The Milky Way Galaxy: young at heart?

Bill Worraker

In visible and ultraviolet light, the central few dozen light-years of the Milky Way Galaxy are obscured by dust clouds. However, radio, infra-red, X-ray and gamma-ray observations reveal a wealth of astrophysically interesting phenomena, including an invisible central object (generally thought to be a black hole) over three million times more massive than the sun. Evidence from the galaxy centre suggests that the contents of the region may be much younger than uniformitarian scientists believe. This includes: (1) the centrally located clusters of hot, bright stars, the formation of which eludes satisfactory explanation in evolutionary terms; (2) a ring of gas several light-years across orbiting the centre, despite processes which should have destroyed it well within a million years; and (3) extremely hot X-ray–emitting gas which should have escaped and cooled within a few tens of thousands of years.

The Milky Way represents our view of the great spiral galaxy which hosts the solar system and planet Earth (figure 1). The dark patches are clouds of dust, which obscure the light from distal stars. According to present-day estimates, the Milky Way Galaxy is over 100,000 light-years across.[1] Our solar system is in the plane of the spiral and about 26,000 light-years from the centre,[2,3] which is in the direction of the constellation Sagittarius (figure 1).

The dark obscuring material prevents us from directly observing the galactic centre itself in visible light (at visible wavelengths the extinction is approximately 27 magnitudes,[4] an intensity reduction factor of about 60 billion). However, radio, infrared, X-ray and gamma radiation do penetrate the Milky Way's gas and dust clouds. The first of these to provide astronomical information was radio; indeed when Karl Jansky, the founder of radio astronomy, first detected radio emissions from space in 1932, the source turned out to be the galactic centre. Infra-red, X-ray and gamma-ray observations lagged behind radio observations by 2–3 decades until the advent of space-based observatories (radiation in these wavelength ranges is largely absorbed by the earth's atmosphere).

Combined observations from all these four parts of the electromagnetic spectrum have now provided astronomers with a detailed picture of the galactic centre. Not only is this picture rich in astrophysically interesting features,[5] but it also provides evidence that the Milky Way Galaxy may be much younger than its generally accepted uniformitarian age of 12–13 billion years.[6]

General picture of the galactic centre

Tanner[7] gives a recent overview of the observable objects and phenomena in, and around, the galactic centre, starting from a visible-light photographic view several tens of degrees across and zooming in progressively to the central arcsecond, which corresponds to about 0.13 light-years. More detailed reviews of the central 10 parsecs (33 light-years) have been produced by various authors, notably by Genzel and Townes.[8]

Near-infrared images of the galactic centre, spanning a few degrees, show not only dense masses of stars but also a background glow over a width of about 500 light-years (one degree), corresponding to the inner part of the galactic bulge. Radio observations of the same region at 90 cm wavelength show a ridge of strong emission centred along the galactic plane. This is accompanied by several ring-like structures, which appear to be supernova remnants at various stages of expansion, and a series of filaments (threads and arcs) up to 100 light-years long, aligned roughly at right angles to the galactic plane (figure 2). Such filaments are observed only near the galactic centre. The radiation from the filaments, which stand out very clearly at 20 cm wavelength (figure 3), is probably synchrotron emission, which is caused by high-speed charged particles spiralling around magnetic-field lines. This highlights the fact that there is a significant magnetic field in the galactic centre region. Carroll and Ostlie[9] quote a figure of around 1,000 microgauss for the maximum field strength in this region (the field in the spiral arms of the galaxy is around 4 microgauss).

Sagittarius A* and the creation of its stellar neighbours

Zooming in further to a scale of 50 light-years, we come to the powerful radio source Sagittarius A. The eastern side of its central bright oval, Sagittarius A East, spans about 50 light-years (it is the very bright region in figures 2 and 3). Sagittarius A East appears to be a supernova remnant with an estimated age of 10,000 years.[10] The western side, Sagittarius A West, contains a three-armed spiral structure, the Mini-Spiral, the most prominent feature of which is the Northern Arm (figure 4). The Mini-Spiral lies inside a roughly elliptical ring, the Circumnuclear Ring (or Disk), which has projected dimensions of about 15 x 7 light-years (figures 5 and 6), though its less obvious outer region extends several times as far as this. A little to the north-west of the centre of the Mini-Spiral is a point-like radio source, Sagittarius A* (or Sgr A*, pronounced 'Sagittarius A star'), which is recognized as the true dynamical centre of the galaxy.

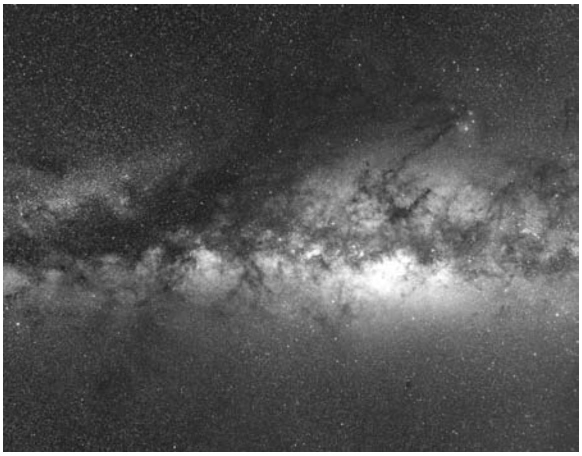


Photo by Wei-Hao Wang

Figure 1. *Wide-field visible-light photograph of approximately 80° of the Milky Way. The brightest region (to the lower right of centre) is the Sagittarius star cloud, which is close to the centre of the galaxy. North is toward the left and east is downwards.*

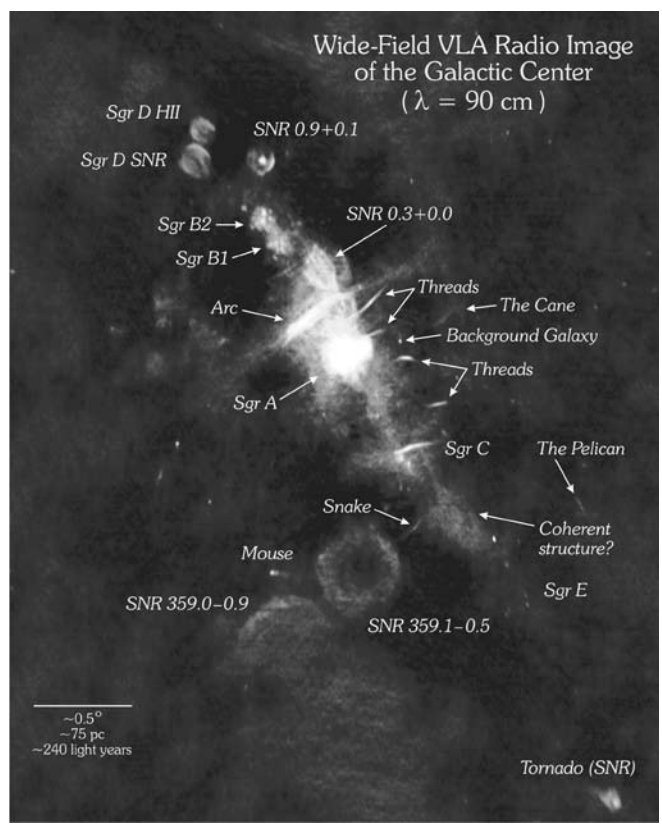
Observations of the motion of material in the arms of the Mini-Spiral, which appears to be falling rapidly into Sgr A*, suggest that a very massive object is lurking there. Recent observations of star movements within an arcsecond of Sgr A* indicate a mass of about 3.6 million times the mass of the sun.[11] This unseen central mass is generally taken to be a black hole, though Hartnett notes that no adequate theoretical description of how a black hole can form has ever been found.[12] Recent high-resolution observations have identified a strongly variable infrared source coinciding with Sgr A*.[13] Ghez *et al.*[13] suggest that the radiation from this source could be due either to inflowing (i.e. accreting) or outflowing material. They also note that the total radiation from Sgr A* is remarkably weak; it does not exceed about 10^{29} watts, 250 times the solar luminosity, whereas the mass involved is over three million solar masses. The Milky Way's central mass is clearly a mysterious, possibly unique, object, and may well provide surprises in the future. Its significance in a creation context is considered in the Discussion section.

