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The Music of the Spheres in Education: Using Astronomically Inspired Music

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Abstract

We list and briefly describe over a hundred pieces of classical and popular music inspired by reasonable astronomical ideas, and we discuss ways that instructors (and those working in informal settings) can use music to enhance an astronomy class or program. Written and Web-based resources for exploring astronomical influences in music are also provided.

1. Introduction

This article is part of a series discussing interdisciplinary approaches and resources in the introductory astronomy classroom. Previous articles in the series have covered the use of poetry (Fraknoi 2002) and science fiction (Fraknoi 2003). In the present article, we discuss ways to incorporate music in classes and labs. And, more than the other interdisciplinary topics, music can be used outside the classroom as well—in museums, summer camps, community fairs, youth groups, amateur club meetings, and other informal education settings.

The relationship between astronomy and music was explored in a series of four papers in the 1970s (Fraknoi 1977, 1979; Ronan 1975, 1976), but not much has been written about it in the recent educational literature. Laurie Reed gave a brief paper on the subject at *Cosmos in the Classroom* 2004 (Reed 2004), and the editors of *Physics Today* organized a showcase of songs inspired by physics and astronomy in their July 2005 issue. With the advent of CDs, MP3 files, and other technologies for formally disseminating and informally sharing music, it's probably time for a new look at what kind of music educators might find both useful and available.

2. Selecting the Music

When we discuss astronomically inspired music, we have a more restrictive definition in mind than do most of our students. To qualify for our list, a piece (or the composer's vision for it) has to include some real science and not just an astronomical term in the title or in a few lyrics. For example, we do not list "The Planets" by Gustav Holst because it treats the astrological view of the planets. Nor do we list the popular song "Black Hole Sun" by the group Soundgarden because the use of the term *black hole* is more an emotional than a scientific reference. On the other hand, we do include "Cygnus X-1" by the group Rush, which is full of correct scientific images about a black hole in an accreting binary system.

In the same spirit, we don't include the thousands of popular songs that use the Moon or the stars for an easy rhyme or a quick romantic image ("Blue Moon," "Stardust," and so on). And, although many jazz pieces have astronomy in the title, it is often hard to know just how the piece and the astronomy go together—so we've sadly omitted jazz too.

Despite these restrictions, we have found over a hundred pieces of music that make use of serious astronomy (see Appendix A). Most can be found on CD via one of the larger Web search services (such as amazon.com or arkivmusic.com). Because many pieces are being returned to circulation via CDs and music Web sites like Apple's iTunes every year, we list in Appendix B some that are out of print as well. We might note that for those with old-fashioned ears, like the author, no warranty is made that these pieces are easy to listen to, but each takes some key idea from astronomy and makes music out of it.

3. Using Music in Educational Settings

Many instructors have used astronomical music in their classes over the years. From discussions we have had with colleagues around the world, such use can generally be divided into four categories:

1. Some simply play some music with astronomy in the title as students walk in for a class period, and encourage them to discuss what the piece is. For this purpose, more familiar pieces are far better (even if they don't contain good science) than the mostly obscure pieces listed in the appendixes. Some instructors make a point of starting every class with an astronomical piece of music. For example, the lecture on the Moon may start with "Walking on the Moon" by the Police and the lecture on the scale of the universe with the "Galaxy Song" from Monty Python's *Meaning of Life*.
2. Others divide students into small groups and ask each group to come up with as many pieces of astronomical music as they can. Here, again, most instructors encourage students to go by the title (rather than serious scientific content). This can be a great ice-breaker to help students get to know each other in a first lab or section meeting. Some instructors bring Milky Way or Mars candy bars for the group that comes up with the largest number of pieces. You could have students continue this activity as homework, giving them a chance to consult their music collections and not just their memories. This activity was inspired by Dennis Schatz's (1987) more general article, "Astronomy in the Marketplace." He has used this activity in workshops since the late 1970s.
3. After having discussed the relevant astronomy, more ambitious instructors actually introduce a piece of music about the topic at hand right in the middle of class. They put some information (e.g., lyrics, composer's statement) on the screen, play an excerpt, and let students discuss how effective the use of astronomy seems to them. (See section 4 of this paper for a few stories about various pieces that have been effective in getting student discussion going.)
4. Instructors who assign a free-choice term paper for their introductory students sometimes allow the

option of a paper analyzing the science in one or more musical pieces. The paper has to have enough science in it—the student should discuss the astronomical background, speculate on the composer's or lyricist's intentions, and evaluate how successful the use of science in the music has been.

