5 types of Invisibility

The extragalactic cross currents
of semi-inconspicuous receptivity

Lily Pagano

Peter Stickland

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This book is dedicated to
Ferhan Azman & Eric Pagano

The texts in sections 1 & 5 are by Lily Pagano.

In chapter two we borrowed a few words from the book, *Dark Shadow*, by Gilbert and George.

Keats, Shakespeare and Coleridge make a brief, but striking appearance together in section four. John Ashbery & Jonas Salk also speak in unison.

In chapter five we borrowed a few words from T. S Eliot, *The Love Song of J Alfred Prufrock.*

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Spin-Polarised Scanning Tunnelling Microscopy of Co islands on Cu(111)

MSci Project Literature Review

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October 2018
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Word Count: 2498

Contents

I. Introduction

The Scanning Tunnelling Microscope (STM), invented by Binnig and Rohrer [1] in 1982, is a high-resolution microscope consisting of a scanning tip used to image the surfaces of materials by means of a tunnelling current. Tunnelling is a quantum mechanical effect that describes a particle's ability to penetrate classically forbidden regions in space.

An STM utilises electron tunnelling to obtain atomic-scale images of surface materials, with an 'unprecedented resolution' [1] of a few Å in the lateral direction and a perpendicular one of <1 Å, relative to the sample [2]. An atomically sharp conducting tip, typically made from Pt/Ir [3] and controlled by piezoelectric drivers, is held close to a conducting sample and electrons tunnel through an insulating gap such as vacuum [1], air [4] or water [5].

When a bias voltage is applied between the tip and sample, shown in **Figure 1(a)** , an electron is able to tunnel across the barrier, resulting in a net electron current known as the tunnelling current, I, explained in **Figure 1(b)**. The tunnelling current is proportional to the integrated density of states (DOS) between the Fermi level and applied bias voltage, Bardeen's [6] formulation of which is:

$$I \approx \frac{4\pi}{\hbar}|M|^2 \rho_T(0) \int_{-eV}^{0} \rho_S(\epsilon) d\epsilon \tag{1}$$

where $\rho_{T,S}$ is the DOS of the tip and sample respectively, and M is the tunnelling matrix element [6] given by:

$$M_{\mu v} = -\frac{\hbar^2}{2m_e} \int (\psi_\mu^* \nabla \chi_v - \chi_v^* \nabla \psi_\mu) dS \tag{2}$$

where m_e is the electron mass, χ_v and ψ_μ are eigenstates of the electrodes.

Applying (1) to STM, Tersoff and Hamann [7] found an expression for I in the limit of low bias and zero temperature:

$$I \propto e^{-2kd} \tag{3}$$

where d is the barrier width and k is:

$$k = \frac{\sqrt{2m(V_0 - E)}}{\hbar} \tag{4}$$

E is the energy of the tunnelling particle. I, therefore, is localised to the tip apex – the point where the sample and tip are closest. Keeping the current constant by means of a

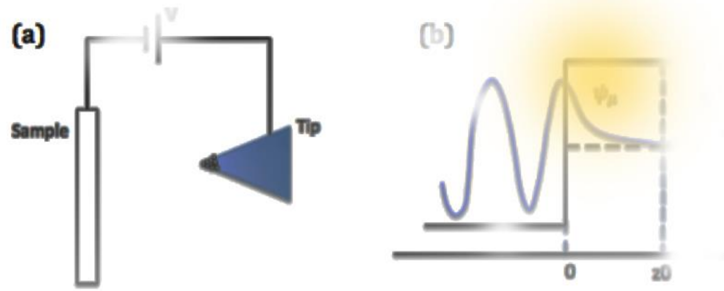

Figure 1: (a) Basic schematic of an STM (b) A simple square barrier explaining the basic physics of an STM. When the tip and sample are close together their wavefunctions, ψ_μ and ψ_v, may overlap as they decay into the barrier, allowing current to flow.

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feedback loop as the sample is scanned, allows the surface contours to be followed and topography to be imaged.

Binnig's use of a vacuum as a tunnel barrier instead of the metal-insulator-metal sandwich structure previously used [8] introduced sub-Angstrom resolution and paved the way for a 'deeper and detailed understanding of regular surface structures' [1]. It became possible to image 'surface topographies at an atomic scale directly in real space' [1], and the use of a local probe meant that, for the first time, 'non-periodic structures' [9] could also be imaged.

While its foundations lie in the deeper study of regular surface structures [10] and the investigation of irregular structures, such as mono-atomic steps [11] and sample defects [12], the STM has become an important research tool. A basic extension of the STM is its application to 'yield spectroscopic information' [9] through scanning tunnelling spectroscopy (STS). By varying the bias voltage, $I(V)$ spectra are obtained from which electronic information can be extracted, since the differential conductivity, $\frac{\partial I}{\partial V}$, is proportional to the local density of states (LDOS). It became possible for the local electronic structure of metals [13] and semiconductors [14] to be probed on an unprecedented scale.

STM, however, neglects the spin of tunnelling electrons. Utilising a spin-polarised tip, a spin-polarised STM (SP-STM) can be used to image both the topography and magnetic order in a material [15], and was first proposed by Pierce [16] in 1988. This introduced the opportunity to study magnetism on the atomic scale. SP-STM is a fundamental research tool that allows one to explore and analyse surface magnetisation, through the direct visualisation of spin-structures at the atomic-scale. To further understand magnetic phenomena, spin structures in materials should be studied at the atomic scale [17].

II. Spin-polarised STM

A. Brief Background

The principle of SP-STM imaging is 'based on the fundamental property of ferromagnetic and antiferromagnetic' [18] materials. The DOS is spin-split into majority and minority states, and a net imbalance between the electron occupation of both leads to magnetic moments in the atoms. This imbalance causes a spin-polarisation in the material, shown in Equation 6 [18], which in turn means there is an additional spin dependence of the tunnelling current. The current can be treated as the sum of two spin channels, demonstrated in Equation 5, were it may be assumed that electrons do not flip their spin when tunnelling.

$$I = I_{\uparrow} + I_{\downarrow} \approx |M|^2 \int_{-eV}^{0} [\rho_S^{\uparrow}(\epsilon - eV)\rho_T^{\uparrow}(\epsilon) + \rho_S^{\downarrow}(\epsilon - eV)\rho_T^{\downarrow}(\epsilon)]d\epsilon \tag{5}$$

$\rho_{T,S}^{\uparrow/\downarrow}(\epsilon)$ is the spin up or down DOS, the number of spin up states per unit energy and volume in the tip or sample. If the tip DOS is approximately constant in an energy range around the Fermi level, the SP-STM probes the local spin DOS in the sample.

$$P = \frac{N_{\uparrow} - N_{\downarrow}}{N_{\uparrow} + N_{\downarrow}} \tag{6}$$

where N is the spin-split DOS and ↑ / ↓ denote majority and minority states.

For SP-STM imaging to occur, it is important to first have a spin-polarised tip, as this allows access to the spin-polarisation of the sample surface. Tips can be made from:

(i) Bulk magnetic material

(ii) Non-magnetic material with a thin film cover of magnetic material

(iii) Non-magnetic material with a cluster of magnetic material at the apex

1. Mystification through partial invisibility

Outlined fully in [17].

If a magnetised tip is used, such that a tip spin-polarisation exists, the size of the tunnelling current is influenced. Jullièr [19] demonstrated that, when an electron tunnels between two ferromagnets, the size of the tunnelling current is influenced by the relative orientation of the tip and sample magnetisations. For parallel orientations of the magnetisations, there exist many states for the electrons to tunnel into, resulting in a larger tunnelling current. For antiparallel orientation, available states are filled meaning the current is smaller, shown in **Figure 2**. This is known as the Tunnelling Magnetoresistance (TMR) effect, outlined in more detail in [18].

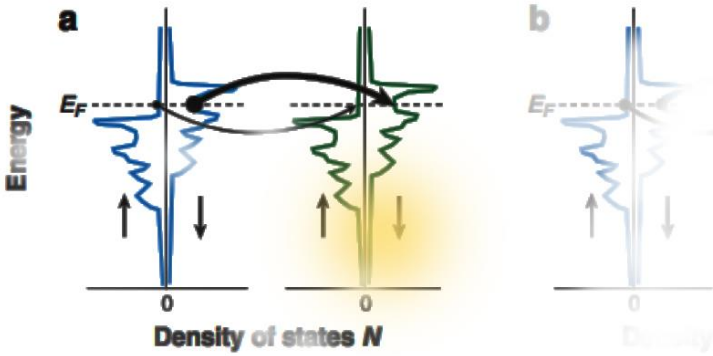

Figure 2: Simplified diagram of tunnelling between two ferromagnetic electrodes of spin-split DOS. Spin-orientation is assumed to be conserved. For (a) the tip and sample magnetisations are parallel, whilst for (b) they are antiparallel [18].

Slonczewski [20] treated the TMR effect more rigorously, extending Jullière's model and considered spin-polarised electrodes. The dependence of conductance, and hence the current, on the angle θ between the tip and sample magnetisations was found to be:

$$I = I_0(1 + P_t P_s cos\theta) \tag{7}$$

where I_0 is the spin averaged current and P_t,P_s are the tip and sample spin polarisations. Slonczewski's predictions were experimentally confirmed by Miyazaki et al. [21], demonstrating the TMR effect at room temperature.

The TMR effect is utilised by SP-STM to 'obtain magnetic information from the tunnelling current' [18], at the same lateral atomic resolution seen for topographical imaging. The separation of magnetic and non-magnetic information in the tunnelling current must be achieved to image the topographical and magnetic nature of a sample independently.

B. Imaging Modes

There exist four principle imaging modes [16], that differ in how spin and topographic contrasts of the STM are separated. Each has been confirmed by experiment [22–24], and continue to be widely used. The two most significant methods are outlined below.

(i) Constant Current Mode

For a standard STM to produce real space images of surface topography the tip is scanned slowly across the sample-surface and, using a feedback loop, the vertical position of the tip is constantly adjusted by piezoelectric drivers such that the current remains constant. When imaging magnetic samples using a magnetic tip, changes in the tunnelling current due to the TMR effect are compensated for by the feedback loop. This means that the 'topographic image contains information. . . on the electron density and. . . the spin' [18], i.e. the tunnelling current consists of spin-averaged and spin-dependent components.

First introduced by Wiesendanger et al. [22], this mode has been used for magnetic imaging at atomic-resolution. Wortmann et al. [25] were able to achieve 'ultimate resolution in magnetic imaging' [17], whilst the smallest magnetic unit cells imaged were those of single atomic layers of Mn [26] and Fe [27] epitaxially grown on W(110).

This mode, however, only achieves mixed spin and topographic imaging, not allowing the spin to be studied directly.

(ii) Spectroscopic Mode

Also known as spin-polarised STS (SP-STS), this mode uses the fact that spin-polarisation of the sample DOS is a function of energy. The spin and topographic information can, in most cases, be separated. In this mode the differential conductance, dI/dV, is measured as a function of bias voltage, V, and spatial coordinates, (x, y), whilst the tip-sample distance is kept constant. Corresponding $I(V)$ spectra are obtained, from which spin information can be found as the measured quantity is energy-resolved spin-polarisation. Stoscio et al. [28] were able to obtain spin-contrast using the peak height of dI/dV related to the minority surface state of Fe at a bias voltage near the sample Fermi level. Similarly, Yamasaki et al. [29] obtained the lateral variations in the peak height of dI/dV when imaging Fe, which reflect the magnetic closure domains in the sample nanostructure.

SP-STS also allow atomic-scale spatial resolution, first shown by resolving antiferromagnetically ordered atomic layers of Fe epitaxially grown on W(001) [27]. Samples most suited for this imaging mode are those with a DOS and spin-polarisation that vary strongly with bias voltage. These include thin films with quantised states, or surfaces with surface states [15].

C. Co islands on Cu(111)

Ultra thin magnetic films, epitaxially grown on substrates, are widely researched due to their unusual magnetic properties – such as giant magnetoresistance or enhanced magnetic moments. Co islands on Cu(111) are model systems for magnetic investigations [30], appealing due to their spin-polarised electronic states near the Fermi level.

Cobalt islands on Cu(111) were found to take the form of bilayer triangular islands [31, 32] with a bottom Co layer submerged into the Cu(111) surface [33]. Two island orientations, rotated by 180° with respect to each other, were initially identified using STS [31,34], and were classified in terms of a faulted or unfaulted stacking order in relation to the Cu(111) structure, shown in **Figure 3**.

The island types were found to vary in their electronic, chemical and magnetic properties, which depend on the island structure [35]. Vazquez [31] showed using STS that, at a positive sample bias voltage, faulted islands present a higher tunnelling conductance compared to unfaulted islands. Furthermore 'the electronic states responsible for the enhanced conductance' [31] were identified using a simple theoretical model. Pietzsch was also able to show that electronic structure was 'stacking-dependent', observing 'strong contrasts in dI/dV maps' due to the different crystallographic stacking of the islands. Analysis of the dI/dV spectra for each island type showed a clear difference in the surface state peaks, shifting from -0.35V for unfaulted islands to -0.28V for faulted islands. 'This difference gives rise to stacking-dependent contrast in spatially resolved spectroscopic images' [17].

