Analysis of CME arrival times at 1 AU with neural network

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Prediction means using some initial parameters of CMEs
- First parameter: speed in LASCO, \( v \)
- Second parameter: CMD position of associated flare, literature (Gopalswamy et al. 2001; Zhang et al. 2003; Manoharan 2006; Zhang et al. 2007; Marubashi et al. 2015, Vršnak et al. 2005)
- We also need TT: Richardson & Cane (2010) list
- Total of 153 events with \( v \), CMD & TT
Input parameter space

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Neural networks

- Output (TT) is a non-linear combination of input parameters ($v$, CMD). Calculations from left to right.
- Unknown factors (parameters of the fit) are weights and are set to random values initially.
- Backpropagation to the rescue.
- Too many weights: overfitting.
- Solution(?): divide the full sample (153 events) to learning sample (130) and validation sample (23).
- Rule of a thumb: 10 events per one weight (fitting parameter).

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Activation Function

We used the logistic function, but this also works:

\[ f(x) = \frac{1}{1 + e^{-x}} \]

\[ f(x) = \tanh(x) \]
Observed and calculated TT

![Graph showing observed and calculated TT over ID numbers, with a range from 0 to 120 hours. The graph is divided into Learning and Val. sections.]
Convergence of $|T_c - T_o|$
Distribution of $|TT_c - TT_o|$
Error map

- 10 trained NNs
- Different learning sample
- Stability of the best fit
- Error of the mean curve

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TT(v) around CMD = 0 deg

Hyperbolic function is $a=0, \ v = \text{const}$
- Slower arrive sooner and faster later than $v = \text{const}$
- It's a drag
- Intersect is the speed of the moving medium (aka solar wind) = 500 km/s
Predicted vs reality
Calculated/predicted TT

- Faster arrive sooner
- Western CMEs arrive sooner than eastern CMEs
Closer look at east-west asymmetry

- TT(v=1300)
- NN problem when extrapolating
- Minimum on the western hemisphere

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Another view of east-west asymmetry

![Graph showing east-west asymmetry with two curves labeled -30 deg and +30 deg.](Graph.png)

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Conclusion

- This NN can't predict:
  - if CME will actually hit (every CME hits)
  - TT to any distance other than 1 AU (Earth, STEREO)
- Motion of CME influenced by drag in a moving medium
- CMEs originating on the western hemisphere arrive sooner. Probably as a result of deflection in interplanetary space.
- Average difference between calculated and observed TT in our study is ~ 12 hours. Everyone gets the same regardless of the approach to the problem (Gopalswamy et al. 2001; Fry et al. 2003; Schwenn et al. 2005; Vršnak et al. 2014; Mays et al. 2015).