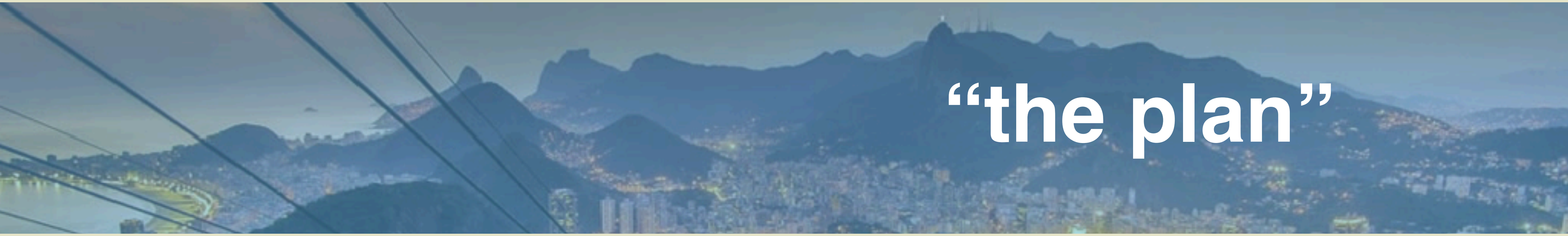
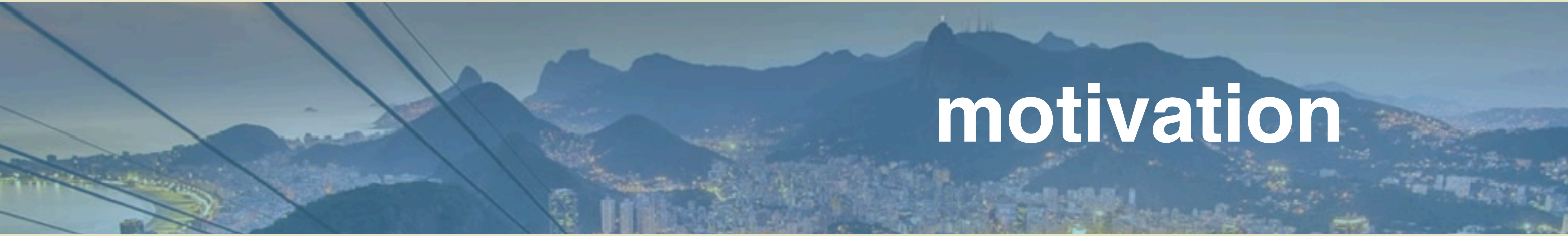

Welcome
to
CBPF Python Summer Camp 2018



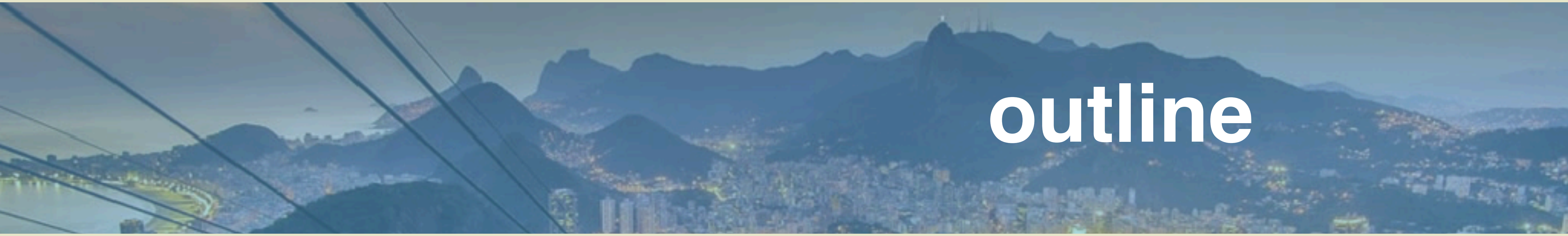
“the plan”

* work in small groups on projects
* “mão na massa”
* no lectures only discussions!
* presentation of results in last week



motivation

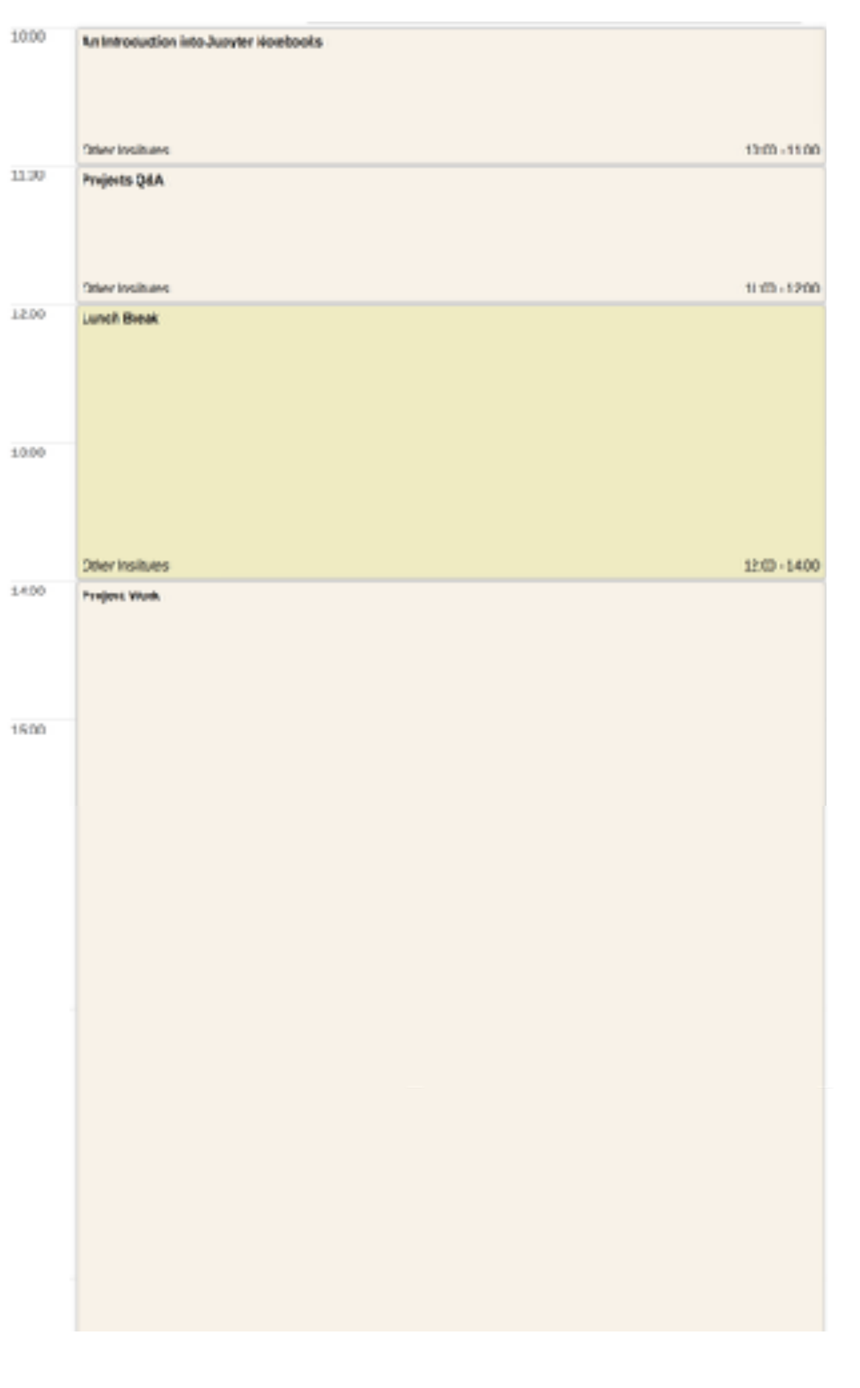
* develop expertise in scientific computation
* connect people with different backgrounds
* increase discussions & collaborations
* bridge gap between academia and "outside world"



