

# Curriculum Vitae for Adriaan (Ard) A. Louis

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## EDUCATION

- Ph.D.** Cornell University, Theoretical Physics (January 1998)  
**Thesis title:** *Quantum Dissipation from Phonons; Metallic Hydrogen; Electron-Ion Mixtures*  
**Thesis advisor:** Professor Neil W. Ashcroft
- M.S.** Cornell University, Theoretical Physics (September 1995)
- Drs.** Rijks Universiteit Utrecht, Netherlands, Physics (August 1992, *Cum Laude*)

## PROFESSIONAL EMPLOYMENT

October 2003 to present: Class A Fellow at Hughes Hall

October 2002 to present: Royal Society University Research Fellow (Academic Staff post) in Theoretical Chemistry, Cambridge University.

January 2000 to September 2002: Isaac Newton Trust Fellow in Theoretical Chemistry, Cambridge University.

October 1998 to September 2003: Research Fellow (class B) at Hughes Hall

January 1998 to January 2000: Postdoctoral Research Fellow (EC: TMR) in Theoretical Chemistry, Cambridge University. Supervisor: Professor Jean-Pierre Hansen.

October 1997 to November 1997: Environmental Consultant for Gabon Vert, a small Gabonese owned company specialising in the preservation and restoration of tropical rainforest.

May 1994 to September 1997: Graduate Research Assistant at the Laboratory of Atomic and Solid State Physics, Cornell University. Supervisor: Professor Neil W. Ashcroft.

August 1992 to May 1994: Teaching Assistant, Cornell University Physics Department, (20 hr/week) appointment. Taught physics for biology students (Fall 1992), electricity and magnetism for engineering students (Spring 1993), waves and optics for physics honour students (Fall 1993) and advanced mechanics for physics honour students (Spring 1994).

Summer 1993: Summer Research Assistant at the Laboratory of Atomic and Solid State Physics, Cornell University. Worked on theories of quantum tunnelling with dissipation (<http://www.lassp.cornell.edu/ardlouis/dissipative/QAtunneling.html>). Supervisor: Professor James P. Sethna.

October 1991 - July 1992: Undergraduate Research Assistant at the FOM Institute for Atomic and Molecular Physics (AMOLF). Worked on theories of entropic de-mixing. Supervisor: Professor Daan Frenkel.

## PROFESSIONAL ACTIVITIES

### Professional Teaching Experience:

Director of Studies in Natural Sciences (Physical) at Hughes Hall (From October 2000).

Courses Lectured: *Computer Simulation Methods in Chemistry and Physics*, lectures for Cambridge Chemistry part III course (Lent 2003, Lent 2004).

Practicals: Demonstrator for part IB and part II theory practicals for Cambridge Chemistry (Junior demonstrator January 1998 - January 2000; Senior demonstrator January 2000 - present)

### Conferences Organised:

*Protein-Protein Interactions in Vitro and in Vivo*, an Isaac Newton Institute Workshop, 21-23 June 2004, Cambridge UK: co-organiser (<http://www.newton.cam.ac.uk/programmes/SMC/smcw03.html>).

*Effective Many-Body Interactions and Correlations in Soft Matter*, a CECAM/SIMU workshop, 7-9 July 2003, Lyon, France: co-organiser (<http://www.phys.uu.nl/mdijkstr/cecam/cecam.html>), co-edited the related special issue J. Phys. Condens. Matter **15**, Number 48 (2003).

*Thermodynamics 2003*, 9-11 April 2003, Cambridge, UK: local organiser (<http://www.the-conference.com/thermo2003/>).

*Interactions, Phases, and Flow of Colloids*, an interdisciplinary workshop held 29-31 March 1999, Cambridge, UK: co-organiser. (<http://www-theor.ch.cam.ac.uk/people/ardlouis/colloid/>).

## Professional Societies:

Royal Society of Chemistry: Member of the steering committee for the Statistical Mechanics & Thermodynamics Group (SMTG) since October 2001 ([www.louis.ch.cam.ac.uk/smtg/](http://www.louis.ch.cam.ac.uk/smtg/)).

Christians in Science: Member of national committee, and International Secretary, since March 2004 ([www.cis.org.uk](http://www.cis.org.uk)).

