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Art and Astrophysics in Conversation with KM3NeT Deep in the Mediterranean Sea

Donald Fortescue,[a] **Gwenhaël de Wasseige,**[b] **Jonathan Mauro,**[b,*] **Paschal Coyle**[c] **and Alin Ilioni**[d] **on behalf of the KM3NeT Collaboration**

[a] *California College of the Arts, San Francisco California*
[b] *Centre for Cosmology, Particle Physics and Phenomenology - CP3, Universite Catholique de Louvain, B-1348 Louvain-la-Neuve, Belgium*
[c] *Aix-Marseille Université, CNRS/IN2P3, CPPM, 163 Avenue de Luminy, Case 902, 13288 Marseille Cedex 09, France*
[d] *Université de Paris, CNRS, Astroparticule et Cosmologie, F-75013 Paris, France*
E-mail: dfortescue@cca.edu, gwenhael.dewasseige.@uclouvain.be, jonathan.mauro@uclouvain.be

We present the result of a cross-disciplinary collaboration between the California College of the Arts, San Francisco and the KM3NeT Collaboration.
The project involved creating an analog sound producing instrument which was installed within a standard KM3NeT pressure resistant glass sphere housing along with sound and video recording equipment. The instrument, titled "Bathysphere", was deployed in the sea for the first time adjacent to the ORCA array of KM3NeT off the coast of Toulon, France on September 23, 2021.
One outcome of this project is the video work "Below the Surface". It incorporates sound and video recorded from within the "Bathysphere" as it floated on the surface of the Mediterranean and then as it dived down to 300 m depth. As the "Bathysphere" dived, the analog instrument it contained quietened. The sound in the dive portion of the video is created from the sonification of data from the KM3NeT array that was recorded during the deployment of the "Bathysphere". "Below the Surface" highlights the extraordinary environment in which the KM3NeT array is being created and operates. The data sonification illustrates the potential of this method of data representation to connect with viewers in a deeply physical way and offers new perspectives on the data collected by KM3NeT.

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*Speaker

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1. Introduction

We present here the result of a cross-disciplinary collaboration between the California College of the Arts, San Francisco and the KM3NeT Collaboration, which builds on the success of a previous art/science work [1] that was carried out in collaboration with the IceCube Neutrino Observatory [2].

KM3NeT is a European particle astrophysics research infrastructure located deep in the Mediterranean Sea [3]. It is being constructed to search for neutrinos from distant astrophysical sources, and it consists of two discrete detector arrays: ORCA situated off the coast of Toulon, France, and ARCA situated off the coast of Sicily, Italy.

The current project involved one of us (Fortescue) creating an analog instrument which was installed within a standard KM3NeT pressure resistant glass sphere housing along with sound and video recording equipment. This instrument, titled "Bathysphere"[1], was deployed for the first time, adjacent to the ORCA array of KM3NeT, off the coast of Toulon, on September 23, 2021.

One outcome of this project is the video work "Below the Surface". The work incorporates sound and video recorded from within the "Bathysphere" as it floated on the surface and as it dived down to 300 m depth. As the "Bathysphere" dived, the analog instrument it contained quietened. The sound in the dive portion of the video was created from the sonification of data from the ORCA array. "Below the Surface" is publicly available at https://vimeo.com/844369324

2. The Bathysphere

The "Bathysphere" is an idiophonic instrument that operates on the surface and at depth to transduce water oscillations into sound. It consists of seven stainless steel hemispheric bells activated by six hammers as shown in Fig. 1. Sounds are produced by the hammers hitting the bells and by them running around the rim of the bells. A standard GoPro Hero 8 and Sony Digital Audio Recorder are attached to the "Bathysphere" to record video and sound.

Figure 1: The "Bathysphere" internal mechanism.

Deployment involved lowering the "Bathysphere" with its attached ballast and connected flotation buoy to the sea surface (Fig. 2). The "Bathysphere" was allowed to float on the surface some 50 m from the deployment vessel for about 15 minutes, then the flotation buoy was released and retrieved back to the ship. With the release of the buoy, the ballast sank and towed the "Bathysphere" along with it. Once the "Bathysphere" reached approximately 300 m depth, it was hauled back to the surface and retrieved.