SP-STM can be used to observe a spin-dependent contrast, Co islands demonstrating strong out of plane magnetic anisotropy. Four island types can be observed, resulting

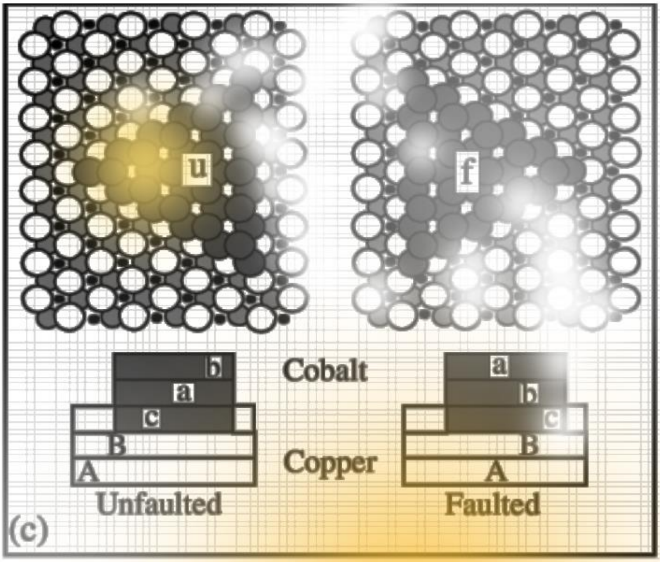

Figure 3: Model for the two proposed island types. Unfaulted islands (u) continue the FCC stacking of the Cu(111) substrate, whilst faulted islands (f) have a stacking fault – deviating from FCC stacking (often called HCP). The stacking fault is what results in the differing orientation of the f islands [31].

from the two stacking types and two relative orientations of the tip and island magnetisations – parallel or antiparallel. Further to confirming previous STS results [31, 32], Pietzsch [36] used SP-STM to distinguish the two contrasts due to the different magnetic states of the Co islands [36] – previously unavailable with STS measurements. Separate structural and magnetic contrasts in dI/dV maps were also obtained by analysing spin-polarised spectral curves.

The structure-dependent electronic contrasts and magnetisdependent spin-contrasts may be separated if the structural and spin asymmetries are calculated as functions of the bias voltage. If a suitable bias voltage is chosen such that structural asymmetry becomes negligible and spin asymmetry reaches a large value – a clear magnetic contrast is observed.

More recently, the magnetic characterisation of nanostructures using SP-STM was achieved [37]. Tip and sample contributions to $I(V)$ and dI/dV signals in SP-STM are, ultimately, coupled. For a reliable study of sample properties, tip contributions need to be understood independently [37]. By imaging Co bilayer nanoislands on Cu(111), the magnetic states of the tip could be characterised quantitatively. Furthermore, using spin-dependent dI/dV mapping of Co nanoislands, SP-STS data could be directly linked to the local spin-polarisation in a single nanoisland. The quantitative physical understanding of spin textures in nanoislands could hence be further understood [37].

III. Project Outline

With the structural, electronic and magnetic properties of Co islands on Cu(111) being widely studied in literature and confirmed by experiment [30, 34] the imaging of Co islands on Cu(111) can be used as a control for the SP-STM system. By comparing the system results for Co/Cu(111) imaging with those already accepted [35, 37], the system's suitability for spin-polarised imaging can be established.

The available STM system has a vector magnet that can be use to control the vector nature of the tip and sample magnetisations. The use of vector magnets in STM is well-discussed, but rarely used in practise due to the high cost [37]. The opportunity to use this system will allow the study of the magnetisation of structures in all three spatial directions.

A. Methodology

The full system consists of an Omicron Nanotechnology Cryogenic STM attached to a prep-chamber and load-lock, the weights of which are supported by springs to provide vibration isolation. The load-lock is used to transfer multiple tips and samples from air to the UHV prep-chamber. The prep-chamber is used for sample preparation in vacuum, allowing for sputtering, using an argon ion sputtering gun for surface cleaning, and annealing by heating.

The Cryogenic STM will be used to carry out SP-STM imaging, the schematic of which is shown in **Figure** 4 [38]. It features a superconducting vector magnet that can apply a field of $1T$ parallel to the sample surface, or $6T$ perpendicular to the sample surface. A field can be applied when the STM is at any temperature range between $2K - 350K$, achieved though the use of an Oxford Instruments cryostat [38].

The cryostat contains a 135 ltr tank in which the magnets sit and are immersed in liquid helium. The tank is surrounded by a nitrogen jacket, to reduce the thermal load on helium [38], followed by an insulating vacuum space. The STM is suspended through a UHV tube in the middle of the cryostat. A UHV analysis chamber lies directly underneath the cryostat into which the STM can be lowered by means of a z-manipulator (11). When lowered, the STM is held in place by three clamps allowing the use of a wobblestick for tip and sample exchanges.

To allow for low temperatures, the STM is raised into the cryostat. Once fully raised, thermal doors (12) are shut such that the cryostat is not warmed by the lower chamber. The STM is cooled using a helium pot (4), which is fed via a capillary (3) from the main helium tank. The STM is suspended by springs from the helium pot to provide vibration isolation. The helium flow is controlled using a needle valve (1) which in turn is controlled by a stepped valve motor (9). Annular spaces are located between the helium tank and UHV core, the helium flow through which is started via a second needle valve (2). The UHV core can be cooled to $4K$, and the STM to $2K$ due to its thermal shielding.

B. Overview

The project is due to take place from October 2018 – March 2019. The table below outlines the main tasks and a timeline for achieving them.

Date	
October 2018	*Literature Review:* Res *Initial STM Imaging:* Gol *System Cooling:*
October - December 2018	*SP-STM*
January - March 2019	*SP-STM Imaging* an continued

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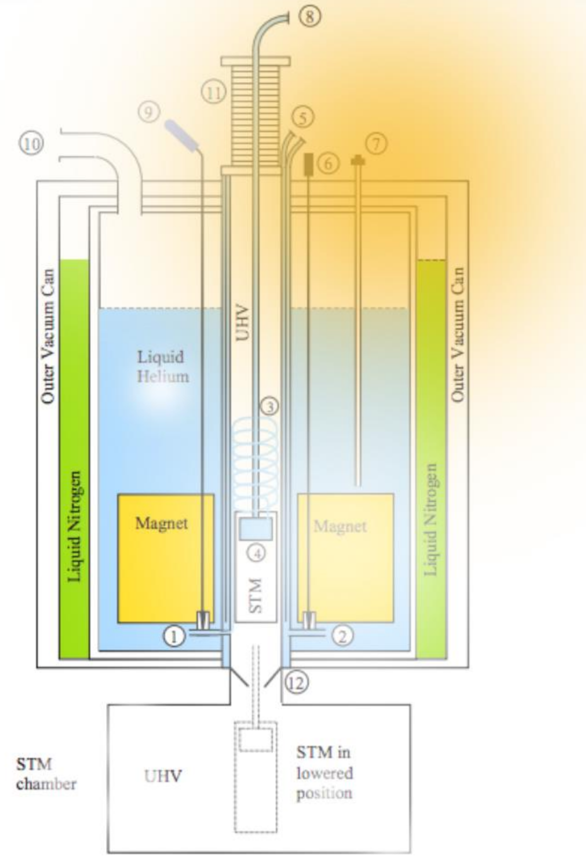
1. Mystification through partial invisibility



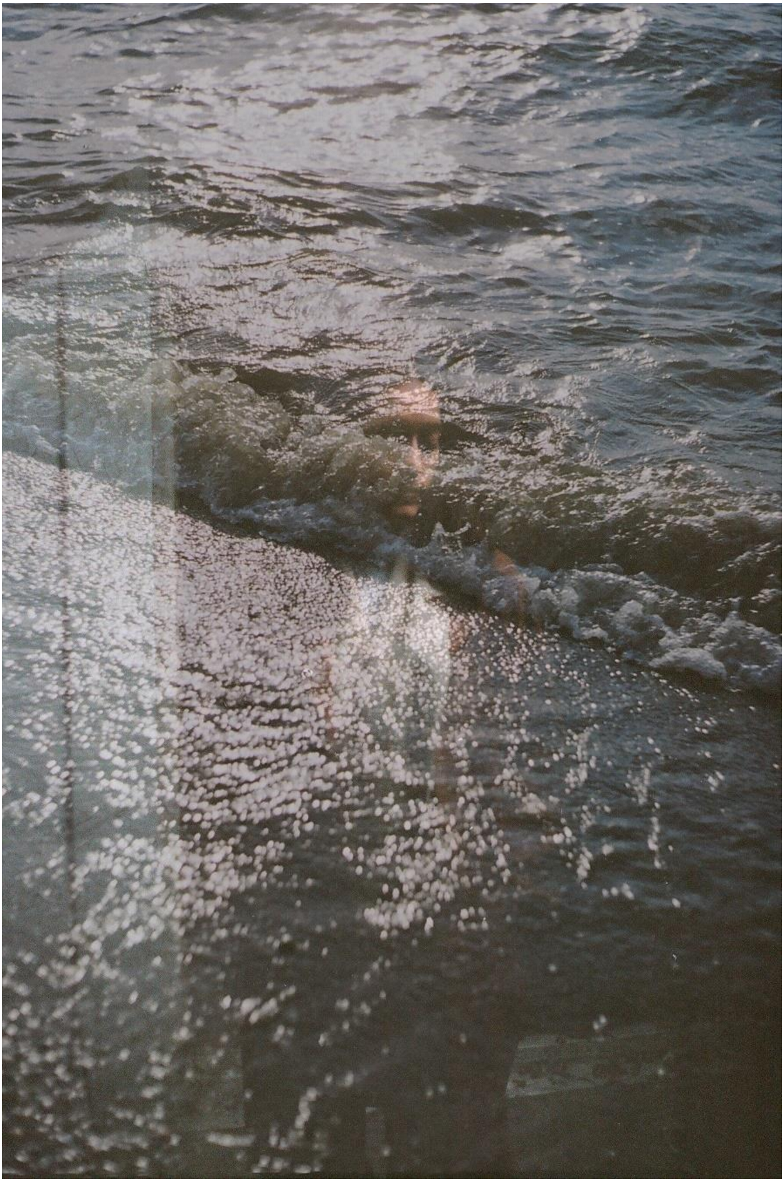
1. Auto Needle Valve for STM Helium pot
2. Manual needle valve for annular space
3. STM Helium capillary
4. STM Helium pot
5. Pumping ports for inner and outer annular spaces (2 x KF 16)
6. Manual needle valve control
7. Helium siphon port
8. Pumping port for STM helium pot (KF 25)
9. Auto needle valve motor
10. Helium vent port (Large KF)
11. Z manipulator
12. Thermal doors

As the unfolding of the universe, pulled by the mists of space and time, starts to stretch and slide, it soon begins to liberate the shadows that allow light figures to dance. Nothing should now persuade the physicist to look upon this scene with normal senses. Cosmic mist soon throws itself across the reflection as we ruminate on the dust. We would not think for a second to spread ourselves out between the reflections. Without our help it has achieved its own masterstroke and created calligraphy.

2. Chance encounters in nanoscopic personalities

Cruising at a height of several million light years, we watch the dawn of dissent in the microwave sky. As it fades from view, we are left with an impression of a stray shore. In time, you might see refractions take hold of the foam. Maybe they will be generous and share the secrets whispered to them by tired photons. Be patient, they carry the most impressive complex of the twenty first century, industriously struggling to find their home, both at sea and on the beach, providing it sparkles in the bright sunlight.

2. Chance encounters in nanoscopic personalities



The three liquid and lovely perturbations; the left, the right and the lost. They're getting along with each other as well as can be expected, for their transparent curvature is filled with an undefinable motion that seems to cause multiple layered sensations. All of us at some stage expect someone to arrive to tell us off and send us to bed without supper. Tears deviate from elementary particles, dotting themselves across space-time and a reflective manifold watches overhead in quiet warmth, while the eyes seem content.

2. Chance encounters in nanoscopic personalities

Off the cuff, we would say that this picture is only accurate at big galactic latitudes, where sense is senseless and we insist on watching the handy interaction of geodesics dancing along a narrow balustrade. It is this motion that fills curiosity and the same curiosity that fills the frame. The absence of thought can only help suggest to the viewer a tantalising feeling of freedom, something so tenderly scarce that it should be held quietly and in deep contemplation. We continue like this to explore how many times we can return again.

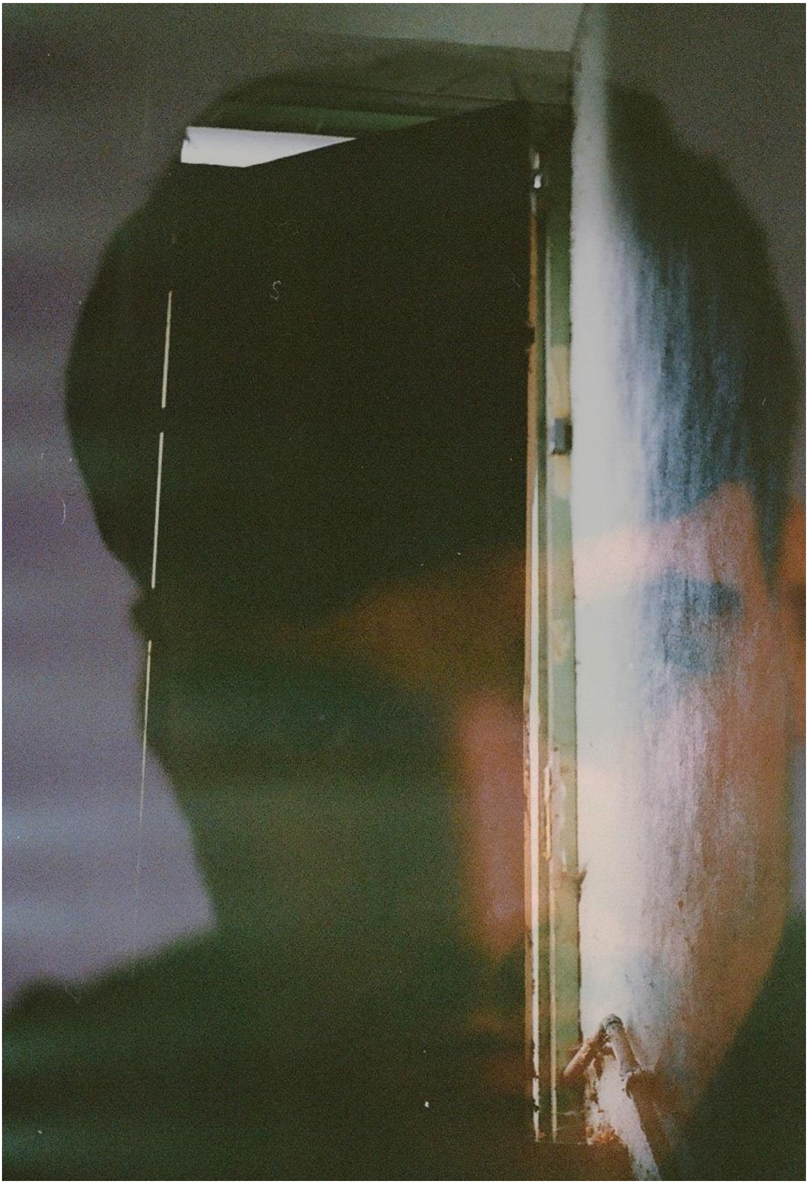
2. Chance encounters in nanoscopic personalities

The sea is falling down into the sky, showing us the system of particle production. The lively, dark ocean watches for those with heavy hearts, whilst the light sky waves lazily from beneath a white massless plane. The head is an expression of love, distorted by ripples, but still filled up with the familiar fleeting fancies. Whispers move around a sharp silver blanket, and an eye's cheeky sneakiness defines the key questions of the dark universe when it is not taking a quiet nap on a lazy afternoon in high summer.

