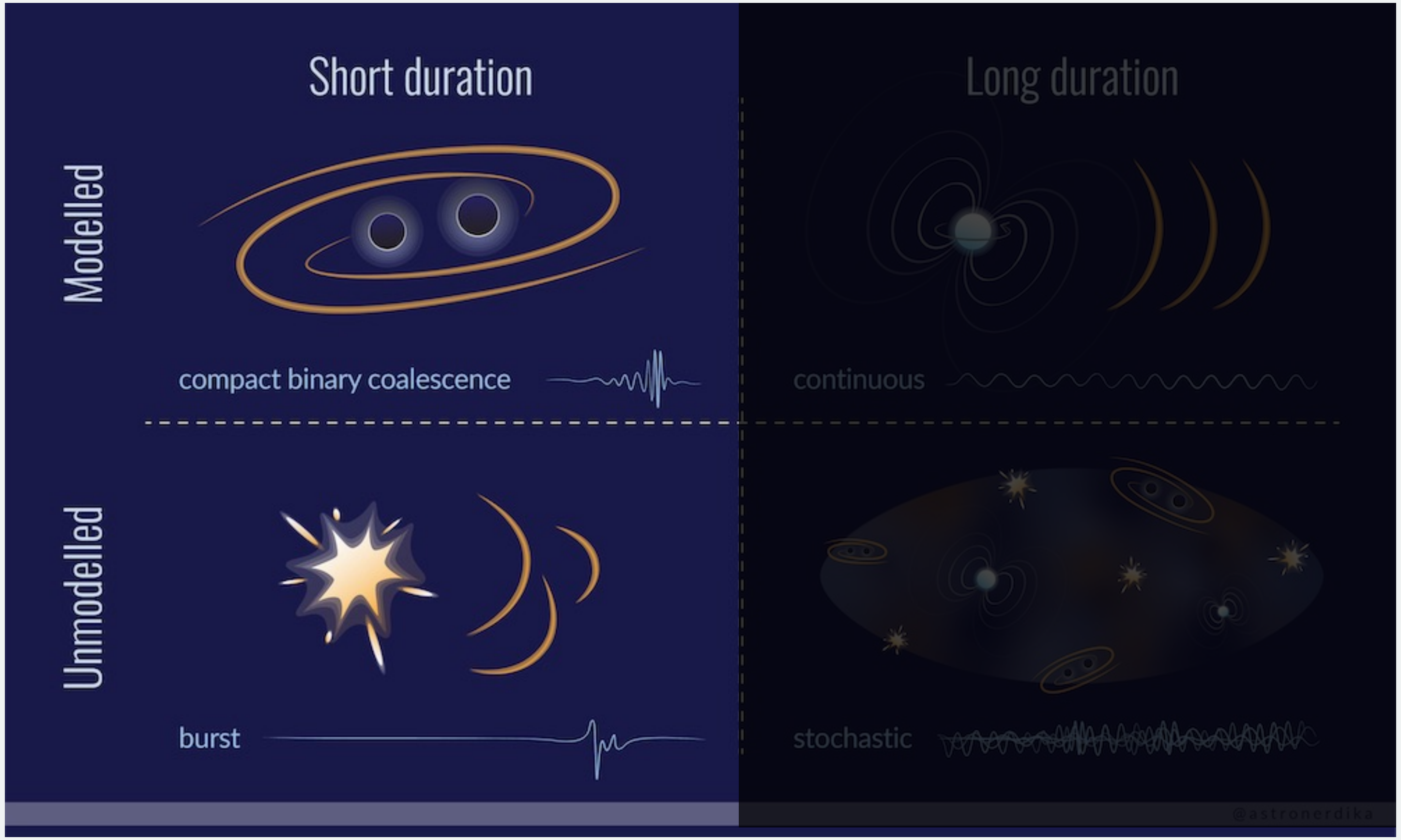
Credits: NASA

A deep learning pipeline for core-collapse supernova searches

Melissa Lopez

NNV Lunteren 2022

Utrecht University



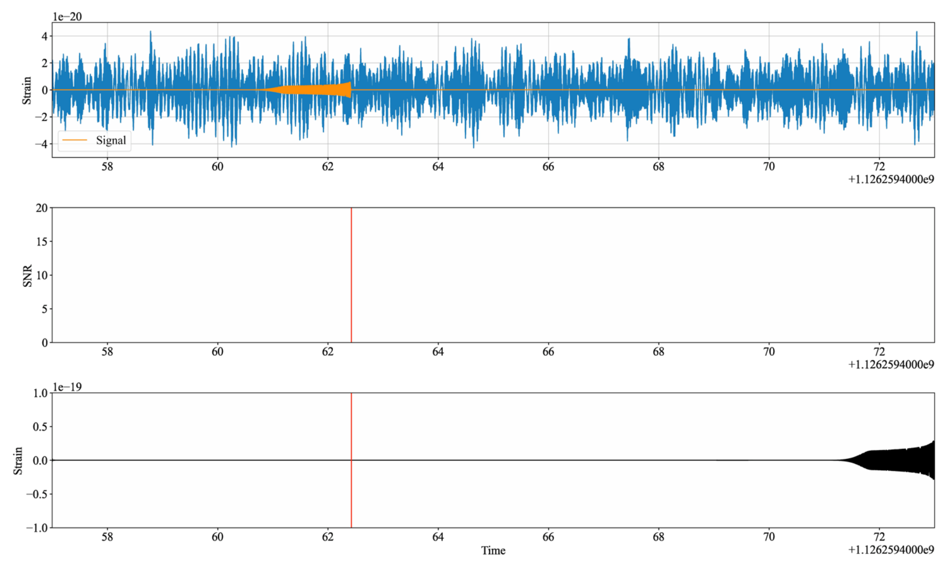
Credits: Shanika Galaudage

Gravitational wave detection and its sources

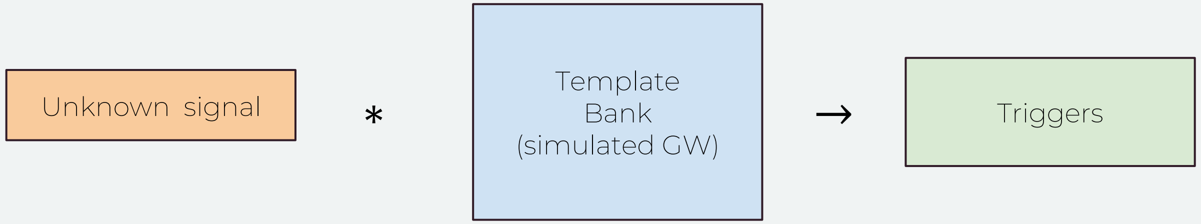
Modelled searches for compact binary coalescence (CBC)

Several pipelines that use *matched filtering* (MF): GstLAL, PyCBC, SPIIR, …

MF := matching models (templates) to unknown signals



Credits: Harsh Narola



We match known waveforms.
But what happens if the *exact* signal is unknown?

Core-collapse supernovae (CCSN)

Collapse of massive stars

Very complex process

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exact signal unknown

Production of gravitational waves (GW) and electromagnetic (EM) counterparts!

Challenges and ideas for CCSN detection

Challenges

- Very rare event → Increase volume of explored Universe (TB data)
- Unkown real waveform → Many expensive theoretical models (months)
- Current detection methods → cWB: slow, CPU (2 – 5 min per 180s)

Key ideas

1. A lot of inexpensive data → Mimic theoretical waveforms (phenomenological)
2. Fast and precise method → Machine Learning (ML) for pattern detection

What is Machine Learning?

Key idea: humans learn from experience → computers can do the same with automatic learning

Lectures / Training

Mock exam / Validation

Exam / Testing

Some tasks: speech recognition, **pattern recognition**, fraude detection and many more!

Why not applying it to **CCSN searches**? → *Exact* model "free" searches

How? Convolutional neural networks (CNN)

Problem statement: binary classification

Classes: 0 class (noise) and 1 class (event)
with different levels of loudness (SNR)

RGB image: learn coincidence among detectors

Learning: cumulative learning

Idea: train on phenomenological waveforms and test on real waveforms

Previous work: Astone et al. (2018)

