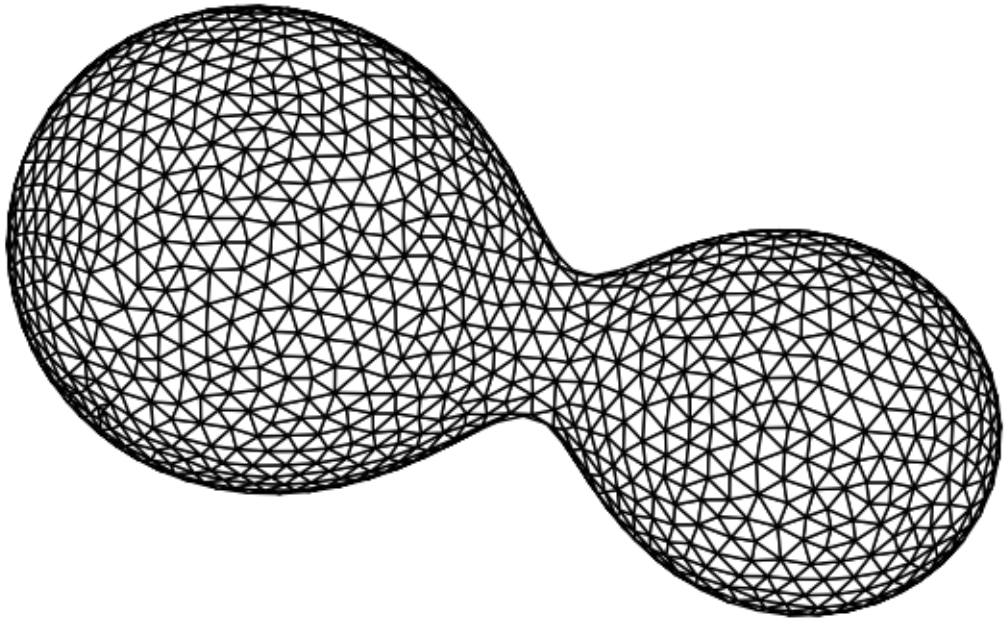
The present and the future in modeling eclipsing binary stars

Andrej Prša
Villanova University



Binary and multiple stars in the era of big sky surveys Litomyšl, CZ, Sep 9-13, 2024

Is eclipsing binary science (still) popular?

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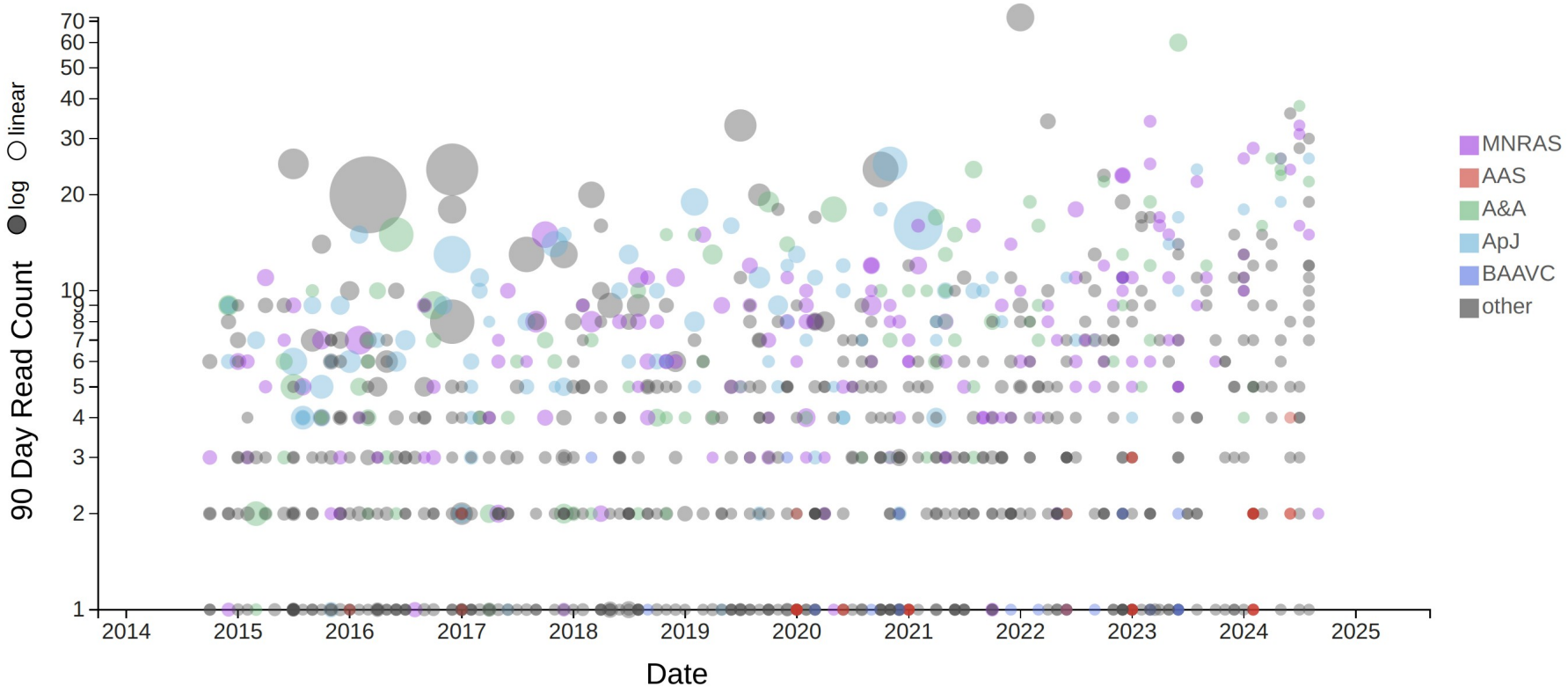
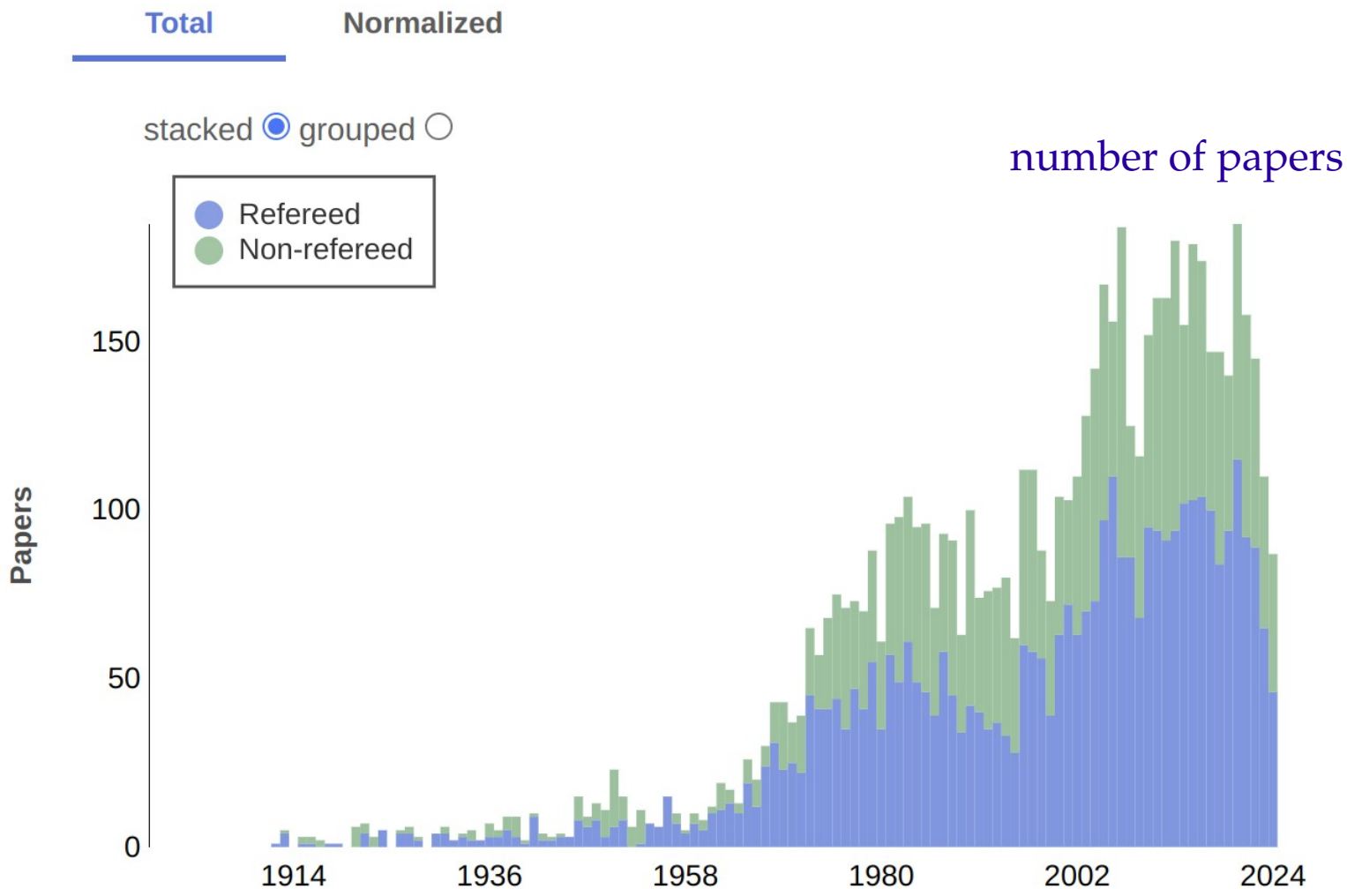


ADS query `title: “eclipsing binaries”` on Sep 9, 2024

Is eclipsing binary science popular?



number of papers

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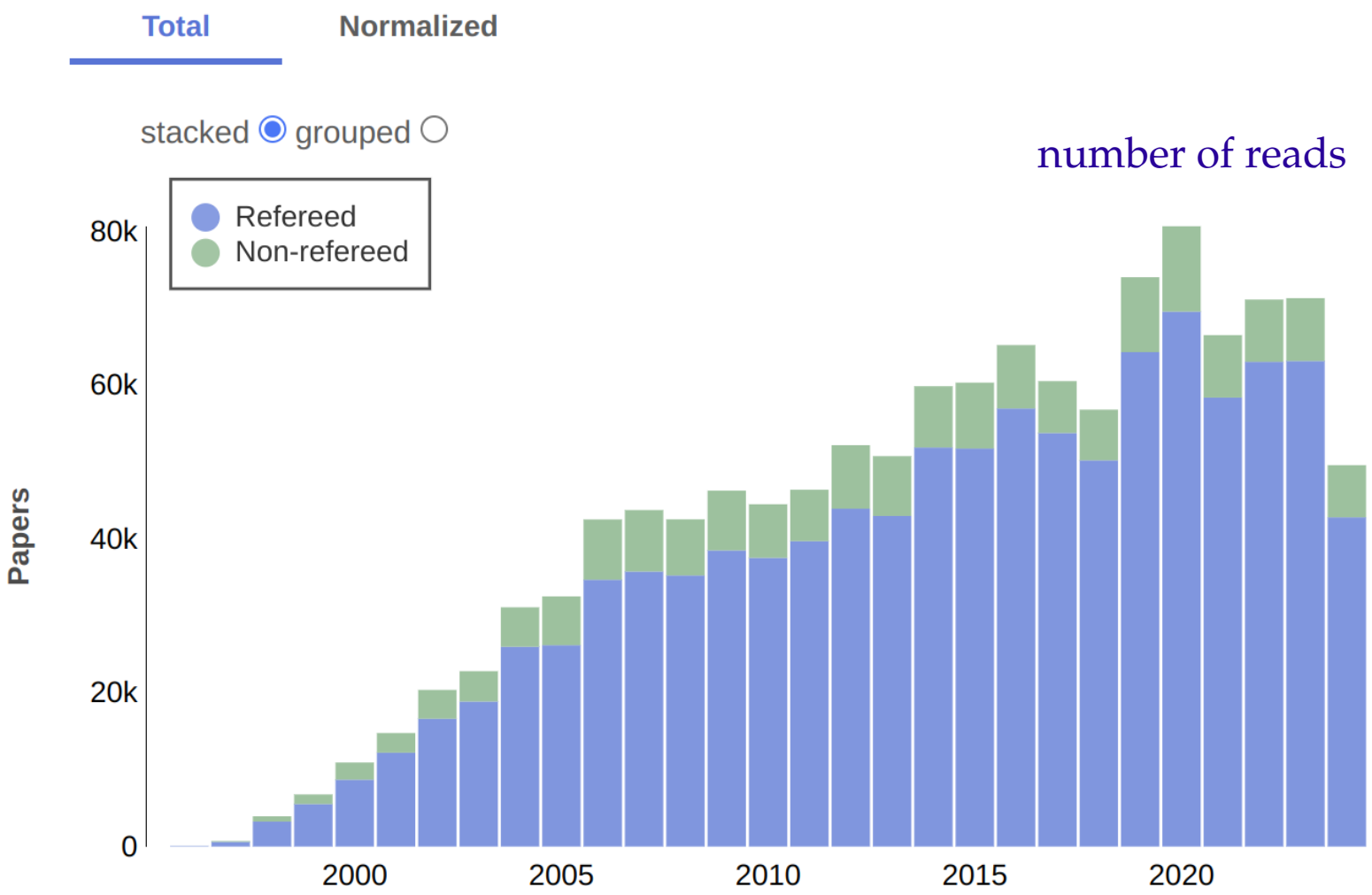
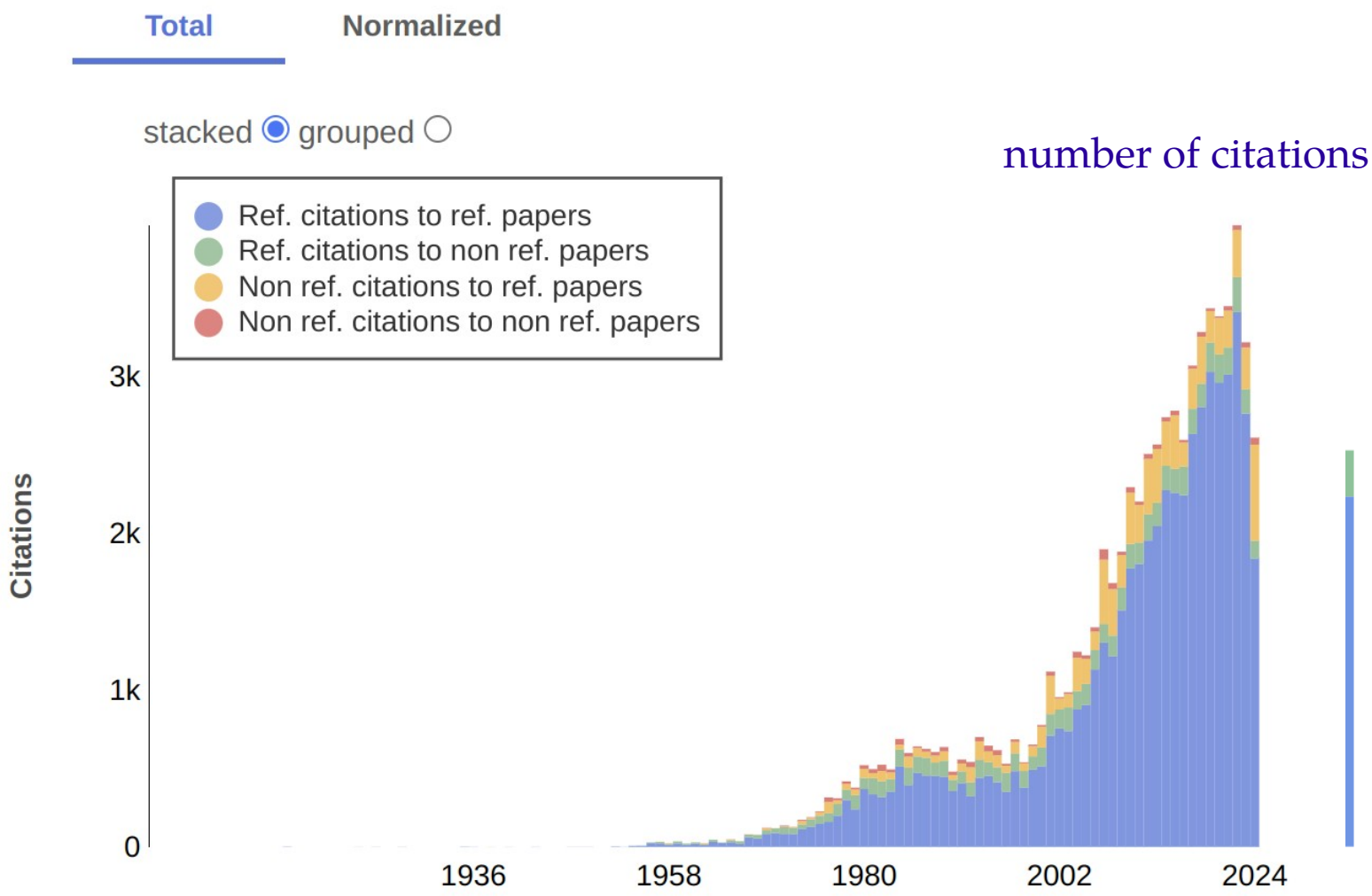


number of reads

ADS query `title: “eclipsing binaries”` on Sep 18, 2024

Is eclipsing binary science popular?



number of citations

ADS query `title: “eclipsing binaries”` on Sep 18, 2024

yes, binaries are still important!