A few musicians have put together CDs of "educational" songs with good astronomy and physics, and these are listed in part 4 of Appendix A. For example, the Chromatics, a singing group based at NASA's Goddard Space Flight Center, offer a K–12 curriculum guide to the various doo-wop and easy-listening-type songs that they have created. Typical college students these days don't react as well to such old-fashioned songs as they do to their own kind of music, but the songs probably work better in the earlier grades. And if you ever get a chance to see "The Physics Chanteuse," a physics instructor who creates an entire cabaret show based on modern physics (also listed in Appendix A), she is a phenomenon not to be missed.

Appendix C gives further Web sites for astronomy and music in general, and includes some suggestions for finding unrecorded or unpublished astronomy and physics songs that your students might enjoy reading (and perhaps even performing). A last class or section meeting with astronomy music performances can certainly end the semester with a bang.

The author would welcome additional suggestions for how to use astronomy music in the classroom and for other pieces of music our lists have missed.

As we suggested above, there is no need to confine the use of astronomical music to the limits of space and time in a formal classroom. Colleagues in informal education have used astronomical music to accompany a booth at a community fair, to start a family workshop in astronomy, or as part of a planetarium show or museum demonstration. Having a session on astronomy and music (with examples at hand) can be especially effective in a summer or weekend camp that includes an astronomy unit or an astronomy walk. And some Web sites on astronomy now come with astronomy music soundtracks.

Note, however, that although a one-time use of a song in a class or museum probably meets the fair-use test of the current U.S. copyright law, one has to be careful to pay attention to copyright issues when using other people's songs or compositions on a Web site, in an ongoing show or program, and in other projects in which publishing or repeated public use is involved.

4. Some Examples of Interesting Music and Astronomy Connections

4.1 Solar System Music

Kepler had a deep conviction, as did the Pythagorean school of ancient Greek thought, that there was a connection between the mathematical regularities of the orbital motions of the planets and the regularities that give us a sense of harmony in music (Ronan 1976; Stephenson 1994 [Note 1]).

His work on the "harmony of the spheres" has inspired a number of composers over the years, particularly Paul Hindemith, who wrote an opera in 1957 called *The Harmony of the World*, which is now available on a Wergo CD set. In the opera, Hindemith explores the search for order in politics, science, and music through episodes in Kepler's life and thought. In the late 1970s, a geology and a music professor at Yale used a computer and sound synthesizer to construct a piece of music based on the instantaneous orbital speeds of the planets starting on Kepler's birthday in 1571 (Rodgers & Ruff 1979). You can purchase a CD on Ruff's own Kepler label (see Appendix A).

When the Voyager mission to explore the outer planets was being planned, Carl Sagan and Frank Drake got a group together to design an audio-video record to be placed on board both spacecraft. One part of the record was devoted to the "greatest hits of Earth," music from many cultures that would be representative of the best of our planet. Students often enjoy speculating about the committee's choices and making their own suggestions. The full list of music can be found in Sagan et al. (1978; see Note 2) or on the Web at <http://voyager.jpl.nasa.gov/spacecraft/music.html>.

In a similar vein, the European Space Agency commissioned a group of avant-garde musicians to place four pieces of music aboard the Huygens spacecraft that landed on Saturn's moon Titan (see the Music2Titan Web site in Appendix C).

4.2 The Music of the Stars

Appendix A includes a number of songs relevant to the study of stellar evolution. As you might imagine, rock musicians find the deaths of stars particularly fascinating, and such songs as Epidemic's "Factor Red" (about red giants), Pink Floyd's "Shine on You Crazy Diamond" (about white dwarfs), and Amanda Lear's "Black Holes" make for a nice break in class discussion.

There are also a number of pieces on our list that make use of constellation patterns. An especially bizarre example is *Atlas Eclipticalis* by the contemporary composer John Cage. The composer placed his music score right on top of old star maps and then put the notes where the dots corresponding to stars happen to fall on the page. (We don't endorse these ideas, folks, we just pass them on to you!)

4.3 Galaxy and Quasar Music

Fiorella Terenzi, who earned a Ph.D. in physics in Italy, has combined work in science and music, including an ongoing career as a performance artist. Her first CD, *Music from the Galaxies*, uses optical and radio data from galaxy UGC 6697 as the basis for some of the music. Another Ph.D. student who has moved completely over to the music side is Brian May, a member of the rock group Queen. He started his music career while he was an astronomy student in Britain. Queen's song "39" is about the loneliness of relativistic travel.

Back in the 1960s, there was a brief flurry of public attention paid to quasar CTA 102 because some claimed that its radio signals included coded information from an advanced civilization. There was nothing there, but the singing group The Byrds wrote a song entitled "CTA 102" on their *Younger than Yesterday* album.

