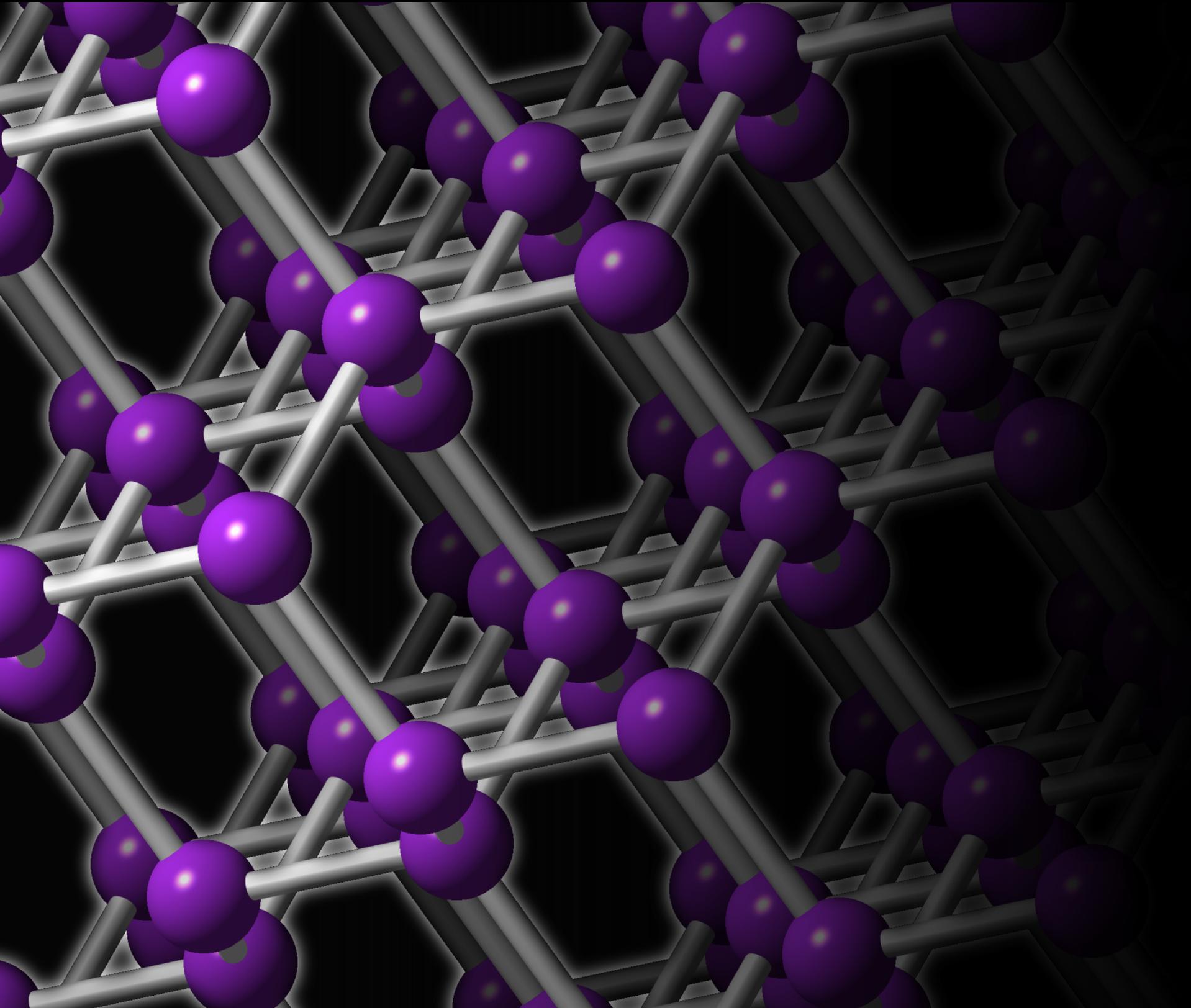


# Music for 88 keys

a suite for player piano and electronics

Marco Buongiorno Nardelli

To Conlon Nancarrow, *in memoriam*

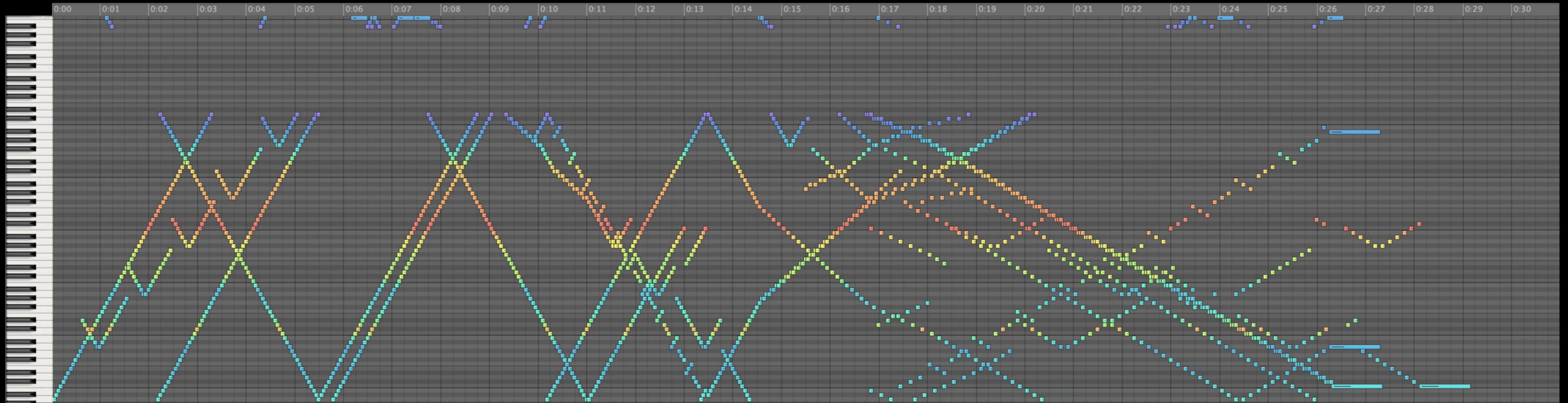


## materialsoundmusic

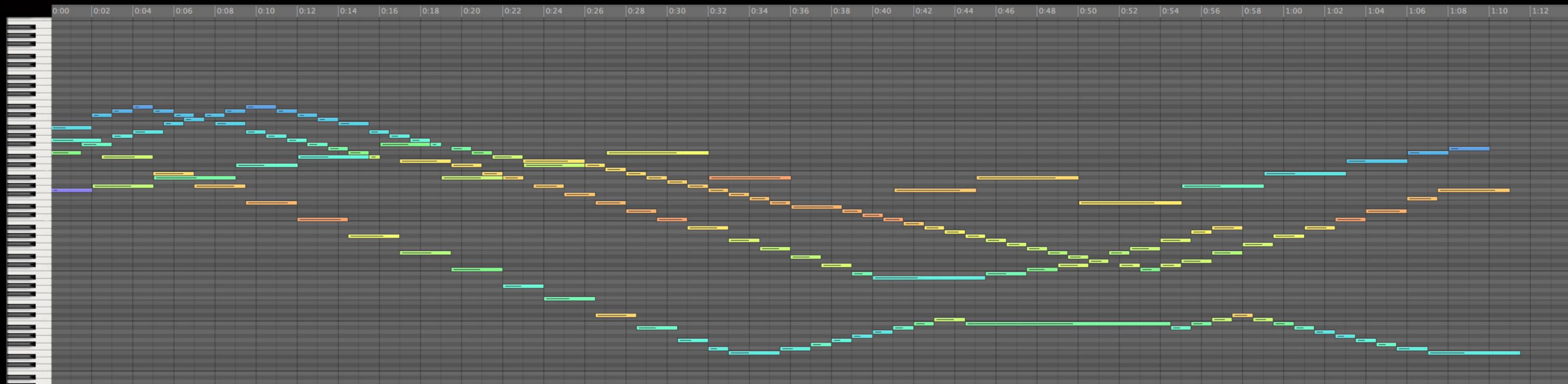
Sonification of scientific data, i.e. the perceptualization of information through acoustic means, not only provides a useful alternative and complement to visual data representation, but provides also the raw data for potential artistic remixes and further musical interpretation. *Music for 88 keys* is the first example of a composition based on the sonification and remix of materials property data from the online computational materials repository AFLOWLIB, the heart of the materialsoundmusic project. AFLOWLIB is an extensive (~1,000,000 entries and growing) repository of materials property data (phase-diagrams, electronic structure and magnetic properties to name a few) generated using the high-throughput computational framework AFLOW and freely available on the website of the AFLOW research consortium at <http://AFLOWLIB.org>. Databases such AFLOWLIB are of enormous scientific and technological value because they provide the materials scientist with complete compilations of materials properties that can be used for materials discovery, development and rational design. Notwithstanding the impact of materials databases in research and industry, the connection with general audiences beyond scientists and engineers is quite feeble, and these projects are not receiving the interest and engagement that they deserve. We are familiar with the intricacies and vastness of the universe but we give little thought to the universe of processes that happen constantly inside the materials that surround us and on which we depend in our everyday lives. Part of the reason is that over millennia we have developed a familiarity with celestial objects, seen as obeying mathematical and musical laws, and we have embodied a synergy between the scientific and artistic interpretation of this aspect of the physical world. A similar concept has never existed for the world of materials. With the materialsoundmusic project I want to engage and educate audiences on the inner reality of crystalline structures and materials properties via a range of art and science collaborations originating from the sonification and musical reinterpretation of the data in the AFLOWLIB repository.

