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Daskalakis *et al*. publish a key paper in *Phys. Rev. Lett*.

Demonstrate formation of organic plasmon condensate at room temp

Surface plasmons in Widom-Larsen theory LENR-active site behave like condensate

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World first: Significant development in the understanding of macroscopic quantum behavior

Researchers from Polytechnique Montréal and Imperial College London demonstrate the wavelike quantum behavior of a polariton condensate on a macroscopic scale and at room temperature

POLYTECHNIQUE MONTRÉAL

For the first time, the wavelike behaviour of a room-temperature polariton condensate has been demonstrated in the laboratory on a macroscopic length scale. This significant development in the understanding and manipulation of quantum objects is the outcome of a collaboration between Professor Stéphane Kéna-Cohen of Polytechnique Montréal, Professor Stefan Maier and research associate Konstantinos Daskalakis of Imperial College London. Their work has been published in the prestigious journal *Physical Review Letters*.

http://www.eurekalert.org/pub_releases/2015-07/pm-wfs071415.php

Daskalakis *et al*.'s observations effectively support two key ideas in the Widom-Larsen theory's concept of a many-body LENR active site: (1) maximum size of sites is ~100 microns; (2) surface plasmon electrons within such sites are quantum mechanically entangled, i.e. they are coherently and collectively oscillating at ambient temperatures

Screenshots from: EurekAlert! The Global Source for Science News | AAAS

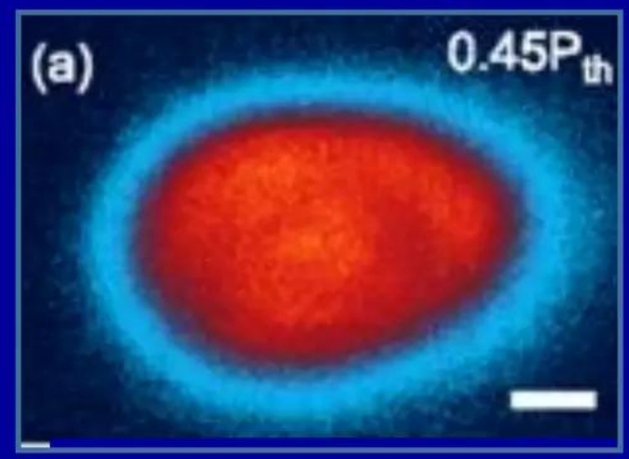
http://www.eurekalert.org/pub_releases/2015-07/pm-wfs071415.php

To produce the room-temperature condensate, the team of researchers from Polytechnique and Imperial College first created a device that makes it possible for polaritons - hybrid quasi-particles that are part light and part matter - to exist. The device is composed of a film of organic molecules 100 nanometres thick, confined between two nearly perfect mirrors. The condensate is created by first exciting a sufficient number of polaritons using a laser and then observed via the blue light it emits. Its dimensions can be comparable to that of a human hair, a gigantic size on the quantum scale.

Quantum objects visible to the naked eye

Quantum mechanics tells us that objects exhibit not only particle-like behaviour, but also wavelike behaviour with a wavelength inversely proportional to the object's velocity. Normally, this behaviour can only be observed at atomic length scales.

***Phys. Rev. Lett.* Fig. 5 (a)**



The size of the condensate is a limiting factor

In addition to directly observing the organic polariton condensate's wavelike behaviour, the experiment showed researchers that ultimately the condensate size could not exceed approximately 100 micrometres. Beyond this limit, the condensate begins to destroy itself, fragmenting and creating vortices.

"To date, the majority of polariton experiments continue to use ultra-pure crystalline semiconductors," says Professor Kéna-Cohen. "Our work demonstrates that it is possible to obtain comparable quantum behaviour using 'impure' and disordered materials such as organic molecules. This has the advantage of allowing for much simpler and lower-cost fabrication."

Contents

Many-body collective effects enable ultralow energy neutron reactions (LENRs)

Widom-Larsen theory LENR-active site has condensates

Site comprises many-body collective 'patch' of protons and plasmons

Born-Oppenheimer breakdown and collective quantum effects enable W-L LENRs

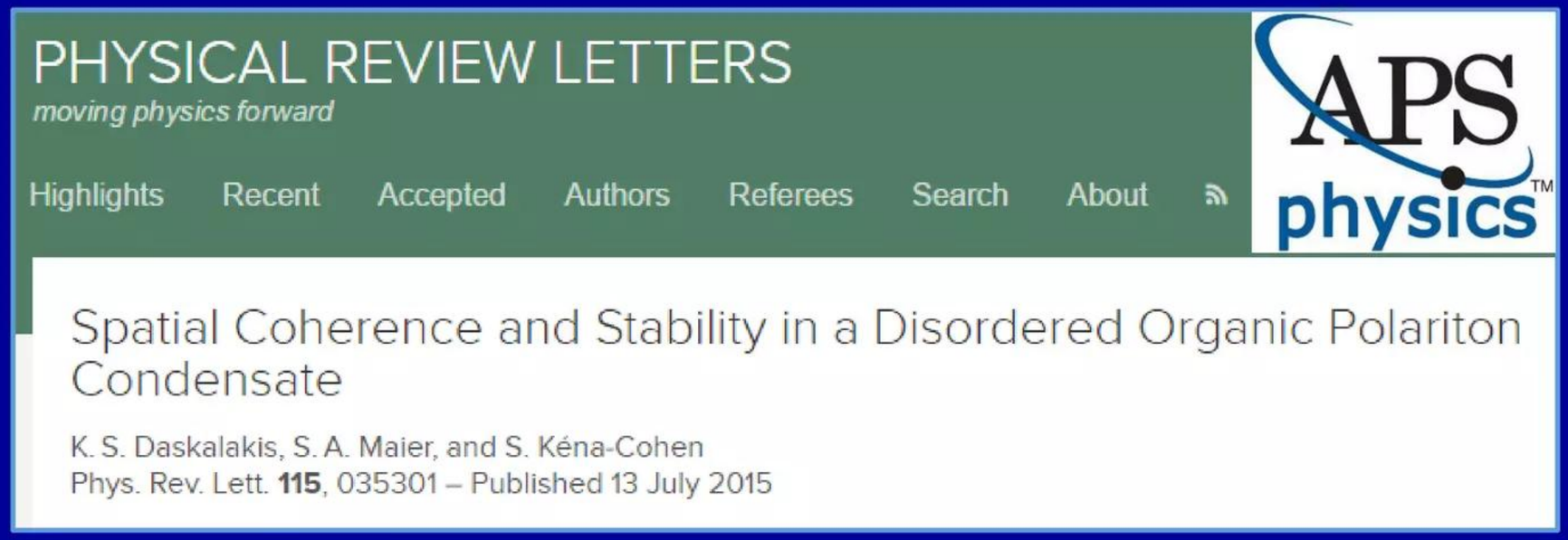
- ✓ "Spatial coherence and stability in a disordered organic polariton condensate"
  K. Daskalakis *et al. Physical Review Letters* 115 pp. 035301 - 06 (2015)
- ✓ Inside a laser-pumped microcavity, they demonstrated the formation of spatially localized, entangled plasmon condensates in 100 nm layer of organic TDAF molecules at room temperature in a disordered system
- ✓ Quoting: "Microcavity is identical to that of Ref. [2]. It uses 9 dielectric mirror pairs on opposite sides of a layer of 2,7-bis[9,9-di(4-methylphenyl)-fluoren-2-yl]-9,9-di(4-methylphenyl)fluorene (TDAF) and was impulsively pumped high above the polariton energy (i.e. nonresonantly)."
- ✓ Created plasmon condensates have spatial dimensions that seem to max-out at diameters of ~100 μ ; beyond this critical size limit they destabilize
- ✓ First-order temporal coherence of condensates = 0.8 picoseconds (ps); this is in reasonable agreement with coherence decay time estimate of 1 ps which is calculated from the observed emission linewidth

