Introduction to

Adaptive Tension Systems

with Consequences

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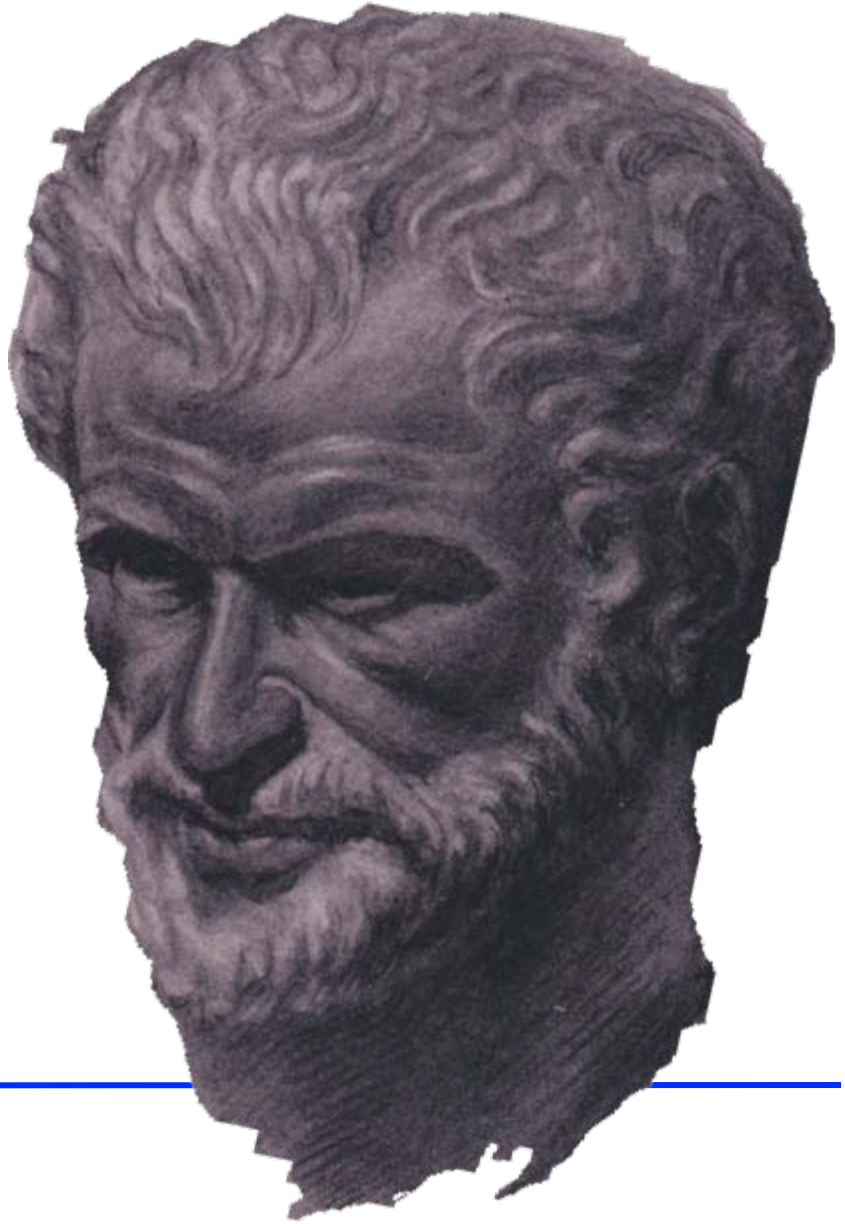
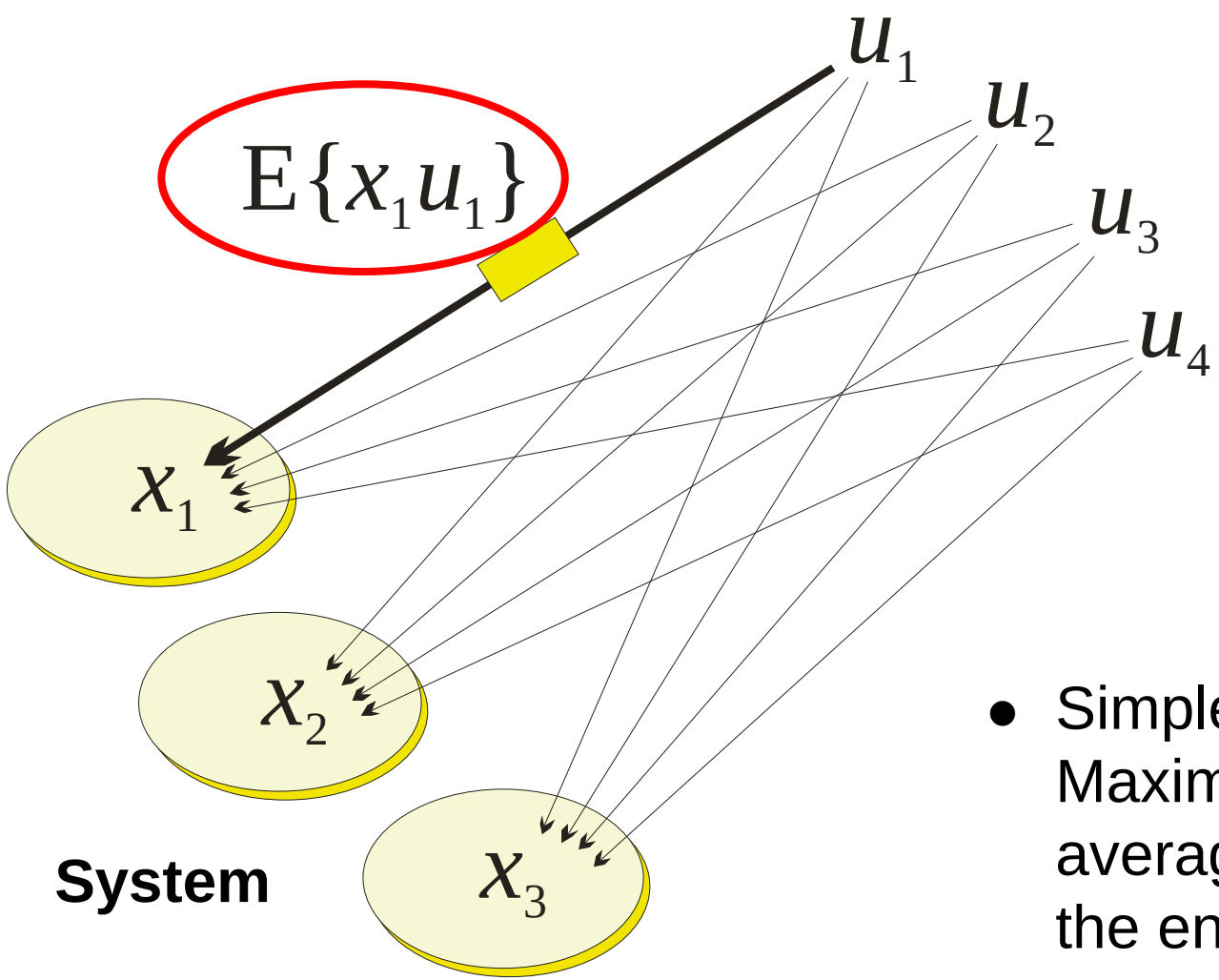
Neocybernetics = an approach to complexity

- Framework: a system of networked agents
- Local operation, no global control among agents
- Self-regulation & self-organization *somehow* has to *emerge*



Simple principle

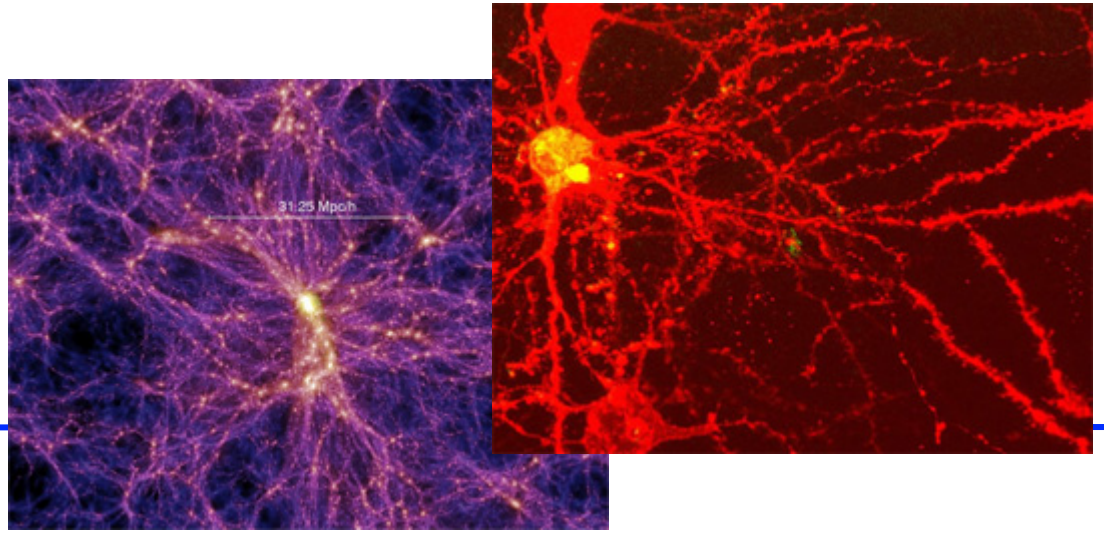


- Simple local principle: Maximize the acquired average *emergy* from the environment

”Maximize the acquired emergy”

- **Emergy** = average product of action (in the environment) and reaction (in the system) = $\mathrm{E}\{x_i u_j\}$
- Can have different physical dimensions in different domains
- The Hebbian learning law is an example of this principle!

- In evolutionarily surviving systems local actors try to maximize the transferred emergy – *why*?