Any sonification process starts with the identification of the properties that better ascertain the character of the data, in our case, each individual material in AFLOWLIB. Among all possible choices, I opted for the sonification of the electronic band structure of a solid, the set of data that describes which ranges of energy an electron within the solid may have (called energy bands) or not have (called band gaps), and of the density of states, a measure of the number of states per interval of energy that are available to be occupied by electrons – a sort of histogram of the electronic band structure. This process of sonification provides us with an abstract representation of the data that can be used for navigation and data mining of the database on scientific grounds (for instance, materials with similar electronic band structure will have similar sonic signatures that can be used to filter database entries that can be suitable for specific classes of applications - as an auditory materials descriptor). The sonification algorithm behind *Music for 88 keys* maps the electronic structure data into sound material by encoding energy into MIDI events in an automated high-throughput fashion. The sonic data are then fed to audio generating patches written for MAX and Ableton Live through a DataPlayer app developed by myself. The algorithm used in the creation of *Music for 88 keys* maps energies in the range from -15eV to 5eV to the MIDI notes 21 through 108 (the 88 keys of the piano) and associates an amplitude (MIDI velocity) to each note according to the value of the density of states at that energy. The duration of any MIDI event (that is a representation of rhythm and meter) is inferred from the rate of variation of the data (i.e. their derivative in time), making each material soundscape completely internally consistent. The MIDI stream so generated is then treated as a collection of musical structures for further compositional elaboration. *Music for 88 keys* is a suite born from the remix of the data from diamond, zinc oxide and gold. The piece is scored for player piano and electronics and is dedicated to the memory of Conlon Nancarrow, the American composer who made the player piano his instrument of choice throughout his career. In *Music for 88 keys* the original datasets from AFLOWLIB.org are variably manipulated through different techniques: from simple variations of tempo and meter to extensive reordering of pitches or regions and various orchestration choices. The suite starts with a *preludio* that uses the sonic mapping of the density of states of carbon in the diamond structure as starting compositional material. The same concept is used in the *interludio*, but with data from a different material, zinc oxide. *Interludio* separates the two principal sections of the suite: *largo* and *andante*, with the piano accompanied by sampled percussions sounds and based again on data from diamond, from *continuo*, based on the data for zinc oxide for piano with a drone of brass, and *contrappunto aureo*, based on the data from gold, where the brass and the percussions are both combined with the piano. The two principal sections are created using the electronic band structure data. The suite ends with a *postludio*, where the piano alone states again a sonic mapping of density of states that now combines data from all the three materials.

