Something in the air

for chamber ensemble

To celebrate the 50th anniversary of the *Clean Air Act*:
a musical map of the decline of six air pollutants,
as well as the congressional voting records
that successfully enacted and amended this law.

Eric Banks

Commissioned by the *Verge Ensemble* in January and February 2014,
to be premiered on 6 April 2014 in the concert, *Sonic ecologies*.

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About this work

When Dan Visconti approached me about composing a work for the *Verge Ensemble*, I knew that I wanted to construct a musical map.
At first, we tossed around the idea of mapping the super-storm Hurricane Sandy, but I decided to focus a more positive event.
In order to acknowledge that the United States Congress was once proactive and responsible for good environmental policy,
I wanted to create a piece that would tell the success story of the Clean Air Act, which was voted into law 50 years ago.

This piece is a musical map. It renders into sound the declining densities of six different air pollutants between 1980
(when the EPA began to measure these pollutants) and 2010. Each pollutant is represented by a different instrument in the ensemble:
Carbon monoxide (CO) by the flute, Ground-level ozone (O_3) by the violin, Sulfur dioxide (SO_2) by the clarinet, Nitrogen dioxide (NO_2)
by the cello, Lead (Pb) by the vibraphone, and two different sizes of Particulate Matter (PM 2.5 and 10) by the marimba.

Every year, each of the six pollutants is recorded as a **MEAN** (in parts per billion, or PPB) or in micrograms per cubic meter.
Each yearly mean is represented as a reciting tone in the melodies of the piece, played on weaker beats or partials of the beat.
Each pollutant also has a standard **DEVIATION** (up to the 90th above the mean and down to the 10th percentile below the mean).
These deviations are represented by the range of pitches that wander above and below the reciting-tone mean for each year.

There are 31 years of statistics encompassed by this score, and each year is a 6-bar section (or stave) in a single key.
With each ensuing year, there is a slight modulation, to the next (sharper) key in the circle of fifths.

Here is a table of the data that I collected from the EPA's website:

Pollutant		1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Carbon Monoxide	90%	13000.000	13000.000	12900.000	13200.000	11900.000	12200.000	11700.000	9600.000	10300.000	10400.000	10000.000	9400.000	8000.000	7600.000	8000.000	7400.000	6900.000	6400.000	5900.000	6200.000	5400.000	4800.000	4400.000	3800.000	3700.000	3300.000	3300.000	2900.000	2600.000	2500.000	2300.000
CO	Mean	8931.461	8838.764	8371.536	8528.464	7975.843	7398.315	7670.787	6905.618	6725.843	6822.472	6355.805	6076.779	5507.865	5233.708	5367.416	4820.225	4468.539	4128.090	3995.506	4006.742	3485.393	3302.247	2864.045	2688.764	2511.236	2291.573	2219.101	1943.820	1757.303	1679.775	1564.045
89 sites (PPB)	10%	4400.000	3900.000	4600.000	4000.000	4400.000	4000.000	3900.000	3900.000	4100.000	3700.000	3500.000	3300.000	3300.000	3100.000	3200.000	2700.000	2700.000	2400.000	2300.000	2400.000	2000.000	1900.000	1800.000	1700.000	1500.000	1400.000	1300.000	1200.000	1100.000	1000.000	900.000
Ground-level Ozone	90%	131.000	118.000	119.500	131.000	121.500	114.000	110.000	119.000	133.500	110.000	110.000	111.500	97.000	107.000	102.500	108.500	98.000	103.000	106.500	103.500	98.500	100.500	105.000	96.000	87.000	94.000	93.000	92.500	89.000	79.000	84.000
O3	Mean	101.057	95.104	93.463	101.483	93.798	92.952	91.050	95.121	104.586	88.830	89.443	90.072	83.937	86.267	85.920	90.287	85.263	84.709	89.846	87.961	81.728	83.709	87.730	82.230	74.904	79.709	79.067	78.883	75.022	69.648	73.183
230 sites (PPB)	10%	70.000	70.000	68.000	71.000	71.000	68.000	70.000	73.500	76.000	69.500	70.000	68.000	68.000	66.000	68.500	71.500	70.500	66.000	71.000	71.500	66.500	69.000	67.500	69.000	65.000	65.000	65.000	62.000	64.000	61.000	63.000
Sulfur Dioxide	90%	271.000	251.000	250.000	300.000	263.000	249.000	248.000	280.000	267.000	261.000	226.000	218.000	210.000	200.000	181.000	216.000	160.000	181.000	185.000	195.500	163.000	203.000	145.000	176.000	172.000	143.000	138.000	137.300	111.000	96.000	84.300
SO2	Mean	147.300	141.027	129.170	138.450	129.951	128.168	129.094	125.667	129.067	123.951	109.473	103.961	101.141	93.490	95.409	85.563	81.816	82.407	82.209	84.807	77.621	78.502	68.825	72.467	68.732	67.248	62.289	56.988	51.210	44.662	40.284
57 sites (PPB)	10%	40.000	40.000	25.000	34.000	30.000	30.000	30.000	25.000	30.000	30.000	22.000	26.000	20.000	30.000	26.000	25.000	24.000	23.000	26.000	25.000	26.000	26.000	17.000	17.000	18.000	16.000	20.000	17.000	16.000	9.500	9.667
Nitrogen Dioxide	90%	190.000	190.000	190.000	165.000	145.000	175.000	180.000	165.000	182.500	170.000	170.000	175.000	140.000	140.000	133.500	157.000	133.750	112.000	117.500	121.500	114.000	101.000	98.500	100.000	89.000	77.000	83.500	78.250	81.750	73.400	65.900
NO2	Mean	115.600	111.600	111.267	101.567	97.872	100.078	101.800	99.733	104.383	103.200	96.667	97.300	83.700	81.233	84.000	84.300	76.350	71.800	68.833	73.683	66.667	65.517	63.500	63.150	58.239	57.094	55.200	53.883	53.583	49.060	48.033
30 sites (PPB)	10%	62.500	60.000	62.500	60.000	60.000	60.000	60.000	66.000	62.500	59.000	56.500	58.500	53.000	53.500	53.500	52.500	48.000	49.000	45.000	48.500	44.500	45.500	45.000	43.500	40.000	41.500	40.000	39.500	38.500	35.000	34.500
Lead	90%	2.640	2.020	1.920	2.390	2.380	2.810	1.960	2.700	1.570	1.620	1.070	1.310	1.100	0.850	1.130	0.680	1.000	0.840	0.780	0.920	0.880	0.810	0.650	0.410	0.930	0.400	0.360	0.360	0.370	0.285	0.200
Pb	Mean	1.481	1.160	0.990	1.002	0.972	1.106	0.639	0.837	1.058	0.535	0.368	0.342	0.298	0.257	0.385	0.268	0.246	0.214	0.212	0.232	0.220	0.265	0.192	0.157	0.249	0.237	0.150	0.152	0.268	0.123	0.102
13 sites (micg/m3)	10%	0.360	0.360	0.400	0.450	0.450	0.280	0.160	0.100	0.070	0.060	0.060	0.050	0.040	0.040	0.040	0.030	0.030	0.030	0.030	0.030	0.020	0.020	0.020	0.020	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Particulate Matter 10	90%											142.000	134.000	115.000	108.000	108.000	120.000	104.000	106.000	99.000	109.000	102.000	100.000	96.000	113.000	85.000	92.000	95.000	94.000	91.000	80.000	79.000
PM10	Mean											84.360	82.238	73.127	71.248	70.500	69.973	63.958	64.452	62.291	67.575	64.431	63.778	62.642	65.149	55.490	59.565	59.063	61.100	57.280	51.000	51.406
239 sites (micg/m3)	10%											44.000	43.000	41.000	41.000	39.000	39.000	36.000	36.000	37.000	37.000	36.000	36.000	37.000	34.000	32.000	34.000	33.000	35.000	32.000	27.000	29.000
Particulate Matter 2.5	90%																					17.849	17.295	16.309	16.007	15.382	16.804	14.941	15.497	13.506	12.115	12.992
PM2.5	Mean																					13.782	13.462	12.939	12.513	12.132	13.119	11.778	12.138	10.942	9.813	10.007
239 sites (micg/m3)	10%																					9.093	9.203	8.846	8.275	8.381	8.227	8.170	8.093	7.722	7.195	6.883

And here is how I rendered this data into pitch: (I apologize for the size of the tables. I can provide the original files if you are interested.)