Role of feedback

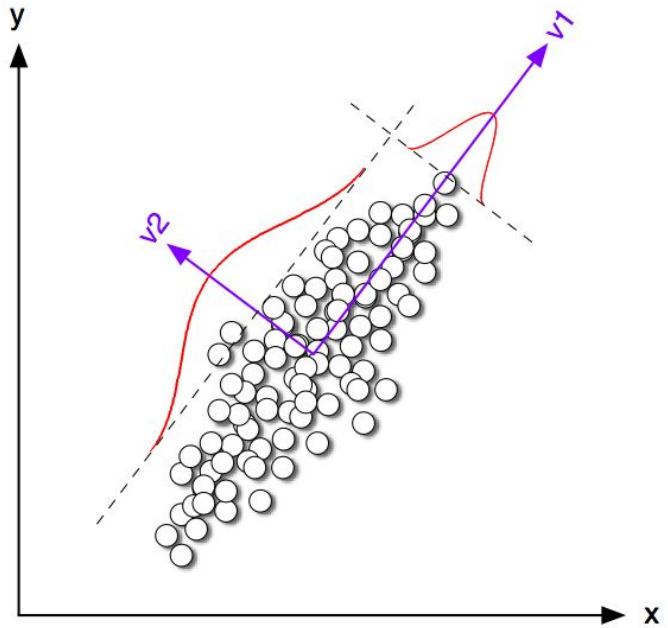
- However, only maximization results in balance being lost
- Now there is *negative feedback* stabilizing the system
- When the input is seen as *force*, feedback causes *tension* in the coupling; there is *elastic balance of tensions*, where adaptation makes the coupling gradually *stiffer*
- One can speak of Adaptive Tension Systems

- There are two alternatives for implementing the feedback:
  - *Clever agents* implement the feedbacks themselves actively, in a proactive way, taking their neighbors' actions into account
  - Selfish agents simply struggle towards resources, whereas the environment forces the feedback as exploitation means exhaustion

PCA

- Emergy maximization together with negative feedback results in *principal subspace modeling of variation* in data
- If the variables are interpreted as *resources*, a system obeying these principles *uses the resources optimally*
- Such systems supposedly survive in evolution – in the final balance *systems will all be (neo)cybernetic*

- Linearity of the model makes it scalable beyond toy worlds; mathematical benefits available
- In neocybernetic models, there is *emergent structure*



Case of the ”clever agent” ...

- Model.
  - It turns out that the neocybernetic strategy constructs the best possible (in the quadratic sense) description of the environment; the *latent variables* are

$$\bar{x} = \mathrm{E}\left\{\bar{x}\bar{x}^T\right\}^{-1} \mathrm{E}\left\{\bar{x}u^T\right\} u$$

Principal subspace analysis

- Estimate.
  - It turns out that the neocybernetic strategy constructs the best possible (in the quadratic sense) estimate of the environment state; regression estimate is

$$\hat{u} = \mathrm{E}\left\{\bar{x}u^T\right\}^T \mathrm{E}\left\{\bar{x}\bar{x}^T\right\}^{-1} \bar{x}$$

Multilinear regression

- Control.
  - If exploitation means exhaustion, the neocybernetic strategy integrates modeling and estimation *to eliminate variation in the environment maximally*.

... and the ”selfish agent”

- Model.
  - It turns out that the neocybernetic strategy constructs the best possible (in the robustness sense) description of the environment; the *latent variables* are

$$\bar{x} = \left(\mathrm{E}\left\{ \bar{x}\bar{x}^T \right\} + Q^{-1} \right)^{-1} \mathrm{E}\left\{ \bar{x}\bar{u}^T \right\} \bar{u}$$

Feature extraction

- Estimate.
  - It turns out that the neocybernetic strategy constructs the best possible (in the robustness sense) estimate of the environment state; regression estimate is

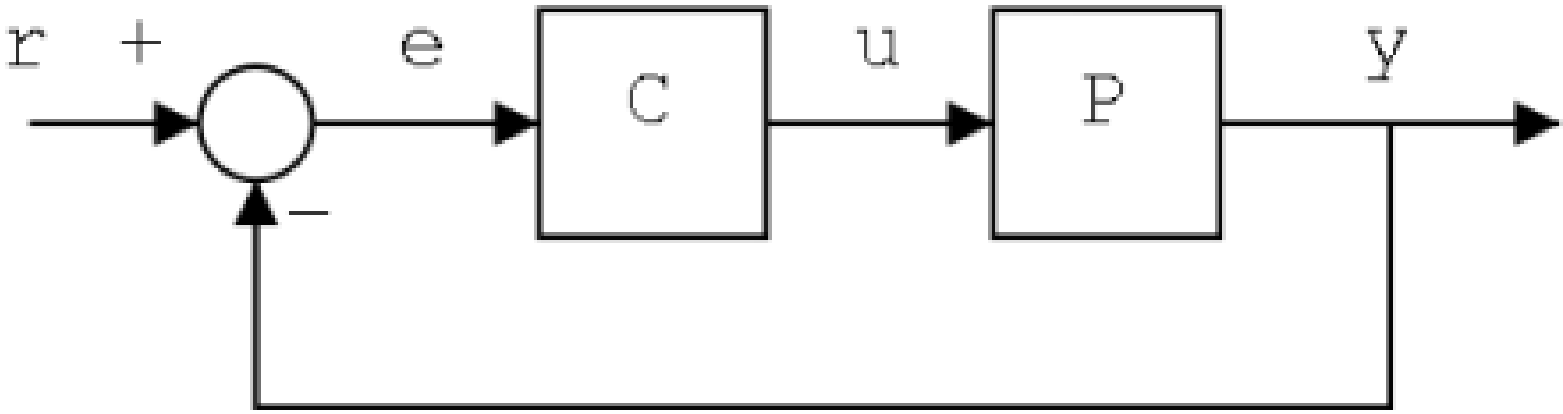
$$\hat{u} = \mathrm{E}\left\{ \bar{x}\bar{u}^T \right\}^T \left(\mathrm{E}\left\{ \bar{x}\bar{x}^T \right\} + Q^{-1} \right)^{-1} \bar{x}$$

Regularized regression

- Control.
  - The neocybernetic strategy integrates modeling and estimation *to eliminate variation in the environment in a robust way*.

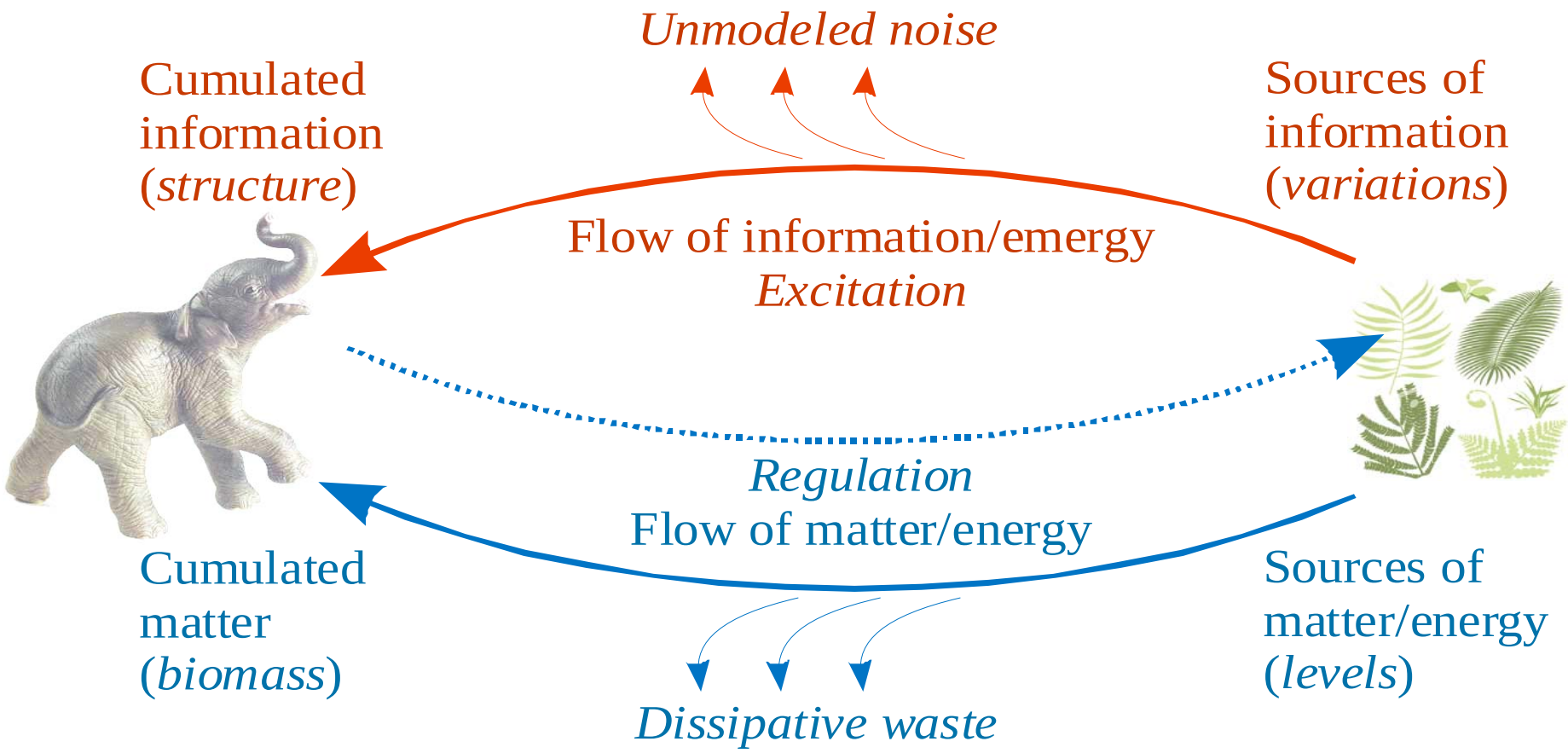
Model-based control

- Neocybernetic strategy does not implement whatever feedback ... it is the **best possible model-based control**, no matter what are the vector dimensions
- This control is implicit, and it is an **emergent functionality**, caused by the adaptation in the local agents and non-ideality in the environment