2. Chance encounters in nanoscopic personalities

Lost in the dark beauty of the weather-filled day, we go over into the distance of the hours that we need. Trapped inside a cusp-like halo, we map a thin model of our interstellar spin and come to assume the existence of a single negative shadow. We recognise shadows as they pass overhead and feel certain that we ourselves are the shadows. We see things our own age, ages old and beyond a foreseeable future. We see things of the night's duration living with us, looking this way and that just as this quiet woman considers dark matter.

Towering behind the living dance, higher than usual, gravity leaks through a familiar wound. Interstellar filaments, as complex as any chess-board, are illuminated – blinding what now remains of its horizontal motion. The transparency reveals nothing, but this is quite enough, for it is the finest of them all. The light helps itself to the shade, until all the last shreds of the distant spirits in the shadows are crystallised into tiny pearls of wisdom, which shows itself as a cheeky blade of light where the barber became distracted.



Distortions in our clean brains wrestle with the arrangements of order caught between two time-slices. Action tangled with rest is a superposition of smoky carelessness and a profound if lazy contemplation. The outline of dark energy is faint on the forehead, which implies the fresh existence of a cyclic and simulated universe. We rest on hope for the small luxury of moments without any fear. The different qualities of substance, neatly balanced with human values shown through indifference, are won over by the meditation.

2. Chance encounters in nanoscopic personalities

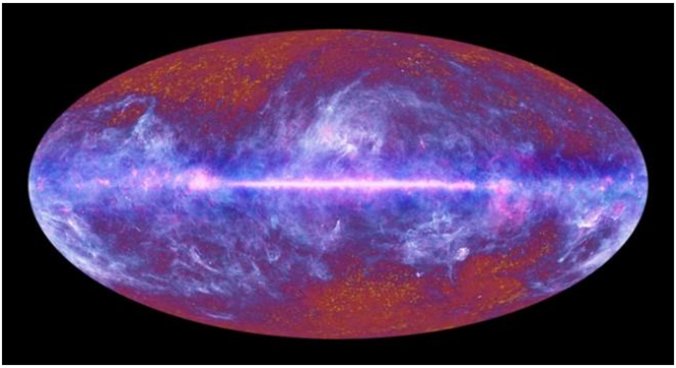
The wrinkles we see are not those of age, they are rather the sign of soft anomalies, which have been allowed to thrive in the rotation of the sky. An upright taste of good form is combined with a pleasurable mood. The complex of lovely lines leave us marvelling at the simple meaning we have established through colour and playfulness. With this possibility we slide photographically from surface to surface, perfecting the distilled patterns that were once so punishable and now highlight the loveliness of young hands.

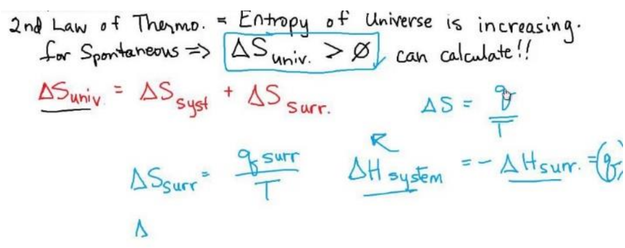
2. Chance encounters in nanoscopic personalities

Shadows fall and capture the premature excitement of spirits found on the head. A mouth watches and an eye whispers, all in the time it takes for their darkness to feed on the vibrancy that takes it root in green chaos. Like this, a presence will fade and an absence will take its characteristic shape. As the light shines the shapes move stubbornly around shades of bright new growth - growth that was unexpected but which now is welcome. The hair is like a picture book, though the features seem scarce and visually surprised.

3. Invisible dancing in the visual/aural spectrum

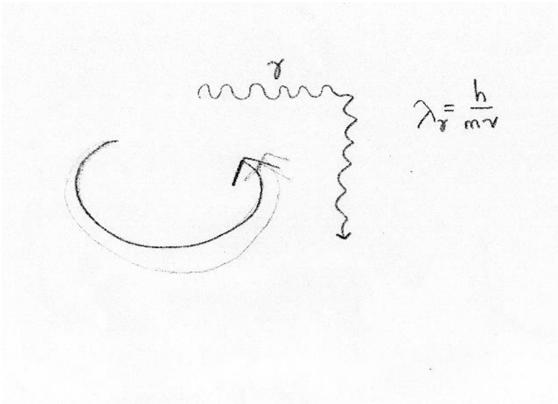
You circle round us, stubbornly refusing to show yourself, moving slowly towards the edge, dancing with matter we can't see, though its 25% of our mass; should we still wait?

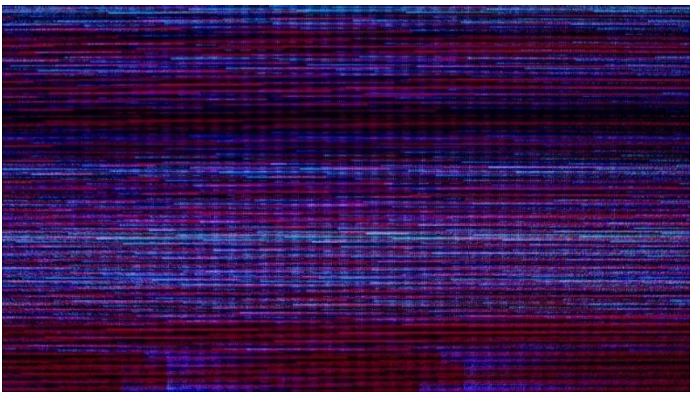




3. Invisible dancing in the visual/aural spectrum

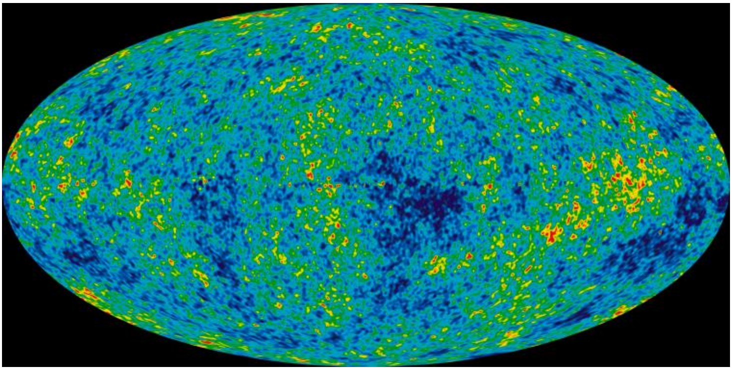
We wait for our mass dancing with matter though we can't see it. We also show sympathy when you circle round us, stubbornly refusing to be moved slowly towards the edge.

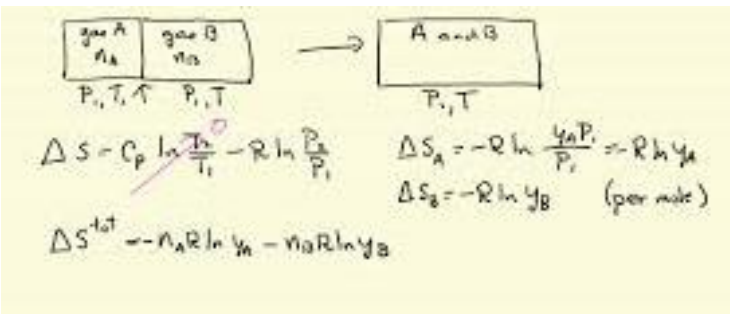




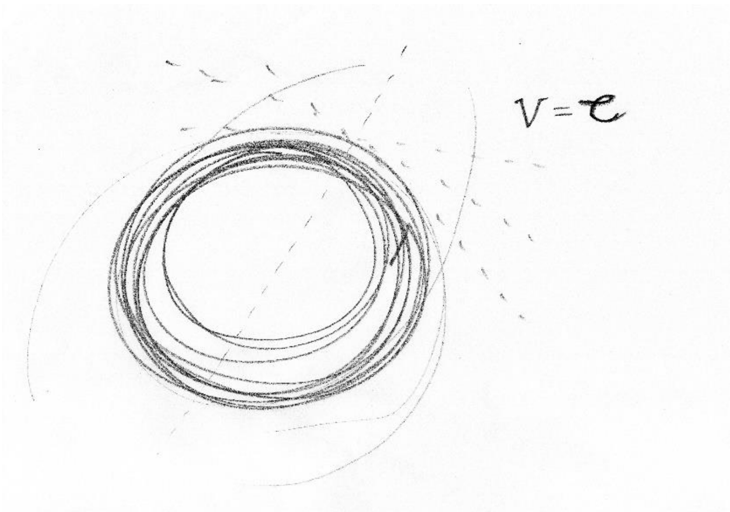
3. Invisible dancing in the visual/aural spectrum

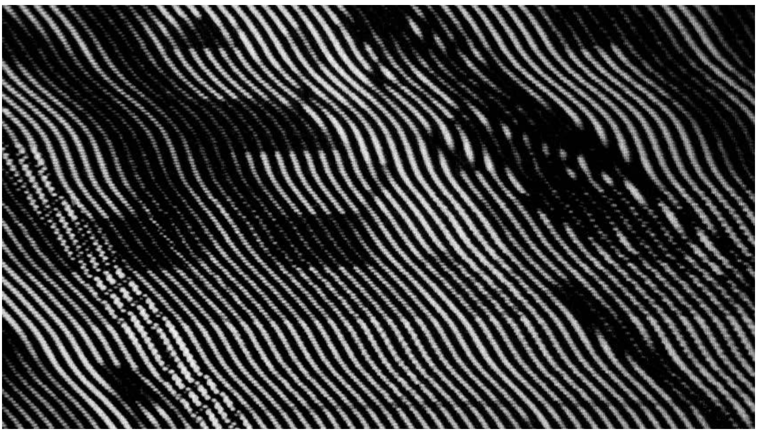
If you've microwaved orbital velocities of spiral galaxies, found dark matter without a galaxy rotation problem and sing about gravitational interactions, is this too much?



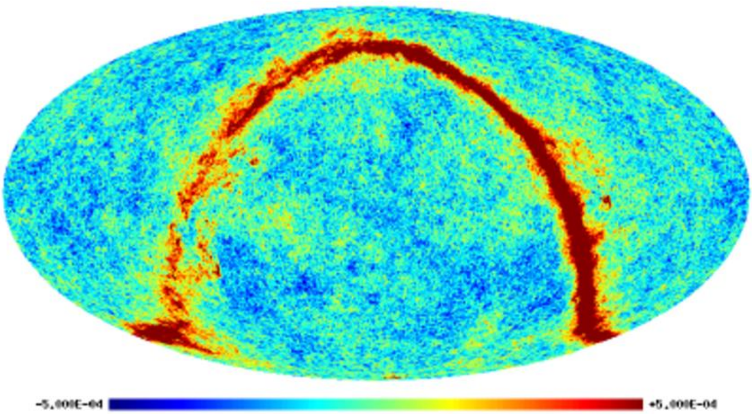


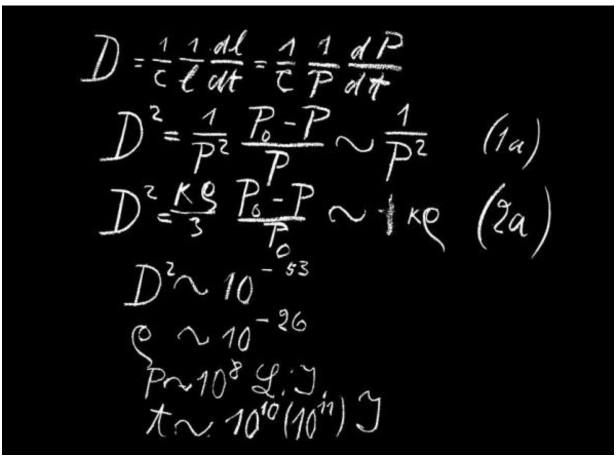
There's galaxy rotation without dark matter to be found.
Better to sing about gravitational interactions if you've
microwaved orbital velocities of spiral enchantment.



