UNIVERSITY OF CALIFORNIA SANTA CRUZ

An introduction to Machine Learning for Astronomy

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université PARIS DIDEROT
institut universitaire de France
INSTITUTO DE ASTROFISICA DE CANARIAS · IAC ·

PROGRAM FOR THE WEEK

- INTRODUCTION TO SUPERVISED ML
- FOUNDATIONS TO NEURAL NETWORKS
- CONVOLUTIONAL NEURAL NETWORKS
- INTRODUCTION TO UNSUPERVISED ML

PRACTICAL INFO

FULL ONLINE COURSE VIA ZOOM:

https://rediris.zoom.us/j/99594075110?pwd=Y0dFcTVZWFFqb0xUQm41NWpweWs5dz09

Meeting ID: 995 9407 5110
Password: 842832

MORNING ~[9h30-12h30]: THEORY / LECTURES

AFTERNOON ~[14H30-17H30]: TUTORIALS

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SOME RULES DURING THE ZOOM MEETING:

Keep your Microphones Muted

If need to ask questions (which I recommend!) use the “raise hand” option

PRACTICAL INFO

OTHER AVAILABLE RESSOURCES:

GITHUB REPO WITH SLIDES AND TUTORIALS:

https://github.com/mhuertascompany/DL_ED127_2020

Slack Channel for interactive discussions / questions:

https://join.slack.com/t/iaed127/shared_invite/zt-f5sohajk-uP00KQtWdaPIC_Znw6H2EA

SOME PRELIMINARY NOTES

I AM NOT A MACHINE LEARNING RESEARCHER

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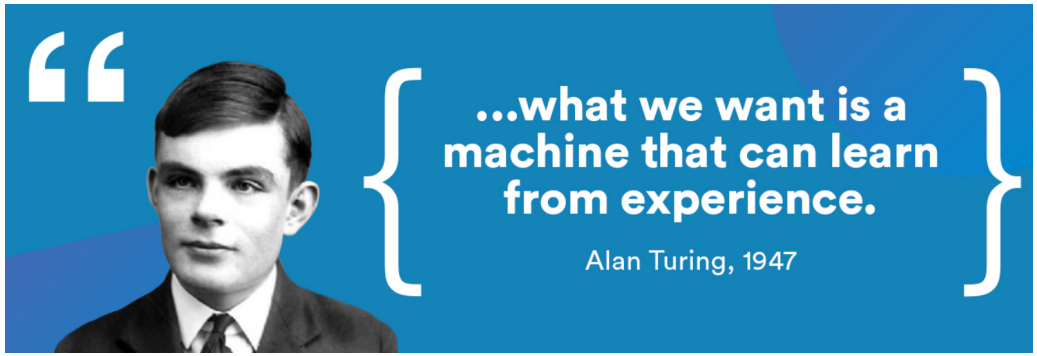
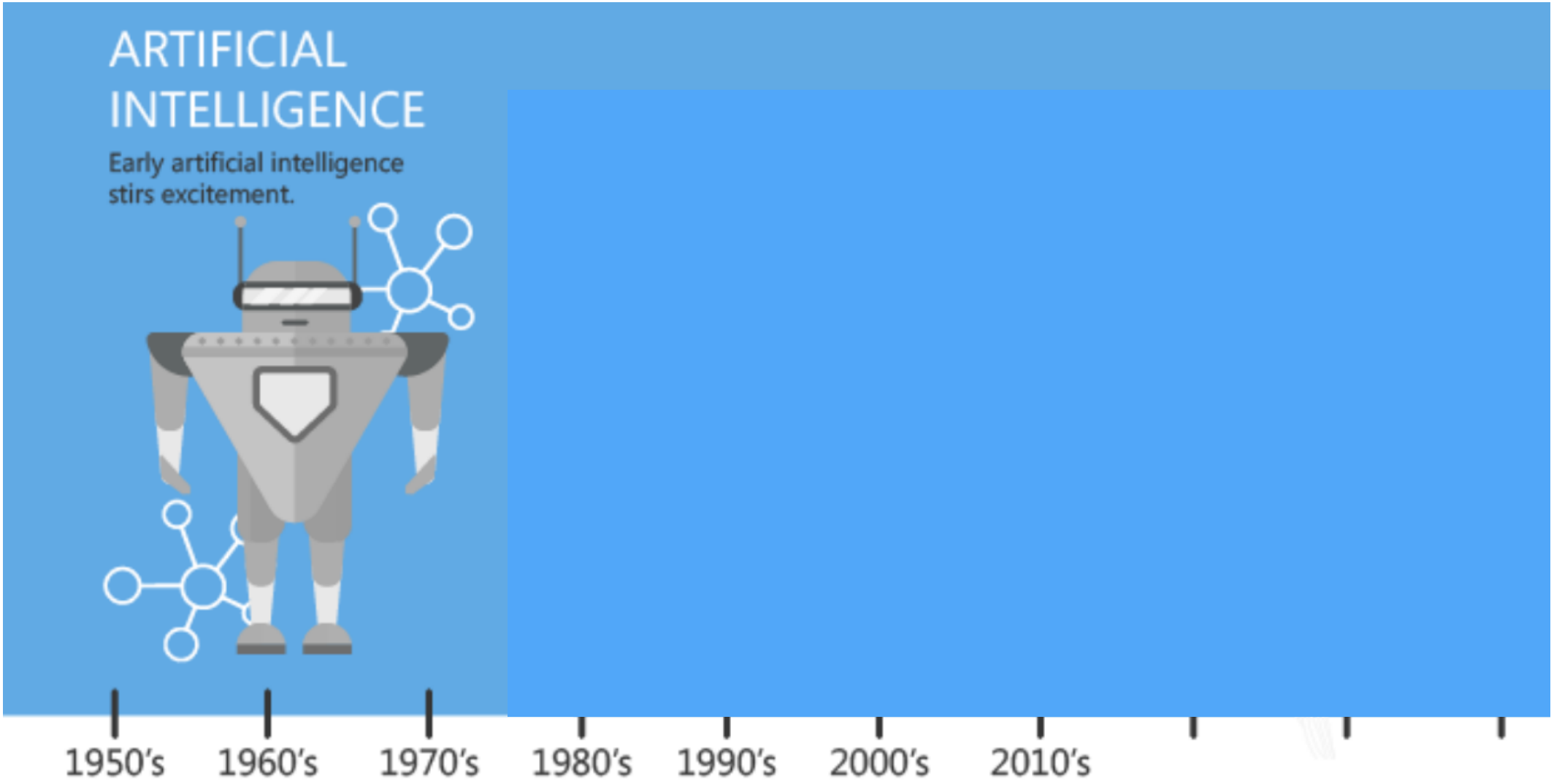
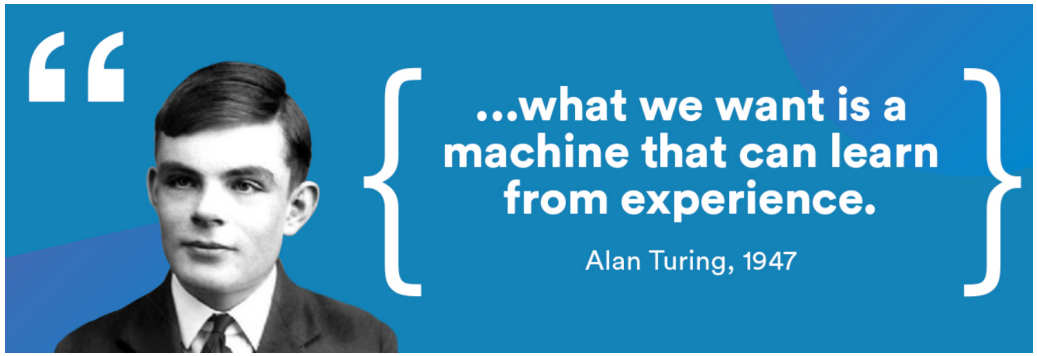
ONLY AN ASTRONOMER WHO HAS BEEN USING MACHINE LEARNING FOR THE LAST ~14 YEARS FOR MY RESEARCH

THESE LECTURES ARE INTENDED TO PROVIDE A **GLOBAL** UNDERSTANDING OF HOW AI TECHNIQUES WORK AND ESPECIALLY **HOW TO USE THEM FOR YOUR RESEARCH**