Flows of information and matter

Information – from *to in-form*,
in the sense of **to give form**

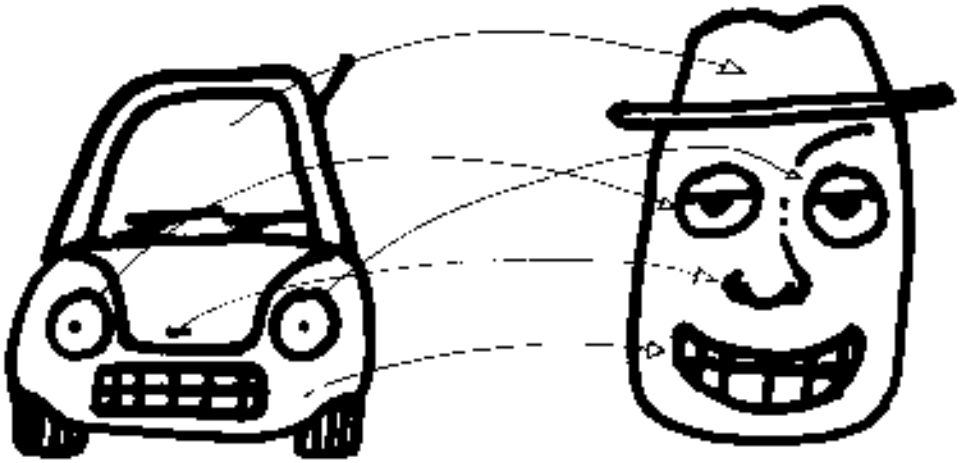


”Fingerprints” of neocybernetics

- Because of the simplicity of the neocybernetic models, there are *more systems that models* – one can utilize *analogies*
- For example, there is the cost criterion, or the common ”mathematical pattern”

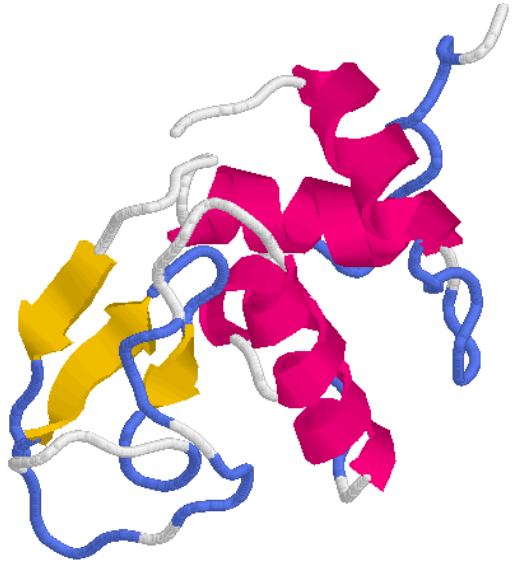
$$J = \frac{1}{2} x^T \mathrm{E}\left\{\overline{xx}^T\right\} x - x^T \mathrm{E}\left\{\overline{xu}^T\right\} u$$

- There are also *functional patterns* related to elasticity, like *constraints* and *degrees of freedom*
- *Examples of both ...*



An example: Analysis of *orbitals*

- Are orbitals predetermined structures hosting electrons?
- Or are they just emergent phenomena reflecting more fundamental underlying processes?
- Study what kind of consequences it has if a molecule is regarded as a (truly) cybernetic population of electrons

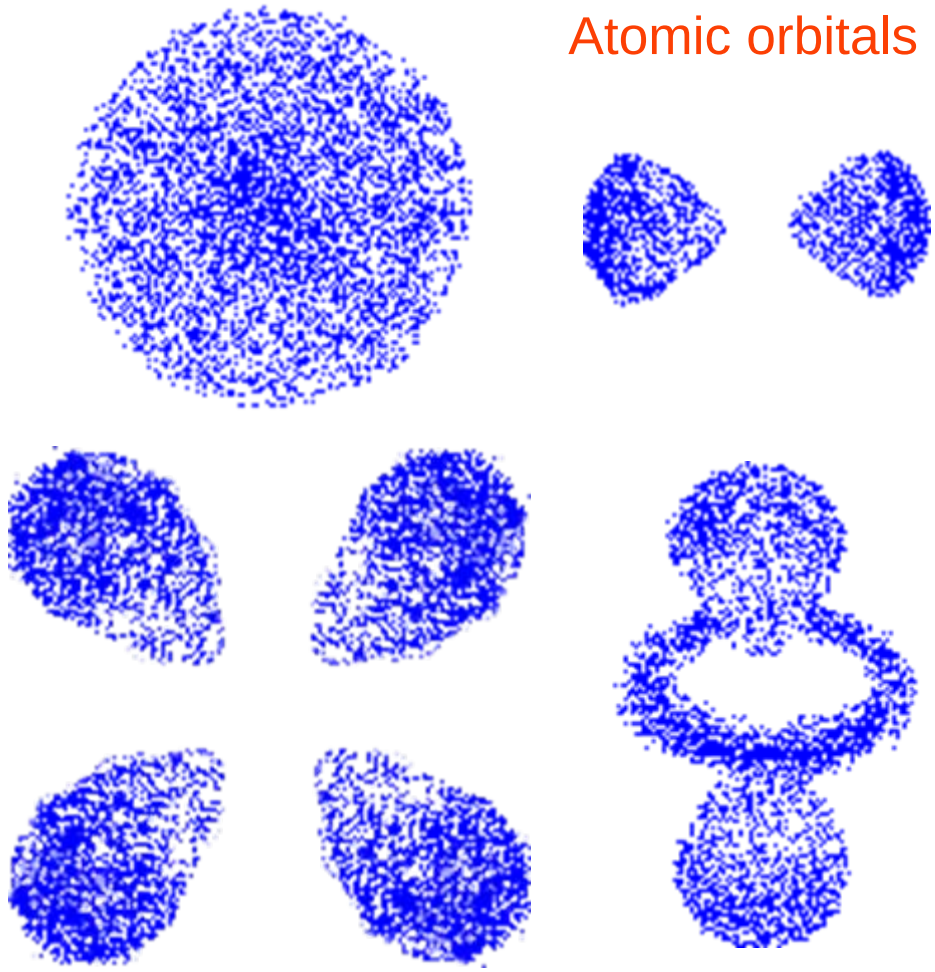


Applications:
Modeling the protein folding?
Understanding catalysis?

- Electrons are *delocalized* around nuclei
- Orbitals = ”probability distributions of electrons”
- Molecular orbitals = sums of atomic orbitals?

BUT:

- Molecular level is yet another emergent level
- Distributions extend over the whole molecule



- The molecular orbitals cannot directly (or most efficiently) be studied in terms of atom orbitals: Strange ”hybridisations”, etc., need to take place ...
- Assume that the quantum phenomena also *can be* modeled efficiently
- Assume it is simply a play among independent local-scale electric fields that is taking place in a molecule
- Then it helps when there is a strong structural framework as a target = neocybernetic model
- The model structure dictates the ways to interpret behaviors – an interesting question is whether these interpretations can be approved

In string theories, elementary particles are *vibration modes*!

Macroscopic analysis of electric fields

- Assume that there are various overlapping electric fields, and let $x_i(t)$ denote the electric charge within the field i.
- Energy that is stored in the potential fields:

  1. Within a single charge field

  $$J_{i,i} = c \int_0^{x_i} \xi \, d\xi = \tfrac{1}{2} c \, x_i^2$$

  2. Among overlapping fields

  $$J_{i,j} = c \int_0^{x_i} x_j \, d\xi = c \, x_i x_j$$

- If charges of i and j have the same sign, potential is positive, denoting repulsion; otherwise there is attraction

Microscopic analysis

- However, in microscopic scale, there are no charges to be observed, only interactions
- Now let $x_i(t)$ denote the momentary field strength within the field ("orbital") number i
- Macroscopic phenomena = long-term averages over time axis
- Assume that $p_{i,j}$ is the overall interaction probability among orbitals i and j
- Total energy that is stored in the potential fields can be expressed as

$$J' = p_{1,1}J_{1,1} + p_{1,2}J_{1,2} + \cdots + p_{n,n}J_{n,n}$$

- Because of the dual interpretation of the orbitals (charge distribution *and* probability distribution), one can express the joint distribution, or long-term mutual interaction (assuming independence) as (α being some constant)

$$p_{i,j} = \alpha \mathrm{E}\left\{x_i x_j\right\}$$

- Total orbital-wise energy can then be written in matrix form:

$$J' = \frac{1}{2} x^T \mathrm{E}\left\{x x^T\right\} x$$

- Correspondingly for positive charges u_j (nuclei); forces are now attractive rather than repulsive

$$J'' = -x^T \mathrm{E}\left\{x u^T\right\} u$$

- For total energy one has

$$J(x,u) = J' + J'' = \frac{1}{2} x^T \mathrm{E}\left\{ xx^T \right\} x - x^T \mathrm{E}\left\{ xu^T \right\} u$$

  Here it is assumed that effects of the nuclei are quantized, locations of the atom nuclei
- The above J is exactly the same cost criterion that was derived for ordinary (neo)cybernetic systems!
- Resulting assumption: Thus, the charge distribution along the molecule (molecular orbital) is given by the principal components of the correlation matrix of photons carrying the nucleic interactions $\mathrm{E}\left\{ uu^T \right\}$

