

The Growing Proportions of Just Intonation

Adam Fong

2010

In mathematics and philosophy, there are questions that have been posed for hundreds, even thousands of years, with many proposed solutions, none of which are definitive. In music, the only analogue might be the problem of tuning. Every musical culture has developed, of necessity, a method for organizing pitch, for creating scales, or at the very least a vernacular standard of how pitches and intonation are handled. Even musical practices focused largely on percussion have tackled the issue, whether directly, through tuned percussion, or indirectly, in the methods used for creating gongs, cymbals, thumb pianos, gourd-based instruments, and the like.

In today's Western culture, the dominant tuning system is twelve-tone equal temperament, in which an octave is divided into twelve equal steps. This became the tuning system of choice only quite recently, in the mid-18th century, during the Classical era, and was gradually adopted until gaining a firm hold in the mid-19th century. The benefits of twelve-tone equal temperament were made abundantly clear in both Romantic and atonal music: each of the twelve steps in an octave became equally available as a tonic, or harmonic "home," allowing the music to continuously move to and from new tonal centers, or to roam without a clear destination, in the case of atonal music. Twelve-tone equal temperament made this possible by 'tempering' pure intervals, approximating consonances so that any of its notes could serve equally well as a tonic.

However, an increasing number of composers have become dissatisfied with the roughness of those 'tempered' approximations, and sought to use just or 'pure' intervals—whose frequencies are based on integer relationships and therefore perfectly in tune—in their work. Such resistance to the existing tuning paradigm is no small matter: not only are most modern instruments designed with twelve-tone equal temperament in mind, most performers are trained, both by auditory and physical memory, to use that particular tuning system. In addition, using a different tuning system inevitably leads to departures from familiar musical styles, and in our culture such novelty in serious music is not often rewarded with support, from institutions or audience members. Regardless, the use of other tuning systems, especially of just intonation, has developed in America in the 20th century to a level of acceptance and recognition befitting a permanent technique of composition. While at first it may have been a curiosity or highly specialized area of study, it has blossomed in the last 80 years into a language that, as a discipline, may be used for a variety of musical styles.

What compelled the mavericks of American music to compose in just intonation? Based on scientific principles, just intonation makes use of pitches whose frequencies are in whole-number proportion to each other. For example, beginning from the common tuning pitch A-440, the major third above, C#, would have a frequency of 550 Hz, a 5:4 relationship, or a "just major third." In twelve tone equal temperament, that C# is tuned to 554.37 Hz; the difference, especially when heard simultaneously with A-440, is quite noticeable.

Henry Cowell (1897–1965), in his highly influential text *New Musical Resources* (published 1930), made use of integer ratios to represent pitch intervals; however for him this was simply a method for creating complex rhythmic relationships. Cowell proposed a "scale of rhythm" based on the intervals approximated by twelve tone equal temperament. So the interval with frequencies in roughly 9:8 proportion (a "just"

major second) would be translated to a measure with one voice playing 9 beats, and the other 8, in the same space of time (for example, one voice at 72 bpm and the other at 64 bpm). Cowell pursued this idea further in commissioning the development of the Rhythmicon, created by Leon Theremin in 1931. This keyboard instrument performed repeated tones in proportional pitch and rhythm.

Very little compelling music was composed for Cowell's Rhythmicon, and the entire pursuit would be of little interest were it not for Cowell's deep influence in the development of American music in the 20th century. As the driving force of the New Music Society, established in California in 1925, Cowell brought together innovative composers and became the forefather of new and experimental music on the west coast. Two composers who benefitted directly from both Cowell's knowledge and the opportunities he created were Lou Harrison and Harry Partch. These two would go on to become the foremost pioneers of their generation in the use of just intonation in new music.

Of the many reasons for the study and use of just intonation, two specific interests help us understand today's practitioners in this area: the scientific purity of just-tuned intervals, and their lineage of historical uses in a variety of cultures. Those compelled by the former argument are often also aesthetic 'purists,' who insist on highly accurate and reliable methods for producing just intervals, and recoil at the acoustical lie perpetuated by equal temperaments. On the other hand, the latter group tends to draw deeper influence from the historical and non-Western uses of just intonation, especially the unique sense of time experienced in the classical traditions of Indian, Javanese, and Balinese music. Of course every composer mixes recognition of both of these areas of interest, and music by nearly all of the contemporary just intonation composers could be termed experimental. However, the use of just intonation in music concerned with these two areas is quite different, and demonstrates just how far-reaching and enduring the departure from twelve-tone equal temperament might be.