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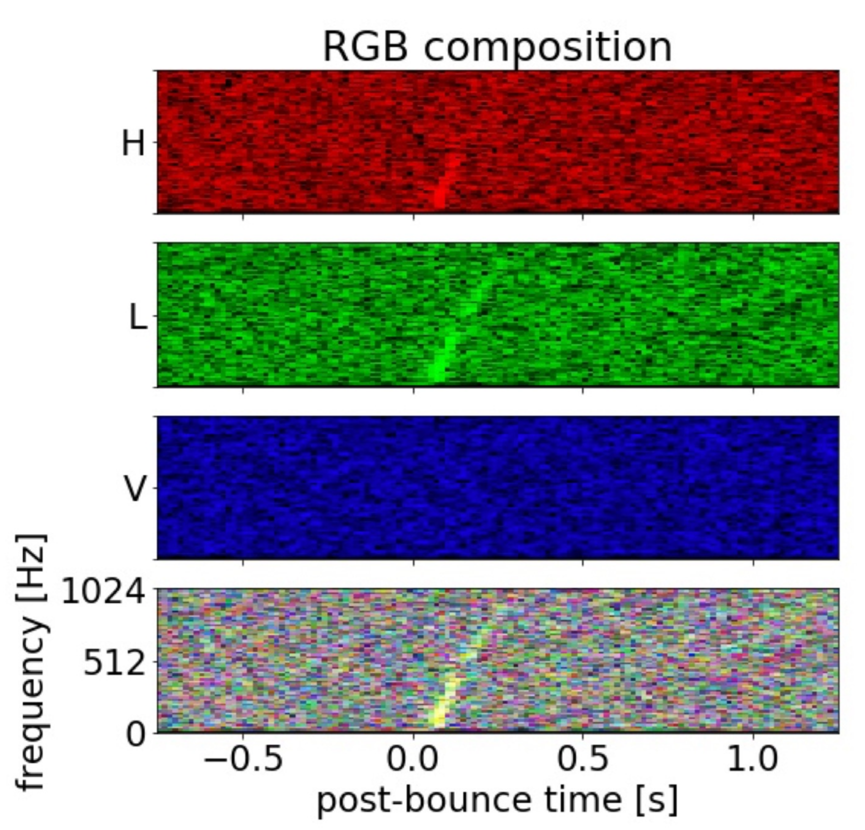
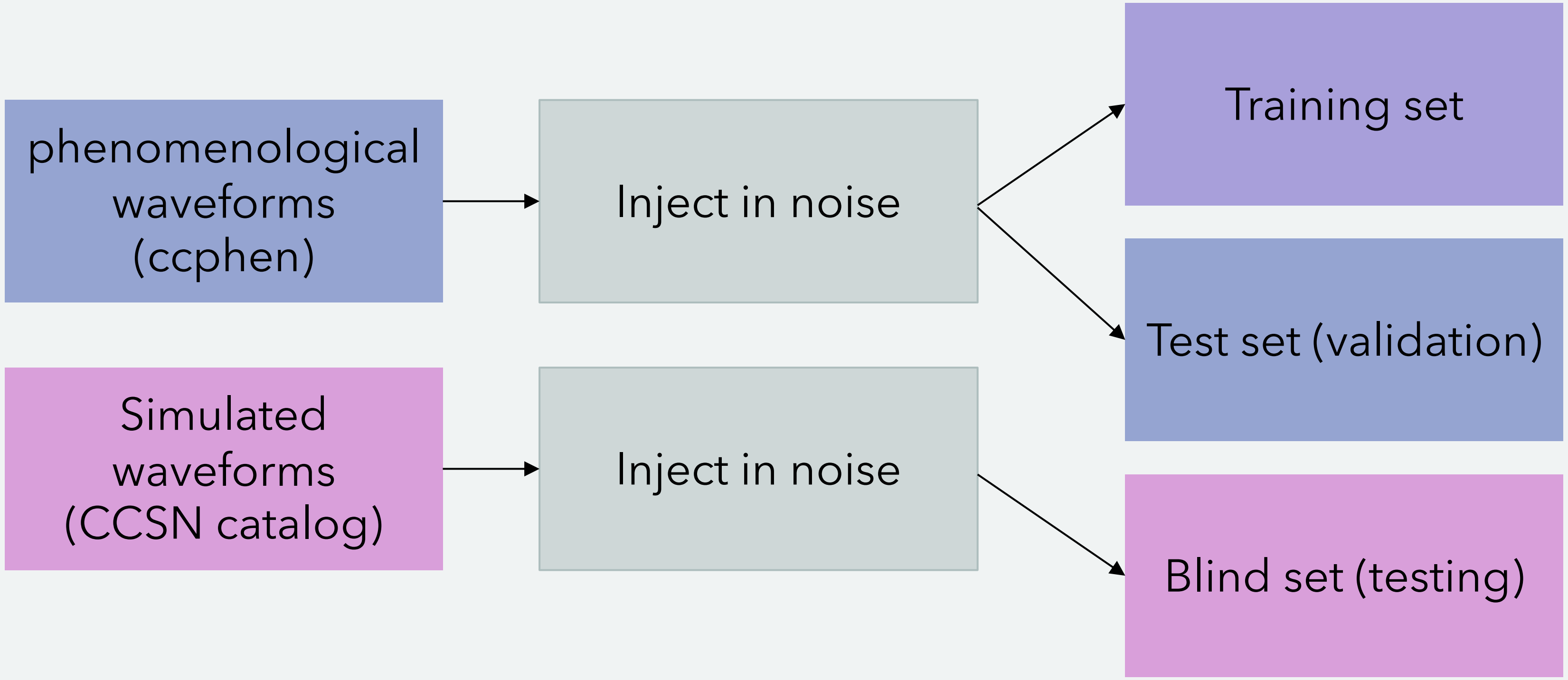