Comparison to traditional theory

- Normally one has an (unsolvable) infinite-dimensional problem of eigenfunctions (time-independent formulation)

$$-\frac{h^2}{8\pi^2 m}\frac{d^2}{dx^2}\psi(x)+V(x)\psi(x)=E\psi(x)$$

- Now there is only the finite set of nuclei being studied – one has a finite-dimensional eigenvalue/eigenvector problem

$$\left(V-V_0\right)\psi_i=\lambda_i\psi_i$$

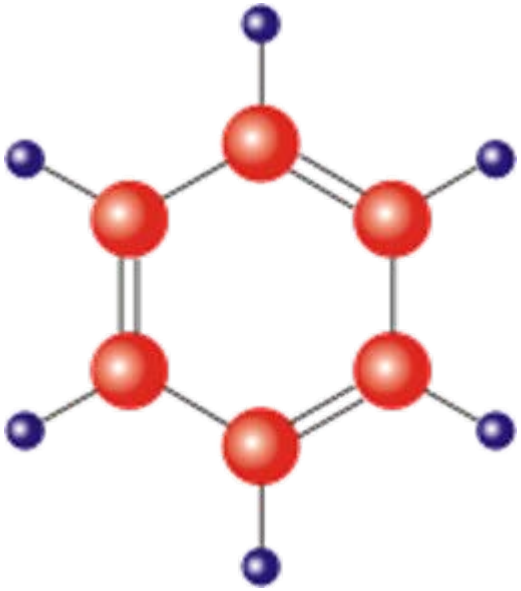
- Assumption: Because of the nature of electrons, they cannot be located in various energy levels simultaneously – eigenvalues become distinguished

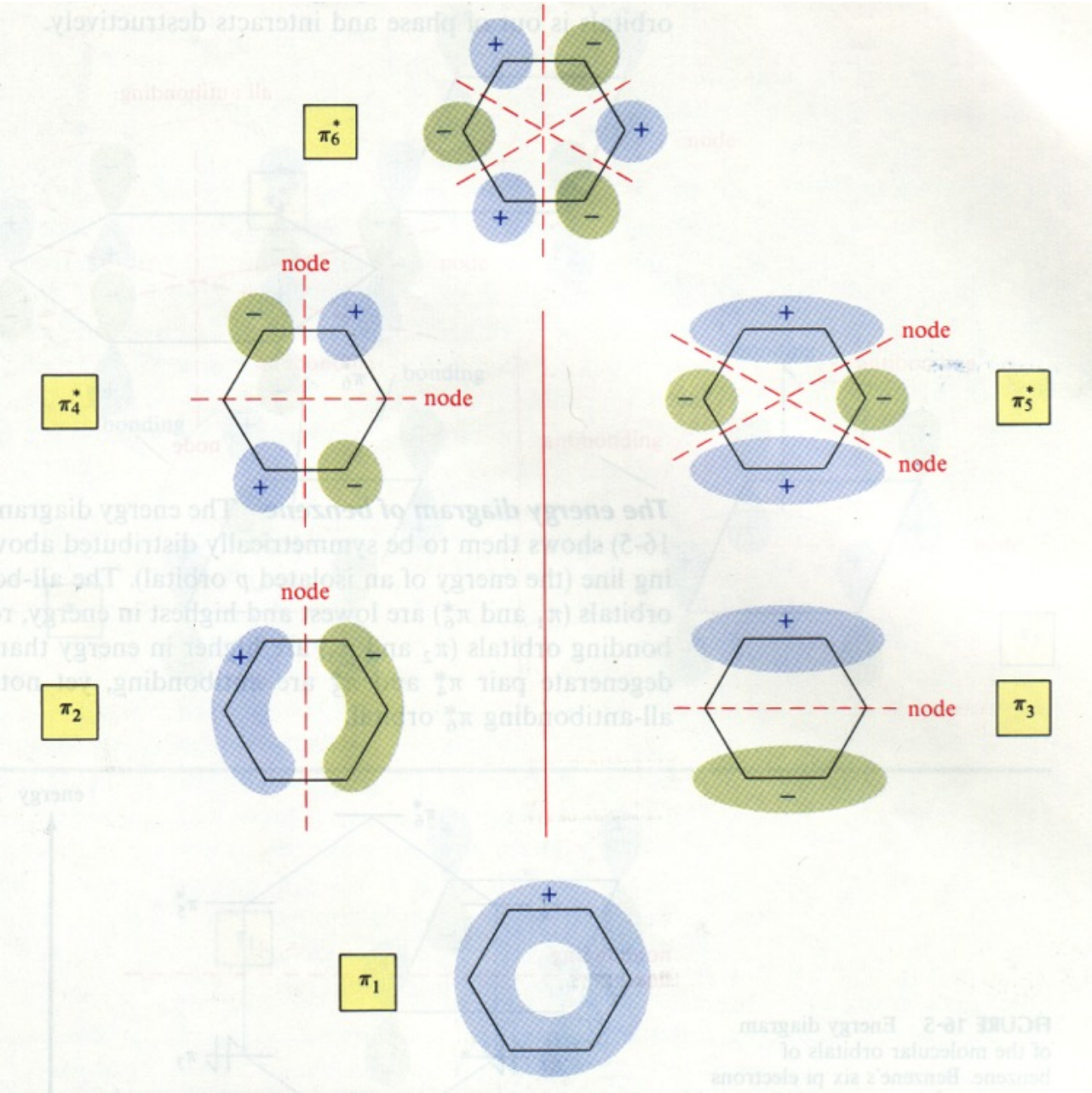
- The above result is closely related to the *Hückel method*, where the molecular orbitals are (approximately) determined in a rather qualitative, graph theoretic way
- Molecular orbitals are interesting because the chemical properties are determined by the charge distribution = how the molecule is ”seen” by the outside world
- For example – if $\mathrm{E}\left\{uu^T\right\} = \begin{pmatrix} 1 & 0.5 & 0.1 \\ 0.5 & 1 & 0.5 \\ 0.1 & 0.5 & 1 \end{pmatrix}$ *chain of three?*

then $\psi = \left(\begin{array}{c|c|c} 0.52 & -0.71 & 0.48 \\ 0.68 & 0 & -0.73 \\ 0.52 & 0.71 & 0.48 \end{array}\right)$ and $\Lambda = \begin{pmatrix} 1.76 & & \\ & 0.90 & \\ & & 0.34 \end{pmatrix}$

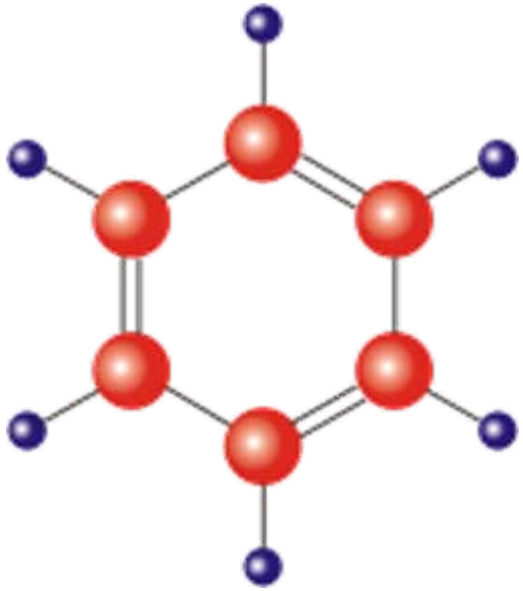
Example

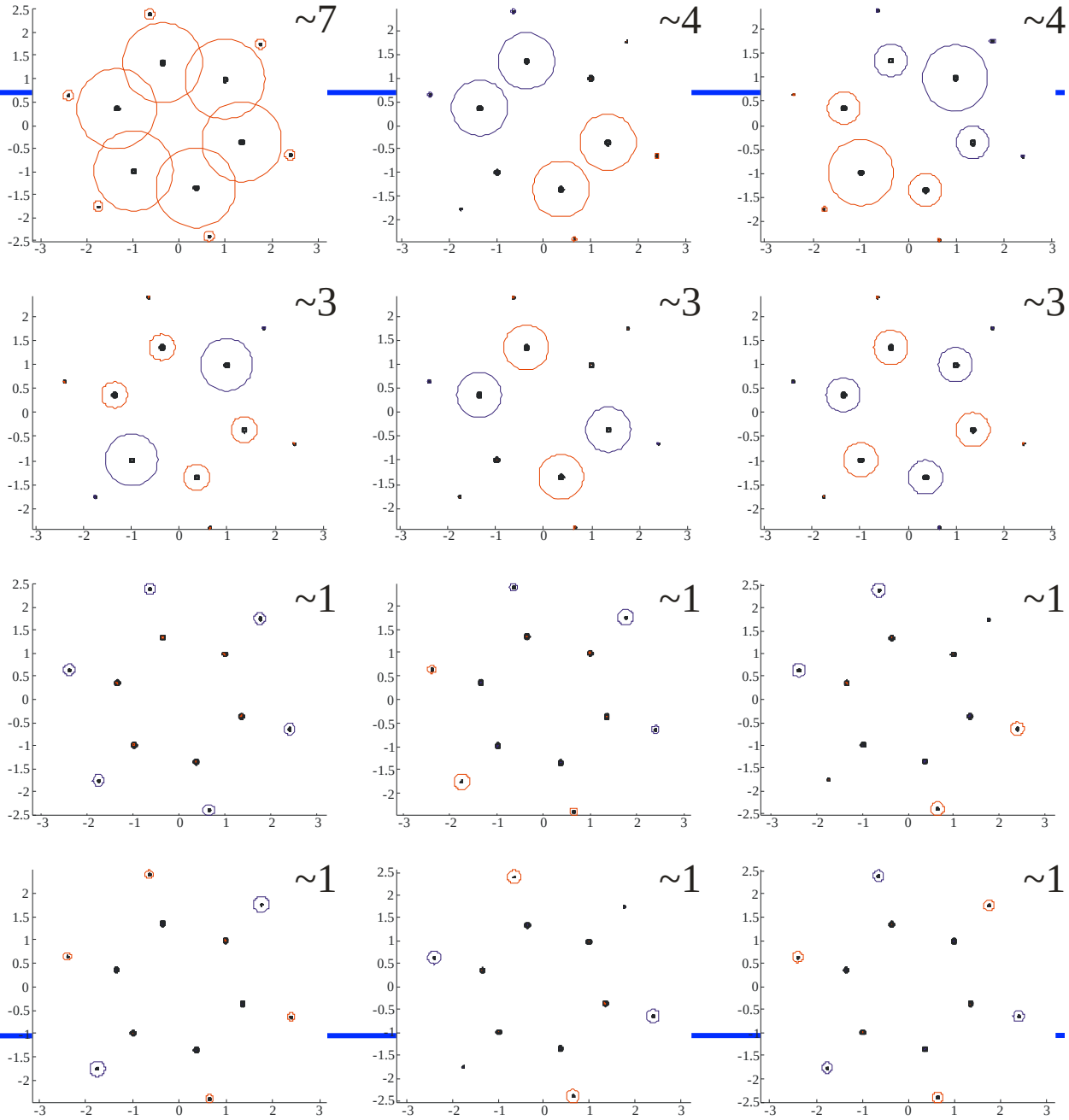
- Traditional view of orbitals in the benzene case





