ROBERTO ALONSO MATILLA

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PROFILE

Roberto Alonso Matilla is a postdoctoral researcher in the department of Biomedical Engineering at the University of Minnesota who studies the biomechanics of cancer and immune cell migration during cancer progression. Combining mathematical modeling, computer simulations and experimental approaches, Alonso Matilla aims at extending the existing base of scientific knowledge and applying fundamental and applied science to address major cancer research problems with the aim of finding novel solutions to treat cancer.

Research interests: cancer, immunology, mechanobiology, fluid dynamics, biological physics, mathematical biology, cell and molecular biology, macrotransport processes.

EDUCATION AND RESEARCH EXPERIENCE

- **Postdoctoral researcher, University of Minnesota**, Biomedical Engineering; Minneapolis — Jul 2020-Present
Used a computational modeling approach to study the mechanobiology of cancer and T-cell migration in tumors. Advisors: Prof. *David J. Odde* and Prof. *Paolo P. Provenzano*.

- **Postdoctoral researcher, Columbia University**, Chemical Engineering; New York — Sept 2018-Jun 2020
Developed biophysical models to study fission yeast cytokinesis, animal cell cytokinesis and cell morphogenesis. Advisor: Prof. *Ben O'Shaughnessy*.

- **Doctor of Philosophy (Ph.D.), University of California San Diego**, Mechanical and Aerospace Engineering; La Jolla — Sept 2013-Aug 2018
Developed a theoretical framework based on hydrodynamic theory and statistical mechanics to study transport, dispersion, stress generation, rheology and microfluidic flow actuation of biological cells. Advisor: Prof. *David Saintillan*.

- **M.Sc. in Engineering Sciences, University of California San Diego**, Mechanical and Aerospace Engineering; La Jolla — Aug 2013-Sept 2014
GPA: 4.0.

- **Visiting researcher, University of Valladolid**, Industrial Engineering (Fluid Dynamics department); Valladolid (Spain) — Mar 2013-Jul 2013
Characterized the aerodynamic stability of swirling flows in combustors. Advisor: Prof. *Teresa Parra Santos*.

- **Research assistant, Yale University**, Mechanical Engineering and Material Science; New Haven — Oct 2011-Dec 2012
Discovered an efficient wide-range-specific-impulse propellant material for electric propulsion applications. Advisor: Prof. *Juan Fernandez de la Mora*.

- **Research engineer, SEADM S.L.**, Boecillo, Valladolid (Spain) — Dec 2010-Oct 2011
Development of experimental devices aimed at detecting explosives and screening viruses.

▪ **Master Thesis, University of Valladolid**, Industrial Engineering (Fluid Dynamics department); Valladolid (Spain) — Dec 2010
Theoretical design and manufacture of a condensation nucleus counter. Advisor: Prof. *Juan Fernandez de la Mora* (Yale University).

▪ **B.S. degree in Industrial Engineering, University of Valladolid**; Valladolid (Spain) — Jun 2010

HONORS AND AWARDS

▪ Cytoskeleton Journal Front Cover Image — Dec 2019
▪ M.A.E. Distinguished Fellowship Award, University of California San Diego — Mar 2016

DIVERSITY SERVICE

▪ Participation in the ENLACE summer research program, an outreach initiative intended to use science and engineering as a bridge to promote scientific interactions between students from the United States and Mexico. — Jun-Aug 2017
▪ Participation in the UMN Biomedical Engineering High School Internship Program, a summer program intended to encourage and support women and students of color in STEM career. — Jul-Aug 2022

JOURNAL PUBLICATIONS IN PREPARATION

3. R. Alonso-Matilla, P. P. Provenzano, D. J. Odde, "Physical Modeling to Optimize Migration of Therapeutic T Cells".
➡We developed a novel single-cell T cell migration simulator, a tool that we have used to understand the mechanics of T cell migration within tumors. Our model suggests that T cells might employ a hybrid adhesion-based, bleb-based migration mode for optimum motility, and predicts that higher extracellular matrix stiffnesses hinder bleb-based T cell migration, consistent with experiments. It also identifies the existence of an intermediate level of membrane-cortex adhesion and cortical contractility for optimum migration. The developed model is helping us identify novel strategies for improving T cell migration within tumors, thereby increasing the effectiveness of cancer immunotherapies.
2. R. Alonso-Matilla, P. P. Provenzano, D. J. Odde, "Cellular regimes and traction force production of single cell protrusions on compliant extracellular media".
➡We developed a mean-field model to gain a better understanding of traction force production of single-cell protrusions on compliant extracellular substrates. We derived an analytical expression for the optimum substrate stiffness that maximizes cellular traction forces, predicted the existence of an intermediate rigidity of cell adhesion complexes for optimum force transmission and identified three different cellular regimes: an adhesion-dominated regime characterized by stiffness-independent traction forces, an intermediate regime characterized by a myosin-dependent optimum stiffness, and a motor-dominated regime characterized by a myosin-insensitive optimum stiffness. The model provides new insights about adhesion-based cellular force generation that could have major implications in cancer metastasis.
1. R. Alonso-Matilla et al., "Dynamic transitions of the actomyosin cortex can trigger single cell morphogenesis", *BioRxiv*.
➡We showed that controlled cortical instabilities can trigger morphogenesis at the cellular level. We found that for sufficiently low membrane-cortex drag, an initially homogeneous cortex spontaneously develops stripes associated with stable furrows.