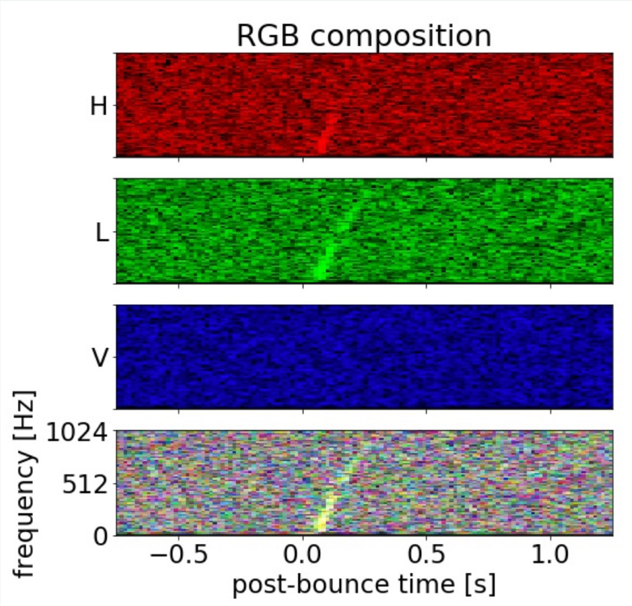
Proof-of-concept in Gaussian noise
CNN 6000 parameters