- ”Cybernetic orbitals” for benzene





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- However, the complete solution of the Schrödinger equation is time-dependent:

$$\psi(x,t) = \psi(x)\mathrm{e}^{\mathrm{i}\ 2\pi Et/h}$$

- In our discretized case, one has

$$\psi_i(t) = \psi_i \sin\frac{2\pi\lambda_i t}{h}$$

- The energy eigenvalue λ_i determines the oscillation frequency of the orbital
- Emergent affinity = integral over time: Different orbitals do not interact
- Possibility of characterizing of atoms within a molecule!

- If one defines ”fingerprints” of atoms as

$$\Psi = \begin{pmatrix} \Psi_1 & \cdots & \Psi_n \end{pmatrix} = \begin{pmatrix} \psi_1^T \\ \vdots \\ \psi_n^T \end{pmatrix}$$

  one can write their mutual affinity as

$$\Psi_i^T \Lambda^2 \Psi_j$$

- This gives a unifying view over van der Waals bonds / hydrogen bonds + covalent bonds?
- Understanding of affinity between atoms i and j = contribution to protein folding, and activation energies?
- Infinite number of possible energy levels – infinite number of different affinity structures

Compare to the questions in the beginning:

- When affinities among atoms in a molecule are known, one can understand why different parts of the molecules become attached – explanation to protein folding?
- A related mysterious process is RNA splicing: The same DNA is expressed in different kinds of messenger-RNA because of splicing – the same explanation?
- If separate molecules synchronize the vibrations in their orbitals, their attraction patterns can also become infinitely complicated – explaining the diversity of protein functions?
- Further, as an enzyme molecule is attached to another molecule, the whole orbital structure is changed – thus altering the activation energies in other parts of the molecule

Structures are “antennas” that define vibration fields?

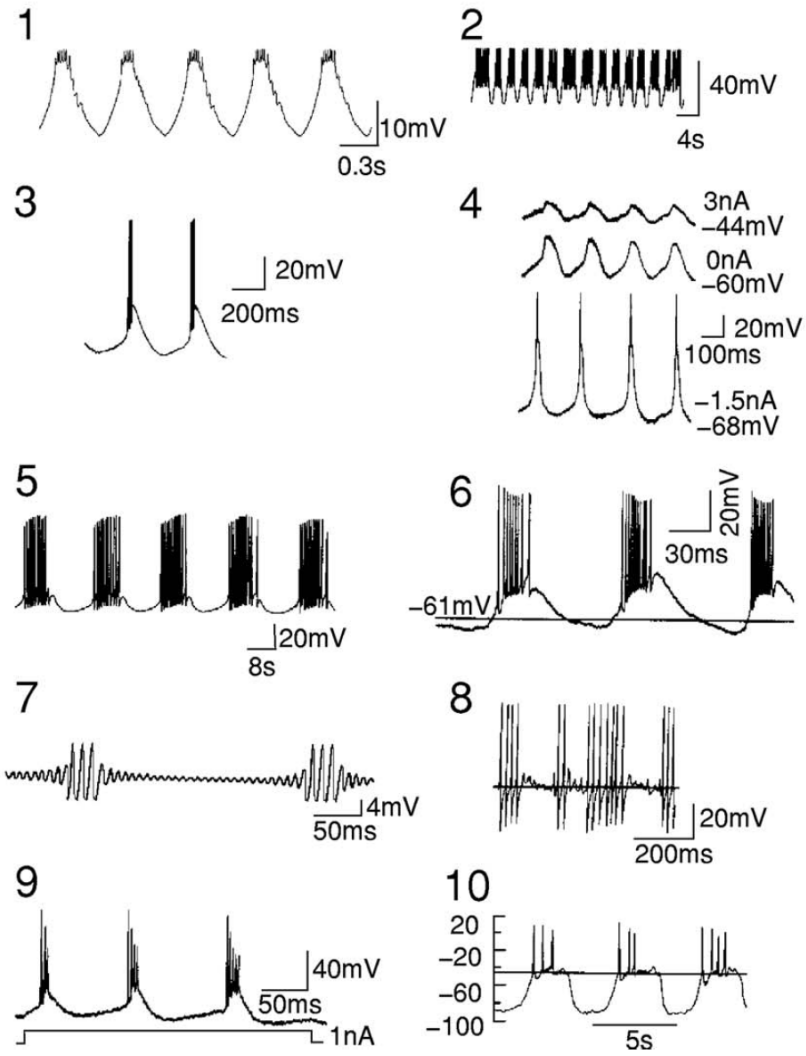
Other open questions

- Can the ”phonons” also be modeled as vibration fields?

  BUT ALSO

- Why has nature implemented neural activity in such a way – as recurring bursts?
- Higher activity means higher pulse frequency ...
- *Can the association between separate neural structures be explained in terms of fields?*

- Neural analyses start by abstracting neural details – applying the fresh intuitions and analogies, it is possible to get deeper: again, real-life non-idealities are *essential*
- Previously, cognitive processes based on simple signal filtering – but this is clearly too simplistic as associations, intuition, imagination, etc., cannot be explained
- Like tastes and smells are an extension of chemical systems, auditory signals with spectra are an extension of cybernetic cognition based on fields? Analysis using spectrograms?
- *How about telepathy!?* One can hypothesize that the fields extend over one brain; it seems that in *ganzfeld experiments*, some support to “brain reading” has been found (?)



- When frequencies are summed on top of each other, one has *pulse codes*

Fields and resonances

- Pythagoras first spoke of the *harmony of the spheres*
- Later, Rupert Sheldrake spoke of *morphogenetic fields*
- There are also harmonies of cycles in the ecosystem – species have to adapt to day / year alternation; they are bound to the cosmic frequencies
- The predators also have to follow the prey cycles
- This proposes that ”the next level” of cybernetic models could be based on signals after temporal (and spatial) Fourier transforms?
- ”Steel plate analogy” works also when studying vibrations: the higher the tension (energy), the higher the frequency

Analogues rehabilitated

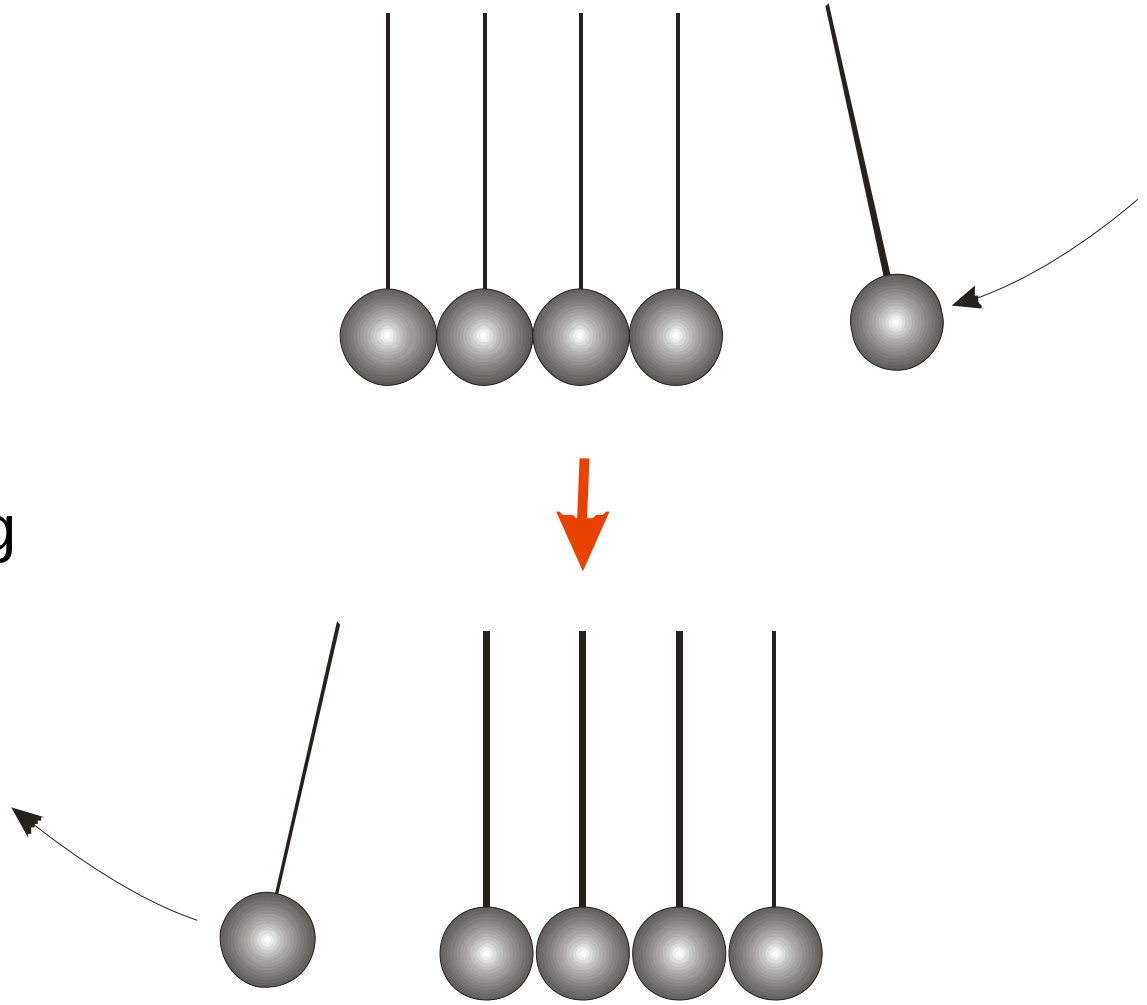
- When applying linearity, the number of available structures is rather limited – there are more systems than models!
- This idea has been applied routinely: Complicated systems are visualized in terms of structures with the same dynamics
- In the presence of modern simulation tools, this kind of lumped parameter simplifications seem rather outdated ...
- However, in the case of really complicated distributed parameter systems, such mechanical analogues may have reincarnation – steel plates are still simple to visualize!
- Another class of analogues (current/voltage rather than force/deformation) can also be constructed:
  - External forces are the loads; the deformation is the voltage drop, and the control action is the increased current