Radio astronomer Eugene Epstein then thought it would be a lark to include the names of the Byrds in a reference in an article on CTA 102 in the *Astrophysical Journal*. He got it past the editors in proof stage (see vol. 151, p. L31, second paragraph), referring to the song as "private communication." He sent a note with the paper to Columbia Records, and eventually Roger McGuinn, the leader of the group, came to visit him and even attended a colloquium with him on the search for life elsewhere.

4.4 Cosmology Music

The year 1973 was the 500th anniversary of the birth of Copernicus, and a number of musical pieces were commissioned for the occasion. Perhaps the most intriguing is *Copernicus: Narrative and Credo* by Leo Smit, which includes a modern declaration of belief written and read by astronomer Fred Hoyle. Smit and Hoyle were friends who used to go mountain hiking together and have long conversations about speculative issues. One day, they talked about who would be more useful if transported to the far future: a modern-day physicist, like Hoyle, or a modern-day composer, like Smit. Hoyle continued to toy with the idea in his novel *October the First Is Too Late*, a working out in fiction of the many-worlds interpretation of quantum mechanics. Eventually, Hoyle and Smit gave lecture-concerts together, both in Europe and in America.

The Big Bang theory has provided inspiration for several classical pieces, usually those concerned with creation or genesis ideas. But by far the strangest is electronic composer Karl-Heinz Stockhausen's piece *YLEM*, named after the ancient Greek term for the primordial substance from which everything came (revived in our time by George Gamow.) The composition tries to convey the notion of the Oscillating Universe theory in musical terms. The players perform a Big Bang, clustered tightly together on stage, and then expand away from their position, much as the galaxies do. They come together again, play another bang, and then expand outward and go home.

For more such examples, see Fraknoi 1977 and 1979, and Ronan 1975 and 1976.

5. Conclusion

Some people claim that there is nothing that will destroy a student's enjoyment of music as quickly as dissecting it in a classroom. We don't agree. Over the years, students have cited the use of musical examples as memorable parts of introductory astronomy courses at several colleges and universities. For many students who come into an introductory science course feeling nervous and inadequate, the notion that classical or rock musicians are excited by some of the things they are learning in the course can be reassuring.

Who knows whom you might inspire in your introductory course. Estimates are that some 250,000 students per year take introductory astronomy in the United States and Canada alone. Among these non-science majors are sure to be some budding composers and lyricists. To the degree that our courses (or museum or camp experiences) make an impression on these young people, we are likely to have an increase in the number of musicians who help make a public connection between music and astronomy.

Notes

Note 1. Stephenson (1994) is a scholarly account of Kepler's metaphysical views.

Note 2. The record carried by the Voyager spacecraft includes a wide-ranging selection of Earth's music, and this book describes the process of selecting it. The record itself was briefly available in 1992 as a CD entitled *Murmurs of Earth* from Warner New Media. **Acknowledgements**

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Appendixes

Appendix A. Music Inspired by Serious Astronomy

Appendix B. Astronomically Inspired Music Not Currently Available on CD

Appendix C. Other Web Resources on Astronomy and Music

Appendix A.

Music Inspired by Serious Astronomy

This is not a comprehensive listing, but a sampling of some of the pieces that are currently available on CD and may be of particular interest to educators and astronomy enthusiasts. The company issuing the CD is given in parentheses, with the CD number when available. For classical music, an excellent listing of recorded pieces organized by composer can be found at <http://www.arkivmusic.com>. (Note that their prices tend to be higher than other online vendors and that used copies can sometimes be found for those on budgets.) Suggestions for additions to this list are most welcome and can be sent to the author at fraknoi@fhda.edu.

1. Classical Music

Applebaum, Mark. *Martian Anthropology*. (Innova 617). An electronic piece in which we are to imagine that scholars from Mars try to piece together the essence of our destroyed Earth civilization from three objects they dig up.

Bedford, David. *Great Equatorial*. (Voicepoint VP156CD). Electronic music commissioned for the 1993 renovation at the Royal Observatory in Greenwich. The composer writes that he "tried to imagine what it would be like to travel through the cosmos revealed by the first large telescopes"; and that he uses some of the harmonies envisioned by Kepler in thinking of the orbital speeds of the planets as the "music of the spheres."

Bedford, David. *Star Clusters, Nebulae, and Places in Devon*. London Philharmonic players. (Resurgence 11). A piece inspired by the idea that the Bronze Age people living in England would have seen the same sky as is visible to us today.