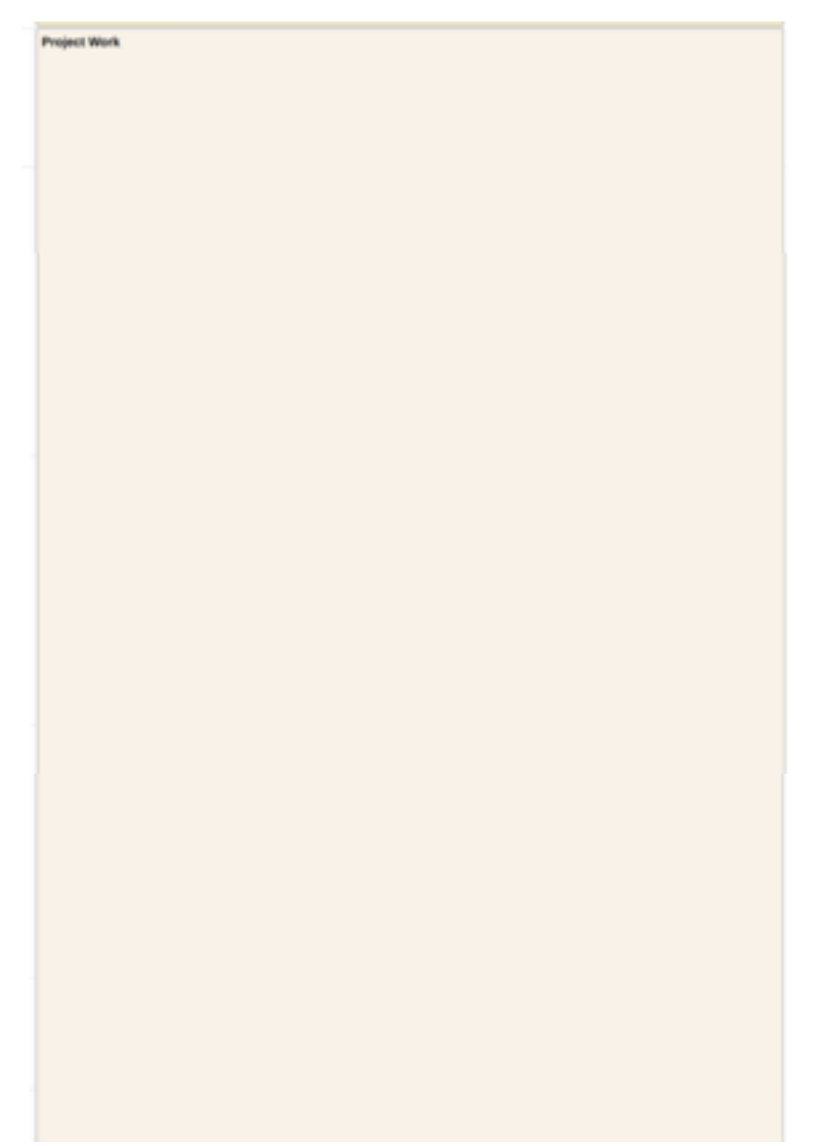
outline

monday

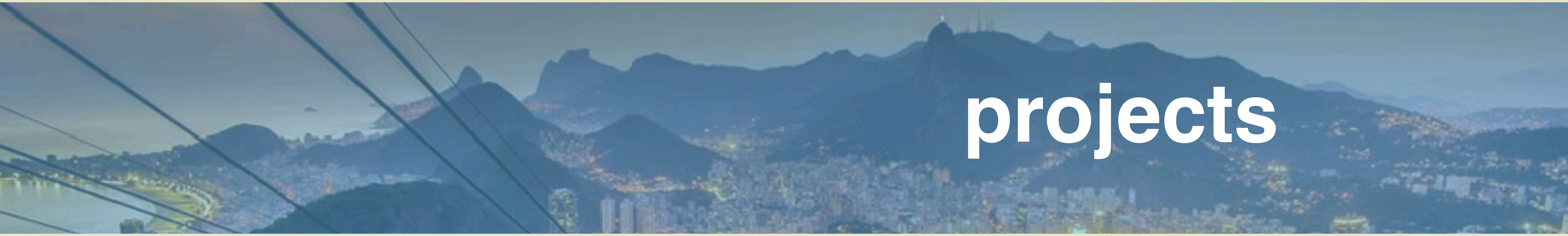
tuesday



wednesday/thursday/friday



second week:
t.b.a. during the week



projects

* condensed matter
* machine learning
* particle physics

project details

condensed matter:

project 1: topological insulators

project 2: dynamical systems

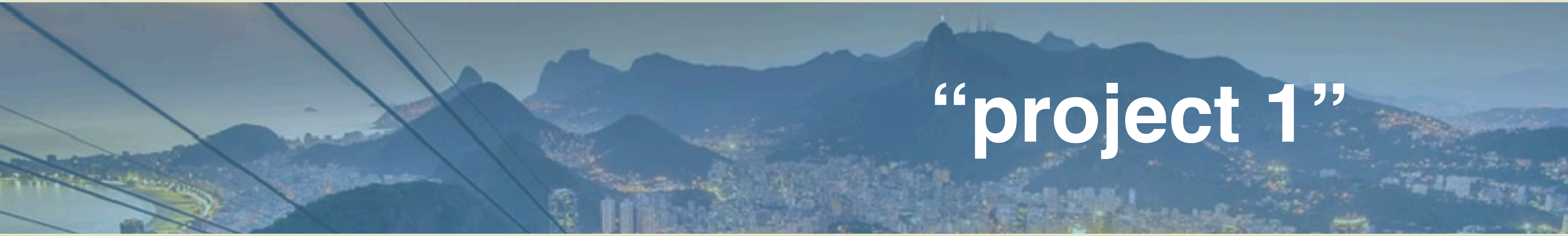
machine-learning:

project 3: from KNN to neural networks

particle physics:

project 4: Z0 cross-section measurement

project 5: top-quark cross-section measurement



topological insulators

from symmetry to topology

symmetry group p4

symmetry group p31m

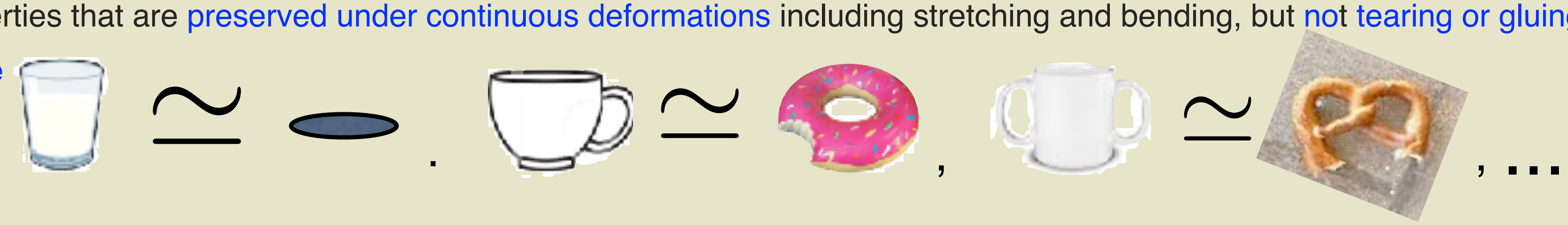
symmetry principle to organize matter:
"what symmetry-operations leave system invariant?" (group theory)

topological ideas to organize matter:
"what stays the same when system is deformed?" (topology)

topology = mathematical study of shapes (spaces)