This work provides new insights about the complex relation between cell morphogenetic events and membrane-cortex interactions.

PEER REVIEWED JOURNAL PUBLICATIONS

8. R. Alonso-Matilla, S. Thiyagarajan, B. O'Shaughnessy, "Sliding filament and fixed filament mechanisms contribute to ring tension in the cytokinetic contractile ring", *Cytoskeleton*, (2019).

➡We developed a coarse-grained continuum model of the fission yeast cytokinetic ring. The model predicts that the ring generates tension via a sliding filament mechanism, a spatially and temporally homogeneous version of that in muscle. The mechanism relies on anchoring of actin filament barbed ends to the plasma membrane. A second fixed filament tension generation component is generated by chains of like-oriented actin filaments encircling the ring, independent of cell membrane-actin filament anchoring. We also showed that the fission yeast ring protects itself from instabilities inherent to cellular actomyosin contractile machines via fast turnover of cortical components. This study advanced our basic scientific understanding of force production and robustness and stability of constricting rings during cytokinesis, and could have important implications in diseases such as cancer.

7. R. Alonso-Matilla, D. Saintillan, "Interfacial instabilities in active viscous films", *Journal of Non-Newtonian Fluid Mechanics*, 259 59 (2019).

➡We studied the interfacial stability of active viscous films. In the absence of gravitational forces, we found that puller suspensions are always stable, whereas films containing pushers become unstable above a critical activity level where active stresses overcome the damping effects of viscosity and surface tension and drive interfacial deformations. We also found that inverted fluid films subject to the Rayleigh-Taylor instability are stabilized by active stresses generated by suspensions of pullers.

6. R. Alonso-Matilla, B. Chakrabarti, D. Saintillan, "Transport and dispersion of active particles in periodic porous media", *Physical Review Fluids*, 4 043101 (2019).

➡We developed a framework based on generalized Taylor dispersion theory to understand and control the spreading of biological cells subjected to interstitial viscous flows in complex crowded environments. We showed that fast-moving cells disperse more than slow-moving cells when subjected to weak external flows, but fast-moving cells disperse less than slow-moving cells when subjected to strong external flows. We also discovered the existence of an optimum porosity of the medium and an optimum external flow strength for maximum cell dispersion. These results could have potential applications in cancer and immune cell migration, in areas of the body where cells experience interstitial fluid flows, such as immune cell motion within the thymus or through tissue extracellular matrix.

5. R. Alonso-Matilla, D. Saintillan, "Microfluidic flow actuation using magnetoactive suspensions", *Europhysics Letters*, 121 (2), 24002 (2018).

➡We developed a continuum kinetic theory to study the rheological behavior of magnetotactic bacterial suspensions and predicted the ability of magnetotactic suspensions to internally drive steady unidirectional flows in microchannels upon a simple application of a magnetic field. By tuning the magnetic field strength and direction, the apparent viscosity can be enhanced or reduced, and the direction and strength of the generated flows can be controlled. This work paved the way for understanding and analyzing the dynamics of self-propelled nano-magnetic units, and it is a major step towards the development of anticancer drug targeted delivery systems that would allow for better cancer patient treatments and reduced adverse effects.