## Other Professional Activities:

Hughes Hall: Member of various committees at Hughes Hall including: a working group to review the research contribution of Hughes Hall, chairman of a committee to review the visiting fellow scheme, Discipline Committee, the Fellowships Committee. Academic mentor to over 30 science post-grads with whom I met regularly and gave advice and support.

Cambridge Chemistry Department:

Informal Theoretical Chemistry Seminar Series (<http://www-theor.ch.cam.ac.uk/people/ardlouis/FriSeminar/>) (Organiser from October 1998)

Wednesday Theoretical Chemistry Colloquia (<http://www.ch.cam.ac.uk/CUCL/theo/>) (Organiser from October 1998)

Templeton Foundation: Co-organiser, with the “Cambridge Consortium”, of *The Emergence of Biological Complexity*, a \$3,000,000 inter-disciplinary funding programme of the John Templeton Foundation, with particular responsibility for the *Fine-Tuning in Biochemistry* sub-programme, together with Dr. Jonathan Doye. Other members are: Prof. Simon Conway-Morris, Dr. Chris Scarre, Prof. Graeme Barker, and Prof. Derek Burke. Request for proposals scheduled for January 2005.

Referee for: EPSRC, Chemical Physics Letters, European Journal of Physics E, Europhysics Letters, Journal of Chemical Physics, Journal of Computational Chemistry, Journal of Physics: Condensed Matter, Journal of Statistical Mechanics: Theory and Experiment, Molecular Physics, Physica A, Physical Review E, Physical Review B, Physical Review Letters, Templeton Foundation.

## SOLICITED RESEARCH AWARDS/GRANTS

October 2004: Royal Society annual research expenses grant, award value £11,000.

June 2004: PI on a Royal Society Research Grant, *New methods to coarse-grain hydrodynamics in complex fluids and porous media*, award value: £15,000.

October 2004: EPSRC CASE PhD studentship award, *Computational modelling and design of responsive industrial fluids*, industrial sponsor Schlumberger Cambridge Research, candidate: Jimaan Sané, award value: £48,257 from EPSRC and £21,000 from Schlumberger.

November 2003: EPSRC award GR/S77936/01 for *Protein Interactions in Vivo and in Vitro* conference, jointly with R. Sear (PI), J.P.K. Doye, and M. Vendruscolo. Award value: £5,202.

October 2003: EU Framework 6 Programme “Structuring the European Research Area: Human Resources and Mobility” FP6-509249, title: *Theory and computer simulations of interfacial phenomena*. Project for joint (salaried) visits between Cambridge, the University of Lublin, Poland (PI), and a number of other universities and institutes in Germany, Spain, Austria and the Czech Republic. Total award value approximately £150,000.

October 2003: Royal Society annual research expenses grant, award value £11,000.

June 2003: PI on EPSRC Impact Faraday award GR/S45409/01: *Computational modelling and design of responsive industrial fluids*. Award value: £137,006.

May 2003: Royal Society additional research expenses claim, award value £1000.

October 2002: EPSRC CNA PhD studentship award, *Modelling complex fluids*, industrial sponsor Schlumberger Cambridge Research, candidate: Stelios Karanikas. Award value  $\approx$  £40,000 from EPSRC and £15,000 from Schlumberger Cambridge Research.

October 2002: Royal Society annual research expenses grant, award value £13,000.

January 1998: 2 year TMR Marie Curie (Personal) Postdoctoral Research Fellowship award, GB/hr/977/340/026452, *Density Functional Theory of Electron-Ion Mixtures: Phase Transitions in Liquid Metals*, held at Dept. of Chemistry, Cambridge, with Prof. Jean-Pierre Hansen.

## STUDENTS AND POSTDOCS SUPERVISED

**I-Chun Lin**, Part III student 2003/2004, thesis “Investigation of crystallisation of globular proteins using coarse-grained models”, currently PhD student at EPFL with Ursula Rötlishberger.