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(also made evident by the number of young people here!)

Binaries are good because …

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Ubiquity	Plethora of spectral types	Coalescence and gravity waves
Role in stellar evolution	Distances	Blue stragglers, yellow giants
Intrinsic pulsators	Dynamical interaction	Circumbinary planet hosts
Spots, flares, rotation	Contaminators	Tidally induced pulsations
Fundamental parameters	Multiplicity rates	Magnetic dynamos
Plethora of luminosity classes	Kozai cycles	Stellar populations
Ideal physical laboratories	Calibrators	Progenitors of SN, PNe, ...
Contact binary coalescence	Magnetic coupling	Asteroseismic relations

yet it won’t work without good models...

What are the makings of a good model?

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- generality
- accuracy
- fidelity
- reproducibility
- practicality

- ease of use
- open source
- documentation
- tutorials, workshops
- disambiguation

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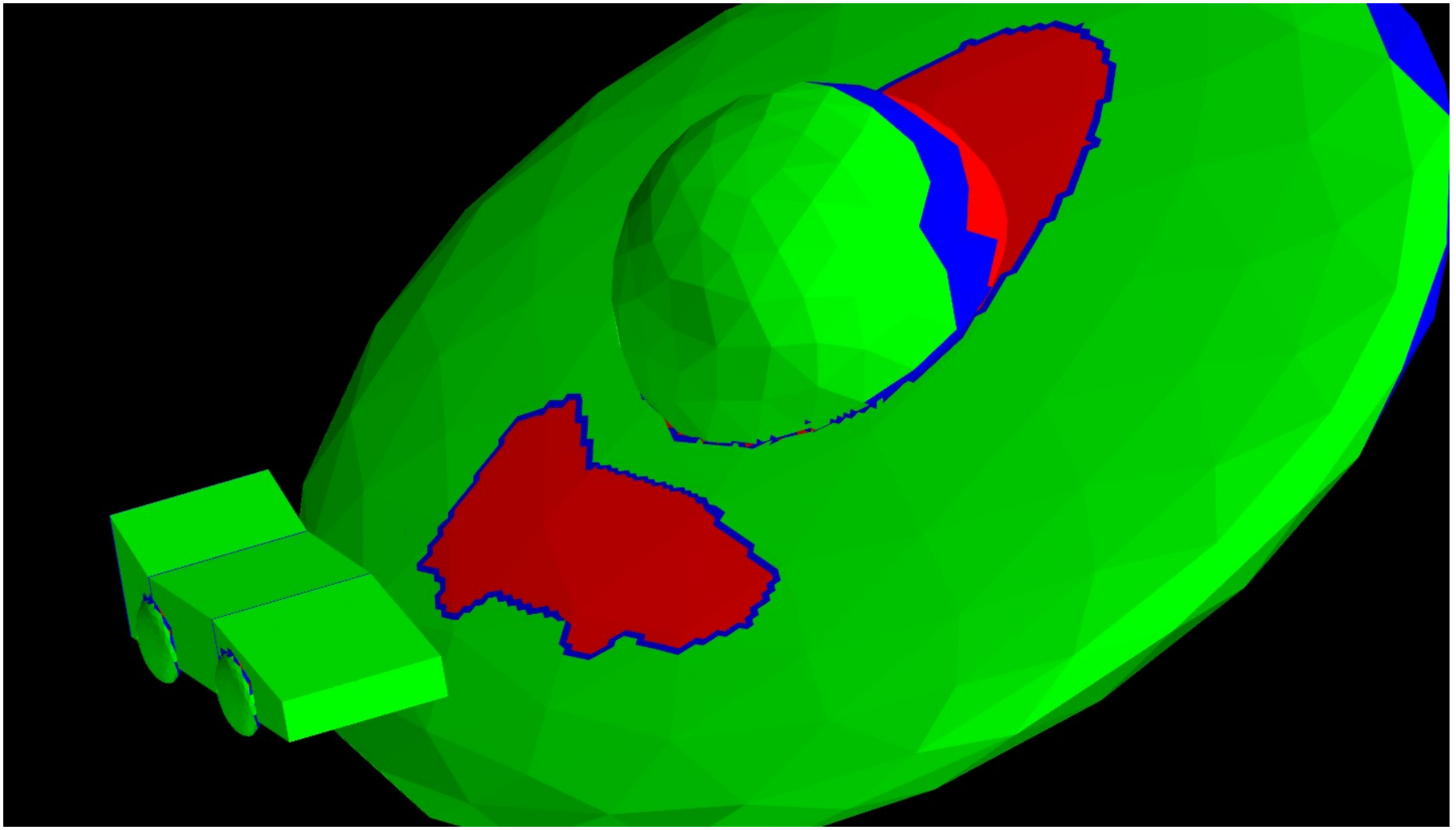
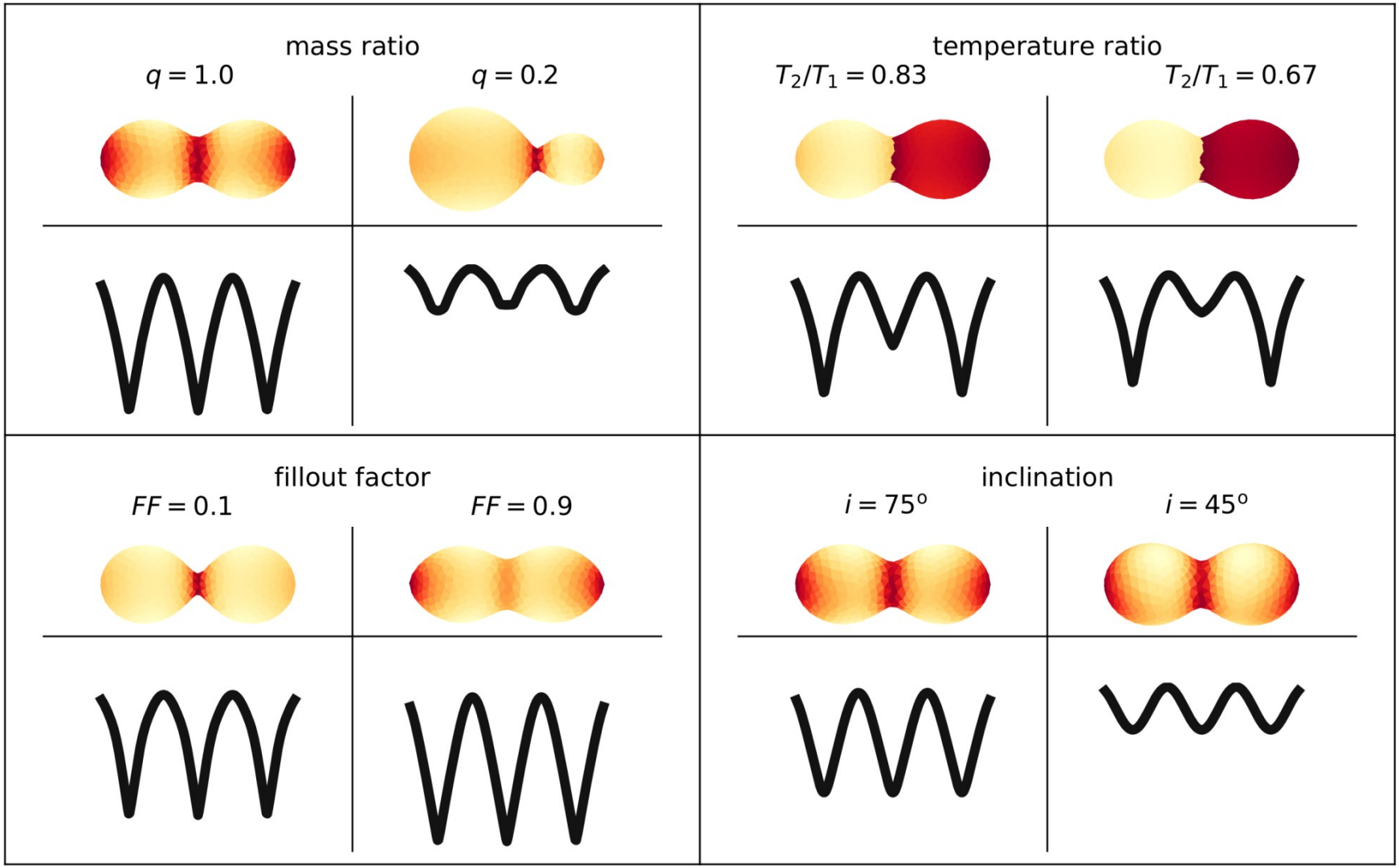
What are the makings of a good modeler?

- well versed in theory
- good grasp of statistics
- can read the code
- can apply the code sanely
- can interpret the results critically
- familiarity with the literature
- thinking out-of-the-box
- working with others
- learning from others
- having fun doing science

What are the makings of a good model?



Quick example: contact binary star model



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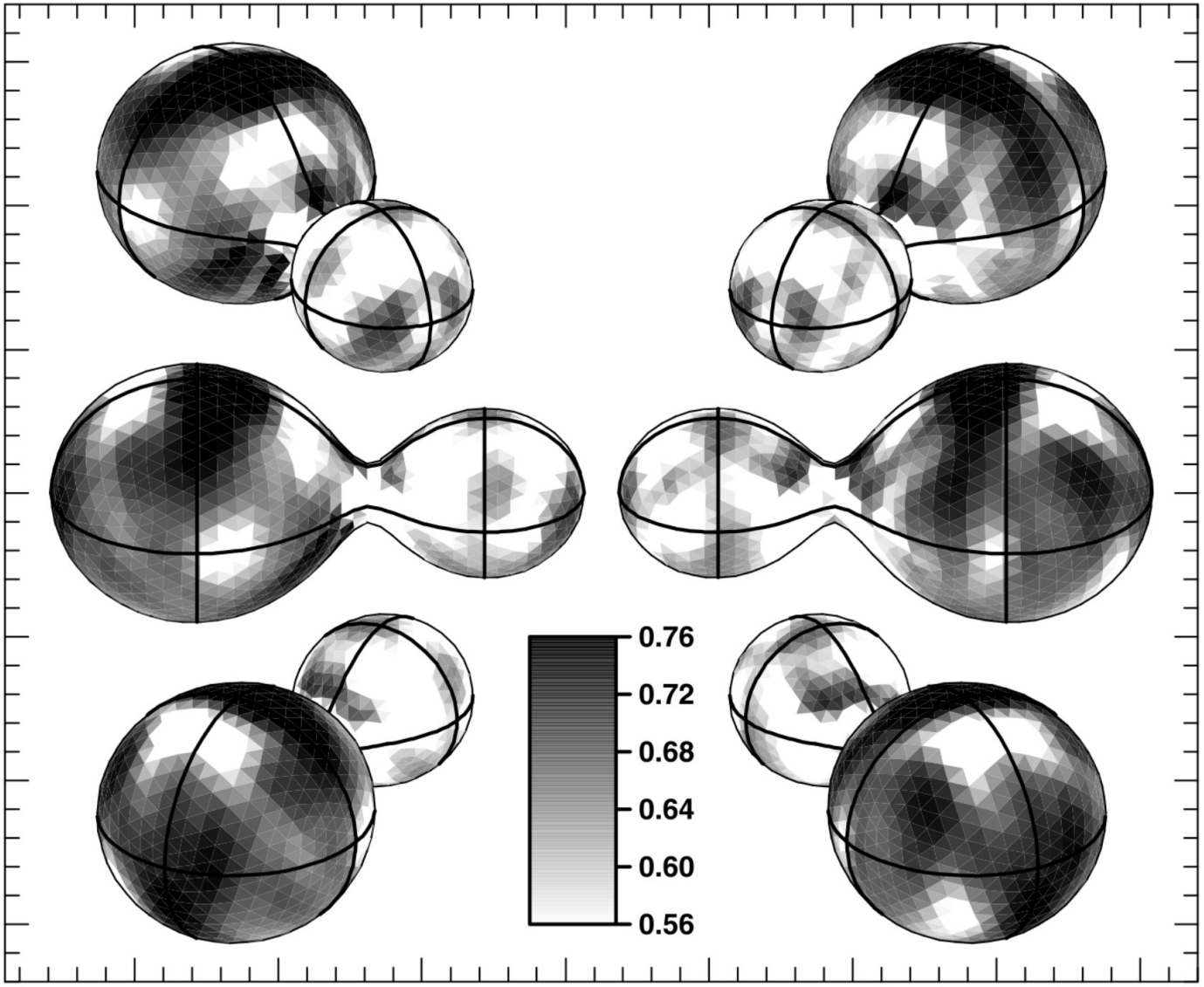

VW Cephei
Hendry &
Mochnacki (2000)

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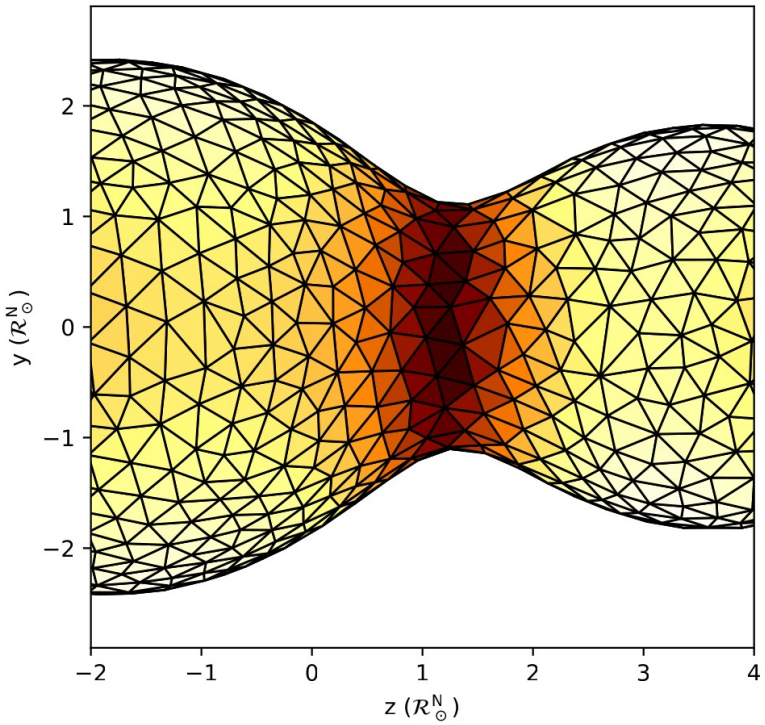
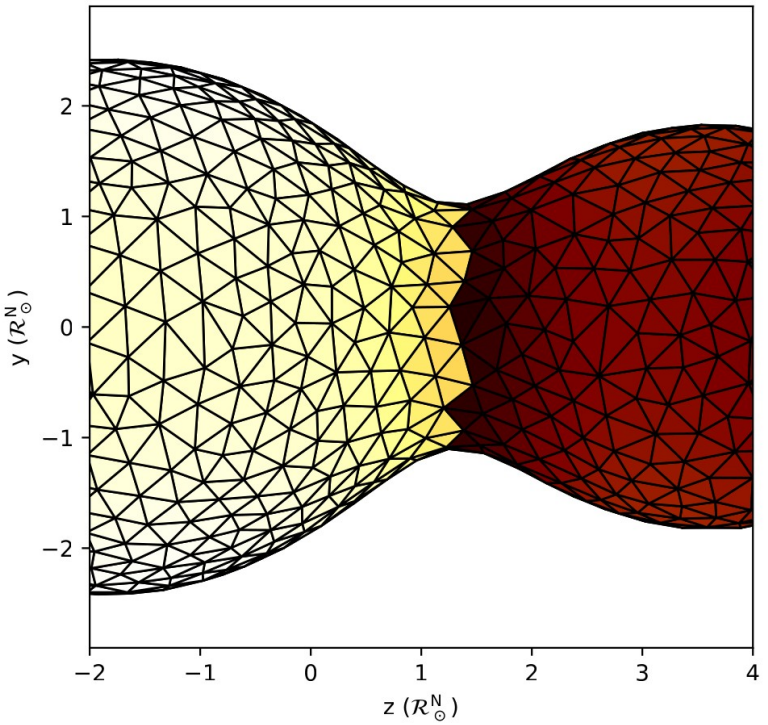