rules of the game: properties that are preserved under continuous deformations including stretching and bending, but not tearing or gluing

topological equivalence

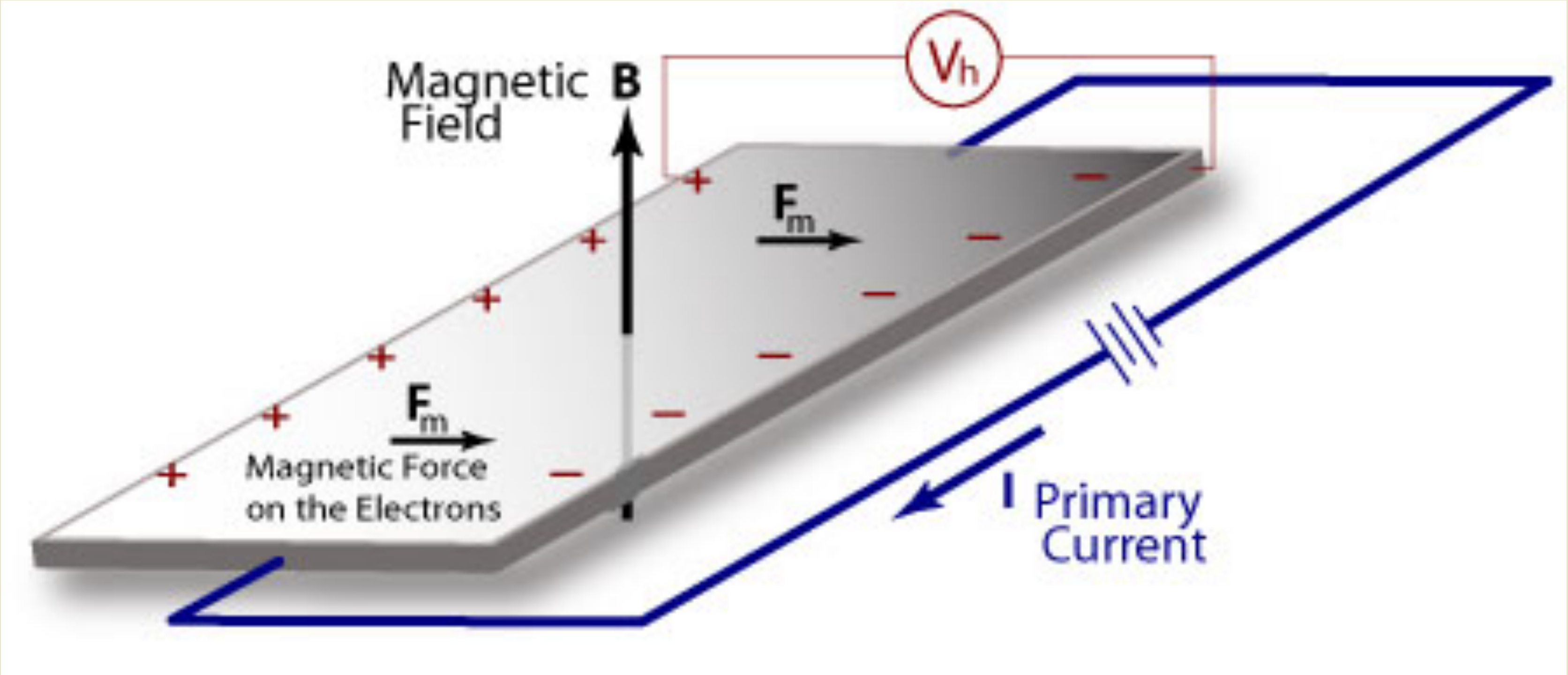


topological equivalent insulators/superconductors $\hat{H} \simeq \hat{H} + \delta\hat{H}$

rules of the game: continuous deformations of Hamiltonian that preserve property of Hamiltonian (here: system remains gap for excitations!)

history: quantum-hall effect

two-dimensional electron-gas in a **strong** (perpendicular) **magnetic field**

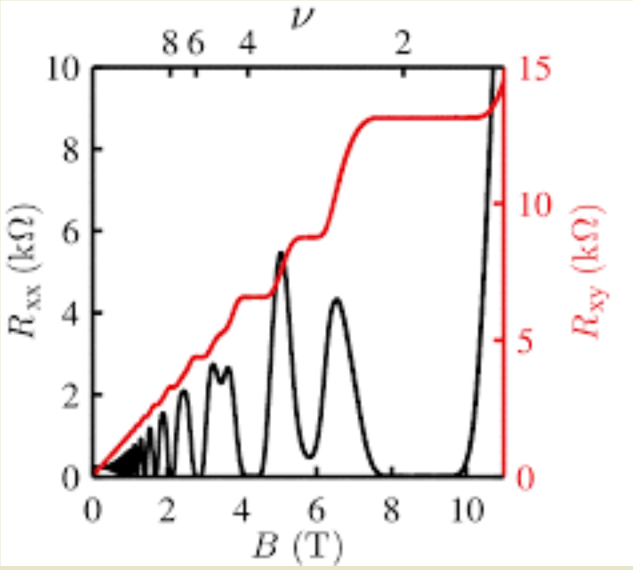


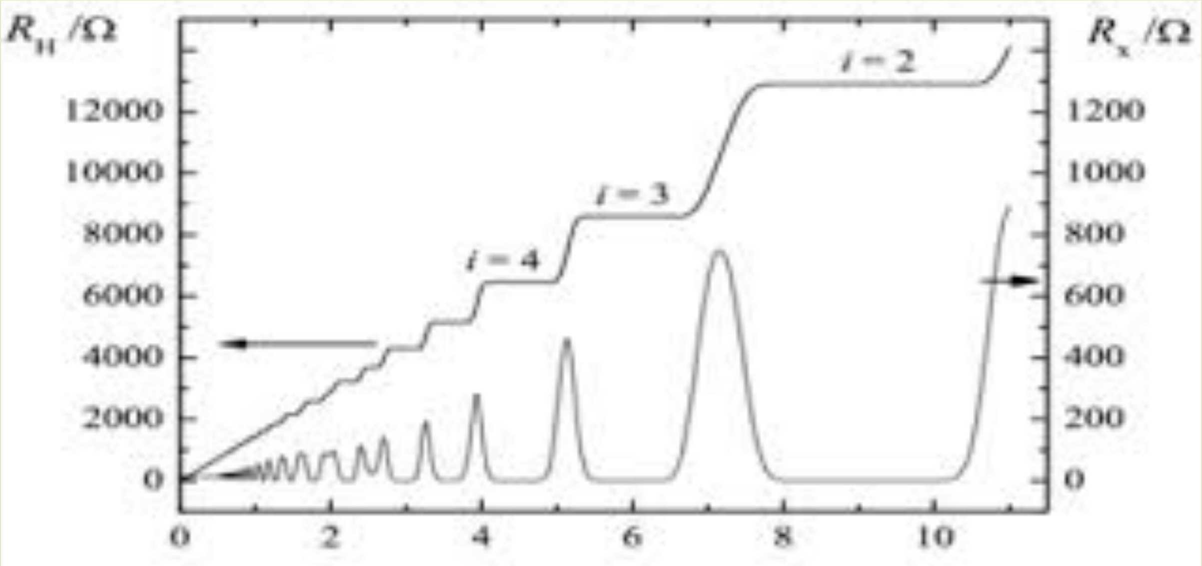
longitudinal resistance

$$R_{xx}$$

perpendicular (Hall-) resistance

$$R_{xy}$$

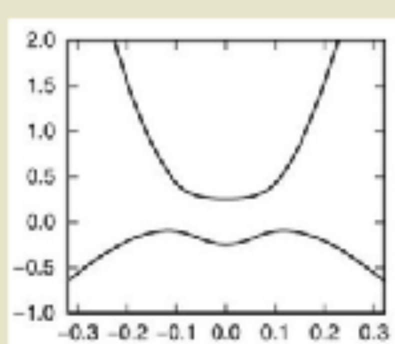




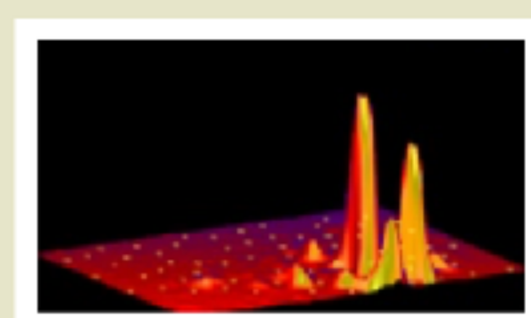
the “topological insulator revolution”