4. M. Theillard, R. Alonso-Matilla, D. Saintillan, "Geometric control of active collective motion", *Soft Matter*, 13, 363-375 (2017).
➡We analyzed the dynamics of bacterial suspensions in two-dimensional geometries. We captured the transition of the system from equilibrium, to bacterial vortices and fluid net pumping, to traveling waves and to chaos, and found that these complex collective dynamics are a result of hydrodynamic interactions.
3. R. Alonso-Matilla, B. Ezhilan, D. Saintillan, "Microfluidic rheology of active particle suspensions: Kinetic theory", *Biomicrofluidics*, 10, 043505 (2016).
➡We studied the rheology of a dilute suspension of cells subjected to a pressure driven flow. We found that pushers decrease the suspension viscosity, whereas pullers enhance it. Our results captured and explained the apparent transition to superfluidity of pusher suspensions.
2. B. Ezhilan, R. Alonso-Matilla, D. Saintillan, "On the distribution and swim pressure of run-and-tumble particles in confinement", *Journal of Fluid Mechanics: Rapids*, 781, R4 (2015).
➡We developed a kinetic model to study stress generation of cells in confinement, and found that confinement caused a decrease in the force per unit area exerted by the cells on the confining walls.
1. R. Alonso-Matilla et al., "Search for liquids electrospraying the smallest possible nanodrops in vacuo", *Journal of Applied Physics*, 116, 224504 (2014).
➡We discovered an efficient propellant material, a mixture of sulfolane and the ionic liquid ethylammonium nitrate. The discovered mixture produces the smallest possible nanodrops when charged by electrospray ionization techniques, providing high propulsion efficiency for a wide range of specific impulses and scalable thrusts.

PEER REVIEWER

- Journal of Fluid Mechanics — 2017-Present
- New Journal of Physics — 2019-Present
- Soft Matter — 2019-Present
- Physical Biology — 2020-Present
- Journal of PLOS Computational Biology — 2021-Present
- Communications Biology — 2021-Present
- eLife — 2022-Present

INVITED TALKS

- UC Merced, Applied Mathematics, Nov 2022
- University of Minnesota, Biophysics, Sep 2021
- University of Minnesota, Biophysics, Mar 2021
- University of Minnesota, Biomedical Engineering, Feb 2020

CONFERENCE TALKS

- Center for Multiparametric Imaging of Tumor Immune Microenvironments retreat, University of Wisconsin-Madison, Jul 2022
- 12th Southern California Flow Physics Symposium, Apr 2018
- 2018 American Physical Society March Meeting, Mar 2018
- 70th Annual Meeting of the APS Division of Fluid Dynamics, Nov 2017
- 11th Southern California Flow Physics Symposium, Apr 2017
- 69th Annual Meeting of the APS Division of Fluid Dynamics, Nov 2016

- 10th Southern California Flow Physics Symposium, Apr 2016
- 68th Annual Meeting of the APS Division of Fluid Dynamics, Nov 2015
- 9th Southern California Flow Physics Symposium, Apr 2015

CONFERENCE POSTERS

- 2022 Annual meeting - Biomedical Engineering Society, Oct 2022
- Center for Multiparametric Imaging of Tumor Immune Microenvironments retreat, Jul 2022
- 2020 Annual meeting - Biophysical Society, Feb 2020
- 2019 meeting of the American Society for Cell Biology, Apr 2019

WORKSHOPS

- Summer School on Living and Active Soft Matter, Corsica (France), Jul 2016
- Open Science Grid Summer School on High-Throughput Computing, University of Wisconsin-Madison, Jul 2015

TEACHING EXPERIENCE

During my Ph.D. program, I imparted over 15 graduate lectures in Advanced Fluid Mechanics. As a graduate student at UC San Diego and as a postdoctoral researcher at Columbia University, I combined research work with Teaching Assistant job responsibilities. I worked as a Teaching Assistant in the following subjects:

- Teaching Assistant, CHAP 4120 — Statistical Mechanics, Columbia University, Fall 2018
- Teaching Assistant, MAE 105 — Introduction to Mathematical Physics, University of California San Diego, Spring 2017
- Teaching Assistant, MAE 210B — Fluid Mechanics II, University of California San Diego, Winter 2016
- Teaching Assistant, MAE 210A — Fluid Mechanics I, University of California San Diego, Fall 2015

RESEARCH ADVISEES

- Mohammed Mohammed and Avery Timmerman (high school interns), University of Minnesota. Project: Modeling of CD 200 immunotherapy in glioblastoma tumors.
- Irisz Mertus (M.S. student), University of Minnesota. Project: Development of an osmotic-engine cell migration model.
- Hongkang Zhu (Ph.D. student), Columbia University. Project: Modeling of glue secretion in the Drosophila salivary gland.
- Aric Bandera and Elizabeth Diaz (undergraduate interns), University of California San Diego. Project: Dispersion of swimming microorganisms in porous materials.
- Harrison Congdon (Undergraduate intern), Yale University. Project: Computation of ion trajectories in an electrostatic focusing device to identify optimal electrode configurations for maximum current transmission.

PROFESSIONAL REFERENCE LIST

- **Prof. David J. Odde**: Postdoctoral advisor

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- **Prof. Ben O'Shaughnessy**: Postdoctoral advisor
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