Analysis of CME arrival times at 1 AU with neural network

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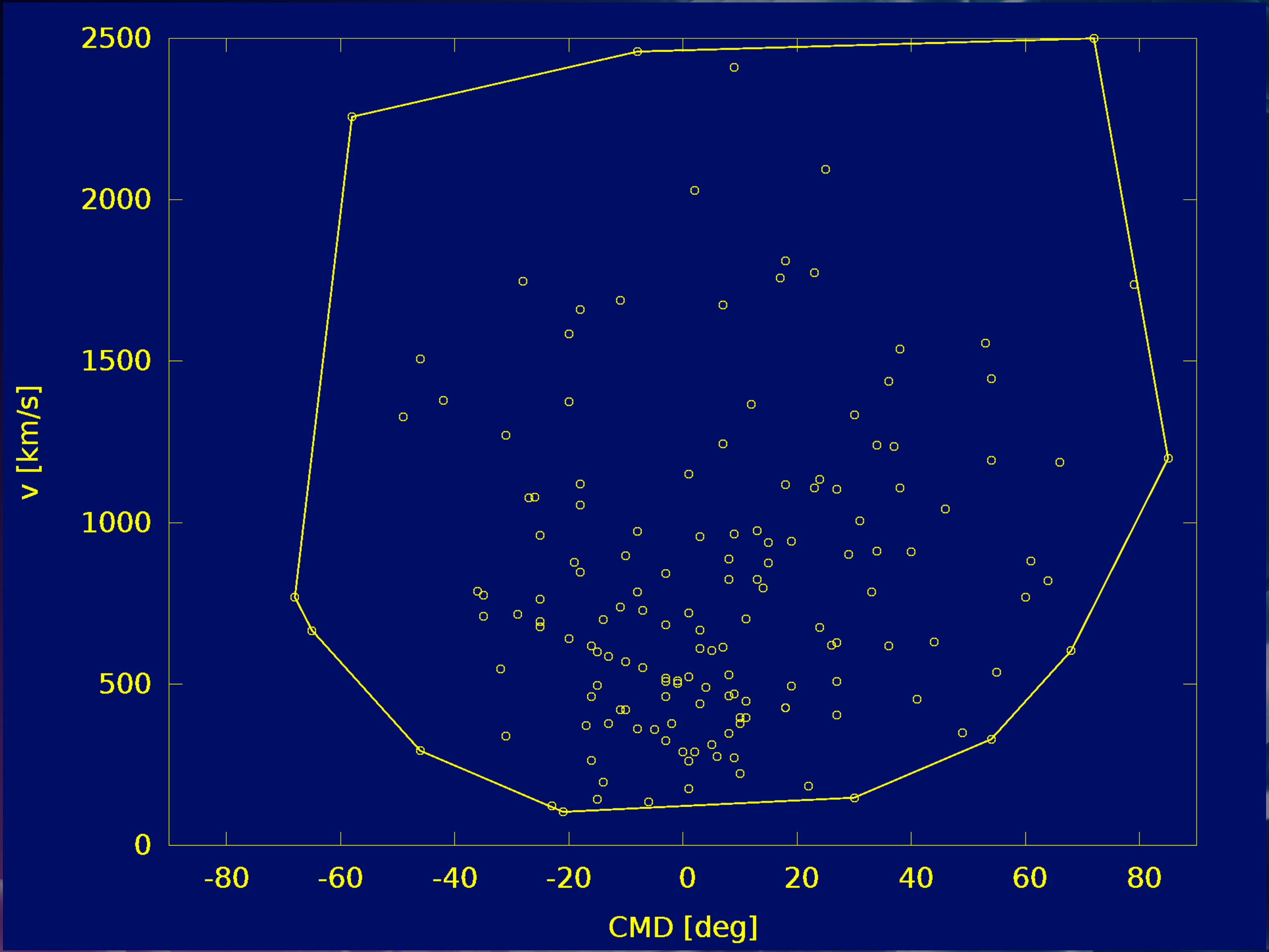
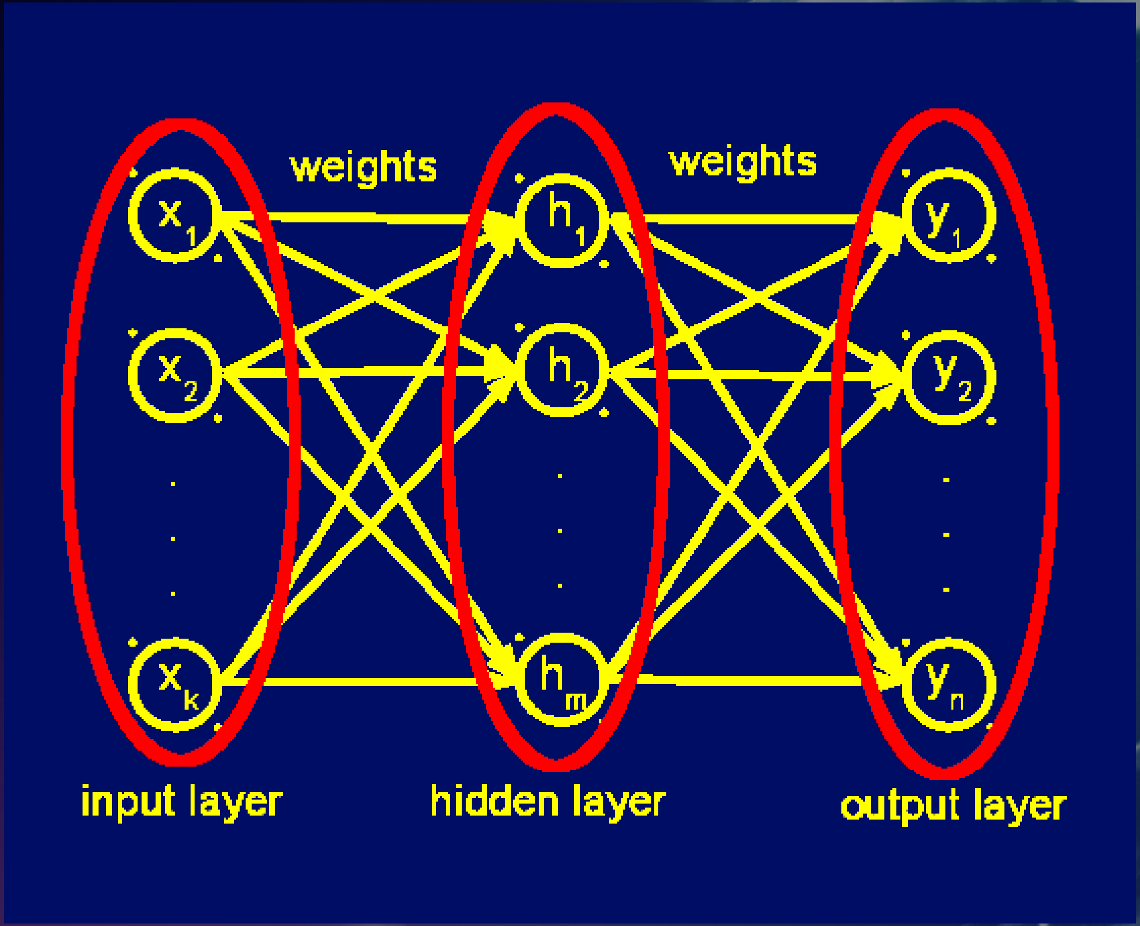
Prediction means using some <u>initial parameters</u> of CMEs

