- [Blank slide]

Three short notes before I begin.

First: when I proposed this paper, I had intended to focus on the practical approximation of tuning ideals—in a word, temperament—but the more I worked, the more I found it necessary to take a step back, set aside temperament, and focus on the more fundamental problem of the tuning ideals themselves. A better title for the paper as it stands is "The ethics of *harmony* in Italian Renaissance tuning theory".

Second: after you hear the last two musical examples I present, you may be curious about how they are notated on paper, and how I have chosen to interpret their notation. I made the handout to contextualize those two examples for you; it's not part of the presentation, but it may help you make sense of it.

Third: I'd like to thank Roger for coming up with the idea for this panel, and for bringing the four of us together to make it happen. I'd also like to thank the friends who offered feedback on drafts of this paper.

Harmony unifies, consolidates, and intensifies. It disciplines an unruly, heterogeneous mass to produce order, regularity, and hierarchy. Harmony seduces musicians, music theorists and philosophers, who laud its beauty and glorify its power. They love to impose harmony and to take part in it, to celebrate it in sound, thought, word, and deed. For those who study music and practice it, harmony is not only an ideal of music-making; it is an ideal of life in general. The harmonious individual tunes a mind to a body, an action to a discourse, a song to a mood.

We are of course familiar with the harmonies of music: the masses of voices and instruments sounding together as one. Another type of harmony has nothing to do with sound at all; it involves a deeper notion of consonance. This is the *ethical* harmony between one's thoughts, discourse, and actions. Plato himself considers this ethical harmony to be the *true* harmony, of which audible musical harmony is but a shadow. The *true* musician, he says, is the man at harmony with himself, who "has made a true concord of his own life between his words and his deeds."

To speak of harmony, then, may be to speak of music or of ethics: on one hand, the tuning of strings; on the other, the tuning of one's nature. The simple problem is this: these two harmonies don't necessarily have anything to do with each other. For each fully harmonious individual, there is another who is only half-harmonious: someone musical and evil, or virtuous and tone-deaf. There is yet another harmony, however—call it metaphysical—developed by Plato precisely to correct such human abominations, or to deny their existence. Plato's metaphysical harmony bridges the gap between *playing* in tune and *being* in tune, between the truth of *music* and the truth of the *musician*. "Ugliness and discord and inharmonious motion," Plato writes, "are nearly allied to ill words and ill nature, as grace and harmony are the twin sisters of goodness and virtue and bear their likeness." [pla2008a] There is a little Platonist in every musician who believes that musical sounds are a reflection of their inner state; that musical responsibilities are, in fact, ethical responsibilities; and, in general, that good people make good music.

As Plato understands, it is not enough just to assert that ethics relates to music, because the relation is far from obvious or necessary. To bind music and ethics together in metaphysical harmony, one needs a metaphysical instrument. For Plato, this is the *soul*—the obscure machine that allies musical harmony with ethical virtue. This strange alliance is possible because the dimensions of the soul are, Plato believes, literally the ratios of musical intervals [pla2008b], which you will now hear:

- [Video 0: intervals of the world soul, according to Plato]

Plato's soul may be a metaphysical speculation, but its dimensions are perfectly audible and playable: they are the interval ratios of octaves, fourths, fifths, and whole steps. The implication is clear: those who are at harmony with themselves should make music using these ratios, the virtuous numbers of the soul. *Real* musicians, then, may be *true*, ethical musicians after all—but only if they restrict themselves to a meager scale of fifteen pitches. If they want to sweeten the harmony of the soul with the ratios 5/4 or 6/5, if they are curious about the sound of 81/80, 7/4, 283/281, or—heaven forbid—the twenty-fifth root of 5 over 1, or—even worse—pi over e, they are no longer playing for *virtue's* sake, but rather for the sake of *musical sound itself*. Musicians who play for musical sound itself are guilty of "abandoning the harmony of moderation" [cor2008], which is the only harmony that musical ethics can comprehend. In short, musical ethics *prohibits* musicians from playing, hearing, or representing too many sounds.

Until the Renaissance, music theorists devote more energy to establishing the correct limit of the ethical, musical soul than to studying musical sound itself. For a theorist such as Gioseffo Zarlino, the goal of music theory is not to encourage musicians to explore musical sound in general, but rather to confine their music to the soul's harmony in particular. As he explains, "Music is a certain law and rule of modesty." [cor2008] Zarlino's syntonic diatonic scale, as you will see, is similar to Plato's soul in its limited dimensions and restrictive ethical function. Rather than establishing the limit of musical ethics once and for all, however, Zarlino's scale has the opposite effect of triggering a metaphysical crisis. Vincenzo Galilei, who is too interested in sounds and numbers to worry much about his own soul, invents countless experiments to demonstrate that Zarlino's modest harmony is an ethical illusion. His experiments challenge an ancient and venerable harmonic metaphysics with the new science of *acoustics*. Galilei interrupts Zarlino's monotonous ethical discourse with the possibility of musical sound *as such*—that is, musical sound beyond the soul and its ethical limits.