Recordings from the dive were edited and used to create the video work "Below the Surface", which incorporates both recorded "Bathysphere" sounds and sonified data from the ORCA array.

[1]Named in honor of the Bathysphere developed by Otis Barton and deployed by Barton and William Beebe during the first deep-water dives in Bermuda in the early 1930's.

3. Sonification

Sonification is the transduction of non-audio data into audible sound. "Below the Surface" incorporates the sonification of digital signals derived from the detection of photons by the ORCA array.

The way in which data is transduced into sound is selected to reflect the underlying physics and to satisfy aesthetic considerations. To play the sounds from "Below the Surface" sonification, we use a digital instrument based on the glockenspiel as it is a close analog to the sounds produced by the "Bathysphere".

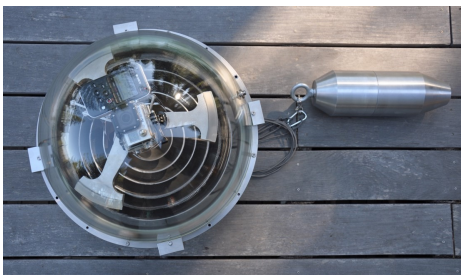

Figure 2: The "Bathysphere" ready for deployment.

During the "Bathysphere" deployment, six Detection Units (DU) were active in the ORCA array (18 currently active). Each DU holds 18 Digital Optical Modules (DOMs) and each DOM houses 31 Photomultiplier Tubes (PMTs) [4].

The sonification process we developed involved assigning four discrete notes to each DOM. In a manner similar to tuning a musical instrument, each DOM has been assigned a unique sound given by the choice of the four notes that it covers, avoiding strong dissonances.

Lower octaves are mapped to the bottom of the detector, while higher octaves are found at the top. This allows us to reproduce the dimensionality of the detector and of the sonified signal. A filter was used on the data to get rid of most of the incoherent noise. The sonified signals are expected to be produced by the decay of sea salt (^{40}K), and from bioluminescent species, as well as Cherenkov photons from the interaction of atmospheric muons and neutrinos. The detected charge is used to modulate the volume of the notes.

4. Objective approaches to art making

The underwater audio for "Below the Surface" was obtained by establishing an objective set of constraints on the data set selected and the way this data was then transduced into sound. This approach has a strong precedent in contemporary art. In fact, an objective methodology was first established by the minimalist and conceptual artists of the 1960's and 70's who were striving to reduce artistic agency in reaction to the dominant paradigm of Abstract Expressionism. The renowned conceptual artist Sol LeWitt explained in his Paragraphs on Conceptual Art: *"To work with a plan that is preset is one way of avoiding subjectivity. It also obviates the necessity of designing each work in turn. The plan would design the work. ... the artist would select the basic form and rules that would govern the solution of the problem. After that the fewer decisions made in the course of completing the work, the better. This eliminates the arbitrary, the capricious, and the subjective as much as possible" [5].*

The objective approach provides a strong link between the methodological practices of science and art and can help delineate the required conditions for effective art/science collaborations, that is, the common ground where the two methodologies may coalesce.

5. Value of sonification

Sonification is a methodology that is generating wide interest in contemporary data science. We readily discern sound as occurring in three dimensions, so it would seem that 'listening' to data that derives from interactions across three-dimensional space could be more intuitively informative than 'looking' at graphic analysis or animated renderings on a 2D screen. Also, sonification permits access to data sets by researchers for whom vision might not be their primary sense, thus enabling a broader diversity of scientific researchers. And finally, more general audiences have a direct visceral connection to sound which can facilitate a deeper direct connection with the phenomena being studied by leading research institutions.

Figure 3: The team who participated in the successful deployment of the "Bathysphere". From L to R. Prof. D. Fortescue, Prof. G. De Wasseige, Dr. V. Bertin, C. Bertrand, A. Cornillon, A. Ilioni, and (foreground) Dr. P. Coyle.

