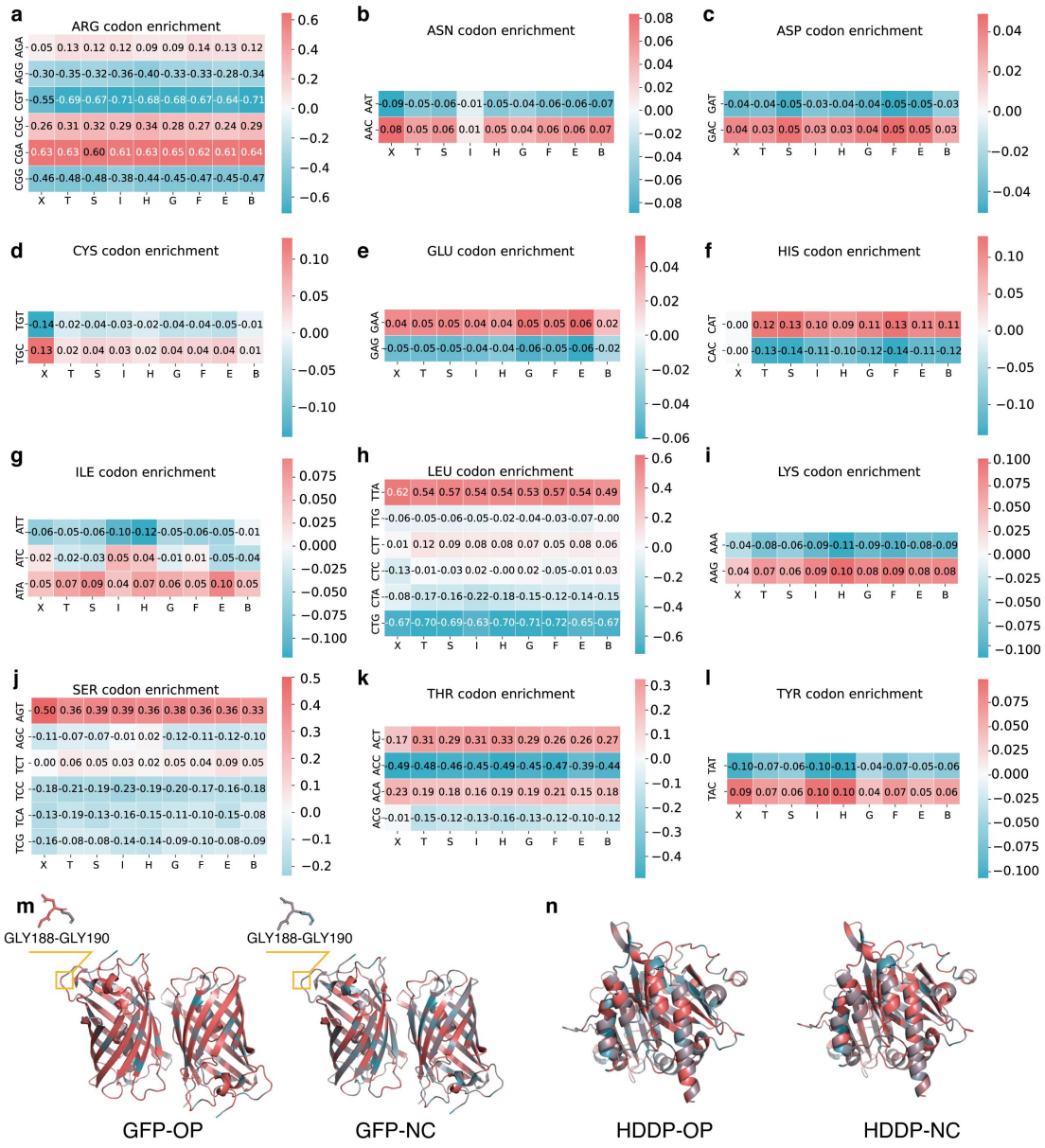

Extended Data Fig. 2: **Interpretability analysis of the model via Integrated Gradients (IG) and structural implementation. a – l,** Attribution maps of codon-structure feature importance via Integrated Gradients (IG). Heatmaps display the IG attribution scores for 12 representative amino acids, quantifying the contribution of specific synonymous codons (vertical axis) and their associated secondary structure tokens (horizontal axis: X, T, S, I, H, G, F, E, B) to the model's output. **m-n,** Structural visualization of codon-optimized (OP) versus non-optimized/native (NC) GFP and HDDP variants.