- 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

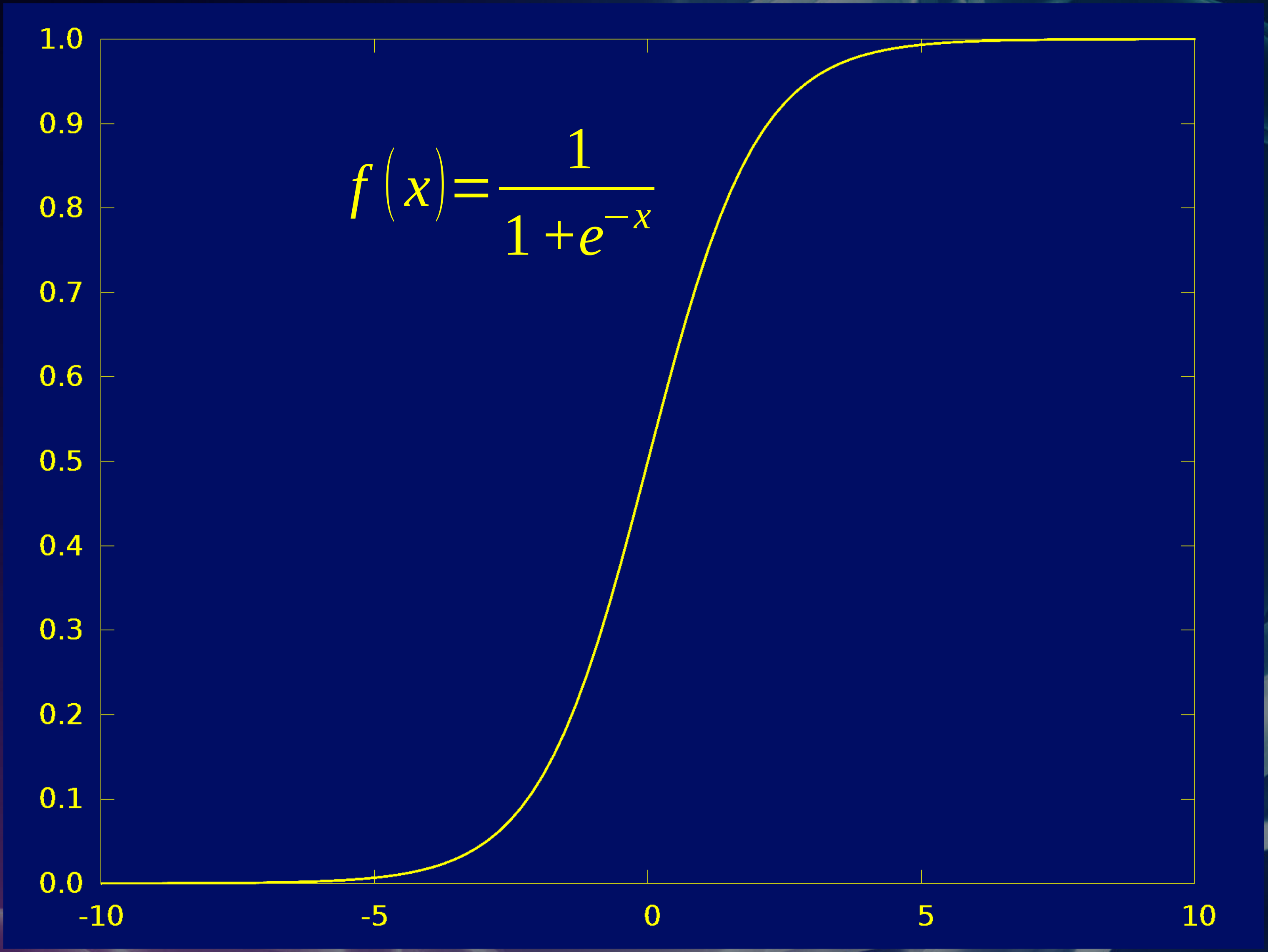


Neural networks



- 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)