From the Ancient, A New Tradition

Harry Partch (1901–1974) dated the beginning of his departure from European musical conventions to 1923, when he first discovered *On the Sensations of Tone* by the German physicist Hermann Helmholtz. [Gann 78] This text, offering a "physiological basis for the theory of music," exposed to Partch what he considered a deep deception: the impurity of the equal-tempered tuning system.

As one of the first 20th-Century composers to dedicate himself to microtonal scales, Partch needed to blaze his own trail. He accomplished this by building many of his own instruments, some based on conventional instruments, but most designed and constructed from scratch. His preferred musical scale contained 43 notes within one octave, and made available an enormous number of intervals, allowing for both scientific inquiry and musical expressivity. The centerpiece of Partch's system therefore was his Chromelodeon, a pedal-pumped reed organ that was tuned to include all 43 tones (the name is a portmanteau of *chrome* meaning color, and *melodeon*, the 19th-Century organ which he modified). Although Partch had already completed early adapted guitars and adapted violas, the Chromelodeon became the standard-bearer to which all his other instruments were tuned. Among those were Harmonic Canons and Kitaras, both resembling very large zithers, a multitude of marimbas including the bass marimba (whose longest block is 1.3 meters), and cloud chamber bowls, a dangling array of 13 Pyrex carboys salvaged from a radiation laboratory.

Throughout his life, Partch was most deeply interested in a new form of opera. He designed his instruments not of simple creative whim, but in an effort to build an orchestra that would support dramatic speaking and singing. His early works often pair an instrument with an intoning voice, as in *Seventeen Lyrics by Li Po* (1930–33) and *Barstow* (1941), which uses text from eight pieces of graffiti spotted on a highway railing in California. As he developed more instruments in the 1940s and '50s, Partch expanded the scope of his work, leading towards large-scale dramas that would later include choreography. The most significant among these are: *Oedipus* (1950, '52–54, '67) using text from both Sophocles and W. B. Yeats; *Revelation in the Courthouse Park* (1960), which alternates between Euripides's *The Bacchae* and a modern re-telling of the same; and *Delusion of the Fury* (1965–66), a two-act drama based on an 11th-Century Japanese story and an African folk tale.

Partch's choice of mythical and at times ancient tales is well-matched to the oddity of the sounds of his instruments and his musical language. He scorned what he considered "abstract" music, preoccupied with formal considerations, and instead sought to write "Corporeal music" which "is emotionally 'tactile.' It does not grow from the root of 'pure form.' It cannot be characterized as either mental or spiritual." [Partch 8] His preoccupation with the physical and tactile nature of music was revealed in his attempts to fuse drama, poetry, music, and dance in his work, and also in his commingling of the everyday and the mythical in his subject matter.

Like many musical innovators, Partch explained his ideas in a kind of treatise, titled *Genesis of A Music*, first published in 1949, and expanded in its second edition in 1974. In this wide-ranging text, Partch attempts to state and argue for his own artistic values, most importantly Corporealism, define and detail his understanding and use of just intonation, survey the historical development of intonation in both western civilization and western scientific study, demonstrate the majority of his instruments, describe six of his major works, and address both theoretical and pragmatic compositional issues in his work. The language of the text is often dense, but Partch was forging a new path, where no textbook could have guided him. Of necessity, he includes an entire chapter of definitions pertaining to intonation, and a separate chapter describing his "language of ratios." The text is far from methodical, but does exhibit both scientific investigation and steadfast aesthetic views. These are two qualities he would share with many subsequent pioneers in just intonation.

In *Genesis*, Partch shows the progression of his work that led to his 43-tone division of the octave. He also explains his theory regarding the emotional content of specific intervals, an idea he expresses with a graphic termed the "one-footed bride" for its curving, billowing shape. This "graph of comparative consonance" explains that perfect fourths and fifths express "power," those in between (tri-tone equivalents) provide "suspense," intervals around equal tempered thirds and sixths express "emotion," and intervals equivalent to seconds and sevenths provide an "approach" to the tonic.