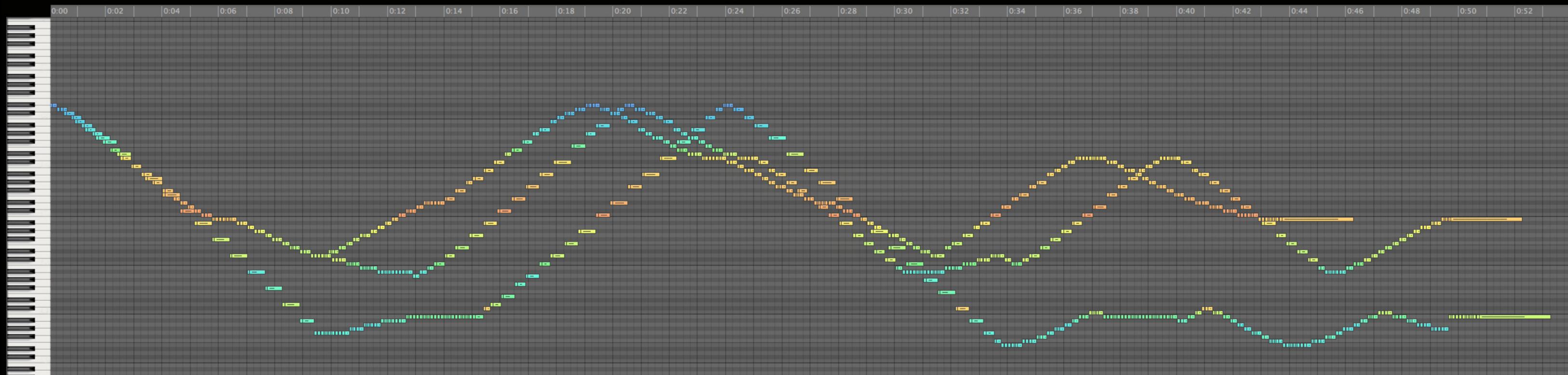
the piano rolls



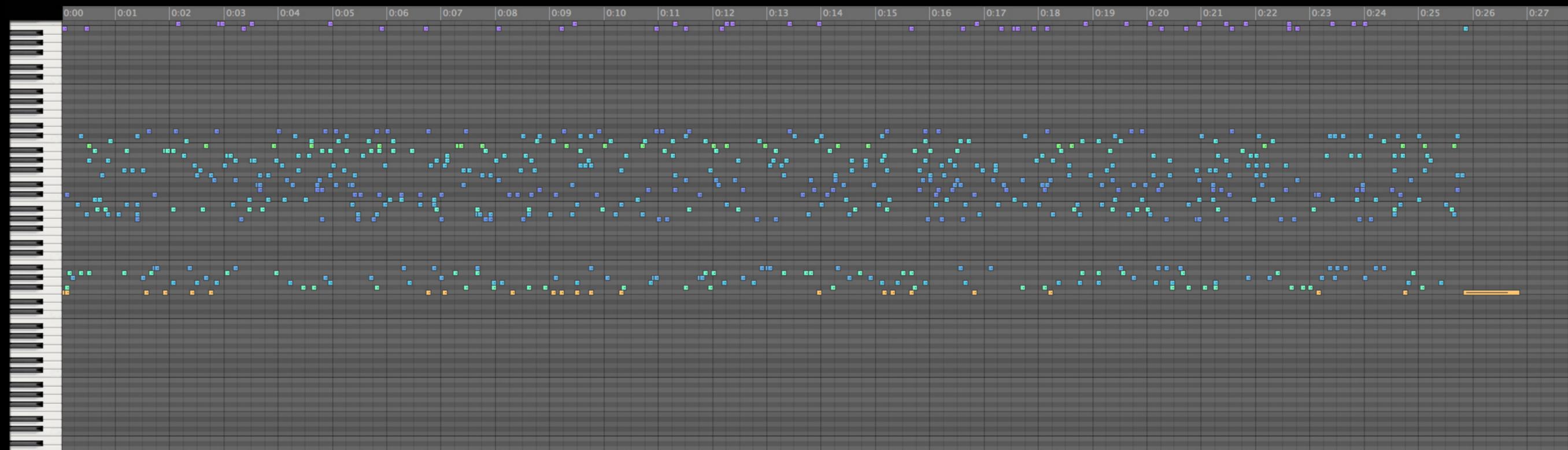
n.1 Preludio



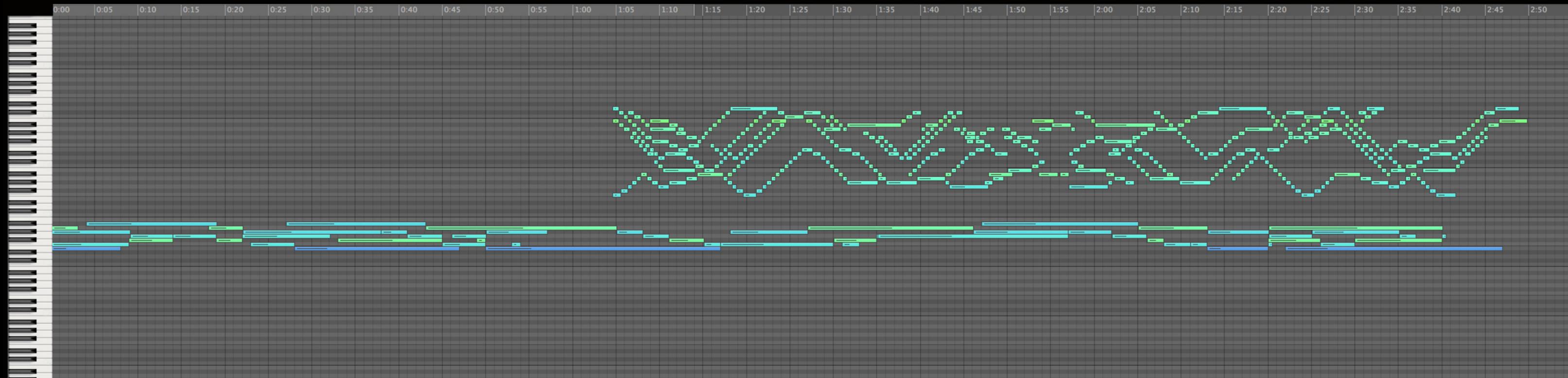
n.2 Largo



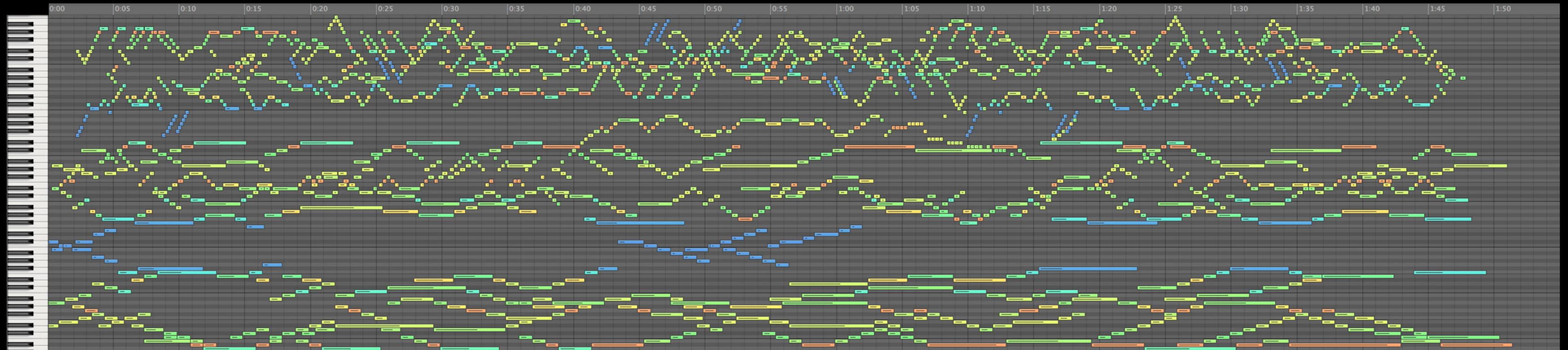
n.3 Andante



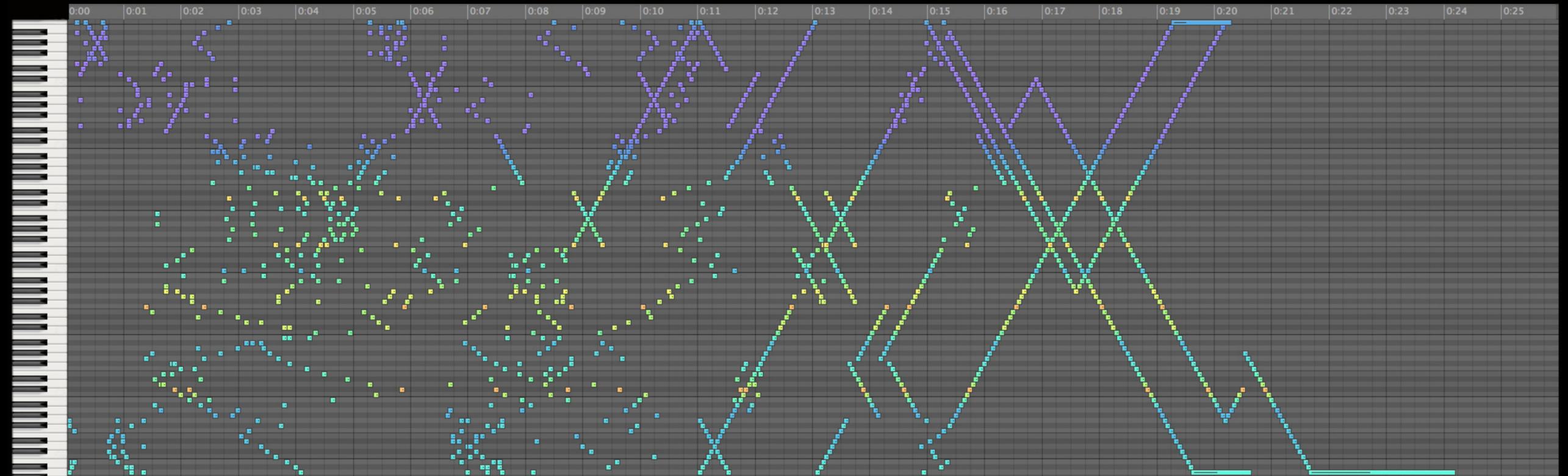
n.4 Interludio



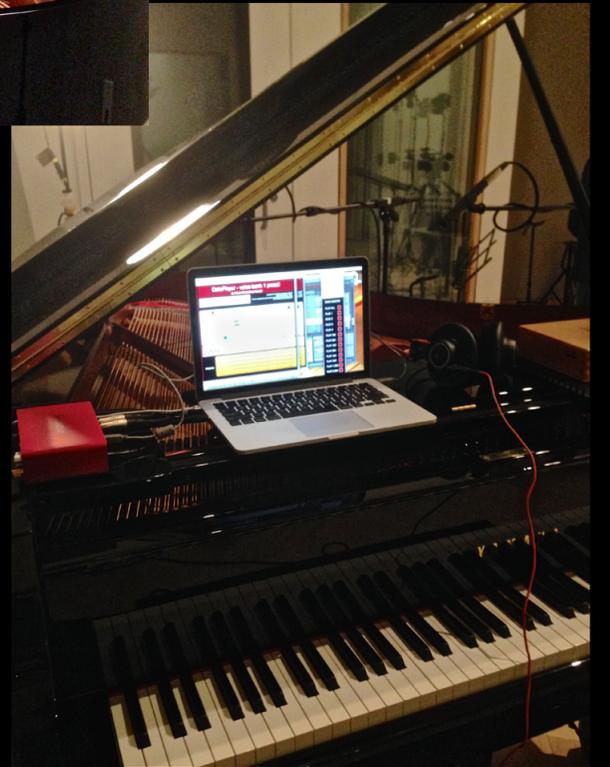
n.5 Continuo



n.6 Contrappunto aureo



n.7 Postludio



Many people have played a role in the development of the [materialssoundmusic](#) project and have given me continuous support and encouragement. My gratitude goes first of all to my family, my wife Antonella and my sons Simone and Luca; to Scot Gresham-Lancaster (University of Texas at Dallas) for his enthusiasm and for “quenching my thirst at the watering hole”; to my friends at the University of North Texas, David Stout (iARTA, initiative for Advanced Research in Technology and the