The data set

Injection performed on Gaussian noise (well-behaved) **or** real noise (not so nice)





The algorithm: Mini Inception ResNet (Mini IR)

- Inception-Resnet v1 → combination of Inception and ResNet
- Modified version of this network
- Total number of parameters: 98997
- 30 times more complex than previous work!

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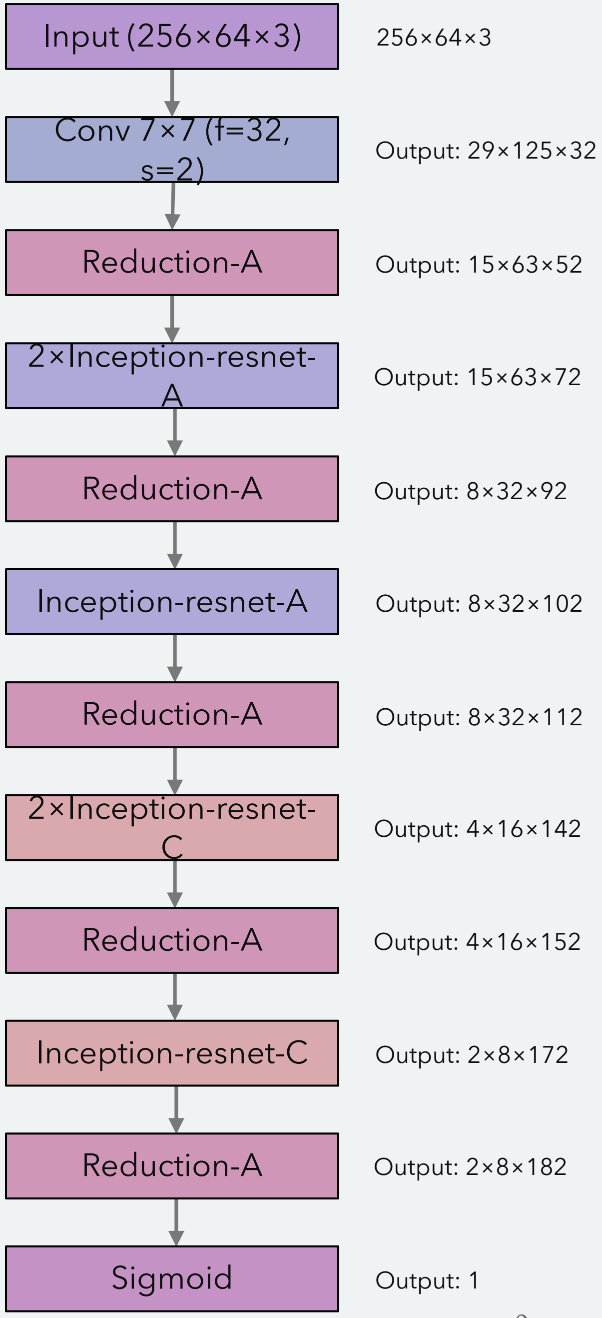
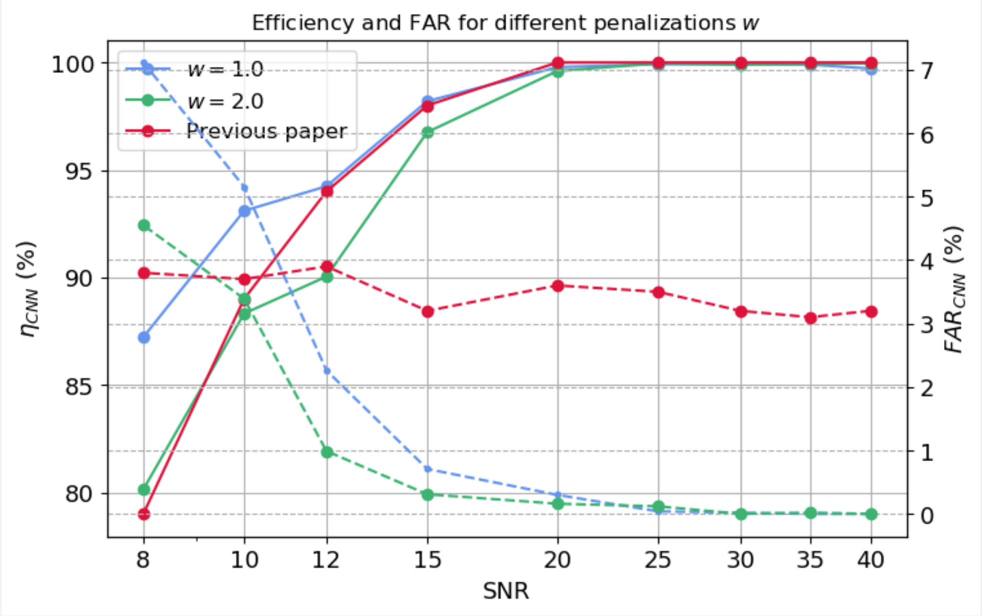


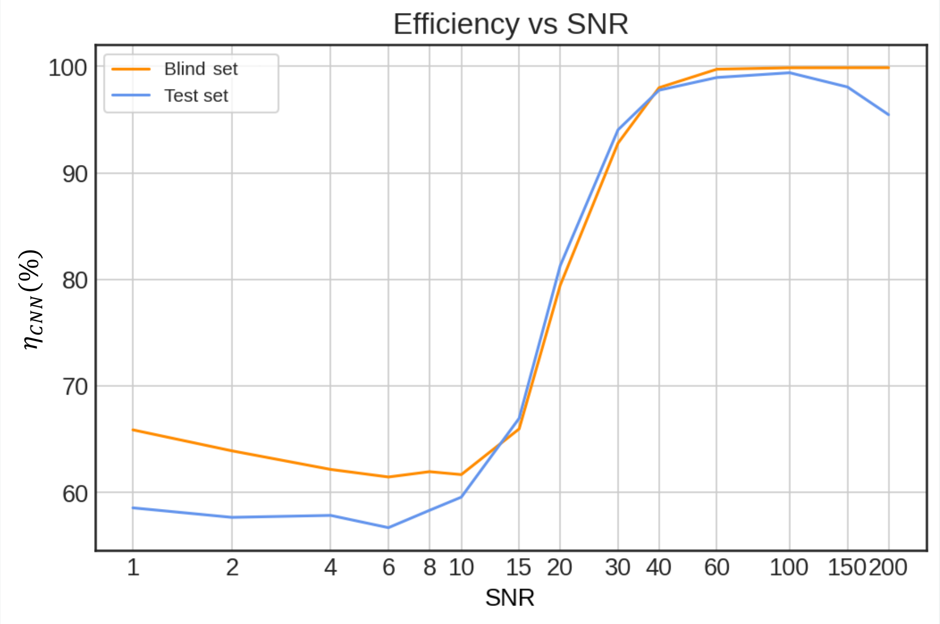
Results: Gaussian and real detector noise