Bedford, David. *Star's End*. (Virgin CDV 2020). A piece written for orchestra and extra instruments and concerned with entropy and the heat death of the universe. Bedford has written several other astronomical pieces, including one called "Sword of Orion," which he says is based on actual observations through his own telescope.

Bentzon, Niels. "Chronicle on Rene Descartes" on *Contemporary Danish Orchestra Music, vol. 1*. Danish National Radio Symphony Orch. (BIS 79). The first movement is inspired by Descartes's ideas on "heavenly vortices."

Brant, Henry. *Orbits*. (CRI American Masters CD 827). Written for 80 trombones arranged in a semicircle (with organ and voice), this piece experiments with sound and space. For more on Brant, who has written many other pieces with astronomical themes, see <http://www.jaffe.com/brant.html>.

Brant, Henry. "Litany of the Tides" on *Henry Brant Collection vol. 3*. (Innova 410) During this complex piece, four sopranos sing science facts about the tides.

Cage, John. *Atlas Eclipticalis*. S.E.M. Ensemble Orchestra (Asphodel 2000). Cage put note paper on the pages of a star atlas and let the arrangement of the stars determine the pattern of the notes.

Crumb, George. *Makrokosmos I, II, III, IV* (many recordings exist). Modern piano music that extends the kinds of sounds that can be drawn from a piano and uses many astronomical (and astrological) references. On *I*, for example, the last piece is called "Spiral Galaxy," and the score is in the shape of a spiral. *II* has references to Stonehenge and Corona Borealis. *IV* is called "Celestial Mechanics." Crumb has done other pieces with astronomical references, including *Otherworldly Resonances*, *Night of the Four Moons*, and *Star Child*.

Del Tredici, David. *Syzygy* (Deutsche Grammophone 000141502). Partially inspired by the astronomical meaning of the title word: the alignment of celestial bodies.

Dessau, Paul. *Einstein*. Otmar Suitner, conductor. (Edel 0091092BC) An Eastern European opera from the early 1970s, focusing on Einstein's "decisions and their social consequences." The plot perpetuates the myth that Einstein was one of the "fathers of the atomic bomb" and has quite a bit of anticapitalist propaganda. Galileo and Giordano Bruno also make an appearance.

Eotvos, Peter. "Cosmos" on *IMA* (Budapest Music Center 085). This piece for two pianos includes a Big Bang, comets, asteroids, and meteorites, with the piece ending "a quarter of a second before the next big bang."

Glass, Philip. *Einstein on the Beach*. Philip Glass Ensemble, Michael Riesman, Conductor (Elektra Nonesuch 79323-2). A minimalist opera in which Einstein and his work serve as "mantras" for meditating on current events, mental illness, space, and time.

Glass, Philip. *Orion*. (Orange Mountain Music 21). Commissioned for the 2004 Olympics in Athens, this complex multicultural piece, played on instruments and performed by players from around the world, draws its inspiration from the different myths based on the constellation of Orion.

Gorecki, Henryk. *Symphony 2 (Copernican)*. Polish National Radio Symphony Orchestra. (Naxos 8.555375) Commissioned to celebrate the 500th anniversary of Copernicus's birth; includes some text from his book *De Revolutionibus*.

Handel, George F. "Total Eclipse": an aria from the oratorio *Samson* (many recordings). Poignant song comparing Samson's blindness with an eclipse of the Sun.

Haydn, Franz. *Il Mondo della Luna* on *Haydn Operas vol. 2* (Phillips 473851). 1777 comic opera involving an amateur astronomer who is tricked into believing that he is on the Moon.

Hindemith, Paul. *The Harmony of the World*. Berlin Rundfunk Symphony, Janowski (Wergo 6652 2). An opera, first performed in 1957, about the life and musical ideas of Johannes Kepler, who thought that there was an intimate connection between the harmony of planetary motions and the harmonies in music. (A symphonic suite has been drawn from the opera and is available separately.) (See <http://www.hindemith.org/E/summary.htm>)

Hovhannes, Alan. "Saturn" on *Magnificat* (Crystal 808). Hovhannes was a prolific Armenian American composer with hundreds of pieces to his credit. This piece for soprano, clarinet, and piano celebrates both the astronomical and mystical Saturn, with words by the composer. One section is entitled "Titan, Moon of Saturn."

Hovhannes, Alan. *Star Dawn*. Ohio State Concert Band, Keith Brion. (Delos DE 3158). About this piece, the composer wrote, "My life-long interest in astronomy has suggested the thought and hope that we may colonize Mars . . . the [title] phrase from Dante suggested traveling in space."

Howe, Mary. "Stars" on *American Treasures*. The Virginia Symphony. (Hampton Roads Classics HRC 001). A symphonic poem that "evokes the gradually overwhelming effect of a starry, crystal clear night."