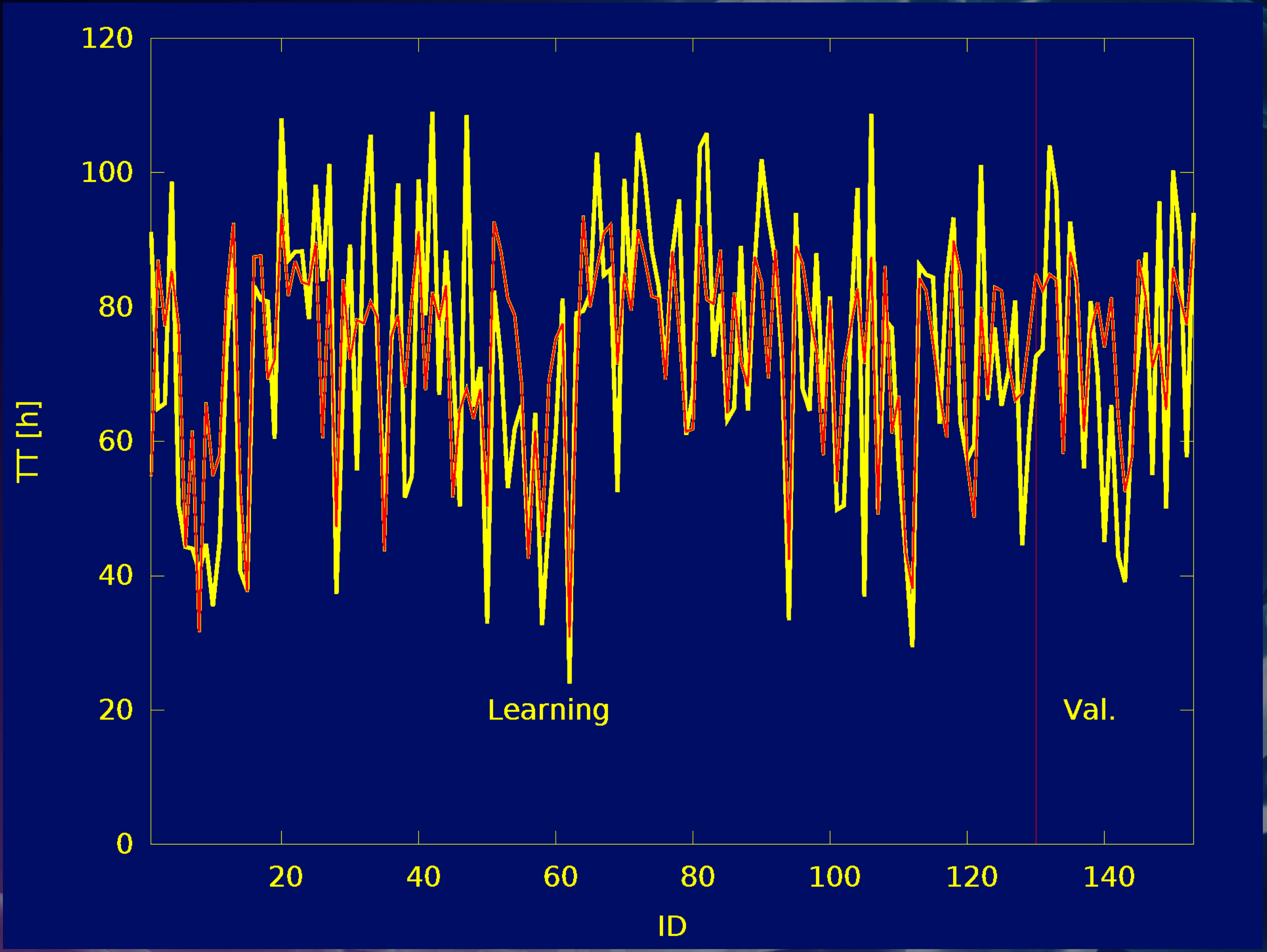
Activation Function



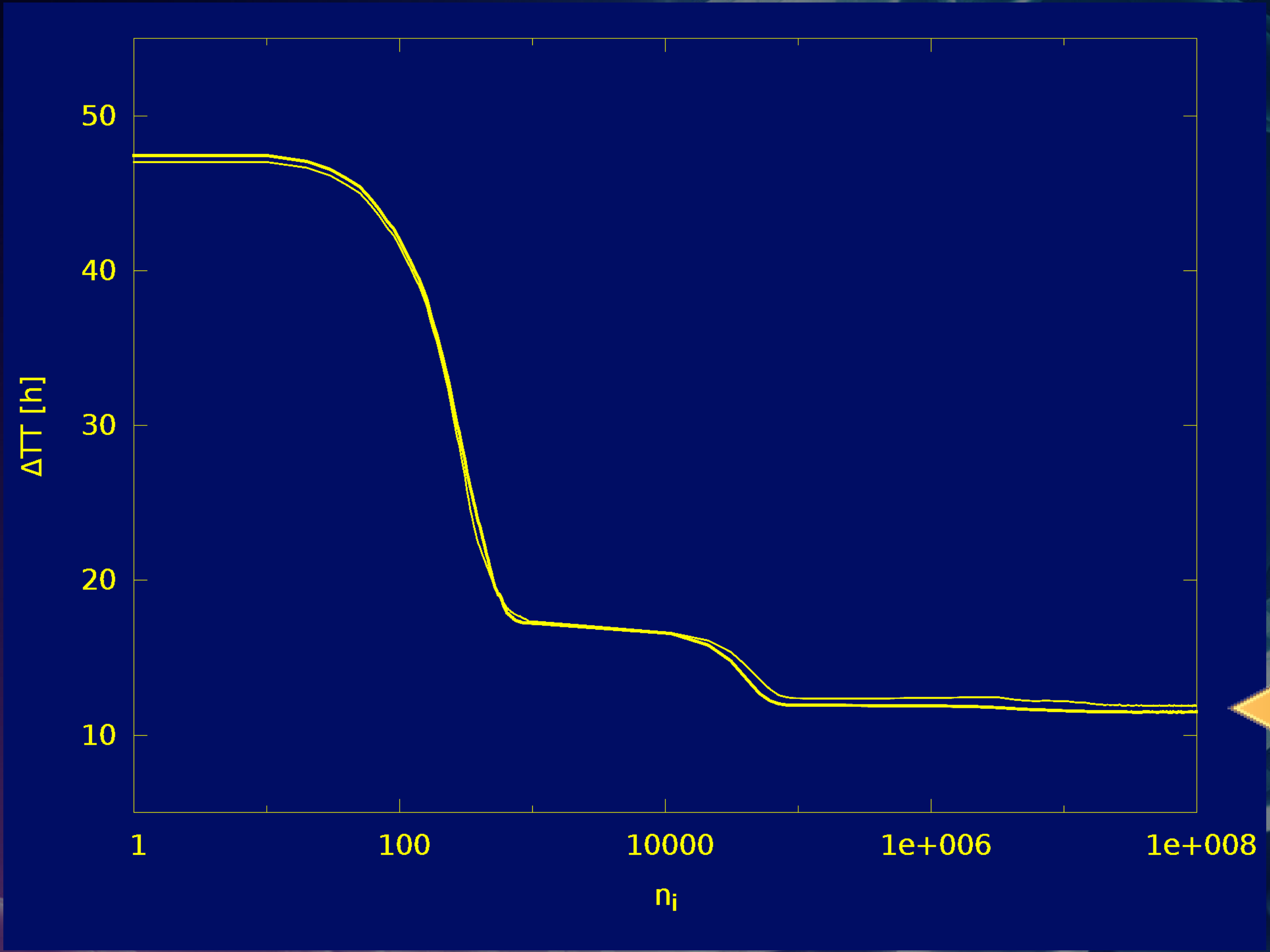
We used the logistic function, but this also works:

