Quest for the moons of Krynn

by Darren J. Bellisle

…"I—I did th-think once, just for an instant, mind you, about how—er—how much fun and interesting and, well, unique it would be to—uh—visit a—uuh…um…"
"Um what?" Caramon demanded.
"A…mmmmmm."
"A what?"
"Mmmmmm," Tas mumbled.
Caramon sucked in his breath.
"A moon!" Tas said quickly.

—Dragonlance Legends, Volume III, *Test of the Twins,* Margaret Weis and Tracy Hickman

I agree with Tasslehoff: traveling to one of the moons of Krynn does sound like fun. Sadly, the laws of reality prevent me from hopping aboard the *Cloudmaster* or just, um, "borrowing" the Device of Time Journeying for a quick trip up there. Still, it *is* a fascinating idea…it appeals to the kender blood in me. (You see, my mother's third cousin twice removed by marriage on her father's side was the stepfather of Uncle Trapspringer's aunt's great-granddaughter…)

I digress.

Since *getting* to the moons of Krynn isn't possible, I decided on the next best thing: cranking out the numbers for them. There are lots of references to the white moon Solinari, the red moon Lunitari, and the black moon Nuitari throughout the Dragonlance novels and game books, but there isn't much hard data on their sizes and relative distances from Krynn. Believe me, I am *no* astronomer, and the average gully dwarf could probably calculate orbits better than me, but still, when the idea came to me, I couldn't let it go. So, with calculator in hand and books all over the place, I set out on a quest for the moons of Krynn. (Incidentally, if there *are* any ambitious gnomes out there with degrees in astrophysics, please feel free to double-check my calculations!)

Making some assumptions

Before I could even begin this Krynnish moonquest, I had to make several basic assumptions about the world of Krynn and its satellites:

1. *Krynn's size and mass are identical to the Earth's.* I've seen nothing in the books to suggest otherwise. Gravity seems to work the same, the days are just as long, the seasons are the same, the climate and atmospheric conditions seem to be the same, etc.
2. *Solinari is the same size as our own moon.* Just another assumption for convenience's sake: if one of Krynn's moons is the same size as our own moon, that will give us some real numbers to start working with.
3. *Solinari is the moon furthest away from Krynn.* Two sources back up this assumption: the Moon Tracking Chart on page 28 of the *Dragonlance Adventures* game book (assuming that the moon furthest away has the longest period), and the cover art of *Night of the Eye—Defenders of Magic Trilogy, Volume I.* The illustration clearly shows the three moons nearly in alignment, with Solinari behind the other two moons. (There is a snag here, but I'll get into that later.)
4. *All three moons follow elliptical orbits around Krynn.* There are many different types of orbital paths that they *could* follow (circular, elliptical, parabolic, hyperbolic, quasi-periodic, ergodic, and so on), but I will stick with Occam's Razor and go with plain vanilla ellipticals.

With these four assumptions in place, the number crunching can begin. The plan is to take existing data on our Earth–Moon system, apply it to the Krynn–Solinari system, adjust the numbers to establish the orbit of Solinari, and from *that,* extrapolate all the figures for the other two moons.

Collecting data

Substituting "Krynn" for "Earth" and "Solinari" for "moon," we get the following:

Krynn
Mass: 5.97×10^{24} kg
Radius: 6,378.15 km
Diameter: 12,756.30 km
Circumference: 40,075.10 km
Density: 5.52 g/cm^3

Solinari
Mass: 7.35×10^{22} kg
Radius: 1,738 km
Diameter: 3,476 km
Circumference: 10,920.18 km
Density: 3.34 g/cm^3
Avg. distance from Krynn: 384,400 km
Orbital period: *27.3 days*

Here's where reality and data clash: according to the Moon Tracking Chart, Solinari has a period of 36 days, not 27.3. In order for the initial calculations to get off the ground, we're going to have to shove Solinari further away from Krynn to increase its orbital period. The question is: how far away does it have to go?