**Arturo Monch Jordá**, Postdoc 2002-2003. Currently teaching at University of Granada.

**Stelios Karanikas**, EPSRC CNA PhD student, started October 2002

**Johan Padding**, EPSRC funded postdoc, June 2003 - June 2006.

**Jimaan Sané**, EPSRC CASE PhD student, started October 2004  
**Alex Wilber**, Part III student 2004/2005  
**Ainsley Mayhew Seers**, Part III student 2004/2005  
**Pauline Wong**, Part III student 2004/2005  
**Chris Ogden**, Part III student 2004/2005

## INVITED TALKS

- (1) *Attraction through Repulsion: Phase Separation in Hard Core Mixtures*, invited talk given at the 1992 National Seminar Statistical Mechanics in Utrecht, the Netherlands, June 5, 1992.
- (2) *Atomic Tunnelling from an AFM/STM tip: Dissipative Effects from Phonons* invited talk given at the Department of Theoretical Physics, Rijks Universiteit Utrecht, the Netherlands, August 19, 1994.
- (3) *Liquid Metallic Hydrogen*, invited talk given at the Department of Materials, Oxford University, July 11, 1996.
- (4) *Liquid Metallic Hydrogen*, invited talk given at the Department of Physics, Katholieke Universiteit Leuven, July 29, 1996.
- (5) *Liquid Metallic Hydrogen*, invited talk given at Lawrence Livermore National Laboratories, CA, September 15, 1997.
- (6) *Metallization of Fluid Hydrogen*, invited talk given at the Department of Physics, Bristol University, March 11, 1998.
- (7) *Giving Entropy a Hand, the Critical Role of Non-Additivity in Binary Colloidal Mixtures*, invited talk given at the Physical and Theoretical Chemistry Laboratory, Oxford University, January 25, 1999.
- (8) *Liquid Metallic Hydrogen: When/What is a Metal?*, invited talk given in the Mineral Physics seminar series, Department of Earth Sciences, Cambridge University, February 1, 1999.
- (9) *A Quantum Mystery in Plain Language: The Einstein-Podolsky Rosen Paradox*, invited talk given in the Hughes Hall seminar series, Cambridge, February 23, 1999.
- (10) *Is There a Semi-Universal Picture of Depletion in Binary Mixtures?*, invited talk given at the Department of Physics, Edinburgh University, May 5, 1999.
- (11) *Electron-Ion Correlations in Liquid Metals*, invited talk given at the "Liquid State of Matter: Opportunities From Advanced Radiation Sources" conference in Trieste, Italy, June 28 - July 2, 1999.
- (12) *Liquid Metals as Electron-Ion Mixtures: Correlations and Interactions*, invited talk given at the 1999 Gordon Conference on "Molten Salts and Liquid Metals", in Henniker, New Hampshire, July 25-30, 1999.
- (13) *Effective Potentials in Complex Fluids*, invited talk given to the Polymers and Colloids Group, Dept. of Chemistry, Bristol University, January 14, 2000.
- (14) *Mixing Polymers and Colloids: The Dark Hand of Entropy*, invited talk given at Dept. of Chemistry, Birmingham University, May 22, 2000.
- (15) *Effective Potentials for Polymers and Colloids*, invited talk given at the Royal Society Discussion Meeting, "Interactions, structure and phase behaviour of colloidal dispersions", London, Oct 26, 2000.
- (16) *Can complex fluids be modelled with the theory of simple fluids?*, invited talk given at the BP Institute for Multiphase Flow, Cambridge, May 17, 2001.
- (17) *Les potentiels effectifs dans les colloïdes: mélanges binaires et polymères comme colloïdes mous*, invited talk at the Laboratoire du Physique, E.N.S. Lyon, Lyon, France June 25, 2001.
- (18) *Les potentiels effectifs dans les colloïdes: mélanges binaires et polymères comme colloïdes mous*, invited talk at the Département de Physique des Matériaux, Université Lyon I., Lyon, France June 27, 2001.
- (19) *Polymers as soft colloids: effective interactions, phase behavior and depletion forces*, invited talk given at the 21st IUPAP International Conference on Statistical Physics STATPHYS21, Cancun, Mexico, July 19, 2001.
- (20) *Ion-ion and electron-ion correlations in liquid metals*, invited talk given at the Liquid and Amorphous Metals 11 conference, Yokohama, Japan, 10 Sept, 2001.
- (21) *Polymers as soft colloids, or how to model long string as balls of yarn*, invited talk given at the dept. of Physics, Kyoto University, Kyoto, Japan, 14 Sept, 2001.
- (22) *Modelling complex fluids with the theory of simple fluids: analogies and their breakdown*, invited talk given at the WE-Heraeus Seminar 261, Recent developments in the physics of liquids, Bad Honeff, Germany, 16 October 2001.
- (23) *Polymers as soft colloids: How to model long strings as balls of yarn*, invited talk given at the Polymer IRC in Leeds, November 21 2001.
- (24) *Modelling complex fluids with the theory of simple fluids: Analogies and their breakdown*, invited talk given at the Department of Chemical Engineering, University of Amsterdam, Netherlands, December 21, 2001.
- (25) *Polymers as soft colloids*, invited talk given at the Newton Institute on Soft Condensed Matter activities in Cambridge termly meeting, January 14, 2002.