$$f(x) = \tanh(x)$$

Observed and calculated TT

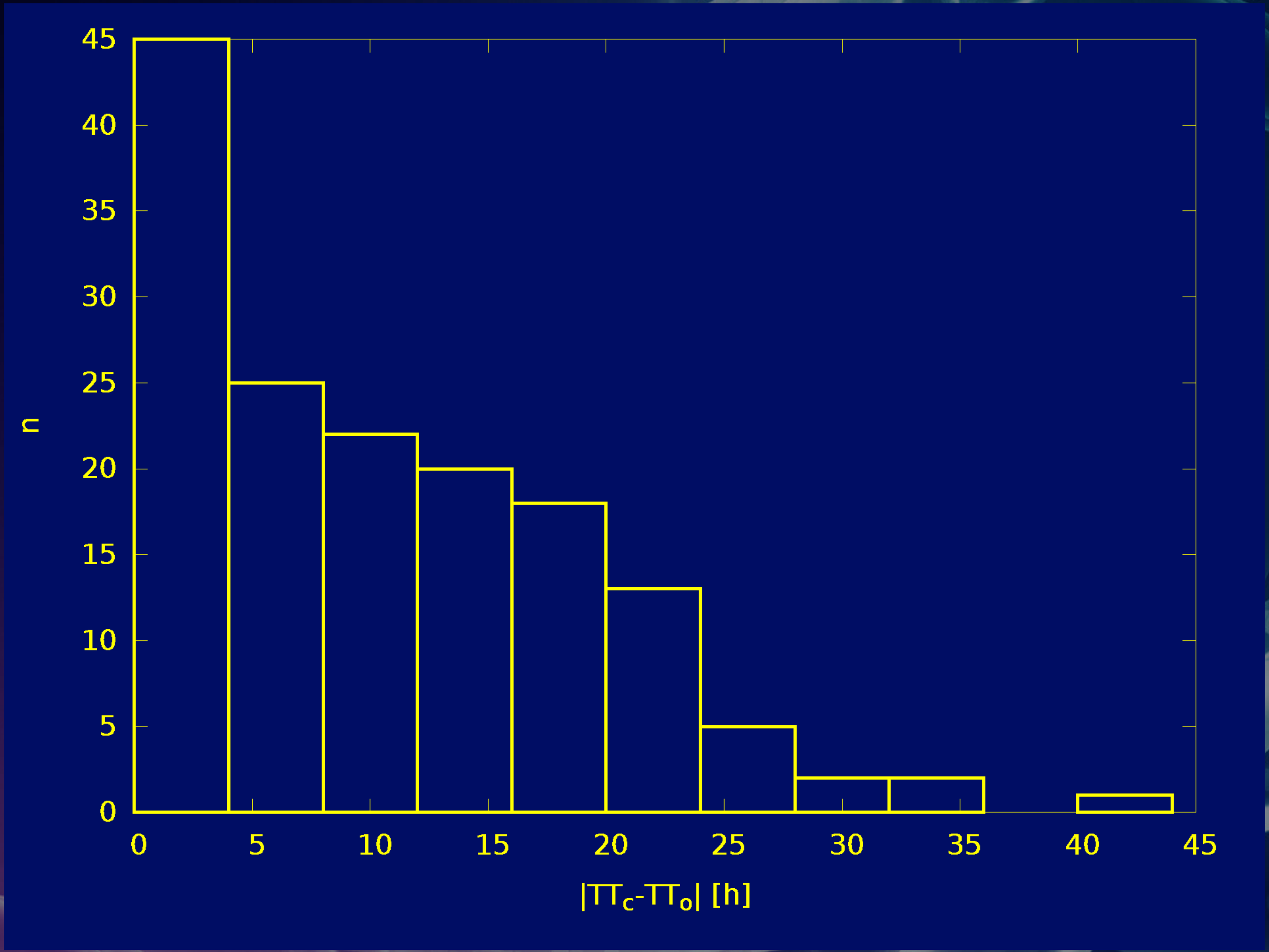


Convergence of $|T_c - T_o|$