	Year	1980	1981	1982	VOTE	1983	1984	1985	1986	VOTE	1987	1988	1989	1990	VOTE	1991	1992	1993	1994	1995	VOTE	1996	1997	1998	1999	2000	VOTE	2001	2002	2003	2004	2005	2006	VOTE	2007	2008	2009	2010
Pollutant	Key	C	G	D	A	E	B	F#/Gb	Db	Ab	Eb	Bb	F	C	G	D	A	E	B	F#/Gb	Db	Ab	Eb	Bb	F	C	G	D	A	E	B	F#/Gb	Db	Ab	Eb	Bb	F	C
Instrument	Bar	m1-6	m7-12	m13-18	m19-24	m25-30	m31-36	m37-42	m43-48	m49-54	m55-60	m61-66	m67-72	m73-78	m79-84	m85-90	m91-96	m97-102	m103-108	m109-114	m115-120	m121-126	m127-132	m133-138	m139-144	m145-150	m151-156	m157-162	m163-168	m169-174	m175-180	m181-186	m187-192	m193-198	m199-204	m205-210	m211-216	m217-222
Carbon Monoxide	H	C6	C6	B5		C#6	A#5	A#5/Bb5	Bb5		F5	G5	G5	E5		E5	D5	C#5	C#5	C#5/Db5		C5	Bb4	Bb4	Bb4	A4		G4	F#4	E4	E4	E#4/F4	F4		Eb4	Eb4	D4	E4
Flute	RT	E5	E5	D5		E5	C#5	C#5/Db5	Db5		C5	C5	C5	A4		B4	A4	A4	G#4	G#4/Ab4		G4	G4	F4	F4	F4		E4	E4	E4	D#4	D#4/Eb4	Eb4		D4	D4	D4	C4
	L	G4	F#4	G4		F#4	F#4	F#4/Gb4	Gb4		F4	G4	F4	F4		E4	E4	E4	E4	D#4/Eb4		Eb4	Eb4	Eb4	D4	D4		D4	D4	C#4	C#4	C#4/Db4	Db4		C4	C4	C4	C4
Ground-level Ozone	H	G5	D5	D5		F#5	D#5	C#5/Db5	C5		Eb5	G5	C5	C5		B4	F#4	B4	G#4	B4/Cb5		Ab4	Ab4	Bb4	A4	G4		A4	A4	F#4	E4	F#4/Gb4	Gb4		F4	F4	C4	E4
Violin	RT	A4	F#4	F#4		G#4	F#4	F#4/Gb4	F4		G4	Bb4	F4	F4		E4	D4	E4	E4	E#4/F4		Eb4	Eb4	F4	F4	D4		D4	E4	C#4	B3	C#4/Db4	Db4		C4	C4	Bb3	C4
	L	A3	A3	A3		A3	G#3	G#3/Ab3	Bb3		Bb3	C4	A3	A3		A3	A3	A3	A#3	B3/Cb4		Bb3	Ab3	Bb3	Bb3	A3		A3	A3	A3	G#3	G#3/Ab3	Ab3		Ab3	G3	G3	G3
Sulfur Dioxide	H	C5	B4	B4		C#5	B4	A#4/Bb4	Bb4		C5	C5	C5	A4		G4	F#4	F#4	E4	G#4/Ab4		Eb4	F4	F4	G4	D4		G4	D4	E4	E4	C#4/Db4	Db4		C4	Bb3	Bb3	A3
Clarinet	RT	C4	C4	B3		C#4	B3	B3/Cb4	C4		C4	C4	C4	B3		A3	A3	A3	A#3	G#3/Ab3		Ab3	Ab3	G3	A3	G3		G3	F#3	G#3	F#3	F#3/Gb3	Gb3		F3	F3	F3	E3
	L	E3	E3	E3		E3	D#3	D#3/Eb3	Eb3		Eb3	Eb3	E3	D3		E3	D3	E3	E3	D#3/Eb3		Eb3	Eb3	Eb3	E3	E3		E3	D3	D#3	D#3	D#3/Eb3	Eb3		Eb3	Eb3	D3	D3
Nitrogen Dioxide	H	E4	E4	E4		C#4	A#3	D#4/Eb4	Eb4		C4	Eb4	D4	D4		D4	A3	A3	G#3	B3/Cb4		Ab3	Eb3	F3	F3	E3		D3	D3	D#3	C#3	B2/Cb3	C3		Bb2	C3	Bb2	A2
Cello	RT	F3	E3	E3		D#3	C#3	D#3/Eb3	Eb3		D3	Eb3	D3	D3		D3	B2	B2	C#3	C#3/Db3		Bb2	Bb2	Bb2	Bb2	A2		A2	A2	A2	G#2	G#2/Ab2	Gb2		G2	G2	F2	F2
	L	A2	G2	A2		G#2	G#2	G#2/Ab2	Ab2		Ab2	A2	G2	G2		G2	F#2	F#2	F#2	F#2/Gb2		F2	F2	F2	F2	F2		F#2	F#2	E2	E2	E#2/F2	F2		F2	F2	E2	E2
Lead	H	G5	D5	D5		F#5	F#5	A#5/Bb5	Db5		Ab5	Bb4	Bb4	F4		A4	F#4	E4	F#4	D#4/Eb4		F4	Eb4	Eb4	F4	F4		E4	D4	C#4	E4	B3/Cb4	C4		C4	C4	Bb3	B3
Vibraphone	RT	A4	G4	F#4		F#4	F#4	F#4/Gb4	Eb4		Eb4	F4	D4	C4		B3	B3	B3	B3	B3/Cb4		Bb3	Bb3	Bb3	Bb3	B3		B3	B3	A3	B3	B3/Cb4	Bb3		Bb3	Bb3	Bb3	B3
	L	C4	C4	B3		C#4	C#4	B3/Cb4	Bb3		Bb3	Bb3	A3	A3		A3	A3	A3	A3	A3		Bb3	Bb3	Bb3	Bb3	A3		A3	A3	A3	A#3	A#3/Bb3	Bb3		Bb3	Bb3	Bb3	A3
Particulate Matter 10	H													A5		G5	E5	D#5	D#5	C#5/Db5		Db5	D5	C5	D5	C5		C#5	B4	E5	A#4	B4/Cb5	C5		C5	Bb4	A4	A4
Marimba	RT													A4		A4	F#4	F#4	F#4	F#4/Gb4		F4	F4	F4	F4	F4		E4	E4	E4	E4	D#4/Eb4	Eb4		Eb4	Eb4	D4	D4
	L													C4		B3	B3	B3	B3	B3/Cb4		Bb3	Bb3	Bb3	Bb3	B3		B3	B3	B3	A#3	B3/Cb4	Bb3		Bb3	Bb3	Bb3	A3
Particulate Matter 2.5	H																									A5		A5	F#5	F#5	E5	G#5/Ab5	Eb5		F5	C5	A4	B4
Marimba	RT																									C5		B4	B4	A4	G#4	B4/Cb5	Ab4		Ab4	F4	E4	D4
	L																									D4		D4	D4	B3	C#4	B3/Cb4	C4		C4	Bb3	Bb3	A3

Above, you can see the keys that are attached to each ensuing year (and 6-bar segment). You can also see the reciting tone (RT) of each year, as well as the high and low pitches (H and L) that wander above and below each reciting tone. Notice that PM 10 was not measured until 1990, and that PM 2.5 was not tracked until the year 2000. This is precisely why there is no marimba part for the first third of the piece.

This piece also tracks the congressional voting record for the Clean Air Act. These episodes occur during the gray VOTE stripes above. There were three votes for the Clean Air Act: the first in 1963 to enact the law, and two subsequent votes to amend it, in 1967 and 1990. I decided to represent these votes as a "rapid roll call" of staccato sixteenth-notes. Imagine if all 435 members of the House were to say "Yea" or "Nay" in quick, sixteenth-note succession, in alphabetical order by state, and in numerical order by district. Then, insert a single sixteenth-rest between each state's listing in the roll call. The endless string of 435 votes becomes a stuttering series of 484 sixteenth notes and rests, or 121 quarter-note beats. Divide this total by 6, and you will get about 20 beats (or, in 4/4 meter, about 5 measures of staccato "rapid roll call" for each the 6 gray VOTE episodes above.

