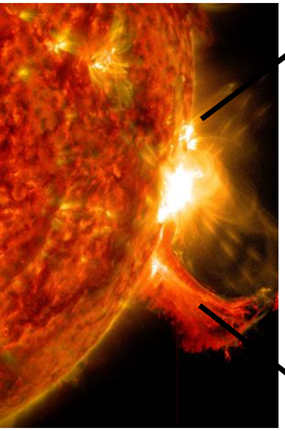
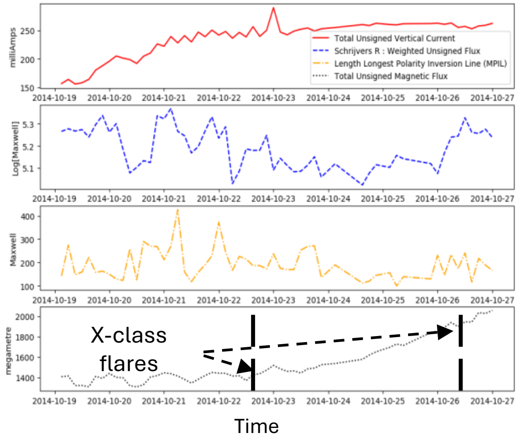
Cause-mic Universe : Causal Approaches Probing Solar and Astrophysical Variability

Solar Outbursts



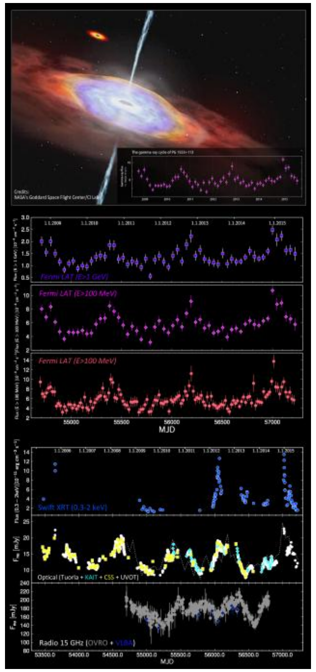


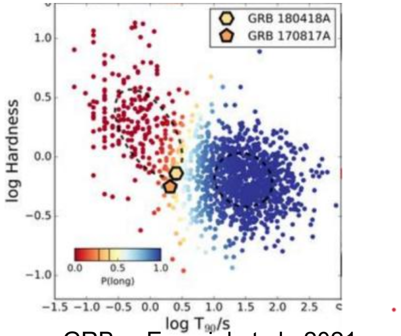
$y^{n:0}_{i-1}$

$y^{n:0}_{i}$

$y^{n:0}_{i+1}$

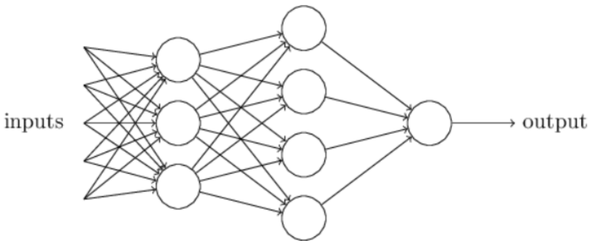
Extragalactic Sources (transients)





GRBs : Escorial et al., 2021

Statistical Learning or Inference



Machine (Deep) Learning

Bayesian Networks

Physics Drivers

- Competing mechanisms (variables) driving variability
- Their sequence via lags
- Transient classes (progenitors)

Forecasts

- Solar outbursts impact space weather
- Feature-set for timely and precise ML-based forecasts (Met-Office)

