates the stone skeleton of the passage and chamber, illuminating the dark corners and casting slowly shifting shadows as the sun tracks its course above the horizon. Along the passage, the dust raised by the feet of the visitors and the moisture in the air swirl hypnotically within the beam.

To catch these moments on camera is a privilege and a challenge. The low entrances and narrow passages of the typical passage tomb ensure that, even on the rare occasions when the weather is amenable, the passing of the light is fleeting. The chambers can accommodate only a very small crowd, and only the most patient and determined observers will witness such events firsthand. As simple a tool as the camera is, the photographic record of these moments in the way the Neolithic builders experienced them, with their eyes their most complex instrument, contributes to our understanding and appreciation of these phenomena much more than measurements and statistics.

Conclusions
Writing about Newgrange in the context of religion in later prehistoric Ireland, the late Dáithí Ó hÓgáin recognised that a critical element of the transformation of Newgrange in later belief into the home of the father deity the Daghdha, his consort Bóinn and son Aonghus, and the burial place of the kings of Tara, was a recognition of its connection with the rising sun as a metaphor for rebirth. It is plausible to link this with the powerful presence of the remains of the dead originally placed in passage tombs during the Neolithic. This cosmological perspective appears to be the
best explanation of the focus placed by the builders on facing key passage tombs towards the sun at critical times of the year. Thinking more broadly, the marking and turning of the seasons and the agricultural cycle provide a critical underpinning of later Christian and other major religious systems.

At this remove we can only speculate on the significance of Neolithic interest in the solstices. It may have reflected basic concerns around the seasons, or perhaps an indication that the sun was seen to be itself a living being. These broad explanations do not sit easily, however, with the subtlety of passage tomb thinking as we know it from the art, architecture and funerary rites practised by those responsible for the passage tombs. They appear to have been a people who dealt in nuanced and complex references, some of them developed across other parts of north-west Europe and even the Mediterranean region. This suggests that it is more likely that the sun was not so much an object of adoration in its own right but rather a symbol for something metaphysical in the mythology of the time.

It should not be surprising, then, that the orientation of passage tombs should have a particular resonance today for people who are seeking a reconnection with prehistoric monuments as expressions of elementally based religious systems. At the same time, we have to be careful not to confuse cosmological beliefs grounded in a particular and complex cultural world-view during the Neolithic with our beliefs and knowledge of today. What we can share is this extra-ordinary seasonal phenomenon.
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