Symmetry				d							
AZ	Θ	Ξ	Π	1	2	3	4	5	6	7	8
A	0	0	0	0	$\mathbb{Z}$	0	$\mathbb{Z}$	0	$\mathbb{Z}$	0	$\mathbb{Z}$
AIII	0	0	1	$\mathbb{Z}$	0	$\mathbb{Z}$	0	$\mathbb{Z}$	0	$\mathbb{Z}$	0
AI	1	0	0	0	0	0	$\mathbb{Z}$	0	$\mathbb{Z}_2$	$\mathbb{Z}_2$	$\mathbb{Z}$
BDI	1	1	1	$\mathbb{Z}$	0	0	0	$\mathbb{Z}$	0	$\mathbb{Z}_2$	$\mathbb{Z}_2$
D	0	1	0	$\mathbb{Z}_2$	$\mathbb{Z}$	0	0	0	$\mathbb{Z}$	0	$\mathbb{Z}_2$
DIII	-1	1	1	$\mathbb{Z}_2$	$\mathbb{Z}_2$	$\mathbb{Z}$	0	0	0	$\mathbb{Z}$	0
AII	-1	0	0	0	$\mathbb{Z}_2$	$\mathbb{Z}_2$	$\mathbb{Z}$	0	0	0	$\mathbb{Z}$
CII	-1	-1	1	$\mathbb{Z}$	0	$\mathbb{Z}_2$	$\mathbb{Z}_2$	$\mathbb{Z}$	0	0	0
C	0	-1	0	0	$\mathbb{Z}$	0	$\mathbb{Z}_2$	$\mathbb{Z}_2$	$\mathbb{Z}$	0	0
CI	1	-1	1	0	0	$\mathbb{Z}$	0	$\mathbb{Z}_2$	$\mathbb{Z}_2$	$\mathbb{Z}$	0

clean systems (band insulators)

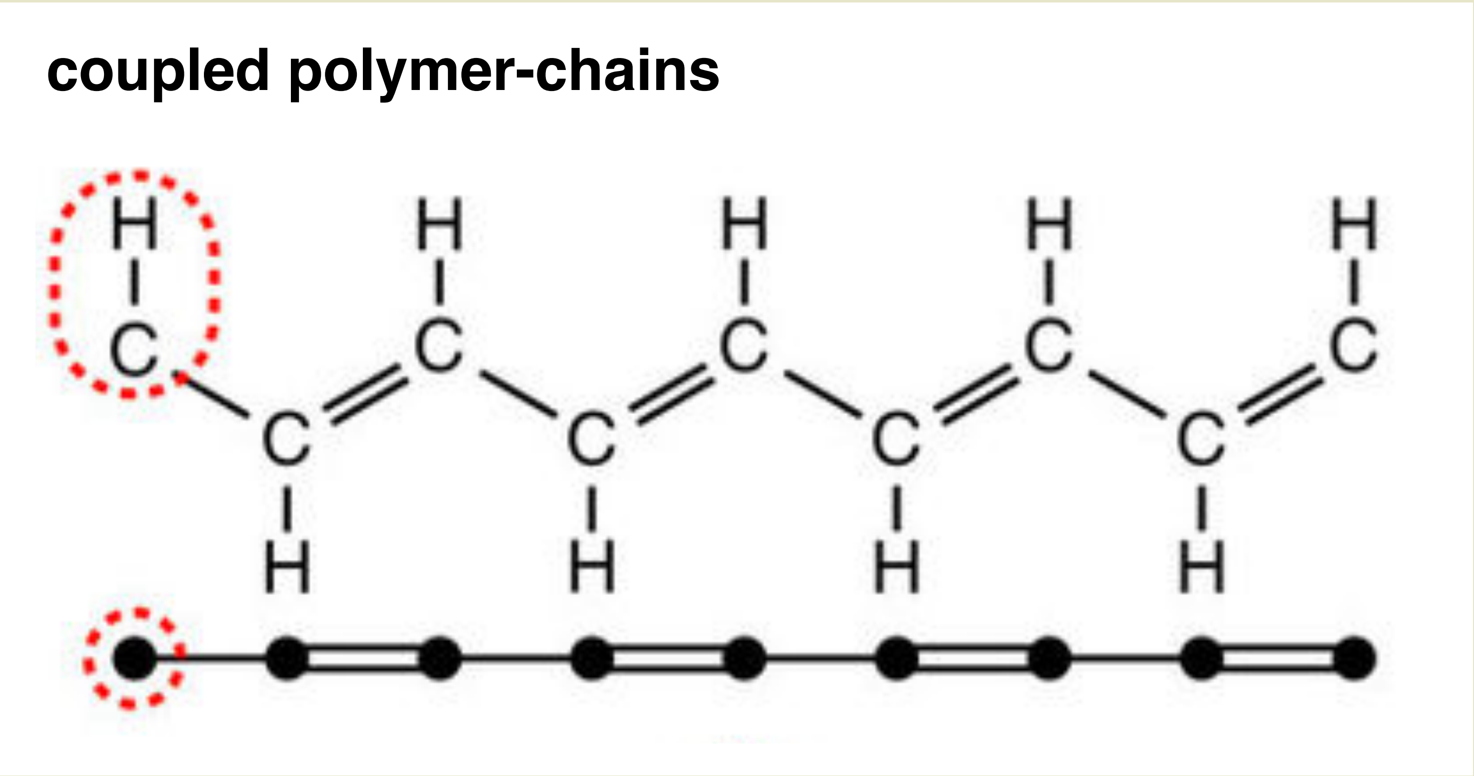


disordered systems (Anderson insulators)



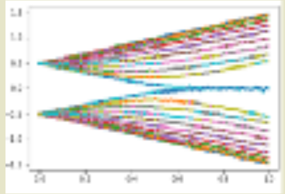
project-outline:

coupled polymer-chains

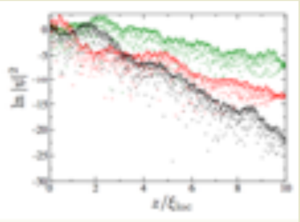


Symmetry				d							
AZ	Θ	Ξ	Π	1	2	3	4	5	6	7	8
A	0	0	0	0	$\mathbb{Z}$	0	$\mathbb{Z}$	0	$\mathbb{Z}$	0	$\mathbb{Z}$
AIII	0	0	1	$\mathbb{Z}$	0	$\mathbb{Z}$	0	$\mathbb{Z}$	0	$\mathbb{Z}$	0
AI	1	0	0	0	0	0	$\mathbb{Z}$	0	$\mathbb{Z}_2$	$\mathbb{Z}_2$	$\mathbb{Z}$
BDI	1	1	1	$\mathbb{Z}$	0	0	0	$\mathbb{Z}$	0	$\mathbb{Z}_2$	$\mathbb{Z}_2$
D	0	1	0	$\mathbb{Z}_2$	$\mathbb{Z}$	0	0	0	$\mathbb{Z}$	0	$\mathbb{Z}_2$
DIII	−1	1	1	$\mathbb{Z}_2$	$\mathbb{Z}_2$	$\mathbb{Z}$	0	0	0	$\mathbb{Z}$	0
AII	−1	0	0	0	$\mathbb{Z}_2$	$\mathbb{Z}_2$	$\mathbb{Z}$	0	0	0	$\mathbb{Z}$
CII	−1	−1	1	$\mathbb{Z}$	0	$\mathbb{Z}_2$	$\mathbb{Z}_2$	$\mathbb{Z}$	0	0	0
C	0	−1	0	0	$\mathbb{Z}$	0	$\mathbb{Z}_2$	$\mathbb{Z}_2$	$\mathbb{Z}$	0	0
CI	1	−1	1	0	0	$\mathbb{Z}$	0	$\mathbb{Z}_2$	$\mathbb{Z}_2$	$\mathbb{Z}$	0