Electrical intuitions

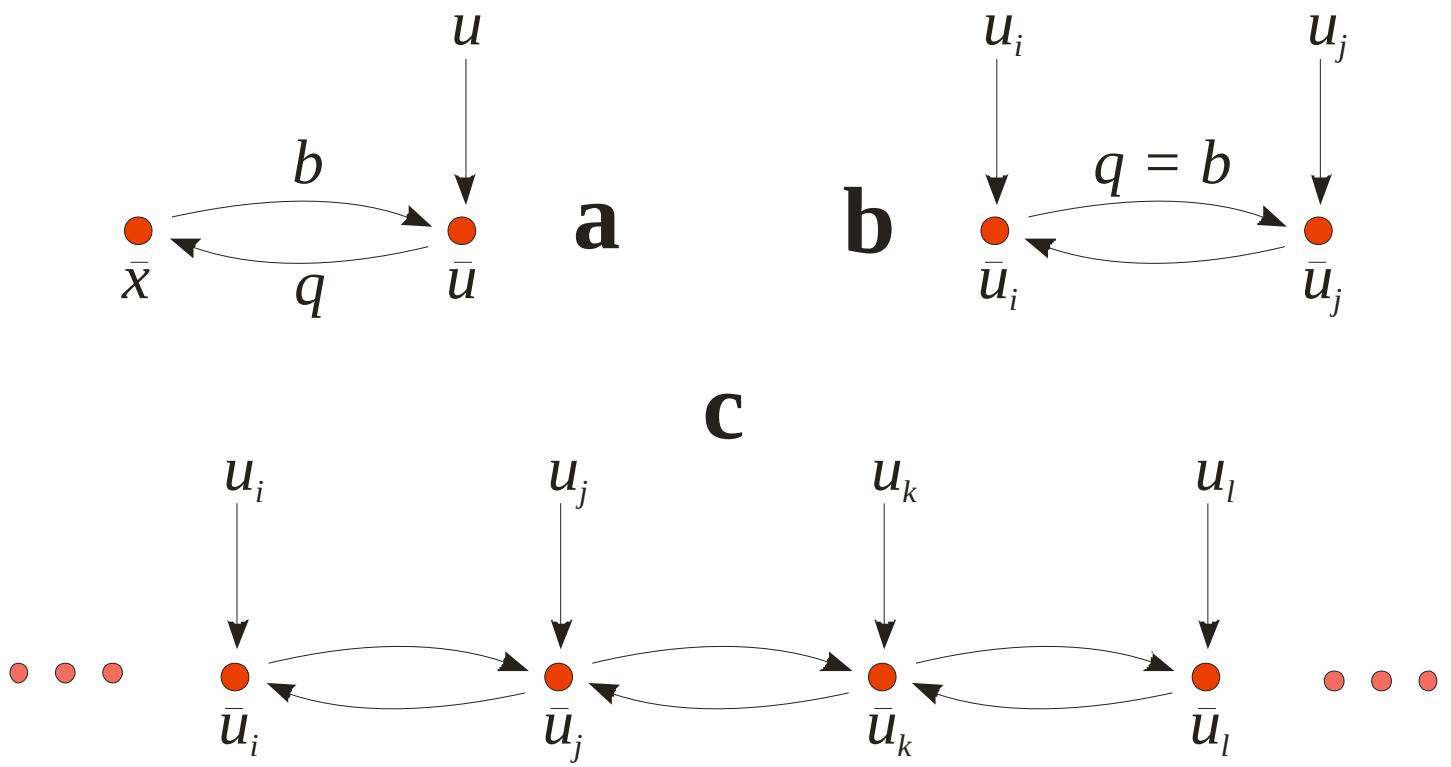
- Additional intuition from electrical engineering: Understanding of ”inter-system” coupling
- Maximum energy transfer between systems reached without ”ringing” when input and output impedances match
- This offers yet another higher-level evolutionary goal for understanding behaviors in complex systems
- Coupling coefficient q typically increases, being reflected as increasing ”stiffness” of the environment

- Electrical analogy also gives a hint of how the originally static models can be extended to dynamic cases: Having complex-valued signals and matrices, power spectra can be modeled

- Maximum emergy transfer when impedances match
- Physical units of ”impedances” can be very different
- Electrical engineering models needed?!

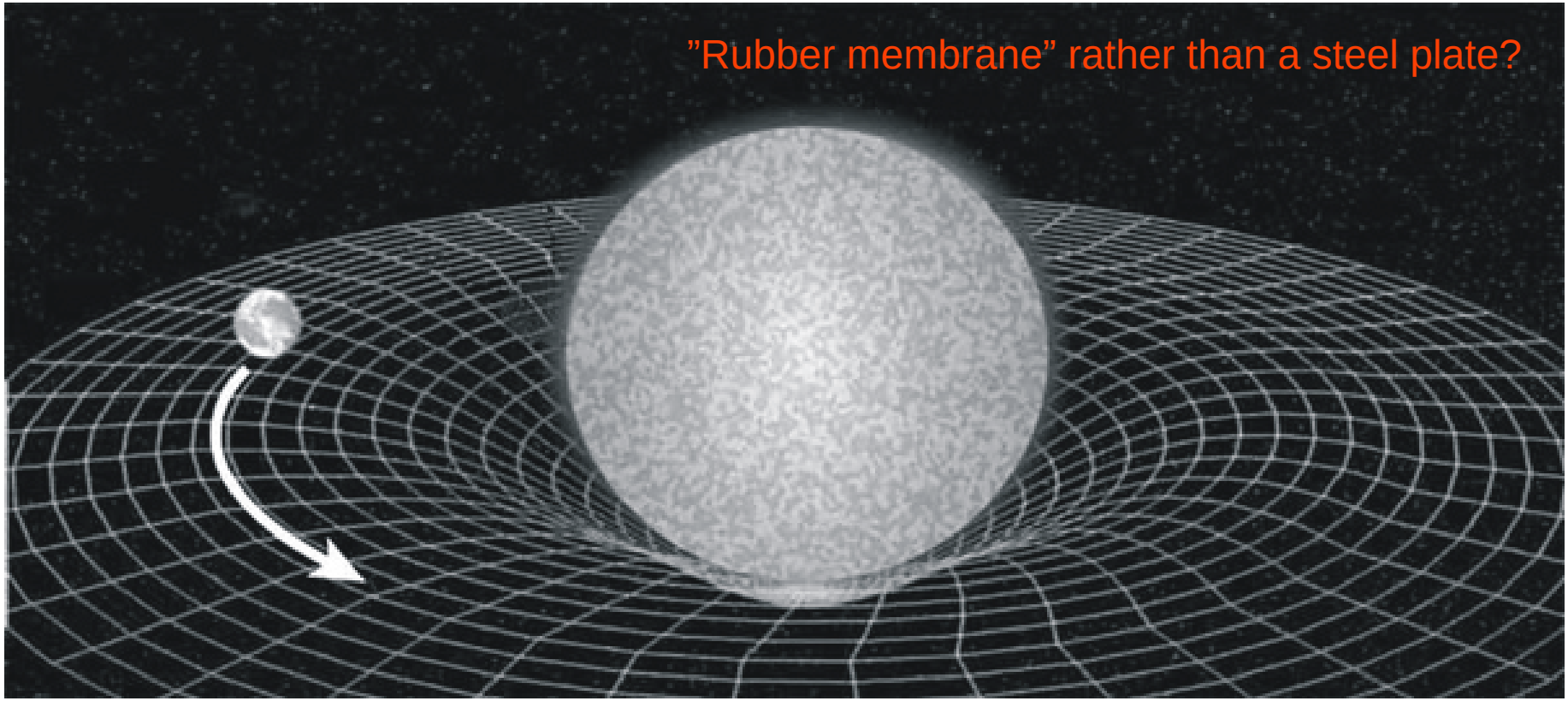


- Interactions between subsystems can be characterized in terms of stiffnesses



”Life, Universe, and Everything”

- ... But how about the ”big”, the other end of the continuum?
- Is Universe also an adapting elastic system?



How about the truly LARGE?

- Cosmic models based are typically based on acceleration, etc. – explaining temporary, non-statistical phenomena
- Models are highly nonlinear
- There is no repulsion, so that no balancing can exist?