Stars concentrate toward Sgr A* in cusp-like fashion. Genzel *et al.*[14] reported high-resolution near-infrared observations of the stars within about 10 arcseconds (1.3 light-years), which include the IRS13 and IRS16[15] groups and the 'Sgr A* cluster' (figures 7 and 8). They found that, although the general stellar population is 'old' in evolutionary terms and metal-rich[16] as expected for the galactic bulge, there are several dozen hot, bright, massive stars in the region—the heaviest of these contains 120 solar masses. Genzel *et al.* deduce that the most massive stars form two distinct disk-like streams orbiting Sgr A*, and that they must be less than one million years old because of the high rate at which they consume nuclear fuel. This creates a problem in explaining their origin because a parent gas cloud *in situ* would be tidally disrupted by the strong gravitational field of Sgr A*, while formation elsewhere, followed by inward migration, would take much longer than a million years. A further problem is that the magnetic field in this region is expected to inhibit star formation.[17] Genzel *et al.* speculate that the stars probably result from the collision and subsequent infall of two dense gas clouds. However, this idea has not been checked quantitatively, and it does not explain, for example, why the two streams should now appear to be unconnected (one stream lies entirely inside the other). Schödel *et al.*[18] comment:

> 'Currently, there exist no satisfactory models on how such stars can form at this location or migrate there during their lifetime.'

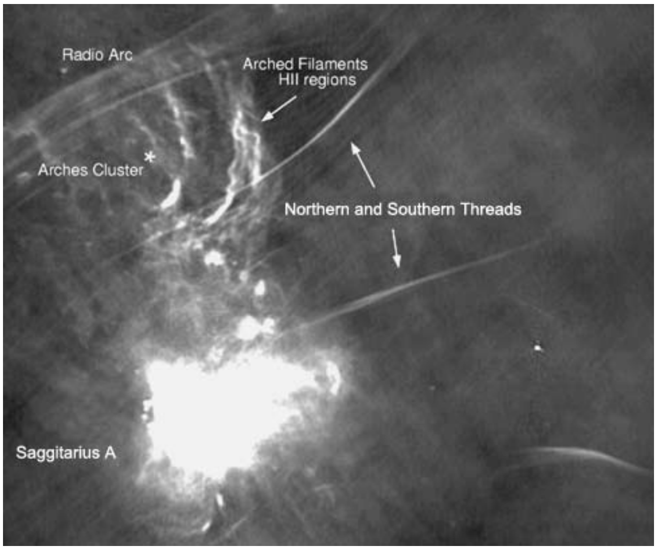
Alternatively, Schödel *et al*. suggest, these stars could be 'blue stragglers' (anomalously hot, bright stars) produced by smaller stars merging together. However, Genzel *et al*. find that, even with favourable assumptions, the most massive stars, e.g. the helium stars in the range 30–100 solar masses, could not have arisen in this way. Only stars containing up to about 10 solar masses and lying within a few tenths of an arcsecond of Sgr A*—members of the 'Sgr A*' cluster—fit the required parameters for this mechanism.

Infrared absorption lines have now been observed in the spectrum of one of the Sgr A* cluster stars (S2 or S0-2, the



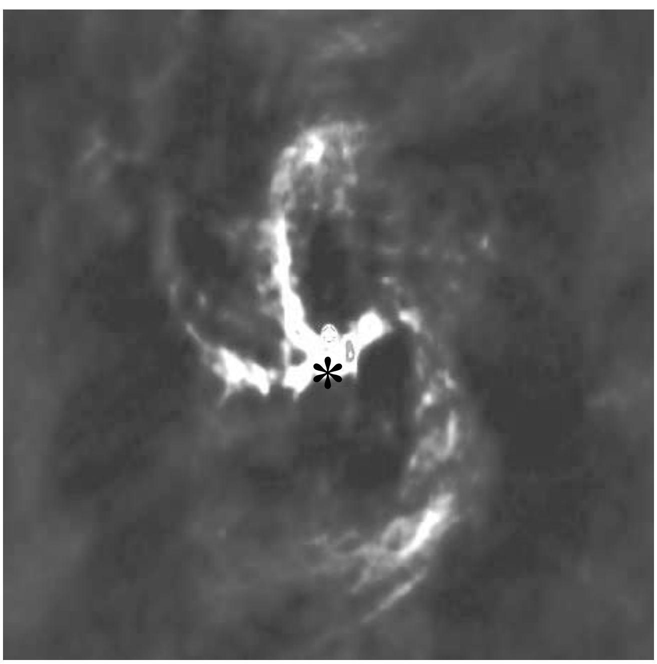
NRAO / AUI / NSF

Figure 2. *Wide-field VLA (Very Large Array) radio image (about 3° or 1,400 light-years wide) of the galactic centre at 90 cm wavelength. North is upwards and east to the left. Image courtesy of NRAO/AUI and N.E. Kassim, Naval Research Laboratory.*



NRAO / AUI / NSF

Figure 3. *VLA image (30 arcminutes or 230 light-years wide) at 20 cm wavelength of arched filament complex close to the galactic centre. North is upwards and east to the left.*



NRAO / AUI / NSF

Figure 4. *Radio continuum map (1.6 arcminutes or 12 light-years wide) of the Mini-Spiral at 3.6 cm wavelength. The bright arm which points from the centre toward the upper left and then turns upwards is the northern arm. The dot of emission just above the centre of the Spiral is Sgr A*. North is toward the left (roughly in the 10 o'clock position) and east downwards (7 o'clock position).*

closest to Sgr A* in 2002 and 2003), revealing that it is a main-sequence star of spectral type between B0 and O8.[19] Thus its surface temperature is about 30,000 K, its luminosity about 1,000 times the solar value and its mass about 15 times solar. Although there is insufficient information currently available to assign S2 to a stellar population type,[20] these findings pose a major problem in explaining its origin. It cannot have formed *in situ* because the density of the local interstellar medium is 10 orders of magnitude too small.[20] Because of its energy output, S2 must be less than 10 million years old, but the formation problems noted above still apply—tidal disruption when near Sgr A* and too long a migration time if formed elsewhere. Ghez *et al.*[11,19] make several suggestions to explain the observed characteristics of S2 in terms of interactions with other stars in its dense stellar environment, but conclude that none, including a sequence of mergers that would make it a blue straggler, are really satisfactory. The origin of the stars in the Sgr A* cluster as blue stragglers thus seems even harder to explain than the origin of blue stragglers in globular clusters.[21]

After a summary of the relevant issues, Hansen and Milosavljević[22] propose instead an additional black hole of a few thousand solar masses in a close binary orbit with Sgr A* to explain how the cluster stars might have reached their present locations within a few million years. However, Kim *et al.*[23] deem this scenario unlikely to produce the desired migration.