It is easy to declare a harmonic limit, but it is difficult to convince others to be faithful to it. Every harmonic metaphysics therefore needs its own logic of necessity, however convoluted and superficial it may be. In the *Harmonic Institutions* of 1558, we can follow the twists and turns of Zarlino's thought as he constructs the syntonic diatonic scale, which we know today as the major scale in just intonation. The syntonic diatonic scale is a metaphysical instrument like the Platonic soul: although it uses different proportions, it too harmonizes music and ethics through an injunction against acoustic excess. The better we understand Zarlino's metaphysics, the more we can appreciate Galilei's acoustics and its challenge to musical ethics.

- [Slide] Zarlino's *Senario* (*Harmonic Institutions* Bk. 1 Ch. 15) [cor2008]

The source of the proportions of the syntonic diatonic scale is the *Senario*. The *Senario* contains the numbers one through six, which Zarlino arranges in his figure's central ring. Majestic arcs circumscribe consonant intervals produced by the ratios of the numbers at the arcs' endpoints. The *Senario*, Zarlino writes, generates not only the musical consonances, but also the six categories of harmony in general. "Six are the types of musical intervals among which every harmony is contained: unisons, *equisone*, concords, *emmele*, discords, and *ecmele*" (*HI* Bk. 1 Ch. 14).

The figure is spectacular, but not itself sonorous; Zarlino presumes the reader's ability to translate the silent printed symbols into audible, ethical harmony. To make the numbers resound as musical intervals, a sixteenth-century musician would have had to derive string lengths "according to the numbers shown." Larger numbers represent shorter strings: the number 6, for example, represents a string one-sixth the length of the reference string, and it produces a pitch six times as high.

As you will now see and hear, the figure displays intervals from the first *four* of Zarlino's harmonic categories.

- Open [Video 1: senary intervals, arranged by harmonic category]

(In the next several videos I play, you'll see Zarlino's figure to the right, and representations of musical strings corresponding to the figure's numbers to the left. Each figure contains many different intervals, which you'll see and hear in sequence, one-by-one. Above the strings, you'll find three labels for each interval, in red: first, an integer ratio; second, the conventional name of the interval; third, the category of interval according to Zarlino's system. Also note that the reference pitch of "1" is very low—it will sound like a series of clicks—so that as the numbers increase in the following videos, the corresponding pitches don't exceed the comfortable listening range. We begin in harmony's metaphysical depths.)

- [Play video]

1. The unisons are the implicit ratios of each number to itself: 1:1, 2:2, and so on.
2. The *equisone* are octaves and octave multiples: the ratios 1:2, 1:4, 2:4, and 3:6.
3. The concords are perfect consonances: 1:3, 1:6, 2:3, 2:6, 3:4, and 4:6.
4. The *emmele* are imperfect consonances: 1:5, 2:5, 3:5, 4:5, and 5:6.

The *Senario*, then, despite Zarlino's claim to the contrary, accounts for *most*, but not all, of his categories of musical harmony. Four out of six isn't bad.

But it's not quite good enough. Indeed, the two last categories, discords and *ecmele*, require a bit more finesse. An ecmelic interval is itself a type of discord; specifically, it is a discord unfit for music, a sound that by definition lies beyond the limits of the harmonic system. The ecmelic is unethical, for it obeys no harmonic law. Therefore Zarlino *cannot* account for it in the *Senario*; indeed, he must exclude its noise to establish his own harmonic limit. Theorists of harmony must take care to silence unethical sound, even if this means—as it always does—including too little music rather than too much. Zarlino's challenge, then, is to extend his *Senario just enough* to incorporate the discords without bringing in ecmelic intervals as well. His solution is an imaginative four-step procedure:

1. [Slide] First, multiply all the numbers of the *Senario* together;
2. [Slide] Second, remove duplicate values;
3. [Slide] Third, arrange those that remain in ascending order;
4. [Slide] Fourth and finally, construct interval ratios out of the adjacent values. (Source: Zarlino's figure of senary products (HI Bk. 1 Ch. 15))

This procedure is clearly arbitrary; no doubt Zarlino uses it to justify a predetermined outcome. In other words, Zarlino's mathematics do not produce his discords; to the contrary, his discords produce his mathematics. According to the logic of musical ethics, Zarlino's procedure is justified because it establishes the expected musical limit: we now see the greater and lesser tones (represented by the ratios 8:9 and 9:10), and the diatonic and chromatic semitones (15:16 and 24:25). This small half step marks the limit, as it should, between harmonic sense and acoustic nonsense. Anything smaller is ecmelic, literally unseen and unheard in Zarlino's theory.