Kamen, Michael. *The New Moon in the Old Moon's Arms*. Slatkin & the National Symphony. (Decca 289 467 631-2). Written for the Millennium, this symphonic poem was inspired by the composer's visit to Anasazi ruins in Arizona. The title refers to the smallest waning crescent moon. Most of the piece concerns the rituals and aspirations of the Anasazi, but the last section, entitled "Reaching for the Stars," takes the listener forward to the year 2000.

Kornicki, Steve. *Morning Star Rising* (available on at least two different CDs). An orchestral piece inspired by Mayan notions of astronomy, as discussed in astronomer Anthony Aveni's book *Conversing with the Planets*.

Langgaard, Rued. "Music of the Spheres" on *Music of the Spheres, etc.* Danish National Radio Symphony, Rozhdestvensky. (Chandos 9517). Based on a line from a Danish poem that goes, "The stars seem to twinkle kindly at us, yet the writing of the stars is cold and merciless."

Lehar, Franz. *Der Sterngucker (The Stargazer)*. German Chamber Academy of Neuss, Goritzki. (CPO 999 872-2). A 1916 operetta in which one character is an astronomer, but the term *stargazer* is also used to denote someone not in touch with reality.

Messiaen, Olivier. *Visions de l'Amen* (several CD versions are available). Piece for two pianos, combining astronomical and religious images. The first two views of the word *Amen* are the Amen of Creation and the Amen of the Stars and the Ringed Planet.

Messiaen, Olivier. *Illuminations of the Beyond* (several CD versions available). This mixture of religion and mysticism just barely makes our list, but the patterns in the section "Constellation of Sagittarius" breaks the orchestra into small groups representing the pattern of Sagittarius, and there is a motif that the composer calls "a nebula image." Those who have seen the score report that it has a frontispiece of galaxy and nebula photographs.

Miller, Kelvin, & Bach, J. S. *Winds of Mars and the Music of Johann Sebastian Bach*. Roderick Kettlewell, piano. (Music Crest MCPcd 0898). Wind data from the weather station of the Mars Pathfinder are converted into sounds and mixed with piano pieces by Bach. Comes with an informative booklet explaining the concept behind the music and the exploration of Mars. (See <http://www.windsOfMars.com/>)

Norgard, Per. *Luna (in 4 Phases) for Orchestra*. (Marco Polo Dacapo 8.224041). Based on aspects of the Moon, this piece was written by a composer who, like Kepler, has a strong interest in the relationship between astronomy and mathematics.

Parmegiani, Bernard. *La Creation du Monde (The Creation of the World)* (INA GRM C1002). Electronically created (electroacoustic) music that draws its inspiration from ideas of the Big Bang and the development of matter and structure from a chaos of "black light" or energy. The album cover has an image of Centaurus A. (See <http://www.scaruffi.com/avant/parmegia.html>)

Penderecki, Krzysztof. *Kosmogonia* (no current CD, but part of it was used in the soundtrack for David Lynch's 1990 film *Wild at Heart*). 1970 piece commissioned to mark the 25th anniversary of the United Nations, has two sections, Beginning and Infinity, and uses quotes from Copernicus, John Glenn, and the Bible.

Rands, Bernard. *Canti Trilogy* (Arsis 156). Accompanied vocal pieces with texts from several languages. "Canti del Sol" deals with a day from sunrise to sunset, "Canti Lunatici" is about the Moon as seen at night, and "Canti del L'Eclisse" treats both the astronomical and philosophical concepts of eclipse. (The first Canti won the Pulitzer Prize in 1984.)

Ruders, Poul. *Solar Trilogy* (Marco Polo Dacapo 8.224054). Symphonic poems based on astronomical (and other) ideas about the Sun. The three sections are called "Gong," "Zenith," and "Corona," and in his liner notes, the composer quotes from a popular book about the Sun by astronomer/science popularizer John Gribbin.

Ruff, Willie, & Rodgers, John. *The Harmony of the World* (Kepler CD). A computer-synthesizer realization of Kepler's music of the spheres, with the notes for each planet determined by its relative velocity in orbit. (Available through <http://www.willieruff.com/>, where you can also find liner notes.)

Smit, Leo. "Copernicus: Narrative and Credo" on *American Masters Leo Smit Collection* (CRI CD 826). With text by astronomer Fred Hoyle. Written in honor of the 500th anniversary of Copernicus's birth; contains a moving declaration of cosmic belief from Hoyle. This collaboration is also featured in *October the First Is Too Late*, Hoyle's novel about a physicist and a composer in the future.