Widom-Larsen theory LENR-active site has condensates

Involves many-body 'patches' of protons coupled to surface plasmons

Surface plasmons in LENR-active sites behave like Daskalakis *et al*. condensate

- ✓ Widom-Larsen theory of ultralow energy neutron reactions (LENRs) provides detailed descriptions of the structure, particle composition (plasmons + protons or deuterons), and quantum, E-M, electroweak, chemical & nuclear processes that occur at LENR-active sites
- ✓ Remarkable type of many-body collective nuclear catalysis at LENR-active sites enables either $e + p$ or $e + d$ neutron-producing electroweak reactions to occur in condensed matter systems at substantial rates at ambient temperatures under exactly the right conditions and with proper energy inputs (called "pumping" in lexicon of paper by Daskalakis *et al.*)
- ✓ According to Widom-Larsen theory of LENRs, many-body collective quantum and electromagnetic effects are crucial and enabling to the operation of electroweak nuclear catalysis at ambient temperatures; quantum entanglement amongst protons and plasmons at LENR sites is inferred; 1 ps lifetime of plasmon condensate is very ample time for LENRs
- ✓ In 2006 *EPJC* paper (Widom & Larsen) we estimated size of coherence domains in LENR sites on metallic hydride surfaces to be ~ 1 - 10 μ. As discussed later in this document, in 2009 Larsen extended Widom-Larsen theory to cover occurrence of LENRs on organic aromatic molecules; increased maximum estimated size of W-L coherence domains to ~ 100 μ. Not known whether similarity to Daskalakis *et al.*'s limit of 100 μ is coincidental
- ✓ W-L active site functions like a microcavity; seems reasonable to speculate that the surface plasmons in LENR-active sites form condensates similar to what Daskalakis *et al*. observed



http://journals.aps.org/prl/abstract/10.1103/PhysRevLett.115.035301

http://arxiv.org/pdf/1503.01373v2.pdf

Abstract: "Although only a handful of organic materials have shown polariton condensation, their study is rapidly becoming more accessible. The spontaneous appearance of long-range spatial coherence is often recognized as a defining feature of such condensates. In this Letter, we study the emergence of spatial coherence in an organic microcavity and demonstrate a number of unique features stemming from the peculiarities of this material set. Despite its disordered nature, we find that correlations extend over the entire spot size, and we measure $g^{(1)}(r,r')$ values of nearly unity at short distances and of 50% for points separated by nearly 10 μm. We show that for large spots, strong shot-to-shot fluctuations emerge as varying phase gradients and defects, including the spontaneous formation of vortices. These are consistent with the presence of modulation instabilities. Furthermore, we find that measurements with flat-top spots are significantly influenced by disorder and can, in some cases, lead to the formation of mutually incoherent localized condensates."

Daskalakis *et al*. condensate behaves like SPs in LENR site

Q-M entanglement of plasmons occurs at ambient temperatures in both

- ✓ Quoting from their paper, "Here, we study in detail the onset of spatial and temporal coherence in an organic polariton condensate. We show that even in the presence of disorder, correlations can span the entire system size."
- ✓ "Although a number of other criteria exist, the spontaneous onset of long-range spatial coherence is often recognized as a defining feature for condensation."
- ✓ "We obtain a coherence length of up to $\lambda_c = 38\ \mu$, which is ultimately limited by the pump size."
- ✓ "Although the effect of disorder is apparent in the intensity patterns, the long coherence length and high degree of first-order coherence suggests the presence of a single condensate with a large condensate fraction." The same interferometry setup was used to measure the first-order temporal coherence of the polariton condensate. Here, the decrease in fringe contrast is measured over long time delays for two points spatially separated by 3 μ. The temporal coherence, shown in Fig. 3(b), exhibits a Gaussian prole with a coherence time $\tau_c = 0.8$ ps. Due to the impulsive pump, this value is not dominated by fluctuations, but instead agrees well with our calculation of the condensate survival time. From the emission linewidth, we find a condensate decay time of 1 ps, which is in good agreement with the measured temporal coherence."

Background image of microcavity used in experiments
credit: Konstantinos Daskalakis,
Imperial College, London

Daskalakis *et al.* plasmon condensate created in microcavity

Note abundant aromatic rings in TDAF molecule; system is laser-pumped

Microcavity with TDAF layer

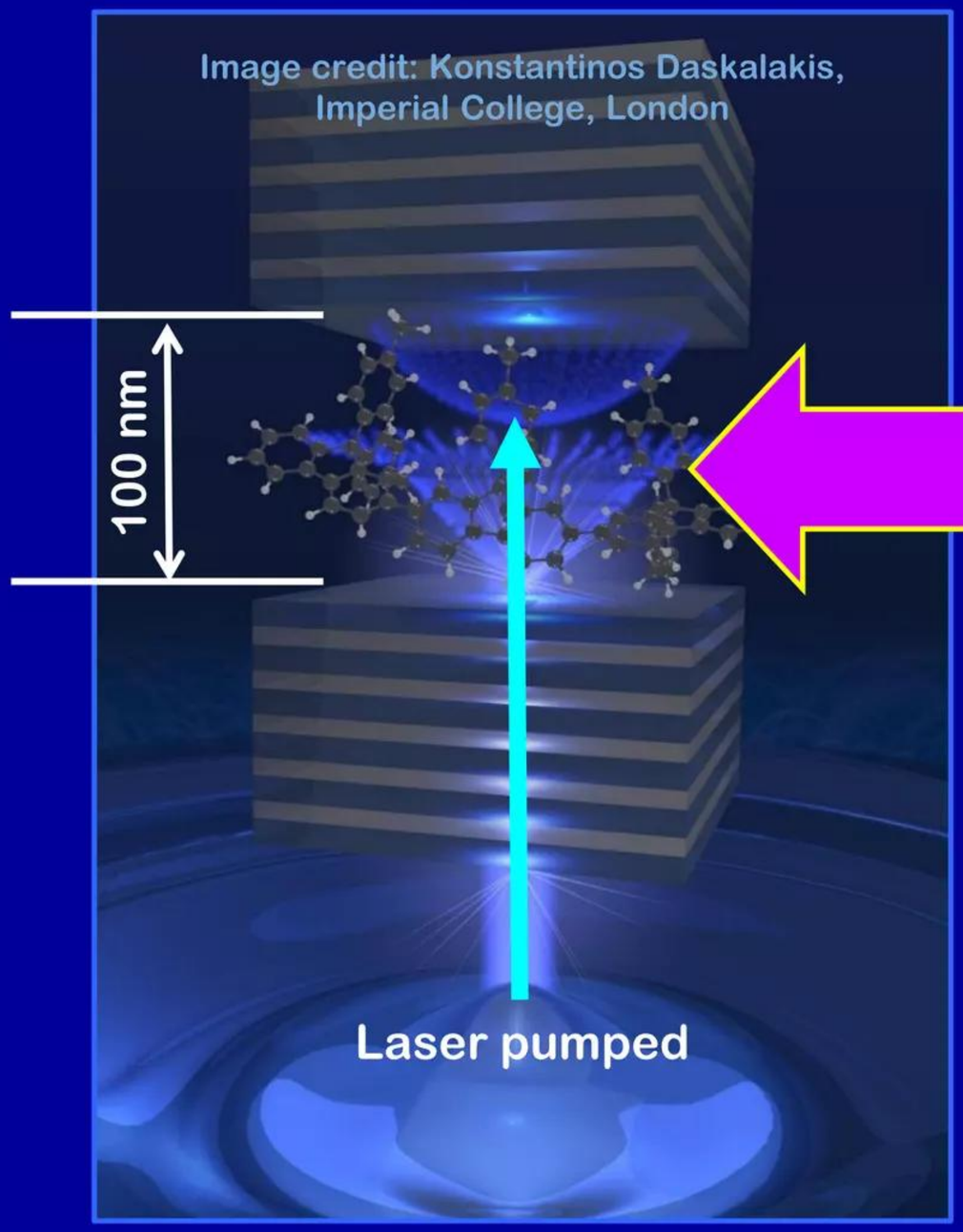
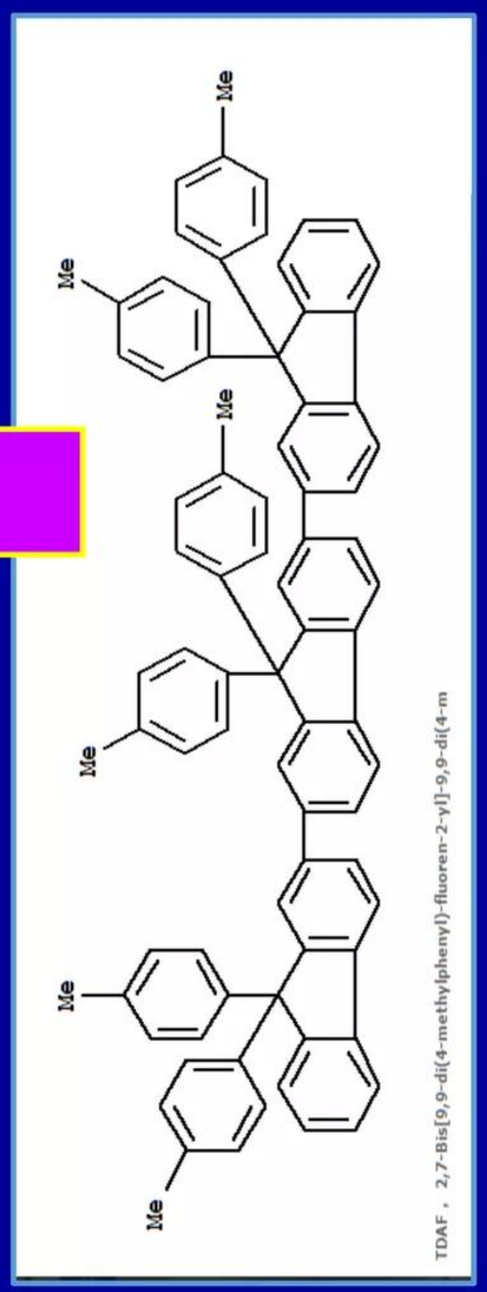