Partch may have been the only composer to work with his "one-footed bride" in mind, but *Genesis* would prove to be highly influential for nearly every other composer working in just intonation. Partch's radically new understanding of harmony, particularly consonance, pointed the direction for a new discipline in music. Whereas earlier generations of Western composers were often preoccupied with categorizing intervals as consonant or dissonant (and cataloguing the methods by which those qualities should be managed), Partch sought to scientifically establish a *spectrum* of consonance. In his view, increasing the odd numbers involved in a just-tuned interval gradually

decreases the amount of consonance: therefore the interval 13:10 is less consonant than 7:5 [Partch 87]. He saw the history of western music therefore as slowly developing its awareness of the outer reaches of consonance: "man's use of musical materials... has progressed from the unison in the direction of the great infinitude of dissonance." [94] For Partch, dissonance is a *direction* along the spectrum of consonance. He felt he was a part of that history, continuing the study of harmony in its progression towards the "infinitude of dissonance."

Partch was a college dropout and largely self-taught. Although he worked in residence at the University of Illinois and other colleges, he did not teach more than an occasional guest lecture. As a result, the only way for curious students to learn from him was to work as an apprentice. Two young composers who did just that were Ben Johnston and James Tenney.

Like Partch, **Ben Johnston** (1926–) encountered Helmholtz's text at a young age: he was 11 when he heard a lecture about the book's influence on Debussy. As a college student, Johnston was given a copy of *Genesis of A Music* by a teacher, and subsequently became determined to work with the book's author. He moved to Gualala, California, in 1950, to work as Partch's apprentice, tuning string instruments. Johnston later professed that while "Partch could have wished for a carpenter or for a percussionist... [he had] someone who understood his theory almost without explanation, and who could hear and reproduce the pitch relations accurately." [Von Gunden 11]

Johnston's ability to hear pitch relations in terms of just intonation would lead him to extend Partch's harmonic developments. However, Johnston quite deliberately focused on integrating his harmonic principles with the existing Western tradition, and wrote for conventional instruments and ensembles, often in established musical forms. In his article "The Corporealism of Harry Partch" (originally published in *Perspectives of New Music*), Johnston explained how he viewed his mission: "I felt that my eventual task would be to alter attitudes, especially theoretic currents within the mainstream, from the mainstream, to the mainstream. It would be my role to bring his [Partch's] work into relation with accepted traditions and recognized challenges to tradition, and to whatever extent necessary and possible to bring these enormous trends into relation to some of his most important achievements." [Johnston 228]

To date, his most well-known piece is *String Quartet No. 4* (1973), often called the "Amazing Grace" Quartet, as it is composed of variations on the English hymn, using three different systems of just intonation. In this work and many others such as *Knocking Piece* (1962), *Sonata for Microtonal Piano* (1964), and the challenging orchestral work *Quintet for Groups* (1965), Johnston extends Cowell's original idea where whole-number proportions define the relationships between a number of musical elements in addition to pitch, such as rhythms, large-scale form, and instrumentation. In Johnston's music, this often brings about highly complex rhythms, and bustling polyphonic textures.

The way Johnston applies a series of integers to different aspects of music is reminiscent of serial composing techniques, and indeed Johnston began composing in that style. In his early works he tries to use just intonation to achieve a new kind of atonality, but he abandoned his commitment to serial ideas as he focused more intently on tuning and intonation. His research into "extended just intonation" resulted in a number of innovations: he developed and worked with a variety of scales, including a 53-tone scale that incorporated twelve-tone equal temperament and allowed for clean modulations; he invented a new system of notation with more accidentals, making

seemingly impossible music merely difficult to perform (his music could never be simple); and, perhaps most importantly, he developed strategies in his composing that would aid performers of his music. In addition to the new notation, Johnston would often provide explanatory notes, highlight important pitch relationships in the score that could be verified by ear, and avoid entrances or solos requiring performers to "find" a note without a clear reference pitch.

In the process of this work, Johnston made enormous achievements, not the least of which is exemplified in *String Quartet No. 4*: he composed music using just intonation that appealed to a large audience. While much of Johnston's music is modernistic and harmonically challenging, he has also made explicit reference to folk songs, pop music, and jazz standards in his works. Unbound by stylistic genres, Johnston's method for bringing together just intonation and other music trends has led to a wide-ranging body of highly expressive work. In 2010, in the twilight of his career, Johnston remarked, "I have devoted my life to a cause, and I don't regret it."