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with
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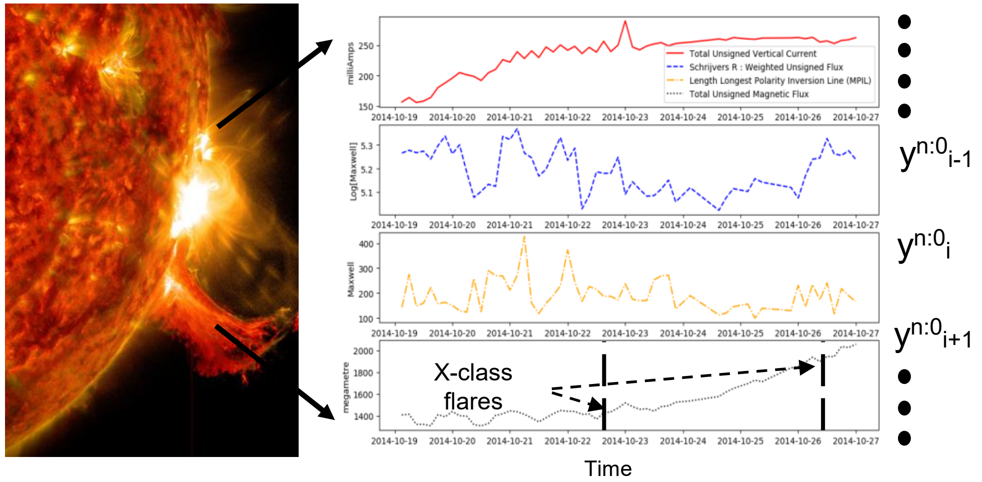
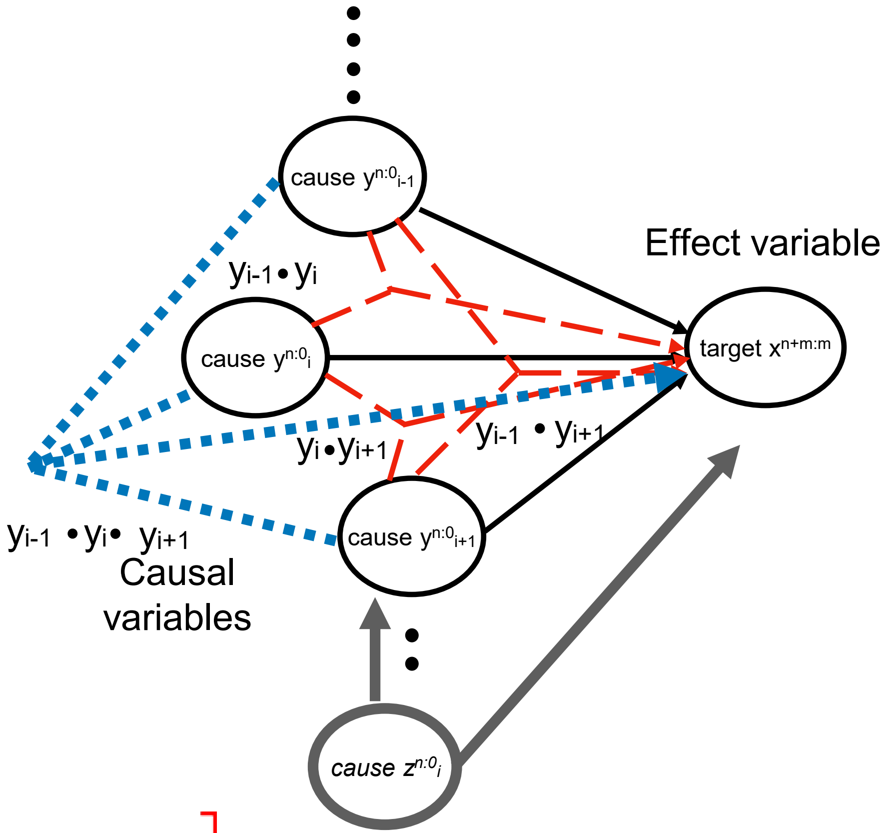
Generalised, Hierarchical Information Graphs

Limitations

- Non-linearity, non-Gaussianity
- No consensus on classes
- Black box ML/DL
- Ceiling in forecast performance

Solar Outbursts





Information Theoretic
Entropic Measures

$$(y \to x)_{\text{total}} = I(x;y|z) + \frac{1}{2}\left[I(x;y) - I(x;y|z)\right]$$

$$(y_i \to x)_{\text{total}} = (y_i \to x)_{1link} + \frac{1}{2}(y_i \to x)_{2links} + \frac{1}{3}(y_i \to x)_{3links} + ... + \frac{1}{N}(y_i \to x)_{\text{N}links}$$

Van Leeuwen et al., 2021, Chaos, Chakraborty et al., 2022, Phys. Review R. (Non-linear Lags)

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Conclusions:

Hierarchical information graphs provide

• Standalone inference or *diagnostics* for ML/DL

• Causal information including *synergistic influence* due to multiple variables

• New comprehensive, *explainable "feature-set importance"* vital for both physics and space weather forecasting with ML

• *Accurate time-lags* for non-linearity

Poster Id : 63 (T1c)

Session A (Wednesday 12:00 - 15:00)

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