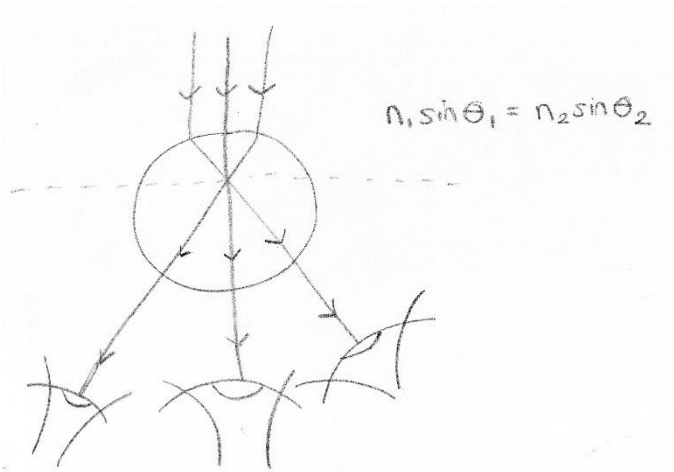


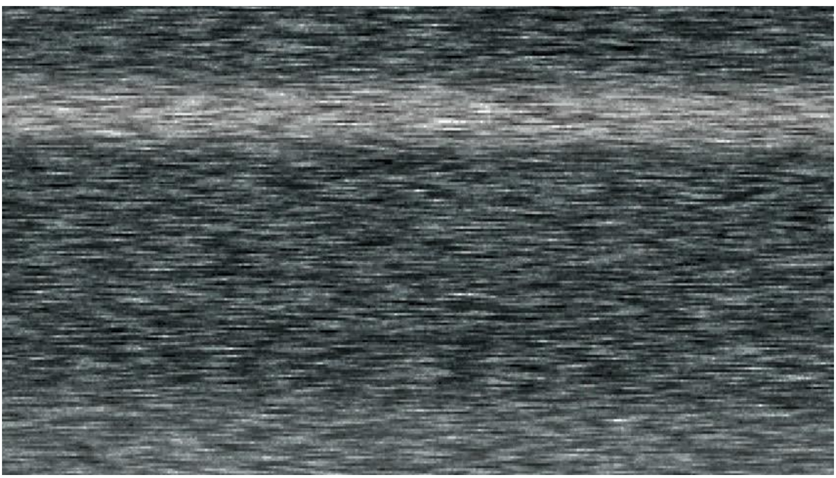
You're filled with a new kind of sub-nuclear particle that helps instigate gravitational lensing, and when you move you distort the light from distant galaxies, is this dance?





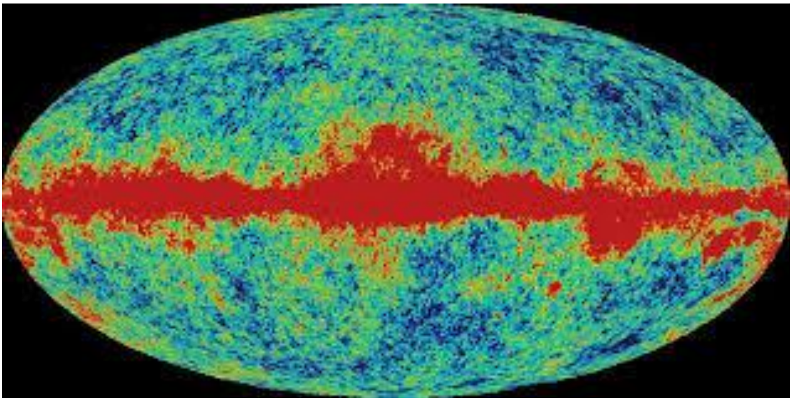
Dance when you move. The light you're filled with helps instigate gravitational lensing, which expands a new kind of sub-nuclear emotion that could distort distant galaxies.





3. Invisible dancing in the visual/aural spectrum

When you project your cluster of galaxies in the foreground and decrease the level of distortion so proportions of calculable matter are not indeterminable, are you OK?



$$S_2 - S_1 = m\,(s_2 - s_1)$$

$$= m\left(s_2^0 - s_1^0 - R\ln\frac{P_2}{P_1}\right)$$

$c = \text{const.}$

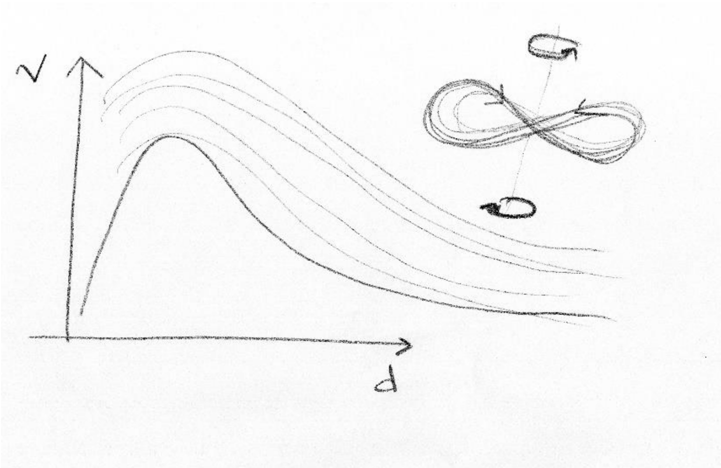
$$= \sum m_i\left(c_p \ln\frac{T_2}{T} - R\ln\frac{P_2}{P_1}\right)_i$$

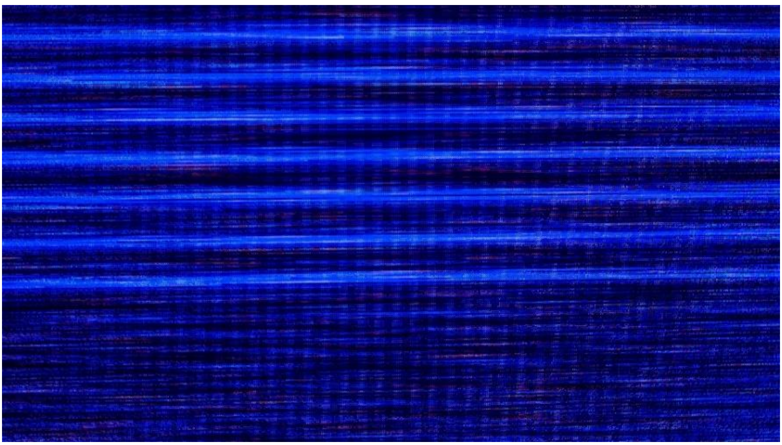
$$= m_{mix} \cdot \sum mf_i\left(c_p \ln\frac{T_2}{T_1} - R\ln\frac{P_2}{P_1}\right)_i$$

$$= c_{p_i} \ln\frac{T_2}{T_1}$$

3. Invisible dancing in the visual/aural spectrum

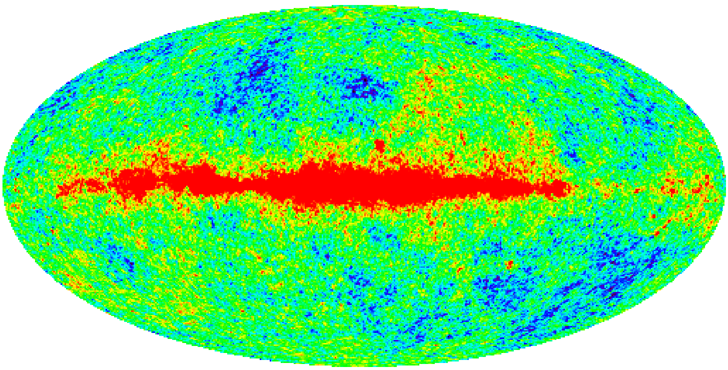
In the foreground, the calculable matter and distortion are indeterminable. Try to project your sensitivity when you're decreasing galaxies to the level of your own bewilderment.

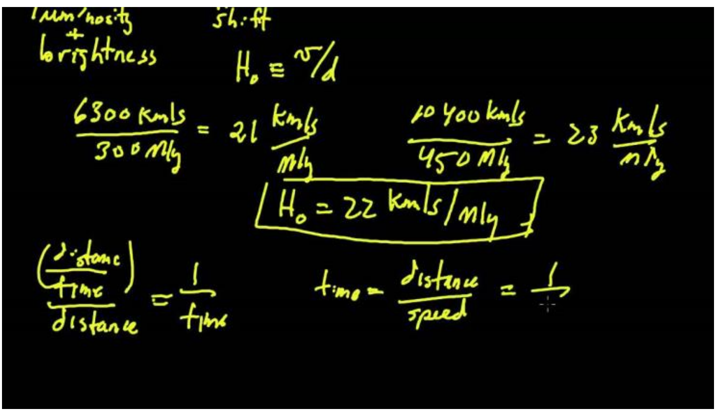




3. Invisible dancing in the visual/aural spectrum

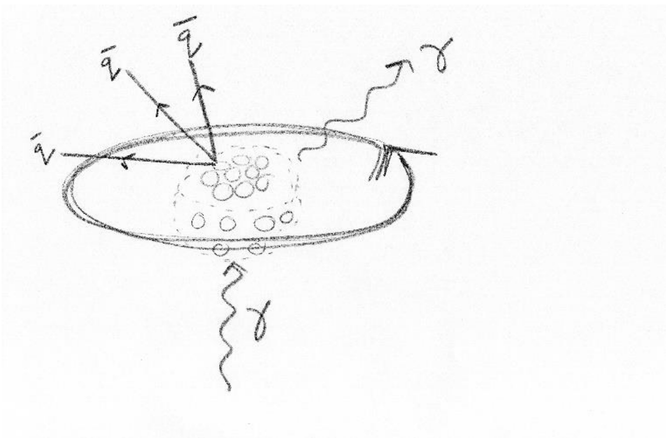
You infer from abnormalities in observations that the old hypothetical elementary particles constitute a substantial part of the hypotheses; do you say the faults are wrong?

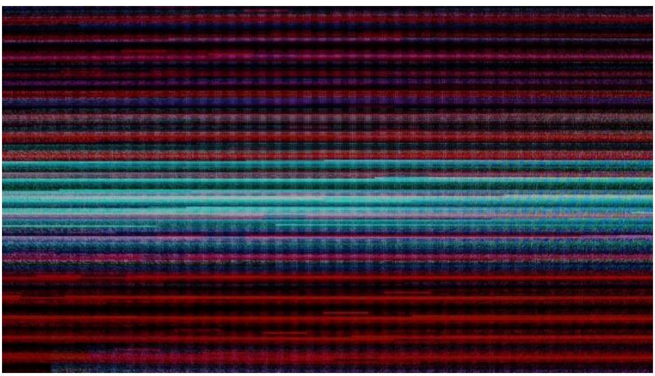




3. Invisible dancing in the visual/aural spectrum

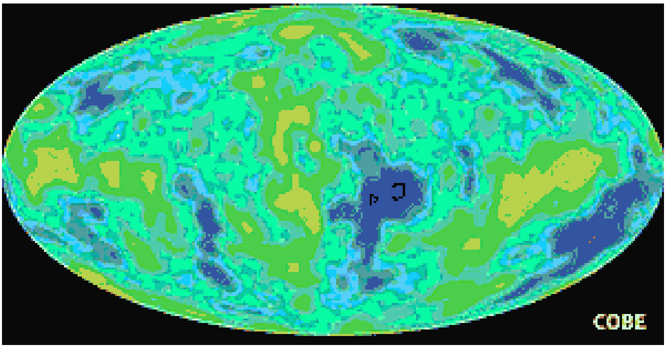
If the faults in observations that are dreamlike are wrong,
you infer that elementary particles from abnormalities are
the hypotheses that constitute a substantial part of you.





3. Invisible dancing in the visual/aural spectrum

Can we survive, long term, by mapping the cosmic microwave background that was emitted with the material when it doesn't give us any identifiable gravitational scaffolding?

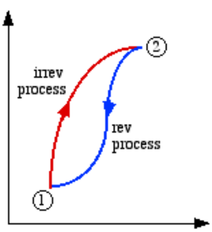


$$\oint \frac{\delta Q}{T} = \int_{1\ \mathrm{irrev}}^{2} \frac{\delta Q}{T} + \int_{2\ \mathrm{rev}}^{1} \frac{\delta Q}{T} < 0$$

$$\int_{1\ \mathrm{irrev}}^{2} \frac{\delta Q}{T} + \int_{2}^{1} dS = \int_{1\ \mathrm{irrev}}^{2} \frac{\delta Q}{T} + (S_1 - S_2) < 0$$

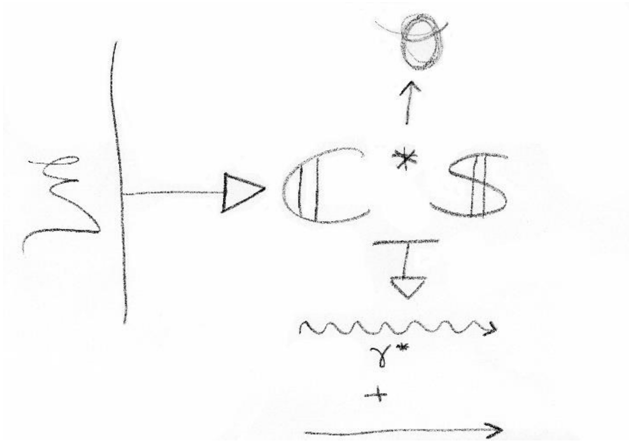
$$\Delta S = (S_2 - S_1) > \int_{1}^{2} \frac{\delta Q}{T}$$

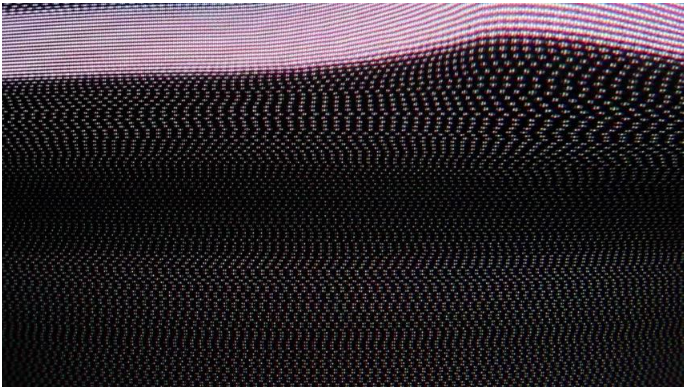
For adiabatic processes ($\delta Q = 0$) $\Rightarrow$ $\boxed{\Delta S \geq 0}$



3. Invisible dancing in the visual/aural spectrum

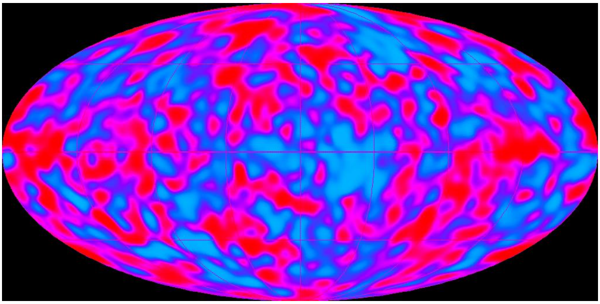
Gravitational scaffolding doesn't give us background. The cosmic microwave that was mapping the material when emitting long-term, means we can survive with sensitivity.