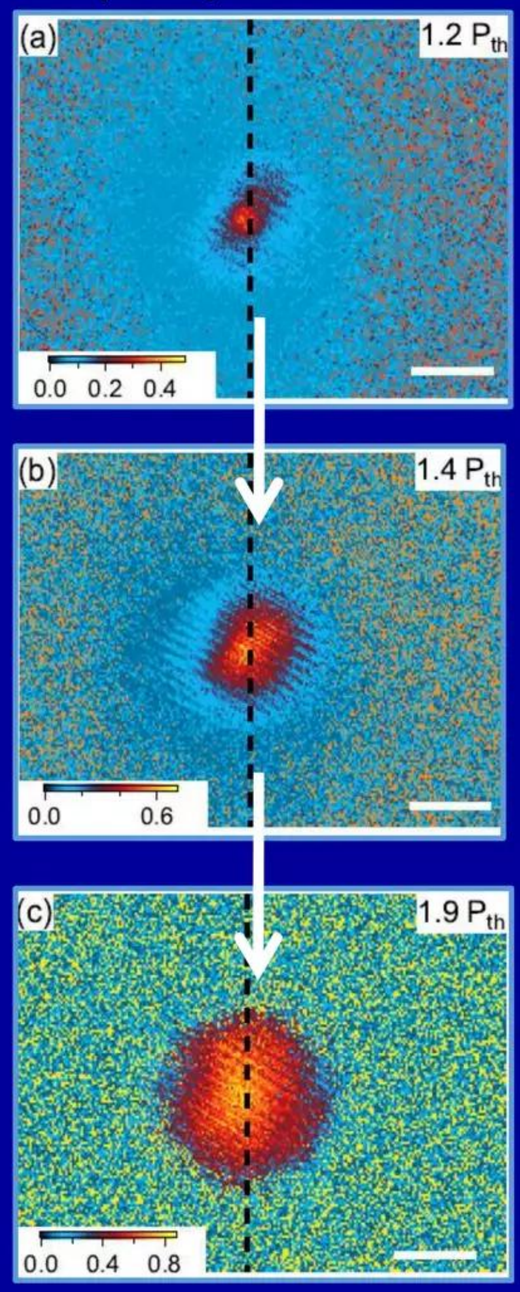
Figure has been adapted by Lattice

TDAF molecule



Aromatic rings in TDAF

$g^{(1)}$ (-r,r) for increasing pump fluence



Adapted by Lattice

Many-body collective quantum effects crucial to LENRs

Surface plasmon electrons e^-_{sp} are quantum mechanically entangled

SPs involve 10^{10} electrons and are macroscopic but nonetheless Q-M entangled

nature

"Plasmon-assisted transmission of entangled photons" E. E
E. Altewischer *et al.*, *Nature* 418 pp. 304 - 306 (2002)
http://home.physics.leidenuniv.nl/~exter/articles/nature.pdf

- ✓ "Here we investigate the effects of nanostructured metal optical elements on the properties of entangled photons. To this end, we place optically thick metal films perforated with a periodic array of subwavelength holes in the paths of the two entangled photons. Such arrays convert photons into surface-plasmon waves --- optically excited compressive charge density waves --- which tunnel through the holes before reradiating as photons at the far side. We address the question of whether the entanglement survives such a conversion process. Our coincidence counting measurements show that it does, so demonstrating that the surface plasmons have a true quantum nature."
- ✓ "From a general perspective, the observed conservation of quantum entanglement for the conversion from photon → surface plasmon → photon is a demonstration of the true quantum nature of SPs."
- ✓ " … a simple estimate shows that SPs are very macroscopic, in the sense that they involve some 10^{10} electrons. Our experiment proves that this macroscopic nature does not impede the quantum behaviour of SPs …"

Many-body collective quantum effects crucial to LENRs

Q-M entanglement of protons & electrons is very widespread in Nature

Observed in variety of small and large molecular structures containing Hydrogen

- ✓ Protons found within a wide variety of many-body condensed matter molecular systems spontaneously oscillate coherently and collectively; their quantum mechanical (Q-M) wave functions are thus effectively entangled with each other and also with nearby collectively oscillating electrons; amazingly, this behavior occurs even in comparatively smaller, much simpler molecular systems such as $(NH_4)_2PdCl_6$, ammonium hexachlorometallate (see Krzystyniak *et al.*, 2007 and Abdul-Redah & Dreismann, 2006)

- ✓ Quoting from 2007 paper by Krzystyniak *et al.*: "… different behaviors of the observed anomaly were found for LaH_2 and LaH_3 … As recognized by Chatzidimitriou-Dreismann *et al.* … Coulombic interaction between electrons and protons may build up entanglement between electrons and protons. Such many body entangled states are subject to decoherence mechanisms due to the interaction of the relevant scattering systems with its environment … one can conclude that the vibrational dynamics of NH_4^+ protons as fairly well decoupled from the dynamics of the [attached] heavier nuclei."

- ✓ Elaborating further from Chatzidimitriou-Dreismann (2005), "Further NCS experiments confirmed the existence of this effect in quite different condensed matter systems, e.g., urea dissolved in D_2O, metallic hydrides, polymers, 'soft' condensed matter, liquid benzene, and even in liquid H_2-D_2 and HD."

Many-body collective quantum effects crucial to LENRs

Protons go in-and-out of entanglement in 100-500 x 10^{-18} s time-frames

LENRs can take advantage of this because they work on even faster time-scales

- ✓ C. Chatzidimitriou-Dreismann (Technical University of Berlin) and collaborators have published extensively on collective proton entanglement since 1995; see:

  "Attosecond quantum entanglement in neutron Compton scattering from water in the keV range" (2007) http://arxiv.org/PS_cache/cond-mat/pdf/0702/0702180v1.pdf

  Quoting from paper: "Several neutron Compton scattering (NCS) experiments on liquid and solid samples containing protons or deuterons show a striking anomaly, i.e. a shortfall in the intensity of energetic neutrons scattered by the protons; cf. [1, 2, 3, 4]. E.g., neutrons colliding with water for just 100 - 500 attoseconds (1 as = 10^{-18} s) will see a ratio of hydrogen to oxygen of roughly 1.5 to 1, instead of 2 to 1 corresponding to the chemical formula H_2O. … Recently this new effect has been independently confirmed by electron-proton Compton scattering (ECS) from a solid polymer [3, 4, 5]. The similarity of ECS and NCS results is striking because the two projectiles interact with protons via fundamentally different forces, i.e. the electromagnetic and strong forces." Proton entanglement is widespread in Nature

- ✓ Also see: "Entangled mechanical oscillators," J. Jost *et al.*, *Nature* 459 pp. 683 - 685 (2009) in which they state that the "… mechanical vibration of two ion pairs separated by a few hundred micrometres is entangled in a quantum way."
  See Jost's thesis: http://www.nist.gov/pml/div688/grp10/upload/Jost2010thesis.pdf

Proton Q-M entanglement extends to mesoscopic scales

"Protons are unique to understanding quantum entanglement"

Measurements show entanglement of protons is present at 300º K

"Evidence of macroscopically entangled protons in a mixed isotope crystal of $KH_pD_{1-p}CO_3$"
F. Fillaux, A. Cousson, and M. Gutmann
Journal of Physics: Condensed Matter 22 pp. 045402 (2010)
http://iopscience.iop.org/0953-8984/22/4/045402/pdf/0953-8984_22_4_045402.pdf

Quoting directly: "The proposed theory is based upon fundamental laws of quantum mechanics applied to the crystal in question: the structure is periodic; dimers are centrosymmetric; indistinguishable protons are fermions; indistinguishable deuterons are bosons. It leads to macroscopically entangled states and, in the special case of protons, to super-rigidity and spin-symmetry with observable consequences. This theory is consistent with a large set of experimental data (neutron diffraction, QENS, INS, infrared and Raman) and, to the best of our knowledge, there is no conflict with any observation. There is, therefore, every reason to conclude that the crystal is a macroscopic quantum system for which only nonlocal observables are relevant."