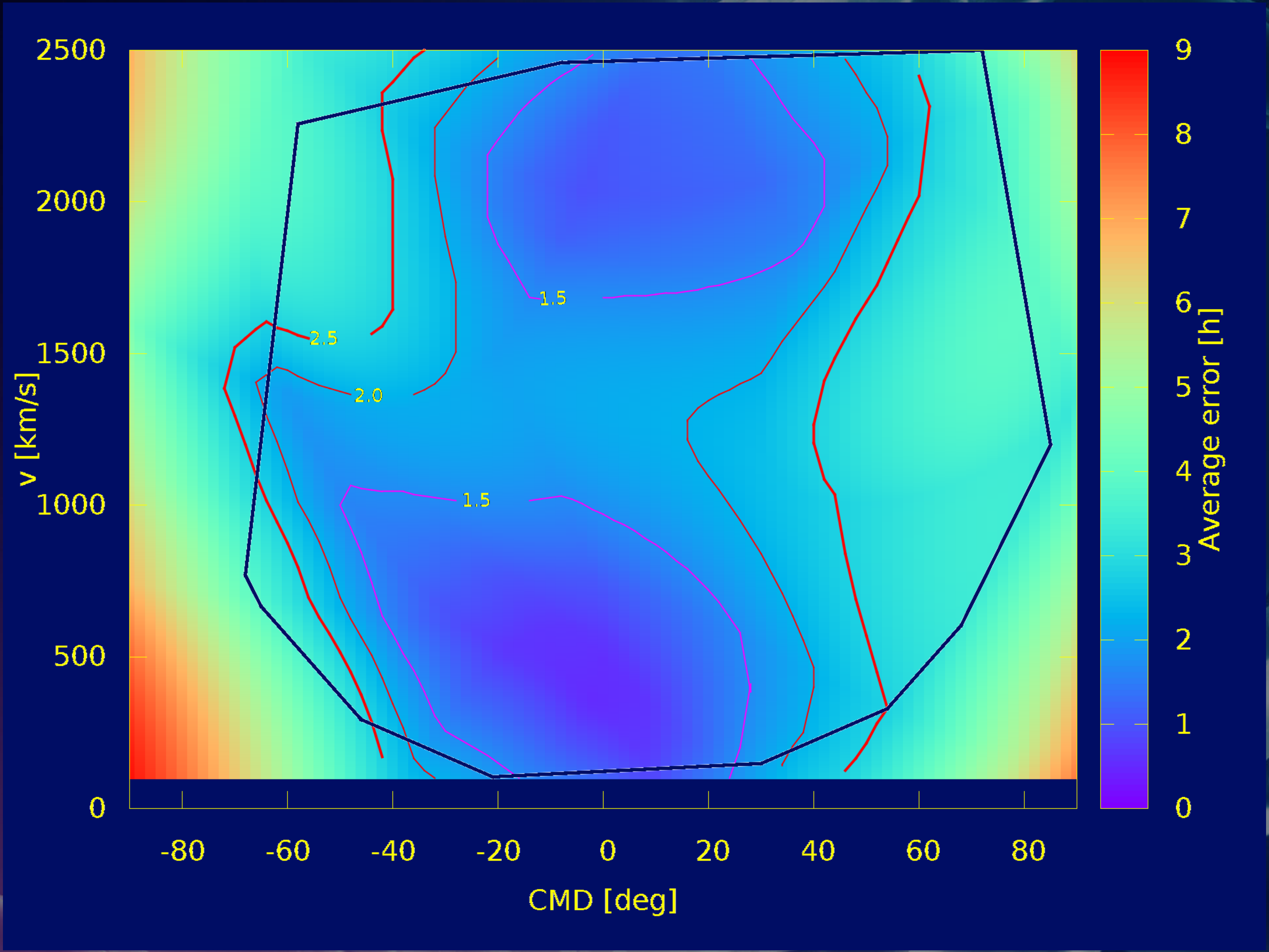


12 hours error :(

Distribution of $|TT_c-TT_o|$

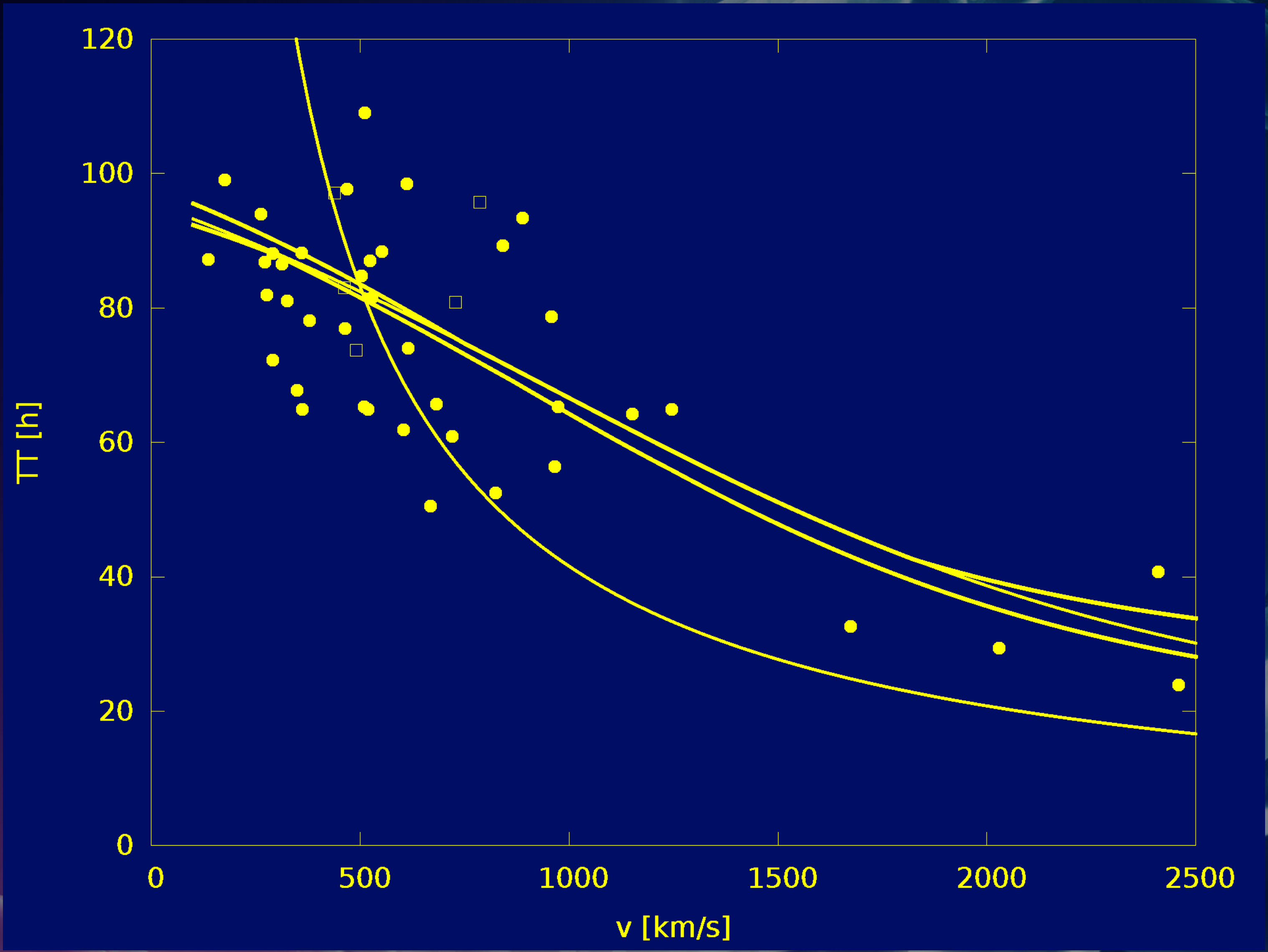


Error map