...what we want is a machine that can learn from experience.
Alan Turing, 1947


ARTIFICIAL INTELLIGENCE
Early artificial intelligence stirs excitement.
1950's
1960's
1970's
1980's
1990's
2000's
2010's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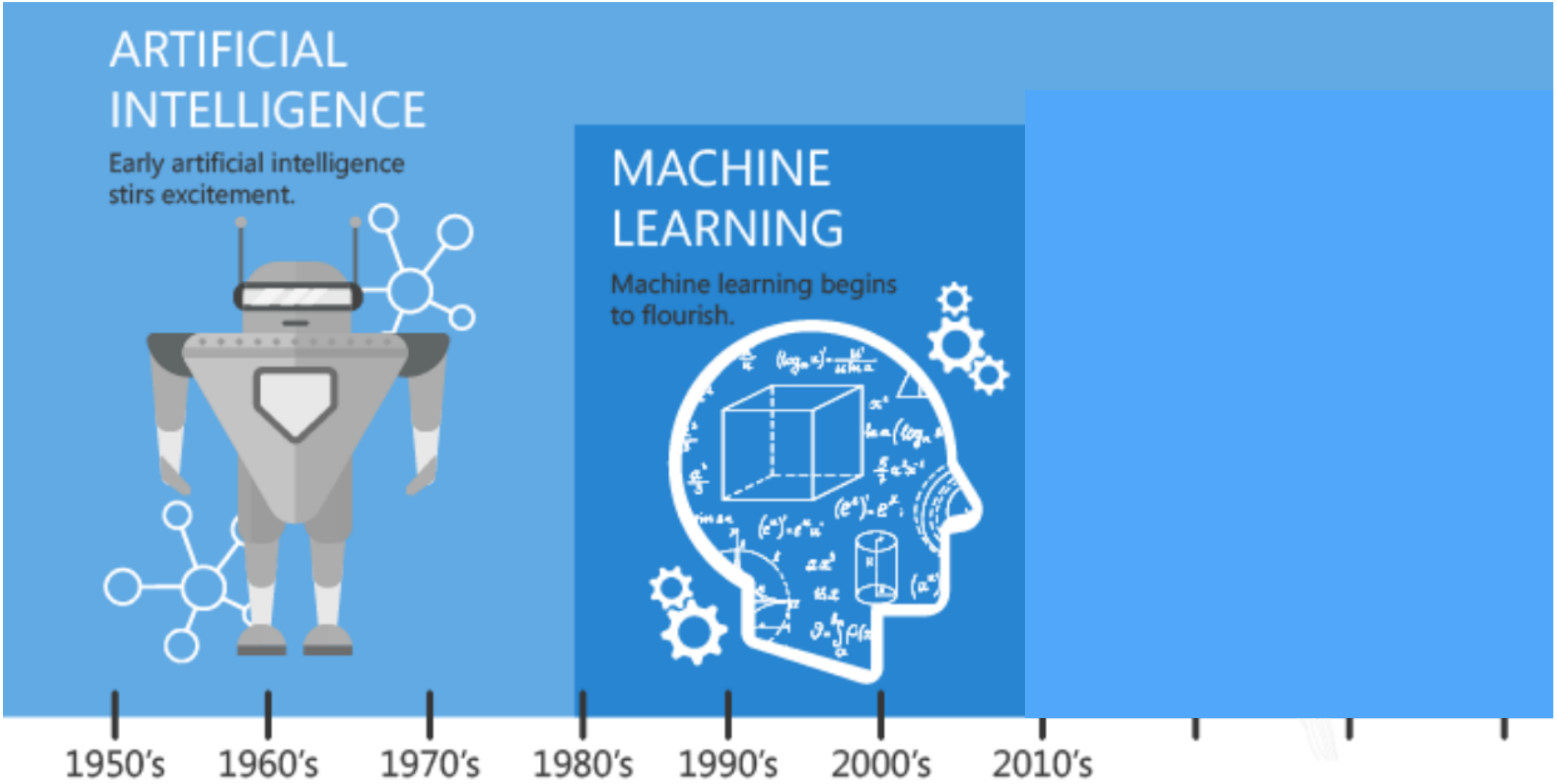
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MACHINE LEARNING
Machine learning begins to flourish.
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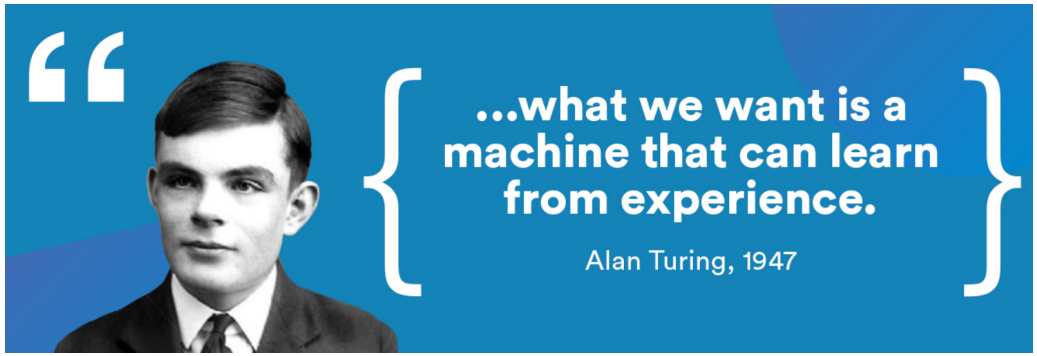