contact binary in thermal equilibrium



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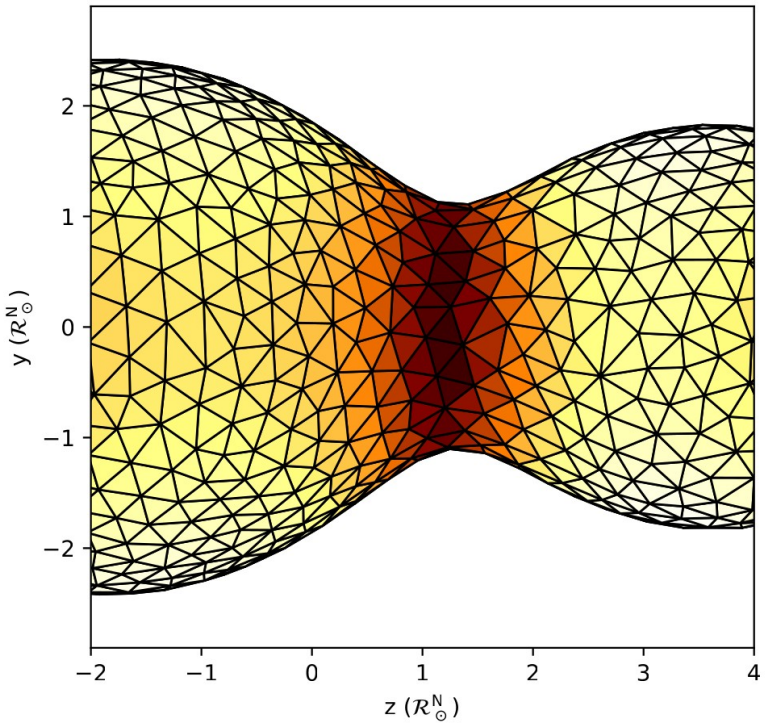

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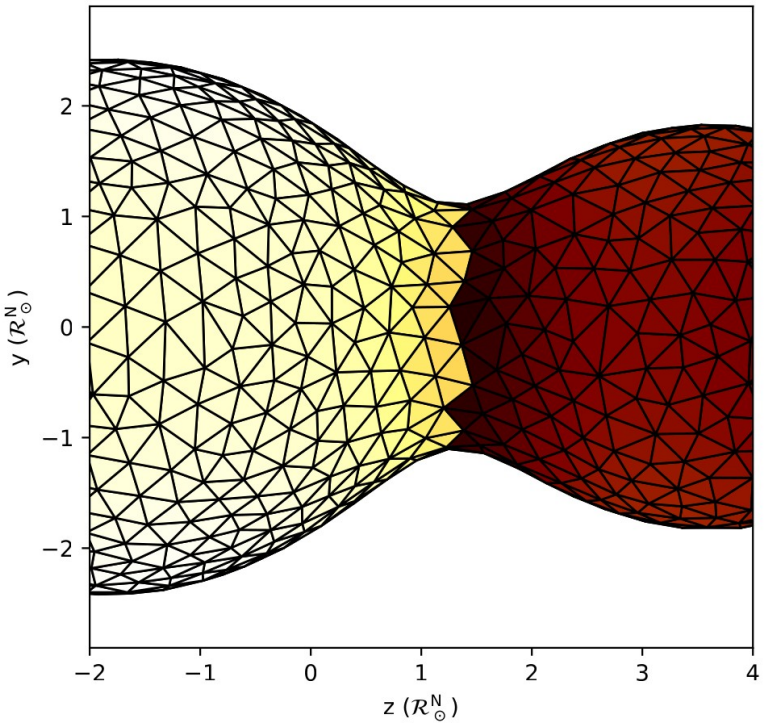
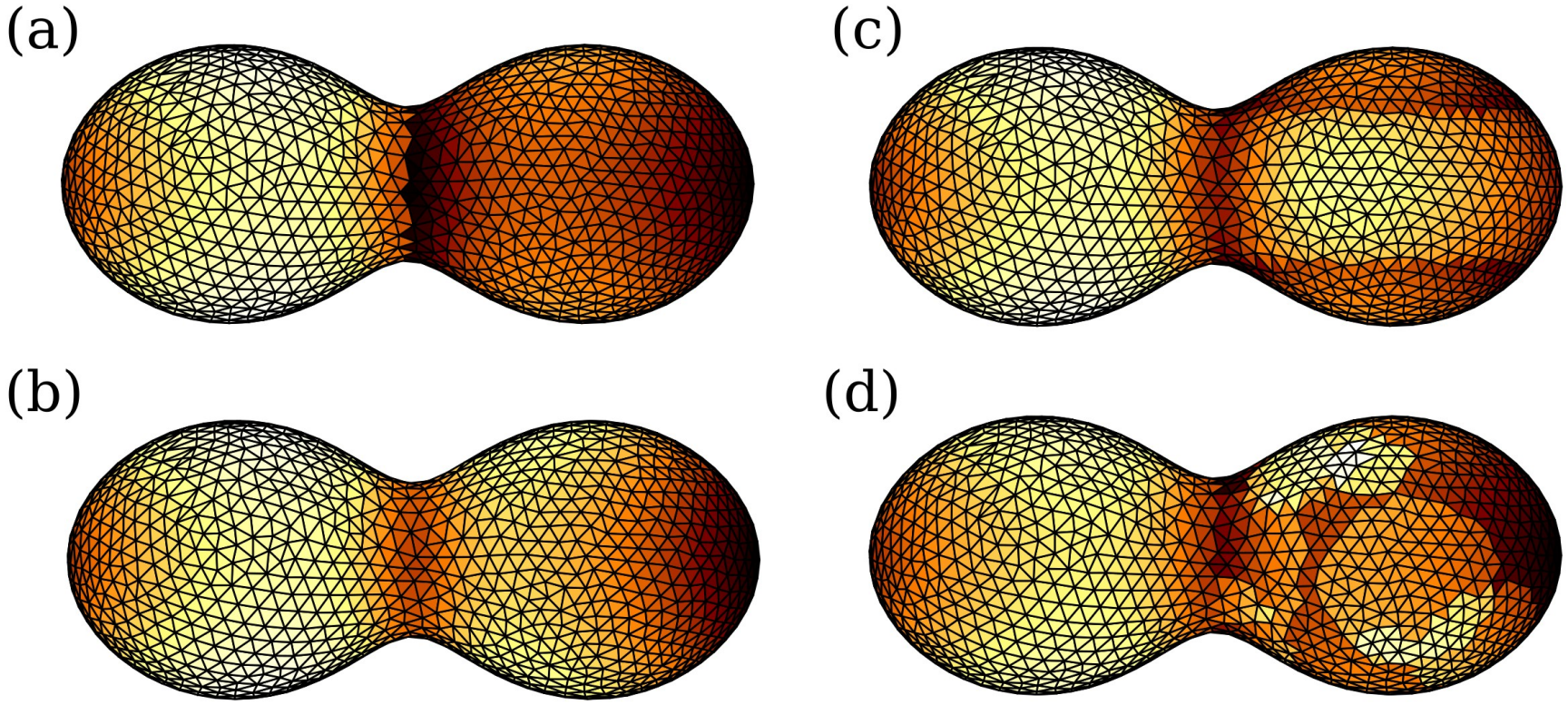


contact binary out of thermal equilibrium

this is clearly an unphysical circumstance!

Quick example: contact binary star model



(a) original mesh without mixing, where the secondary star is 5% cooler;
(b) envelope dominated by radial mixing that scales linearly with neck distance;
(c) envelope dominated by lateral mixing that scales with distance from the equator;
(d) envelope dominated by magnetic activity that is mixed on the spot timescales.

THE DATA

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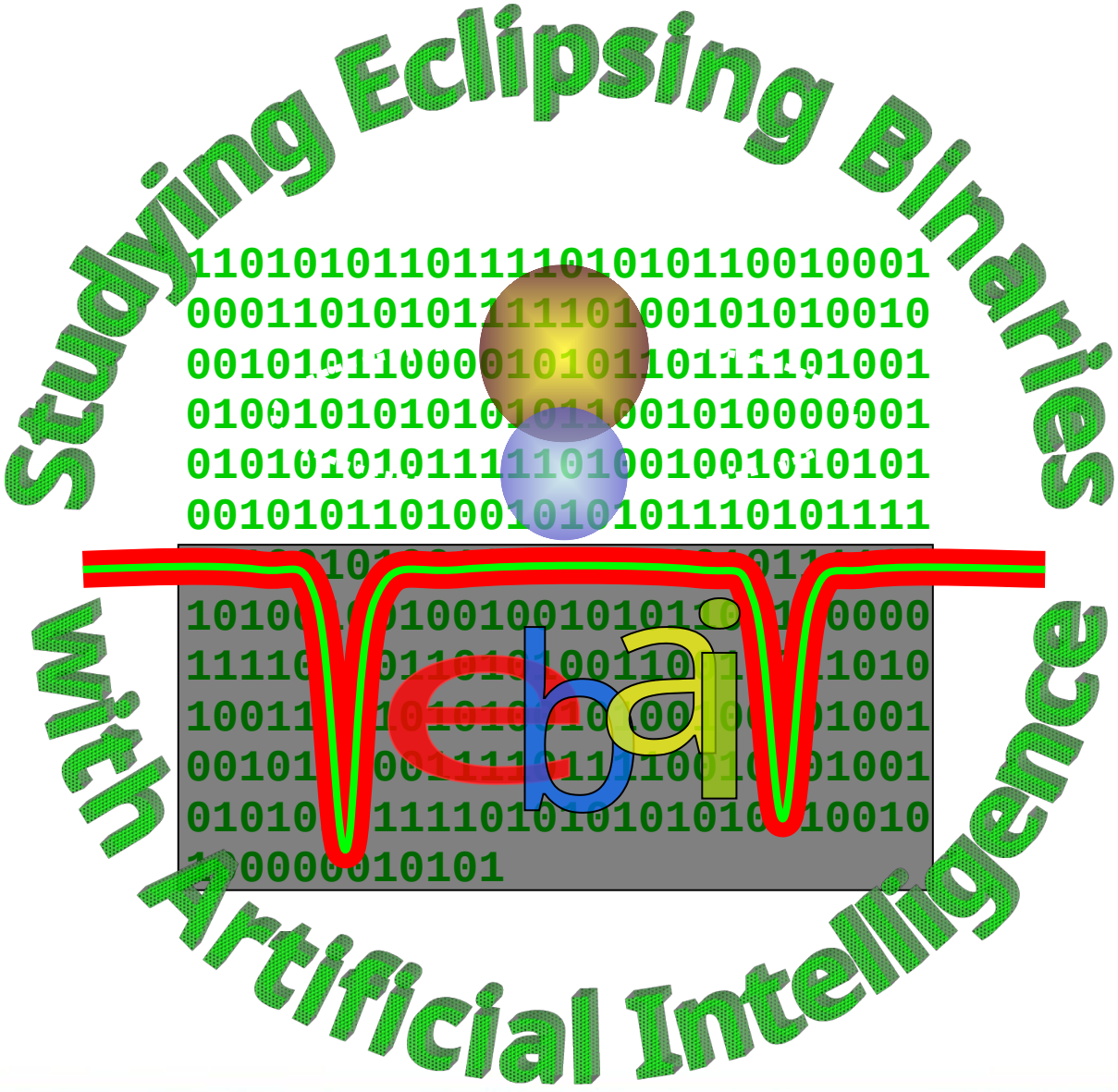
Modeling EBs correctly is the main bottleneck in stellar astrophysics

The EBAI project



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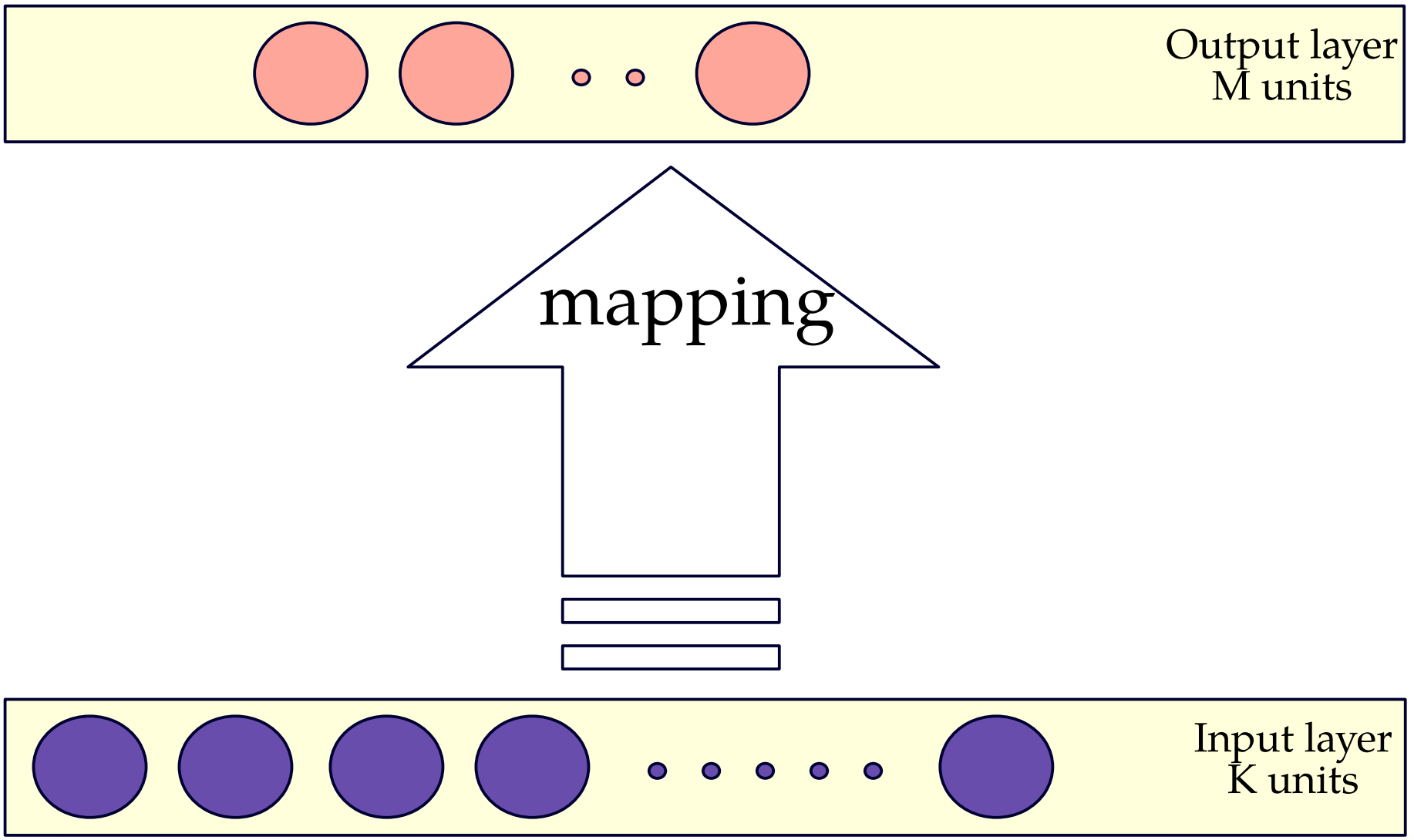