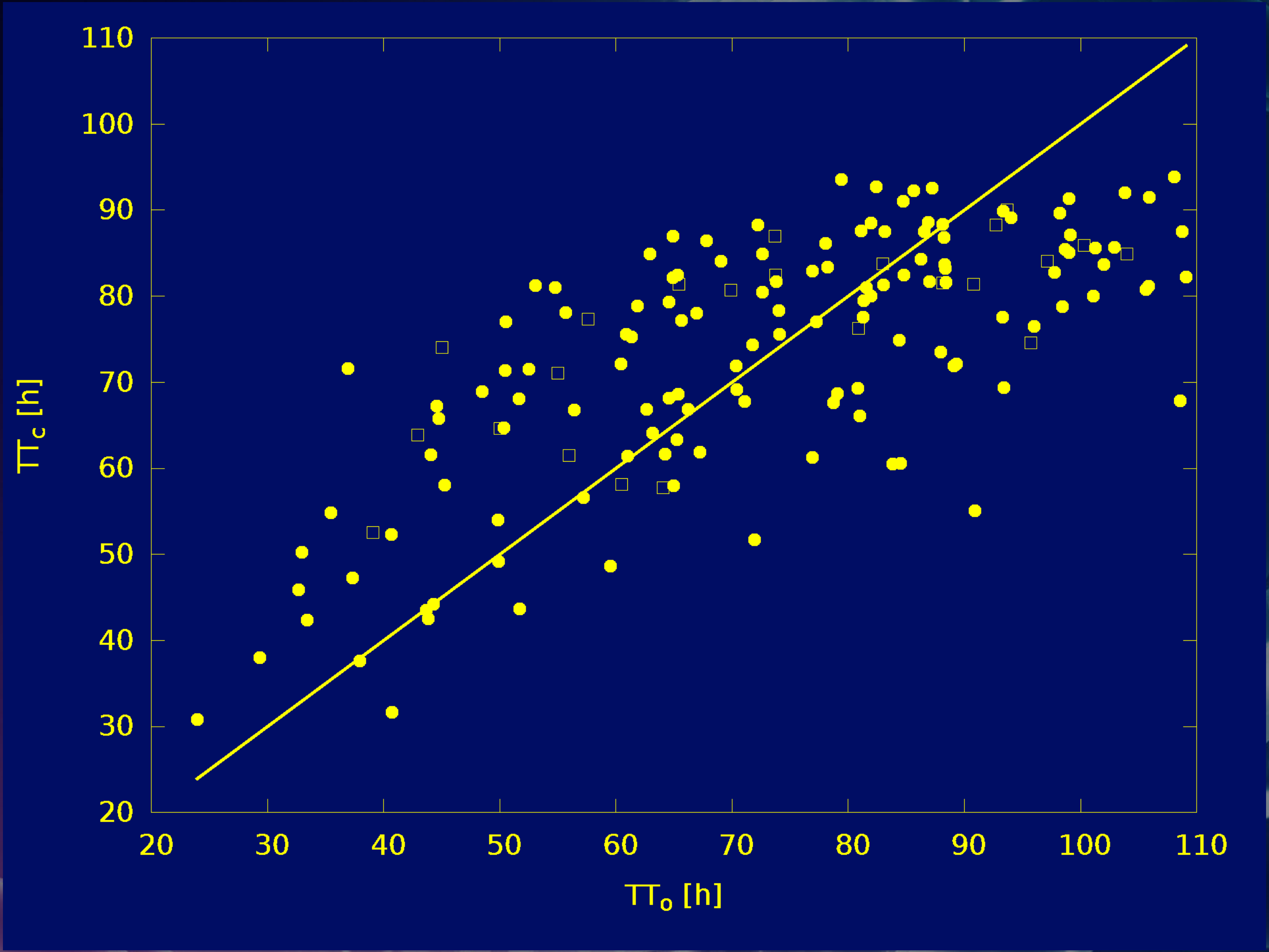
- 10 trained NNs
- Different learning sample
- Stability of the best fit
- Error of the mean curve