"Protons are unique to demonstrating quantum entanglement, because they are fermions and because the very large incoherent cross-section can merge into the total coherent cross-section. No other nucleus can manifest such an increase of its coherent cross-section. The enhanced features can be, therefore, unambiguously assigned to protons, in accordance with their positions in reciprocal space. They are evidences of macroscopic quantum correlations which have no counterpart in classical physics."

"This work presents one single case of macroscopically entangled states on the scale of Avogadro's constant in a mixed isotope crystal at room temperature. The quantum theory suggests that such macroscopic quantum effects should be of significance for many hydrogen bonded crystals."

Concept of Widom-Larsen theory's LENR-active site

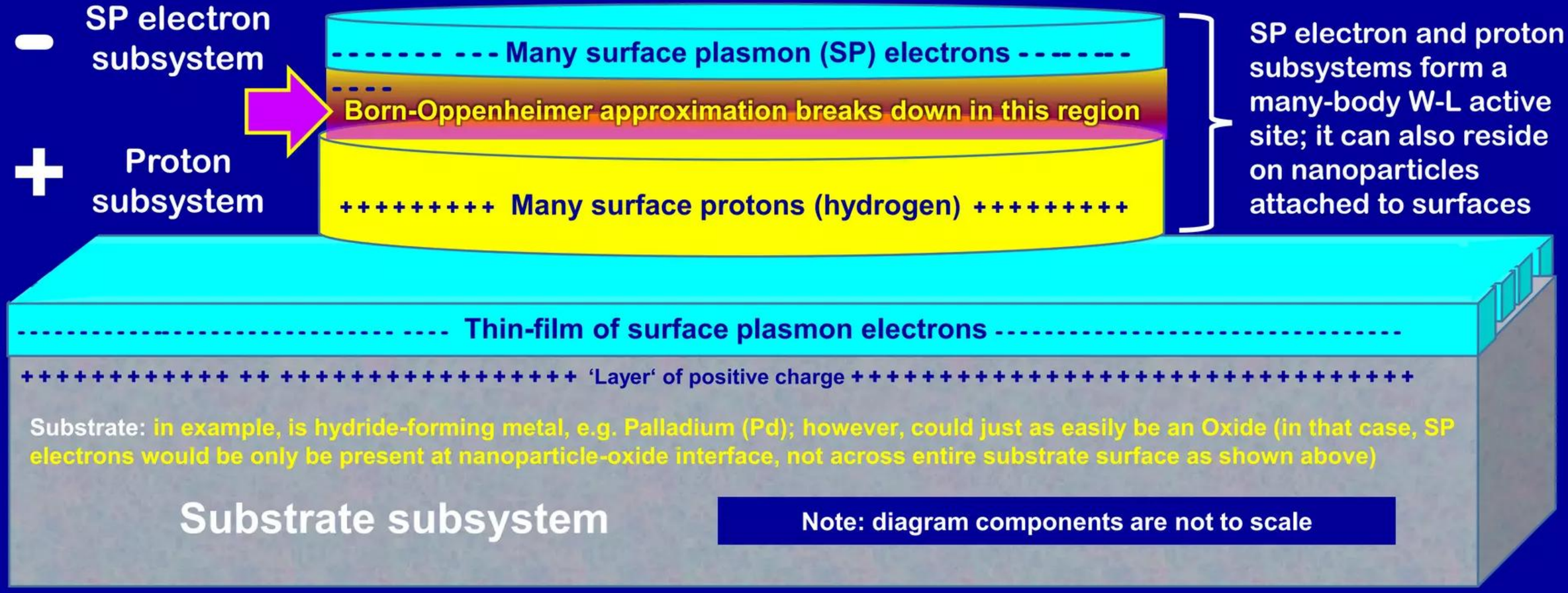
Comprised of many-body patches of protons/electrons on surface

SP electrons and protons oscillate collectively and are mutually Q-M entangled

Diameters of many-body active sites randomly range from several *nm* up to ~ 100 microns

SP electron and proton subsystems each comprise Q-M entangled, many-body collectively oscillating collections of oppositely charged particles; behave like two 'mirror' condensates that interact with each other via electromagnetic field

Microscopic details of Widom-Larsen theory LENR-active site



Patches of p^+ protons form spontaneously on surfaces

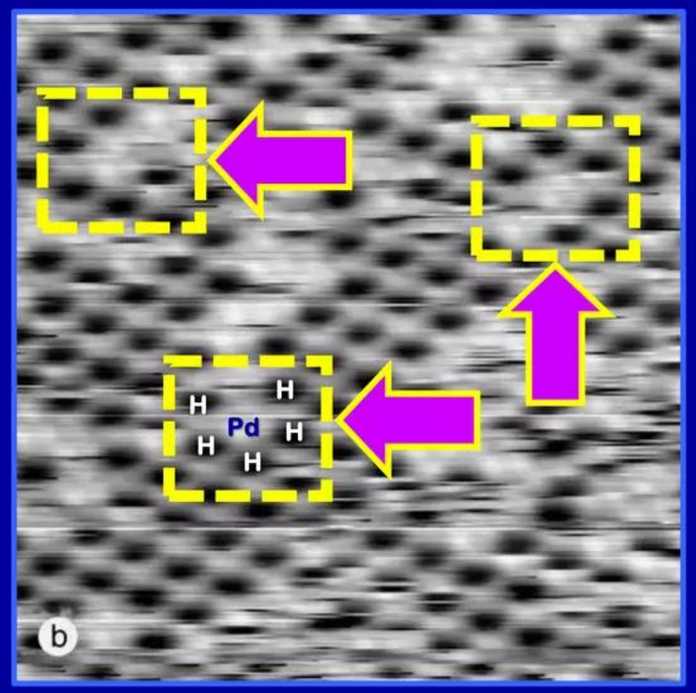
Physical size of LENR active sites ranges from 2 nm to 100+ microns

With metal hydrides bulk lattice loading H/metal must be > 0.80 for sites to form

Example illustrates formation of hydrogenous patches on metallic hydride surface

- ✓ **Lattice comment:** image shows small many-body patches of protons on Pd surface. Visual inspection of STM image in adapted version of Fig. 1 reveals that under Mitsui *et al.'s* experimental conditions, PdHx ratios at many surface sites would appear to be comfortably above the minimal critical value of H/Pd > 0.80 known to be necessary for LENR triggering; PdHx H/Pd ratios seen at some sites can apparently range as high as x = 5.0 (see Figure 1)
- ✓ Therefore, similarly high PdHx ratios would seem to be plausible in the case of high % surface coverage of hydrogen atoms (protons) on fully loaded Pd(111) surfaces at room temperature of 273 K and beyond. **Thus, high PdHx ratios could reasonably be expected to occur within nm to micron-sized, many-body, entangled hydrogenous active sites conjectured in the Widom-Larsen theory of LENRs**

STM image of H on Pd(111) adapted from Fig. 1 in Mitsui *et al.* (2003)



"Hydrogen absorption and diffusion on Pd (111)" T. Mitsui *et al.* *Surface Science* 540 pp. 5 - 11 (2003)

http://www.researchgate.net/publication/229342506_Hydrogen_adsorption_and_diffusion_on_Pd(111)