Each vote in the "rapid roll call" is also represented by pitch. In each tetrachord, the highest pitch represents a Democratic "Yea," the second-highest a Republican "Yea," the second-lowest a Democratic "Nay," and the lowest a Republican "Nay" or silence. Remember that there were three votes (in 1963, 1967, and 1990). These three "rapid roll calls" are superimposed in each episode. The 1963 and 1967 "roll calls" are homophonic with each other. However, due to redistricting between 1967 and 1990, the rests that demarcate each new state in the list of the 1990 "roll call" fall differently than in the earlier votes. Each of these three "roll calls" is still 484 sixteenths in duration, and their superimposed episodes are marked *battibecchi* (or bickering) in the score. (These voting episodes are found at the rehearsal letters A, C, E, G, I, and K).

Wait; there's more! The melodies in this piece are meant to be recited or sung (*colloquiale* or *cantabile* in the score) because they are based on texts that describe each of the six pollutants (and coda that is a bit of a mission statement). These texts are adapted from the official website of the EPA:

Carbon monoxide is a colorless, odorless gas, emitted from combustion processes. Nationally, and particularly in urban areas, the majority of carbon monoxide emissions to ambient air come from mobile sources. Carbon monoxide can cause harmful health effects by reducing the delivery of oxygen to the tissues and the organs of the body. At extremely high levels, carbon monoxide can cause death.

Ground-level ozone is not emitted directly into the air, but is created by chemical reactions between oxides of nitrogen and volatile organic compounds in the presence of sunlight. Emissions from industrial facilities and electric utilities, motor vehicle exhaust, gasoline vapors, and chemical solvents are some of its major sources. Ground-level ozone can have harmful effects on sensitive vegetation, and adverse impacts on ecosystems, including: loss of species diversity, changes to habitat quality, and disruption of water and nutrient cycles.

Sulfur dioxide is one of a group of highly-reactive gasses known as "oxides of sulfur." The largest sources of sulfur dioxide emissions are from fossil-fuel combustion at power plants and other industrial facilities. Smaller sources of sulfur dioxide emissions include industrial processes, such as: extracting metal from ore, and the burning of high sulfur-containing fuels by locomotives, large ships, and off-road equipment. Sulfur dioxide is connected to a number of adverse effects on the human respiratory system.

Nitrogen dioxide is one of a group of highly-reactive gasses known as "oxides of nitrogen" or "nitrogen oxides." The National Ambient Air Quality Standard of the EPA uses nitrogen dioxide as the indicator for the larger group of nitrogen oxides in the air. Nitrogen dioxide forms quickly from emissions from cars, trucks, busses, power plants, and off-road equipment. In addition to contributing to the formation of ground-level ozone, and fine-particle pollution, nitrogen dioxide is connected to a number of adverse effects on the human respiratory system.

Lead is a metal that is found naturally in the environment as well as in manufactured products. The major sources of lead emissions have historically been from motor-vehicle fuels and industrial sources. As a result of regulatory efforts from the Environmental Protection Agency that removed lead from motor-vehicle gasoline, emissions of lead and levels of lead in the air have both dramatically declined in the transportation sector. Today, the highest levels of lead in air are usually found near lead smelters, and the major sources of lead emissions are ore and metals processing, and aircraft that operate on leaded aviation gasoline.

Particulate matter, also known as "particle pollution," is a complex mixture of extremely small particles and liquid droplets. Particle pollution is made up of a number of components, including acids, organic chemicals, metals, soil, and dust. The size of these particles is directly related to their potential for causing health problems. The Environmental Protection Agency groups particle pollution into two categories. "Inhalable coarse particles" are found near roadways and dusty industries. "Fine particles," such as those found in smoke and haze, can be directly emitted from sources such as forest fires, or can form when gasses from power plants and automobiles react in the air. These particles pass through the throat and nose and enter the lungs. Once inhaled, these particles can cause serious health effects.

In recent years, the EPA has acted to dramatically improve America's air quality by designing and developing national programs that, when fully implemented, will achieve significant reductions in air emissions. The benefits associated with a better quality of air will lead to improved health, longevity, and quality of life for all.

The texts of these 7 paragraphs create the rhythms found at the beginning of the piece, as well as at rehearsal letters B, D, F, H, J, and L.

In order for this map to be an accurate depiction of *relative* pollutant density, the ranges are particularly low. Also, it's important to remember that this is an actual *success* story for governmental regulation, and pollution levels *decrease* over the course of the piece. Therefore, please make room for the very low register of the flute, and understand why the smaller melodic ranges will "bumble along" toward the end of the piece. If the vibraphone and marimba lines cannot be performed simultaneously by the same player, I suggest playing both lines on the vibraphone, but using soft mallets for the written marimba part and hard mallets for the vibraphone part (however, never with tremolo).

Thank you to Dan and the entire *Verge Ensemble* for this opportunity!
I hope that you and your audience will enjoy this coming together
of science, nature, politics, history, and music.