- [Video 2: Senary products, arranged by harmonic category]

(Let's listen to the intervals in this second figure. We'll go around the circle once to hear all the unisons, and then we'll hear the intervals arranged by harmonic category; as you will see, this is different from their order

in the circle.)

1. Unisons
2. Equisone: 1:2
3. Consone: 2:3, 3:4, 6:8
4. Emmele: 4:5, 5:6, 10:12, 12:15, 20:24, 25:30, 30:36
5. Dissone: 8:9, 9:10, 15:16, 16:18, 18:20, 24:25

The second figure establishes a harmonic limit, but by way of mathematical operations far removed from the concerns of practicing musicians, and in the context of an unusual harmony. To reestablish his hierarchy of harmonic categories, and to highlight their relevance to an ethical practice, Zarlino rearranges the sonorous numbers once again, this time into a pattern that, for theorists of harmony more than 450 years later, remains synonymous with musical virtue.

- [Slide] Zarlino's syntonic diatonic scale (*HI*, Book 2, Ch. 39) [zar1558].

This is the syntonic diatonic scale. Zarlino writes out the relative string lengths necessary to produce one octave of the scale (larger numbers representing longer lengths):

- [Slide]

Below his numbers, I have written the corresponding relative pitches (larger numbers representing higher sounds):

- [Slide]

The syntonic diatonic scale is the epitome of harmonic logic. The nested hierarchy of arches reveals the harmonic categories of the *Senario* in their proper order, from the octave imposing the scale's boundaries down to the discords between each step, as you will now see and hear:

- [Video 3: major scale intervals, arranged by harmonic category]

1. Unisons
2. Equisone: 24:48
3. Consone: 24:32, 24:36, 27:36, 30:40, 32:48, 36:48
4. Emmele: 24:30, 30:36, 32:40, 36:45, 40:48
5. Dissone: 24:27, 27:30, 30:32, 32:36, 36:40, 40:45, 45:48

Zarlino presents this magnificent coincidence of sounds and numbers as a harmonic law, justified by the logic of numbers, sanctioned by the wisdom of antiquity, and verified by musical common sense itself. Ptolemy's syntonic diatonic tetrachord lies at its heart, between the third and sixth scale degrees. Furthermore, Ptolemy's authority is in accord with the practice of modern singers who harmonize with the scale intuitively, or so Zarlino claims. Mathematical, historical and practical logic all point to the syntonic diatonic scale as the *true* harmony, a harmony fit for *true* musicians. Zarlino's metaphysics stops *here*; enchanted by the harmony of the syntonic diatonic scale, the theorist shuts out the ecmelic noise that lies beyond it.

Ethical musicians, who would like to defend music against the invasion of sound in general, refuse to play, listen, or calculate beyond a certain point: their practice stops at the threshold of noise. And yet, since the

sixteenth century, a handful of *acousticians* have practiced a counter-ethics of limitless calculation, applying their reason sometimes cheerfully, sometimes miserably, but always indiscriminately to sound in general. For these acousticians, there is no *harmonic* reason, nor *ethical* reason; there is only *reason*. And this reason, applied in excess, will always reveal the noise within harmony and beyond its limits.

Vincenzo Galilei, father of Galileo and insubordinate pupil of Zarlino, uses simple arithmetic to prove that his master's figure is disingenuous. In his *Discourse on Ancient and Modern Music*, published in 1582, Galilei points out that there are missing arches in Zarlino's third figure, and that they are missing for a good reason: Zarlino has kept hidden the ecmelic intervals inconvenient to his argument. [gal2003] Two unacknowledged intervals are particularly devastating for Zarlino's scale as it appears here.

1. First, the interval between the second and fourth scale degrees, 27:32, is not the emmelic minor third, but an ecmelic Pythagorean third, which is *a little bit* smaller.
2. Second, the ratio between the second and sixth scale degrees, 27:40, is likewise *just slightly* less than the 2:3 ratio of the consonant perfect fifth.

The following video highlights these ecmelic intervals, comparing them to consonant ones built on the second scale degree. As you will see, these corrections introduce values foreign to the syntonic diatonic scale, which are themselves ecmelic in relation to Zarlino's numbers.