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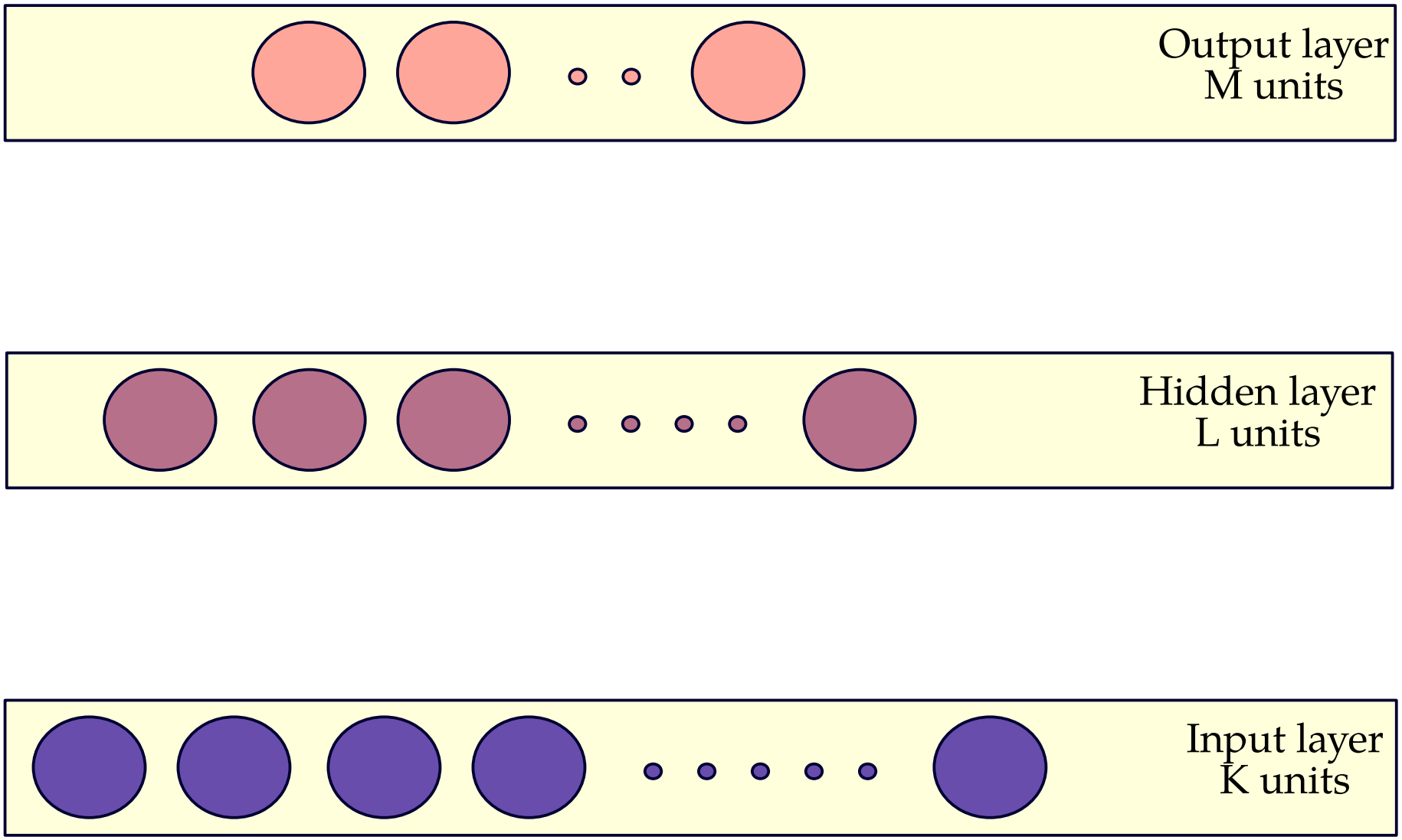

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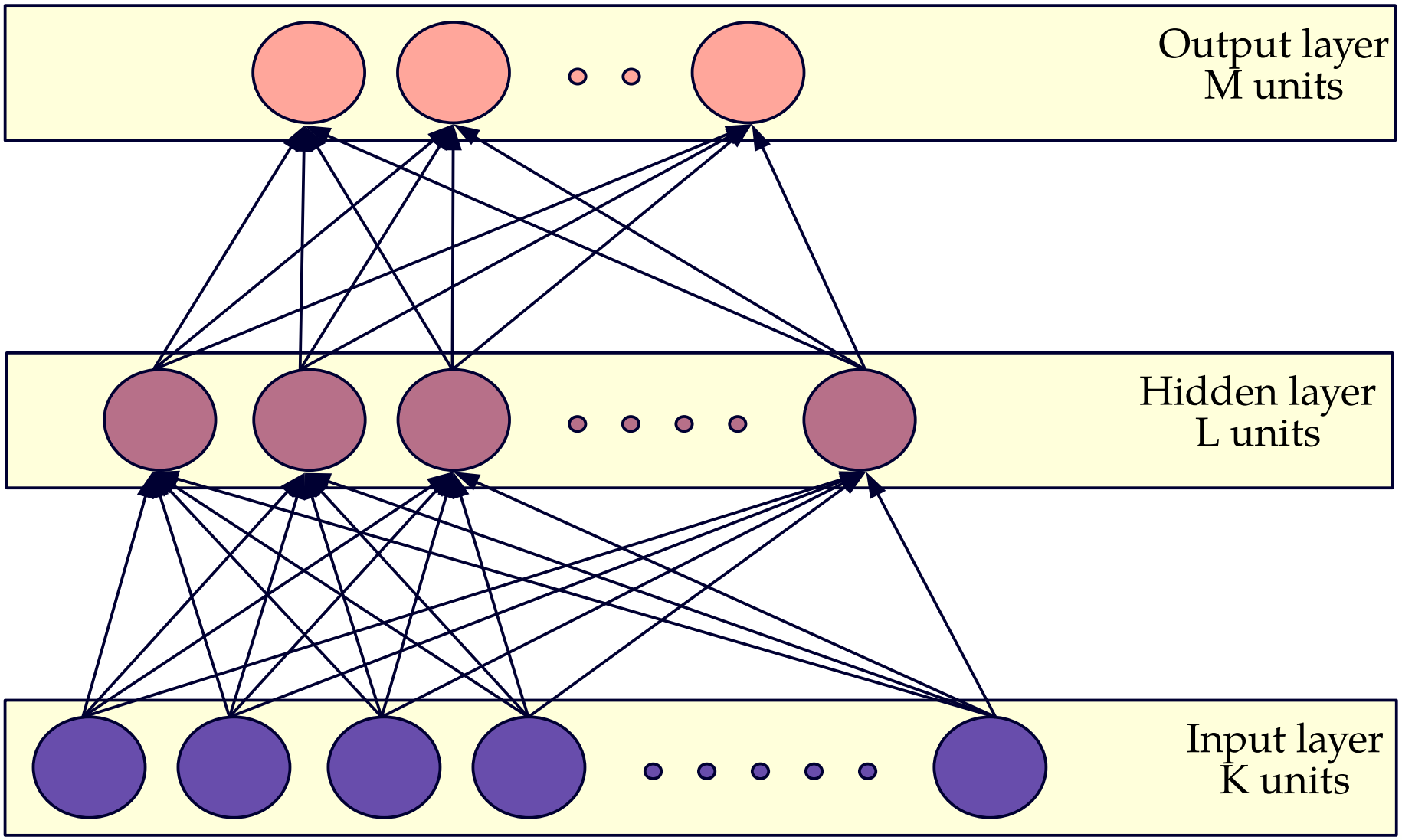

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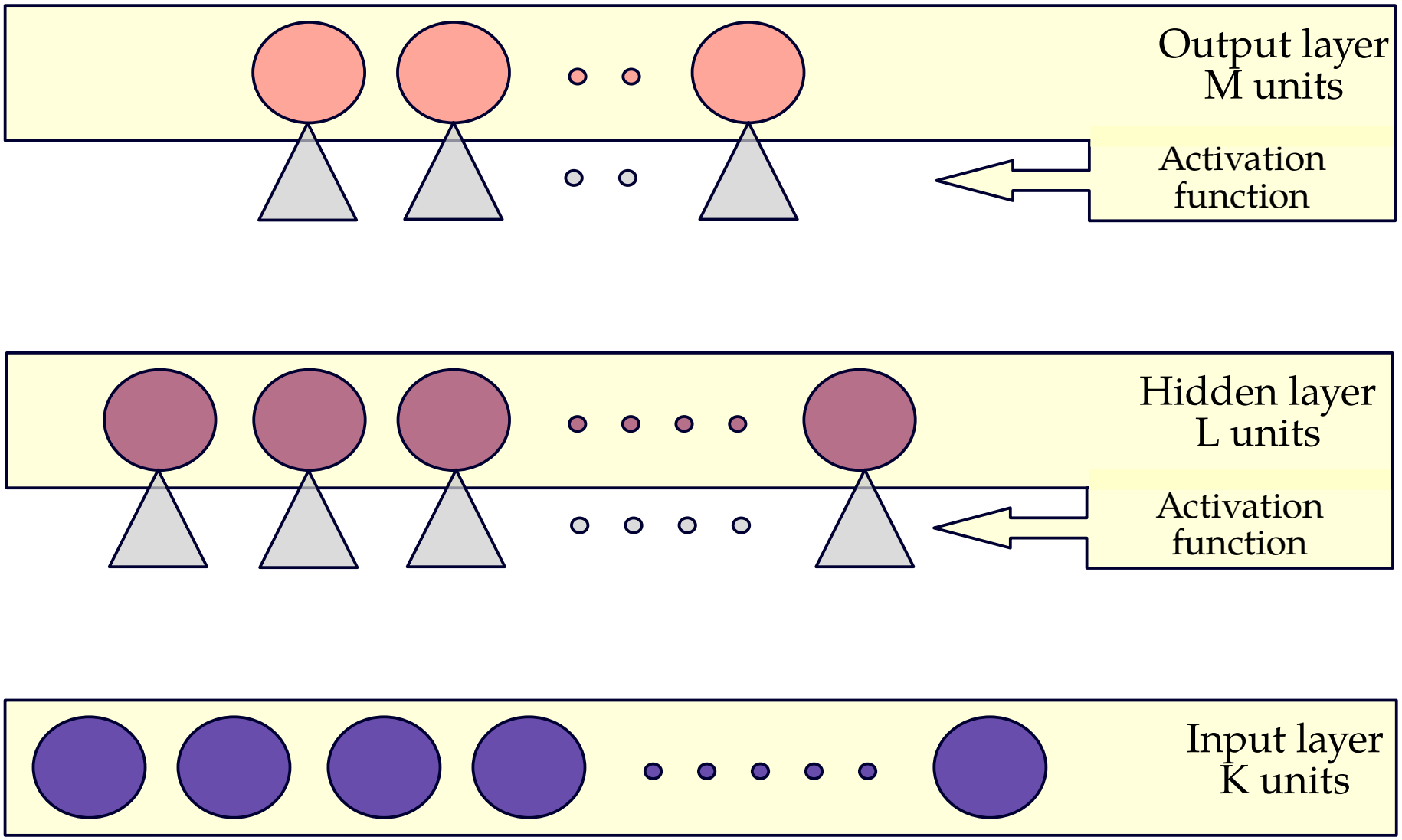

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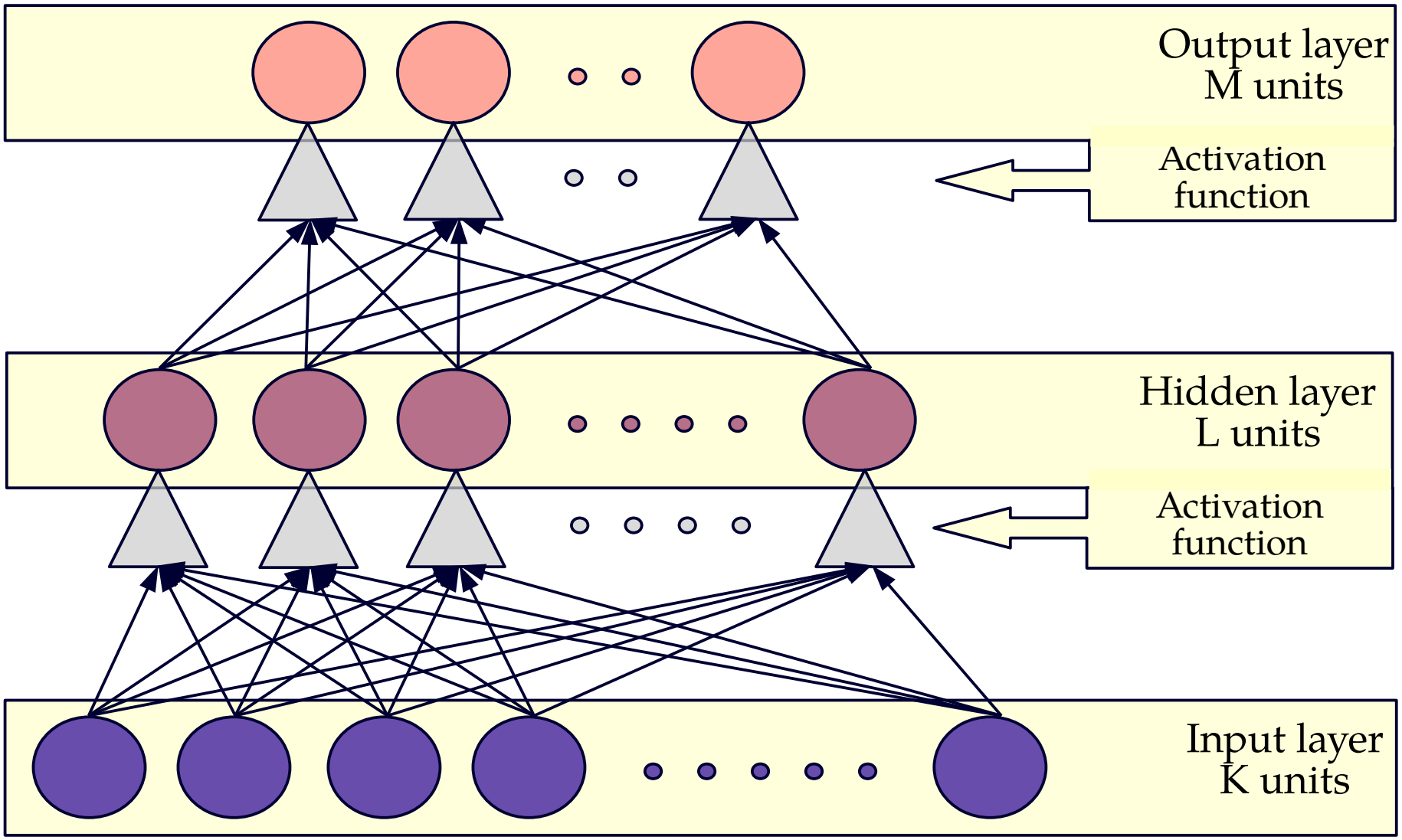