Following Morris,[17] Miralda-Escudé and Gould[24] estimate that around 25,000 black holes, each containing an average of about seven solar masses, must have migrated within 3.3 light-years of the galaxy centre over its uniformitarian lifetime. On this basis Alexander and Livio[25] try to explain the inward migration of the Sgr A* cluster stars through close encounters between black holes and stars, which would throw some of the latter into the very elongated orbits round Sgr A* which we observe. They claim that about 25% of the stars in question can be accounted for in this way, and that the true number is probably higher. However, their calculations assume an order of magnitude more black holes (150,000 within 2.3 light-years of Sgr A*) than predicted by Miralda-Escudé and Gould. Since Alexander and Livio's proposal would fail without this unjustified favourable assumption, it is unlikely that it explains the origin of the Sgr A* cluster. This remains a major problem for the uniformitarian paradigm.

This remains a major problem for the uniformitarian paradigm.

The prediction that thousands of stellar-size black holes cluster around the galactic centre is a natural consequence of the uniformitarian paradigm, but it has limited observational support. Muno *et al.*[26] have found four objects undergoing X-ray transients within three light-years of Sgr A*, and three more within 75 light-years. Such transients are normally associated with X-ray binaries, some of which probably contain black holes.[27] However, the transients observed by Muno *et al.* are atypical: both the maximum and the change in X-ray brightness are smaller than usual. Hence, these systems may not belong to recognized types, and may not contain the sought-after black holes. Furthermore, no attempt to look for similar objects elsewhere has been reported, so their general distribution in space is unknown.

More direct pointers to the predicted cluster of black holes include the distribution of mass close to Sgr A*, which can be probed by high-precision measurements of stellar orbits,[28] and the observation of gravitational lensing events in infrared wavebands.[24] Within the next few years, stellar orbital measurements should provide strong constraints on the mass distribution around Sgr A*, and thus test uniformitarian expectations. Creationists should follow the results with interest.

It is extremely difficult to explain the origin of the central star clusters within a uniformitarian framework, suggesting that they may have been created more or less where we see them now, and with similar physical characteristics to those we observe now. This view is consistent with the account of the creation of the stars in Genesis 1:16.

The Circumnuclear Ring

The Circumnuclear Ring (or disk) is inclined at an angle of about 60–70° from the face-on position. It consists of warm neutral gas (largely molecular and atomic hydrogen, neutral oxygen, carbon monoxide and hydrogen cyanide, with temperature in the range 300–2,000 K) orbiting the galactic centre at radial distances between about six and 25 light-years. It orbits approximately in the galactic plane with a typical velocity of around 110 km/s, though there are some marked irregularities in its shape and motion and the disk is significantly warped. The orbiting gas is subject to large, turbulent motions, the average velocity dispersion being about 55 km/s near the inner edge and 37 km/s at half-radius.[29] The inner boundary is much more sharply defined than the outer boundary, with a thin ring of ionized gas just inside the inner boundary.

Genzel and Townes[8] note that the ring is subject to various disruptive effects, each of which would render it unrecognizable well within a million years: (1) it contains gas clouds and a sharp inner edge, both of which are subject to tidal disruption and dispersion due to velocity differences. Neither radiation pressure nor thermal pressure from ionized hydrogen in the cavity inside the disk can maintain the sharp edge. Furthermore, stronger magnetic fields than those observed in this region would be required to maintain the integrity of the gas clouds against turbulent dispersion. The disk warp is subject to similar dispersive effects. Genzel and Townes cite a timescale of a few rotation periods, or a few times 100,000 years, for the disk lifetime against such effects; (2) The turbulent energy in the disk dissipates by ‘shock cooling’, which involves infrared radiation and submillimetre radio emission. The disk’s lifetime in years against these processes is given by Genzel and Townes as $8.5\times10^4/\eta$, where $\eta \leq 1$ is the efficiency of conversion of turbulent energy into radiation; (3) In the absence of forces pressurizing the central cavity, the lower-velocity gas at the inner edge of the disk will fall inward and thus eliminate the sharp density discontinuity there on a timescale of the order of 100,000 years.

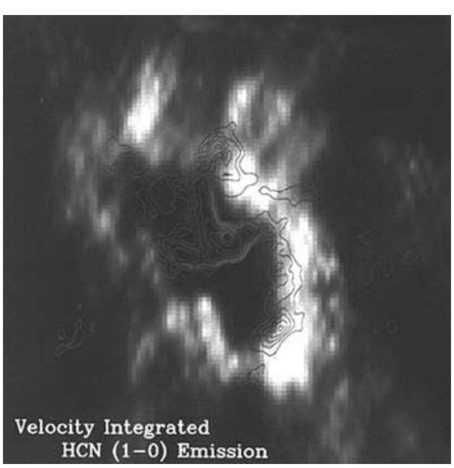


Figure 5. BIMA (Berkeley Illinois Maryland Association) radio map of the Circumnuclear Ring (2 arcminutes or 15 light-years wide) based on hydrogen cyanide emission at 6 cm wavelength. A map of shorter-wavelength emission is superimposed to show the location of the Mini-Spiral. North is upwards and east to the left. Image courtesy of Leo Blitz, University of Maryland. (Copyright©1995, Board of Trustees, University of Illinois.)

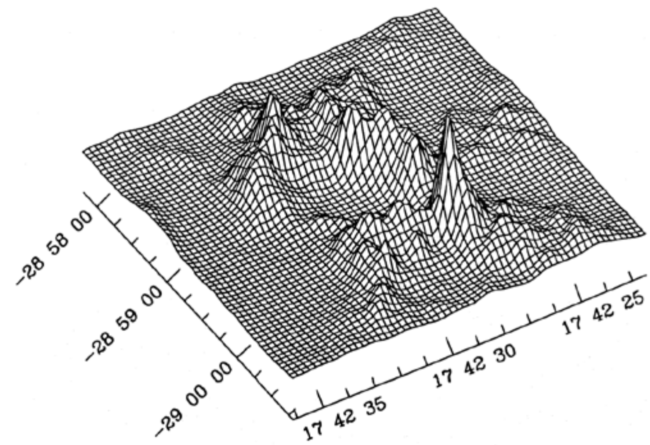


***Figure 6.** Relief representation of the velocity-integrated hydrogen cyanide line emission at 88.632 GHz (wavelength 3.38 mm) from the Circumnuclear Ring, based on Hat Creek observations. The numbers along the lower right give the Right Ascension (RA) and those along the left, Declination (Dec). RA and Dec are the celestial equivalents of longitude and latitude, respectively, RA increasing eastwards and Dec increasing northwards. The major axis of the Ring is about 2 arcminutes (15 light-years) long. (From figure 1 in Güsten* et. al.*, ref. 29.)*