$\eta_{CNN}(\%)$: efficiency → CCSN signals correctly classified

Gaussian noise



Real O2 noise



Blind (phenomenological) and test (catalog) match closely

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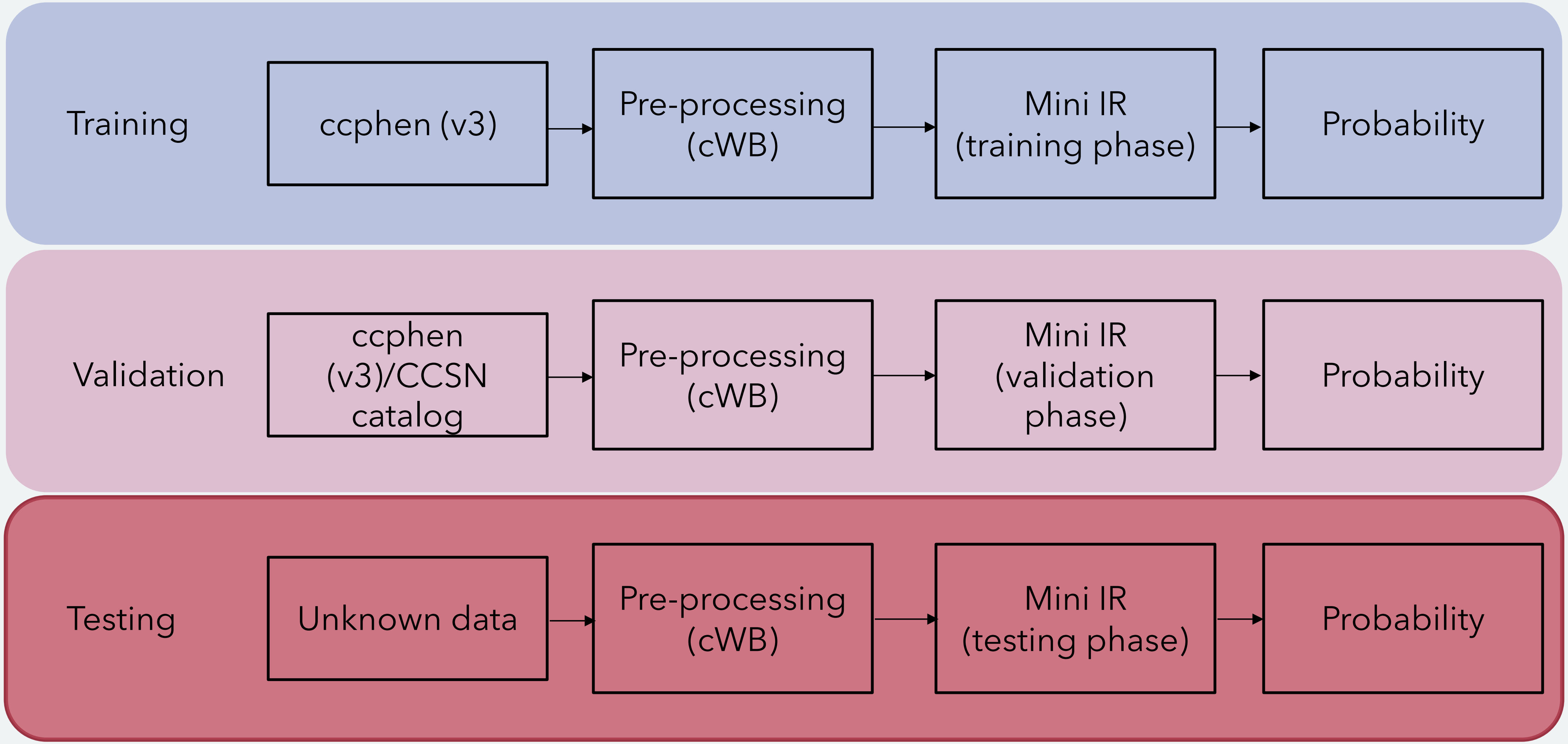
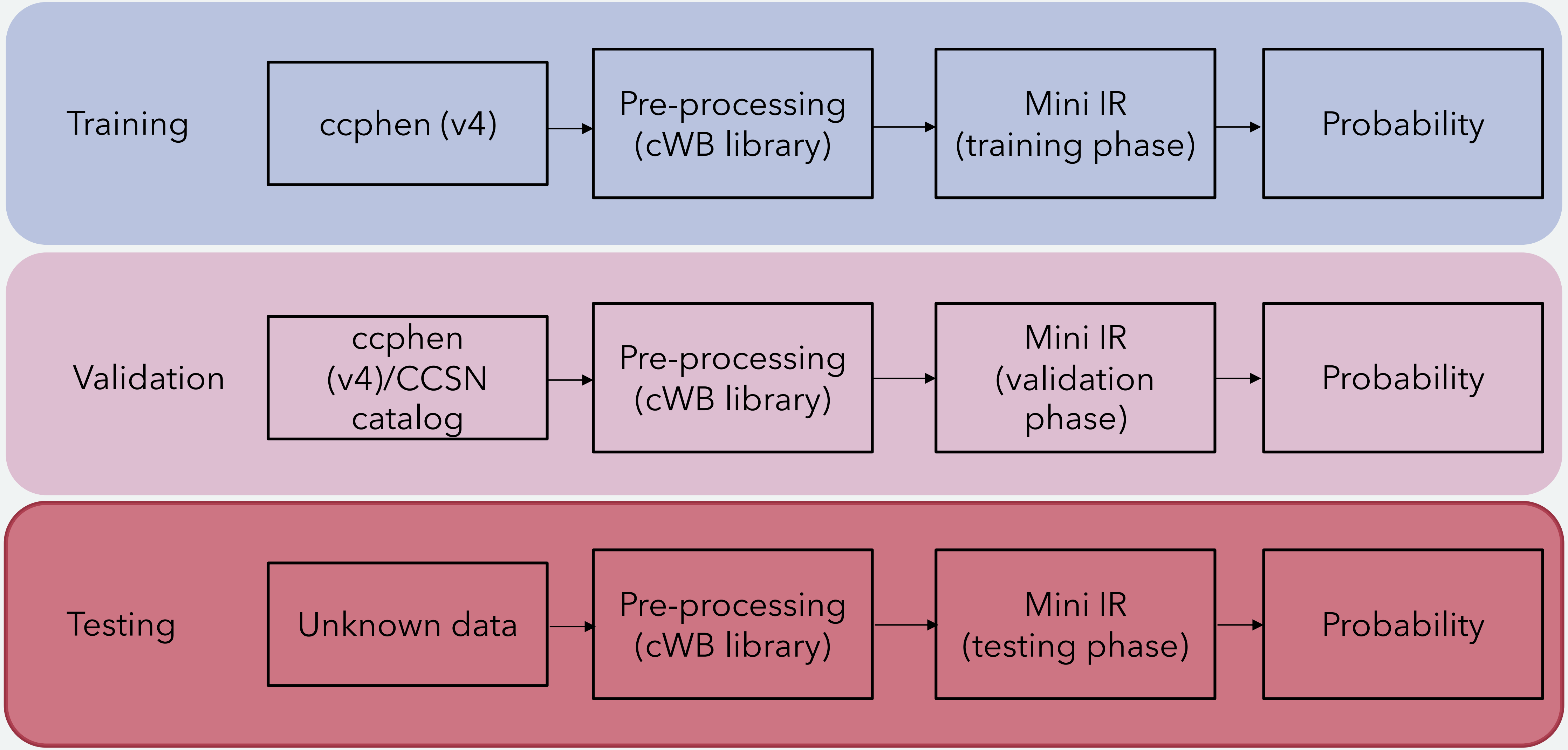
Main paper