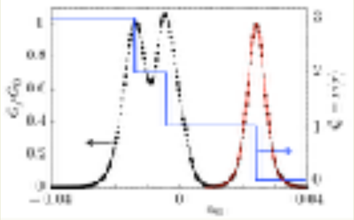
-**clean system:** band-insulator

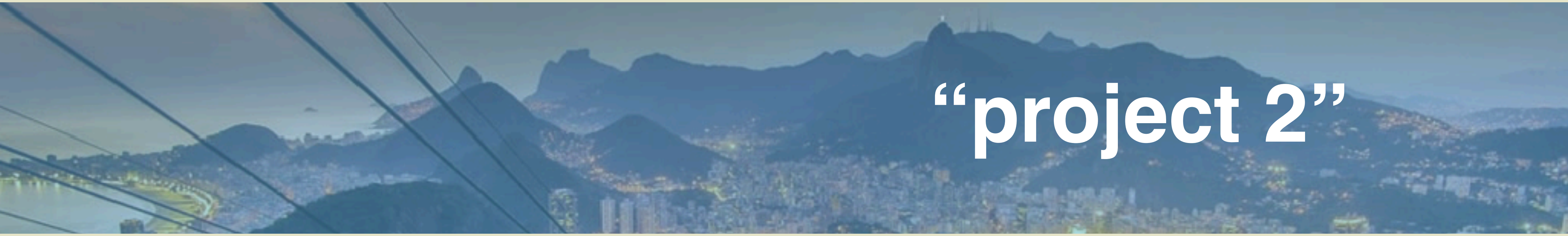


-**disordered system**: Anderson insulators



-“class AIII **topological-Anderson insulator**”

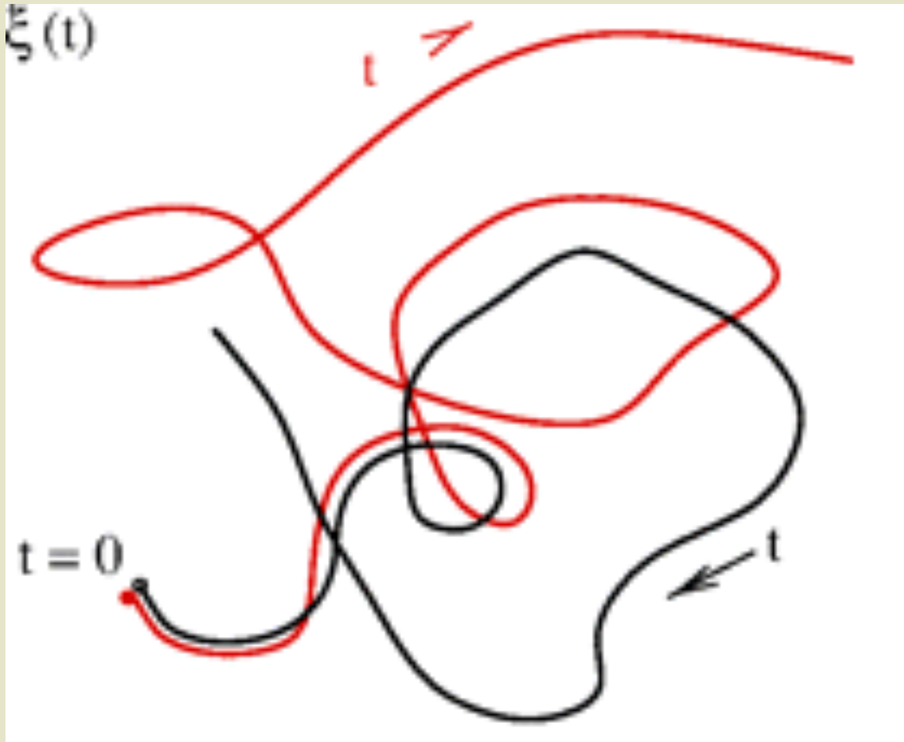




“project 2”

dynamical systems

classical chaos

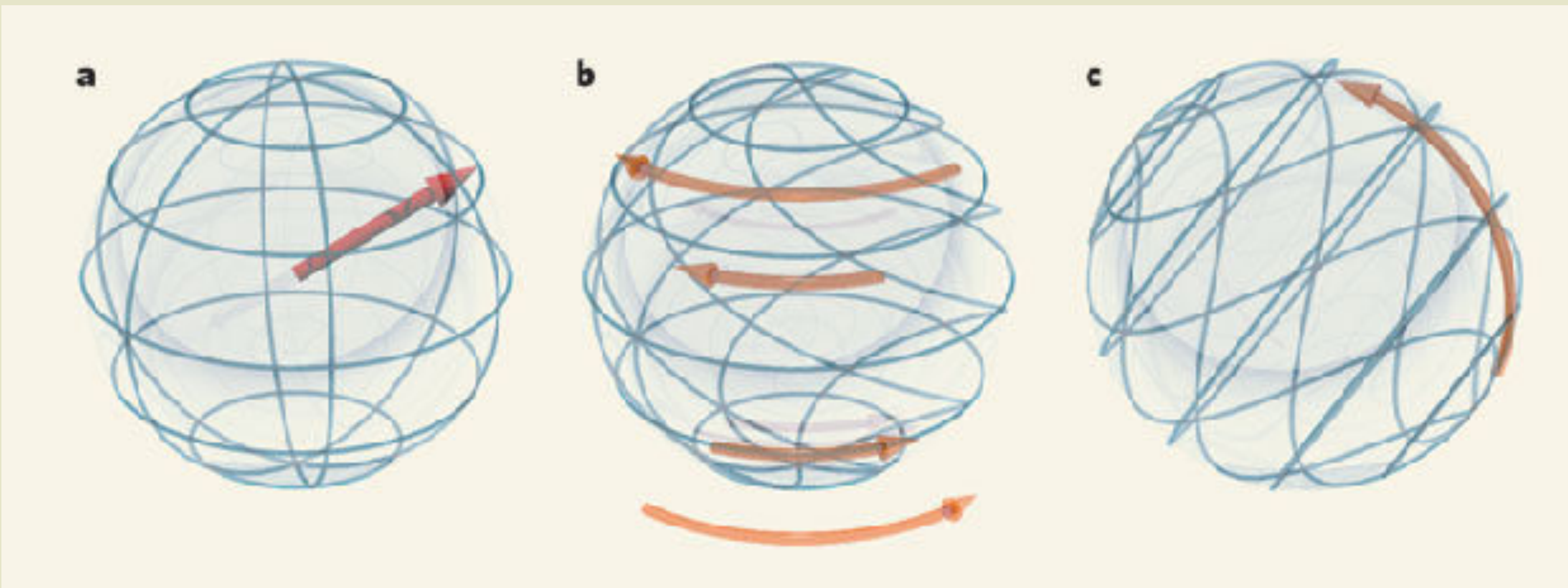


“butterfly effect”
(exponential sensitivity to initial conditions)