6. Collaboration

Artists are rarely considered key components of collaborative science research teams. They are often seen as addenda to the core science, as illustrators or designers who can help with posters or presentations for public outreach. The durable art/science collaboration developed by the authors over many years provides a model for imbedding artists within science teams to facilitate new perspectives and audiences. The current collaboration provides the potential for ongoing art/science projects as the one described in these proceedings (Fig. 3).

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Full Authors List: The KM3NeT Collaboration

S. Aiello[a], A. Albert[b,bd], S. Alves Garre[c], Z. Aly[d], A. Ambrosone[f,e], F. Ameli[g], M. Andre[h], E. Androutsou[i], M. Anguita[j], L. Aphecetche[k], M. Ardid[l], S. Ardid[l], H. Atmani[m], J. Aublin[n], L. Bailly-Salins[o], Z. Bardačová[q,p], B. Baret[n], A. Bariego-Quintana[c], S. Basegmez du Pree[r], Y. Becherini[n], M. Bendahman[m,n], F. Benfenati[t,s], M. Benhassi[u,e], D. M. Benoit[v], E. Berbee[r], V. Bertin[d], S. Biagi[w], M. Boettcher[x], D. Bonanno[w], J. Boumaaza[m], M. Bouta[y], M. Bouwhuis[r], C. Bozza[z,e], R. M. Bozza[f,e], H.Brânzaş[aa], F. Bretaudeau[k], R. Bruijn[ab,r], J. Brunner[d], R. Bruno[a], E. Buis[ac,r], R. Buompane[u,e], J. Busto[d], B. Caiffi[ad], D. Calvo[c], S. Campion[g,ae], A. Capone[g,ae], F. Carenini[t,s], V. Carretero[c], T. Cartraud[n], P. Castaldi[af,s], V. Cecchini[c], S. Celli[g,ae], L. Cerisy[d], M. Chabab[ag], M. Chadolias[ah], A. Chen[ai], S. Cherubini[aj,w], T. Chiarusi[s], M. Circella[ak], R. Cocimano[w], J. A. B. Coelho[n], A. Coleiro[n], R. Coniglione[w] P. Coyle[d], A. Creusot[n], A. Cruz[al], G. Cuttone[w], R. Dallier[k], Y. Darras[ah], A. De Benedittis[e], B. De Martino[d], G. De Wasseige[bf], V. Decoene[k], R. Del Burgo[e], U. M. Di Cerbo[e], L. S. Di Mauro[w], I. Di Palma[g,ae], A. F. Díaz[j], C. Diaz[j], D. Diego-Tortosa[w], C. Distefano[w], A. Domi[ah], C. Donzaud[n], D. Dornic[d], M. Dörr[am], E. Drakopoulou[i], D. Drouhin[b,bd], R. Dvornický[q], T. Eberl[ah], E. Eckerová[q,p], A. Eddymaoui[m], T. van Eeden[r], M. Eff[n], D. van Eijk[r], I. El Bojaddaini[y], S. El Hedri[n], A. Enzenhöfer[d], J. de Favereau[bf], G. Ferrara[w], M. D. Filipović[an], F. Filippini[t,s], D. Franciotti[w], L. A. Fusco[z,e], J. Gabriel[ao], S. Gagliardini[g], T. Gal[ah], J. García Méndez[l], A. Garcia Soto[c], C. Gatius Oliver[r], N. Geißelbrecht[ah], H. Ghaddari[y], L. Gialanella[e,u], B. K. Gibson[v], E. Giorgio[w], I. Goos[n], D. Goupilliere[o], S. R. Gozzini[c], R. Gracia[ah], K. Graf[ah], C. Guidi[ap,ad], B. Guillon[o], M. Gutiérrez[aq], H. van