Musical Scientists, Harmonic Inventors

Johnston deliberately worked for the majority of his life in a particular area of inquiry: bringing extended just intonation together with conventional writing styles, techniques, and, most importantly, performance practices. On the other hand, **James Tenney** (1934–2006) was led by a restless dedication to compositional invention. He was among the early pioneers of electronic music, performed with John Cage, Steve Reich, and Philip Glass, and published important early indeterminate works. But he dedicated the last twenty years of his life and work to re-examinations of harmony.

Like Johnston, Tenney worked with Partch, although he could hardly be said to have studied with him, since he was dismissed after just six months of tuning and instrument repair. He had been interested in Partch's instruments and tuning, but wanted further to discuss theory. Partch was not interested in such debates, but Tenney would go on to become both an influential theorist and one of the most influential American composers to make use of just intonation.

Tenney's interest in just intonation sprung from his investigations into psychoacoustics and aural perception. Some of his most powerful pieces are based on acoustic phenomena: *Critical Band* (1988), a work for variable instrumentation, explores all of the unexpected sounds that occur when two (or more) tones pass from sounding as one to two distinct pitches. Another oft-performed work is *Having Never Written A Note for Percussion* (1971), which consists of a very slow crescendo and decrescendo on a one-note tremolo, usually performed on a chau gong. Both of these works reveal intricate acoustic phenomena related to tuning, although neither uses just intonation exclusively.

More often than not, Tenney's connection to just intonation may be found in his use of the harmonic series, the series of pitches resulting from multiplying the frequency of one beginning or "fundamental" pitch by whole numbers. Tenney combines a mindfulness of the differences between just intervals and equal tempered approximations with a penchant for long, sweeping gestures and large-scale forms, encouraging a style of listening where narrative and rhetorical techniques bear no relevance. In another work for variable instrumentation, *In a Large Open Space* (1994), players perform long tones from the F harmonic series, from various positions throughout the performance space. Listeners are therefore free to walk through the slowly transforming chord, their proximity to the various ensemble members determining which parts of the droning chord they are

hearing.

Other works of Tenney's use clear large-scale gestures, but chaotic events in any five-second space of time. This type of "algorithmic" composing offers another solution to the difficulty of performing works in just intonation: players are free to select tones from an available set of pitches, which transforms over time. Tenney uses this technique to great effect in his *Spectrum* pieces, which unfold a harmonic series in a variety of fascinating ways, and in the later works from the *Harmonium* series, which modulate through the "circle of fifths," disproving the notion that the use of just intonation necessitates unmoving, static music.

Another composer whose works often involve a slow unfolding is **La Monte Young** (1935–), who since the 1960s has collaborated with his wife and light artist Marian Zazeela. Early in Young's career he was involved in the Fluxus movement. His *Composition 1960 #7* from this time gives some indication of his musical future: it specifies two pitches (B and F#) and instructs, "to be held for a long time."

Young attributes his interest in long, sustained tones to his years as a saxophone student, when he would practice long-tone exercises. He has since transformed that interest into works that explore acoustic phenomena resulting from specific collections of just tuned intervals, which are layered together to evoke chords unavailable in any other music. Young considers these works to be experiments, following the belief that evoking a "drone state of mind" by presenting specific musical intervals will elicit unique emotional and physiological responses. (He most likely adopted these principles from his teacher, the Hindustani classical singer Pandit Pran Nath, who was also a great influence on Terry Riley.)

Young's ongoing collaboration with Zazeela, *Dream House*, has served as the staging ground for their installations, in which a matrix of just tuned sine waves in elaborate, symmetrical configurations are complemented by chaotic lighting installations. Kyle Gann's description for *The Village Voice* of one of Young's works (the title begins *The Base 9:7:4 Symmetry in Prime Time When Centered Above and Below The Lowest Term Primes in...* and is over 100 words long) reveals the remarkable effect of these installations:

Walk into *The Base 9:7:4 Symmetry* and you'll hear a whirlwind of pitches swirl around you. Stand still, and the tones suddenly freeze in place. Within the room, every pitch finds its own little niche where it resonates, and with all those close-but-no-cigar intervals competing in one space (not to mention their elegantly calculated sum- and difference-tones), you can alter the harmony you perceive simply by pulling on your earlobe. . . . [W]hile *Romantic Symmetry* was more "melodic" in a sense, since its overtones were more evenly spread throughout the range, *The Base 9:7:4 Symmetry* is more textural. Moving your head makes those tones leap from high to low and back, while that cluster in the seventh octave, with its wild prime ratios like 269:271, fizzes in and out. . . . [Gann 187]