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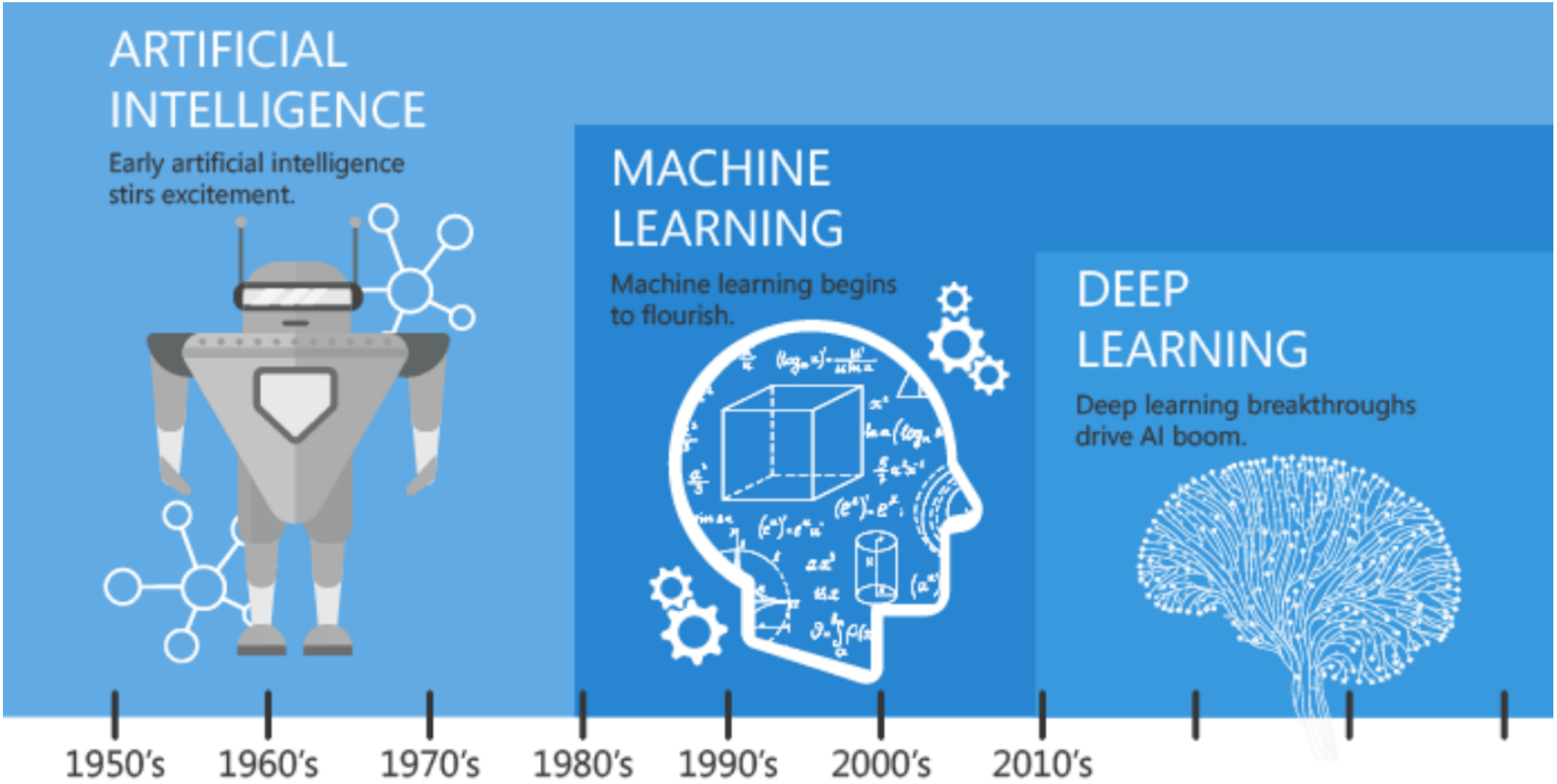
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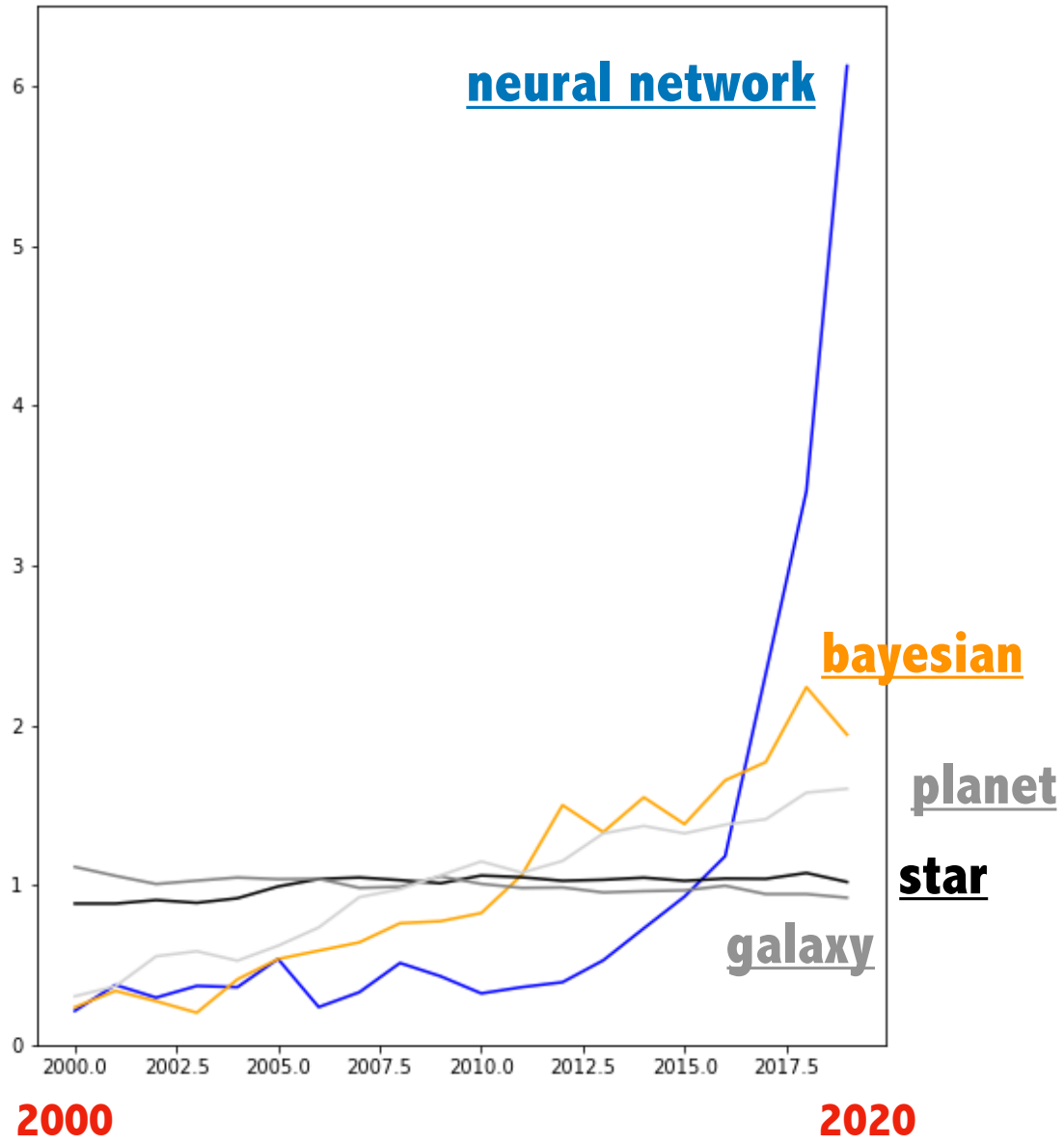
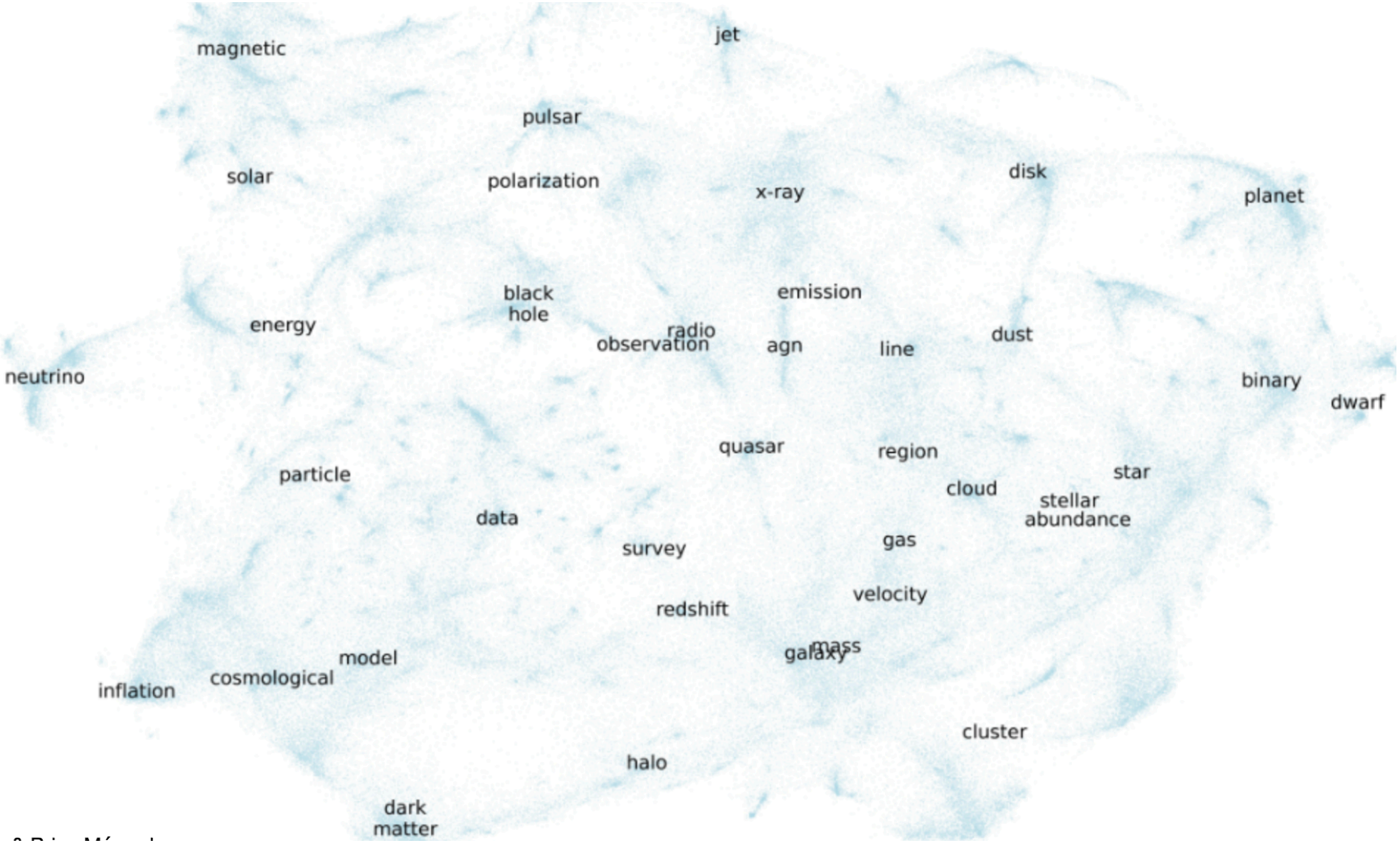
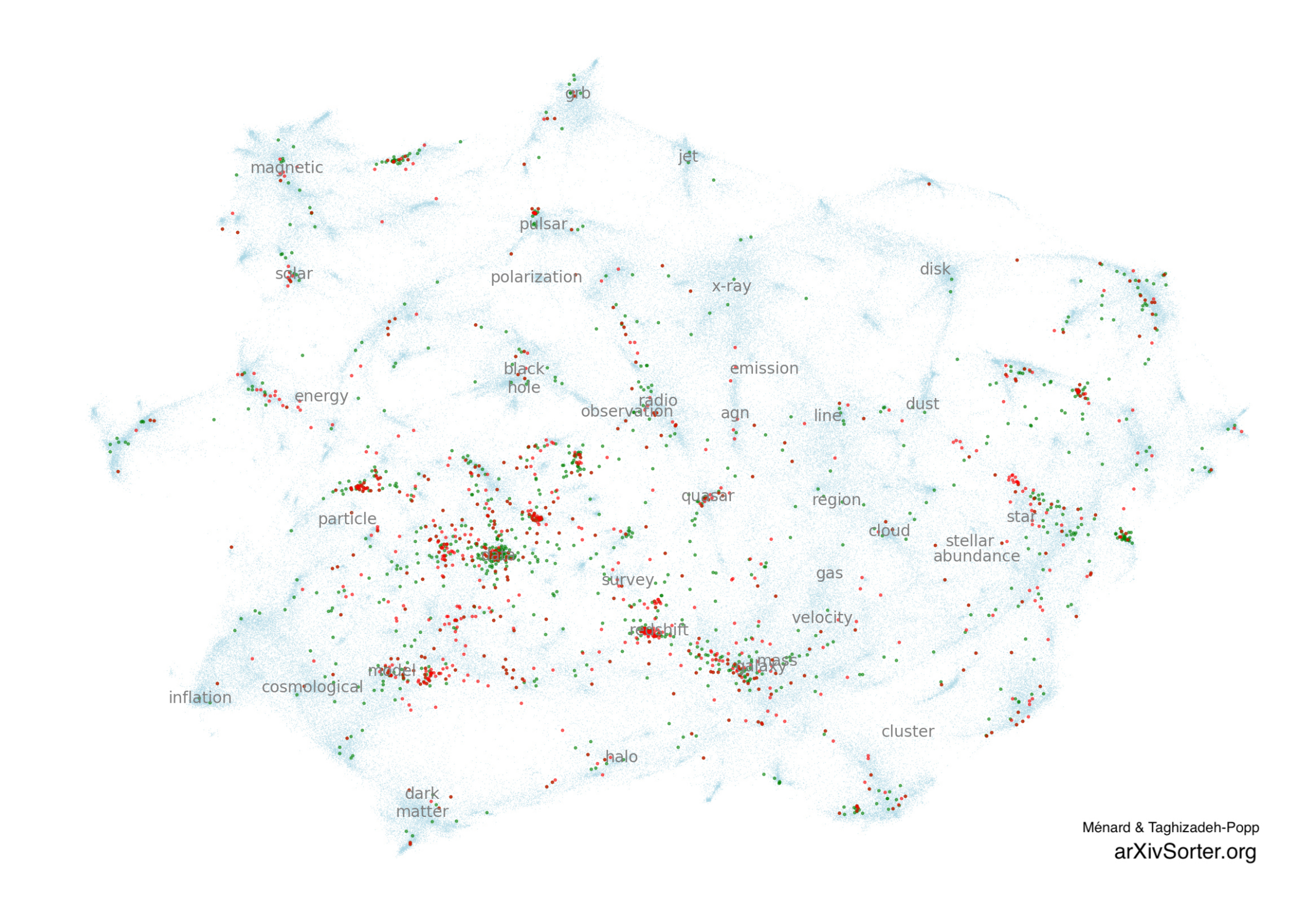
Early artificial intelligence stirs excitement.
MACHINE LEARNING
Machine learning begins to flourish.
DEEP LEARNING
Deep learning breakthroughs drive AI boom.
1950's
1960's
1970's
1980's
1990's
2000's
2010's