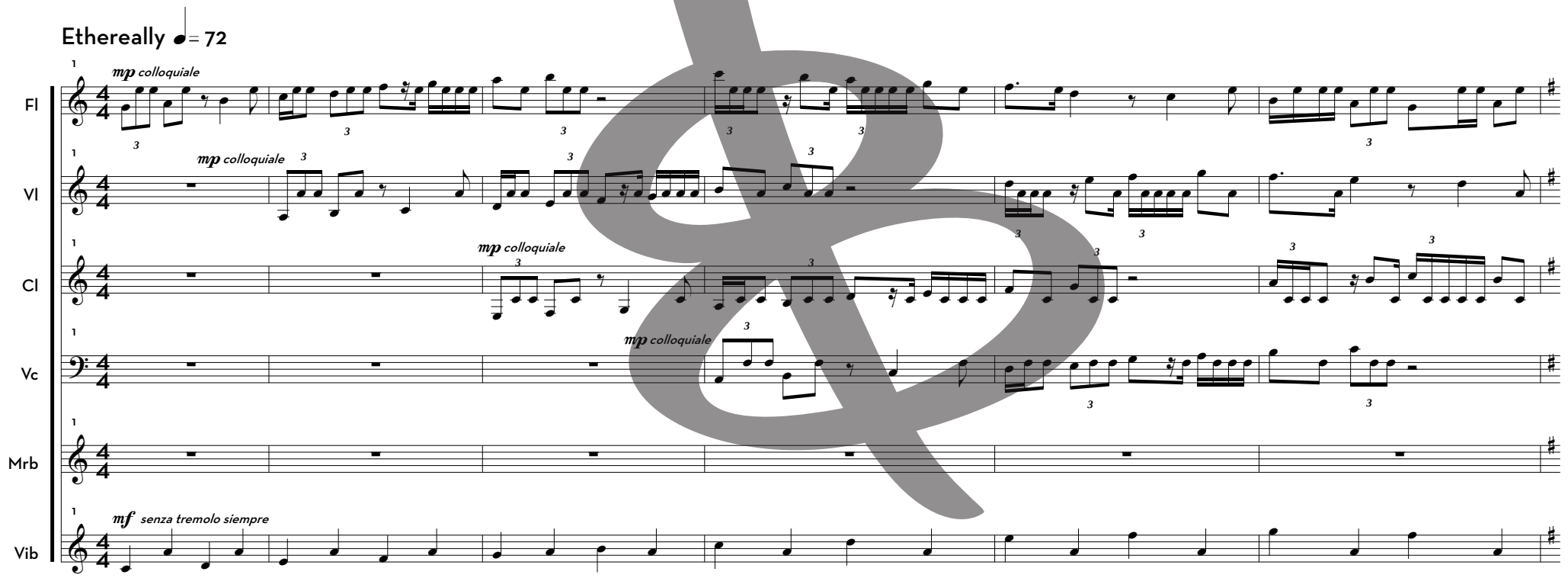
Eric Banks

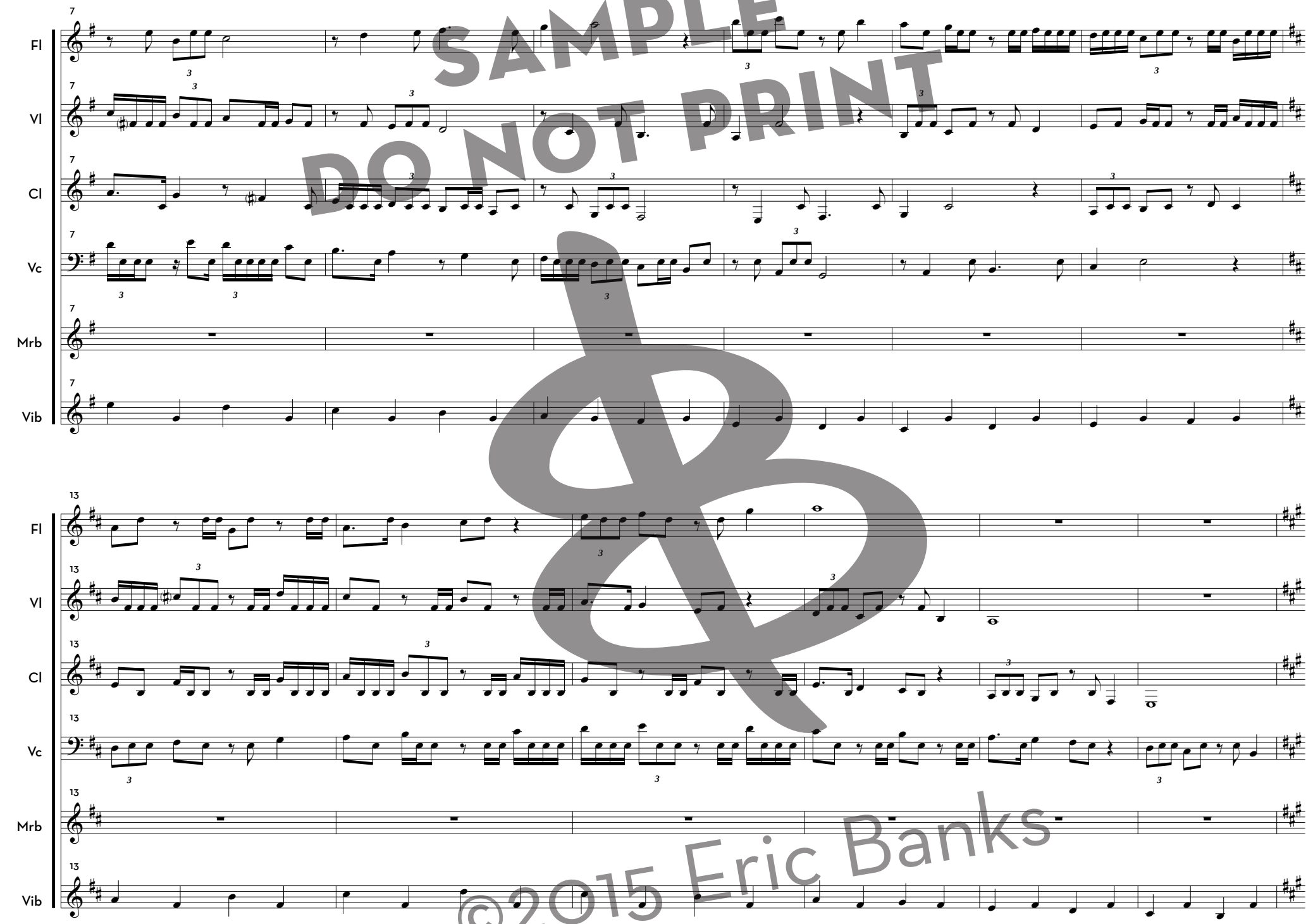
Something in the air

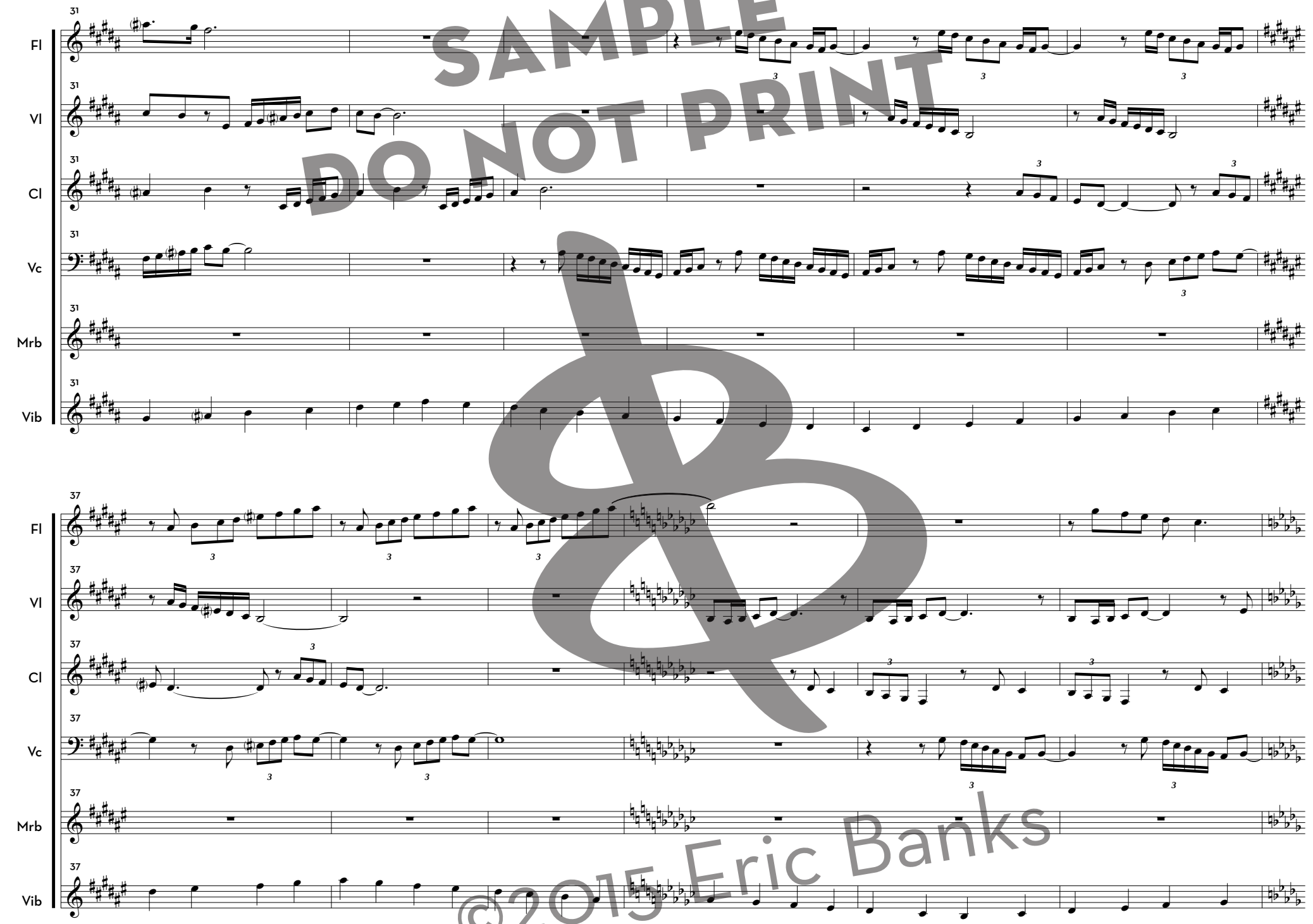
Commissioned by the *Verge Ensemble*
to be premiered on 6 April 2014
in the concert, *Sonic ecologies*