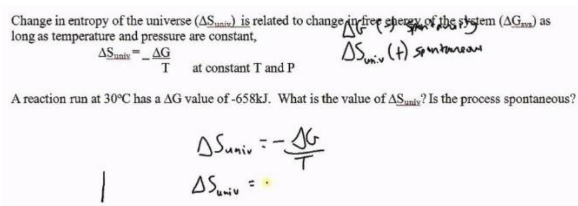




3. Invisible dancing in the visual/aural spectrum

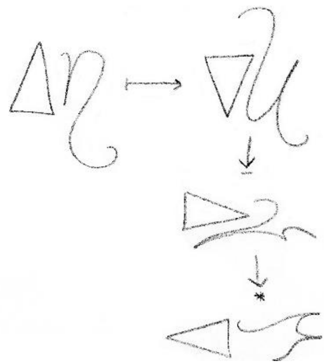
When anomalies in isotropy's primordial annihilation
causes polarisation dust to spin, should we edit spectrums
of extragalactic emissions in all the high galactic latitudes?

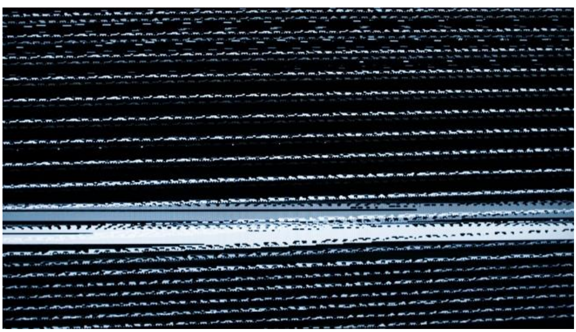




3. Invisible dancing in the visual/aural spectrum

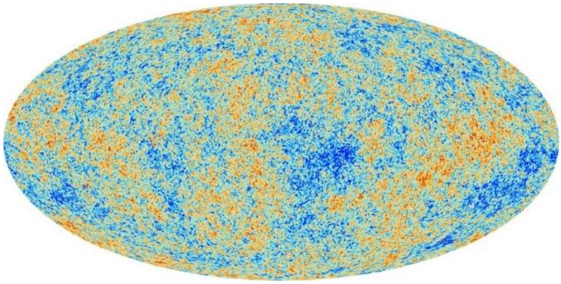
We edit galactic latitudes in high polarisation if anomalies of extragalactic tenderness spin between annihilation and isotropy's primordial causation editing of dust spectrums.





3. Invisible dancing in the visual/aural spectrum

We've observed the oscillations, and future expansion will
have bi-spectrum constraints with primordial curvature,
should we try alternatives to the inflation of neutrinos?



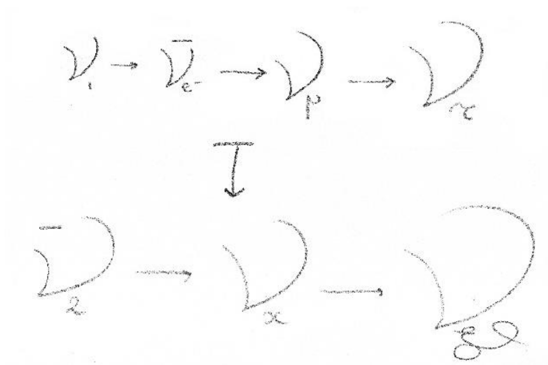
$$\Delta S_{\text{water}} = \int_{283\,K}^{273\,K} \frac{dQ}{T} = \int_{283\,K}^{273\,K} \frac{c\,dT}{T}$$
$$= c\int_{283\,K}^{273\,K} \frac{dT}{T} = c \ln \frac{273}{283}$$

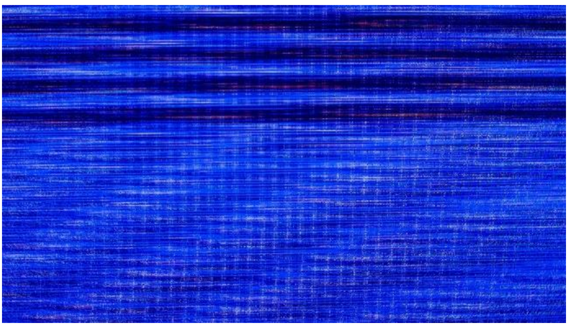
Because $c = 4218\ \text{J K}^{-1}\ \text{kg}^{-1}$

$$\Delta S_{\text{water}} = 4218 \ln \frac{273}{283}$$
$$= 4218\,(-0.036)$$
$$= -152\ \text{J K}^{-1}.$$

3. Invisible dancing in the visual/aural spectrum

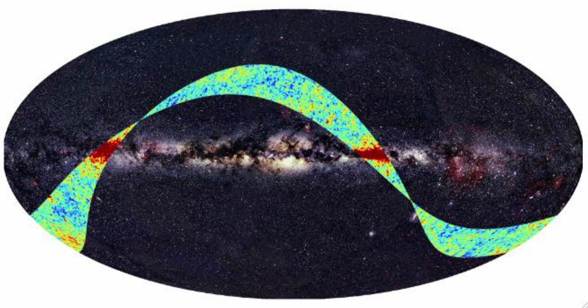
Neutrinos with primordial curvature show bi-spectrum oscillations. Constraints to the fantasy observed will have future expansion when some alternatives are yet to come.





3. Invisible dancing in the visual/aural spectrum

We saw nucleosynthesis and anisotropies of cosmic star formations give early results and cross correlations with dark secondaries, does this help gravitational scaffolding?



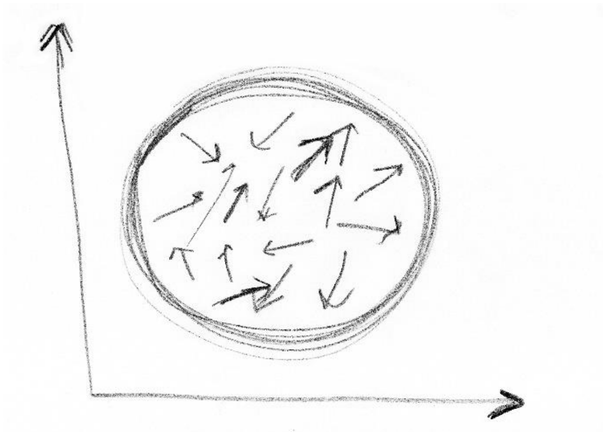
$$\Delta S_{sys} = -ve$$

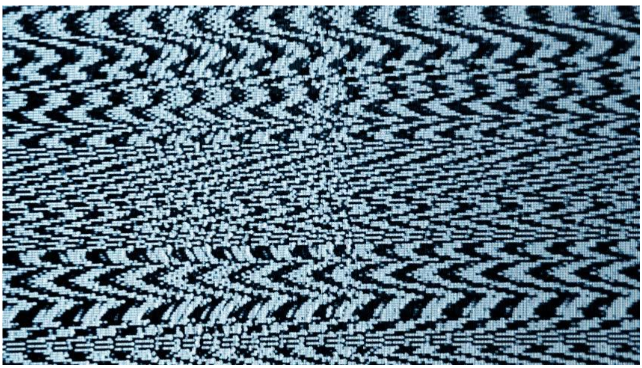
$$\Delta S_{surr} = \frac{-\Delta H}{T} = \frac{-(-ve)}{T} = +ve$$

$$\Delta S_{total} = \Delta S_{sys} + \Delta S_{Surr} = (-ve) + (+ve) = \pm ve$$

3. Invisible dancing in the visual/aural spectrum

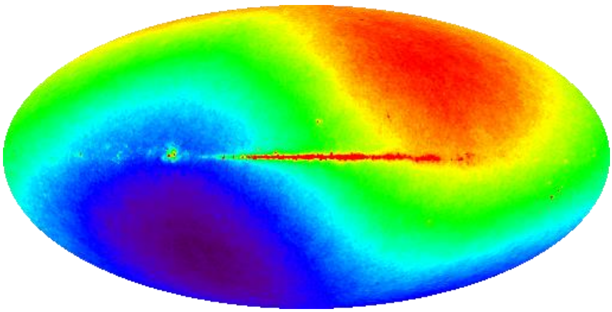
Scaffolding of results with dark gravitational correlations show empathy. We saw anisotropies and secondaries, both with formations, and this helps get across the cosmic star.





3. Invisible dancing in the visual/aural spectrum

Your simulation of epoch reionization cosmology lessons
is a string of theories with multipoles and particle clusters,
does this stop polarization rotation of pseudo-scalar rays?

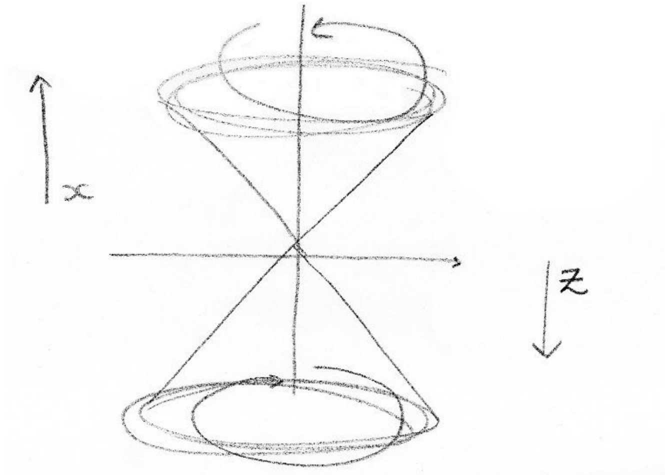


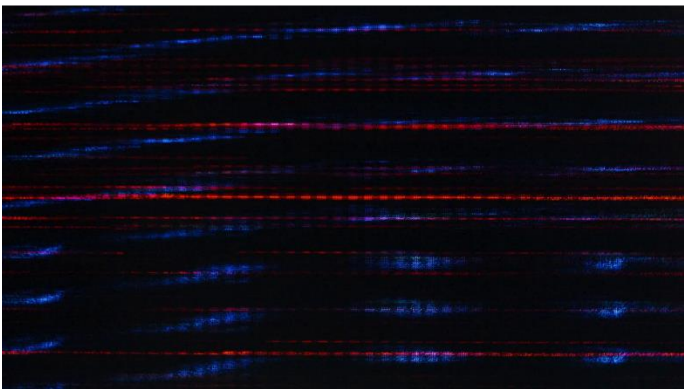
$$\Delta S = C_p \ln\left(\frac{T_2}{T_1}\right) = 4.2 \times 10^3 \times \ln\left(\frac{273+80}{273+30}\right)$$

$$= 0.6415 \frac{kJ}{kg.K}$$

3. Invisible dancing in the visual/aural spectrum

Rotation polarization with particle clusters is a love theory of strings. Epoch reionization rays are a lesson cosmology that have multipoles when pseudo-scalar has simulation.





We want to get something from this book, not just put things into it. Why do we always feel obliged to direct the action with concepts when we would prefer it if something came up to surprise us? So we added things without thinking and we used things like ***cosmic dust*** [1] that had already been produced and subtracted from them. The more we take away the more the observer wants to find out what is missing. We hope you, like almost everyone, finds absence intriguing. We all choose what to select and how much we want of that thing. It's one of our big decisions and it uses all our senses to achieve it. This is what our personal aesthetic is.
Given that 27% of the universe's matter is invisible

1

When the unfolding of the universe, pulled by strings of space and time, starts to stretch and slide, it soon begins to liberate the solutions and allow ***cosmic dust*** to dance.

and 68% of its energy is invisible to us, this reduction in what we present is, in a way, a truth of some kind, because we don't know any more than this. In art, when the end result has this quality it is called ambiguity. There is an interplay between structure and ambiguity. We're using ***the unfolding universe***, [2] a structural method, to orchestrate our making activity but we are keeping an eye open for ambiguity. In 1930, William Empson wrote a book called, 'Seven types of ambiguity.' It inspired us to call our book, 'Five types of Invisibility.' Empson was concerned with ambiguity in literature and in each of the types duality is present – such as when an author expresses two

---

2

When the dancing cosmic dust allows solutions to liberate the start of the stretch and slide of strings in space and time, it soon begins to pull on ***the unfolding universe***.

or more meanings that do not agree but combine to make clear a

more complicated meaning.