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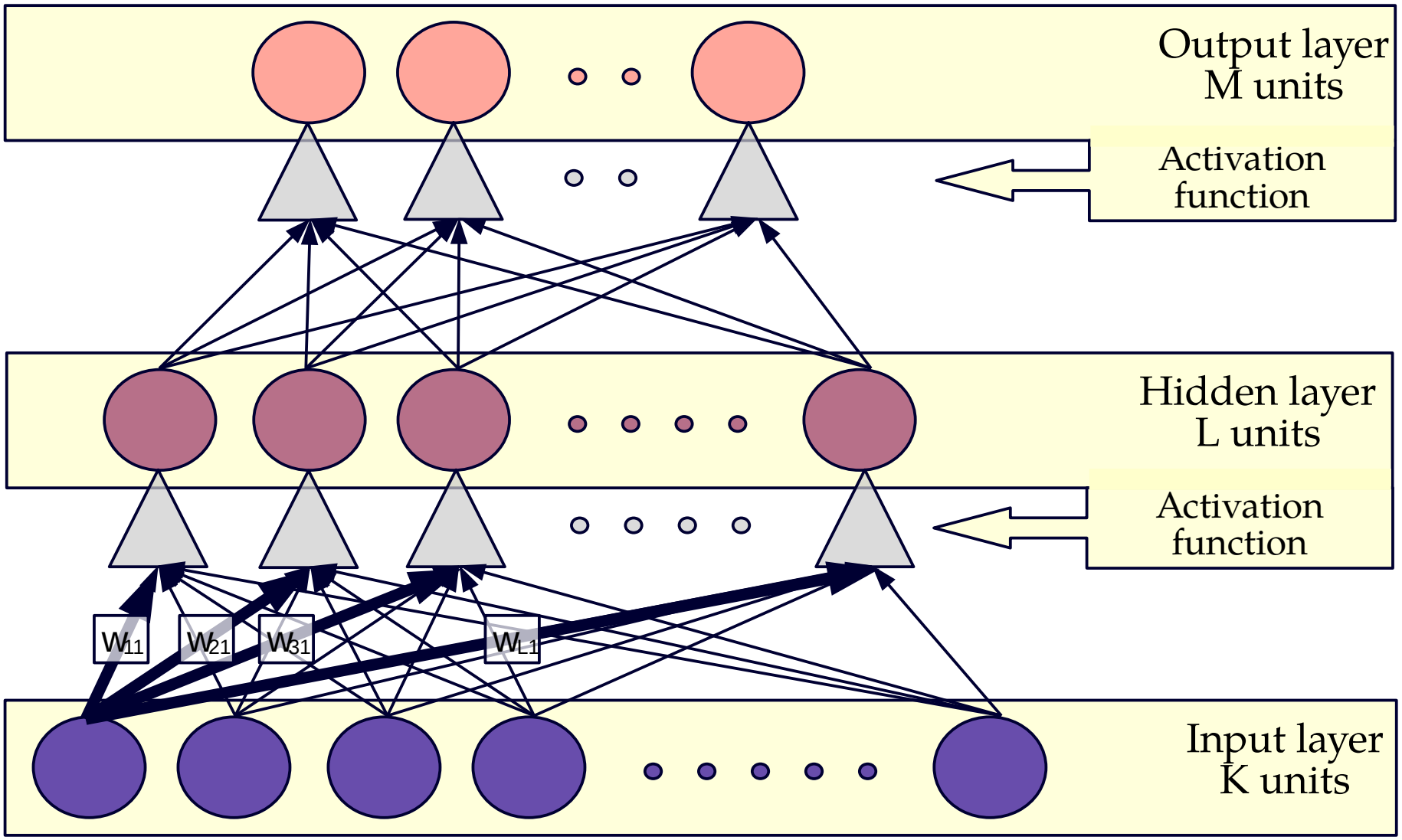

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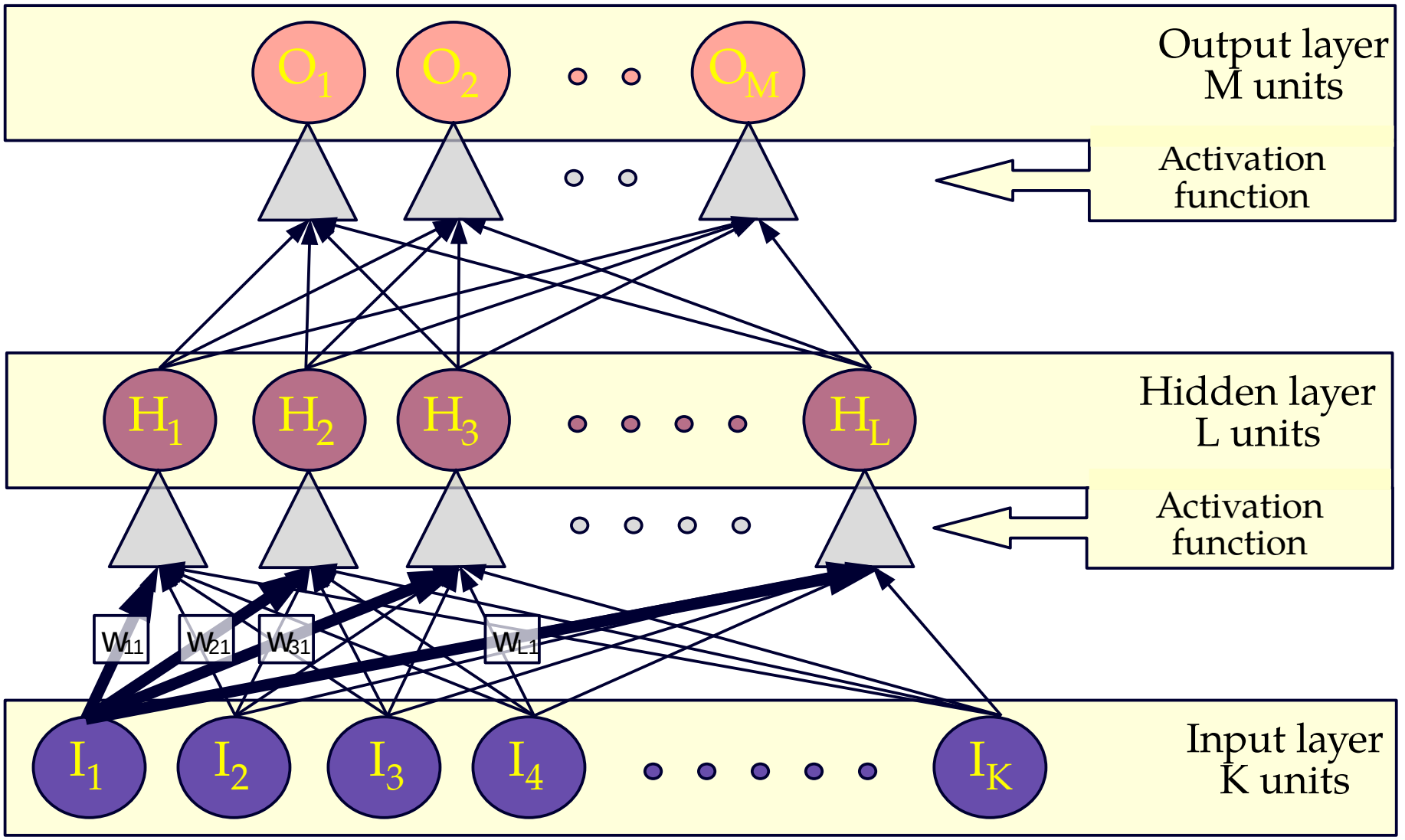

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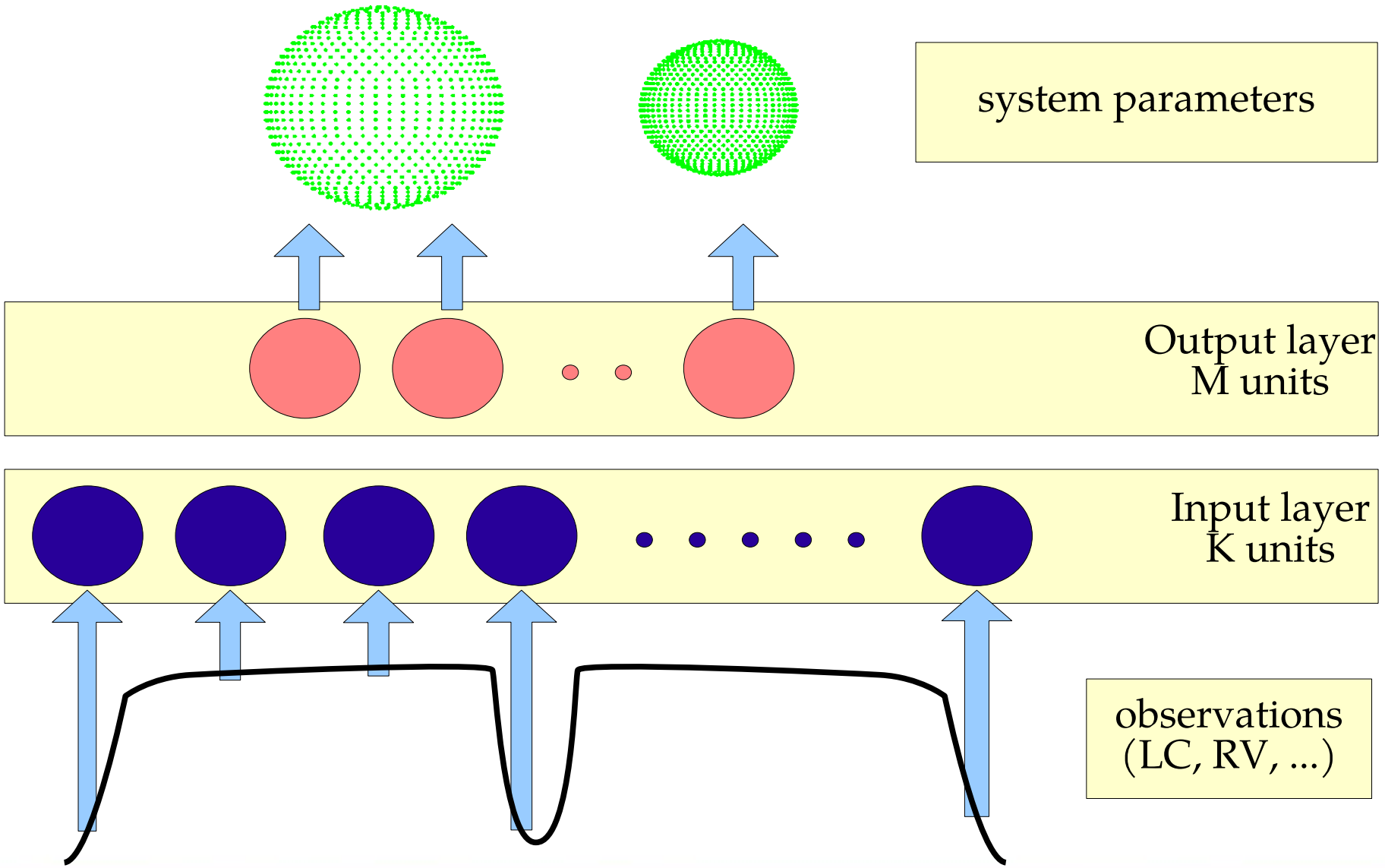

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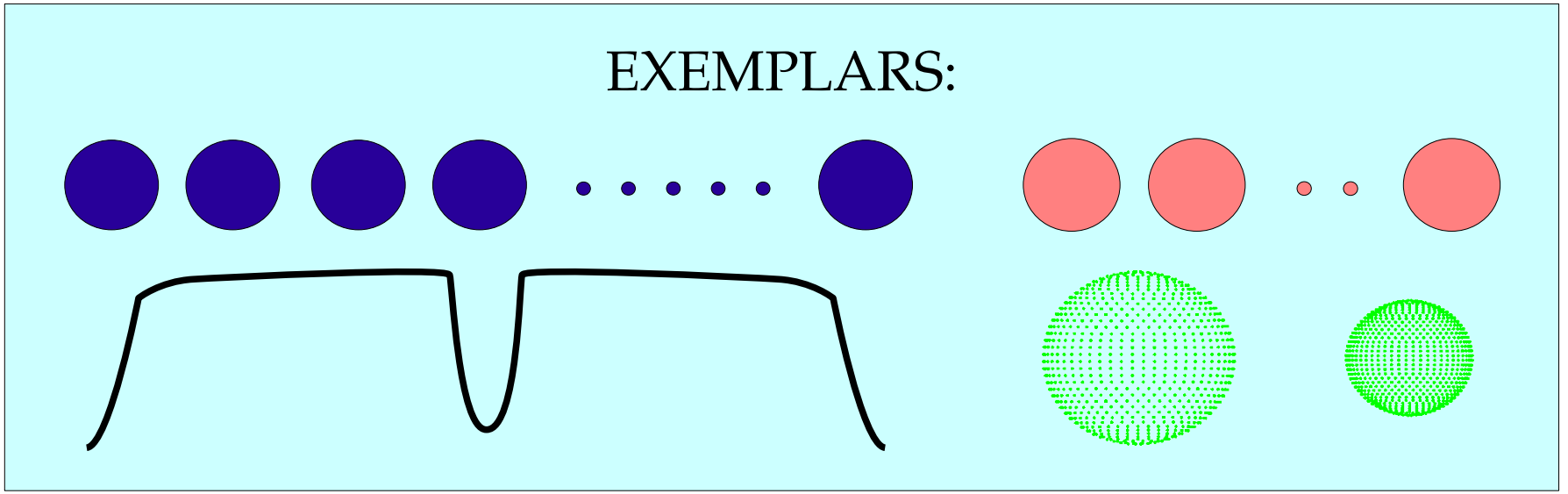
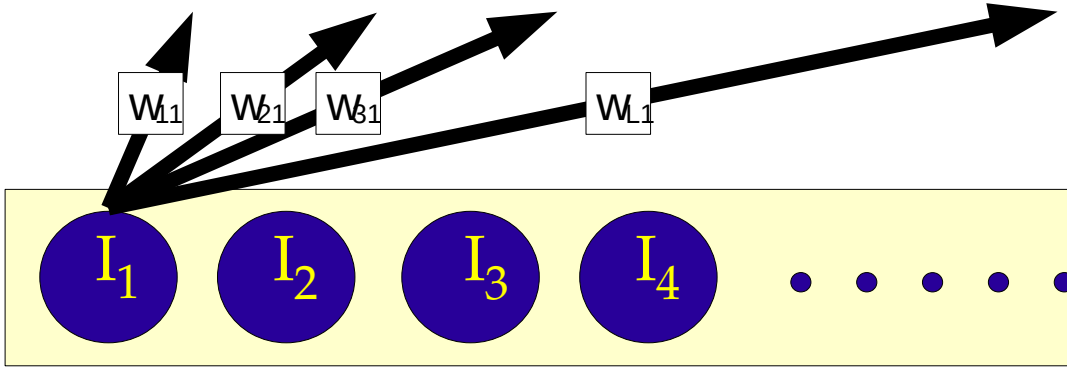
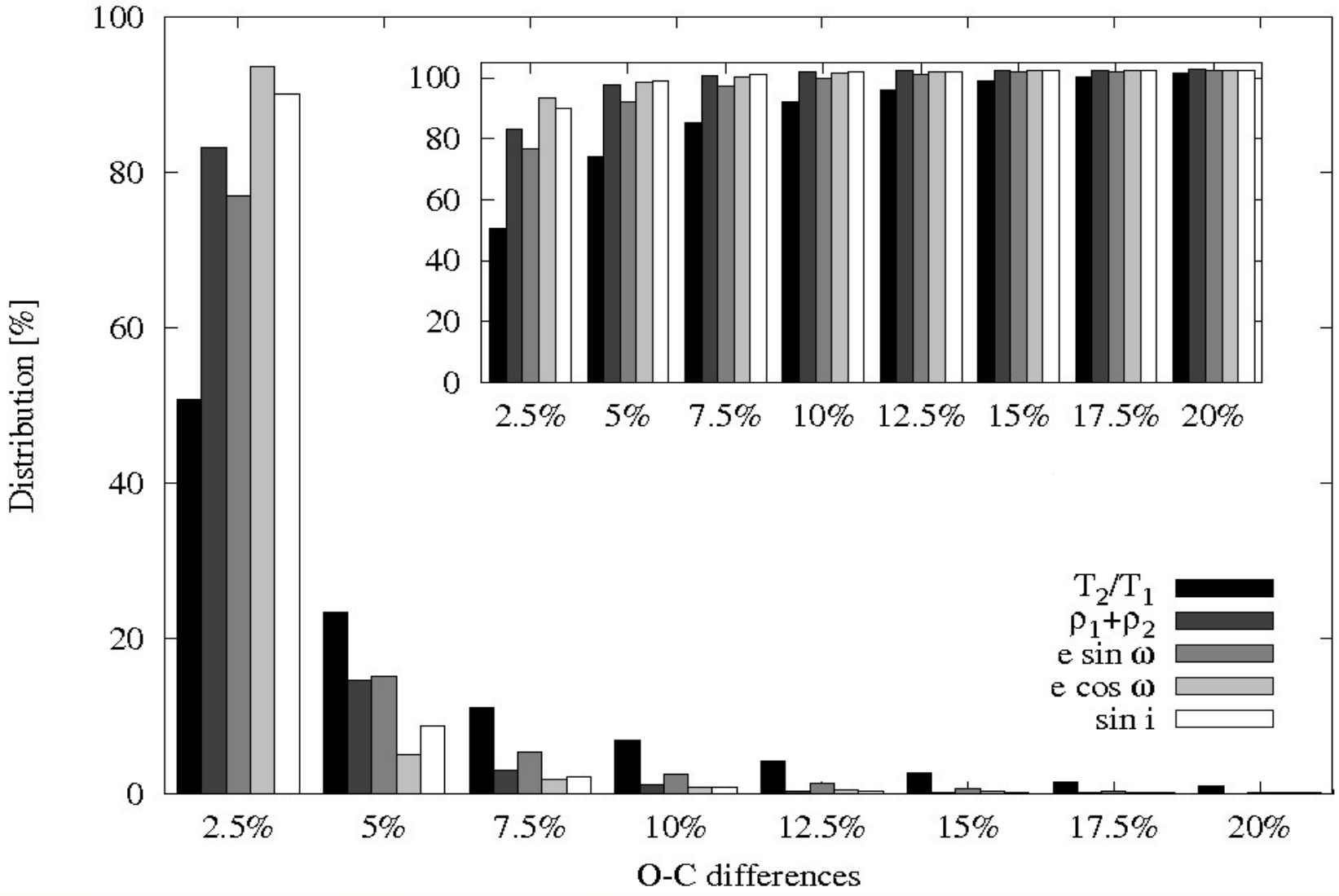




BACK-PROPAGATION:

determining connection weights from exemplars

The EBAI project



How about in the other direction?