Haren[ar], A. Heijboer[r], A. Hekalo[am], L. Hennig[ah], J. J. Hernández-Rey[c], F. Huang[d], W. Idrissi Ibnsalih[e], G. Illuminati[s], C. W. James[al], M. de Jong[as,r], P. de Jong[ab,r], B. J. Jung[r], P. Kalaczyński[at,be], O. Kalekin[ah], U. F. Katz[ah], N. R. Khan Chowdhury[c], A. Khatun[q], G. Kistauri[av,au], C. Kopper[ah], A. Kouchner[aw,n], V. Kulikovskiy[ad], R. Kvatadze[av], M. Labalme[o], R. Lahmann[ah], M. Lamoureux[bf], G. Larosa[w], C. Lastoria[d], A. Lazo[c], S. Le Stum[d], G. Lehaut[o], E. Leonora[a], N. Lessing[c], G. Levi[t,s], M. Lindsey Clark[n], F. Longhitano[a], J. Majumdar[r], L. Malerba[ad], F. Mamedov[p], J. Mańczak[c], A. Manfreda[e], M. Marconi[ap,ad], A. Margiotta[t,s], A. Marinelli[e,f], C. Markou[i], L. Martin[k], J. A. Martínez-Mora[l], F. Marzaioli[u,e], M. Mastrodicasa[ae,g], S. Mastroianni[e], J. Mauro[bf], S. Miccichè[w], G. Miele[f,e], P. Migliozzi[e], E. Migneco[w], M. L. Mitsou[e], C. M. Mollo[e], L. Morales-Gallegos[u,e], C. Morley-Wong[al], A. Moussa[y], I. Mozun Mateo[ay,ax], R. Muller[r], M. R. Musone[e,u], M. Musumeci[w], L. Nauta[r], S. Navas[aq], A. Nayerhoda[ak], C. A. Nicolau[g], B. Nkosi[ai], B. Ó Fearraigh[ab,r], V. Oliviero[f,e], A. Orlando[w], E. Oukacha[n], D. Paesani[w], J. Palacios González[c], G. Papalashvili[au], V. Parisi[ap,ad], E.J. Pastor Gomez[c], A. M. Păun[aa], G. E. Păvălaş[aa], S. Peña Martínez[n], M. Perrin-Terrin[d], J. Perronnel[o], V. Pestel[ay], R. Pestes[n], P. Piattelli[w], C. Poirè[z,e], V. Popa[aa], T. Pradier[b], S. Pulvirenti[w], G. Quéméner[o], C. Quiroz[l], U. Rahaman[c], N. Randazzo[a], R. Randriatoamanana[k], S. Razzaque[az], I. C. Rea[e], D. Real[c], S. Reck[ah], G. Riccobene[w], J. Robinson[x], A. Romanov[ap,ad], A. Šaina[c], F. Salesa Greus[c], D. F. E. Samtleben[as,r], A. Sánchez Losa[c,ak], S. Sanfilippo[w], M. Sanguineti[ap,ad], C. Santonastaso[ba,e], D. Santonocito[w], P. Sapienza[w], J. Schnabel[ah], J. Schumann[ah], H. M. Schutte[x], J. Seneca[r], N. Sennan[y], B. Setter[ah], I. Sgura[ak], R. Shanidze[au], Y. Shitov[p], F. Šimkovic[q], A. Simonelli[e], A. Sinopoulou[a], M.V. Smirnov[ah], B. Spisso[e], M. Spurio[t,s], D. Stavropoulos[i], I. Štekl[p], M. Taiuti[ap,ad], Y. Tayalati[m], H. Tedjditi[ad], H. Thiersen[x], I. Tosta e Melo[a,aj], B. Trocmé[n], V. Tsourapis[i], E. Tzamariudaki[i], A. Vacheret[o], V. Valsecchi[w], V. Van Elewyck[aw,n], G. Vannoye[d], G. Vasileiadis[bb], F. Vazquez de Sola[r], C. Verilhac[n], A. Veutro[g,ae], S. Viola[w], D. Vivolo[u,e], J. Wilms[bc], E. de Wolf[ab,r], H. Yepes-Ramirez[l], G. Zarpapis[i], S. Zavatarelli[ad], A. Zegarelli[g,ae], D. Zito[w], J. D. Zornoza[c], J. Zúñiga[c], and N. Zywucka[x].