Uniformitarian scientists do not assume stability of the Circumnuclear Disk for billions of years, but reject a lifetime measured in hundreds of thousands of years unless it is clear that the disk was produced by an identifiable event (e.g. a supernova), or as part of a long-term ‘cyclic’ process. Thus, Genzel and Townes suggest that the present disk configuration could last for longer than noted above if rotational energy was converted by ‘magnetic friction’ into turbulence. This would cause a gradual shrinkage of the disk. It would also cause the central cavity to fill with gas over a few million years, requiring a mechanism for removing the gas and a source of supply further from the galactic centre. Genzel and Townes suggest that the gas

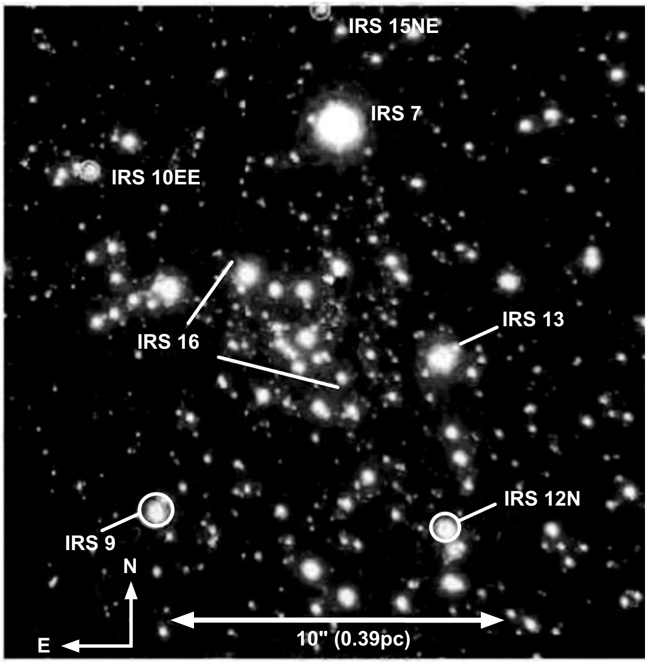


***Figure 7.** Processed infrared K_s band (wavelength 2.16 μ) image of the Milky Way's central 20 arcseconds, showing the IRS13 and IRS16 clusters. The position of Sgr A* is marked by two arrows. (After figure 1 in Genzel* et al.*, ref. 14.)*

could possibly be supplied by the gas clouds within 30–300 light-years of the centre, or by mass-shedding giant stars in the vicinity. However, they clearly prefer the idea that the gas comes from a major explosion, possibly a supernova, which took place within the last 100,000 years. No details of any of these scenarios are given—certainly the idea of a supernova producing a large-scale rotating gas ring has no observational support.

An alternative model is that of Sanders,[30] who applies sticky-particle calculations to a gas cloud orbiting the galactic central mass with low angular momentum. After a simulated time of 850,000 years, he derives a gas distribution very similar to that observed in the disk. Although this result is not unduly sensitive to Sanders' initial conditions, he has to pick carefully the time chosen for comparing model predictions with observation; at later times the disk would shrink and the interior region would fill with gas as in the scenario considered by Genzel and Townes. Thus, if Sanders' model is at all relevant, it implies that the observed disk is due to a gas cloud which ventured near to the central mass at a particular point in the past, and it places an upper limit of about one million years on the age of the disk. Sanders also seeks to explain the presence and general features of the Northern Arm and central star clusters by a similar calculation for a smaller gas cloud starting closer to the central mass. Although his results look plausible, he assumes a smaller central mass (2.5 million solar masses) than indicated by recent observations,[31] and subsequent authors seem not to be impressed, generally preferring to invoke black holes and supernova explosions.[22,25]

In yet another approach, Vollmer and Duschl[32–34] have modelled the disk as a collection of interacting spherical gas-and-dust clouds orbiting the central mass—including clouds subject to both rotation and magnetic fields. Vollmer and Duschl claim that their model reproduces the disk's characteristics very well and that it implies a disk lifetime of order 10 million years. However, they have not accounted for all the destructive effects identified by Genzel and Townes, e.g. shock-induced radiative cooling. Furthermore, in their model, clouds falling from the disk towards the central mass would either disintegrate or form stars (which would then disperse) before getting sufficiently close to the centre to account for the star clusters there.[22,25] Thus, at best, their model is incomplete, since it would require *ad hoc* additions to account for the central star clusters.

A further strange characteristic of the region interior to the Circumnuclear Ring has been pointed out by Coker,[35] who estimates that the total supply of matter due to stellar winds in the inner few light-years surrounding Sgr A* is at least 0.001 solar masses per year, of which about 1% must be captured gravitationally by the central mass. However, observations indicate that the actual accretion rate onto Sgr A* is much lower than this and that the nearby gas density is 100 times lower than it should be if steady-state accretion is occurring. Coker concludes that accretion onto Sgr A* is not in equilibrium, proposing a 'binge and purge' episodic variation on timescales of order 100,000 years. His analysis implies that we are now seeing Sgr A* in an exceptionally 'low' state of accretion. This has an *a priori* probability of order 0.01; we are unlikely to be seeing it thus by chance.

These results imply that, if the Milky Way Galaxy really is billions of years old, seeing the Circumnuclear Ring just now is highly improbable unless either (i) the right sort of gas clouds turn up in the right place just at the right time or (ii) the right sort of supernova explosions occur frequently in just the right place, which also seems improbable. Furthermore, it has yet to be demonstrated that any of the proposed disk maintenance mechanisms can, or do, actually operate. In the absence of such supporting evidence, the existence of the Circumnuclear Ring, a coherent structure subject to several quantifiable disruptive mechanisms, can be taken to imply that the galactic centre may be much younger than its accepted uniformitarian age.

X–ray emission

Astronomers have known for over 30 years that the central plane of the Milky Way produces strong X-ray emission,[36–38] notably from the galactic centre. The earliest observations of this so-called 'galactic ridge' emission could not distinguish between a few extended sources and numerous point sources. Taken at face value, the observations indicated two or more extended components with different temperatures and different thicknesses perpendicular to the galactic plane.[39] However, the consensus of opinion in the

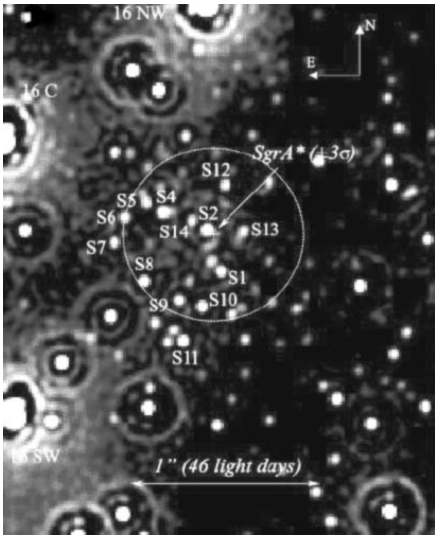


Figure 8. *Processed infrared H band (wavelength 1.65 μ) image of the Milky Way's central 2 arcseconds, showing the Sgr A* cluster—the star S2 is just to the north-east of the cross marking the position of Sgr A*. (From figure 3 in Genzel* et al. *ref. 14.)*

1970s and 1980s was that the ridge emission was largely due to unresolved point sources, not least because significant populations of candidate sources had been identified. These included hot Wolf-Rayet and O-type stars, cataclysmic variable stars (CVs),[40,28] low-mass X-ray binaries, pulsars, 'young' stellar objects and supernova remnants. A recent catalogue of such sources near the galactic centre is given by Muno *et al.*;[41] the most important hard[42] sources seem to be mass-accreting white dwarf stars in magnetic CVs, and accreting neutron stars in pulsars.