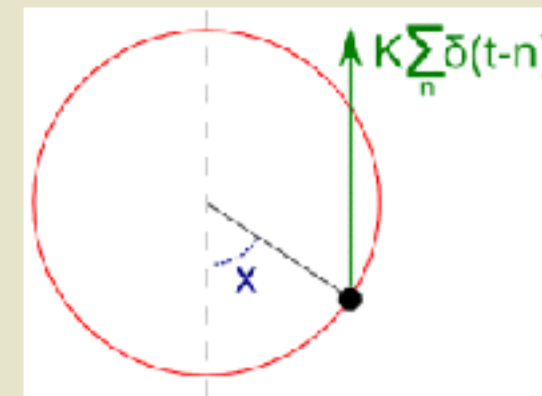
“ergodicity”

two periodically kicked systems

A. **kicked top**



B. **kicked rotor**



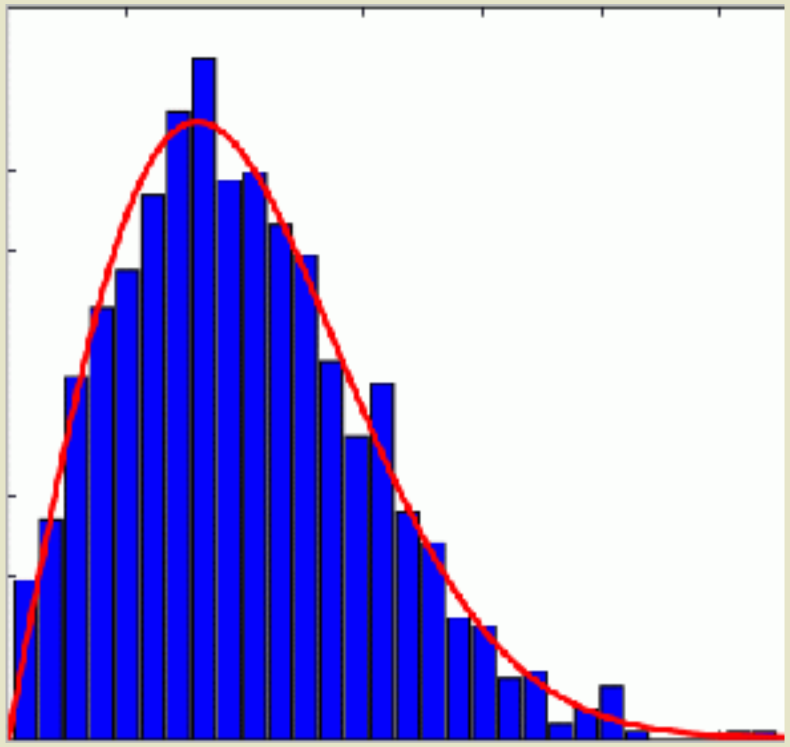
$$\hat{H} = \hat{H}_0 + \hat{V} \sum_{n=-\infty}^{\infty} \delta(t-n)$$

- both show classical regular and chaotic dynamics
- explore their quantum dynamics...