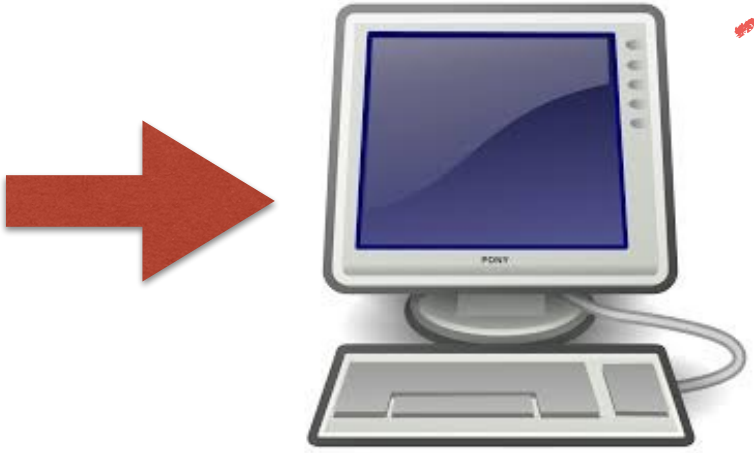
Relative change of the number of papers on arXiv/astro-ph






grb
jet
magnetic
pulsar
solar
polarization
x-ray
disk
black
hole
emission
energy
radio
observation
agn
line
dust
quasar
region
star
particle
cloud
stellar
abundance
gas
survey
velocity
redshift
mass
galaxy
model
cosmological
inflation
cluster
halo
dark
matter
Ménard & Taghizadeh-Popp
arXivSorter.org

BEFORE 2012....