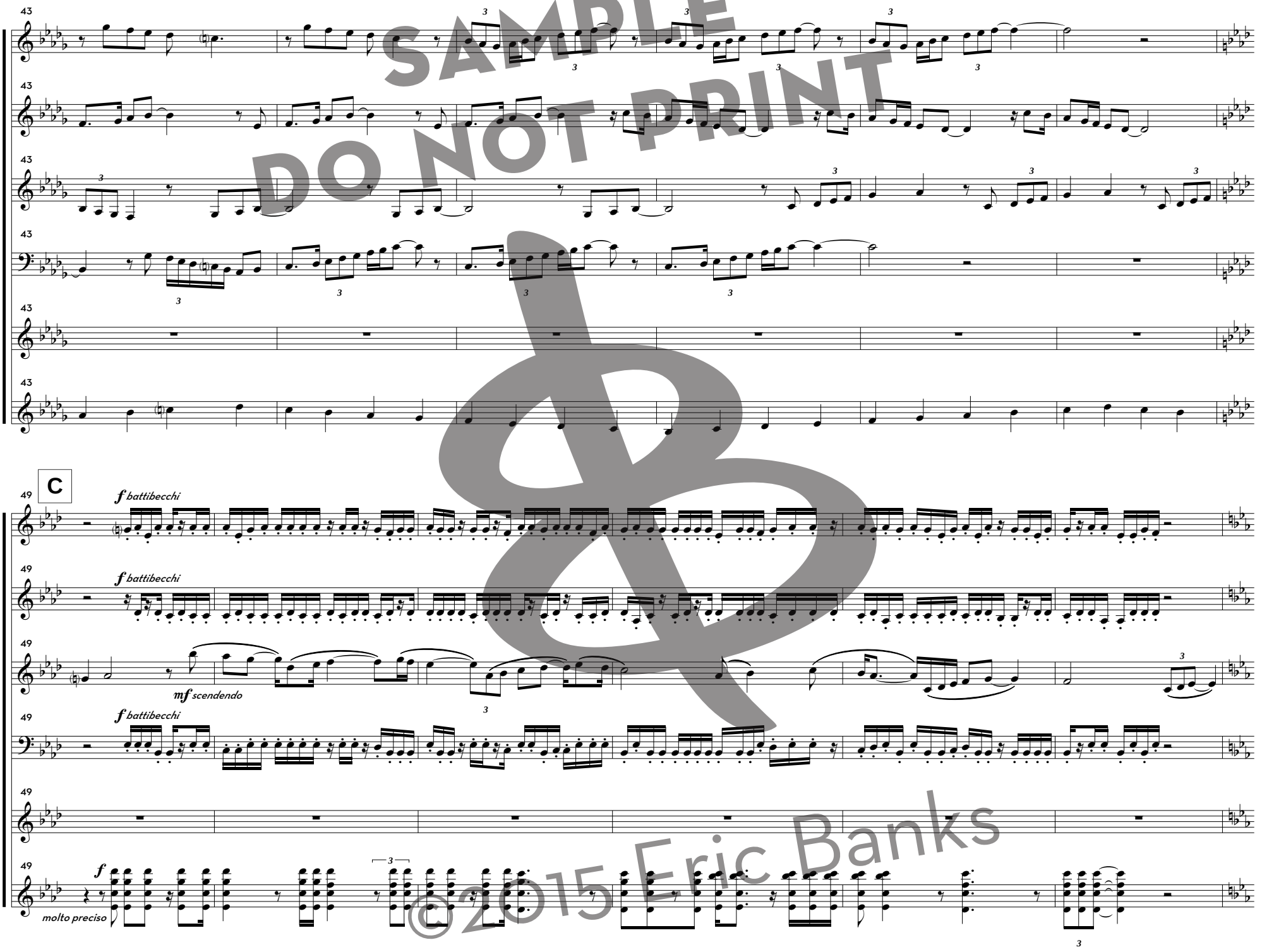
Full Score

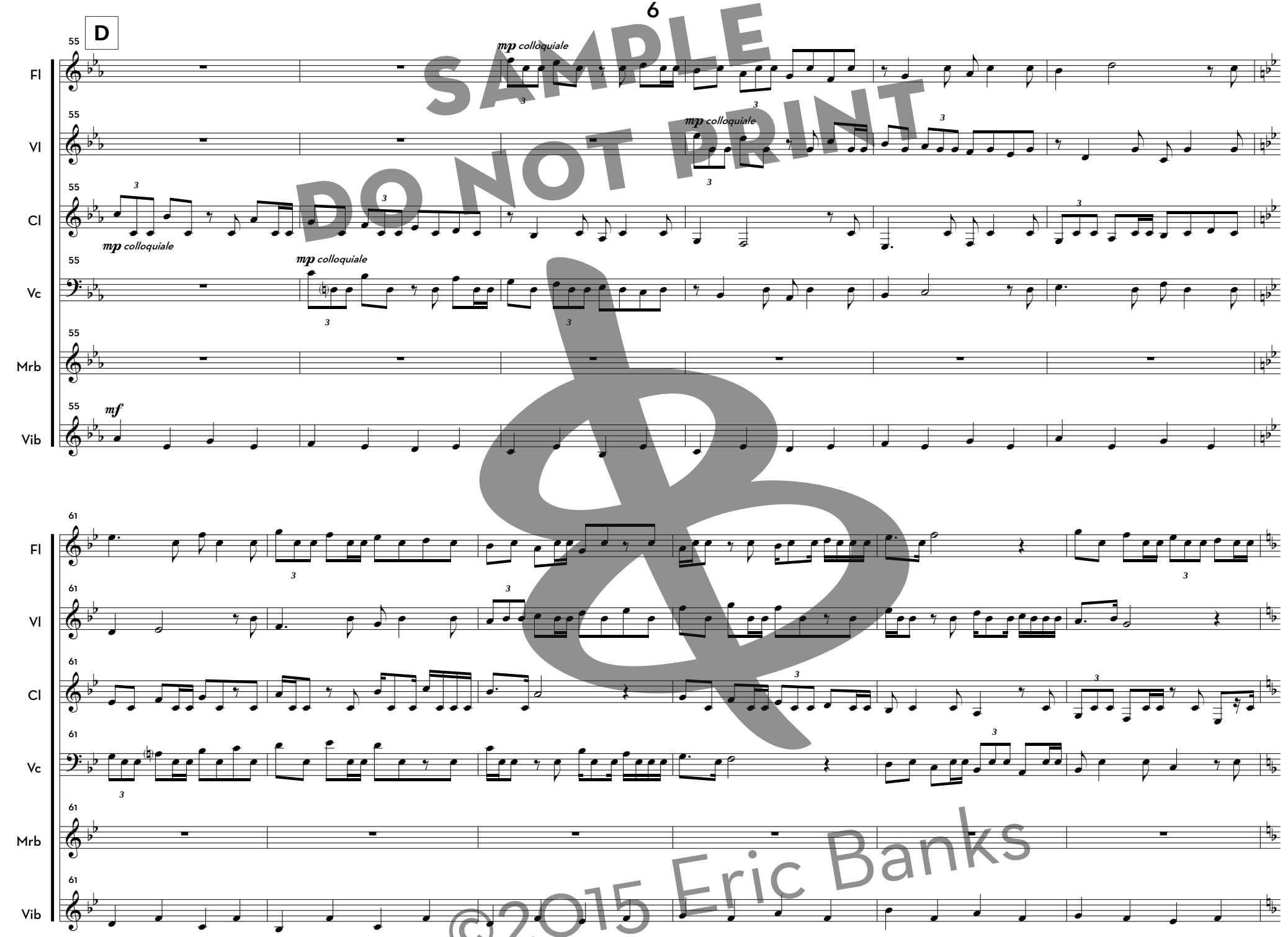
Eric Banks