Recent high-resolution observations of a galactic centre field using the orbiting X-ray observatory *Chandra* now seem to have settled the question of whether the emission comes largely from a few extended sources or numerous point sources. After careful accounting for over 2,300 point sources in their 17 arcminutes square field of view[43] centred on Sgr A*, Muno *et al.*[44] conclude that most of the X-rays originate as diffuse plasma emission. The plasma appears to have two main components, one in thermal equilibrium at a temperature of about nine million K (the 'cool' or 'soft' component), and the other at about 90 million K (the 'hot' or 'hard' component), though neither has a uniform temperature. X-ray emission intensities for these two components are correlated, but spatial variations in the hard component are less marked than in the soft component (see figure 9 for an X-ray emission map; point sources are marked with circles).

Such high temperatures immediately raise the question of how the emitting material could be heated. Muno *et al*. suggest that the soft component is probably heated by supernovae and hot stars, mainly the former. They estimate that within the inner 65 light-years of the galaxy[45] the supernova contribution could be provided by 1% of the kinetic energy released by one explosion every 300,000 years. According to Muno *et al.,* this does not raise any serious difficulties, but the energy source for the hard component is much more problematic. To begin with, supernovae and hot stars are not known to produce temperatures above about 35 million K. How, then, can they heat plasma to nearly three times this temperature? Furthermore, plasma at 90 million K contains such energetic ions that it is not bound by the gravitational field of the galaxy, and hence would form '… a slow wind or fountain of plasma'.[46] They deduce that the hard plasma component must be undergoing adiabatic expansion away from the galactic centre, a process with a power requirement of 10^{31} watts arcmin^{-2}, four orders of magnitude more than needed to sustain its X-ray output. The corresponding figure for the soft plasma component, which would also expand, despite being gravitationally bound to the galaxy, is 3×10^{29} watts arcmin^{-2}, 300 times more than its X-ray output. The corresponding cooling times[47] are 6,000 years for the hard plasma component and 20,000 years for the soft component. In view of these relatively short cooling times, a good explanation of how the plasma components are heated, especially the hard component, is mandatory for the uniformitarian paradigm.

Muno *et al.* estimate that for the hard plasma component to be heated entirely by supernovae, it would require the entire kinetic energy of one supernova every 3,000 years. The resulting plasma outflow from the inner 65 light-years of the galaxy would equal all the mass ejected by supernovae exploding at this unprecedented rate. Muno *et al.* also note that the hard, diffuse X-ray emission is observed throughout the galactic ridge, and so cannot be associated specifically with the Sgr A* central mass. So, taking a step back from the 'hot plasma in thermal equilibrium' model, what could be producing the hard component of the diffuse X-ray emission? One possibility is *magnetic reconnection*—essentially, the mechanism thought to be responsible for heating the solar corona. In the present context it could result from turbulence generated by supernovae in the interstellar medium as suggested by Tanuma *et al.*[48] These authors propose that the hard galactic ridge emission can be explained by this mechanism if the local magnetic field strength reaches about 30 microgauss. Muno *et al.* recognize that such values are possible but note that near the galactic centre the field is predominantly vertical (at right angles to the galactic plane) and would allow plasma to escape in this direction. However, the resulting plasma fountain or wind is not observed, which would seem to rule out this form of heating if steady-state conditions are assumed.

Another suggested mechanism involves non-thermal processes due to supernova shocks, e.g. the interaction of relatively low-energy cosmic rays with the galactic interstellar medium. However, this is dismissed by Muno *et al.* on several grounds, not least the inefficiency of such a process in generating the observed X-rays. A more efficient source for the hard diffuse emission would be a quasi-thermal plasma due to the propagation of supernova shocks through the soft plasma component.[49,50] However, available models of this process do not predict X-ray spectra

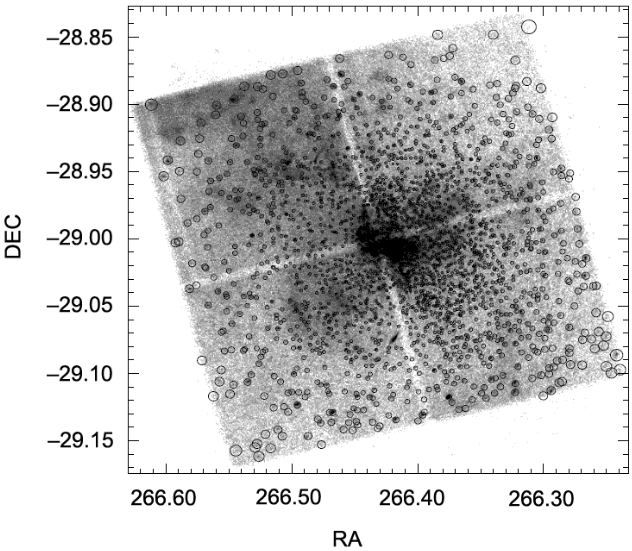


Figure 9. *Raw image of X-ray counts with point sources, removed for the purpose of analysis, shown ringed. The accompanying numbers are RA and Dec, as in figure 6. (After Muno* et al.*, ref. 44, fig. 1.)*

consistent with the *Chandra* data; the observed spectrum, which contains well-defined emission lines of iron and other elements (figure 10), bears a very close resemblance to that of a plasma in thermal equilibrium at 90 million K, thus challenging all such non-thermal models.

The X-ray spectrum of the faintest detected point sources in the galactic central field resembles that of a very hot plasma in thermal equilibrium. Hence, Muno *et al.* evaluate the possibility that faint, hitherto undetected, point sources are responsible for the hard 'diffuse' emission. They conclude that far too many such sources, whether CVs or young hot stars, are required to be consistent with estimates of their populations near the galactic centre. Other candidate sources would either be too faint (e.g. isolated neutron stars accreting mass from the interstellar medium) or produce too soft a spectrum (e.g. RS CVn variable stars[51]). Only a population of hitherto unknown sources could fit the bill.

A reasonable conclusion would be that the source of the hard diffuse X-ray emission from the galactic centre, and probably also from the entire galactic ridge, is best modelled as an extended plasma in thermal equilibrium at about 90 million K, as all proposed alternatives are inadequate in some way. Furthermore, there is no suggestion in the professional literature that this emission is a transient phenomenon. However, we have seen that the inferred plasma is unsustainable on timescales longer than tens of thousands of years; it would escape from the galactic plane and cool at the same time. A simple solution to the problems posed by this result is that the hot galactic ridge plasma, and indeed all associated objects near the galactic centre, are much younger than their assumed uniformitarian age of billions of years.