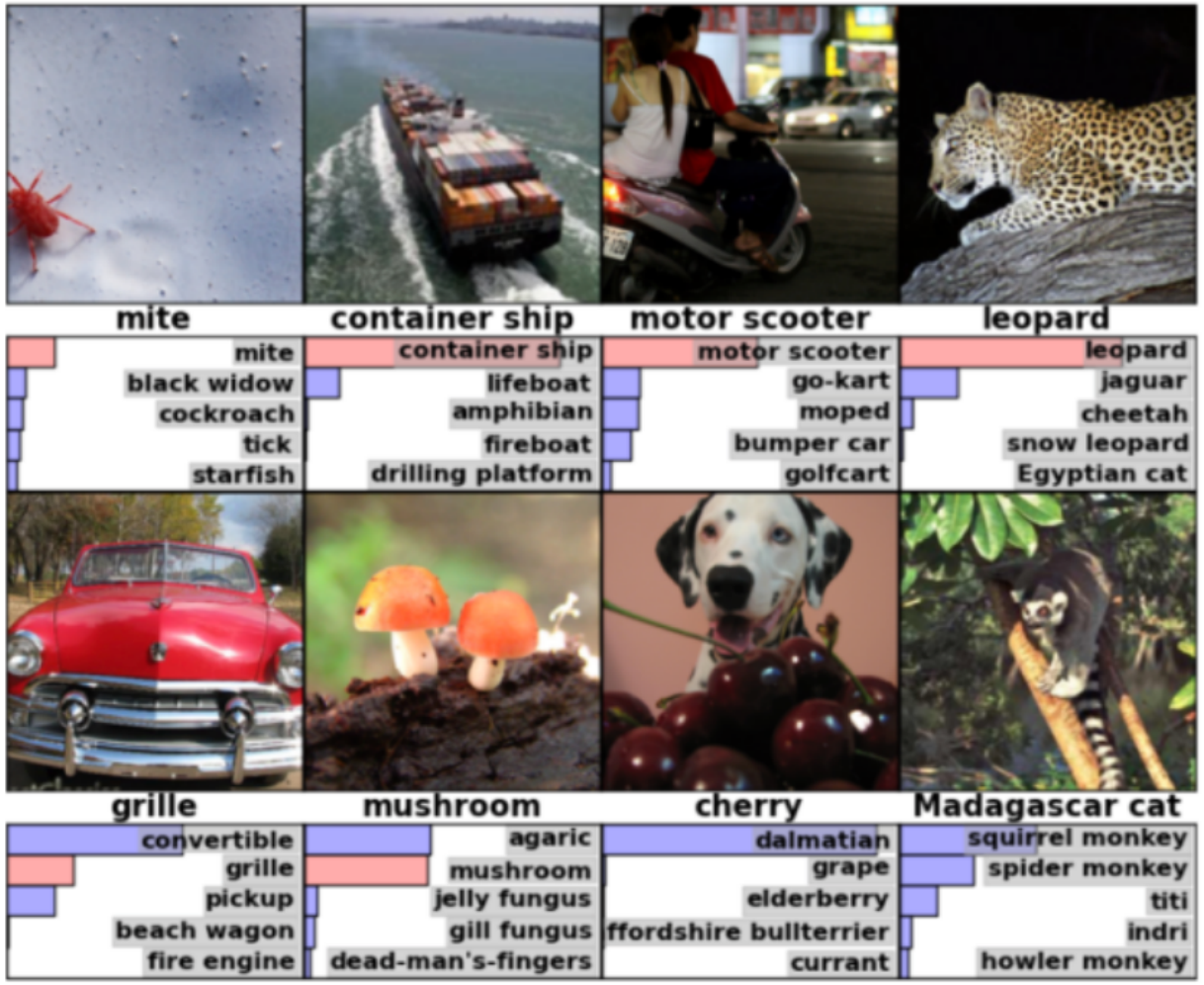


CAT?

DOG?

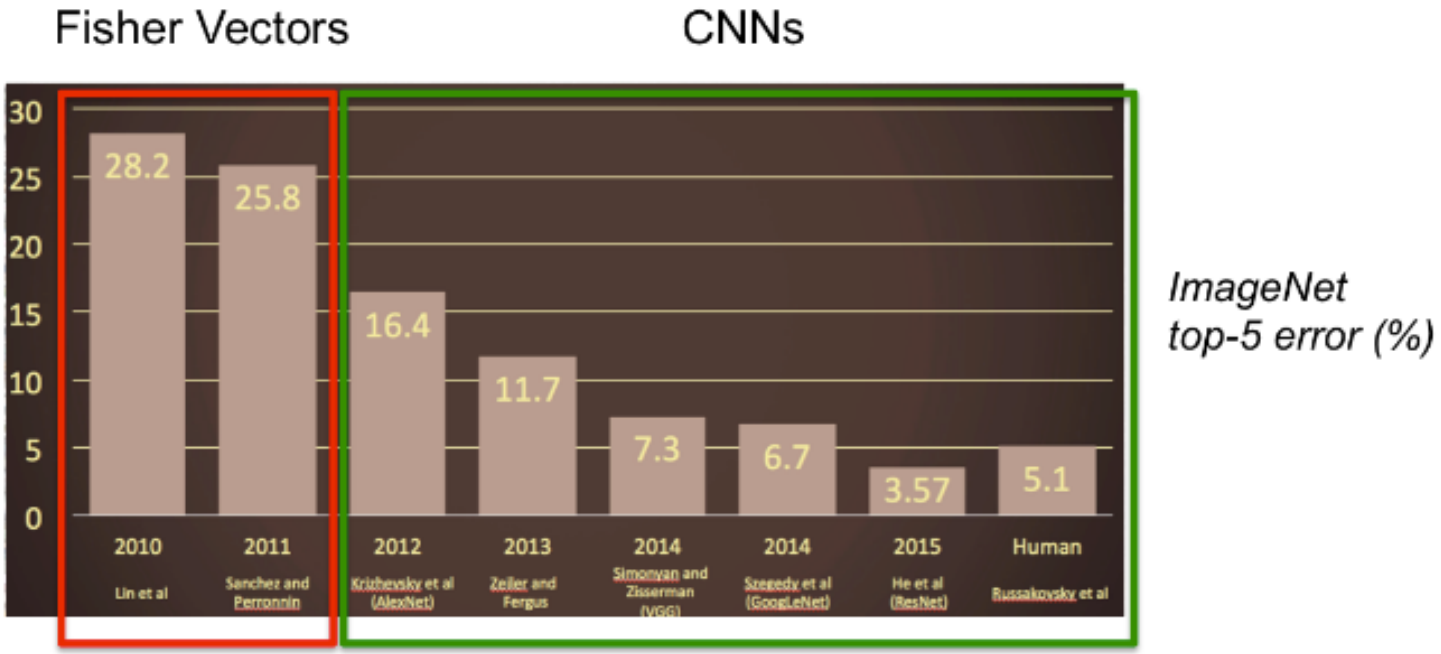
TRIVIAL HUMAN TASKS REMAINED CHALLENGING FOR COMPUTERS

AFTER 2012



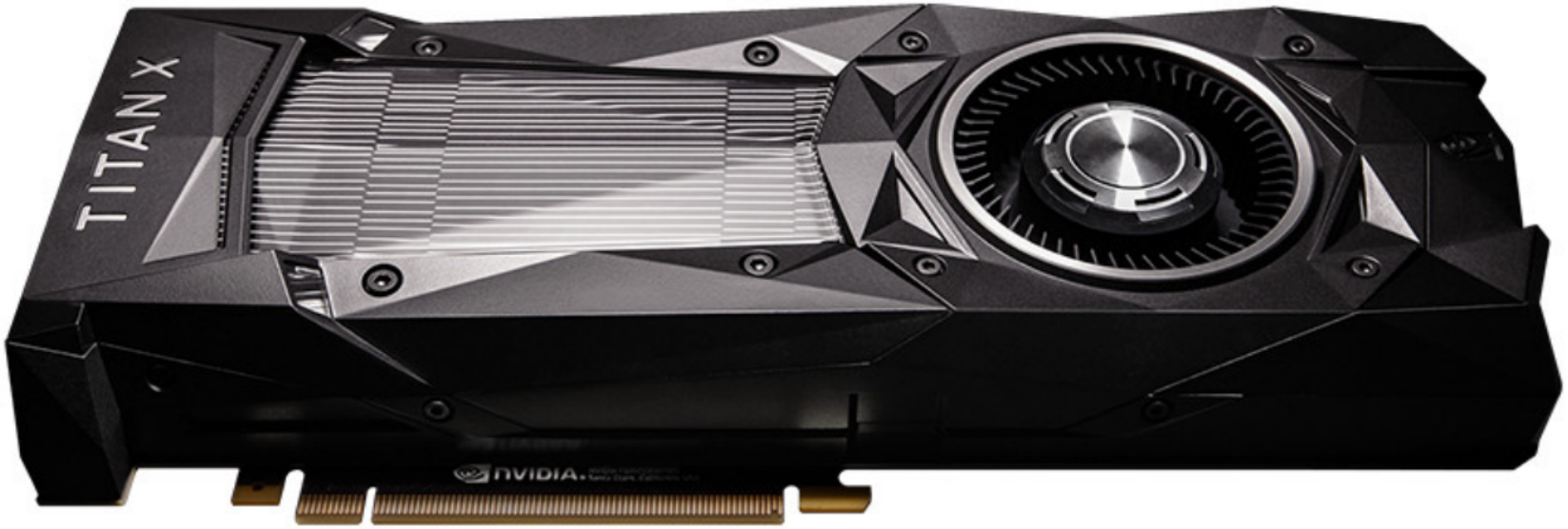
IT HAS BECOME TRIVIAL….

THIS IS A CHANGE OF PARADIGM!