Stockhausen, Karlheinz. *YLEM*. London Sinfonietta. (Stockhausen Verlag CD ST121-2). A piece that takes its title from the ancient Greek term for primeval material, which was revived by George Gamow and tries to portray the oscillating universe in musical terms. Players "expand" through the concert hall, return to the stage, and then expand again. (See <http://www.stockhausen.org/ylem.html>)

Tanaka, Karen. *The Zoo in the Sky* (RCA/BMG BVCC-1094). Subtitled "piano pieces for children with small hands," many of these bear the title of a well-known constellation, while four are entitled "Star Song."

Terenzi, Fiorella. *Music from the Galaxies*. (Island 422-848 768-2). Electronic music based on a digitized visible-light and radio data set from active galaxy UGC 6697. Selections include "Plasma Waves," "Radio Core," and "Galactic Beats." Terenzi, a composer and performer, has done work in astrophysics for her doctorate.

Van de Vate, Nancy. *Distant Worlds; Dark Nebulae*. (Vienna Modern Masters 3008). The composer says that these two pieces were influenced by looking at astronomical and space imagery, among other things.

Varese, Edgard. *Ionization* (found on several CDs, including the Pierre Boulez version on Sony 45844). The iconoclastic 20th-century French American composer Edgar Varese tried to expand the vocabulary of music by including new and different sounds and soundmakers in his pieces. This 1931 composition for 35 percussion instruments and two sirens tries to evoke the process by which atoms lose their outer electrons. (Varese also wrote an opera on ideas by Jules Verne and a piece called "The Astronomer," but these have not been recorded.)

Waterhouse, Graham. "Hale-Bopp" on *Portrait 2*. English Chamber Orchestra. (Meridian CDE 84510). This 1997 piece celebrates the bright comet with scoring that the composer says "evokes an other-worldly atmosphere." It ends with the 16th-century chorale tune, "How Brightly Shines the Morning Star."

Wuorinen, Charles. *Genesis*. (Albany 678). A modern cantata which meditates on creation, and includes a section called "Cosmology" with a Big Bang.

2. Popular Music

Black, Frank. "Places Named After Numbers" on *Frank Black*. (Electra WEA 61467). This is a love song to a black hole, with lyrics such as "And though it seems from here, That she was never there, Light beams disappear, Into her blackened hair."

Byrds. "CTA 102" on *Younger than Yesterday*. (Sony 64848). About a quasar whose radio signals were briefly claimed to include coded information—possibly from an advanced civilization.

Clannad. "Sirius" on *Sirius*. (RC 6846). Enigmatic lyrics appear to be about fleeing the Earth as the Sun becomes a red giant, and trying to reach Sirius.

Cowboy Junkies. "Crescent Moon" on *Pale Sun Crescent Moon*. (RCA 66344). A bluesy rock song that uses images with the phases of the Moon.

Epidemic. "Factor Red" on *Decameron*. (Metal Blade CD). Song about a red giant star. It begins, "Retinas burn, as my eyes raise towards the dying star, Half devoured sky bleeds red, the death of a star has begun. . ."

Gamma Ray. "Beyond the Black Hole" on *Somewhere Out in Space*. (Noise 283). Interesting lyrics about a survivor of a civilization whose star has died diving into a black hole.

Grateful Dead. "Dark Star" on *What a Long Strange Trip It's Been*. (Warner Brothers 3091) [and other CDs]. The song begins, "Dark star crashes, pouring its light, into ashes" and has a memorable line about going through "the transitive nightfall of diamonds." Its sometimes surrealistic words definitely conjure up a number of images of star death.

Hawkwind. "Quarks, Strangeness, and Charm" on *Quarks, Strangeness, and Charm*. (Griffin 132). Humorous song using lots of science ideas (relativity, antimatter, quarks). Makes the mistake of saying Copernicus used a telescope, but the rest is fun.

Iron Maiden. "When Two Worlds Collide" on *Virtual IX*. (Sony). Heavy metal song about cosmic impacts; lyrics include mentions of telescopes, declination, orbit calculations.

Knopfler, Mark. "Sailing to Philadelphia" on *Sailing to Philadelphia*. (Warner Brothers 47753). A song about Mason and Dixon and their surveying expedition; refers to the fact that Mason was an astronomer.

Lear, Amanda. "Black Holes" on *Never Trust a Pretty Face* (1979; song also available on some imported greatest hits CDs). Compares an all-consuming love to a black hole; lyrics include, "Like a black hole in the sky, You crush me from your universe, What you want you just erase without a trace, Like a fantastic goodbye."