Widom-Larsen theory posits LENRs as multi-step process

Summary of key steps that must occur in LENR transmutation process

Six-step green radiation-free process occurs in 200 - 400 nanoseconds or less

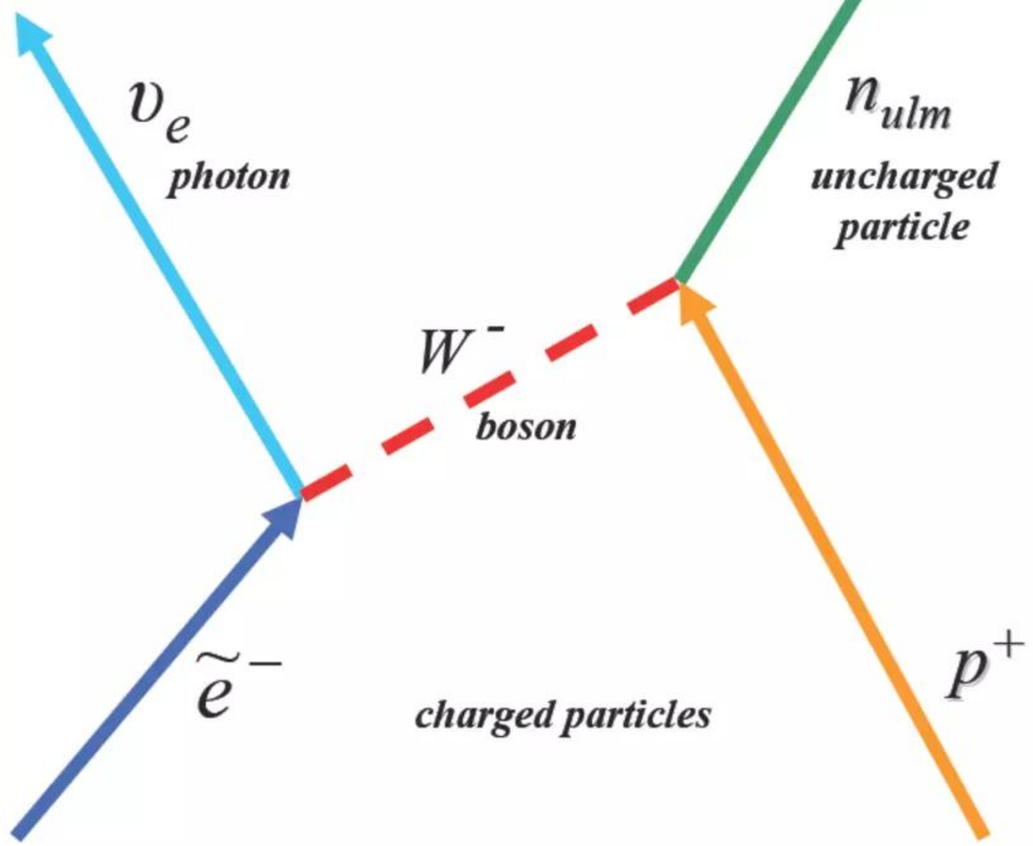
1. Collectively oscillating, quantum mechanically entangled, many-body patches of hydrogen (either protons or deuterons) form spontaneously on surfaces
2. Born-Oppenheimer approximation spontaneously breaks down, allowing E-M coupling between local surface plasmon electrons and patch protons; enables application of input energy to create nuclear-strength local electric fields >> 10^{11} V/m - increases effective masses of surface plasmons located in patches
3. As many-body entangled protons couple loosely to nearby surface plasmon electrons, it induces mirror plasmon condensate to form *a la* Daskalakis *et al.*
4. Heavy-mass surface plasmon electrons formed in many-body patches can react directly with electromagnetically interacting protons; process creates neutrons and benign neutrinos via a collective electroweak $e + p$ reaction
5. Neutrons collectively created in patch have ultra-low kinetic energies; almost all absorbed by nearby atoms - few neutrons escape into environment; locally produced or ambient gammas converted directly into infrared photons by unreacted heavy electrons (US# 7,893,414 B2) - no deadly gamma emissions
6. Neutrons captured, elements transmuted → 'crater' formation at active sites

Many-body collective quantum effects crucial to LENRs

While written as two-body e^- + p^+ reaction LENR catalysis is many-body

Condensed matter many-body collective effects involve quantum entanglement

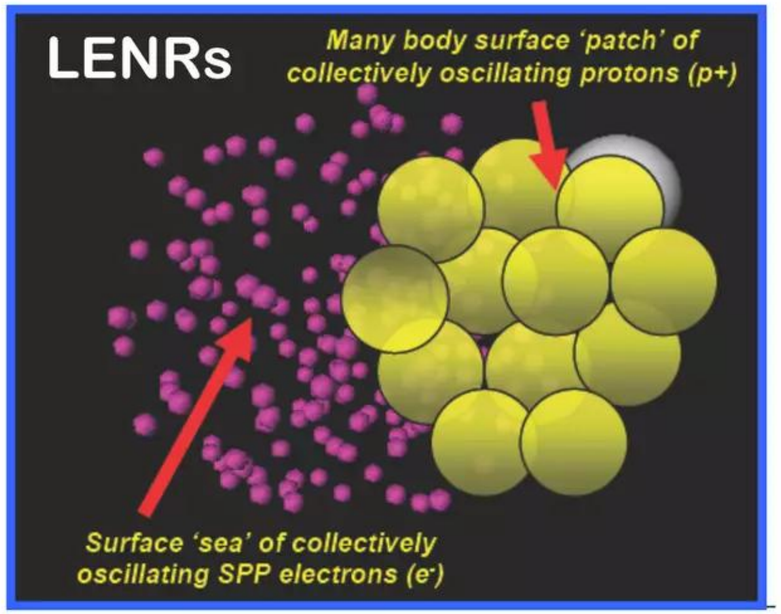
Simple two-body collision shown in Feynman diagram below:



$$\tilde{e}^- + p^+ \longrightarrow n_{ulm} + \nu_e$$

What really happens is many-body

Now add collective rearrangements from condensed matter effects. It is not just a two body collision !!!



Above is what really occurs on metallic hydride cathodes

Electroweak reaction in Widom-Larsen theory is simple

Protons or deuterons react directly with electrons to make neutrons

W-L explains how $e + p$ reactions occur at substantial rates in condensed matter

Input energy (pumping) → Collective many-body electroweak catalysis

Draw energy from electric fields > 2.5 x10^{11} V/m

Heavy-mass e^{-}* electrons react directly with protons

Collective many-body quantum effects: many electrons each transfer little bits of energy to a much smaller number of electrons also bathed in the very same extremely high local electric field

Quantum electrodynamics (QED): smaller number of electrons that absorb energy directly from local electric field will increase their effective masses ($m = E/c^2$) above key thresholds β_0 where they can react directly with a proton (or deuteron) → neutron and neutrino

$$\text{Energy}_{\text{E-field}} + e^-_{sp} \rightarrow e^{-*}_{sp} + p^+ \rightarrow n^0 + \nu_e$$

ν_e neutrinos: ghostly unreactive photons that fly-off into space; n^0 neutrons capture on nearby atoms

LENR ULE neutrons induce radiation-free nuclear transmutations and generate infrared heat

Neutrons + atomic nuclei → heavier elements + decay products

Neutron production in LENR-active sites requires energy

Many different types of input energy sources can be used for pumping

Energy driving $e + p$ reactions comes from E-fields not particle kinetic energies

Input energy is required to drive electroweak W-L nuclear catalysis - to create non-equilibrium conditions that enable nuclear-strength local E-fields that will produce populations of heavy-mass e^{-*}electrons, only small portion of which will then react directly with protons/deuterons to make neutrons & neutrinos in LENR-active sites:

- ✓ **Electrical currents** - i.e., electron current serves as an excellent input energy source
- ✓ **Ion currents -** across interface on which surface plasmon electrons reside (i.e., an ion 'beam' that can be comprised of protons, deuterons, tritons, and/or other types of charged ions); one method used to input energy is an ion flux caused by imposing D_2 pressure gradient across thin-film metal-oxide heterostructure (Iwamura *et al.* 2002)
- ✓ **Incoherent and coherent electromagnetic (E-M) photon fluxes -** can be incoherent E-M radiation found in resonant electromagnetic cavities (i.e., microcavities); with proper coupling, surface plasmon polariton electrons can also be directly pumped with coherent laser beams emitting photons at appropriate resonant wavelengths
- ✓ **Organized magnetic fields with cylindrical geometries (magnetic version of W-L theory) –** operates mainly at very high electron currents; includes organized, non-ideal so-called dusty plasmas; scales all-the-way-up to magnetic flux tubes on stars