Finding the formula

I found a formula for calculating orbital distances on the web, courtesy of G. David Nordley, Hugo award nominee and member of the American Institute of Aeronautics and Astronautics:

$$T = 1.4 \times \sqrt{\frac{r^3}{M}}$$

Where:

T = number of hours in the orbital period of the moon
r = distance of the moon from the planet, in Earth radii (1 radii = 6,378.15 km)
M = mass of the planet the moon is orbiting (M = 1 for the Earth)

For example, in the Earth–Moon system:

$$T = 1.4 \times \sqrt{\frac{(384{,}400/6{,}378.15)^3}{1}}$$

$$T = 655.03 \text{ hours, or } 27.3 \text{ days}$$

Oddly enough, this formula doesn't require foreknowledge of the mass of the moon. In order to figure out the correct orbital distance of Solinari, we just need to plug in slightly different numbers: we already know T = 864 (36-day orbital period × 24 hours/day), M = 1 (Krynn has the same mass as Earth), and a single Krynn radii: 6,378.15 km.

$$864 = 1.4 \times \sqrt{\frac{(x/6{,}378.15)^3}{1}}$$

$$x = 462{,}330 \text{ km}$$

This places Solinari at an average distance of 462,330 kilometers away from Krynn, about 78,000 kilometers further away than our own moon is from the Earth. Since we also know the periods of Lunitari (8 days, or 192 hours) and Nuitari (28 days, or 672 hours), we can use the same equation to find out *their* relative distances:

$$192 = 1.4 \times \sqrt{\frac{(x/6{,}378.15)^3}{1}}$$

$$x = 169{,}620 \text{ km (Lunitari)}$$

$$672 = 1.4 \times \sqrt{\frac{(x/6{,}378.15)^3}{1}}$$

$$x = 391{,}011 \text{ km (Nuitari)}$$

What's the order?

Reality clashes with the data again (the snag mentioned in assumption #3). If the moons furthest away from Krynn have the longest periods, then Solinari should be the furthest out, then Nuitari, then Lunitari. However, the *Night of the Eye* cover art clearly shows the moons lined up with Solinari furthest out, *then* Lunitari, with Nuitari closest to Krynn. This could be explained in a number of ways:

1. *The* Night of the Eye *cover art is wrong.* This would be the easiest explanation, except that the entire book is based on the premise that the moons, when aligned, look like a huge eye in the sky, with Solinari as the white, Nuitari as the pupil, and Lunitari as the (red) iris.
2. *One of the moons has an eccentric orbit.* Pluto's orbit, although elliptical, is eccentric, causing it to sometimes come closer to the sun than Neptune. (Pluto became the furthest planet from the sun again in 1999, and it will remain furthest out until the year 2227.) Could it be that either Nuitari or Lunitari have a similarly eccentric orbit, causing them to change their relative distances to Krynn? Hey, anything's possible, but I want to keep things simple, so instead, I'll go with the third option:
3. *The Moon Tracking Chart is wrong.* Think about it: with Neutrality as the balancing force between Good and Evil, wouldn't it make sense to have the "neutral" moon *between* the other two? Also, consider the descriptions of the Orders of Magic on pages 35–36 of the *Dragonlance Adventures* book:

—Wizards of the White Robes generally gain levels slower than their brothers
—A wizard of the Red Robes gains levels faster than his White-Robed brothers, but slower than his Black-Robed counterparts
—Black Robe wizards gain levels faster than either of the other to orders

Somehow, I find it *very* easy to equate the speed of progression through the Orders with the speeds of the moons through the heavens. (Even more poetic, now that I think about it, would be to have Solinari and Nuitari following orbits that would eventually cause them to collide, but Lunitari's presence *stabilizes* their orbits.)

For the purposes of this article, I will assume that Nuitari *is* closest, then Lunitari, with Solinari furthest out. It's a simple fix: we just give Lunitari the 28-day period and Nuitari the 8-day period.

Size matters

Okay, so we have the distances in place, and the "correct" order for the moons. How big are they?