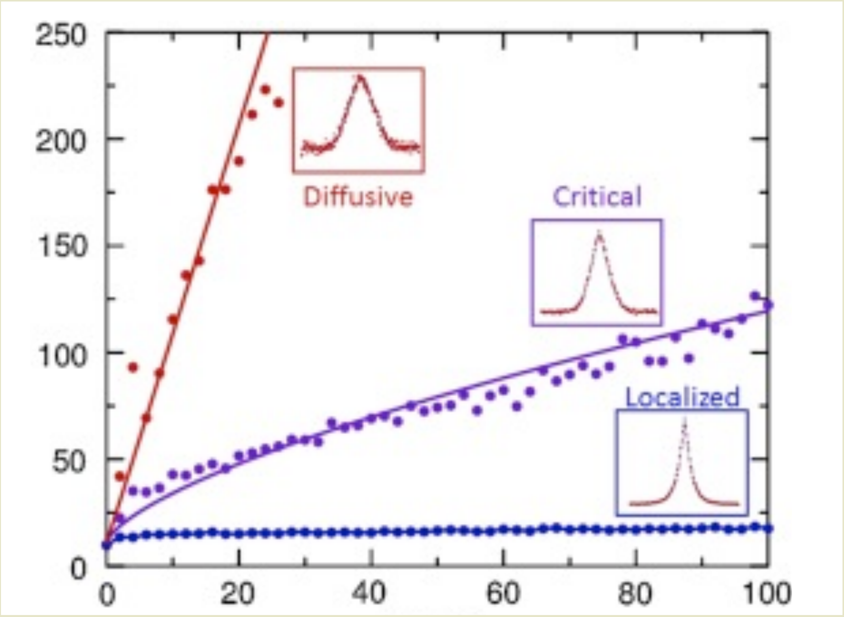
quantum signatures

* spectral properties

* random matrices

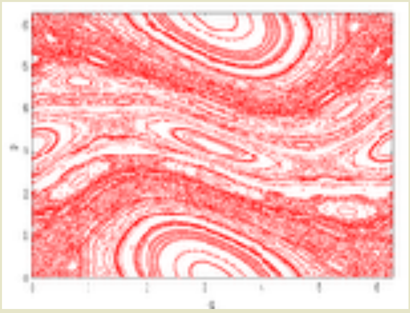


* dynamical localization

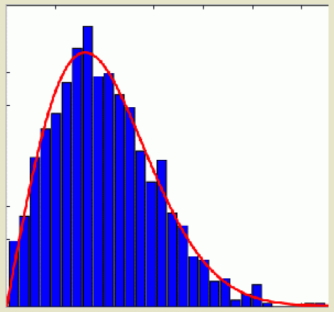


project outline

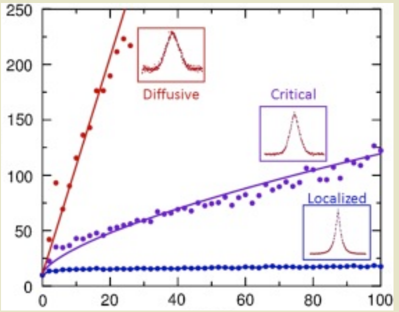
-**classical dynamics** in phase space



-**random matrices**



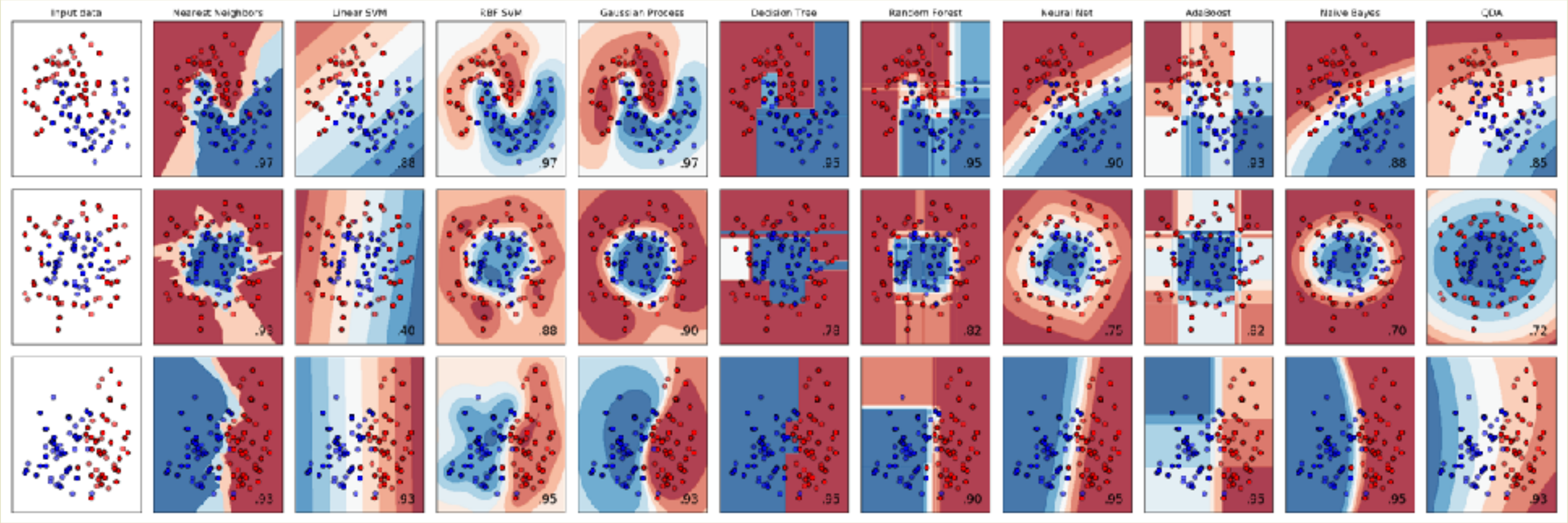
-**spectral** statistics and **quantum diffusion**



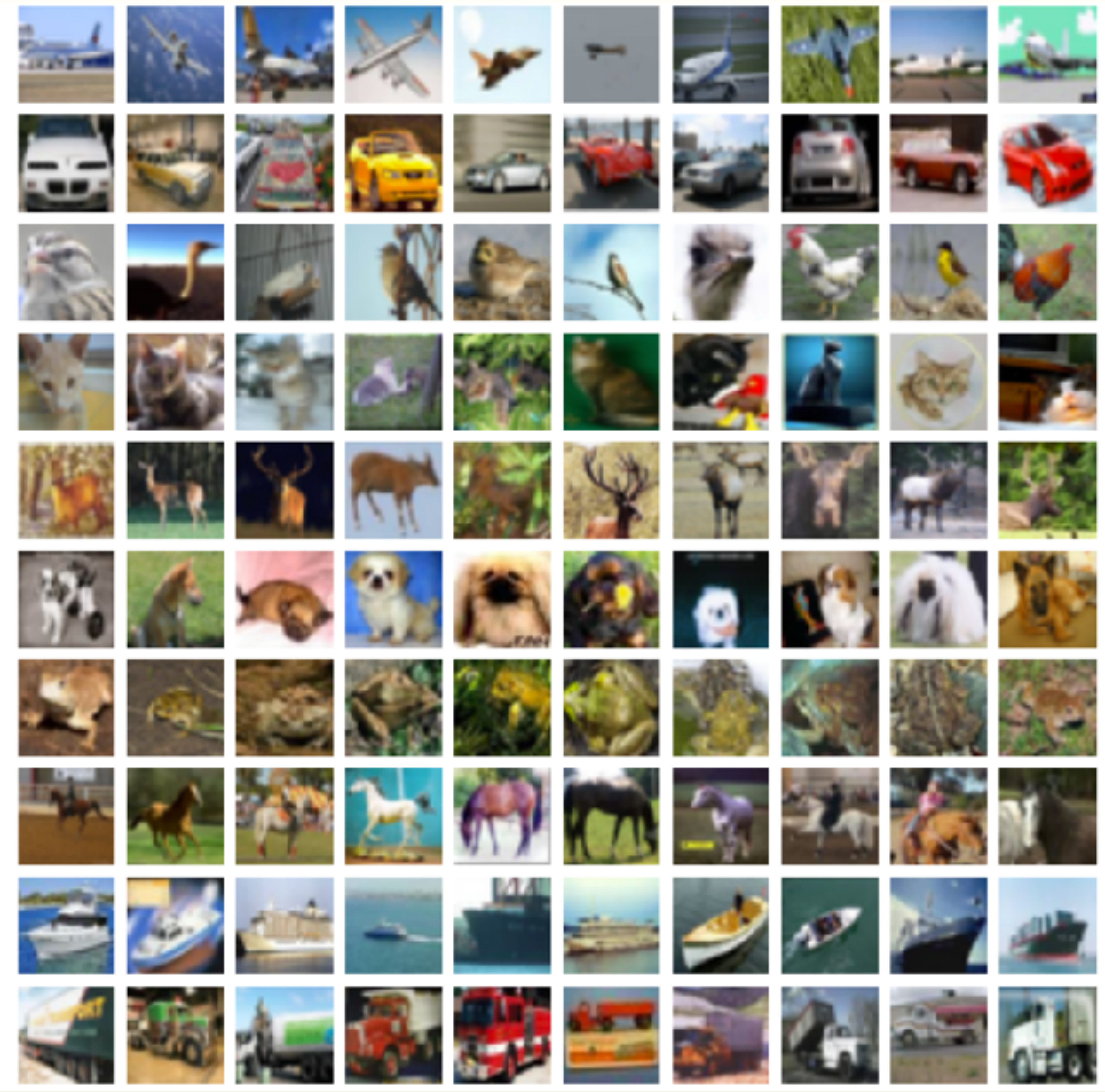
“project 3”

machine-learning

Learning From Data



"In God we trust. All others bring data."
W. Edwards Deming (1900–1993)



If I asked you what a tree is...

tree

/trē/

noun

1. a woody perennial plant, typically having a single stem or trunk growing to a considerable height and bearing lateral branches at some distance from the ground.
2. a wooden structure or part of a structure.

verb

1. NORTH AMERICAN
   force (a hunted animal) to take refuge in a tree.
2. (of an area) planted with trees.
   "sparsely treed grasslands"