LENR electroweak catalysis boosts $e + p$ reaction rate

Collective effects & Q-M entanglement make it a many-body reaction

Energy to drive reaction comes from electric fields not particle kinetic energies

Increased effective electron mass solves the mass deficit problem with $e + p$ reaction rates

- ✓ In coherently oscillating. Q-M entangled patches of surface protons, deuterons, or tritons the Born-Oppenheimer approximation breaks down; this causes local electromagnetic coupling between surface plasmon (SP) electrons and protons, deuterons, or tritons associated/entangled with an LENR many-body active site and enables transient, nuclear-strength, collective local electric fields > 2.5×10^{11} V/m to be created therein. Site conceptually akin to gigantic 'naked' pancake-shaped, micron^{+} diameter atomic nucleus (*sans* strong force) resting on a substrate surface
- ✓ LENR active site SP electrons locally bathed in nuclear-strength electric fields undergo a phenomenon called "mass renormalization" whereby their masses effectively increase. This effect, upon which the W-L theory of LENR electroweak catalysis relies, was first discovered and published by famous Russian physicists in 1970s (Landau & Lifshitz, "The Classical Theory of Fields", Sects. 17 and 47, Prob. 2, Pergamon Press, Oxford 1975 and Berestetskii, Lifshitz, & Pitaevskii, "Quantum Electrodynamics", Sect. 40, Eq. 40.15, Butterworth Heinmann, Oxford, 1997). Effect is uncontroversial and well-accepted among high-energy particle physicists
- ✓ Since such electrons are not increasing mass via kinetic energy associated with high-velocity translational motion, no bremsstrahlung radiation will be produced

W-L explains temporal details of electroweak catalysis

Neutron production/capture occur on time-scales 10^{-22} to 10^{-12} seconds

Fast chemical reactions take nanoseconds (10^{-9} s); 1 nanosec = 10^{9} attoseconds

- ✓ Ultracold neutron production can begin in an LENR many-body active sites sometime after local electric field strength exceeds ~ 2.5 x 10^{11} V/m (i.e., e^{-*} mass renormalization ratio β now greater than the minimum threshold ratio β_0) and an adequate number of mass-renormalized e^{-*} electrons have been created (enabled by local breakdown of the Born-Oppenheimer approximation in ~temporal conjunction with nonequilibrium energy inputs to active sites)

- ✓ Electroweak e^{-*} + p^{+} or e^{-*} + d^{+} reactions will occur during many-body, collectively oscillating protons' brief moments of quantum coherence (evanescent Q-M entanglement within patch); duration of such proton coherence times are on the order of attoseconds (~10^{-18} sec); these times have been measured by Chatzidimitriou-Dreismann (2005) and are cited on Slide #44 in http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewpahs-and-lenrsnov-25-2009

- ✓ Once e^{-*} mass renormalization set-up process has completed and heavy e^{-*} electrons and p^{+} protons are ready to react (i.e., β now > β_0), electroweak reactions that follow will then only require ~10^{-19} to 10^{-22} sec to finish. Thus, while proton Q-M coherence times may be quite short, collective electroweak reactions that produce neutrons operate on even faster nuclear time-scales, thereby allowing collective neutron production to proceed at substantial rates

- ✓ Since collectively produced neutrons are ultra-ultra-low energy and local neutron capture processes occur on time-scales of picoseconds (10^{-12} sec), not nearly enough time for them to thermalize (that requires 0.1 - 0.2 μsec per S. Lamoreaux), so the vast majority of neutrons are captured locally on nearby atoms; systems do not emit any MeV-energy neutron radiation

LENR neutrons are produced at ultralow kinetic energies

Deeply connected to Q-M entanglement of protons in LENR active sites

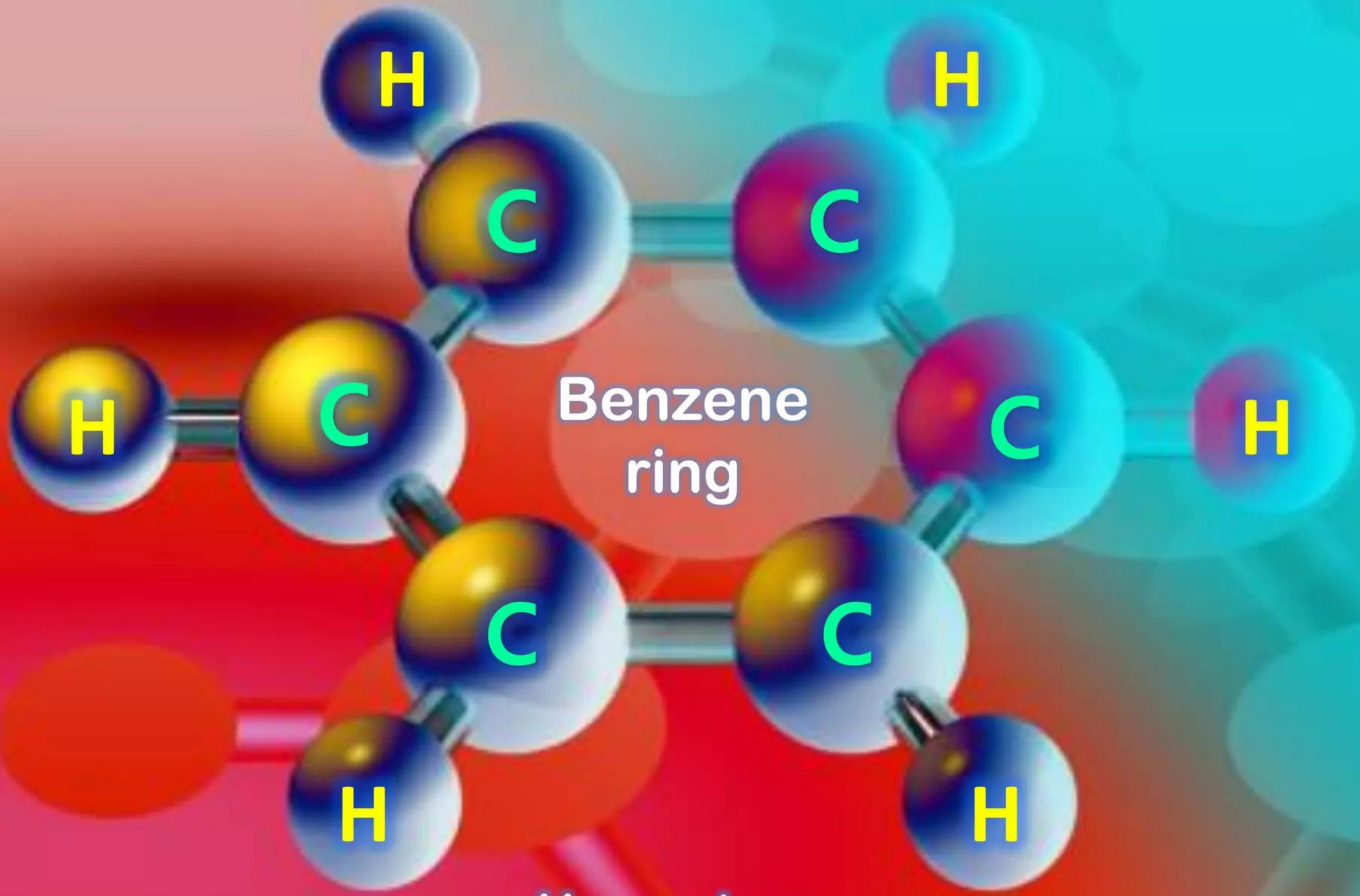
In condensed matter LENRs the system of collective, highly correlated particle interactions is a an active site comprising a many-body surface patch of N_p collectively oscillating protons that are all electromagnetically coupled to many nearby collectively oscillating SP electrons N_e via local breakdown of the Born-Oppenheimer approximation. After SP electron mass renormalization and neutron production via an electroweak $e + p$ reaction occur, the final state of such localized systems contains $(N_p - 1)$ protons, $(N_e - 1)$ SP electrons and according to the W-L theory, one freshly produced neutron. Such a system's final state might be naively pictured as containing an isolated free neutron at roughly thermal energies with a DeBroglie wavelength λ of ~2 Angstroms (2×10^{-8} cm) --- typical for thermalized free neutrons in condensed matter. Here that is not the case: in a many-body collective system's final state, a particular proton, say number k, has just been converted into a neutron. The resulting many-body state together with all the unconverted protons may be denoted by the neutron localized $|k\rangle$. However, neutrons produced by a Q-M many-body collective process are not created in a simple state. Wave functions of such a neutron in a many-body patch of N_p identical protons is in fact a superposition of many N_p localized states best described by a delocalized band state:

$$|\psi\rangle \approx \frac{1}{\sqrt{N_p}} \sum_{k=1}^{N} |k\rangle$$

Thus the DeBroglie wavelength λ of LENR neutrons produced by a condensed matter collective system must be comparable to the spatial dimensions of the many-body active sites in which they were produced. Wavelengths of such neutrons can be on the order of $\lambda \approx 3 \times 10^{-3}$ cm or more; ultra low momentum of collectively created neutrons then follows directly from the DeBroglie relation:

$$p = \frac{h}{\lambda} = \frac{2\pi\hbar}{\lambda} = \frac{\hbar}{\lambda\!\!\!^{-}}$$