Young's works have increased in complexity to a degree hardly imaginable, but most critics agree his masterpiece is *The Well-Tuned Piano*, a project begun in 1964. This work, which continues to evolve, has lasted as long as seven hours, and is performed on a just intuned piano. Like many of Young's early compositions, it is loosely structured, allowing for rule-based improvisation. The piece consists largely of intervals and chords which are slowly introduced, then accumulated together in loud tremolos to create "clouds," where the intervals can interact and produce other acoustic phenomena, like shimmering sum tones and rumbling difference tones (perceived pitches with

frequencies resulting from the sum of or difference between the frequencies of two tones). Apart from Young, the only performer of this work is his protégé Michael Harrison, who has also begun to compose works of a similar nature.

Whereas Young's works are often quite loud and extremely long, the music of **Phill Niblock** (1933–) is often quite long and extremely loud. Niblock uses high amplitudes with both electronics and live instruments to explore complex overtone patterns and interferences that occur at very high frequencies. His loud drones are often paired with films from his series *The Movement of People Working*, creating a powerful combination of the visual rhythms of everyday rural work with the blazing insistence of the music. While Niblock's work does not explicitly explore intervals in just intonation, he continues in the same tradition of abandoning conventional harmony (in Niblock's case, he had no formal training to begin with) in favor of a scientific journey through harmonic invention.

Neither Partch nor Young found a career in American universities, but both Johnston and Tenney taught composition for many years, directly influencing a large number of today's living composers. Like Tenney, with whom he studied at California Institute of the Arts, **John Luther Adams** (1953–) often uses large-scale formal processes and algorithmic solutions in his composition. He has combined this approach with a deep affinity for the natural world: his ongoing installation at the Museum of the North in Fairbanks, Alaska, *The Place Where You Go To Listen* (2008–), translates natural phenomena such as sunlight, fluctuations in the magnetosphere, and seismic activity, into audible events. **Kyle Gann** (1955–), like his teacher Johnston, is something of a stylistic chameleon. A self-described post-minimalist, he draws from his encyclopedic knowledge of American music and a talent for warm lyricism to create works that are often rhythmically driving yet complex. But his harmonic palette is more expressive than most rhythmically driven composers: his works feel closer to interludes than theatrical showpieces, closer to impressionist and jazz harmonies than bombastic prog-rock power chords. **Larry Polansky** (1956–) has made extensive use of computers in his work, continuing Tenney's innovations in algorithmic composition. His ability to integrate complex mathematical principles into his work is complemented by his facility in using computers as a performance tool, for realizations and interactions with other performers. Each of these three composers has expanded the use of just intonation by integrating it into the rest of their musical world. Their success in creating highly original work points to the untapped but fertile field that might grow from the hybridization of just intonation with myriad other musical tools.

Another Harmonic World

Lou Harrison (1917–2003) composed in just intonation for a multitude of instrumental combinations, from solo vocal music to full orchestra to gamelan. Although his music is more often (and perhaps more easily) associated with influences from non-Western cultures, especially Balinese and Javanese gamelan practices, Harrison from a very early age sought ways to move beyond equal temperament, and over the course of his career became one of the most successful composers to bring the sounds of just intervals to audiences beyond avant-garde music cliques and musicological rogues. For Harrison, the use of equal temperament represented a dull standardization, a fault in Western culture, and a soul-less practice that needed reviving through acoustical purity.

Harrison's music is often based in the exploration of a specific scale or mode, drawing more from ancient cultures than modern developments. He offers a mixture of rhapsodic melodies, romantic drama, enchanting rhythmic motifs and carefully controlled

instrumentation and orchestration. Amidst all of this, Harrison constantly investigated tuning, fueled early on by reading of Partch's *Genesis*, but motivated for the majority of his career by such far-flung connections as the relationship of tetrachords in Greek theory to Javanese gamelan tunings. [Miller 111]

Early on, Harrison developed two important compositional principles through which he approached his work. The first was the use of the Javanese terms *slendro* and *pelog* to distinguish types of scales. *Slendro* scales contain only whole steps (of varying sizes), and *pelog* scales use some half-steps. This was an important way of distinguishing modes, which Harrison pursued through a variety of projects intended to index modes from around the world. Another principle Harrison invented was a distinction between what he termed Strict Style, where a piece would use only the pitches in a mode of five, six, or seven pitches. In contrast, Free style was "to freely assemble, or compose with whatever intervals one feels that he needs as he goes along." [Harrison 6] Harrison would compose many works in both styles, and in some cases combinations of the two.