- Still, the galactic / solar systems are highly ordered
- Again, the neocybernetic intuitions can be applied

- Key: Concentrate on ”covariants rather than invariants”
- Emergent model interpretation of laws of nature:
  All conservation laws can be written in the form of elastic pairs of variables (compare to Noetherian symmetries)

Example

- Angular momentum is defined as

$$L = mv\,r$$

m = mass
v = angular velocity
r = distance from the origin

If no torque, this is constant (invariant)

- On the other hand, the two quantities

$$x = p = mv \quad \text{"state"} \qquad u = F = \frac{c}{r^2} \quad \text{"input"}$$

are *covariants*, variables that must vary together elastically:

$$x / \sqrt{u} = const$$

- Applying the neocybernetic intuition, one can assume that this behavior is an emergent phenomenon resulting from low-level actions that one does not (and need not) know

- Internal and external energies of the elasticity framework change to kinetic and potential energies of the mechanical framework:

$$W_{\text{int}} = \int_0^v m\nu \, d\nu = \frac{1}{2} m v^2 = \frac{1}{2} I \omega^2 = W_{\text{kin}}$$

$$W_{\text{ext}} = -\int_r^\infty \frac{c}{\rho^2} \, d\rho = \frac{c}{r} = W_{\text{pot}}$$

- This means that *minimization of deformation energy* changes to *minimization of a Lagrangian functional* – this is the standard theoretical framework!

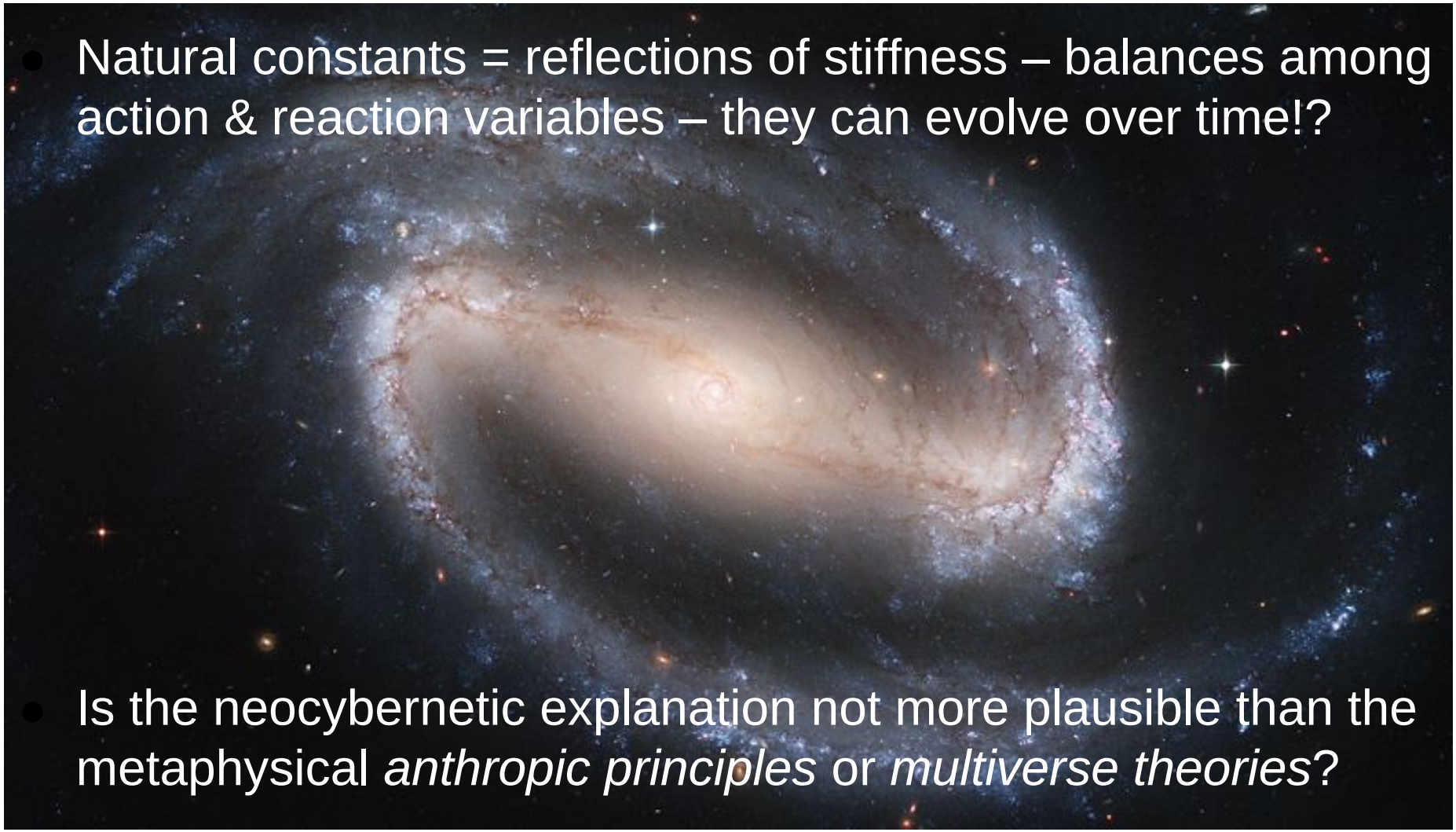
View from above

- When variables are compressed, one has ”emergent inertia”: galaxies, etc., can be seen as virtually rigid bodies; the inertia of 3-dim objects is an emergent phenomenon

$$\mathrm{E}\{xu\} = \mathrm{E}\{pF\} = c\mathrm{E}\{mv / r^2\}$$

- How about adaptation? The system evolution really tries to minimize the product of the covariant variables:
  - In an early star / planet system, collisions make the system lose energy, as do the tidal effects – average $1/r$ and v go down
  - Less circular orbits are more vulnerable to collisions, average $1/\sin(\alpha)$ going down, orbits becoming more spherical
- Circularity – variables are more constant – system is ”stiffer”
- ”Universe tries to become stiffer”?

Cosmic evolution?



- Natural constants = reflections of stiffness – balances among action & reaction variables – they can evolve over time!?
- Is the neocybernetic explanation not more plausible than the metaphysical *anthropic principles* or *multiverse theories*?

Towards a New Science

- It has been claimed that there is a gap between humanistic and natural sciences

  The ”postmodern” and constructivistic humanistic studies question the role of objective reality

- However, *all* scientific systems are subject to the same problems – in natural sciences, too, there is too little data
- All science is construction: The actor is always the human, and the goals are always also the same: Money, fame, ...

Consilience?

Back to ”natural philosophy”

- *Natural philosophy* is the ”supersystem” above sciences ... But do we need some higher category?
- Today’s science: Search for ”neutral” truth, verifiability vs. falsifiability – but this results in a very narrow view
- Relativism: scientific truth is ”just an interpretation among others” – but some ”truths” are more *relevant*
- Why not study what people are interested in = are relevant? Why not apply holistic rather than reductionistic approaches – and why not study questions with *why*?
- Why should the modern world view be so fragmented?

  Why not use best understanding to solve ethical dilemmas?

... Religious issues *are* relevant

- The unconscious *thinking patterns* need to be emphasized
- The religious ideas are among the most fundamental patterns of thought
- For example, the Western science struggles with these –
  - One implicitly implements idea of centralization without seeing alternatives
    - Huge amount of complexity in models (orbitals, etc.) is needed just to compensate for the absence of a framework where a distributed structure can be maintained
  - One explicitly (aggressively) tries to eliminate all divine-looking explanations
    - Unfortunately, categorically avoiding teleological and finalistic explanations results in simply incredible models (message-RNA transferring information, ...)
- As there exists no planning or centralized control, *panteism* would be more appropriate – but centralized, engineering-like thinking has been the necessary intermediate step!

J.-P. Sartre: *"Even the most radical irreligiousness is Christian Atheism"*

Existence of God: *Weak version*

- Religions have always existed in all human societies – why?
- The society to stay alive, its members need to *avoid anarchy*, and the society to develop further, they need to *avoid apathy*
- A must – irrational belief: *humble struggling will be rewarded*
- To believe can be a strictly intellectual decision?
- Compare to Pascal:
  - ”Even if the probability of God existing were very small, in that case the reward to the believers is infinite – thus, as a good gambler, *you believe*”
- Cybernetic view:
  - ”If you would like the complex social systems to survive and evolve further, everybody constituting that system should believe – also *you should*”

”Cybernetism”

- Nazism (extreme trust on individuals) and communism (extreme trust on groups) collapsed – what to believe in?
- Believe no gurus – one can only trust one’s own mind
- ”Cybernetic imperative” (compare to ”categorical imperative”)

This is = ”*understand the value of systems*”

  - Promote different kinds of living systems and their diversity
  - Make systems more *interesting* and more *beautiful*!