TT(v) around CMD = 0 deg

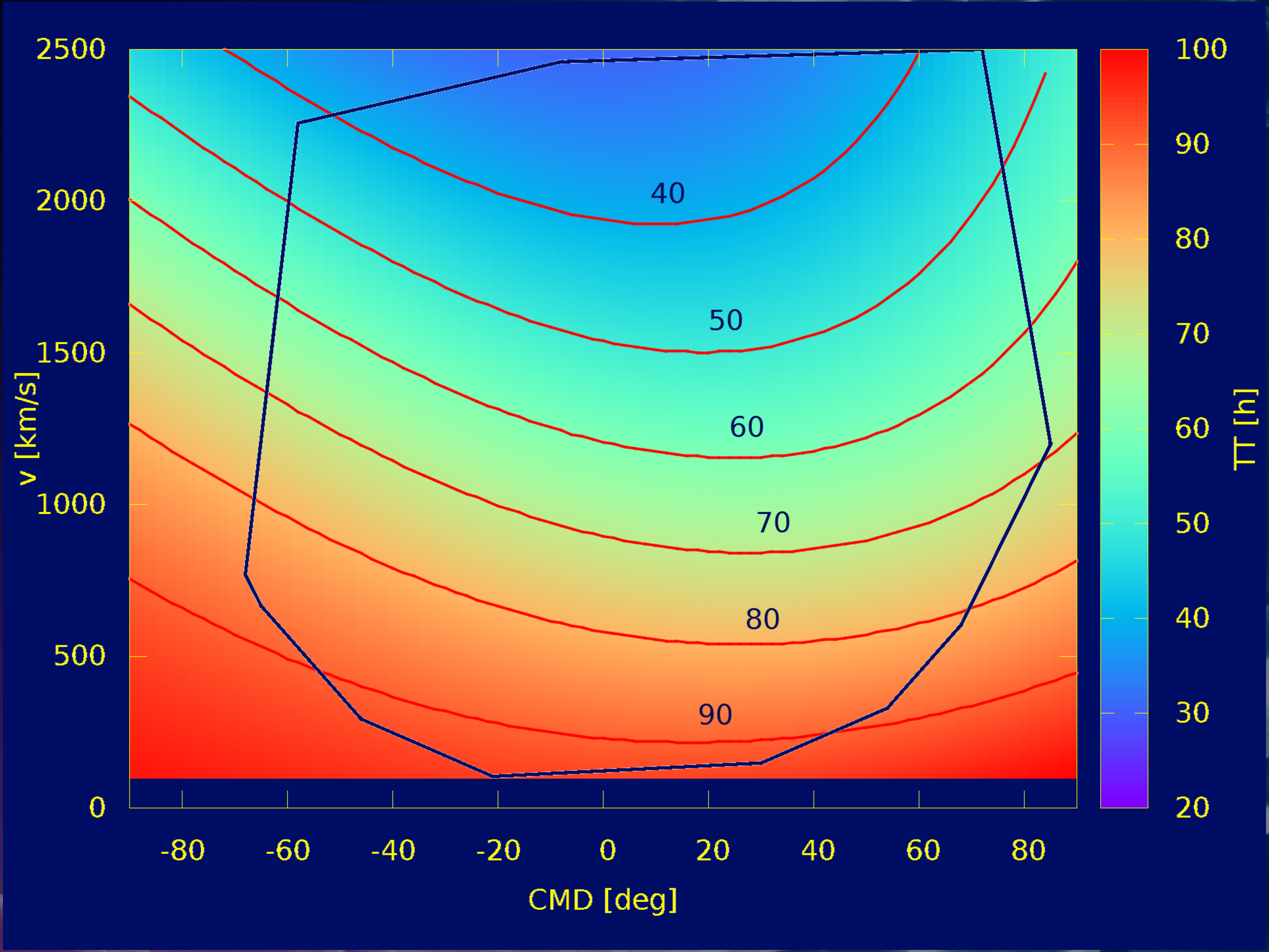


- Hyperbolic function is a=0, v = const
- Slower arrive sooner and faster later than v = const
- It's a drag
- Intersect is the speed of the moving medium (aka solar wind) = 500 km/s