Among Harrison's first attempts to notate just intonation, and an early example of a work in Strict Style using very limited means, is *Four Strict Songs for Eight Baritones and Orchestra* (1955). Harrison wrote his own text for the songs, which are inspired by Navajo interpretations of creation, and addressed to plants, animals, heavens, and minerals. Each song uses a different pentatonic mode, the intervals of which Harrison felt reflected the song's theme.

Harrison's ability to create propulsive rhythms and beautiful melodies, with little of the typical sense of harmonic progression found in Western music, demonstrates a delicate balance of eastern and Western influences. His impulse to combine and bring together seemingly irreconcilable musical practices led to brilliant and unusual instrumentations, and powerful programmatic usage of multiple tuning systems within one piece. In his *Pacifika Rondo* (1963), Harrison calls for a chamber orchestra of both western and eastern instruments in a suite of seven movements, each centered around a specific Pacific culture: Korean, Buddhist, Chinese, and Mexican cultures are represented, and the sixth movement is composed using twelve-tone harmonic language, in a furious protest against the testing of nuclear weapons in the Pacific.

The percussion used in *Pacifika Rondo* includes pak (Korean clapper), chango (Korean double-headed drum), daiko (Japanese drum), elephant bells, and gongs. Harrison's works often make use of special percussion instruments, whether drawn from non-Western cultures, scrounged from amongst flower pots and glass bowls, or built by his collaborators. He and partner Bill Colvig were deeply involved in constructing custom instruments such as specially tuned flutes and viols with movable or independently placed frets. Harrison also tuned a number of gamelans, xylophones, and other conventional instruments, which would be used for music both traditional and contemporary.

While composers like Partch and Johnston might be considered hard-line purist adherents to just intonation, Harrison's personality was reflected in his pragmatic approach to tuning. In works such as his *Concerto for Piano with Javanese Gamelan* (1987), the piano derives its intervals from the gamelan, but makes use of twelve tone equal temperament. It could be said, without derision, that his talent in creating arresting and delightful music took precedence over any theoretical imperatives. As Conductor Dennis Russell Davies explains, with Harrison's music "the audience feels as if it's being spoken to directly. There's effervescence, spontaneity, and enthusiasm. His music has passion and assuredness. There's a vulnerability as well that can be particularly

touching." [Miller xi]

Whereas Harrison's greatest influences came from around the Pacific Rim, **Terry Riley** (1935–) studied with Hindustani classical singer Pandit Pran Nath (Riley also performed in Young's *Theater of Eternal Music* in the 1960s). Although he is most well-known for his pioneering work *In C* (1964), which is said to have 'established' minimalism, Riley has explored time and repeated musical fragments for many years alongside other works that involve straightforward melodies, and influences from jazz, tango, and blues.

Riley's use of just intonation has been largely confined to keyboard works of long duration. His *Shri Camel* (1980) for solo electric organ in just intonation with delay uses raga-like structures, overlapping short musical fragments to create slowly changing and moving patterns. These propulsive ostinatos, presented in nearly static harmonies, evoke an ecstatic suspension of time. *The Harp of New Albion* (1984), a two-hour piece for just intonation piano, works in a quite different way. In this piece Riley takes advantage of unusual but consonant intervals in a variety of forms, including a waltz and a section in ragtime. Throughout the ten movements of the work, Riley's wit and light-hearted approach shine along with his virtuosity as a pianist.

The Harp of New Albion is the third of a series of Native American Mythological Portraits. For Riley, as with Harrison and others, the use of just intonation fits aesthetically with a spiritual and cultural outlook of deep respect for non-Western cultures. It would be impossible to state simply the ways in which Riley draws from Native American, Indian, and Buddhist practices; likewise Harrison's relationship to Balinese and Javanese music is not as clear as it might seem, given that he also devoted a great deal of study to Chinese and Korean music and philosophy. But it is obvious through the nature of their compositions that Harrison and Riley approached just intonation not as a scientific study, but rather as a method with a long musical past, only recently obscured.