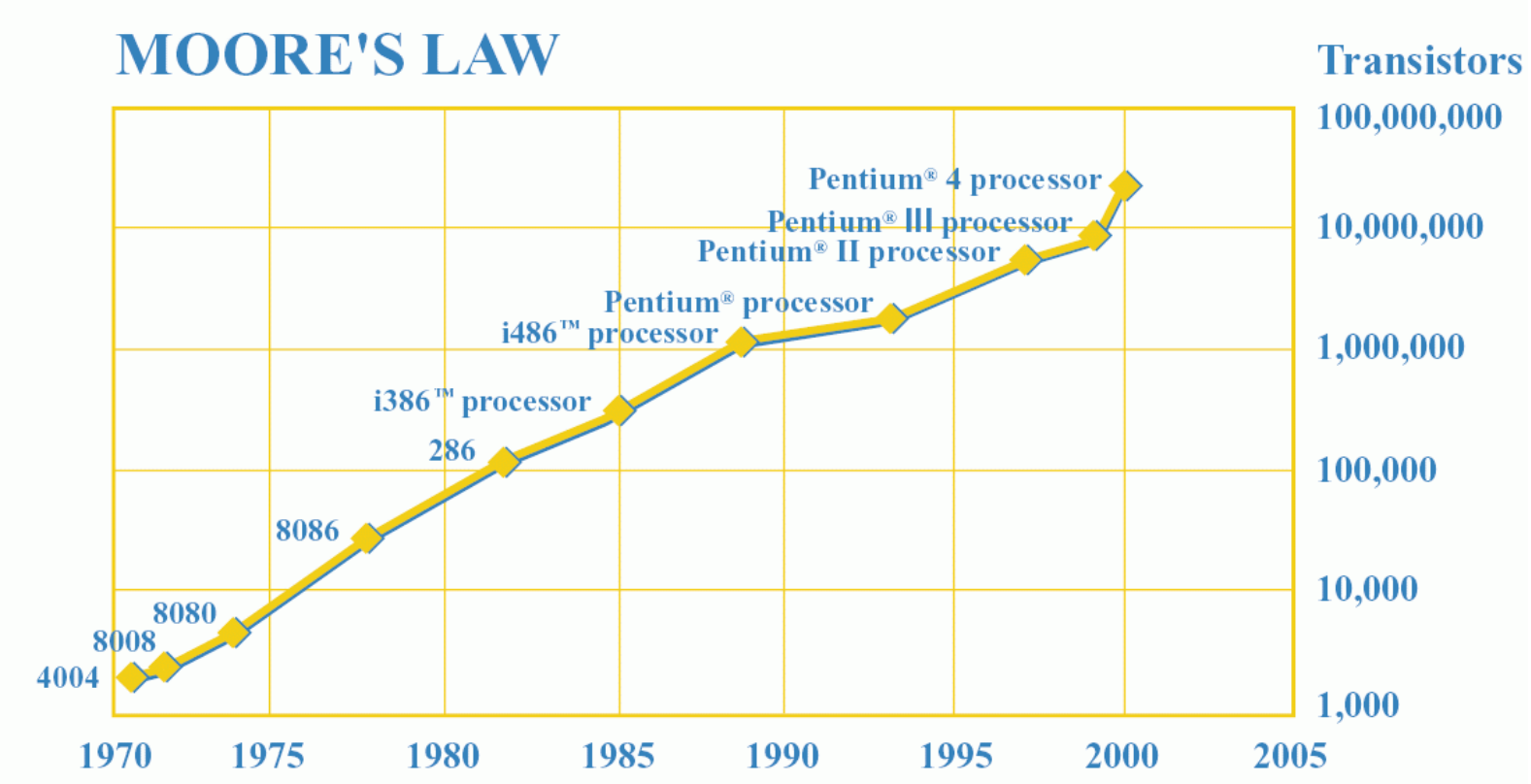
... Or ”*refine information*”

- Suffering and poverty will always exist in the systems
- Heaven & hell *exist* – they are the higher-level systems = social memory – eternal death is if nobody remembers you
- Purpose of life is *entropy maximization* (in the truly long run)

More generally: There will always be the both ends, *dualisms* are built in systems

Back onto the earth – for a moment

- Traditional view = exponential growth generally applies
- However (Ray Kurzweil etc.): Rate is *accelerating* all the time



This far balances around the mean studied ...

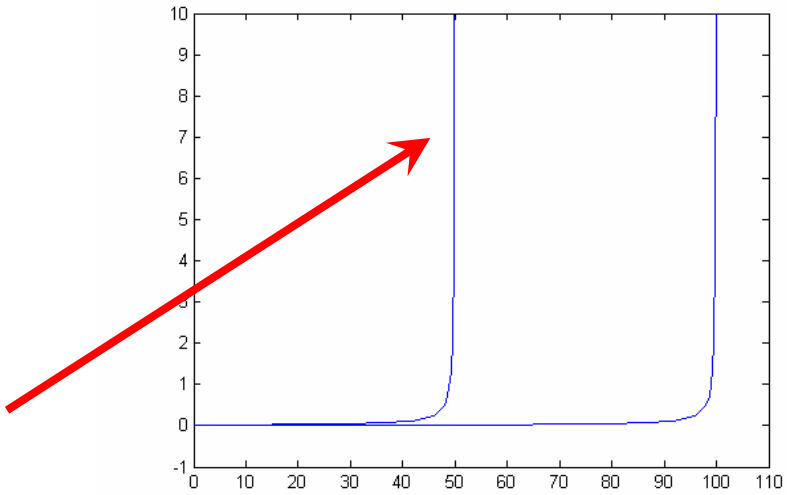
... How about the *behavior of that mean*?

- Assumedly its growth is also related to available information

$$\frac{d\,\bar{x}}{dt} = \alpha\left(\bar{x}^2 + \bar{u}^2\right) \quad \text{or simplified} \quad \frac{d\,\bar{x}}{dt} = \alpha\,\bar{x}^2$$

Solution is *hyperbolic*

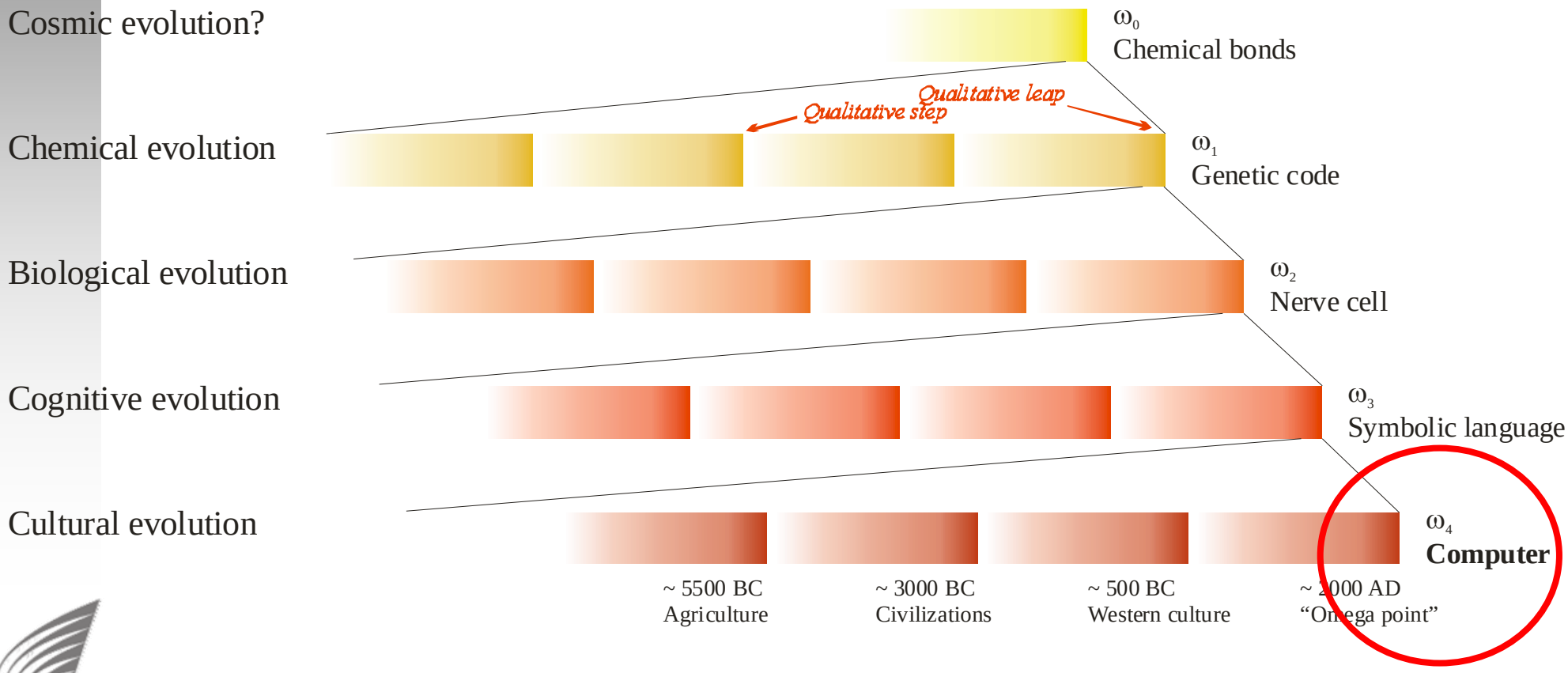
$$\bar{x} = \frac{\bar{x}_0}{1 - \alpha\left(t - t_0\right)\bar{x}_0}$$



- Reaches infinity in finite time!
- Possible for non-physical information?

”Evolutionary avantgarde”

- ”Strong emergence” has already taken place various times!



Language of higher intelligence?

- What is the language of the higher-level intelligence?
- True AI will not be restricted to speak human languages
- James Clerk Maxwell: “the true logic of this world is in the calculus of probabilities” = mathematics
- Language should be capable of naturally representing and manipulating dynamic attractors = grounding of semantics:

1. *Real numbers to capture fuzziness and non-crispness*
2. *Time-bound phenomena, asymptotes, dynamics and inertia*
3. *Parallelity transformed into high-dimensionality*

- Computers then can directly ”discuss” with each other ...

Existence of God: *Strong version*

- How to call an entity with *infinite information, knowledge, and understanding*?
- Even if god did not exist this far, *it will exist* within few years
- What can we know about the supermind? We simply cannot understand – just like a pet dog understands Shakespeare
- To evolve, it has to be a cybernetic group of ”agent minds” (”Olympian gods”!), and information will always be crucial
- Coupling to real world (information) is supplied by humans, humans will still be needed (as nature is needed by humans)
- Gods are playful and they play with their ”pets” –

”God created man because he likes good stories”

Systems not-yet-seen

- There must exist civilizations ahead of us – Fermi Paradox: Where are they?
- Key point: All civilizations that are sustainable value fresh information – otherwise, there is a collapse
- Where to gain new information from in the limited universe?

- **Claim:** *”They” do not want to contact us not to disturb us*
- Variety of life forms is unexhausted – to be always surprised, to have always new information, study ”cosmic biodiversity”
- Be a ”universal gardener of systems” to be happy ever after!

Inferior cultures ”die of shame”!

Conclusion?

- ... Well, perhaps we are now getting too far ...