Predicted vs reality

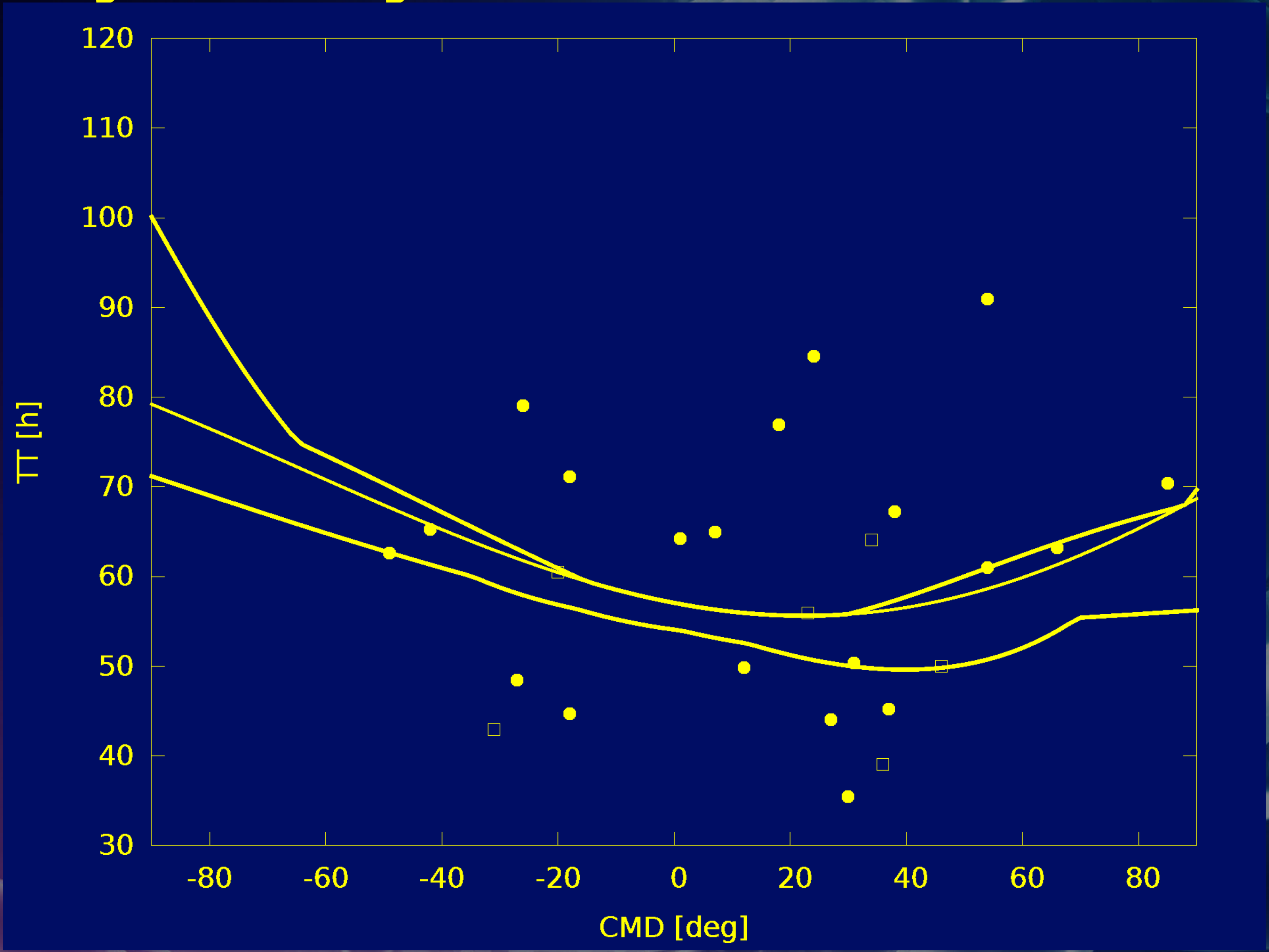


Calculated/predicted TT



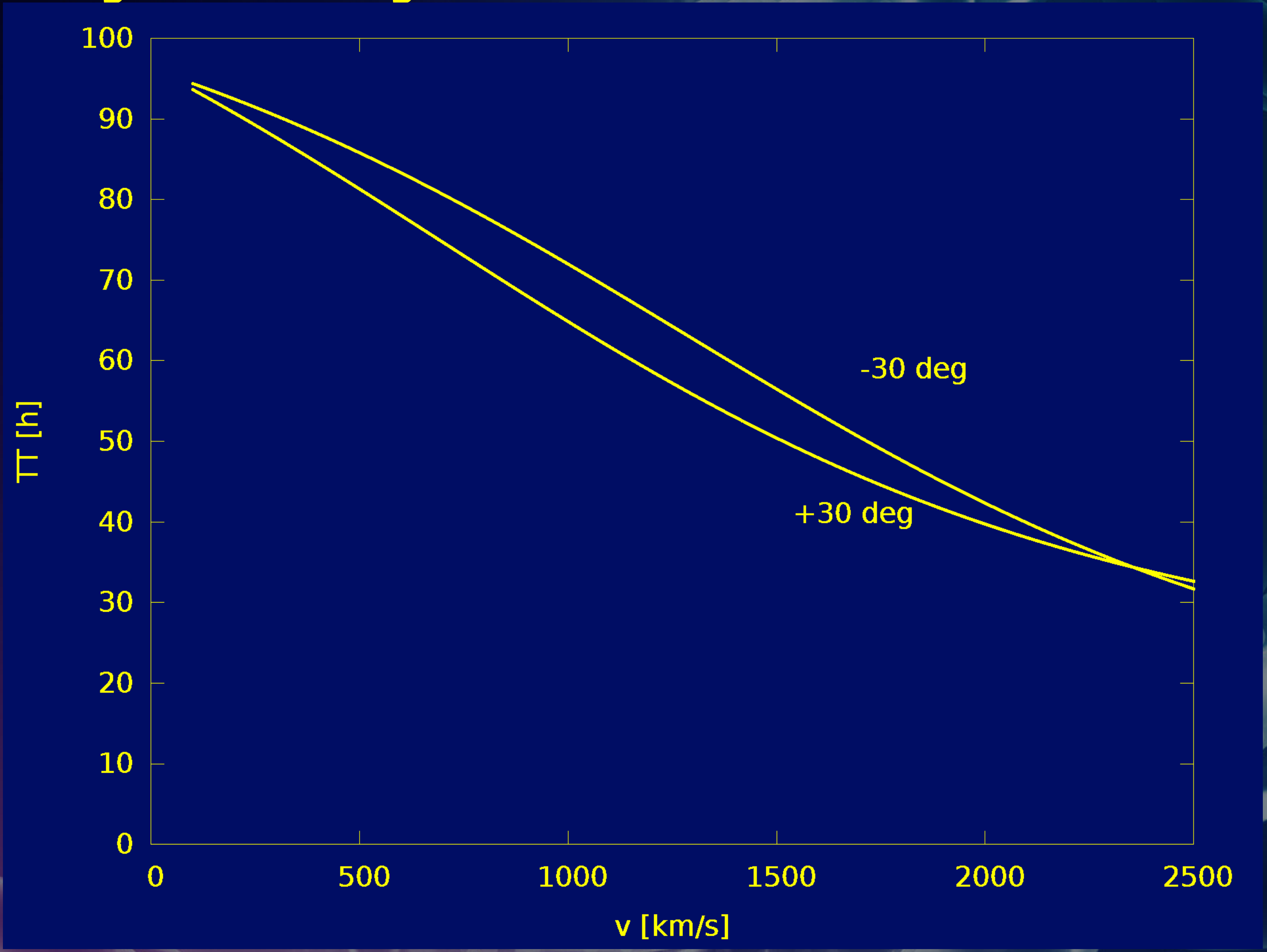
- Faster arrive sooner
- Western CMEs arrive sooner than eastern CMEs

Closer look at east-west asymmetry



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

Another view of east-west asymmetry



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).