Discussion

Readers may object to the above arguments on the ground that other aspects of the galactic centre point to great age. Thus, being about 26,000 light-years distant, it must, the argument goes, be at least 26,000 years old, well in excess of the 6,000 years since creation, which can be deduced from a straightforward reading of the biblical data. Furthermore, the region contains star clusters, the members of which have evolutionary ages measured in millions of years, while the CVs catalogued by Muno *et al.*[41] contain white dwarf stars with evolutionary ages measured in billions of years. A further general argument in favour of great age is that the galactic centre is part of a large, coherent system, the Milky Way Galaxy, which has a natural dynamical timescale of order 100 million to 1 billion years.[52]

There are two distinct, though not unrelated, issues to consider in addressing these arguments. The first is the 'distant starlight' problem, i.e. how can we observe objects more than 6,000 light-years away if the universe was created only 6,000 years ago, as implied by Genesis 1? Any proposed solution must be completely general and must therefore apply to the galactic centre as well as the rest of the universe. In recent years approaches to solving this problem for the original creation have been suggested by Humphreys,[53,54] Newton[55] and Hartnett[56] among others. It is not the purpose here to evaluate these models in detail, except insofar as they impact the subsequent discussion. However, we note in passing that adding 26,000 years to the age of the galactic centre as observed does not relieve uniformitarian science of the problems posed by the evidences of youth described above.

The second issue which arises in a creationist framework is that of apparent age. Just as Adam and Eve were evidently created as adults, not babies, so we may expect many things in God's original creation to have been created fully functioning and bearing signs of apparent age without the (now obvious) degeneration due to the Fall. Applying the apparent age principle to the stars created on Day 4 of Creation Week, we may suppose that they could originally have been visible in a familiar variety and with a distribution across the sky similar to that observed today, though there would have been differences of detail (for example, the constellations would have looked different because of stellar proper motions over the intervening 6,000 years).

Thus, the Milky Way could have been created essentially as we see it now, including its spiral arms, X-ray–emitting gas, Circumnuclear Ring, white dwarf stars, neutron stars, and so on. Indeed, the cosmologies proposed by Newton and by Hartnett allow billions of years of stellar evolution (in a cosmic timeframe) prior to the end of Day 4 of Creation Week, though this time corresponds to no more than a few hours in the terrestrial timeframe with which Genesis is concerned. In both of these cosmologies we would thus

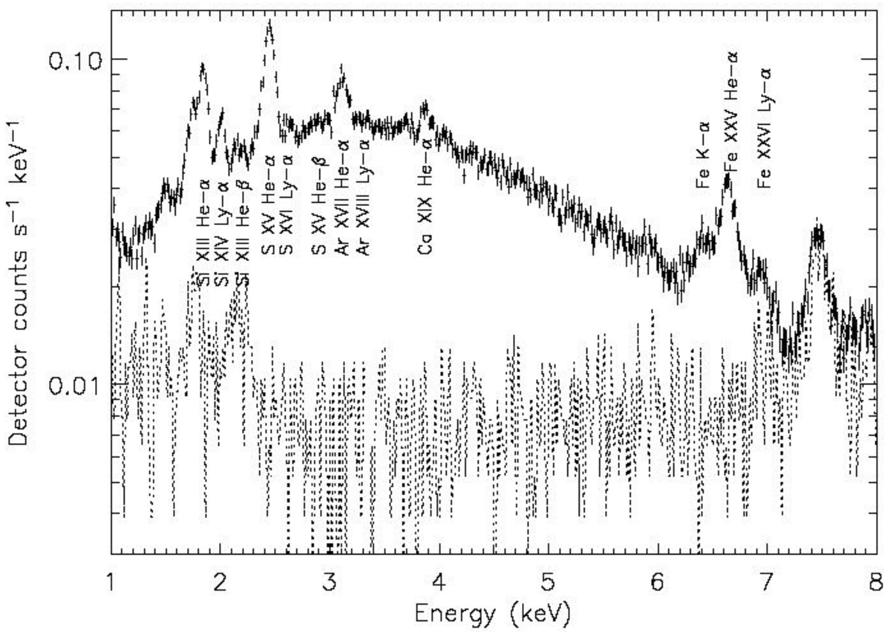


Figure 10. *X-ray energy spectrum of the diffuse emission from the south-east dark region of the field. Instrumental background is indicated by the grey dashed line. Several identified emission lines are clearly visible above the thermal continuum. (From Muno* et al.*, ref. 44, fig. 5.)*

expect to find white dwarf stars and neutron stars among the stars at creation.

However, white dwarf stars and neutron stars are 'dead' objects in the sense that they represent end-points of stellar evolution and do not produce energy by internal fusion reactions. Some would thus argue that they must have formed post-Fall, being unworthy of God's original 'very good' creation.

A possible way of meeting this objection is to postulate that the originally created progenitors of these stars underwent a massively-accelerated evolution, either at the time of the Fall or the Flood, or in between. This accelerated stellar evolution might conceivably be linked to the accelerated nuclear decay proposed in the RATE project.[57]

However, an obvious problem with this suggestion is the vastly increased stellar energy output we would expect; this could have led to the destruction of the earth (if the sun participated). The rapid self-destruction of stars implies a vastly increased supernova rate, resulting in the swamping of night-times on Earth by vastly enhanced starlight (if the sun did not participate), and much more.

Humphreys[57] counters this problem for the earth by suggesting an expansion of space as a major sink of energy, but applied to the stars, this idea is subject to the severe constraint that expansion redshifts within the Milky Way are not observed.

Another issue is light-travel time. For accelerated nuclear decay rates on Earth and accelerated stellar evolution to occur simultaneously as seen by a terrestrial observer, there must have been, to a distant cosmic observer, an 'acceleration wave' travelling inwards toward the earth at the speed of light. This would be similar to the edge of the creation process in Newton's cosmology as it travels inwards toward the earth at the speed of light.

Clearly, to develop a coherent model of accelerated stellar evolution which satisfies all the constraints is challenging, and is beyond the scope of this paper. The alternative for those who regard the above definition of 'dead' stars as arbitrary is to recognize white dwarfs and neutron stars as part of the original creation. Either way, the evidences of youth described above challenge the uniformitarian view of the galactic centre.

A special place in the universe

At this point we may ask, 'What is the significance of the particular form and structure we observe in the Milky Way, with respect to our understanding of Creation as a whole?' In other words, why did God create it thus? It is an impressive sight and can turn human thoughts towards God as it has throughout history. Furthermore, stellar orbits in a spiral galaxy are more ordered and regular than in an elliptical or irregular galaxy, which means, for a given space density of stars, that dangerous encounters with other stars are less common. The sun has a stable, almost circular, orbit at a safe distance from the hostile environment of the galactic centre, thus helping to provide suitable conditions for life on Earth.[58]

We might also ask whether the wealth of discoveries we are now making about our galaxy are meant to teach us anything about God, given that they have been unknown for most of human history. In general terms the sheer size, beauty and complexity of the Milky Way are perhaps intended to show modern man, who seems very inclined in his pride to think that he is approaching a complete understanding of the universe without God, that indeed his understanding is very limited, and that there is always more to the works of the Creator than he has ever realized (cf. Romans 1:20).