- (26) *Modelling complex fluids with the theory of simple fluids*, invited talk given at “Liquid State theory: from white dwarfs to colloids” in les Houches, France, April 1, 2002.
- (27) *Modelling complex fluids with the theory of simple fluids*, invited talk given at the Physics department, University of Surrey, May 1, 2002.
- (28) *Polymers as soft colloids: coarse-graining across length scales*, invited talk given at “Computing Across Different Scales” workshop at the Mathematics Institute, University of Warwick, May 13, 2002.
- (29) *Polymers as soft colloids: coarse-graining across length scales*, invited talk given at the Max Planck Institute für Metallforschung, Stuttgart, Germany, June 4, 2002
- (30) *Polymers as soft colloids: coarse-graining across length scales*, invited talk given at the CECAM conference “Computational models for liquid crystals and complex systems”, Erice, Italy, 16 July 2002.
- (31) *Mixing polymers and colloids: the dark hand of entropy*, invited talk for the Dobson bio-physics group, Cambridge, 11 March 2003.
- (32) *Mixing polymers and colloids: the dark hand of entropy*, invited talk at Departamento de Ciencias Ambientales Universidad Pablo de Olavide, Seville, Spain, 24 April, 2003.
- (33) *Some subtleties regarding the use of effective pair potentials in soft matter systems*, invited talk at CECAM workshop “Effective many-body interactions and correlations in soft matter” Lyon, France, 7 July, 2003.
- (34) *Effective Potentials in Complex Fluids*, invited talk at Department of Physics, University of Messina, 30 October, 2003
- (35) *Coarse-graining polymers as soft colloids*, invited talk at Department of Physics, University of Messina, 30 October, 2003.
- (36) *Polymers as soft colloids: bridging length-scales without tripping up?*, invited talk at Institute for Theoretical Physics, University of Utrecht, 5 February, 2004.
- (37) *Mixing polymers and colloids: the dark hand of entropy*, invited talk in the Oberseminar: Aktuelle Fragen der Theoretischen Physik University of Stuttgart, 25 May 2004.
- (38) *Coarse graining polymers as soft colloids: lessons from bridging length-scales*, invited talk at the 3rd International Conference on Computational Modeling and Simulation of Materials, Acireale, Italy, May 31, 2004.
- (39) *Polymers as soft colloids: bridging length-scales without tripping up?*, invited talk at Cecam Workshop Novel Approaches to Efficient Simulation of Soft Matter Systems, Lyon, France, 24 June, 2004
- (40) *Mixing polymers and colloids: the dark hand of entropy*, invited talk given at the Tata Institute of Fundamental Research, Mumbai, India, 13 July, 2004
- (41) *Mixing polymers and colloids: the dark hand of entropy*, invited talk at the 20th General Conference of the Condensed Matter Division of the European Physical Society, Prague, Czech Republic, 22 July, 2004.
- (42) *Hydrodynamic and Brownian Fluctuations in Sedimenting Suspensions*, invited talk given at the Max Planck Institute for Polymer Research, Mainz, Germany, 2 November, 2004.

#### Upcoming Accepted Invitations:

- (43) *Hydrodynamic and Brownian Fluctuations in Sedimenting Suspensions*, invitation from Department of Chemistry, Bristol University, 24 February, 2005.
- (44) *Coarse-Graining Colloidal Suspensions: the Importance of Brownian and Hydrodynamic Effects*, invitation for plenary lecture, Thermodynamics 2005 conference, 6th-8th April 2005 Sesimbra, Portugal.
- (45) *Inhibition of Protein Crystallization by Evolutionary Negative Design*, invitation for “Recent Advances in Macromolecular Crystallization 2005” conference , 8-11 May, 2005, Le Bischenberg, Strasbourg, France.