This is the part of the number crunching that I am least confident about: there's a lot more guessing involved, and my primary data source is a not-guaranteed-to-be-100%-accurate picture. Still, the quest must go on!

The diagram at the bottom of this page shows a planet (x) with two moons (y and z). When the ratio of z's diameter to y's diameter is the same as the ratio of distance a to distance b, then, to an observer standing on x, z will appear to be the same size as y. (In the illustration, z's diameter is one-half that of y, and the ratio of a/b = ½.) For now, let's call this the Proportional Ratio (PR): when $a{:}b = z{:}y$, z and y appear to be the same size.

We can use this set of ratios, with Krynn as x and Solinari as y, to figure out the PRs for the other two moons:

distance b (from Krynn to Solinari) = 462,330 km
diameter y (Solinari) = 3,476 km
distance a for Lunitari = 391,011 km
distance a for Nuitari = 169,620 km

therefore

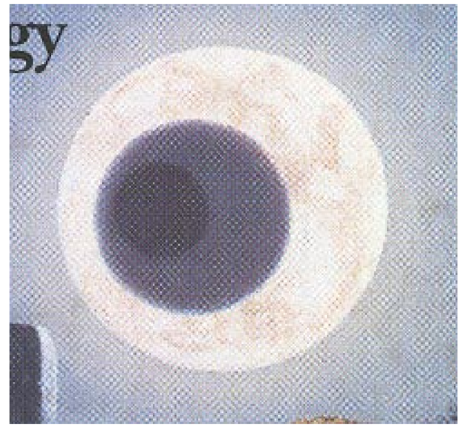
391,011/462,330 = PR Lunitari/3,476
PR Lunitari = 2,940

and

169,620/462,330 = PR Nuitari/3,476
PR Nuitari = 1,275

Using the orbital paths we calculated, we can see that *if* Lunitari's diameter = 2,940 km and Nuitari's = 1,275 km, then all three moons (to an observer on Krynn) would appear to be the same size.

However, as we can see in the illustration from *Night of the Eye*, the two inner



A portion of the cover art for *Night of the Eye—Defenders of Magic Trilogy, Volume I* (artwork © 1993 Larry Elmore). The three moons of Krynn are nearly aligned, showing their relative proportions.

moons look a lot smaller than Solinari. For the final part of the calculation, we need to measure the apparent diameters of the moons *in the picture,* and then apply those ratios to the PRs of Lunitari and Nuitari.

Solinari: 22.86 mm
Lunitari: 13.21 mm
Nuitari: 6.86 mm

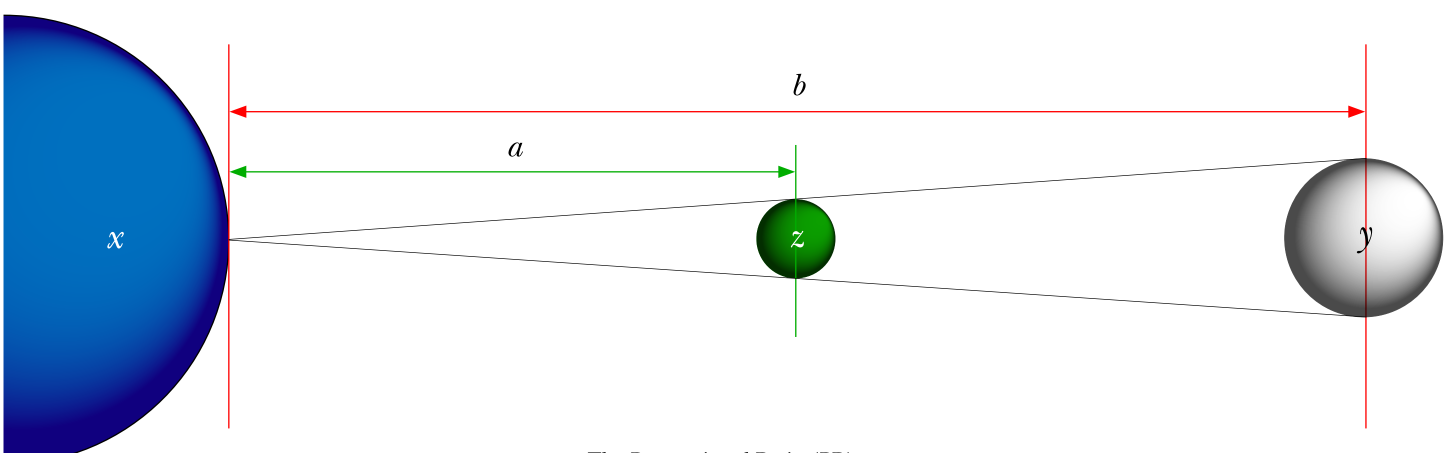
Ratio of Lunitari's apparent diameter to Solinari's = 13.21/22.86 = .58
.58 × PR of 2,940 = 1,705.2 km