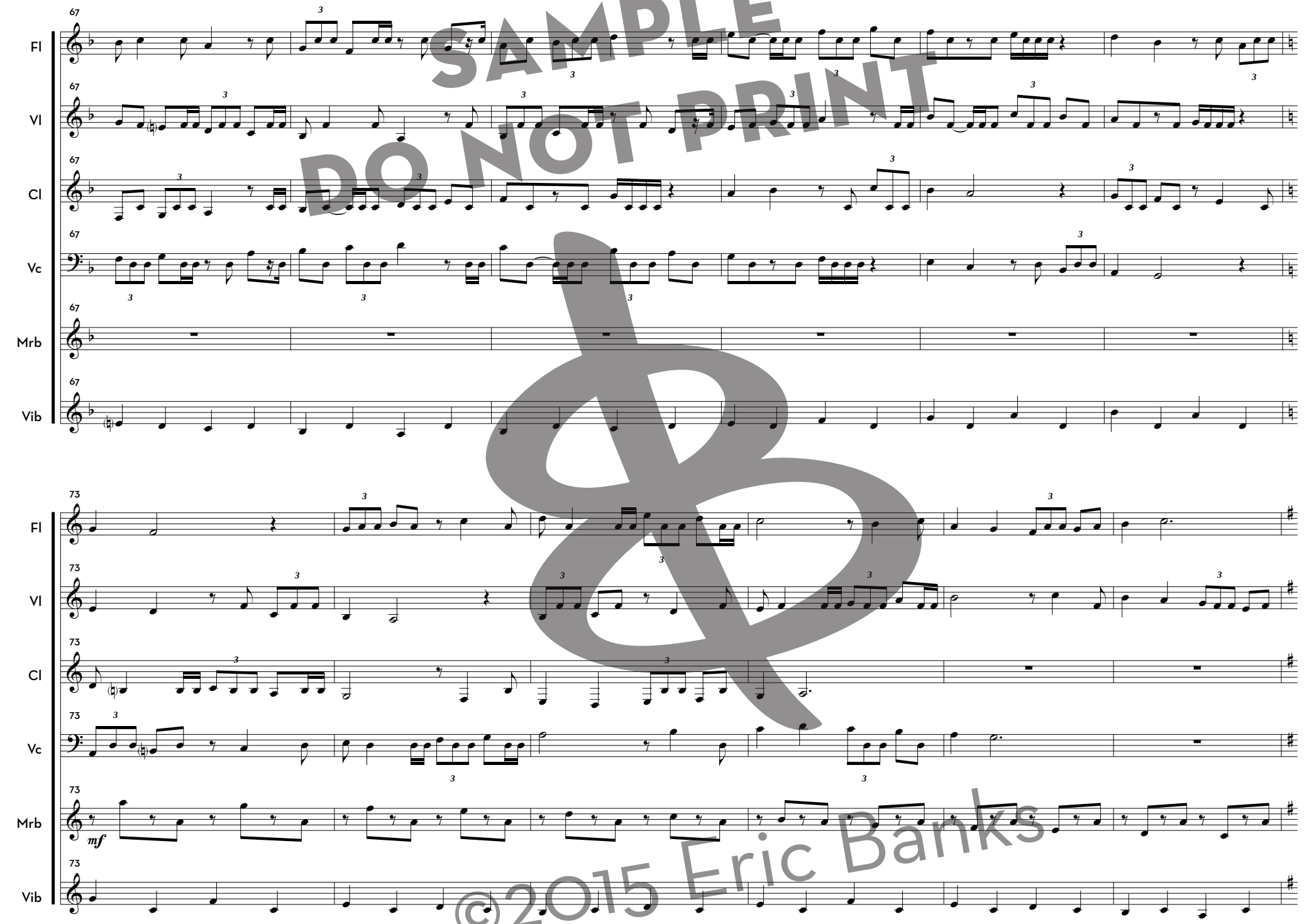


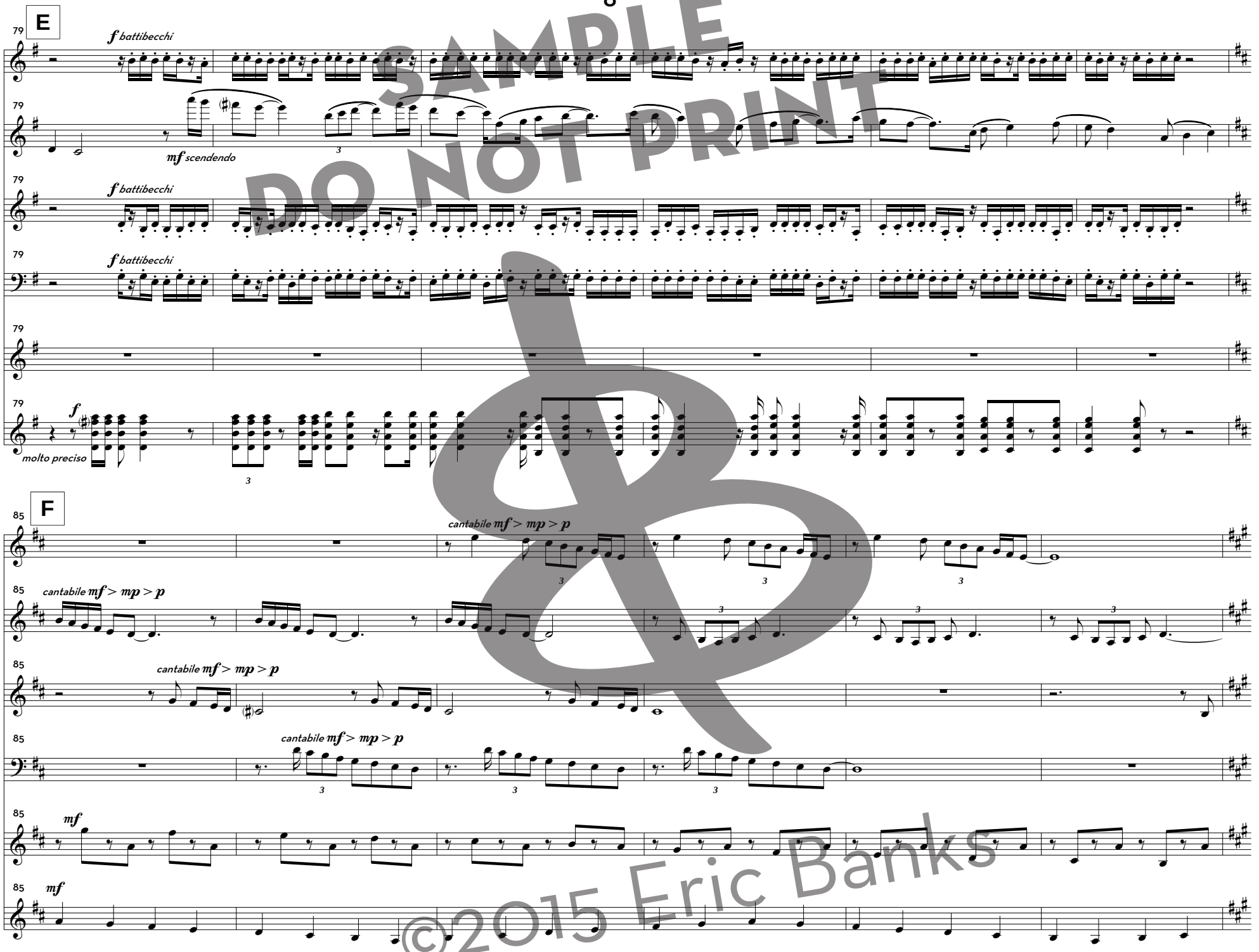


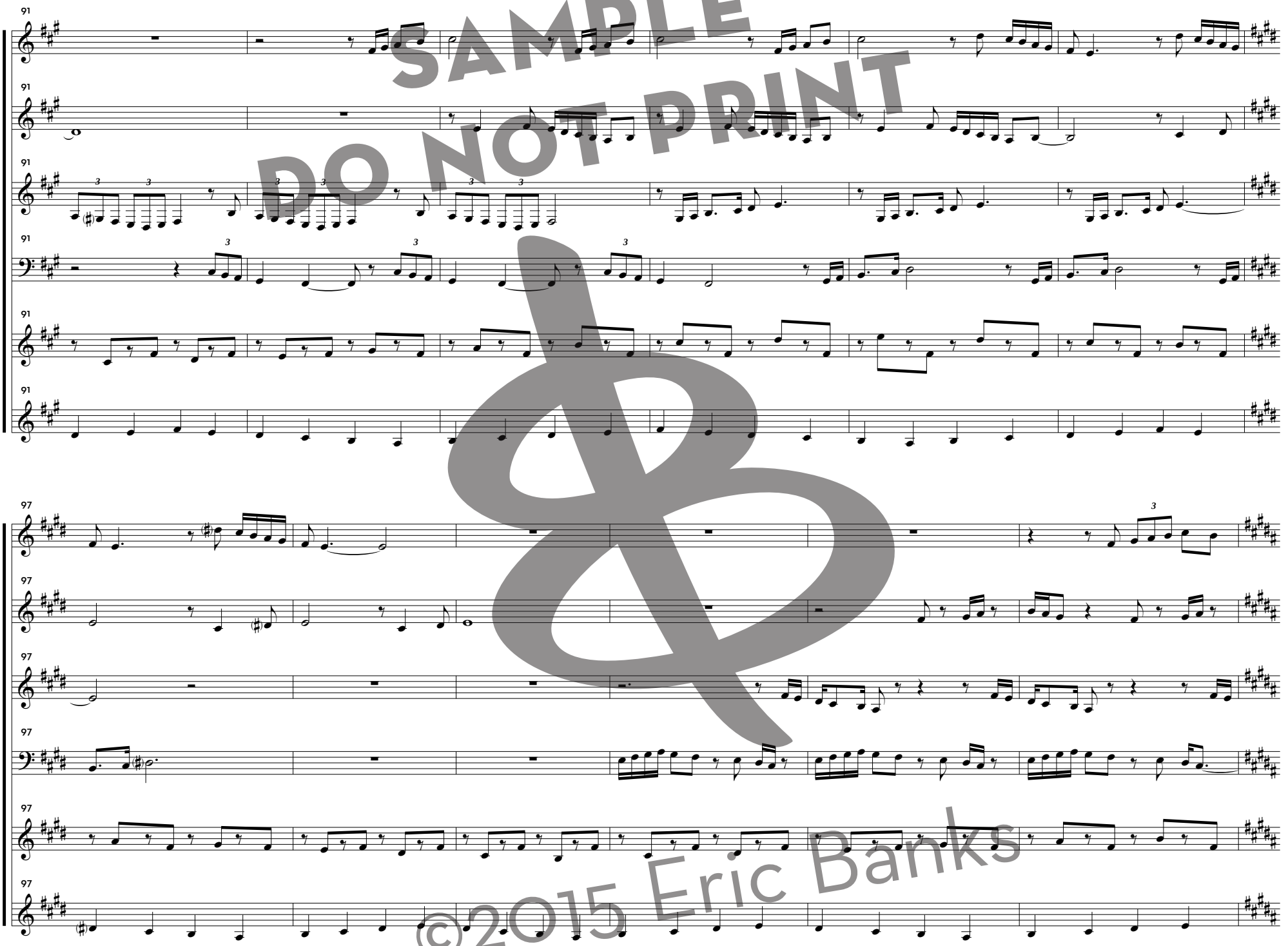