Aromatic molecule: 6 Carbon atoms in ring with Hydrogen



H = proton

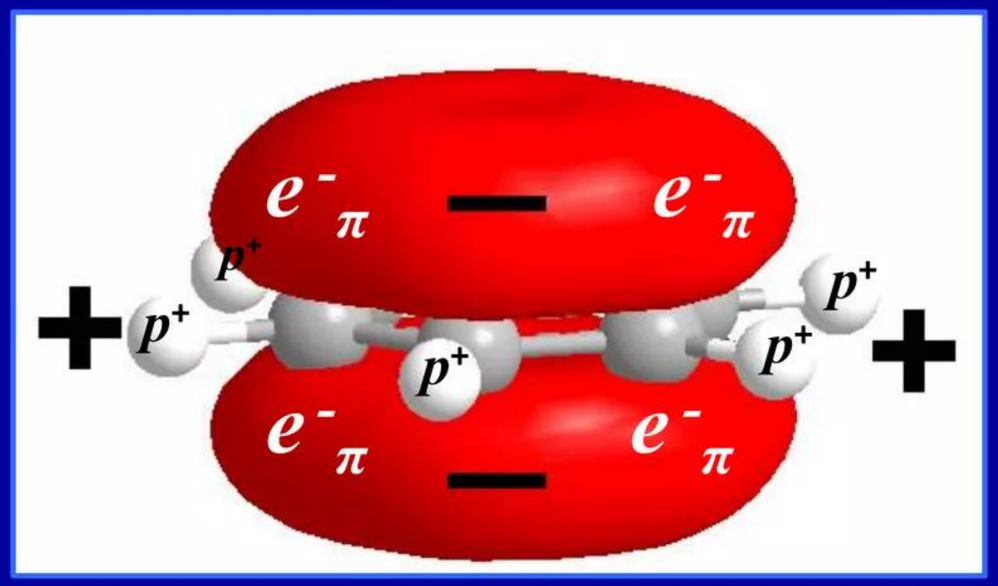
Larsen extended Widom-Larsen theory to aromatic rings

Benzene ring is 2 nm molecular analogue of LENR active site on metal

Protons (Hydrogen) on ring and related π electrons are all Q-M entangled

Larsen's conjecture that electrons on aromatic rings can behave like the functional equivalents of surface plasmons on metals was eventually confirmed by A. Manjavacas *et al*. (2013)

Red indicates π many-electron clouds on both sides of Carbon aromatic ring



Only tiny fraction of total number of π electrons are shown in this graphic

Synopsis: back in 2009, Larsen predicted that under proper conditions, electromagnetic energy can be transferred into hydrogenated aromatic rings such that ultra low momentum neutrons are created from ring hydrogens (protons) via LENR catalysis of an electroweak $e_\pi + p \rightarrow n + \nu_e$ reaction; neutrons then tend to capture on nearby ring Carbon atoms, inducing a nuclear transmutation process

"Technical Overview - PAHs and LENRs"
L. Larsen, Lattice Energy LLC
November 25, 2009 (see slides #42 - 45)

http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewpahs-and-lenrsnov-25-2009

2009: predicted surface plasmons on aromatic rings

Larsen theoretically conjectured experimentalists would observe this

"Tunable molecular plasmons in polycyclic aromatic hydrocarbons"
A. Manjavacas *et al.*
ACS Nano 7 pp. 3635 - 3643 (2013)
http://pubs.acs.org/doi/abs/10.1021/nn4006297

Abstract: "We show that chemically synthesized polycyclic aromatic hydrocarbons (PAHs) exhibit molecular plasmon resonances that are remarkably sensitive to the net charge state of the molecule and the atomic structure of the edges. These molecules can be regarded as nanometer-sized forms of graphene, from which they inherit their high electrical tunability. Specifically, the addition or removal of a single electron switches on/off these molecular plasmons. Our first-principles time-dependent density-functional theory (TDDFT) calculations are in good agreement with a simpler tight-binding approach that can be easily extended to much larger systems. These fundamental insights enable the development of novel plasmonic devices based upon chemically available molecules, which, unlike colloidal or lithographic nanostructures, are free from structural imperfections. We further show a strong interaction between plasmons in neighboring molecules, quantified in significant energy shifts and field enhancement, and enabling molecular-based plasmonic designs. Our findings suggest new paradigms for electro-optical modulation and switching, single-electron detection, and sensing using individual molecules."

Larsen extended Widom-Larsen theory to aromatic rings

Collective electroweak catalysis of neutrons on molecular LENR active site

- ✓ Delocalized clouds of π electrons situated above and below 6-Carbon aromatic ring structures are in very close physical proximity to protons (hydrogen atoms), oscillate collectively, and are mutually Q-M entangled (Manjavacas *et al*. - 2013)
- ✓ Protons that are also attached to an aromatic ring's Carbon atoms oscillate collectively and are Q-M entangled with each other (this was first observed and reported by Chatzidimitriou-Dreismann - 2005)
- ✓ Local breakdown of Born-Oppenheimer approximation occurs on aromatic ring structures; this enables E-M coupling and energy transfers between collectively oscillating π electrons and nearby protons (H) on aromatic ring; during E-M energy input, very high fluctuating local electric fields are created in vicinity of the ring
- ✓ When an aromatic structure is adsorbed onto the surface of a metallic substrate, it will spontaneously orient itself as it approaches so that the ~flat ring plane of an aromatic molecule ends-up ~parallel to the substrate surface. Born-Oppenheimer approximation also breaks down there, enabling further E-M coupling and energy transfers between Carbon-ring π electrons and thin-film 'sea' of surface plasmon electrons covering a substrate's surface (S. Jenkins, *Proc. Royal Soc*. 465 - 2009)
- ✓ Dynamics are analogous to manner in which LENR active sites operate on loaded metallic hydride surfaces. Molecular aromatic ring structure becomes functional analogue of a many-body LENR active site in which neutrons can be produced collectively via electroweak $e + p$ reaction; neutrons will tend to capture on nearby ring Carbons --- this also applies to multi-ring polycyclic aromatic hydrocarbons

Larsen extended Widom-Larsen theory to aromatic rings

Surface plasmons on metals can transfer energy into ring π electrons

Jenkins: aromatic molecules adsorbed on metal surfaces will lay flat as possible

"Aromatic adsorption on metals via first-principles density functional theory"
S. J. Jenkins
Proceedings of the Royal Society 465
pp. 2949 - 2976 (2009)
http://rspa.royalsocietypublishing.org/content/royprsa/465/2110/2949.full.pdf

"[Benzene] adopts a flat-lying … geometry, binding to the surface through donation of electrons through one or both of its degenerate HOMOs and back-donation into one or both of its two degenerate LUMOs."

"The work of Dou *et al.* (2008) reveals a preference for a flat-lying adsorption geometry on Cu{100} in which the fused benzene rings are located above hollow sites, oriented such that two C–C bonds from each lie along one of the 011 directions … amounting to a maximum vertical separation of 0.20Å between the lowest and highest lying C atoms; the height of the molecule above the surface is in the region of 2.20Å."