A deep learning pipeline for CCSN searches: **workflow**



A deep learning pipeline for CCSN searches: **improvements**



Conclusions and future work

- ✓ Improved proof-of-concept work
- ✓ Agreement between ccphen and CCSN catalog
- ✓ Triggers in 0.27s per 180s vs (2 – 5) min
- ✓ Designed an independent CCSN pipeline
- ★ Test with real O3 data and with O4 mock data
- ★ Review pipeline

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Main paper

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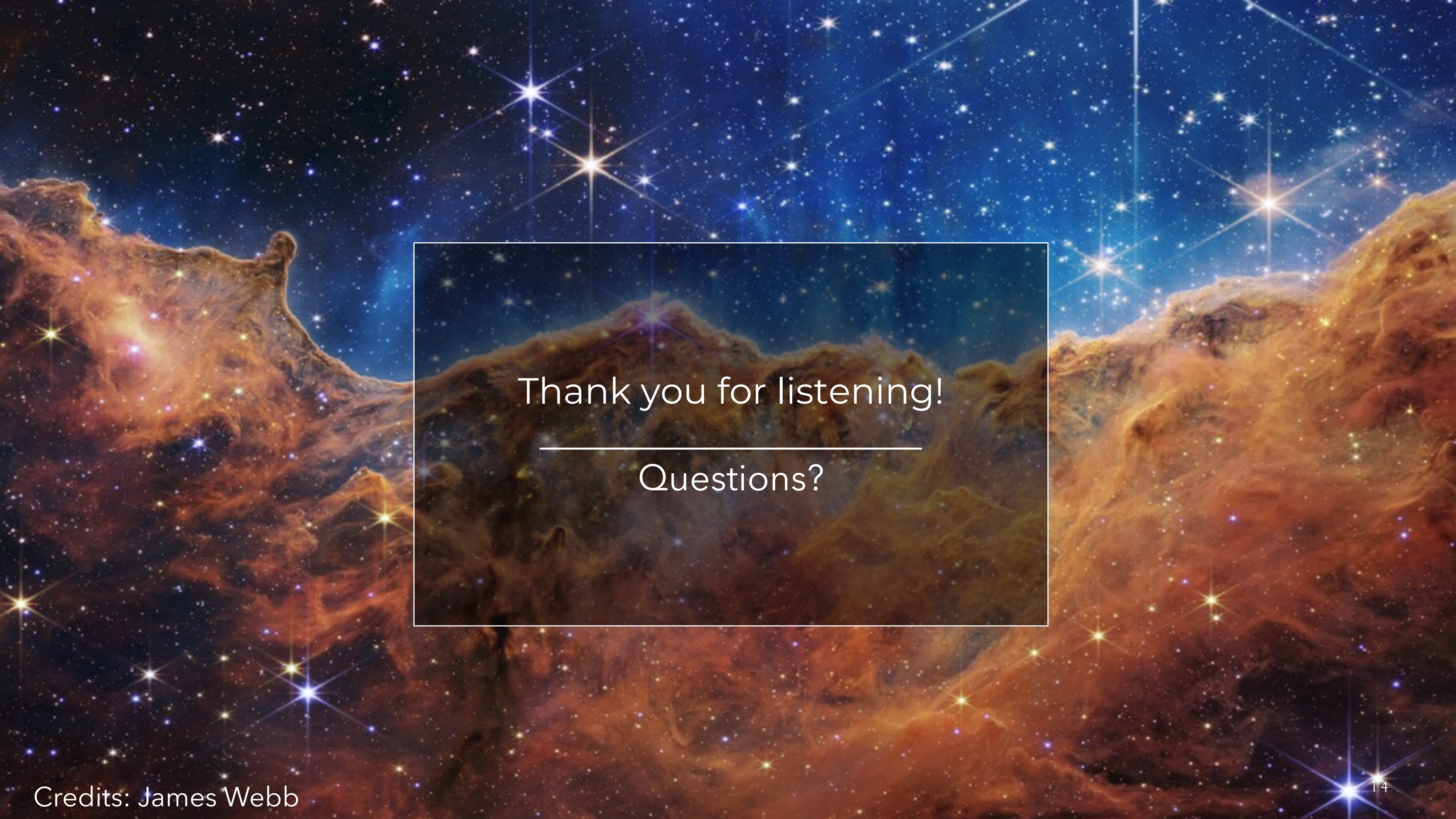

Thank you for listening!

Questions?

Credits: James Webb