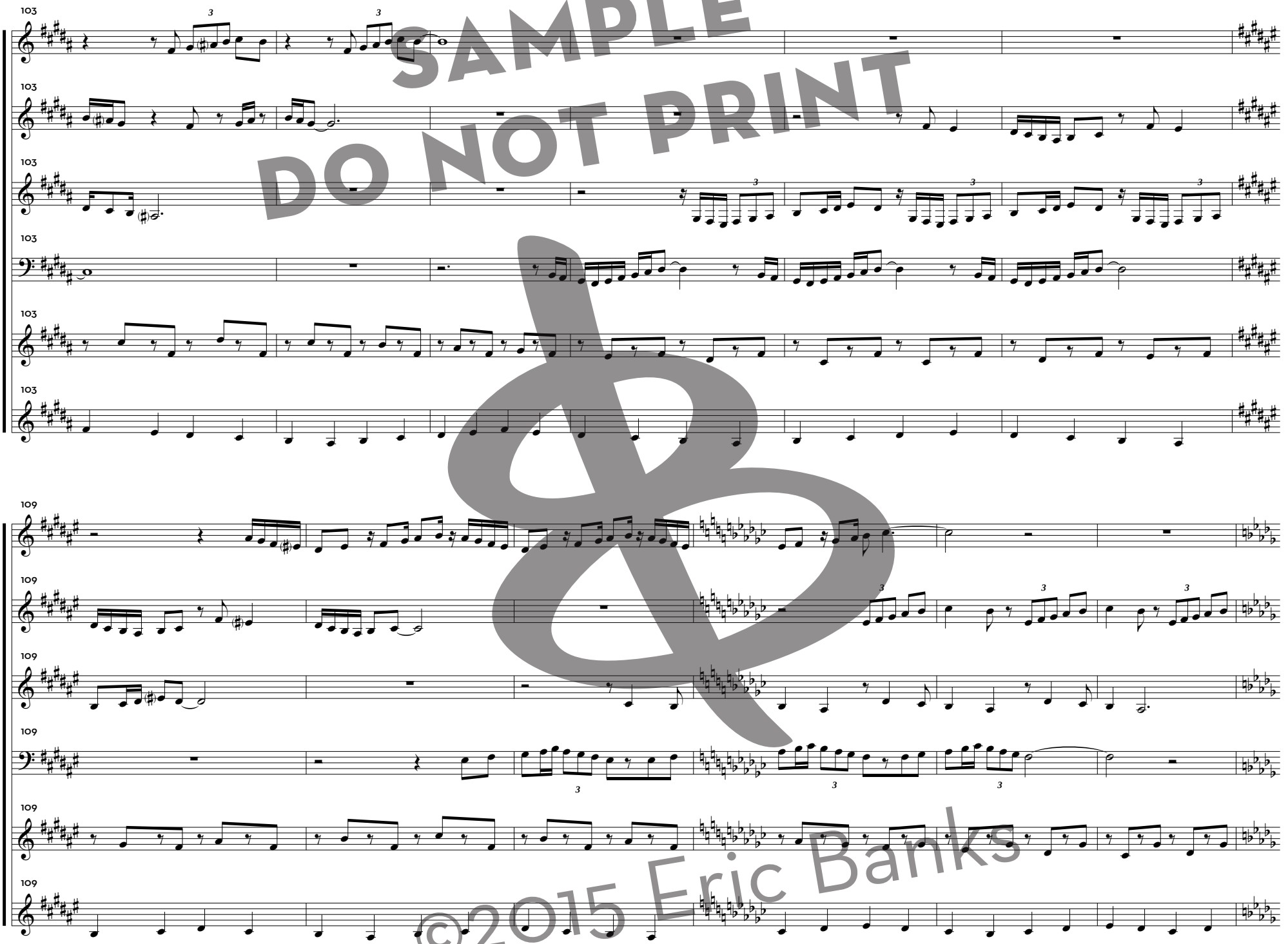


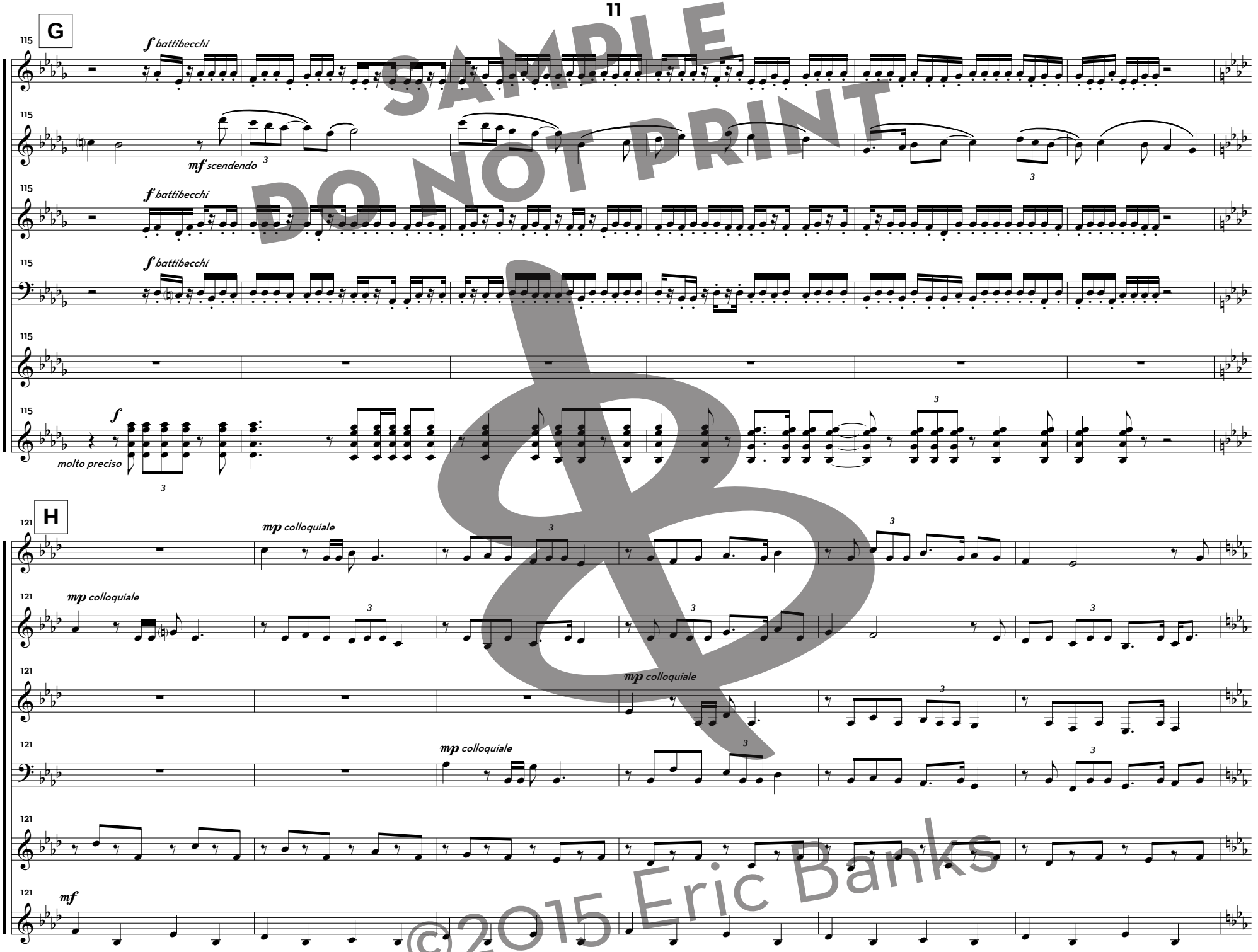


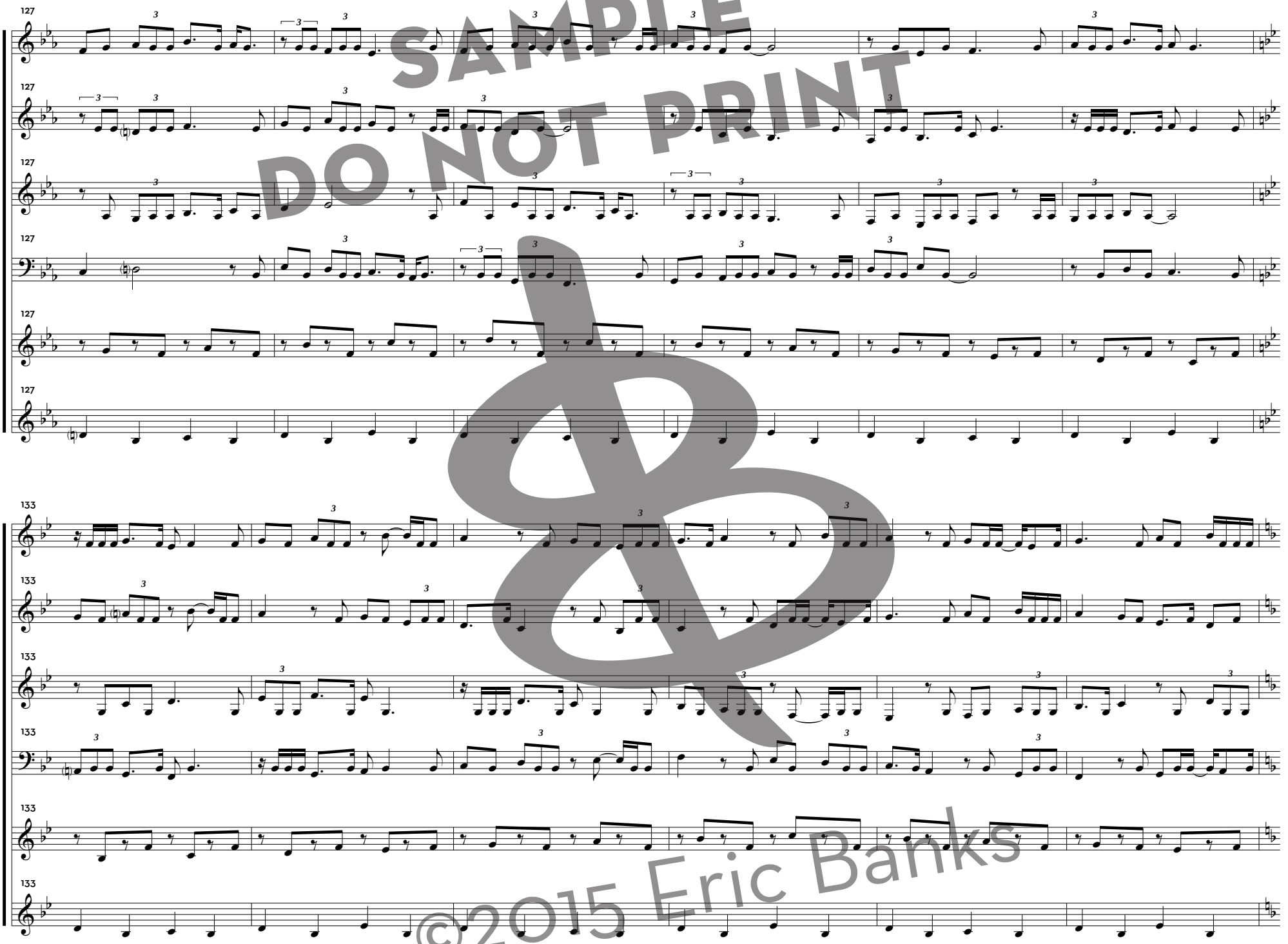