[a] INFN, Sezione di Catania, Via Santa Sofia 64, Catania, 95123 Italy
[b] Université de Strasbourg, CNRS, IPHC UMR 7178, F-67000 Strasbourg, France
[c] IFIC - Instituto de Física Corpuscular (CSIC - Universitat de València), c/Catedrático José Beltrán, 2, 46980 Paterna, Valencia, Spain
[d] Aix Marseille Univ, CNRS/IN2P3, CPPM, Marseille, France
[e] INFN, Sezione di Napoli, Complesso Universitario di Monte S. Angelo, Via Cintia ed. G, Napoli, 80126 Italy
[f] Università di Napoli "Federico II", Dip. Scienze Fisiche "E. Pancini", Complesso Universitario di Monte S. Angelo, Via Cintia ed. G, Napoli, 80126 Italy
[g] INFN, Sezione di Roma, Piazzale Aldo Moro 2, Roma, 00185 Italy
[h] Universitat Politècnica de Catalunya, Laboratori d'Aplicacions Bioacústiques, Centre Tecnològic de Vilanova i la Geltrú, Avda. Rambla Exposició, s/n, Vilanova i la Geltrú, 08800 Spain
[i] NCSR Demokritos, Institute of Nuclear and Particle Physics, Ag. Paraskevi Attikis, Athens, 15310 Greece
[j] University of Granada, Dept. of Computer Architecture and Technology/CITIC, 18071 Granada, Spain
[k] Subatech, IMT Atlantique, IN2P3-CNRS, Université de Nantes, 4 rue Alfred Kastler - La Chantrerie, Nantes, BP 20722 44307 France
[l] Universitat Politècnica de València, Instituto de Investigación para la Gestión Integrada de las Zonas Costeras, C/ Paranimf, 1, Gandia, 46730 Spain
[m] University Mohammed V in Rabat, Faculty of Sciences, 4 av. Ibn Battouta, B.P. 1014, R.P. 10000 Rabat, Morocco
[n] Université Paris Cité, CNRS, Astroparticule et Cosmologie, F-75013 Paris, France
[o] LPC CAEN, Normandie Univ, ENSICAEN, UNICAEN, CNRS/IN2P3, 6 boulevard Maréchal Juin, Caen, 14050 France
[p] Czech Technical University in Prague, Institute of Experimental and Applied Physics, Husova 240/5, Prague, 110 00 Czech Republic
[q] Comenius University in Bratislava, Department of Nuclear Physics and Biophysics, Mlynska dolina F1, Bratislava, 842 48 Slovak Republic
[r] Nikhef, National Institute for Subatomic Physics, PO Box 41882, Amsterdam, 1009 DB Netherlands
[s] INFN, Sezione di Bologna, v.le C. Berti-Pichat, 6/2, Bologna, 40127 Italy
[t] Università di Bologna, Dipartimento di Fisica e Astronomia, v.le C. Berti-Pichat, 6/2, Bologna, 40127 Italy
[u] Università degli Studi della Campania "Luigi Vanvitelli", Dipartimento di Matematica e Fisica, viale Lincoln 5, Caserta, 81100 Italy
[v] E. A. Milne Centre for Astrophysics, University of Hull, Hull, HU6 7RX, United Kingdom