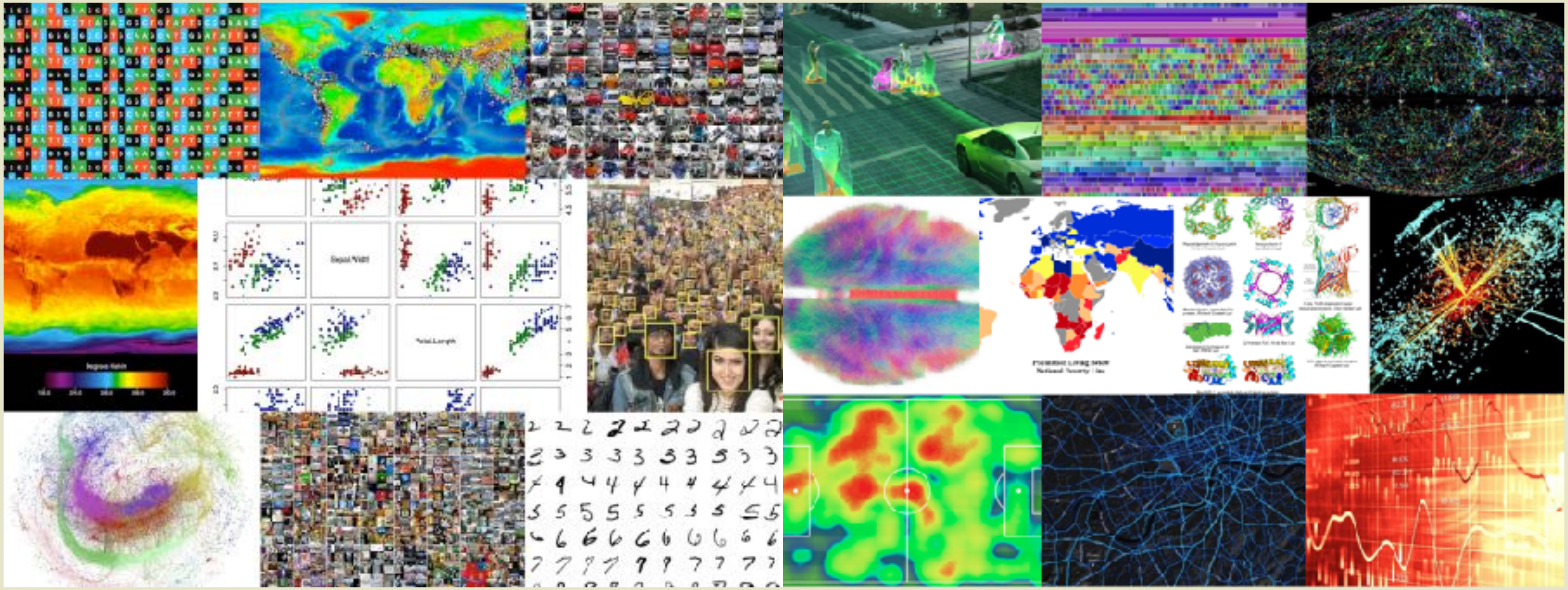
...wouldn’t it be much easier

to simply show me some?

As per Wikipedia,

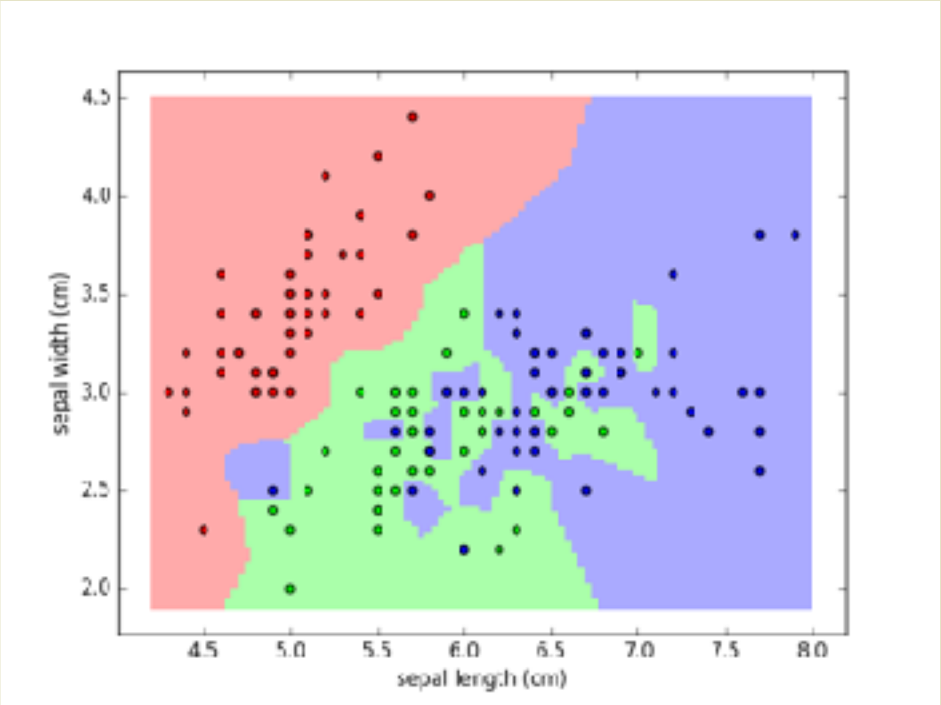
“Machine learning is a field of computer science that gives computers the ability to learn without being explicitly programmed.”

And there is plenty of data to learn from!



So here are the proposed projects!

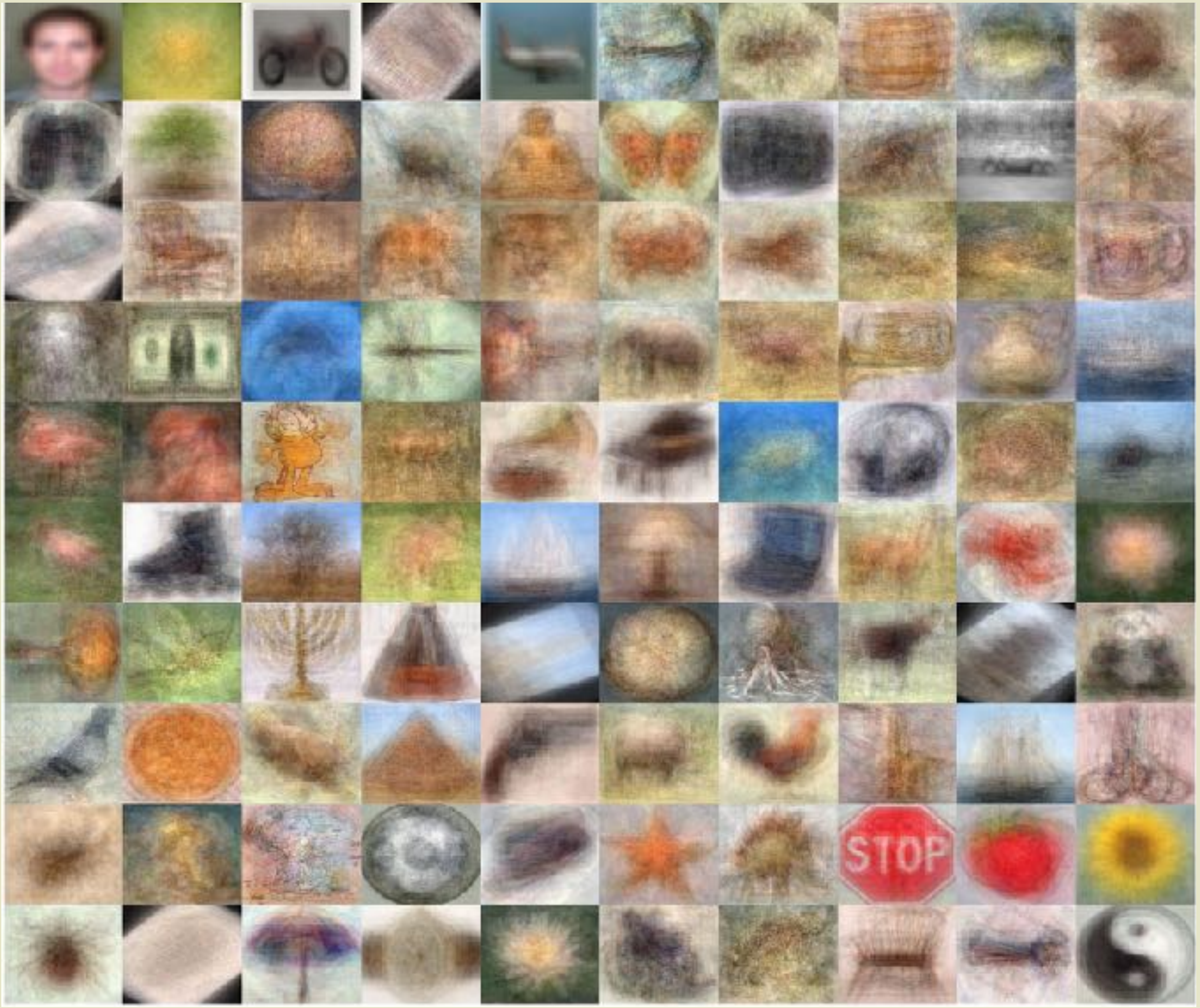
1. Classify the Iris dataset with the KNN and PLA algorithms (easy)



2. Use Gradient Descent with Logistic Regression or SVMs to tackle the MNIST (medium)

3. Train a Deep Neural Net with Backpropagation to recognize cats in images (hard)

Have fun!



“projects 4/5”

particles: after lunch…