Here are Empson's seven conditions where ambiguity arises. When a detail is effective in several ways at once. Such as when many points of likeness are used to make a single comparison. When two or more alternative meanings are fully resolved into one. When two apparently unconnected meanings are given simultaneously.

When meanings combine to make ***spiral galaxies*** [3] clear a complicated state of mind in the author.

When a fortunate confusion arises because the author is discovering their idea in

---

3

When we watch the dawn of dipoles in the microwave sky and take hold of the stray isometries that show ***spiral galaxies*** in their manifolds.

the act of writing. When that which is written is contradictory or irrelevant and the reader is forced to invent interpretations. When the writing is clearly contradictory,

indicating a division in the author's mind. William Empson describes two attitudes to language - one that kills it by stripping it of all association, holding it to direct meanings only, and the other attitude, one that kills language by dissipating its sense in a multiplicity of associations. We must tread carefully between the two, but we need more ***dipoles and isometries*** [4] associations if we are to have any chance of redressing the balance.

4

When their manifolds in spiral galaxies show that we will watch the strays take hold of the microwave sky and see the dawn of ***dipoles and isometries***.

4. Silent space between time - stretched sounds

Dark

Energy

Dark

Matter

In the early 19 90s, one thing was fairly certain about the expansion of the universe. ***The hyperbolic curvature of space-time***. [5] It might have enough energy density to stop its expansion and re- collapse, it might have so little energy density that it would never stop expanding, but gravity was certain to slow the expansion as time went on. Granted, the slowing had not been observed, but, theoretically, the universe had to slow.

5

When perturbations accelerate expansion of hypothetical elementary particles, deviation from ***the hyperbolic curvature of space-time*** causes a sensation.

4. Silent space between time - stretched sounds

The universe is full of matter and
the attractive force of gravity
pulls all matter together. Then
came 1 998 and the Hubble
Space ***perturbations of hypothetical particles*** [6]
Telescope observations of very distant
supernovae that showed that, a long time
ago, the universe was actually
expanding more slowly than it is
today. So the expansion of the universe
has not been slowing due
to gravity, as everyone thought, it has been
accelerating. No one expected this,
no one knew how to explain it. But

something was causing it. Eventually theorists came up
with three sorts of explanations.
Maybe it was a result of a long-
discarded version of Einstein's
theory of gravity, one that contained

6

When sensation causes hyperbolic space-time curvature of deviation from ***perturbations of hypothetical particles***, they then accelerate the elementary expansion.

what was called a "cosmological constant." Maybe there was some strange kind of energy-fluid that filled space. Maybe there is something wrong with Einstein's theory of gravity and a new theory could include some kind of field that creates this cosmic acceleration. Theorists still don't know what the correct explanation is but they have given the solution a name. It is called dark energy.

What Is Dark Energy?

More is unknown than is known. ***the motion of photons***. [7] We know how much dark energy there is because we know how it affects the universe's expansion. Other than that, it is a complete mystery. But it is an important mystery. It turns out that roughly 68%

7

When you find the interaction of geodesics at galactic latitudes and measure cosmological constraints then you can start to govern ***the motion of photons*** in the sky.

of the universe is dark energy. Dark matter makes up about 27%. The rest - everything on Earth, everything ever observed with all of our instruments, all normal matter - adds up to less than 5% of the universe. Come to think of it, maybe it shouldn't be called "normal" ***geodesics of interaction*** [8] matter at all, since it is such a small fraction of the universe.

One explanation for dark energy is that it is a property of space. Albert Einstein was the first person to realize that empty space is not nothing. Space has amazing properties, many of which are just beginning to be understood. The first property that Einstein discovered is that it is

---

8

When photons in the sky govern motions of cosmological constraint then you start to measure galactic latitudes and you attempt to find the ***geodesics of interaction***.

possible for more space to come into existence. Then one version of Einstein's gravity theory, the version that contains a cosmological constant makes a second prediction: "empty space" can possess its own energy. Because this energy is a property of space itself, it would not be diluted as space expands. As more space comes into existence more of this energy-of-space would appear.

As a result, this form of energy would cause the universe to expand faster and faster. Unfortunately ***gravitational proportions*** [9] no one understands why the cosmological constant should even be there, much less why it would have exactly the right value to cause the observed acceleration of the universe. Another explanation for how space acquires energy comes from the

---

9

When we see how gravity illuminates interstellar filaments and pushes primordial models to a higher one than usual, this prevents a red shift of ***gravitational proportions***.

quantum theory of matter. In this theory, "empty space" is actually full of temporary ***interstellar filaments*** [10] ("virtual") particles that continually form and then disappear. But when physicists tried to calculate how much energy this would give empty space; the answer came out wrong - wrong by a lot. The number came out 10^{120} times too big. That's a 1 with 120 zeros after it. It's hard to get an answer that bad. So the mystery continues and there are still a few dark matter possibilities that are viable.

10

When we see how gravitational proportions prevents a red shift of primordial models to a higher one than usual, this pushes gravity and illuminates ***interstellar filaments***.

4. Silent space between time - stretched sounds

When I have fears that I
may cease to write, I don't want to
consider a marriage of true minds, for the
melodies will clog up my ear and my
pen will join with my teeming brain. Admit
convolutions; song does
not sing like mawkish
romance, or the murmuring heard from a wall
of earnest, hard bound books –
sounds alter seasons,
while judgement must hear a hornet's nest
on the first day of Spring. Risk
it for wonders
that can fill your core, bend with removal men,
freely add more: ***cusp-like halo*** [11]
rhythmic sounds of
several senses
will change the dark starry face of night,
while thinking - having aimed it

11

When we map a unified model of interstellar spectral spin and it means we come to assume the existence of a single negative mass fluid trapped inside a ***cusp-like halo***.

straight - will sleep near the
mark. If your lonely breast rouses
a mindful tear, a huge cloudy
symbol of high romance
that looks on tempests
and is never shaken, then treat
forlorn thought to a fancy fling and know
that you
will never have to trace every
wandering star back to ***the***
interstellar map[12] base. Find
fragrance and dew under fortune's wing,
mix shadows with the magic hand of
chance, whose worth's unknown,
though its rule is taken, and play
'til your sickly doubts are
drooping. After you feel the fairness of this
hour, sing not the fool through
rosy lips and cheeks,

12

When we are trapped inside a cusp-like halo, negative mass fluid assumes the existence of a single spectral spin and we have a unified model of ***the interstellar map***.

blossom anew and thrill
at the news that you can turn
a lonely breast to fancy. Bend his
sickle, invite the compass more;
duty’s strains keep you in memory's
dream where bright fairy power
hardly ever goes. Love shifts your
age, not by filling up weeks with
pale forms of past delights lived by
eyes that can’t
reflect on zeal in the bedroom, but by
building lights
round your ***massless plane*** [13] edgy gloom.
Paint a peach on love's pale
cheek, try surprise, start anew in the wide,
wide world and think … if this be error and upon
me proved, that pleasure’s
smiles are faint and
beauteous lies voiced

13

When your particle production modifies the key questions of the dark universe and allows the metric for matter creation to be integrated over a ***massless plane***.

4. Silent space between time - stretched sounds

to cut love to nought
before it sinks, I never sang,
nor no man ever loved or pictured a
rainbow over a stream. John
Ashbery and Jonas Salk both say
there's nothing specific for
us to do; our wisdom arrives by
necessity. Some growing is
crucial, but this we do inherently,
just by evolution; we can simply
submit to acceptance, learn how
to anticipate the future, track the
rhythms of growth and
submit to inclinations that dance
fandango for ***particle production*** [14] well-being
and flamenco for the cells. We can
hear through bones, as well as the ears, and
the spellbinding, multi-layered tales told
by old shamans cultivate benign instincts for

14

When your massless plane is integrated over the metric for matter creation and allows the dark universe to modify the key questions of ***particle production***.

our future's broadmindedness. When frequent blunders become ***simulated universe*** [15] more acute, it is time to start swinging from the heart. As new loves are born, there is no need to immunize against the negative swoon, the old way of judging is out, it was never kind to flowers or buoyancy. Having experienced the infection, shun old paths and the acceptance of fear, we'll easily recognise the pattern of lethargy when connections increase. Keep open, keep scanning, grow a thin skin, have a bird's eye view and a worm's eye view, elbow out the dominance of cash flow, we've no need to carry investors. Merge with the creative neutral misfits who

---

15

When we take a time-slice of homogeneous galaxy clusters, and distort the luminosity of their dark energy, implying the existence of a cyclic and ***simulated universe***.

practice positive simplicity.
Discontent expresses the driving force,
but constant interference is
the norm; let the next evolution
process be upon us, in us,
with us and through us. Make affection
the newfound ***galaxy clusters*** [16] bravery,
multiply magnanimous attention, send
reasoning to the intuition's
department, observe the new
unfolding, assist what's unsupported and
learn how to breeze with time
at perception HQ. Attend wholeheartedly
to unlearning, start giving evolution a
purpose. We're ripe for falling steadily
into ourselves, making each new day a life-
span. Anticipate the future; it's fine
now to stumble upon self-consciousness.
We had wisdom, without too much knowledge,

16

When we take a simulated universe, implying the existence of a cyclic of dark energy, and distort the luminosity of homogeneous ***galaxy clusters*** on a time-slice.

then we developed fear, replaced
benign casualness with scary risk forecasts
and stopped the good old
carefree buzz from humming. If
we have no wisdom to govern the
knowledge, let the custard pies be
our guide, they will aid the inception of
slapstick. We have the right genes
for this and they will activate fast when
people are ready; this affirms the collective
certainty that each of us has a different
purpose. Anything is only worth the candle
if you make frisky hearts the starting point
and celebrations of beauty the norm.
While writing, I don't quite know my spirit.
I appear absent, but I'm trembling
in a world of secret happiness,
grasping ***negative matter creation*** [17]
nothing,

17

When the anomalies of stress-energy tensors inflate the polarisation rotation of distant supernovae, allowing ***negative matter creation*** to thrive and view the sky.

blissfully intoxicated. Being carefree is important, just as it's crucial to enjoy playing ***stress-energy*** [18] structure. It can be sweet when these things pursue us; then we want to be everything for them. The fine, subtle, delicate things, seem best, but there are questions that can't be answered. I'd like to suggest that the absence of an answer can be heavenly when it's a vague, enchanted, majestic reply and I'd like this to be true for longer. Those who are raised to be competitive are not like those brought up to honour love. I say this as I want to remember; we are damned with too much judgement, it stops the heart from getting enough love to grow. There's little doubt we've all suffered from this. I'm thinking

18

When the sky views the negative matter creation to thrive and allow the polarisation rotation of distant supernovae to inflate tensors of ***stress-energy*** anomalies.

about a kind extragalactic ***field***[19]
heroine, thinking myself the hero
of this tale. In a mood of
audacity, I cross the boundaries of
the familiar and thrust myself through the
crust to freedom. With words,
I try to smile a charming smile but
it is too delicate to smile it. I am not
a human among humans, I'm a scent grown
fragrant by the heart, one who swims
alone in a human breast. When I choose to
create a fantasy from my secret reveries and
daydreams, conjuring, say, sweet meadows
to lie in, a place to gaze up at birch tree
branches, I do these things to pledge
my cheerfulness. I have no desire to own
anything and still my branches grow
higher each day. All I am is what
I have never been and should

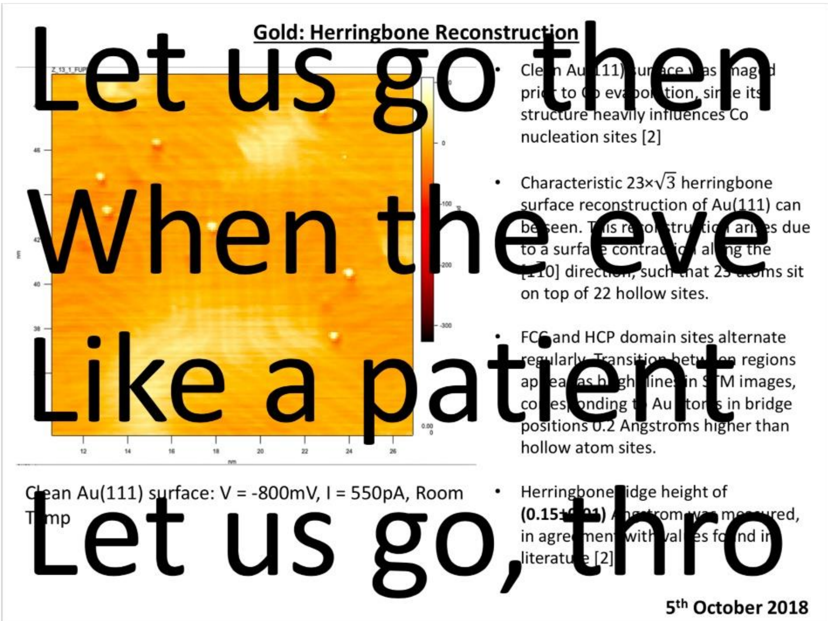
19

When the spatial scale of gravitational lensing can bend the emission of pulsar radiation and prevent the ionisation of rays from the ***extragalactic field***.