Ratio of Nuitari's apparent diameter to Solinari's = 6.86/22.86 = .30
.30 × PR of 1,275 = 382.5 km

Using standard formulas and assuming uniform density, the table on the next page gives the statistics for all three moons. For comparative purposes, Lunitari is a little bigger than Rhea (one of the moons of Saturn), and Nuitari is a little smaller than Mimas, another of Saturn's moons.

Accurate?

I decided to use *Starry Night Backyard* (Space Holding Corp., Inc.) to test the accuracy of the calculations. It allows a user



The Proportional Ratio (PR).

THE MOONS OF KRYNN

Name	Radius	Diameter	Circumference	Orbital Period	Distance from Krynn	Volume	Mass (density = 5.52 g/cm^3)
Solinari	1,738.0 km	3,476.0 km	21,840.4 km	36 days	462,330 km	2.20×10^{19} m^3	7.35×10^{22} kg
Lunitari	852.6 km	1,705.2 km	5,357.0 km	28 days	391,011 km	2.60×10^{18} m^3	1.43×10^{22} kg
Nuitari	191.3 km	382.5 km	1,201.7 km	8 days	169,620 km	2.93×10^{16} m^3	1.68×10^{20} kg

to create their own planet–moon systems and view them at different speeds, dates, and from a variety of viewpoints. What made this program an ideal choice was that the numbers for the Sun, Earth, and Moon were already entered. All that was necessary was to rename Earth as "Krynn," duplicate the Moon and move it further out (to create Solinari), and then punch in the figures for the other two moons and let 'er rip. Sadly, the program doesn't allow you to edit or remove already-existing bodies, so Krynn actually had *four* moons during the simulation. I don't know how accurate *SNB*'s calculations are with regards to the gravitational fields of satellites affecting each other's orbits, but I kept my fingers crossed and said a quick prayer to Reorx.

I ran a 10,000-year-long simulation, and I am happy to report that in that span of time, none of the moons crashed into Krynn, or each other, and none of them spun off into the depths of space, either. Within the limits of my mathematical abilities and the software, I consider the experiment a success. As a final challenge, I created some pictures of how the sky might appear as seen from Krynn and its moons at a specific moment in time (1 A.M. GMT, 12/26/2003). I didn't go the extra step and include the other planets orbiting Krynn's sun (Sirrion, Reorx, Chislev, and Zivilyn) or any of the constellations, although that *does* sound like an interesting future project…does anyone know if gnomes do freelance work?

DJB

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Starry Night Backyard. © 2003 Space Holding Corp. http://www.starrynight.com/.