In the early part of her career **Pauline Oliveros** (1932–) was a sonic experimenter, much like La Monte Young and James Tenney: she was among the early electronic music pioneers in San Francisco, and composed works involving difference tones and other acoustic phenomena. Her tape piece *I of IV* (1967) uses upper overtones from the harmonic series related to the 60-cycle hum of America's electric power frequency.

But over time Oliveros became better known as an improviser, associated directly with her accordion, which she has modified to make available to her two different just intonation tuning systems in the two hands. In addition she often performs with delay processors and other electronics to amplify and layer her playing into more complex and polyphonic textures. She refers to this setup as the Expanded Instrument System, and it can be heard in numerous recorded works, including *The Beauty of Sorrow* (1987), a gorgeous and meditative piece intended to aid the listener in times of spiritual change.

The spiritual, and at times ritual aspect of Oliveros's work has over the years come to the forefront of her musical practice. In 1971 she composed her *Sonic Meditations*, which were followed shortly thereafter by the *Deep Listening Pieces*. The latter collection includes 36 works intended for audience members, encouraging a meditation-like practice of listening, vocalizing, and appreciating environmental sounds as part of the musical experience. Oliveros has from the time of those works extended an aesthetic seed that began in the 20th century with John Cage, creating an ethic of "Deep Listening" or "sonic awareness" that draws from the consciousness and physical discipline of meditation.

The influence of Eastern religion in this practice of Deep Listening is subtle but clear. However, in many works Oliveros has made more explicit reference to the mandala, a circular image used as a meditation object in Tibetan Buddhism, and as a therapeutic tool in Indian sandpainting. She has used the image to determine many aspects of her works, and often creates theatrical (though very understated) performances in which participants sit in a circle, improvising along her guidelines for hours at a time. Oliveros also leads Deep Listening retreats, and performs with her Deep Listening Band, often in uniquely resonant spaces such as cathedrals and caves. Her use of just intonation in these works and other improvised contexts, therefore, is simply one part of a discipline which emphasizes sustained tones and careful attention to listening. But whereas works by Young and Tenney, and even early works of Oliveros, demonstrate acoustic phenomena, the mature works of Oliveros point beyond perceptual matters, evoking a spiritual dimension through their near-religious attention to the individual mind of their performers.

A Technique for Innovators

Although issues related to temperament and tuning were prominent for hundreds and perhaps thousands of years, the recent widespread adoption of twelve tone equal temperament has obscured the scientific basis for harmony almost completely. As a result, musicians pursuing just intonation in America have, for the last 100 years, tended to be highly experimental and adventurous in other aspects of their work. But thanks to the efforts of early pioneers like Partch and Harrison, and teaching from mentors like Johnston, Tenney, and Oliveros, music using just intonation has become more than a novelty in America.

New generations of students, both performers and composers, are learning of the works of their predecessors thanks to the availability of recordings, and to networks of like-minded musicians. Whereas most of the composers discussed here were required to perform their own works, lead their own ensembles, or compose using electronic sound sources, the use of tuning systems other than twelve tone equal temperament is gaining credibility even in conventional circles. Today's mid-career composers are proving that contemporary styles needn't exclude just intonation; instrument builders continue in Partch's tradition but often present works that fall between the avant-garde and popular music. And numerous young composers are inventing their own musical styles that incorporate just intonation. What began as a topic for research has become an open field of inquiry; over the last hundred years, the use of just intonation has emerged as a catalyst for the reinvention of one of music's most essential elements: harmony.

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- Johnston: String Quartets No 2, 3, 4 & 9*, New World Records 80637 (2006)
- Sonata for Microtonal Piano on Sound Forms for Piano*, New World Records 80203 (1995)
- Critical Band on On Edge*, mode 22 (1995)
- James Tenney: Spectrum Pieces*, New World Records 80692 (2009)
- Phill Niblock: Disseminate*, mode 131 (2004)
- Four Strict Songs for Eight Baritones and Orchestra on Lou Harrison—In Retrospect*, New World Records 80666 (2007)
- The Music of Lou Harrison—Pacifika Rondo*, Phoenix USA 118 (1994)
- Shri Camel*, CBS Masterworks 35164 (1990)
- Riley: The Harp of New Albion*, Celestial Harmonies 14018 (1992)
- The Beauty of Sorrow on Oliveros: Tara's Room—Two Meditations on Transition and Change*, Deep Listening 24-2004

Adam Fong is a composer, performer, and producer of new music, residing in San Francisco, California.