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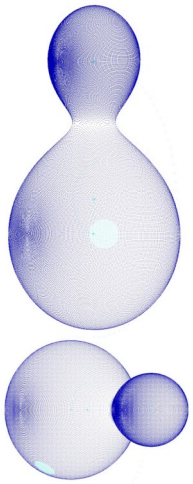
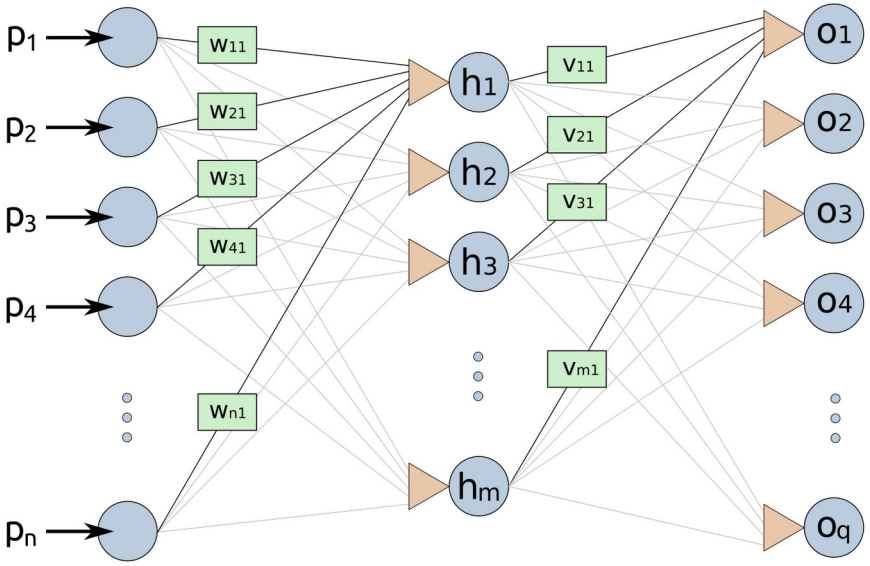
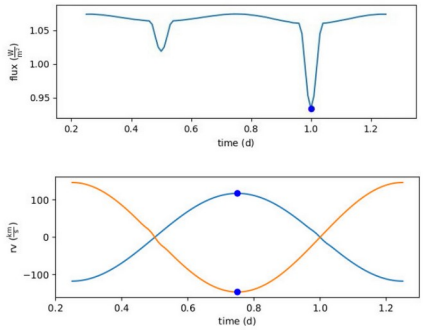
model parameters





mapped observables



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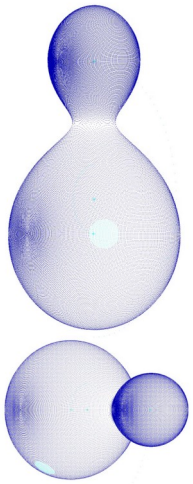

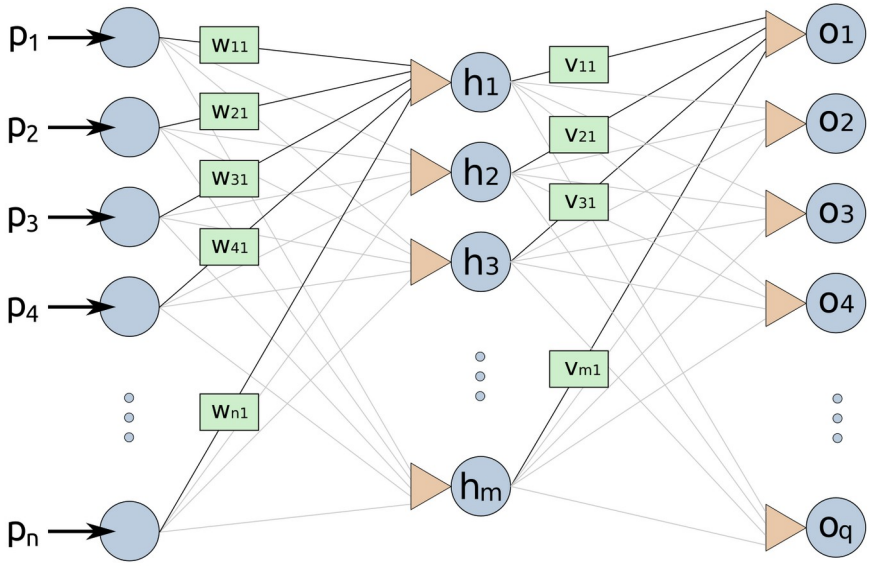

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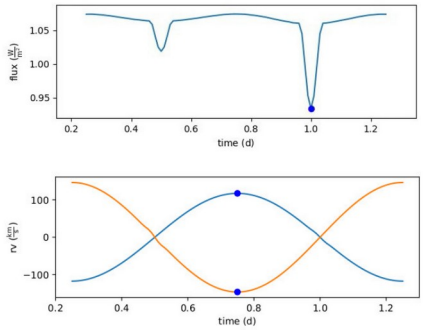

Forward model with PHOEBE: ~2 minutes

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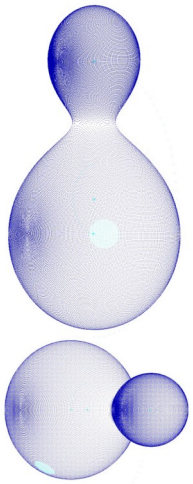

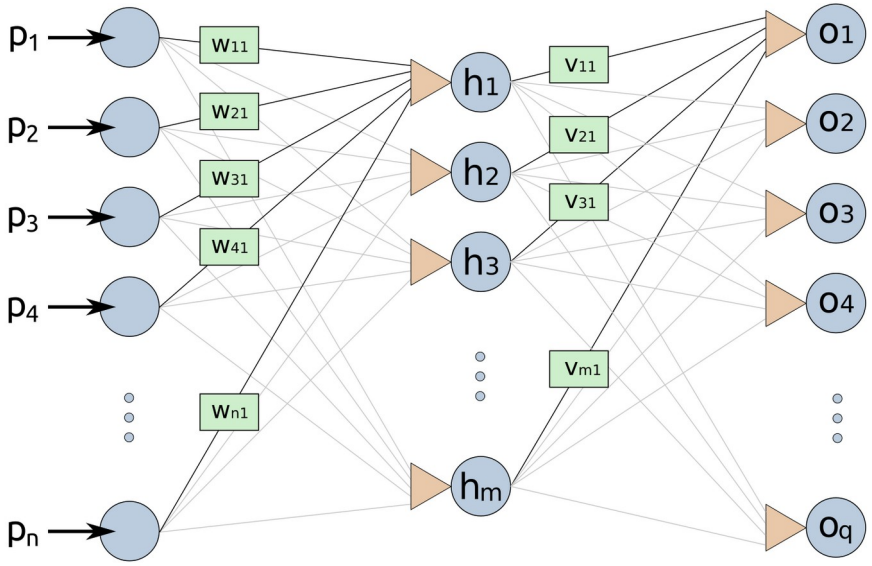

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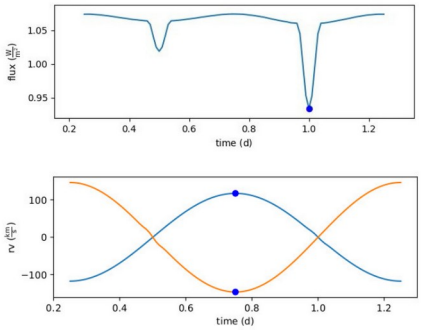

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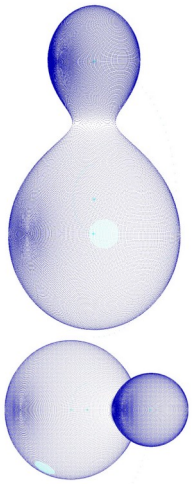

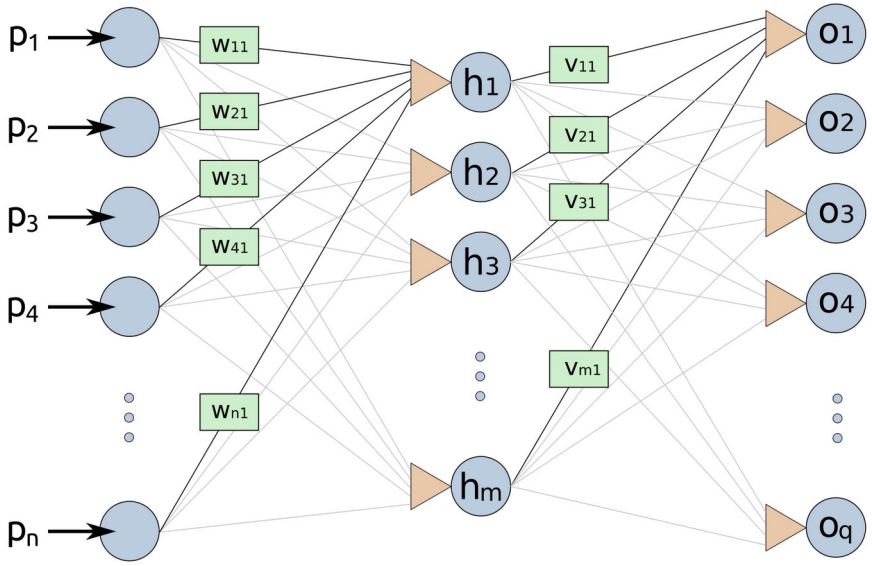

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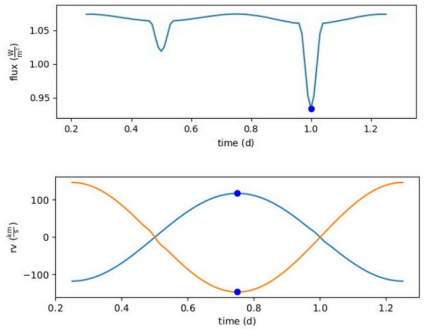

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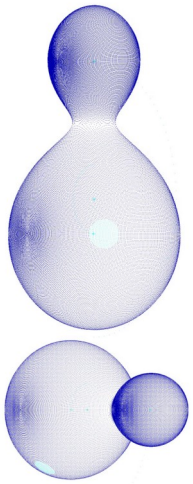

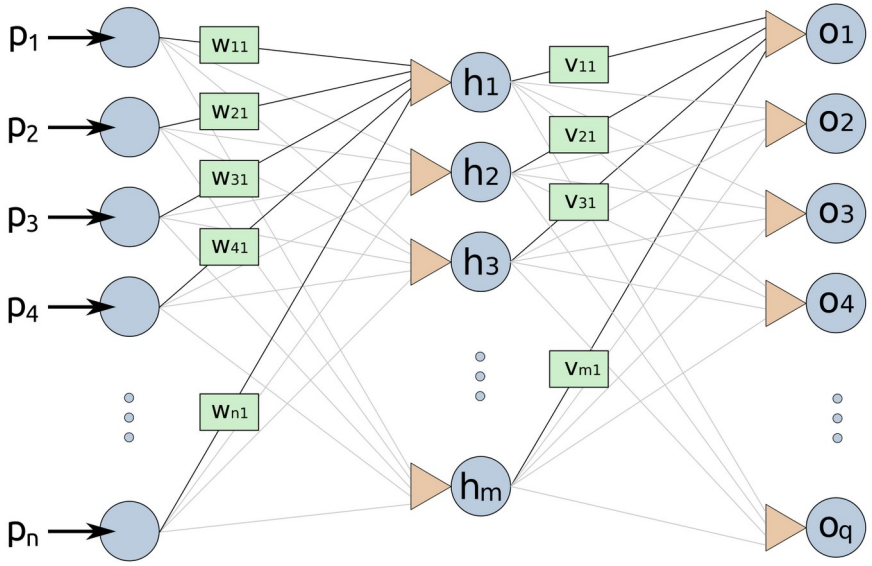

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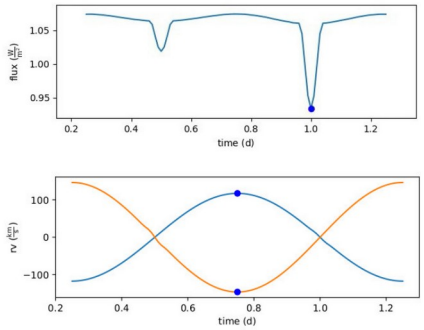

Forward model with PHOEBE: ~2 minutes

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In consequence, we cannot do this without high performance computing.

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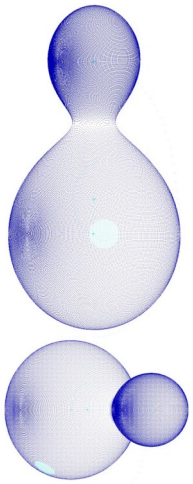

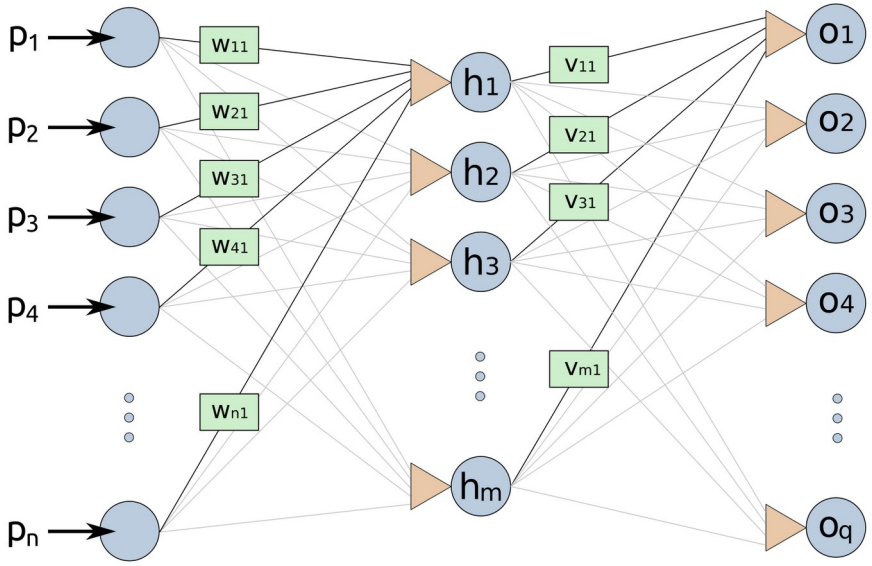

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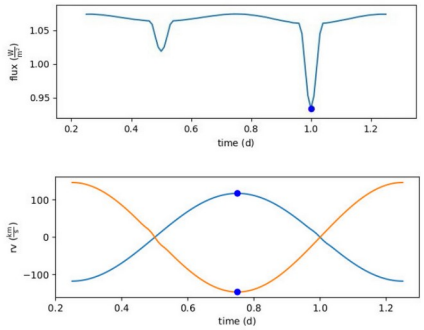

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Unless, that is, if we can “shave off” 6-7 orders of magnitude in runtime.