[w] INFN, Laboratori Nazionali del Sud, Via S. Sofia 62, Catania, 95123 Italy
[x] North-West University, Centre for Space Research, Private Bag X6001, Potchefstroom, 2520 South Africa
[y] University Mohammed I, Faculty of Sciences, BV Mohammed VI, B.P. 717, R.P. 60000 Oujda, Morocco
[z] Università di Salerno e INFN Gruppo Collegato di Salerno, Dipartimento di Fisica, Via Giovanni Paolo II 132, Fisciano, 84084 Italy
[aa] ISS, Atomistilor 409, Măgurele, RO-077125 Romania
[ab] University of Amsterdam, Institute of Physics/IHEF, PO Box 94216, Amsterdam, 1090 GE Netherlands
[ac] TNO, Technical Sciences, PO Box 155, Delft, 2600 AD Netherlands
[ad] INFN, Sezione di Genova, Via Dodecaneso 33, Genova, 16146 Italy
[ae] Università La Sapienza, Dipartimento di Fisica, Piazzale Aldo Moro 2, Roma, 00185 Italy
[af] Università di Bologna, Dipartimento di Ingegneria dell'Energia Elettrica e dell'Informazione "Guglielmo Marconi", Via dell'Università 50, Cesena, 47521 Italia
[ag] Cadi Ayyad University, Physics Department, Faculty of Science Semlalia, Av. My Abdellah, P.O.B. 2390, Marrakech, 40000 Morocco
[ah] Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Erlangen Centre for Astroparticle Physics, Nikolaus-Fiebiger-Straße 2, 91058 Erlangen, Germany
[ai] University of the Witwatersrand, School of Physics, Private Bag 3, Johannesburg, Wits 2050 South Africa
[aj] Università di Catania, Dipartimento di Fisica e Astronomia "Ettore Majorana", Via Santa Sofia 64, Catania, 95123 Italy
[ak] INFN, Sezione di Bari, via Orabona, 4, Bari, 70125 Italy
[al] International Centre for Radio Astronomy Research, Curtin University, Bentley, WA 6102, Australia
[am] University Würzburg, Emil-Fischer-Straße 31, Würzburg, 97074 Germany
[an] Western Sydney University, School of Computing, Engineering and Mathematics, Locked Bag 1797, Penrith, NSW 2751 Australia
[ao] IN2P3, LPC, Campus des Cézeaux 24, avenue des Landais BP 80026, Aubière Cedex, 63171 France
[ap] Università di Genova, Via Dodecaneso 33, Genova, 16146 Italy
[aq] University of Granada, Dpto. de Física Teórica y del Cosmos & C.A.F.P.E., 18071 Granada, Spain
[ar] NIOZ (Royal Netherlands Institute for Sea Research), PO Box 59, Den Burg, Texel, 1790 AB, the Netherlands
[as] Leiden University, Leiden Institute of Physics, PO Box 9504, Leiden, 2300 RA Netherlands
[at] National Centre for Nuclear Research, 02-093 Warsaw, Poland
[au] Tbilisi State University, Department of Physics, 3, Chavchavadze Ave., Tbilisi, 0179 Georgia
[av] The University of Georgia, Institute of Physics, Kostava str. 77, Tbilisi, 0171 Georgia
[aw] Institut Universitaire de France, 1 rue Descartes, Paris, 75005 France
[ax] IN2P3, 3, Rue Michel-Ange, Paris 16, 75794 France
[ay] LPC, Campus des Cézeaux 24, avenue des Landais BP 80026, Aubière Cedex, 63171 France
[az] University of Johannesburg, Department Physics, PO Box 524, Auckland Park, 2006 South Africa
[ba] Università degli Studi della Campania "Luigi Vanvitelli", CAPACITY, Laboratorio CIRCE - Dip. Di Matematica e Fisica - Viale Carlo III di Borbone 153, San Nicola La Strada, 81020 Italy
[bb] Laboratoire Univers et Particules de Montpellier, Place Eugène Bataillon - CC 72, Montpellier Cédex 05, 34095 France
[bc] Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Remeis Sternwarte, Sternwartstraße 7, 96049 Bamberg, Germany
[bd] Université de Haute Alsace, rue des Frères Lumière, 68093 Mulhouse Cedex, France
[be] AstroCeNT, Nicolaus Copernicus Astronomical Center, Polish Academy of Sciences, Rektorska 4, Warsaw, 00-614 Poland
[bf] UCLouvain, Centre for Cosmology, Particle Physics and Phenomenology, Chemin du Cyclotron, 2, Louvain-la-Neuve, 1349 Belgium

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