- [Video 4: Galilei's critique of Zarlino's construction]

Galilei exposes the noise within the harmonious order of Zarlino's scale. At the heart of his demonstration lies the *comma*: the minute interval ratio 80:81, which is about a fifth the size of a conventional half step. Small as the comma is, it is large enough to distort a harmonious consonance into an ecmelic noise. Galilei reminds his audience that even Zarlino is aware of this: by Zarlino's own reckoning, "half a comma added or taken away from any consonant interval is enough to make it dissonant." Galilei proves that the harmonic numerology of the *Senario*, and the syntonic diatonic scale it generates, is full of ecmelic cracks. Filling these cracks requires a proliferation of numbers beyond the limits of musical authority, intuitive practice, or, unfortunately for Zarlino, harmonic metaphysics in general.

Two observations are in order. First, Galilei's logic is the strict inversion of Zarlino's. To construct his metaphysics, Zarlino draws the line between noise and harmony first, then devises a mathematical procedure to justify it. Galilei, however, starts with simple mathematical facts, then demonstrates their indifference to any distinction between harmony and noise. Whether or not the tiny comma is pleasant to behold, it is no more or less rational than, say, the majestic octave: the two intervals are equally audible, equally playable, and equally representable in number.

Second, Galilei's demonstration is a matter of little cleverness and substantial practical inconvenience. Calculating the comma is easy, but *listening* to the comma requires a special instrument. We cannot know for certain if Galilei himself ever heard the comma; the written trace of an acoustic experiment is not proof that anyone actually performed it. This much is certain, however: the two characters of Galilei's dialogue do not only calculate, but also listen. Describing the effects of the dissonant Pythagorean thirds and sixths, the character Piero Strozzi exclaims: "This is music that really infuriates a gentle person who hears it, the kind Timotheus must have used to cause Alexander the Great to become enraged and take up arms." Today, we can infuriate gentle people by typing frequencies into a computer, but in the pre-digital age, the easiest way to produce and perceive ecmelic noises was on a keyboard instrument. Suppose, for example, that Galilei's patient experimental musicians had a two-manual harpsichord. To illustrate the flaws of the syntonic diatonic scale, they could tune one manual to Zarlino's scale, and the other manual to the same scale

transposed up a comma. They could then play the dissonances you heard a moment ago, as you will see here:

- [Video 5: major scale commas demonstration]

To dismantle even the loftiest harmonic metaphysics, what is needed is simply the right instrument, the right experiment, and the willpower to execute it. At least on paper, Galilei is nothing if not willful: the first 75 pages of his dialog are a veritable assault of the ecmelic. Experiment after experiment unveils the comma at every junction of Zarlino's argument. For every consonant interval in Zarlino's theory, there is a jarring noise that is *just barely* larger or smaller. Even the octave, or "queen of consonances", is not spared from Galilei's meticulous experimental deconstruction. Referring again to the hypothetical harpsichord of the previous example, we can reproduce Galilei's demonstration that Zarlino's "natural" ratios for the minor seventh and whole step are incompatible. By adding the two together, Galilei creates an extravagant series of ecmelic octaves:

- [Video 6: Galilei's demonstration of bad octaves]

One bad octave alone would have been sufficient for Galilei to make his point, but twelve in a row is nothing less than a celebration of harmony's shortcomings and a repudiation of musical ethics. The music Galilei produces is not a reflection of his inner being; whether he is good or evil, the facts of sound he demonstrates remain the same. Beyond the limits of harmonic metaphysics, Galilei discovers the unlimited noise of acoustics: a rational, material, and soulless din, indifferent to the words and deeds of virtuous musicians.

When acousticians like Vincenzo Galilei reason about harmony, they conclude, rightly, that the numbers don't add up. For some scholars, the acoustic revelation of the comma seals music's "disastrous fate." Daniel Chua, drawing on the work of Weber and Adorno, interprets Galilei's experiments as the beginning of a process that reduces "the magic essence of music to human logic." [chu2001] Like Chua, we can mourn the loss of the soul and the harmony that keeps musicians in tune with their music. A more interesting possibility, however, is to listen to the noise that becomes audible once we set harmony aside. My last example is a fragment of a madrigal by Nicola Vicentino, a contemporary of Zarlino and Galilei, who, rather than shutting out the ecmelic, incorporates it into a new musical art.

- [Video 7: Vicentino's "Soav'e dolc'ardore"] [vic1996]

As Vicentino demonstrates, acoustics does not destroy music: rather, it splits it in two, between harmony and noise, metaphysics and physics, the limits of ethics and the vastness of sound as such.