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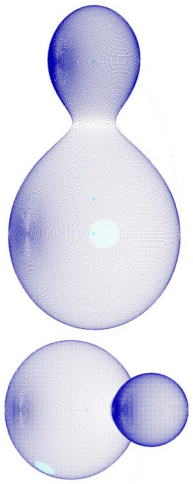
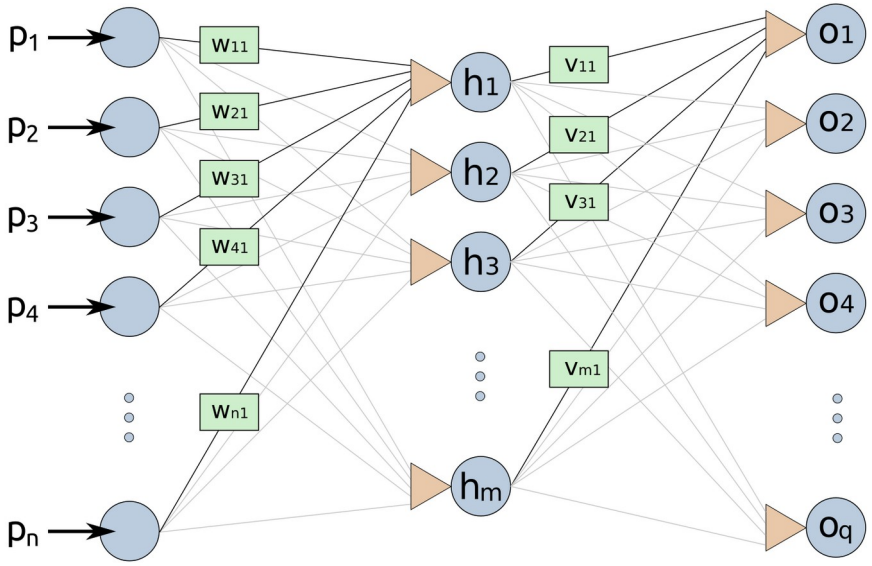
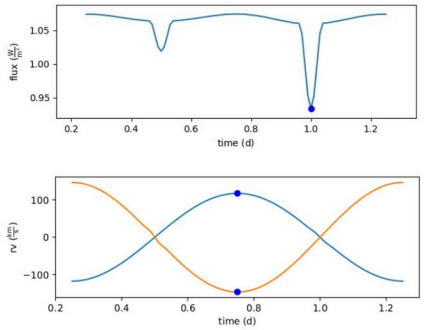




mapped observables



Forward model with PHOEBE: ~2 minutes
Forward model with the BPN: ~10 µs

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The question is: can BPNs stand in for the physical model adequately?

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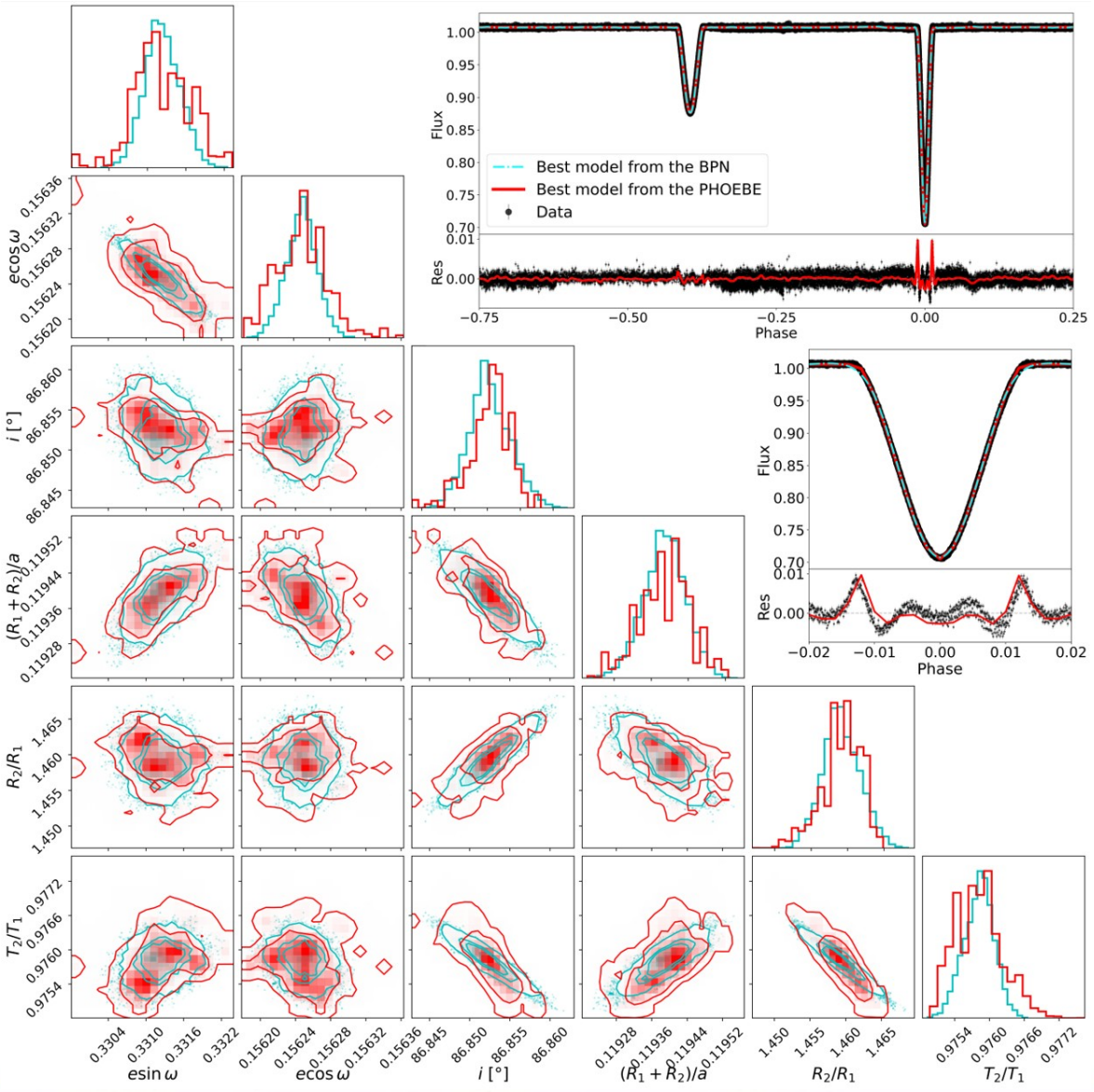

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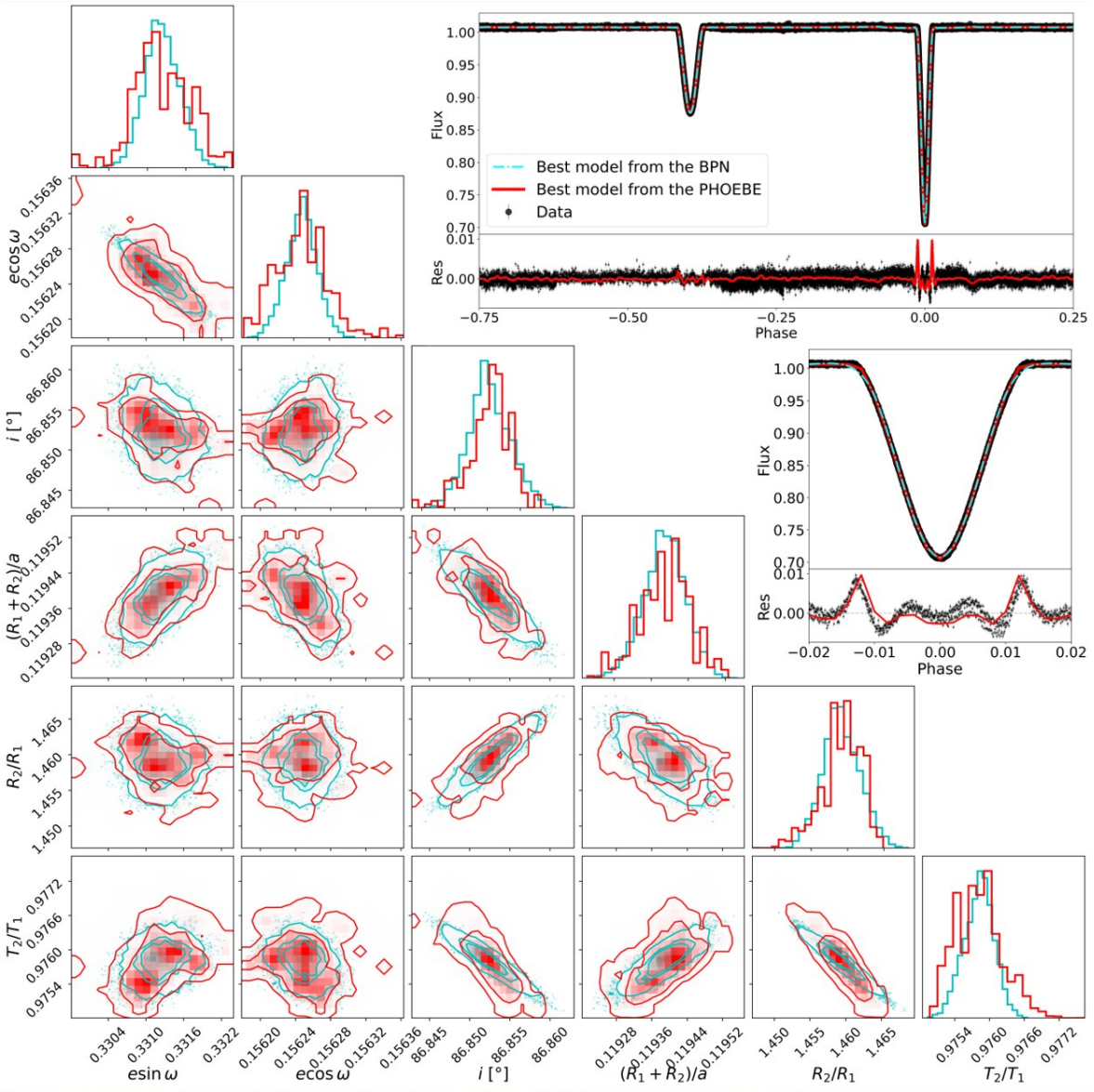

2 weeks on HPC →
~10 seconds + I/O

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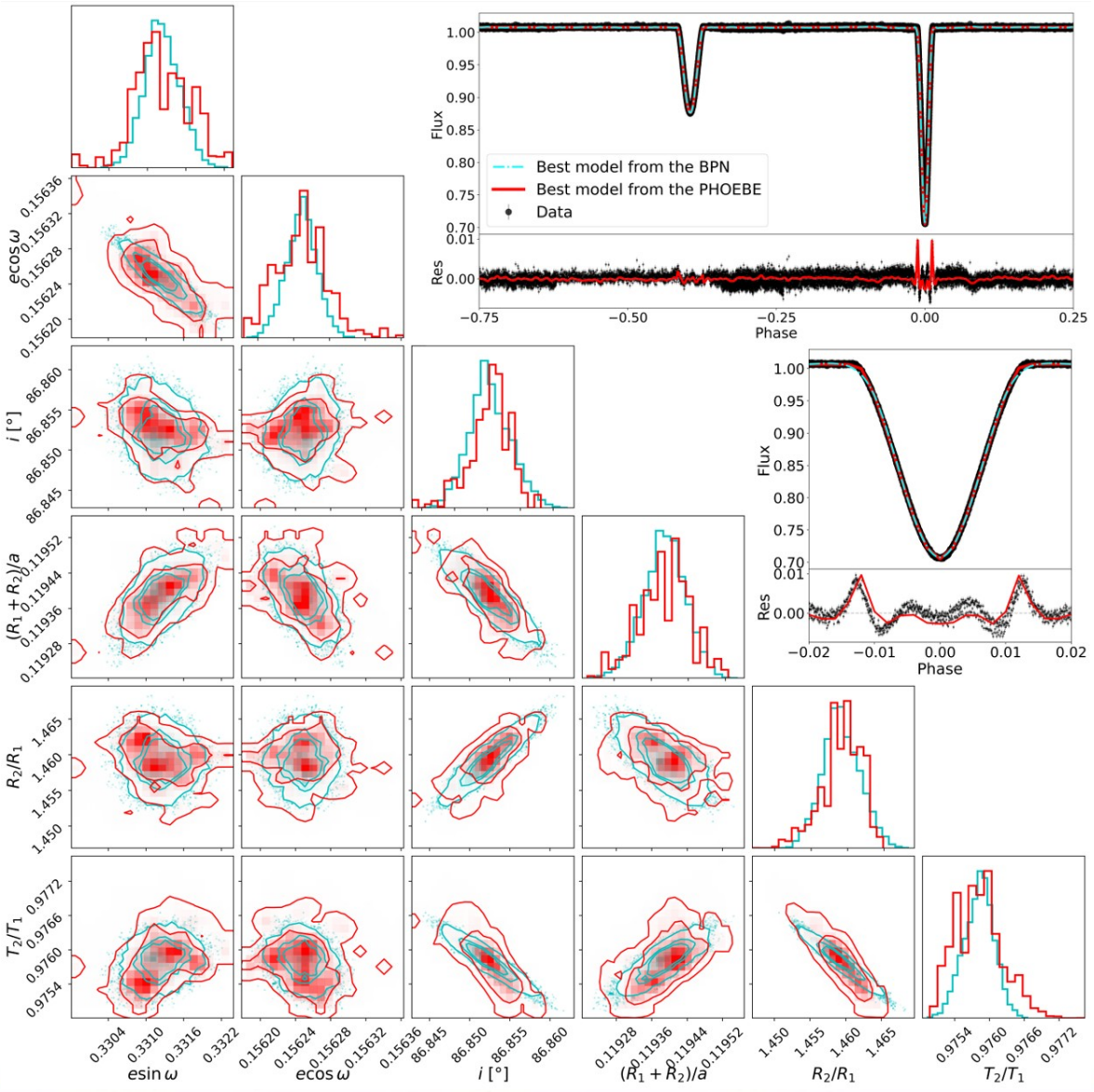

2 weeks on HPC →
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The best part?
We don't even need BPNs!

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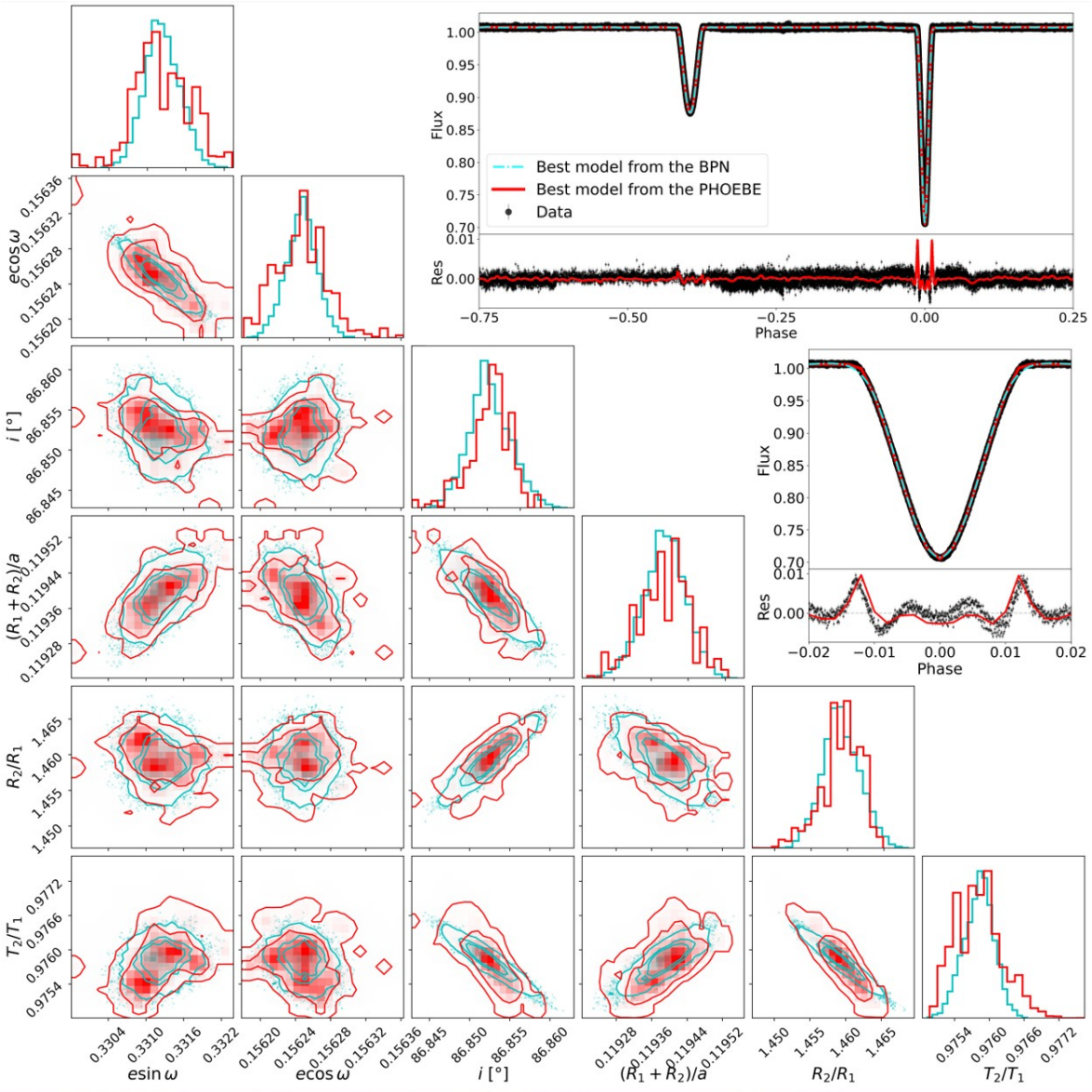