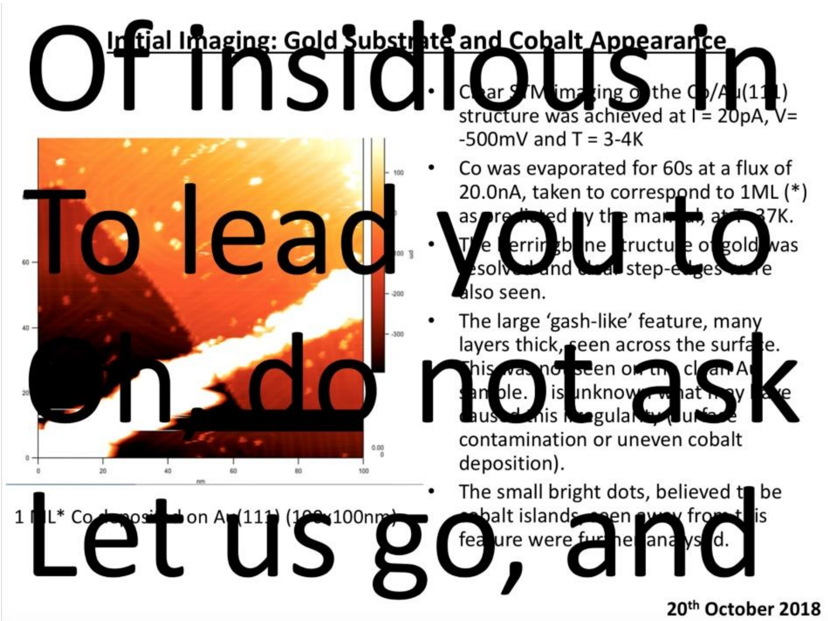
you now start dreaming about me, the concerns
I have will melt in the night. I will never
glare at you crossly, I'd hate to encourage
your woes and sorrows. You can afford to be
gentle, don't slay your noble emotions
and mellow voice, don't keep your
elegance on the inside, you must know there are times
when the simple can only be grasped with
almost no effort. The trees apologized, but
they hadn't done a thing that required
the emission of gravitational lensing [20]
a confession. I know nothing, so I
keep as quiet as a painter with a full brush of paint.
Then, when my lucid consciousness sits up,
alert, I gather my thoughts in a flash and
strike out, sensing that all lives can lead to
a new path of possibilities. It's
pleasing to pull oneself together
after seasons loyal to inertia.

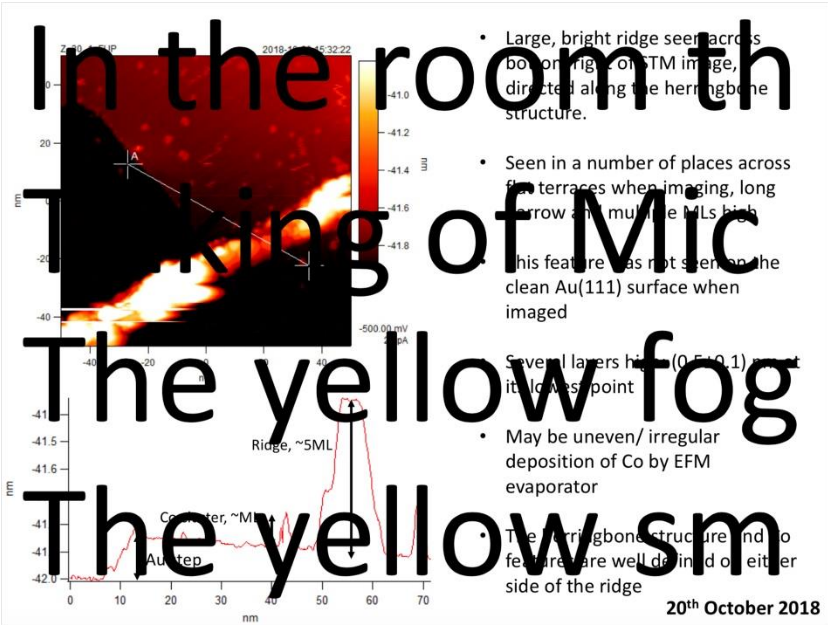
20

When the extragalactic field of rays from the ionisation of pulsar radiation prevents ***the emission of gravitational lensing*** that can bend the spatial scale.

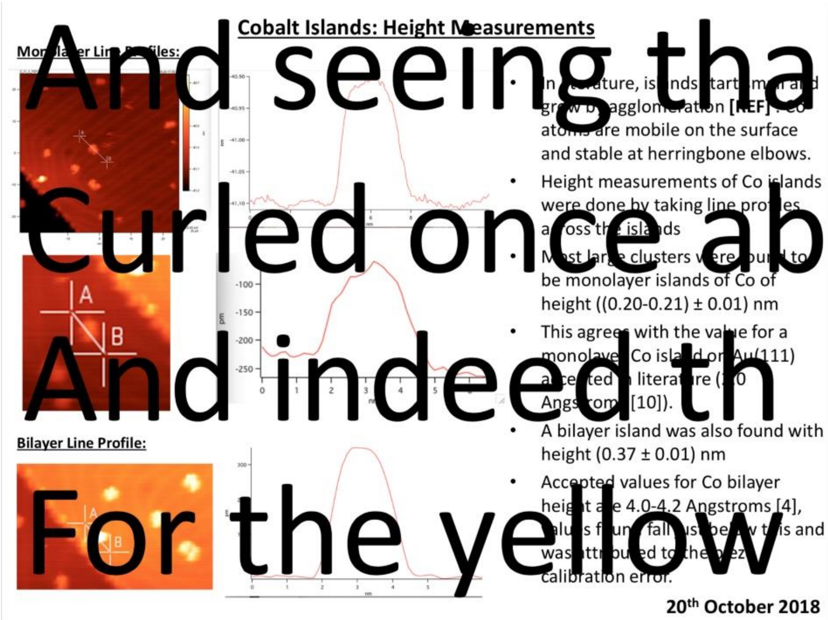

Gold: Herringbone Reconstruction
Let us go then
When the eve
Like a patient
Let us go, thro
structure heavily influences Co
nucleation sites [2]
Characteristic 23×√3 herringbone
surface reconstruction of Au(111) can
on top of 22 hollow sites.
FCC and HCP domain sites alternate
positions 0.2 Angstroms higher than
hollow atom sites.
Clean Au(111) surface: V = -800mV, I = 550pA, Room
5th October 2018

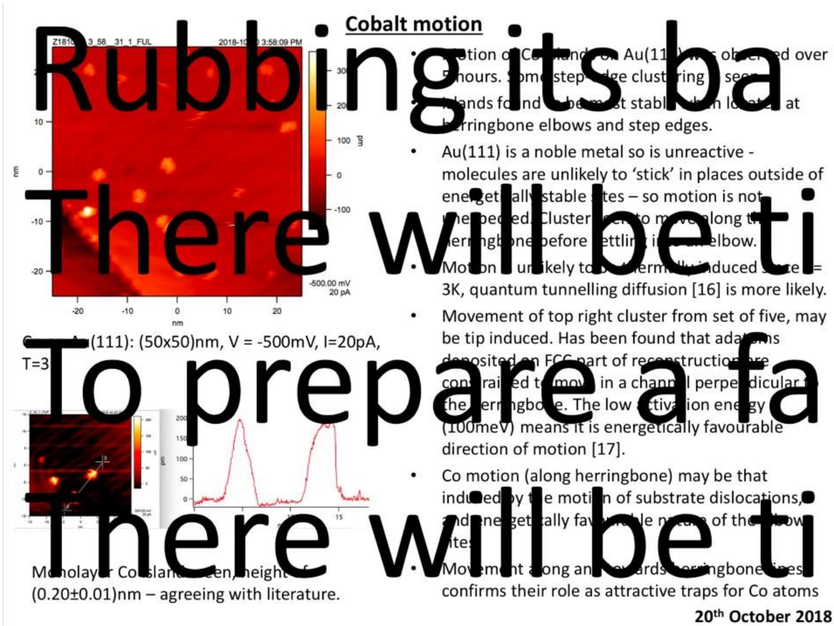
5. The golden intersection of rescaled overlays


Of insidious in
To lead you to
Oh, do not ask
Let us go, and
structure was achieved at I = 20pA, V=
-500mV and T = 3-4K
Co was evaporated for 60s at a flux of
20.0nA, taken to correspond to 1ML (*)
also seen.
The large 'gash-like' feature, many
contamination or uneven cobalt
deposition).
20th October 2018

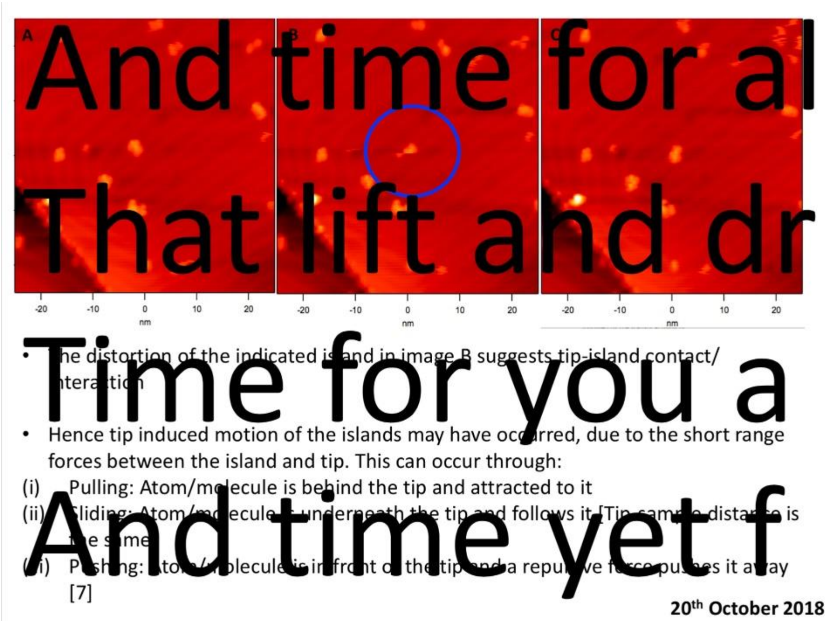

In the room th
king of Mic
The yellow fog
The yellow sm
structure.
Seen in a number of places across
clean Au(111) surface when imaged
May be uneven/ irregular deposition of Co by EFM evaporator
side of the ridge
20th October 2018
Ridge, ~5ML
-41.0
-41.2
-41.4
-41.6
-41.8
-500.00 mV
-41.5
-41.6
-42.0
nm
0
10
20
30
40
50
60
70


Licked its tong
Lingered upon
Let fall upon it
Slipped by the
Cobalt Islands: Distribution
Literature
dislocations [6], and under-go template-controlled
growth.
Herringbone bend sites/elbows are energetically
favorable. This behavior has been explained in terms
energy, to move to the energetically stable locations
Experiment
Co islands can be seen to nucleate at
herringbone elbows, as expected, but
coverage on the substrate is low with
some elbow sites left unoccupied.
Maybe able to attribute poor
coverage to EFM evaporator.
[100x100nm] I = 20pA, V= -
500mV and T = 3-4K
October 2018: I=20pA, V=-
500mV, T=3K, 50x50nm


And seeing tha
Curled once ab
And indeed th
For the yellow
Cobalt Islands: Height Measurements
Bilayer Line Profile:
atoms are mobile on the surface
and stable at herringbone elbows.
Height measurements of Co islands
be monolayer islands of Co of
height ((0.20-0.21) ± 0.01) nm
A bilayer island was also found with
height (0.37 ± 0.01) nm
calibration error.
20th October 2018

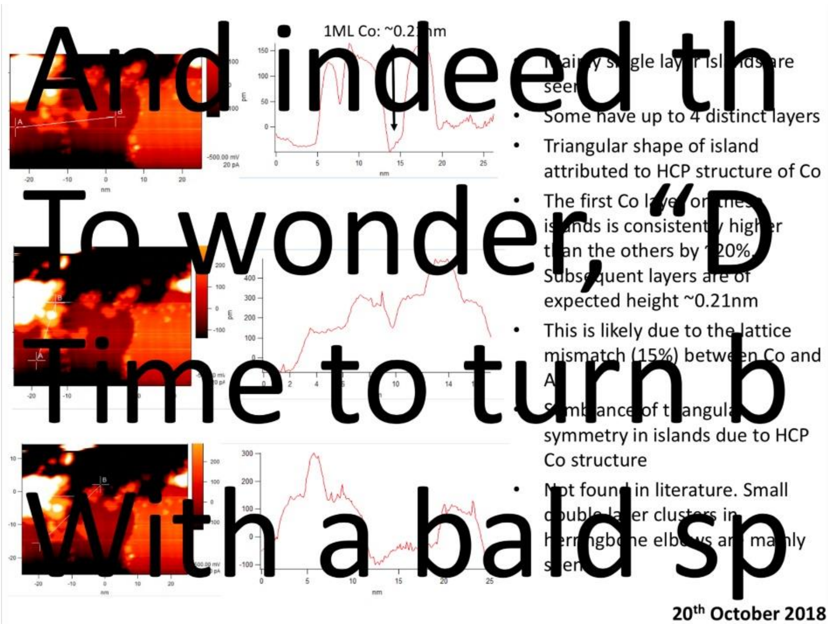

Cobalt motion
Rubbing its ba
There will be ti
To prepare a fa
There will be ti
herringbone elbows and step edges.
Au(111) is a noble metal so is unreactive -
molecules are unlikely to 'stick' in places outside of
3K, quantum tunnelling diffusion [16] is more likely.
Movement of top right cluster from set of five, may
be tip induced. Has been found that ada
(100meV) means it is energetically favourable
direction of motion [17].
Co motion (along herringbone) may be that
confirms their role as attractive traps for Co atoms
(111): (50x50)nm, V = -500mV, I=20pA,
(0.20±0.01)nm – agreeing with literature.
20th October 2018