ONE OF THE MAIN REASONS OF THIS BREAKTHROUGH IS THE AVAILABILITY OF VERY LARGE DATASETS TO LEARN

COMBINED WITH THE TECHNOLOGY TO PROCESS ALL THIS DATA



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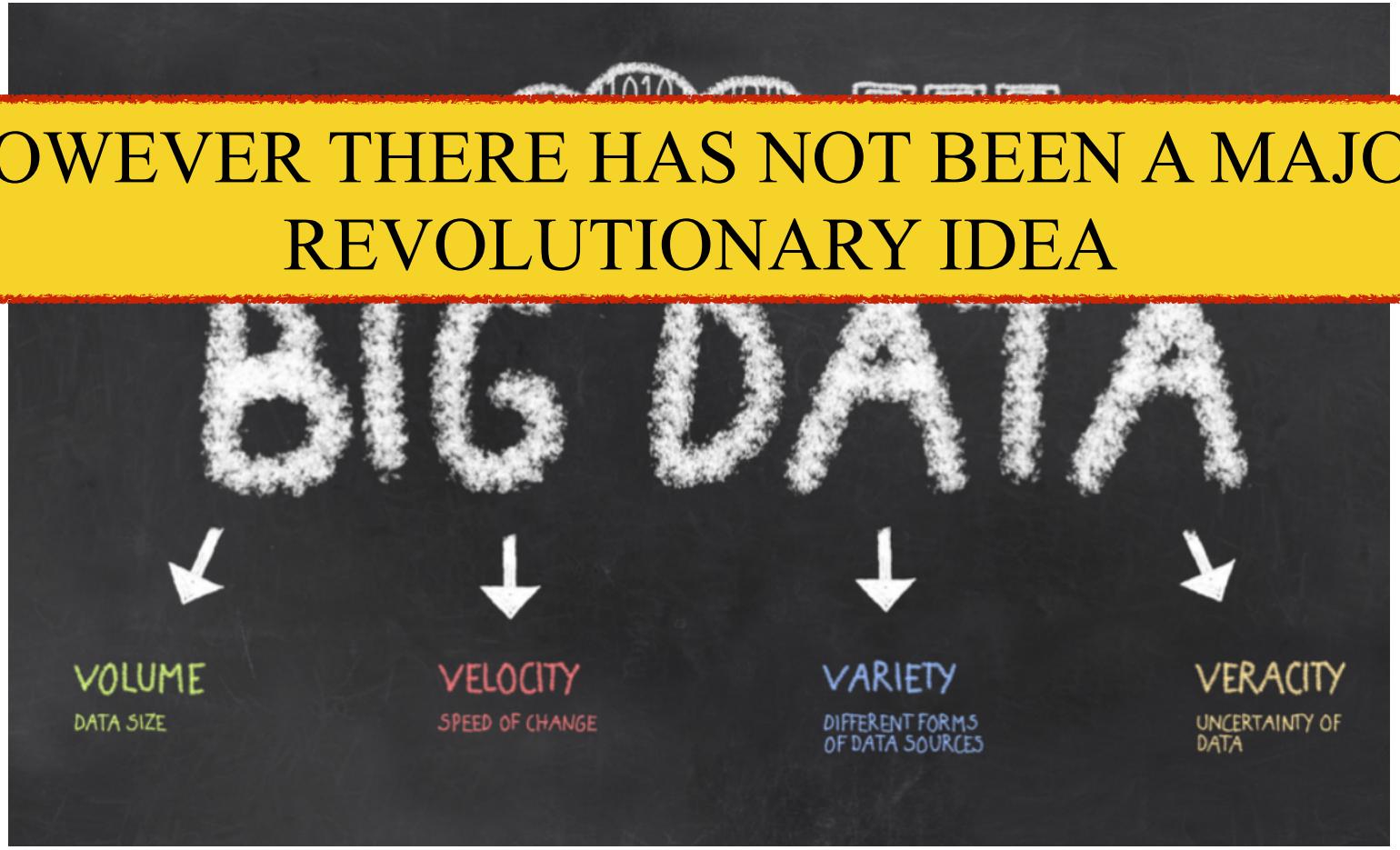
HOWEVER THERE HAS NOT BEEN A MAJOR REVOLUTIONARY IDEA



WHAT IS THESE SERIES OF LECTURES ABOUT?

BASICS OF CLASSICAL MACHINE LEARNING

BASICS OF DEEP LEARNING
(BOTH SUPERVISED AND UNSUPERVISED)

HOPING THAT THIS WOULD BE USEFUL FOR YOUR RESEARCH!

(Apologies in advance for biases on Extra-Galactic Science + imaging)

WHY DO WE NEED THESE TOOLS IN ASTRONOMY?

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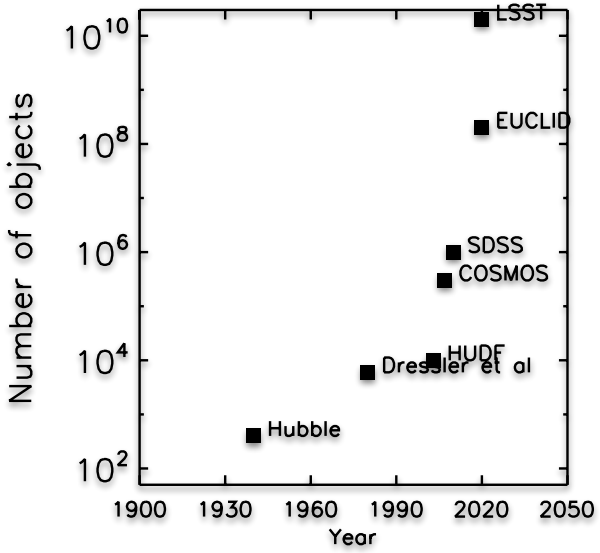
AS IN MANY OTHER DISCIPLINES THE BIG-DATA REVOLUTION HAS ARRIVED TO ASTRONOMY TOO