However, we may venture more specific points related to the galactic centre, in particular the mysterious central mass underlying Sgr A*. Ghez *et al.*[13] note that its total luminosity is only one-billionth of its Eddington limit, the theoretical upper limit beyond which the radiation from a spherically symmetric source will either destabilize the source or, in the case of an accretion-powered source, switch off the accretion process.[59] In contrast, some active galactic nuclei, notably quasars, are thought to radiate at, or even beyond, the Eddington limit.[60,61] Thus, given its size, the Milky Way Galaxy has a very quiescent central mass, a point emphasized by some researchers.[13,35] In a creationist framework this may be a sign that the Creator has honoured our home galaxy with a substantial central mass, while indicating that the galaxy is intended to support life in a not-too-hostile environment.

A further aspect is revealed by considering the *Magorrian relation*, a well-established correlation between the mass of a galactic bulge (M_B) in a spiral galaxy[62] and the mass of that galaxy's central dark mass (M_C), which is currently estimated at $M_C/M_B = 0.0012$. The data scatter in this result has been significantly reduced since the original measurements, and it has been found that active galaxies, including quasars and Seyfert galaxies, obey the same relation as quieter galaxies.[63]

The Magorrian relation is conventionally understood as constraining the formation and subsequent evolution of galaxies,[64] the inferred central black holes being understood as the remnants of former quasars or of galaxy mergers. However, Hartnett[12] has proposed that galaxies represent the later evolutionary stages of quasars ejected from other galaxies. In this case a relationship between the remaining central mass and the total mass of the galaxy or galactic bulge is again hardly surprising.

Since the bulge of the Milky Way has an estimated stellar content of about 10 billion solar masses,[65] it has a M_C/M_B ratio of less than ⅓ of the Magorrian value. This relatively low value of M_C/M_B for the Milky Way may thus indicate that its origin was special in some way. Further research, taking into account the special features of our galactic centre, may reveal how and why, in a biblical framework, our home galaxy is special.

In summary, just as God seems to have left a number of clues that the earth is actually much younger than the 4.6 billion years assigned by uniformitarian science,[66] so we may suppose that he has likewise left clues that the Milky Way is much younger than the 12–13 billion years assigned by the same paradigm. Although the arguments will doubtless change as astrophysical research progresses, perhaps the evidence described in this article represents some of these clues. I suggest that further research into the detailed structure of our home galaxy and its special features is needed, and should prove fruitful for creation science.

Acknowledgment

The author acknowledges extensive use of the online NASA Astrophysics Data System webpage, <adswww.harvard.edu/>, in the preparation of this article.

References

1. Estimates given in the literature vary considerably. See, for example: (1) Webb, S., *Measuring the Universe: The Cosmological Distance Ladder*, Springer–Praxis, Chichester, UK, 1999, who cites 30 kiloparsecs (about 100,000 light-years) for the diameter of the galactic disk; (2) Carroll, B.W. and Ostlie, D.A., *An Introduction to Modern Astrophysics*, Addison-Wesley, Reading, MA, pp. 916–919, 1996, who give 50 kiloparsecs. The galaxy also has a sparsely populated, roughly spherical halo of stars with about twice this diameter. Note that astronomical distances are usually quoted in parsecs, where the parsec is the distance of a star with a parallax of 1 arcsecond; one parsec is approximately 3.2616 light-years. In this article we will use light-years as these are familiar to a wider readership.
2. Reid, M.J., The distance to the center of the galaxy, *Ann. Rev. Astron. Astrophys.* **31**:345–372, 1993.
3. Eisenhauer, F. *et al*., A geometric determination of the distance to the galactic center, *Astrophys. J.* **597**(2):L121–124, 2003.
4. Becklin, E.E. and Neugebauer, G., Infrared observations of the galactic center, *Astrophys. J.* **151**:145–161, 1968. The extinction estimate of 27 magnitudes refers to yellow light of wavelength 0.55 micron.
5. See, for example, the professional-level electronic news service GCNEWS: *A Newsletter for Galactic Center Research*, sponsored by the US National Radio Astronomy Observatory, at <www.aoc.nrao.edu/~gcnews/index.shtml>, 7 January 2005.
6. The quoted age of the Milky Way is generally based on studies related to stellar evolution, notably in globular clusters. See, for example: Hansen, B.M.S. *et al*., Hubble Space Telescope observations of the White Dwarf cooling sequence of M4, *Astrophys. J. Supp.* **155**(2):551–576, 2004, which estimates the age of M4 as 12.1 billion years. See also: Pasquini, L. *et al*., Beryllium in turnoff stars of NGC6397: early Galaxy spallation, cosmochronology and cluster formation, *Astron. Astrophys.* **426**:651–657, 2004, which gives 13.6±0.8 billion years for the age of the Milky Way.
7. Tanner, A., A trip to the galactic center, *Sky & Telescope* **105**(4):44–50, April 2003.
8. Genzel, R. and Townes, C.H., Physical conditions, dynamics and mass distribution in the center of the galaxy, *Ann. Rev. Astron. Astrophys.* **25:**377–423, 1987.
9. Carroll and Ostlie, ref. 1, pp. 935, 968.
10. Maeda, Y. *et al*., A Chandra study of Sgr A East: a supernova remnant regulating the activity of our galactic center? *Astrophys. J.* **570**(2):671–687, 2002.
11. Ghez, A.M. *et al*., Full three dimensional orbits for multiple stars on close approaches to the central supermassive black hole, *Astron. Nachr.* **324**(S1):3–9, 2003.
12. Hartnett, J., Quantized quasar redshifts in a creationist cosmology, *TJ* **18**(2):105–113, 2004.
13. Ghez, A.M. *et al*., Variable infrared emission from the supermassive black hole at the center of the galaxy, *Astrophys. J.* **601**(2):L159–L162, 2004.
14. Genzel, R. *et al*., The stellar cusp around the supermassive black hole in the galactic center, *Astrophys. J.* **594**(2):812–832, 2003.
15. The IRS designation indicates sources of infrared radiation.
16. Metal-rich, in this context, means that there is a relatively high fraction (≥ 2% by mass) of elements heavier than hydrogen and helium; astrophysicists generally believe that these elements have been 'cooked' in the interiors of stars.
17. Morris, M., Massive star formation near the galactic center and the fate of the stellar remnants, *Astrophys. J.* **408**:496–506, 1993.
18. Schödel, R., Genzel, R., Baganoff, F.K. and Eckart, A., On the road toward a deeper understanding of Sgr A* and its environment, *GCNEWS*, vol. **17**, March 2004.
19. Ghez, A.M. *et al*., The first measurements of spectral lines in a short-period star bound to the galaxy's central black hole: a paradox of youth, *Astrophys. J.* **586**(2):L127–L131, 2003.
20. Ghez, A.M., private communication, January 2005.
21. Bernitt, R., Globular clusters and the challenge of blue straggler stars, *TJ* **16**(2):5–7, 2002.

22. Hansen, B.M.S. and Milosavljević, M., The need for a second black hole at the galactic centre, *Astrophys. J.* **593**(2):L77–L80, 2003.

23. Kim, S.S., Figer, D.F. and Morris, M., Dynamical friction on galactic center star clusters with an intermediate mass black hole, *Astrophys. J.* **607**(2):L123–L126, 2004.

24. Miralda-Ecsudé, J. and Gould, A., A cluster of black holes at the galactic center, *Astrophys. J.* **545**(2):847–853, 2000.