## PUBLICATIONS

- [1] Daan Frenkel and A. A. Louis, "Phase separation in a binary hard-core mixture: an exact result.", *Phys. Rev. Lett.* **68**, 3363 (1992).
- [2] A.A. Louis and James P. Sethna, "Atomic tunnelling from a STM/AFM tip: dissipative quantum effects from phonons", *Phys. Rev. Lett.* **74**, 1363 (1995).
- [3] W.J. Nellis, A.A. Louis and N.W. Ashcroft, "Metallization of fluid hydrogen", *Phil. Trans. R. Soc. A.* **356**, 119-135 (1998).
- [4] A.A. Louis and N.W. Ashcroft, "Extending linear response: inferences from electron-ion structure factors.", *Phys. Rev. Lett.* **81**, 4456 (1998).
- [5] A.A. Louis and N.W. Ashcroft, "Electron-ion structure factors and the general accuracy of linear response", *J. Non-Crystalline Solids.* **250-252**, 9 (1999).
- [6] A.A. Louis, R. Finken and J-P. Hansen, "The structure of colloid-polymer mixtures", *Europhys. Lett.* **46**, 741 (1999).
- [7] A.A. Louis, R. Finken and J-P. Hansen, "Crystallisation and phase-separation in non-additive binary hard-sphere mixtures", *Phys. Rev. E* **61**, R1028 (2000).
- [8] J.A. Anta and A.A. Louis, "Probing ion-ion and electron-ion correlations in the quantum hypernetted chain approximation", *Phys. Rev. B* **61**, 11400 (2000).
- [9] A.A. Louis, "Fluid-solid phase-separation in hard-sphere mixtures is unrelated to bond-percolation", comment *Phys. Rev. Lett.* **84**, 1840 (2000).
- [10] A.A. Louis, P.G. Bolhuis, J.P. Hansen, and E.J. Meijer, "Can Polymer Coils be modeled as 'Soft Colloids'?", *Phys. Rev. Lett.* **85**, 2522 (2000).
- [11] A.A. Louis, P.G. Bolhuis, and J.P. Hansen, "Mean Field Fluid Behavior of the Gaussian Core Model", *Phys. Rev. E.* **62**, 7961 (2000).
- [12] P.G. Bolhuis, A.A. Louis, J.P. Hansen, and E.J. Meijer, "Accurate effective pair potentials for polymer solutions", *J. Chem. Phys.* **114**, 4296 (2001).
- [13] A.A. Louis, "Effective potentials for polymers and colloids: Beyond the van der Waals picture of fluids?", *Phil. Trans. R. Soc. A.* **359**, 939 (2001).
- [14] P.G. Bolhuis, A.A. Louis, and J.P. Hansen, "Many -body interactions and correlations in coarse-grained descriptions of polymer solutions" *Phys. Rev. E.* **64**, 021801 (2001).
- [15] A.A. Louis and R. Roth, "Generalized depletion interactions", *J. Phys.: Condens. Matter* **33**, L777 (2001).
- [16] R. Roth, R. Evans, and A.A. Louis, "Theory of asymmetric non-additive binary hard-sphere mixtures", *Phys. Rev. E* **64**, 051202 (2001).
- [17] E. Allahyarov, H. Löwen, A.A. Louis, and J.P. Hansen, "Discrete charge patterns, Coulomb correlations and interactions in protein solutions", *Europhys. Lett.* **57**, 731 (2002).
- [18] P.G. Bolhuis, and A.A. Louis, "How to derive and parameterize effective potentials in colloid-polymer mixtures", *Macromolecules* **35**, 1860 (2002).
- [19] A.A. Louis, P.G. Bolhuis, R. Finken, V. Krakoviack, E.J. Meijer and J.P. Hansen, "Coarse-graining polymers as soft colloids", *Physica A.* **306**, 251 (2002).
- [20] A.A. Louis, H. Xu, and J.A. Anta, "Combining quantum and classical density functional theory for ion-electron mixtures", *J. Non-Cryst. Solids*, **312-314C**, 60 (2002).
- [21] A.A. Louis, E. Allahyarov, H. Löwen and R. Roth, "Effective forces in colloidal mixtures: Depletion attraction to accumulation repulsion" *Phys. Rev. E*, **65** 061407 (2002).
- [22] V. Krakoviack, J. P. Hansen, A. A. Louis, "Relating monomer to centre-of-mass distribution functions in polymer solutions", *Europhys. Lett.* **58**, 53 (2002).
- [23] A.A. Louis, P.G. Bolhuis, E.J. Meijer and J.P. Hansen, "Density profiles and surface tensions of polymers near colloidal surfaces", *J. Chem. Phys.* **116**, 10547 (2002).
- [24] A.A. Louis, P.G. Bolhuis, E.J. Meijer and J.P. Hansen, "Polymer induced depletion potentials between two colloidal particles", *J. Chem. Phys.* **117**, 1893 (2002).
- [25] C. N. Likos, N. Hoffmann, H. Löwen and A. A. Louis, "Exotic fluids and crystals of soft polymeric colloids", *J. Phys. Condens. Matt* **14**, 7681 (2002).
- [26] A.A. Louis, "Beware of density dependent pair potentials", *J. Phys. Condens. Matt* **14**, 9187 (2002).