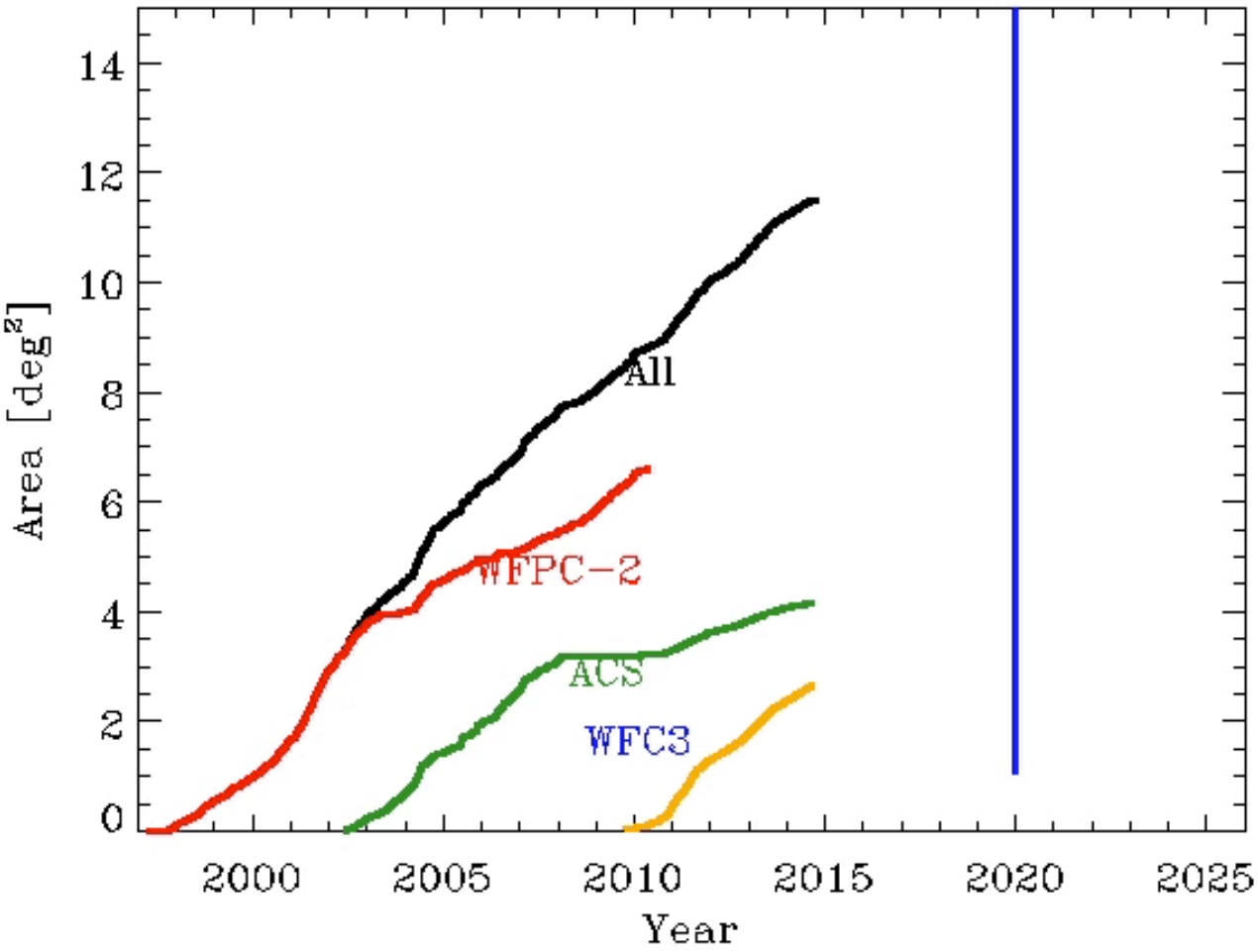


← BIG-DATA REVOLUTION

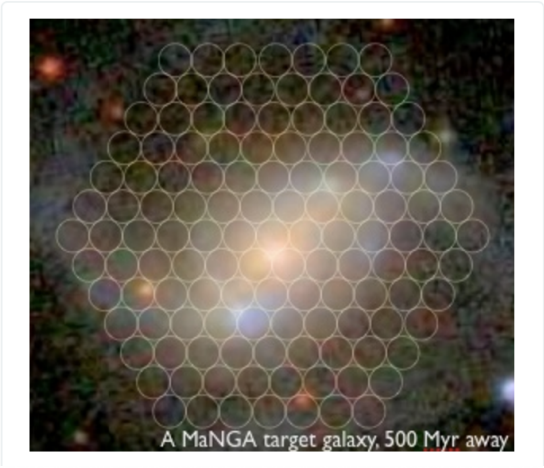
← we are here

EXTREMELY LARGE IMAGING SURVEYS DELIVERING BILLIONS OF OBJECTS IN 2-5 YEARS

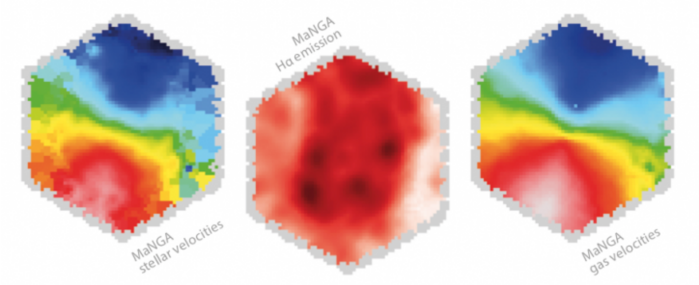
LSST simulation



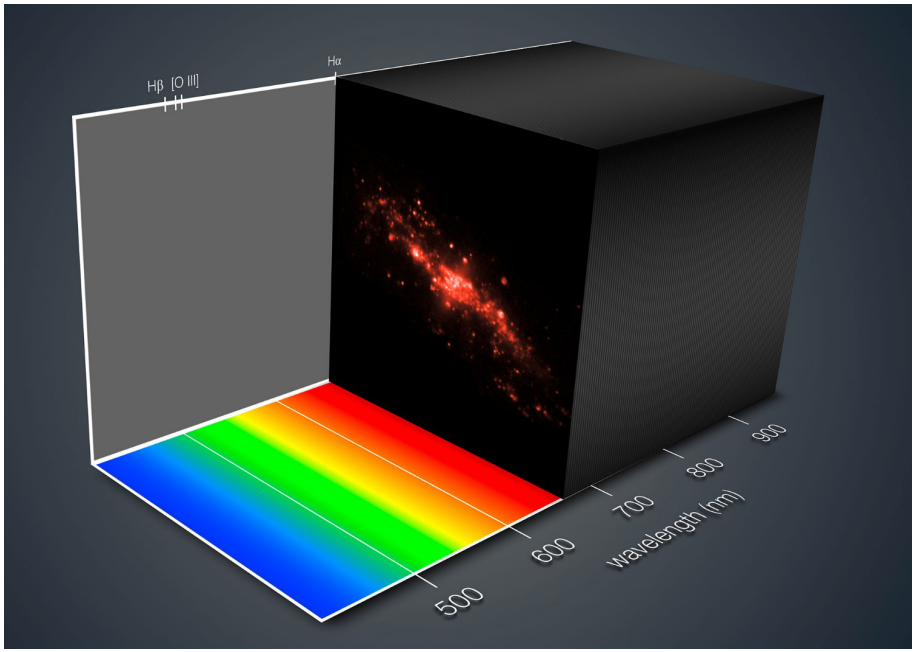
(Thanks to J. Brinchmann)