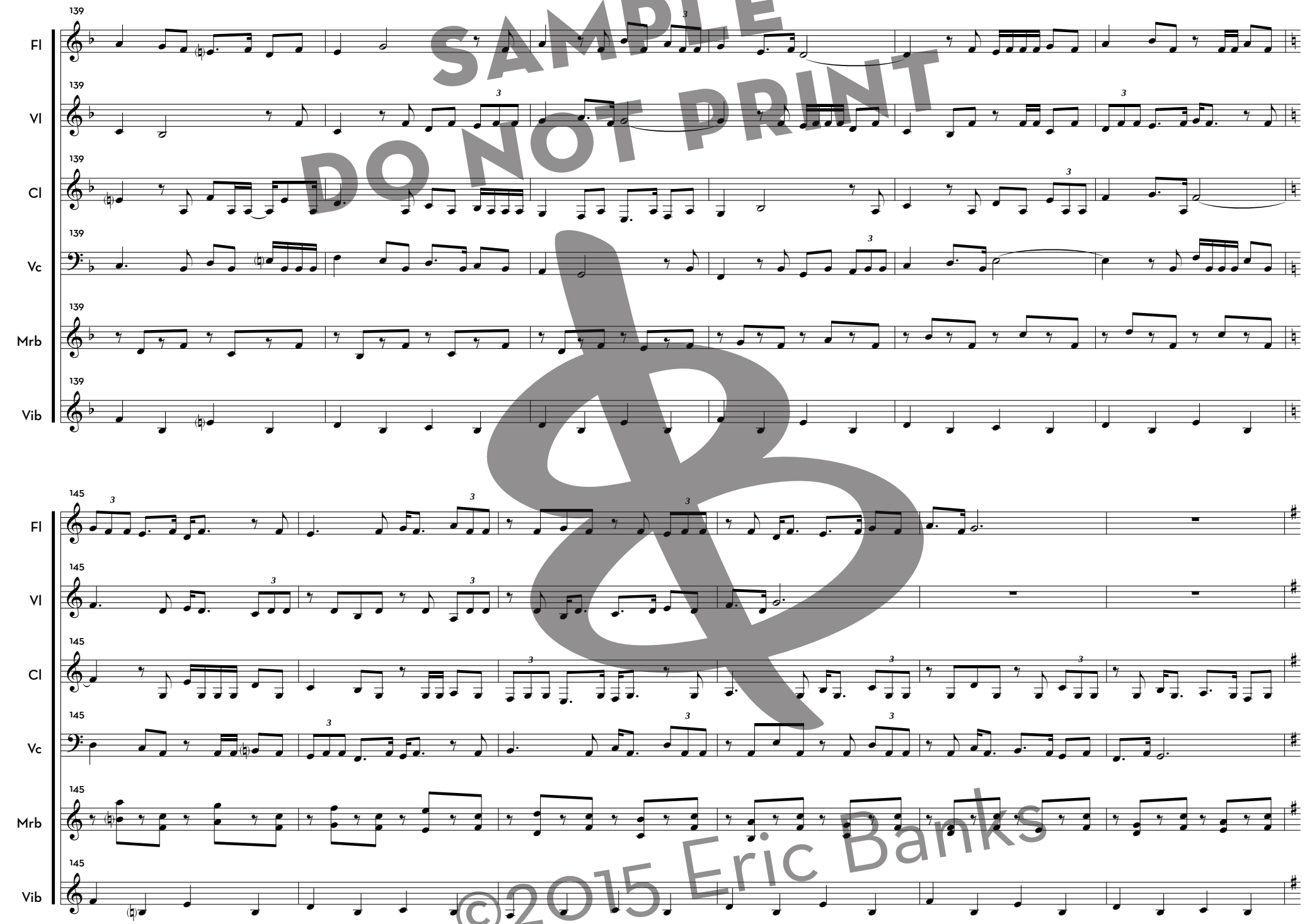












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