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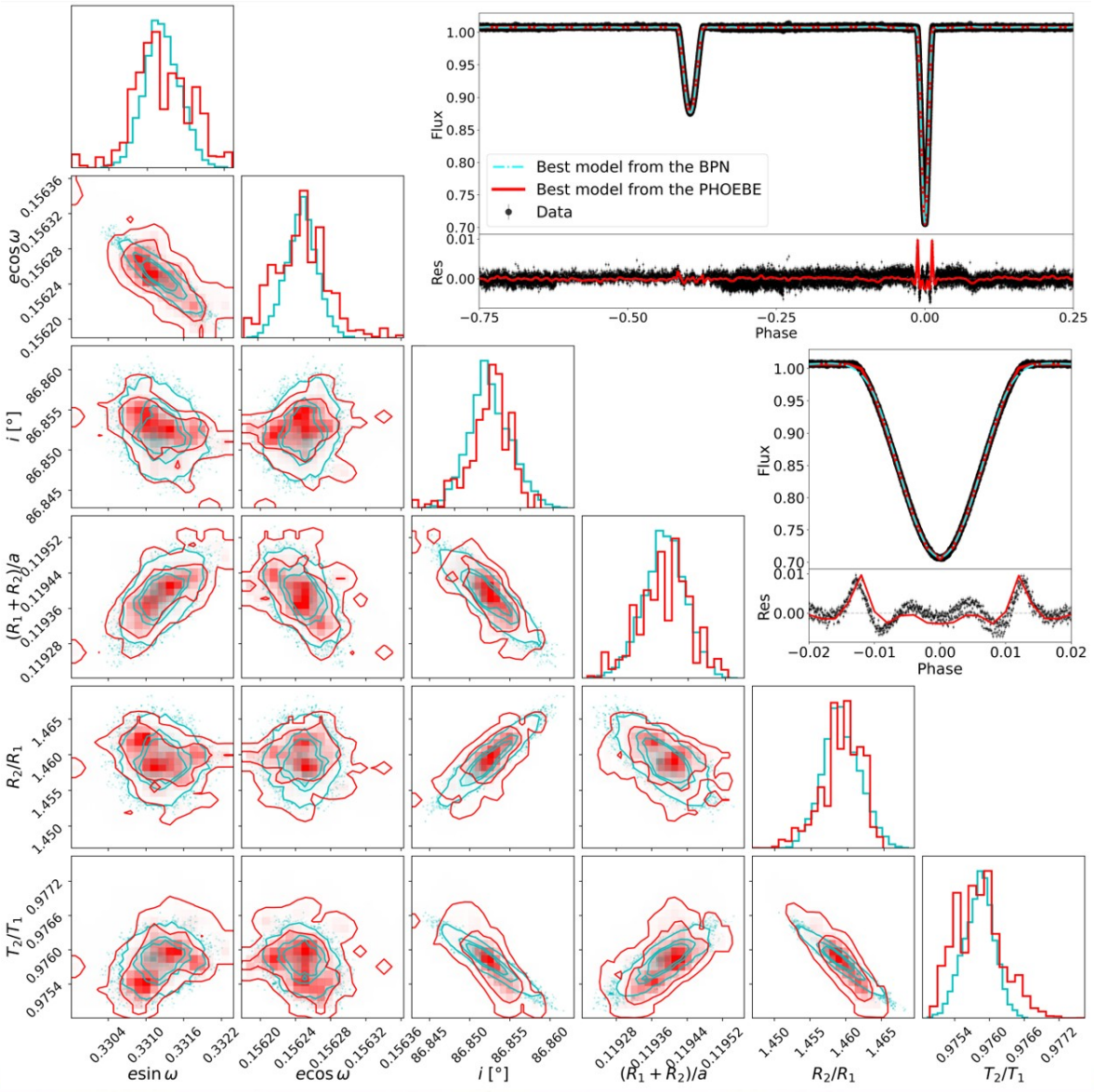

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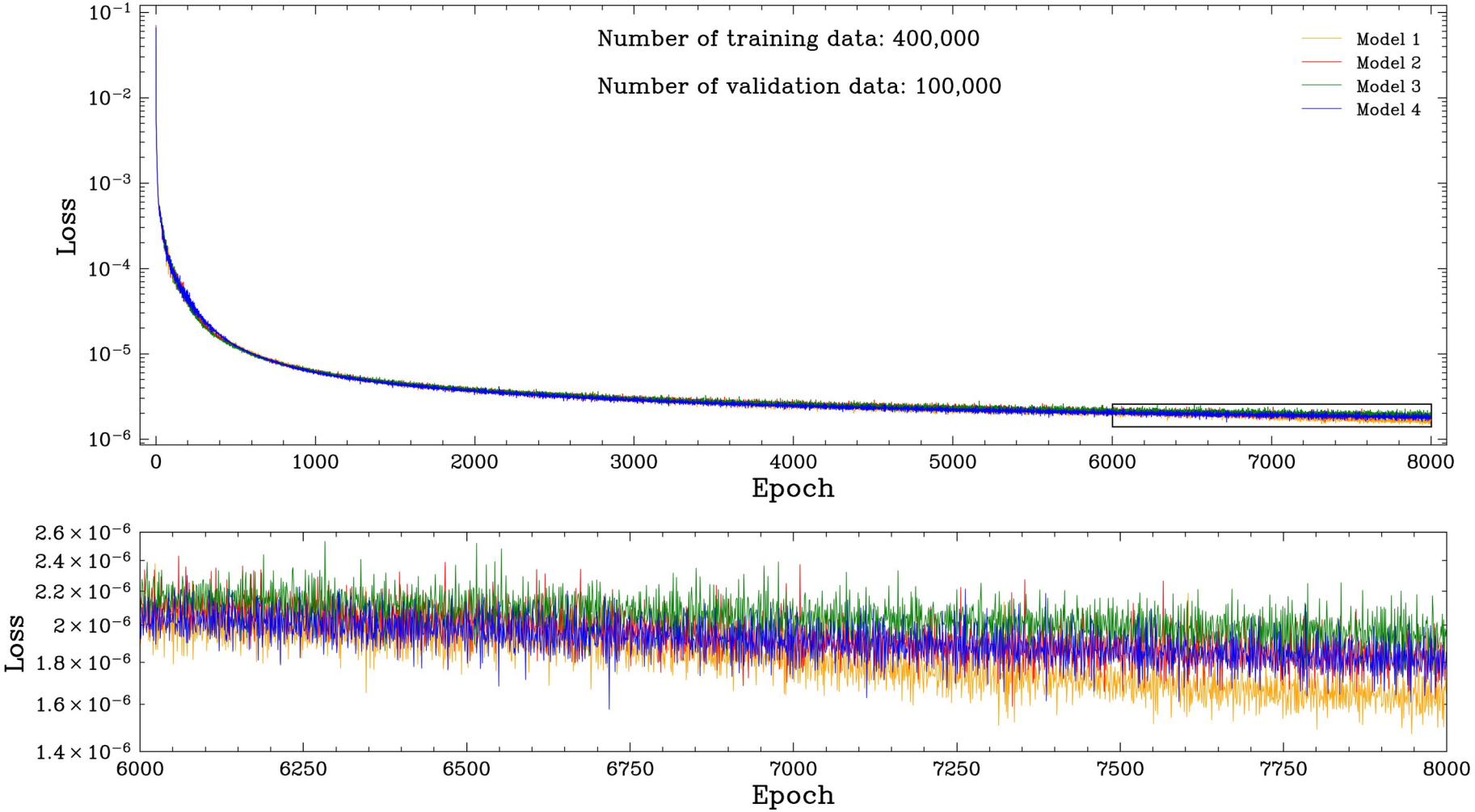

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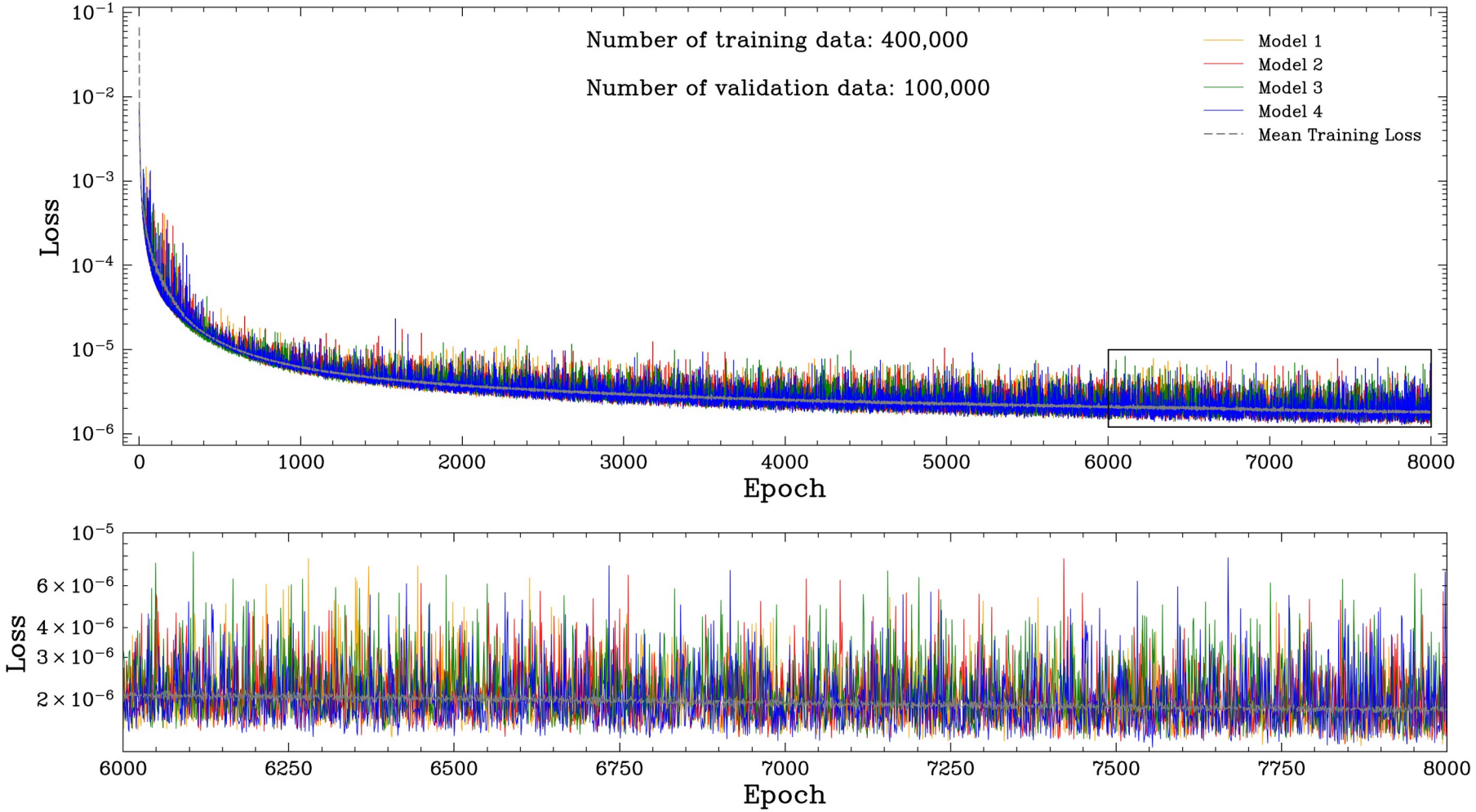

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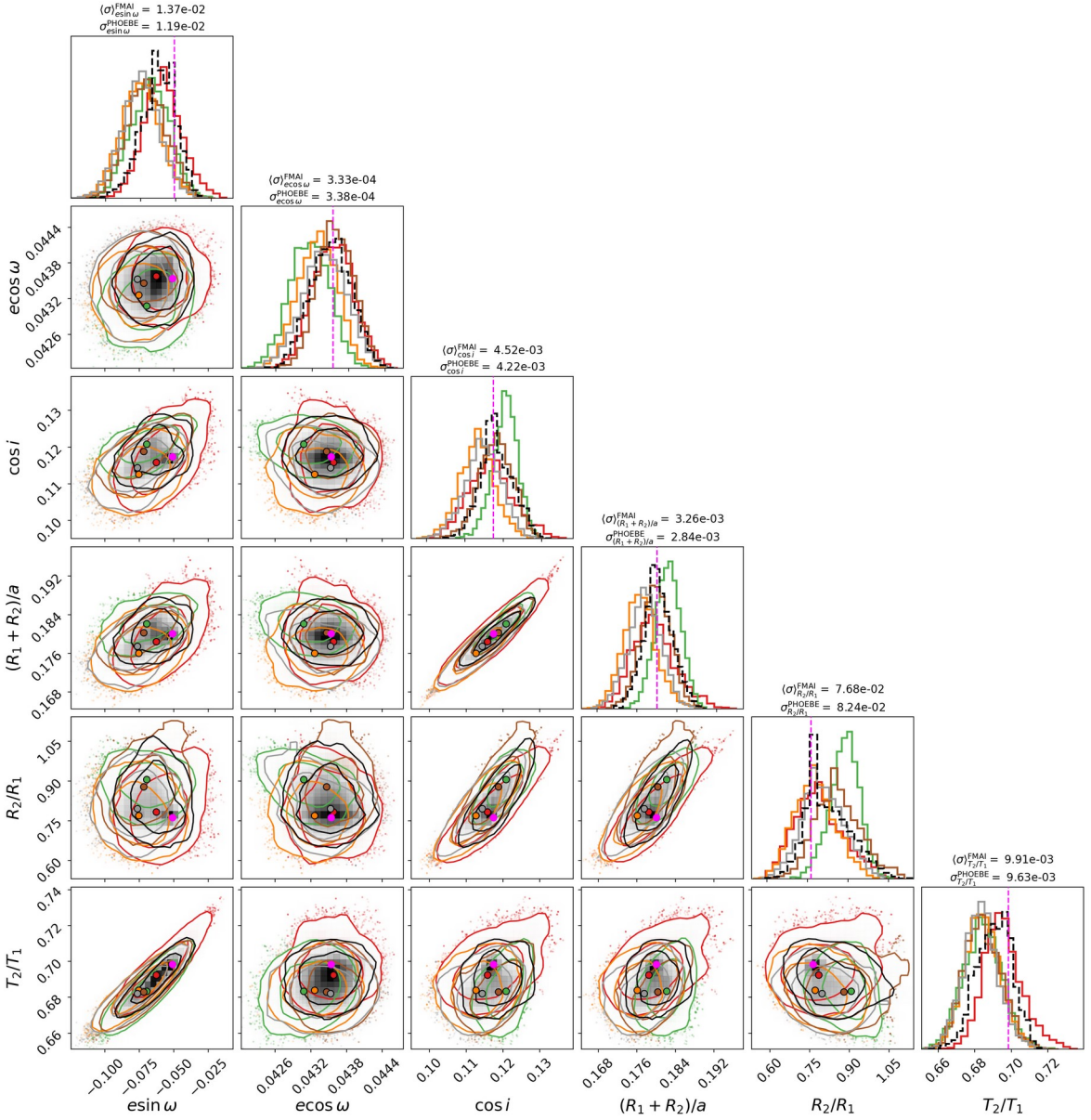

Wrap-up

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Thank you for your attention! Questions? Comments? Bring ‘em on!