5. The golden intersection of rescaled overlays

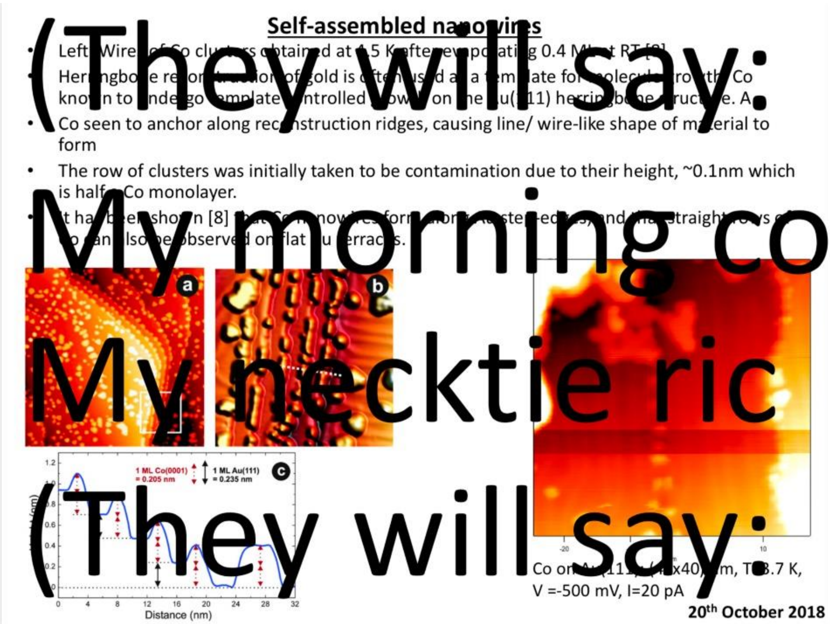


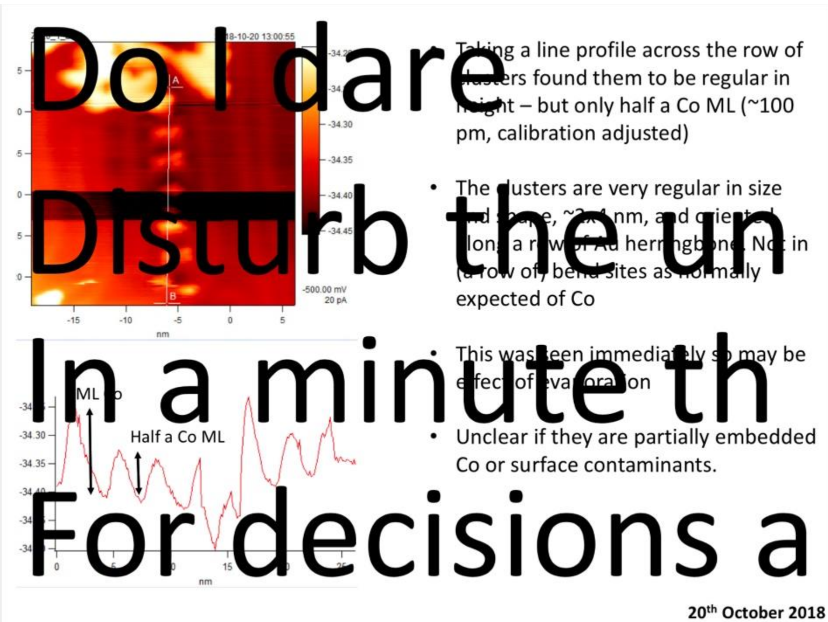

And for a hund
Before the taki
In the room th
Talking of Mich
Co was evaporated for 60s at a flux of 20.0nA, taken to correspond to 1ML (as in manual), at T=3.7K.
Discrepancy between experimental vs literature island height values is explained by the piezo calibration error
20th October 2018

5. The golden intersection of rescaled overlays

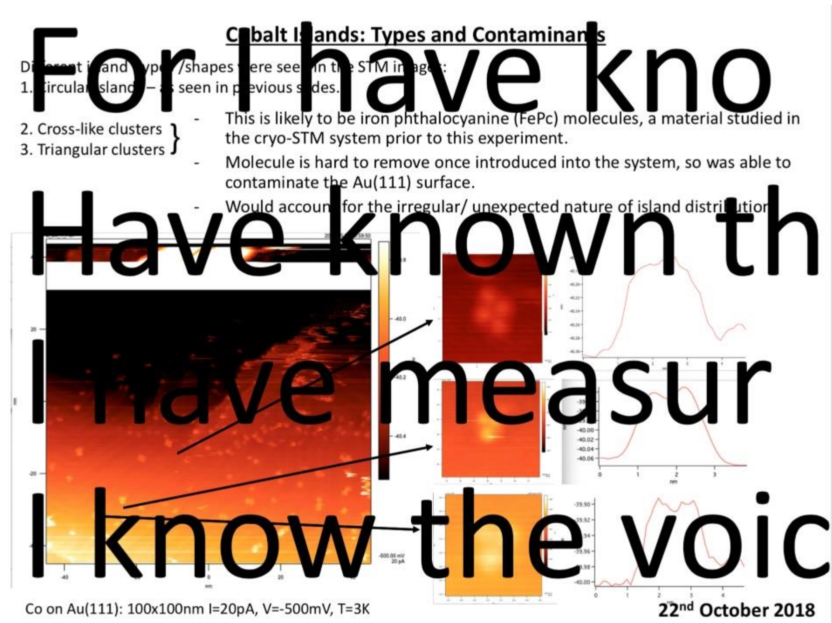


5. The golden intersection of rescaled overlays




Do I dare
Disturb the un
In a minute th
For decisions a
line profile across the row of
rs found them to be regular in
– but only half a Co ML (~100
pm, calibration adjusted)
The
usters are very regular in size
nm,
herr
bend sites as
expected of Co
This was
immedia
may be
Unclear if they are partially embedded
Co or surface contaminants.
Half a Co ML
ML
-500.00 mV
20 pA
nm
20th October 2018

5. The golden intersection of rescaled overlays



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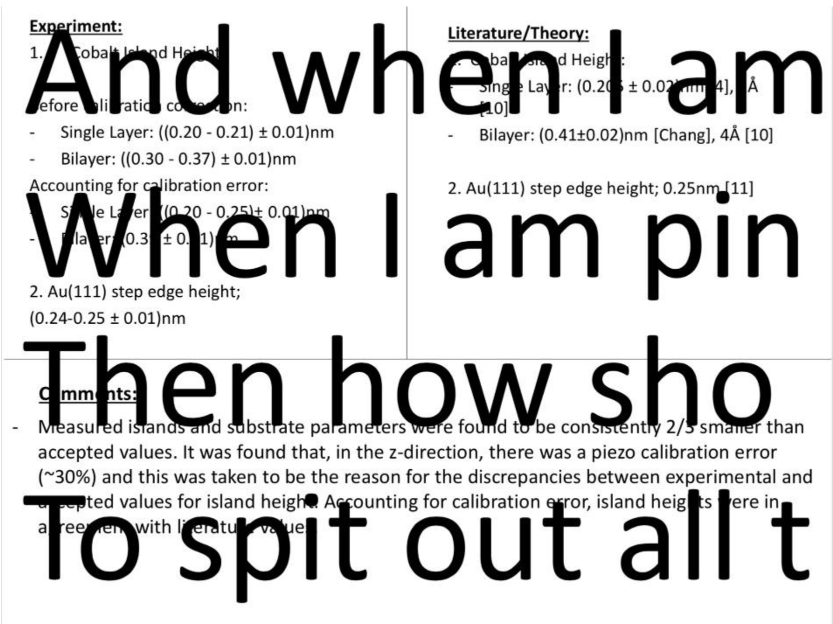


Experiment:

1. Cobalt Island Height:

Before calibration correction:

- Single Layer: ((0.20 - 0.21) ± 0.01)nm
- Bilayer: ((0.30 - 0.37) ± 0.01)nm

Accounting for calibration error:

- Single Layer: ((0.20 - 0.25)± 0.01)nm
- Bilayer: (0.3[illegible] ± 0.[illegible]1)nm

2. Au(111) step edge height;
(0.24-0.25 ± 0.01)nm

Literature/Theory:

1. Cobalt Island Height:

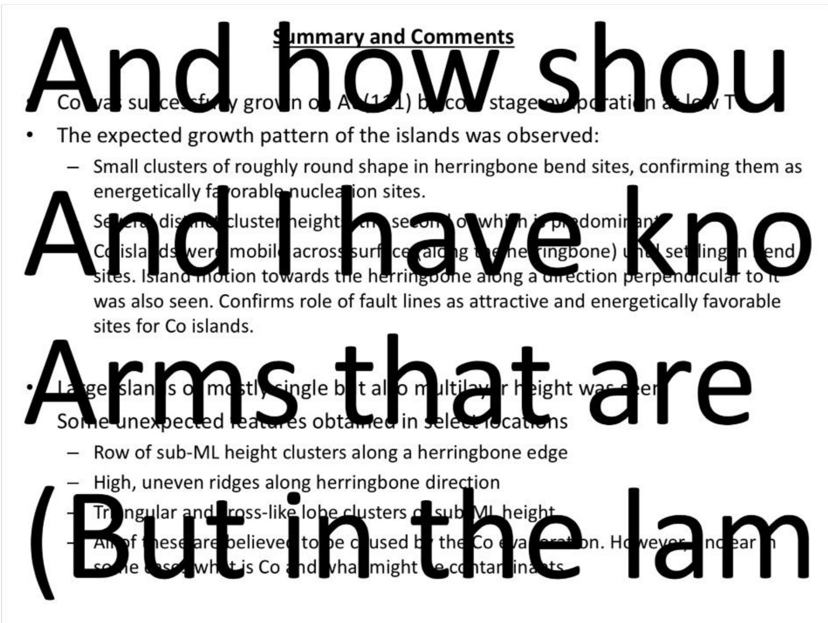
- Single Layer: (0.20[illegible] ± 0.02)nm [4], [illegible]Å [10]
- Bilayer: (0.41±0.02)nm [Chang], 4Å [10]

2. Au(111) step edge height; 0.25nm [11]

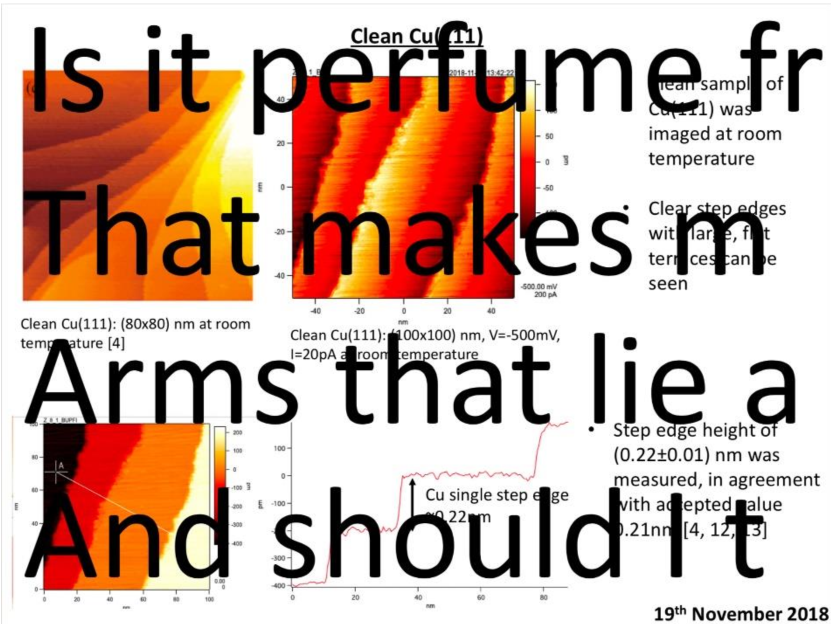
Comments:

- Measured islands and substrate parameters were found to be consistently 2/3 smaller than accepted values. It was found that, in the z-direction, there was a piezo calibration error (~30%) and this was taken to be the reason for the discrepancies between experimental and accepted values for island height. Accounting for calibration error, island heights were in agreement with literature values.

5. The golden intersection of rescaled overlays



5. The golden intersection of rescaled overlays



5. The golden intersection of rescaled overlays

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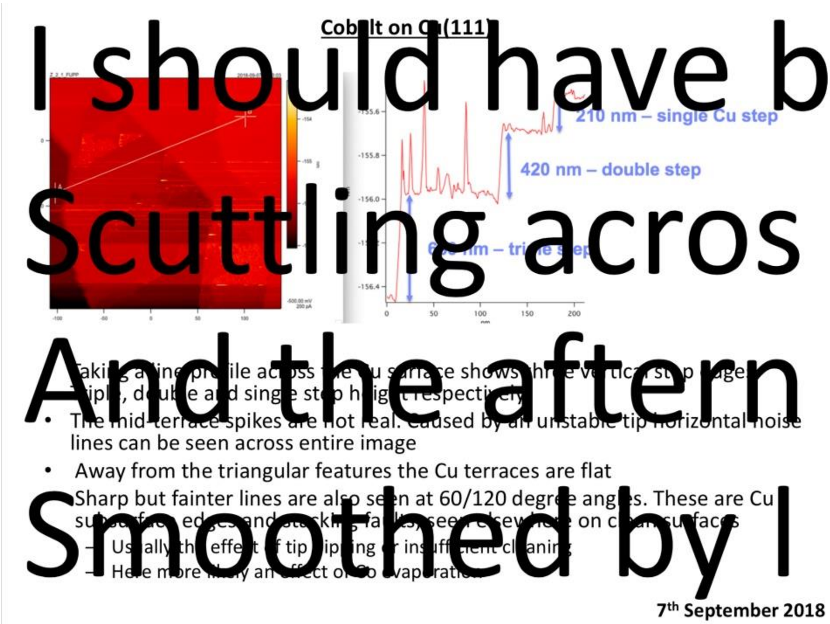

5. The golden intersection of rescaled overlays