- [27] P.G. Bolhuis, A.A. Louis, and J.P. Hansen, "Role of polymer excluded volume in phase behavior of colloid polymer mixtures", *Phys. Rev. Lett.* **89**, 128302 (2002).
- [28] A.A. Louis, "Using isosbestic points to extract interactions from structure factors", cond-mat/0211537 (2002).
- [29] R. Finken, J.-P. Hansen, A. A. Louis, "Phase separation of penetrable core mixtures", *J. Stat. Phys.* **110**, 1015 (2003).
- [30] E. Allahyarov, H. Löwen, A.A. Louis, and J.P. Hansen, "Second virial coefficient of globular protein solutions: nonmonotonicity with added salt concentration", *Phys. Rev. E* **67**, 051494 (2003).
- [31] P.G. Bolhuis, E.J. Meijer and A.A. Louis, "Colloid-polymer mixtures in the protein limit", *Phys. Rev. Lett.* **90**, 068304 (2003).
- [32] V. Krakoviack, J.-P. Hansen, and A.A. Louis, "Influence of solvent quality on effective pair potentials between polymers in solution", *Phys. Rev. E* **67**, 041801 (2003).
- [33] A. Moncho-Jorda, B. Rotenberg, and A. A. Louis, "Effect of polymer-polymer interactions on the surface tension of colloid-polymer mixtures", *J. Chem. Phys.* **119**, 12667 (2003).
- [34] A. Moncho-Jorda, A. A. Louis, P. G. Bolhuis, and R. Roth, "The Asakura-Oosawa model in the protein limit: the role of many-body interactions", *J. Phys.: Condensed Matter*, **15**, S3429 (2003).
- [35] B. Rotenberg, J. Dzubiella, J.-P. Hansen, and A. A. Louis, "Thermodynamic perturbation theory of the phase behaviour of colloid/interacting polymer mixtures", *Mol. Phys.* **102**, 1 (2004).
- [36] R. Finken, J.-P. Hansen, and A.A. Louis, "Phase separation of a multiple occupancy lattice gas", *J. Phys. A: Math. Gen.* **37**, 577 (2004).
- [37] J.P.K. Doye, A. A. Louis and M. Vendruscolo, "Inhibition of protein crystallization by evolutionary negative design", *Physical Biology* **1**, P9 (2004).
- [38] C.I. Addison, A. A. Louis, and J.-P. Hansen, "Influence of solvent quality on polymer solutions: a Monte Carlo study of bulk and interfacial properties", *J. Chem. Phys.* **121**, 612 (2004).
- [39] A. Moncho Jorda, J. Dzubiella, J. P. Hansen, and A. A. Louis, "A density-functional study of interfacial properties of colloid-polymer mixtures", accepted in *J. Phys. Chem. B*.
- [40] J.T. Padding and A. A. Louis, "Hydrodynamic and Brownian Fluctuations in Sedimenting Suspensions", *Phys. Rev. Lett.* **93**, 220601 (2004).
- [41] S. Karanikas and A. A. Louis, "Dynamic colloidal stabilization by nanoparticle halos", *Phys. Rev. Lett.* **93**, 248303 (2004).
- [42] C.I. Addison, J.P. Hansen, and A. A. Louis, "From concentration profiles to polymer osmotic equations of state", accepted in *ChemPhysChem*.