25. Alexander, T. and Livio, M., Orbital capture of stars by a massive black hole via exchanges with compact remnants, <xxx.lanl.gov/PS_cache/astro-ph/pdf/0403/0403425.pdf>, 13 April 2004.

26. Muno, M.P. *et al*., An overabundance of X-ray binaries within 1pc of the galactic center, <xxx.lanl.gov/PS_cache/astro-ph/pdf/0412/0412492.pdf>, 17 December 2004.

27. Hellier, C., *Cataclysmic Variable Stars: How and Why They Vary*, Springer–Praxis, Chichester, UK, 2001.

28. Mouawad, N. *et al*., Weighing the cusp at the galactic center, <lanl.arxiv.org/PS_cache/astro-ph/pdf/0402/0402338.pdf>, 4 January 2005. Accepted for publication in *Astron. Nach.*

29. Güsten, R. *et al*., Aperture synthesis observations of the circumnuclear ring in the galactic center, *Astrophys. J.* **318**:124–138, 1987.

30. Sanders, R.H., The circumnuclear material in the galactic centre: a clue to the accretion process, *M.N.R.A.S.* **294**:35–46, 1998.

31. See Ghez, A.M. *et al.*, refs. 11 and 19. Note that Sanders' model does not work for a central mass larger than his assumed value of 2.5 million solar masses.

32. Vollmer, B. and Duschl, W.J., A cloudy model for the Circumnuclear Disk in the galactic centre, *Astron. Astrophys.* **367:**72–85, 2001.

33. Vollmer, B. and Duschl, W.J., The stability of the Circumnuclear Disk clouds in the galactic centre, *Astron. Astrophys.* **377:**1016–1022, 2001.

34. Vollmer, B. and Duschl, W.J., The dynamics of the Circumnuclear Disk and its environment in the galactic centre, *Astron. Astrophys.* **388:**128–148, 2002.

35. Coker, R.F., The stellar winds of galactic centre and the low accretion rate of Sgr A*, *Astron. Astrophys.* **375**:L18–L21, 2001.

36. Bleach, R.D., Boldt, E.A., Holt, S.S., Schwartz, D.A. and Serlemitsos, P.J., X-ray emission from the galactic disk, *Astrophys. J.* **174**:L101–L106, 1972.

37. Worrall, D.M., Marshall, F.E., Boldt, E.A. and Swank, J.H., HEAO 1 Measurements of the galactic ridge, *Astrophys. J.* **255:**111–121, 1982.

38. Koyama, K., Makishima, K. and Tanaka, Y., Thermal X-ray emission with intense 6.7-keV iron line from the galactic ridge, *Publ. Astron. Soc. Japan* **38:**121–131, 1986.

39. Iwan, D. *et al*., A large scale height galactic component of the 2–60 keV background, *Astrophys. J.* **260**:111–123, 1982.

40. Warner, B., *Cataclysmic Variable Stars*, Cambridge University Press, Cambridge, 1995.

41. Muno, M.P. *et al*., A deep *Chandra* catalog of X-ray point sources toward the galactic center, <arxiv.org/pdf/astro-ph/0301371>, 9 July 2003.

42. In this context, 'hard' means that photon energies are relatively high, usually several keV (kilo-electron volts).

43. For comparison, the sun and moon each have angular diameters of about 30 arcminutes.

44. Muno, M.P. *et al*., Diffuse X-ray emission in a deep *Chandra* image of the galactic center, *Astrophys. J.* **613**(1):326–342, 2004.

45. The X-ray image studied in ref. 44 spans 17 arcminutes, which, at the distance of the galactic centre (26,000 light-years) corresponds to a width of 130 (= 2 × 65) light-years.

46. Muno *et al.,* ref. 44, Abstract.

47. Cooling time is here defined as the ratio of total thermal energy content of the plasma component divided by its rate of energy loss.

48. Tanuma, S. *et al.,* Magnetic reconnection as the origin of galactic ridge X-ray emission, *Publ. Astron. Soc. Japan* **51**:161–171, 1999.

49. Dogiel, V.A., Inoue, H., Masai, K., Schönfelder, V. and Strong, A.W., The origin of diffuse X-ray emission from the galactic ridge. I. Energy output of particle sources, *Astrophys. J.* **581**:1061–1070, 2002.

50. Masai, K., Dogiel, V.A., Inoue, H., Schönfelder, V. and Strong, A.W., The origin of diffuse X-ray emission from the galactic ridge. II. Nonequilibrium emission due to *in situ* accelerated electrons, *Astrophys. J.* **581**:1071–1079, 2002.

51. These are close binaries in which the cool star is thought to be spotty. They are chromospherically very active and produce copious coronal X-ray emissions. See Hoffmeister, C., Richter, G. and Wenzel, W., *Variable Stars*, Springer-Verlag, New York, 1985.

52. See Bertin, G*., Dynamics of Galaxies*, Cambridge University Press, p. 3, 2000. A guideline to this timescale is provided by the time it takes the sun to orbit the galaxy, which is about 200 million years.

53. Humphreys, D.R., *Starlight and Time*, Master Books, Colorado Springs, CO, 1994.

54. Humphreys, D.R., New vistas of space-time rebut the critics, *TJ* **12**(2):195–212, 1998.

55. Newton, R., Distant starlight and Genesis: conventions of time measurement, *TJ* **15**(1):80–85, 2001.

56. Hartnett, J.G., A new cosmology: solution to the starlight travel time problem, *TJ* **17**(2):98–102, 2003.

57. Humphreys, D.R., Accelerated nuclear decay: a viable hypothesis? Vardiman, L., Snelling, A.A. and Chaffin, E.F., *Radioisotopes and The Age of The Earth*, Institute for Creation Research, El Cajon, CA, and Creation Research Society, St. Joseph, MI, chapter 7, 2000.

58. Burgess, S., *He Made the Stars Also*, Day One Publications, Epsom, Surry 2001.

59. Frank, J., King, A.R. and Raine, D.J., *Accretion Power in Astrophysics*, Cambridge University Press, Cambridge 1992.

60. King, A.R. and Pounds, K.A., Black hole winds, *M.N.R.A.S.* **345**(2):657–659, 2003.

61. Pounds K.A. *et al*., A high velocity ionized outflow and XUV photosphere in the narrow emission line quasar PG1211+143, *M.N.R.A.S.* **345**(3):705–713, 2003.

62. For elliptical galaxies, M_B includes practically the entire stellar mass of the galaxy.

63. McLure, R.J. and Dunlop, J.S., On the black hole—bulge mass relation in active and inactive galaxies, *M.N.R.A.S.* **331**:795–804, 2002.

64. Richstone, D. *et al.,* Supermassive black holes and the evolution of galaxies, *Nature* **395**:A14–A19, 1998.

65. Carroll and Ostlie, ref. 1, p. 918.

66. See, for example, Morris, J.D., *The Young Earth*, Master Books, Colorado Springs, CO, 1994.

Bill Worraker has a B.Sc. (Hons) degree in Physics and a Ph.D. in Engineering Mathematics, both from the University of Bristol, U.K. He has experience of academic and industrial research into a wide range of fluid flow phenomena. Currently employed as a developer of industrial software, he has been an active amateur astronomer for over 20 years and has participated in collaborative professional–amateur observing projects on variable stars.