Melua, Katie. "Nine Billion Bicycles" on *Piece by Piece*. (2005 CD released in England, single available by import). As part of a series of large numbers used to describe her love, she mentions the size of the universe. Physicist and popular author Simon Singh then took her publicly to task about using 12 billion instead of 13 billion light-years as the radius of the observable universe, and she eventually did a TV retaping with improved numbers.

Moody Blues. "Higher and Higher" on *To Our Children's Children* (Polygram CD 844770). This 1969 song celebrates the Apollo 11 mission to the Moon and uses the image of tranquility (the mission landed in *Mare Tranquillitatis*).

O'Connell, Robbie. "Galileo" on *Humorous Song*. (Celtic Media CMCD 2000). An apology from the Church to Galileo.

Petty, Tom & the Heartbreakers. "In the Dark of the Sun" on *Into the Great Wide Open*. (MCA 1037). This song, presumably about an eclipse, includes mentions of constellations and Orion's sword. The album notes have constellation diagrams with them, and the CD itself shows circumstellar constellations with the center of the turning CD being the North Celestial Pole.

Pink Floyd. "Shine on You Crazy Diamond" on *Wish You Were Here*. (Capitol 29750). Compares the self-destructive fading away of Syd Barret, the former leader of Pink Floyd, to the fading away of a low-mass star like the Sun into a white dwarf.

Queen. "'39" on *A Night at the Opera*. (Hollywood 61065). Song about an interstellar expedition traveling at relativistic speeds and the loneliness the crew feels because they know that everyone they knew on Earth will be dead when they return. Brian May, a member of this group, trained as an astronomer in England.

The Police. "Walking on the Moon" (found on several of their greatest hits compilations). Compares the feeling of walking in the low gravity of the Moon ("giant steps") to being in love.

Rush. "Countdown" on *Signals*. (Mercury/Universal 534633). Nice description of what it is like to witness a rocket launch at Cape Kennedy.

Rush. "Cygnus X-1" on *Farewell to Kings*. (Mercury/Universal 534628). An interesting attempt to portray the ideas around the discovery of the first stellar-mass black hole in poetic and musical terms. Lyrics include, "Headlong into mystery, The x-ray is her siren song, My ship cannot resist her long, Nearer to my deadly goal, Until the black hole—gains control."

Rush. "Natural Science" on *Permanent Waves*. (Mercury/Universal 534630). Images from astronomy and the evolution of life are entwined with injunctions about morality.

They Might Be Giants. "The Sun is a Mass of Incandescent Gas" on *Why Does a Star Shine?* (Elektra 66272-2). A re-recording of a 1959 educational song from an album called "Space Songs" (lyrics by Hy Zaret, who also wrote "Unchained Melody").

Train. "Drops of Jupiter" on *Drops of Jupiter*. (Sony 69888). Uses image of Jupiter, Venus, and the Milky Way to talk about a girlfriend who had taken either a physical or a spiritual journey and was "back in the atmosphere" now.

Tyler, Bonnie. "Total Eclipse of the Heart" on *Faster than the Speed of Night*. (Sony 38710). 1983 hit song by a Welsh singer which uses eclipse images—shadows, being in the dark, "no one in the universe as magical as you"—to describe a love affair going wrong.

Waterboys. "The Whole of the Moon" on *This Is the Sea*. (Capitol 21543). Interesting use of the image of the crescent moon versus the full moon as a way of expressing that the singer only saw and felt little, but his lover saw the larger emotional picture.

3. Broadway Musicals, etc.

At the Drop of Another Hat. This review of comedy songs by Flanders and Swann (a British duo) included "The First and Second Law (of Thermodynamics)." A shortened version is available on *The Best of Flanders and Swann*. (EMI 7243 8 29399 2 4).

Good News. (CDJay 1291) Revised version of 1927 musical in which the plot revolves around the football hero failing his astronomy exam and being kept out of the big game.

Monty Python's Meaning of Life. (Virgin 1398605). Includes the "Galaxy Song" about our insignificance in the scheme of the universe.

She Loves Me. (Polydor 831 968-2). The song "Perspective" in this old-fashioned 1963 musical takes a cosmic view of human goings-on and has a nice series of astronomy images.

4. Self-Published Science Songs on CD

Artichoke. *26 Scientists, vol. 1* (see <http://artichoketheband.com/>). Eclectic, not always pleasant, songs about scientists, including Galileo, Einstein, and Heisenberg.

The Big Bang Band. *Traveling Star Show* (see <http://www.bigbangband.biz>). Three amateur astronomers offer songs mostly for schoolchildren. They recently won the ASP's Las Cumbres Outreach award for their educational work with schools. Some of their songs are written by others, some by members of the group.