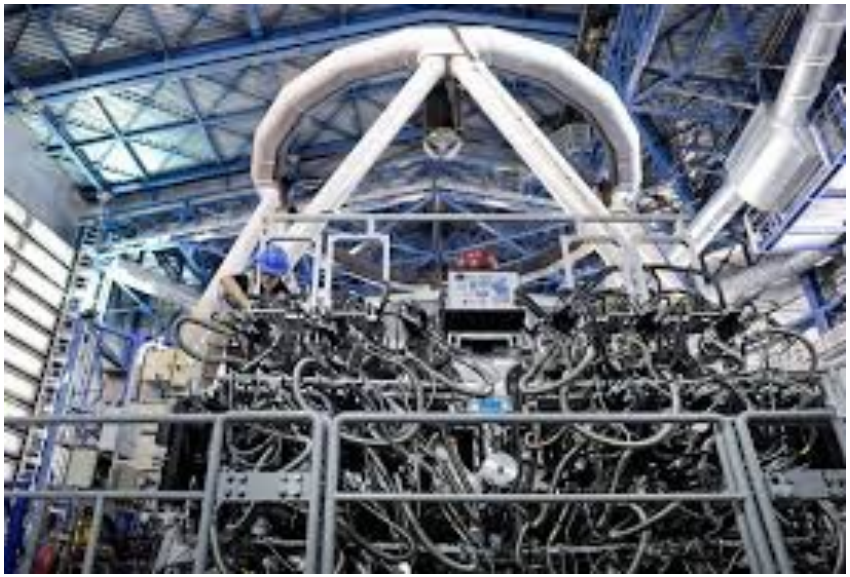


NOT ONLY VOLUME: AN INCREASING COMPLEXITY OF DATA

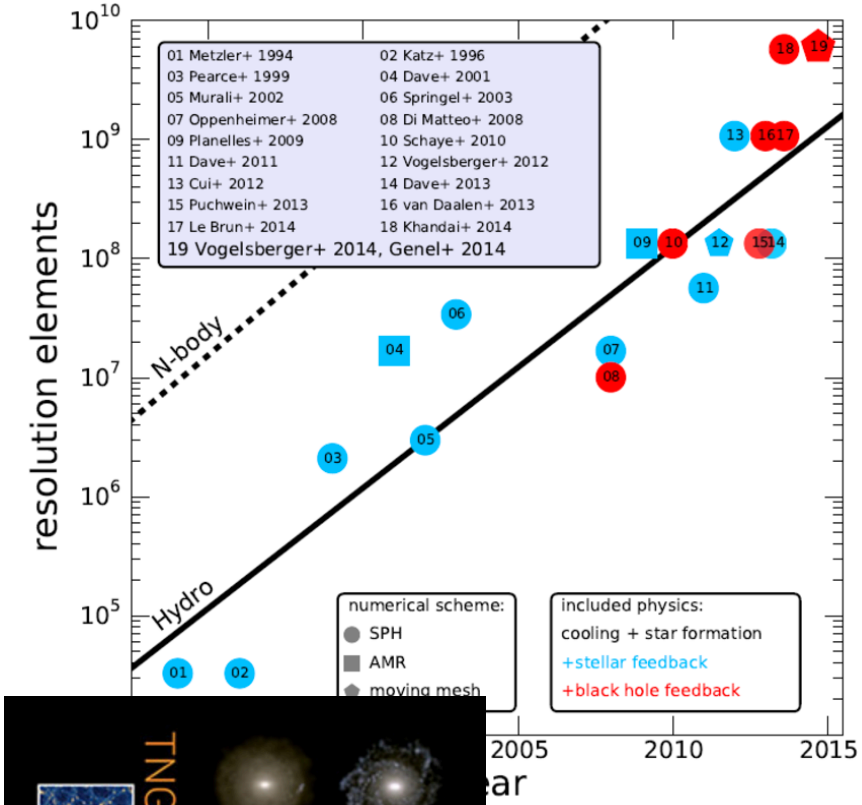


MANGA Survey



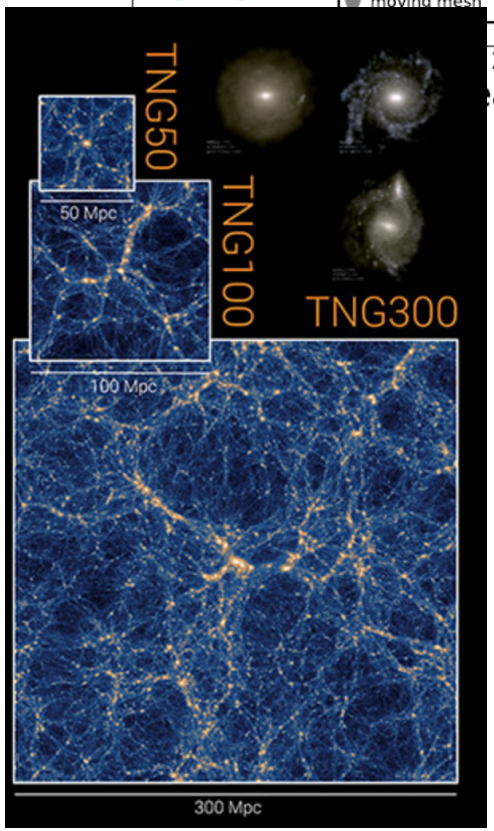


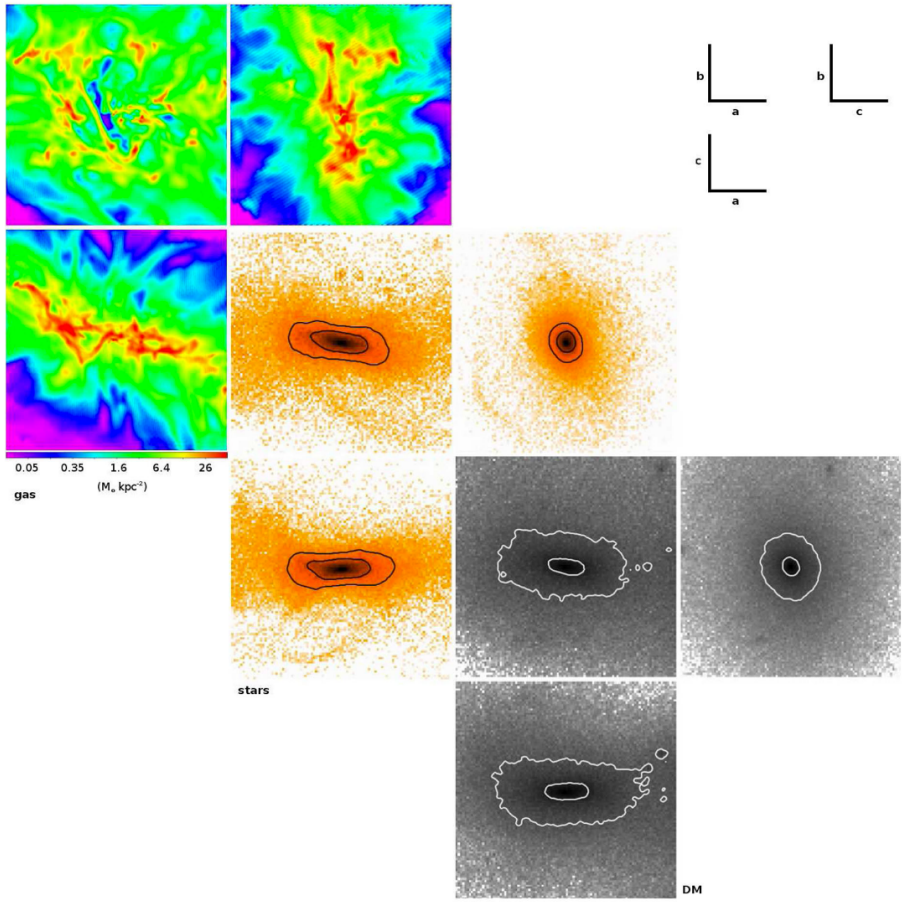
MUSE@VLT



Genel+14

AND ALSO SIMULATIONS!





Ceverino+15

PROGRAM FOR THE WEEK

- **PART I: A VERY QUICK INTRODUCTION TO 'CLASSICAL' SUPERVISED MACHINE LEARNING (FOR CLASSIFICATION)**
  - UNSUPERVISED / SUPERVISED
  - GENERAL STEPS TO "TEACH A MACHINE"
  - "CLASSICAL" CLASSIFIERS: RFs

PROGRAM FOR THE WEEK

- **PART II: FOUNDATIONS OF 'SHALLOW' NEURAL NETWORKS**
  - PERECPTRON, NEURON DEFINITION
  - LAYER OF NEURONS, HIDDEN LAYERS
  - ACTIVATION FUNCTIONS
  - OPTIMIZATION [GRADIENT DESCENT, LEARNING RATES]
  - BACKPROPAGATION
  - LOSS FUNCTIONS

PROGRAM FOR THE WEEK

- **PART III: CONVOLUTIONAL NEURAL NETWORKS**
  - CONVOLUTIONS AS NEURONS
  - CNNs [POOLING, DROPOUT]
  - VANISHING GRADIENT / BATCH NORMALIZATION
  - CNN VISUALIZATION

PROGRAM FOR THE WEEK

- **PART IV: BEYOND CLASSIFICATION WITH CNNs**
  - FCNNs (IMAGE2IMAGE NETWORKS)
  - OBJECT DETECTION
  - INSTANCE AND SEMANTIC SEGMENTATION
  - RECURSIVE NETWORKS

PROGRAM FOR THE WEEK

- **PART V: INTRODUCTION TO UNSUPERVISED MACHINE (DEEP) LEARNING**
  - DIMENSIONALITY REDUCTION
  - CLUSTERING
  - DEEP GENERATIVE MODELS
  - DEEP PROBABILISTIC MODELS

REFERENCES

SEVERAL SLIDES / INFOS SHOWN HERE ARE INSPIRED/ TAKEN FROM OTHER WORKS / COURSES FOUND ONLINE

- Deep Learning Book [Goodfellow, Bengio, Courville]
- Deep Learning: Do-It-Yourself! [Bursuc, Krzakala, Lelarge]
- DEEPLEARNING.AI [COURSERA, Ng, Bensouda, Katanforoosh]
- MACHINE LEARNING LECTURES [Keck]
- EPFL DEEP LEARNING COURSE [Fleuret]
- DEEPMIND / UCL Lecture series [DeepMind]

+ many others!

Thanks to all of them!

HANDS-ON SESSIONS

WE WILL TRY TO PRACTICALLY IMPLEMENT SOME OF THE NOTIONS LEARNED

TUTORIALS WILL USE **GOOGLE COLAB**. YOU WILL NEED A GOOGLE ACCOUNT AND SOME SPACE IN YOUR GDRIVE. WORKS ALSO BETTER ON CHROME.

NOTEBOOKS ARE GENERALLY SELF EXPLANATORY. YOU WILL BE ASKED TO FILL PIECES OF CODE AT DIFFERENT STAGES. SOLUTIONS ARE ALSO PROVIDED.

LET'S TRY TO DISCUSS AS MUCH AS POSSIBLE!

INTERACTION

AS MY COLLEAGUES, I WILL USE POLLING TOOLS

PLEASE GO TO pollev.com/marchuertasc257

ASK QUESTIONS ON SLACK

I WILL BE ON WONDER.ME
AFTER THE LECTURES AS WELL

How would you define Machine Learning?

Have you ever used ML for your work?

Yes

No

I don't know