

IMPACT OF MACHINE LEARNING ON SOLAR & STELLAR PHYSICS

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DATA IS INCREASING EXPONENTIALLY



OUR MODELS ARE OFTEN COMPLEX

- > 2000 x 2000 pixels
- 10 wavelength points
- One observation per minute
- Observe during 3 hours

720 million spectral lines per day

22.8 years to invert assuming 1 s per inversion8.3 days to invert assuming 1 ms per inversion

SCALING WITH CPUS



Magic number : 100 µs per inversion

MODERN MACHINE LEARNING IN SOLAR+STELLAR

- Real-time data management
 - online image correction
 - online inversion
- Classification of events
- Extraction of hidden information
- Robust and fast Bayesian inference

real-time data management: image correction

NOISE FILTERING : SST DATA



Díaz Baso et al. (2019)

POLARIMETRY



15

15

20

20

0 5 10 15 20 0 5 10 15 20 Distance [arcsec] Distance [arcsec]



GENERALIZATION TO UNSEEN DATA



100 images/s

ENHANCE https://github.com/cdiazbas/enhance



courtesy of S. Castellanos Durán

real-time data management:

inversion

AR10933 : INFERENCE



Bz

 τ surfaces

180 ms for 512x512

700 ns per pixel

30 minutes for all Hinode observations

COMPARISON

 $T(\log \tau = -0.8)$

400x400 pixels in 10 seconds

Speed ~ 62 μ s / pixel

Speedup wrt SIR ~10⁵

 $v(\log \tau = -0.5)$ Can be improved with 2D CNNs



Milic & Gafeira (2020, in prep)

K-MEANS INVERSIONS



Sainz Dalda et al. (2019)

classification of events

FAST SOLAR IMAGE CLASSIFICATION



Armstrong & Fletcher (2019)

CLASSIFICATION OF LIGHT CURVES

Classify unevenly sampled light curves



Naul et al. (2017)

ASTEROSEISMOLOGY

Classify Red Giant Branch (RGB) vs Helium Burning (HeB)



Hon et al. (2017)

extraction of hidden information

DEEPVEL https://github.com/aasensio/deepvel



Asensio Ramos, Requerey & Vitas (2017)

SMALL SCALE VORTEX FLOWS



OUR PREDICTIONS



LEARN FROM MILLIONS OF SPECTRA

Variational Autoencoder learns informative features



Sedaghat et al. (2020)

fast bayesian inference

RADYNVERSION : FLARE RIBBON



Osborne, Armstrong & Fletcher (2019)

INVERTIBLE NEURAL NETWORKS: UNCERTAINTIES



ASTEROSEISMOLOGY: EMULATORS

A DNN predicts frequencies from physical properties

Use it to infer parameters from asteroseismological observations



CONCLUSIONS

- Solar & stellar physics are entering the big data era
- Fast synthesis/inversions/classification
- Bayesian inference
- Advanced detection
- Caveats
 - Sim2real
 - Lack of data