The Chromatics. *AstroCapella 2.0* (see <http://www.astrocappella.com/>). This seven-member singing group from NASA Goddard offers a CD of such original songs as "HST-Bop," "Doppler Shifting," "Wolf 359," and "Habitable Zone." On their Web site they have developed some lesson plans for teachers to use with the songs.

Williams, Lynda (The Physics Chanteuse). *Cosmic Cabaret* and *Parody Violation* (see <http://www.scientainment.com/index.html>). Williams, now a physics instructor at Santa Rosa Junior College, entertains as a cabaret singer with such songs as "Love Boson," "Annie Jump Cannon," "Big Bang," "Gravity Wave Vibe," and "Solid State of Mind."

Appendix B.

Astronomically Inspired Music Not Currently Available on CD

1. Classical Music

Absil, Jean: *Les Meteores, Images Stellaires*

Adams, John: *Doctor Atomic* (controversial opera about the atomic bomb)

Ahrold, Frank: *Star Journey* ballet(1975)

Barbier, Renee: *Suite after Plato: The Elements*

Bedford: *Tentacles of the Dark Nebula* (the Solar System moves into an interstellar dust cloud)

Bergmann, Gunter: *The Harmony of the World of Jupiter*

Blomdahl: *Aniara* (space opera)

Boone, Charles: *A Cool Glow of Radiation*

Brant, Henry: *Meteor Farm*

Brott, Alexander: *Spheres in Orbit*

Dodge, Charles: *Earth's Magnetic Field*

Dufourt, Hughes: *Saturn*

Felciano, Richard: *Galactic Rounds*

Glass, Philip: *Galileo Galilei* (opera)

Ivanov, Konstantin: *Cosmic Symphony*

Ivey, Jean: *Aldeberan, Three Songs of the Night* (one of these sets "When I Heard the Learned Astronomer")

Kostal, Arnost: *Cosmic Nocturno*

Lang, Istvan: *Constellations*

Matthus, Siegfried: *Galilei*

Norgard, Per: *Constellations*

Offenbach: *Voyage to the Moon* (operetta)

Pepin, Clermon: *Symphony 3* (Quasars)

Prado, Almeida: *Celestial Maps*

Raitio, Vaino: *The Moonlight on Jupiter*

Riley, Terry: *Sunrings*

Slama, Norbert: *Pulsar*

Smith Brindle, Reginald: *Andromeda M31 for Solo Flute, Worlds without End*

Takemitsu, Toru: *Cassiopeia for Percussion and Orchestra* (soloists sit in the shape of a W)

Widmer, Ernst: *Quasar, Pulsar*

2. Popular Music

Labelle: "Black Holes in the Sky" on *Phoenix* (1975 Epic LP)

Jordin Kare: "Fire in the Sky"

Appendix C. Other Web Resources on Astronomy and Music

Hyperbolic Orbit: <http://www.haverford.edu/physics-astro/songs/hyperbolic.htm> — Benjamin Newman's song compares a comet on a hyperbolic orbit around the Sun (comes in and goes out) to an enticing woman who will not stay after a brief encounter.

Jane Ira Bloom: First Musician in NASA's Art Program:

<http://www.janeirabloom.com/retrospectivespace.html> — Jazz saxophone player and composer Bloom has written a number of pieces about space and astronomy

Jon Bell's Astronomers' Songbooks: http://www.ircc.edu/portal/layout_web1.aspx?PortalPageID=182 — Planetarium director Jon Bell has two large collections of astronomy lyrics that you can download in PDF format at the bottom of the Hallstrom Planetarium page.

Kevin Krisciunas's Astronomy Songs: <http://www.astro.washington.edu/kevin/songs.html> — Astronomer-author-historian Krisciunas has written and performed several astronomy shows for his colleagues and collects a few songs here.

Music to Titan: <http://music2titan.com/> — Four pieces of music were included aboard the Huygens lander which touched down on Titan.

Physics and Astronomy Song Web Site: <http://www.haverford.edu/physics-astro/songs/> — Professor Walter F. Smith of Haverford College keeps a marvelous web site of recorded and unrecorded songs related to physical science.

Science Songwriters' Association Resource Guide: <http://www.science-groove.org/SSA/resource.html> — Here you can find CDs and Web sites from several self-published songwriters (including some of the above) who have formed a professional organization.

Voyager Spacecraft Audio-Video Record Site: <http://voyager.jpl.nasa.gov/spacecraft/goldenrec.html> — The record that is aboard Voyager 1 and 2 includes some music that might be called "The Greatest Hits of Earth." (See *Murmurs of Earth* book listed in section 1.)

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