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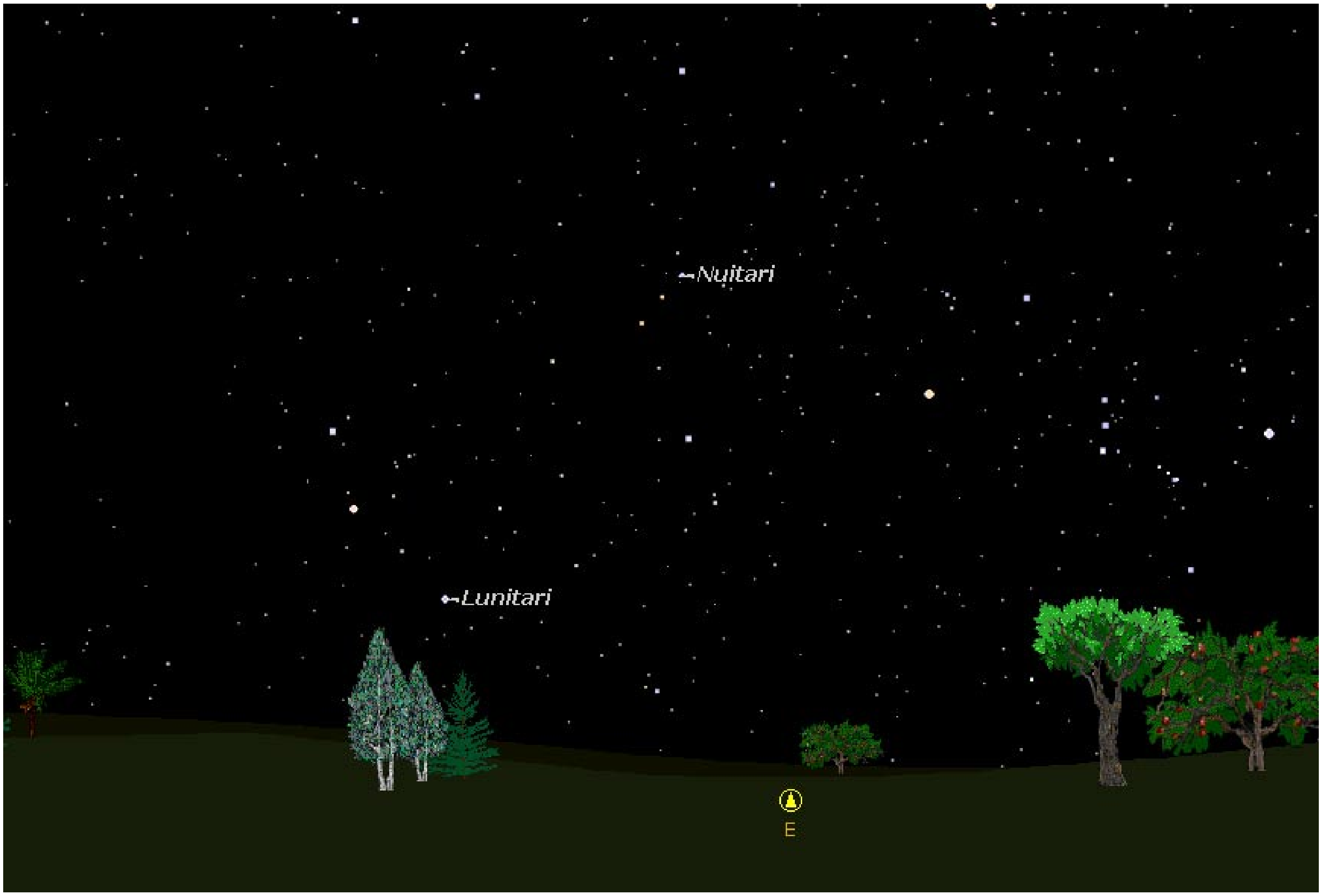

A partial view of the night sky over Krynn, as seen from latitude 43° 4.47´ N, longitude 89° 23.15´ W , at 1:00:00 A.M. GMT, 12/26/2003 (local time 7:00 P.M. 12/25/2003). Looking to the east, Lunitari and Nuitari are both visible; Solinari is below the horizon, and will not rise for another 3 hours and 59 minutes. The software used to generate this image, *Starry Night Backyard,* only shows the *positions* of the moons, not their apparent sizes.

Another view from the same location on Krynn, 4.5 hours later. Solinari is now visible rising over the eastern horizon.