E-M field lines surrounding an aromatic ring

Three-ring polycyclic aromatic hydrocarbon (PAH)

Unsaturated Phenanthrene ($C_{14}H_{10}$)

Schottky barrier forms at metal-molecule interface; can create local interfacial E-fields > 10^{10} V/m

Many-body collective quantum effects crucial to LENRs

"Our experiments prove … quantum wave nature … of up to 430 atoms"

Weight of largest molecule in study = 6.9 kDa; weight of a small enzyme = 18 kDa

"Quantum interference of large organic molecules"
S. Gerlich *et al.*, doi:10.1038/ncomms1263
Nature Communications 2, Article number: 263 (2011)

http://www.nature.com/ncomms/journal/v2/n4/pdf/ncomms1263.pdf

Abstract: "The wave nature of matter is a key ingredient of quantum physics and yet it defies our classical intuition. First proposed by Louis de Broglie a century ago, it has since been confirmed with a variety of particles from electrons up to molecules. Here we demonstrate new high-contrast quantum experiments with large and massive tailor-made organic molecules in a near-field interferometer. **Our experiments prove the quantum wave nature and delocalization of compounds composed of up to 430 atoms, with a maximal size of up to 60 Å, masses up to m = 6,910 AMU and de Broglie wavelengths down to $\lambda_{dB} = h/mv \approx 1$ pm.** We show that even complex systems, with more than 1,000 internal degrees of freedom, can be prepared in quantum states that are sufficiently well isolated from their environment to avoid decoherence and to show almost perfect coherence."

Many-body collective quantum effects crucial to LENRs

From Gerlich *et al*. "Quantum interference of large organic molecules"

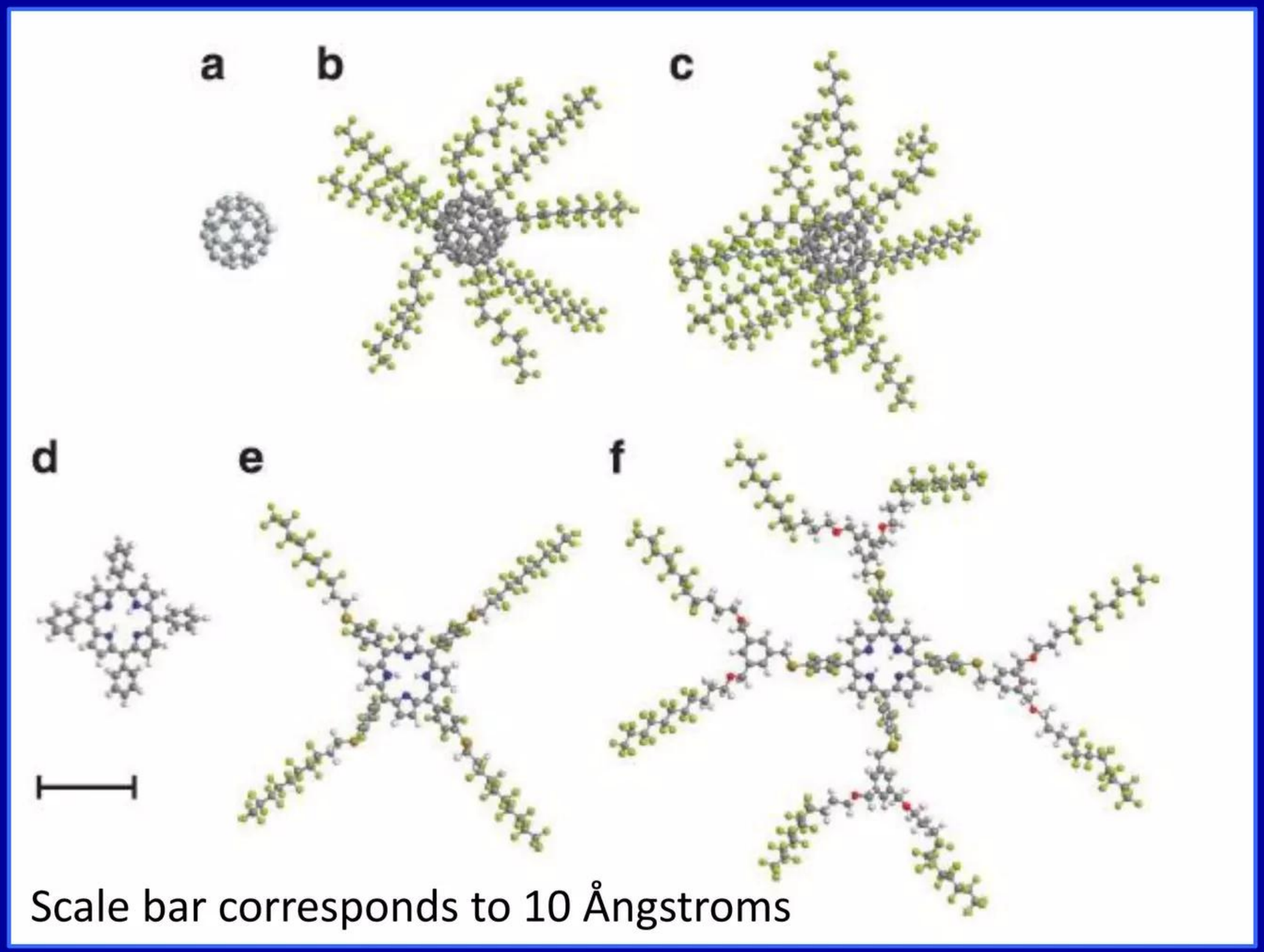
Entanglement is very persistent in large molecules and at elevated temperatures

- ✓ **Experimental setup.** "The particles are evaporated in a thermal source."
- ✓ **"PFNS10 and TPPF152 contain 430 atoms covalently bound in one single particle.** This is ~350% more than that in all previous experiments and it compares well with the number of atoms in small Bose-Einstein condensates (BEC), which, of course, operate in a vastly different parameter regime: The molecular de Broglie wavelength λ_{dB} is about six orders of magnitude smaller than that of ultracold atoms and the internal molecular temperature exceeds typical BEC values (T < 1 μK) by about nine orders of magnitude. **Although matter wave interference of BECs relies on the de Broglie wavelength of the individual atoms, our massive molecules always appear as single entities."**
- ✓ "In our experiment, the superposition consists of having all 430 atoms simultaneously 'in the left arm' and 'in the right arm' of our interferometer, that is, two possibilities that are macroscopically distinct. **The path separation is about two orders of magnitude larger than the size of the molecules."**
- ✓ "In conclusion, our experiments reveal the quantum wave nature of tailor-made organic molecules in an unprecedented mass and size domain. **They open a new window for quantum experiments with nanoparticles in a complexity class comparable to that of small proteins …"**

Many-body collective quantum effects crucial to LENRs

From Gerlich *et al*. "Quantum interference of large organic molecules"

Figure 1 from paper shows "Gallery of molecules used in our interference study"



Widom-Larsen theory of ultralow energy neutron reactions

Three key publications that begin in March 2006 are referenced below

Many-body collective effects enable electroweak catalysis in condensed matter

"Ultra low momentum neutron catalyzed nuclear reactions on metallic hydride surfaces"
A. Widom and L. Larsen
European Physical Journal C - Particles and Fields 46 pp. 107 - 112 (2006)

http://www.slideshare.net/lewisglarsen/widom-and-larsen-ulm-neutron-catalyzed-lenrs-on-metallic-hydride-surfacesepjc-march-2006

"Theoretical Standard Model rates of proton to neutron conversions near metallic hydride surfaces"
A. Widom and L. Larsen
Cornell physics preprint arXiv:nucl-th/0608059v2 12 pages (2007)

http://arxiv.org/pdf/nucl-th/0608059v2.pdf

"A primer for electro-weak induced low energy nuclear reactions"
Y. Srivastava, A. Widom, and L. Larsen
Pramana - Journal of Physics 75 pp. 617 - 637 (2010)

http://www.ias.ac.in/pramana/v75/p617/fulltext.pdf

Lattice Energy LLC

Unique characteristics of ultralow energy neutron reactions

No deadly gamma radiation

No dangerous energetic neutron fluxes

Insignificant production of hazardous radwastes

Revolutionary, disruptive, and environmentally safe

Occurs out in Nature as well as in man's laboratories

Laura 13

Image credit: co-author Domenico Pacifici
From: "Nanoscale plasmonic interferometers for multispectral, high-throughput biochemical sensing"
J. Feng *et al.*, *Nano Letters* pp. 602 - 609 (2012)

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