Arts), Joseph Klein, Jon Nelson and Panaiyotis Korkoras (CEMI, Center for Experimental Music and Intermedia); to Darwin Grosse and Cory Metcalf (Cycling74) for their technical support and last but certainly not least, to my dearest friends and colleagues of the AFLOW Consortium, Stefano Curtarolo, Marco Fornari and Arrigo Calzolari. AFLOWLIB is co-hosted by the Duke University Center for Materials Genomics (S. Curtarolo) and the ERMES group (M. Buongiorno Nardelli) at University of North Texas. Partial support for the AFLOWLIB project comes from the Office of Naval Research, the National Science Foundation, the Department of Energy Office of Basic Energy Sciences and the Duke University Center for Materials Genomics.

all compositions by Marco Buongiorno Nardelli  
recording, editing and mastering: Scot Gresham-Lancaster and Marco Buongiorno Nardelli  
recorded in the studios of the School of Arts, Technology, and Emerging Communication  
of the University of Texas at Dallas on April 10, 2015

graphics design by Marco Buongiorno Nardelli  
piano roll graphics from Logic Pro 9, Apple Inc.  
Crystalline structures from CrystalMaker, CrystalMaker Software Ltd.

the [materialssoundmusic](#) project is funded in part by a University of North Texas Faculty Research Grant

marco.buongiorno.nardelli@gmail.com  
www.materialssoundmusic.com

Marco Buongiorno Nardelli is University Distinguished Research Professor at the University of North Texas, a computational materials physicist, a composer, flutist and a member of iARTA, the Initiative for Advanced Research in Technology and the Arts. He is a Fellow of the American Physical Society and of the Institute of Physics, a founding member of the AFLOW Consortium and a Parma Recordings artist.