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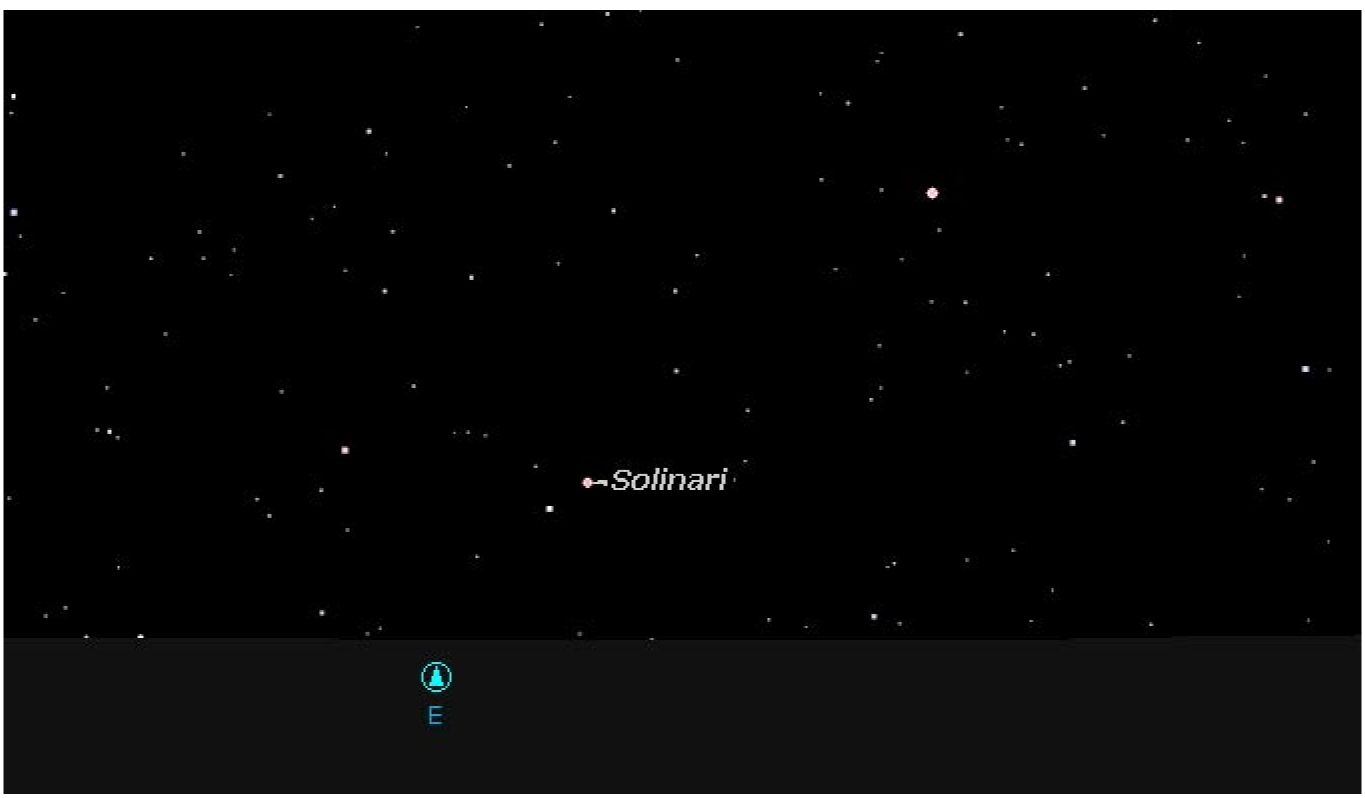
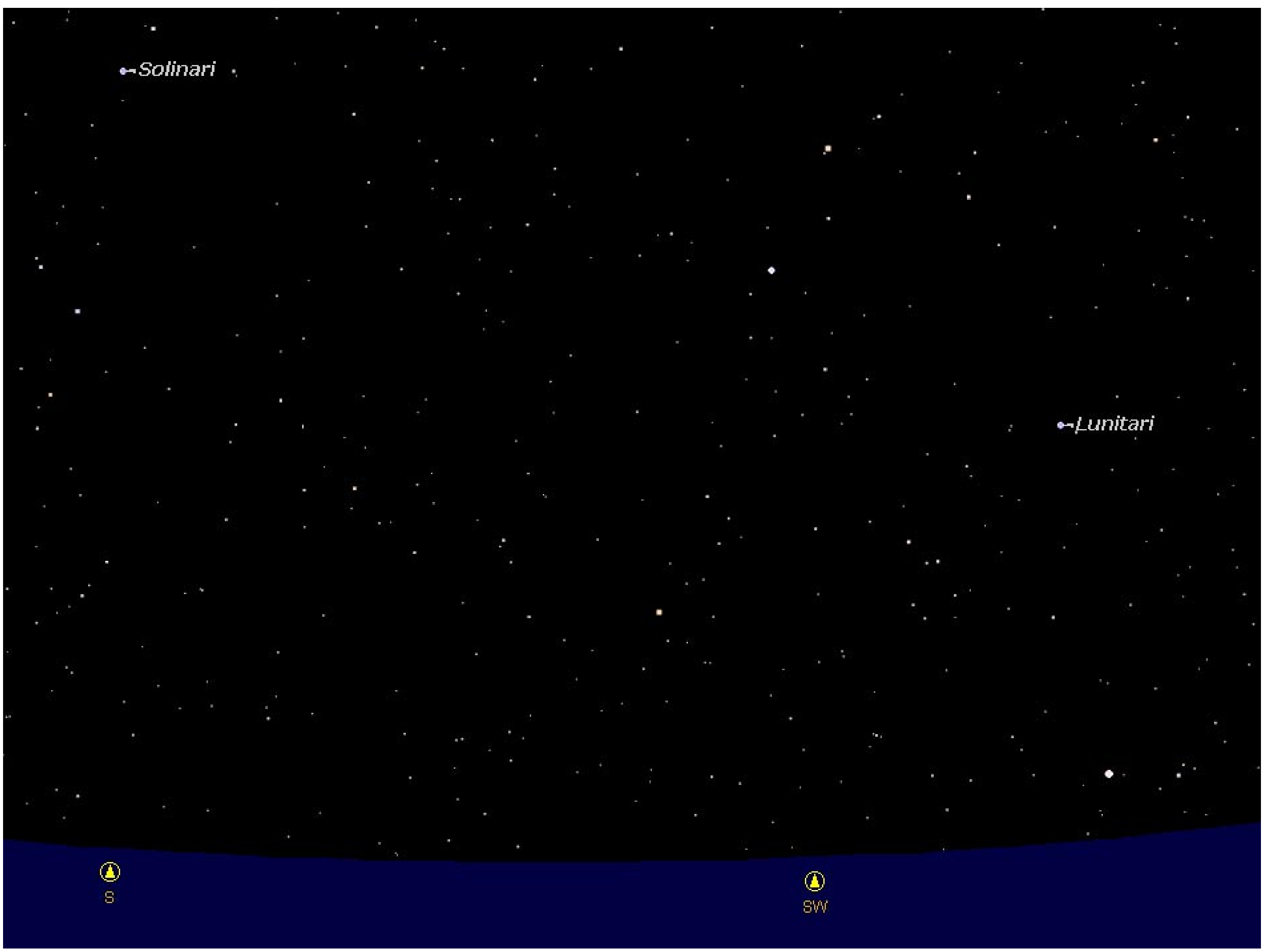
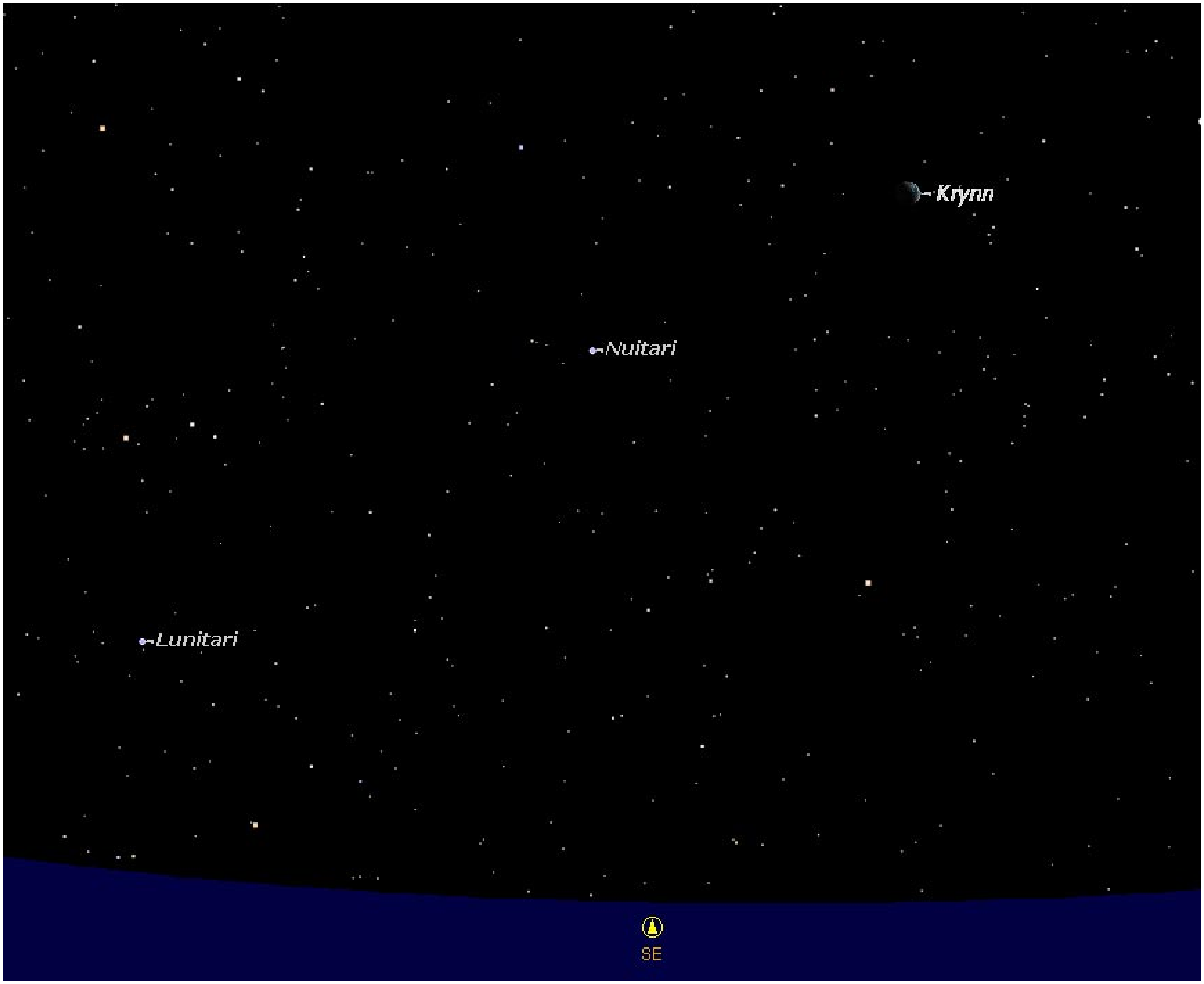


The sky as it appears from Lunitari (1:00:00 A.M. GMT, 12/26/2003). Only Solinari is visible; Krynn and Nuitairi are both below the horizon.

A dramatic view from Nuitari (1:00:00 A.M. GMT, 12/26/2003). Both Krynn and the Sun are low in the eastern sky; Solinari is high in the southern sky, and Lunitari is to the southwest (see figure below).





This final image is the view from Solinari, the outermost moon of Krynn (1:00:00 A.M. GMT, 12/26/2003). Lunitari, Nuitari, and Krynn are all visible, and are very nearly lined up with each other.