

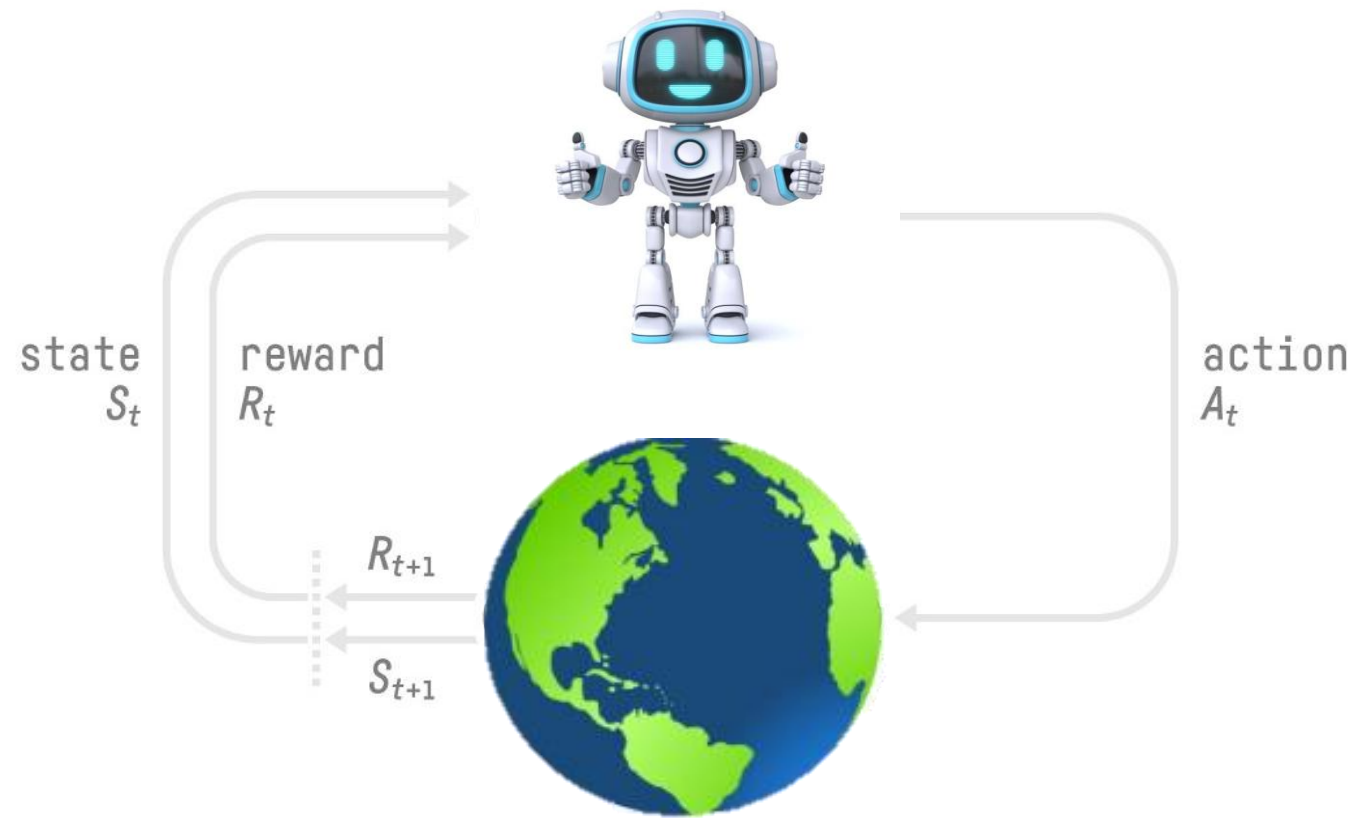
# FOURIER NEURAL OPERATORS

## As Encoder for Model-free Reinforcement Learning

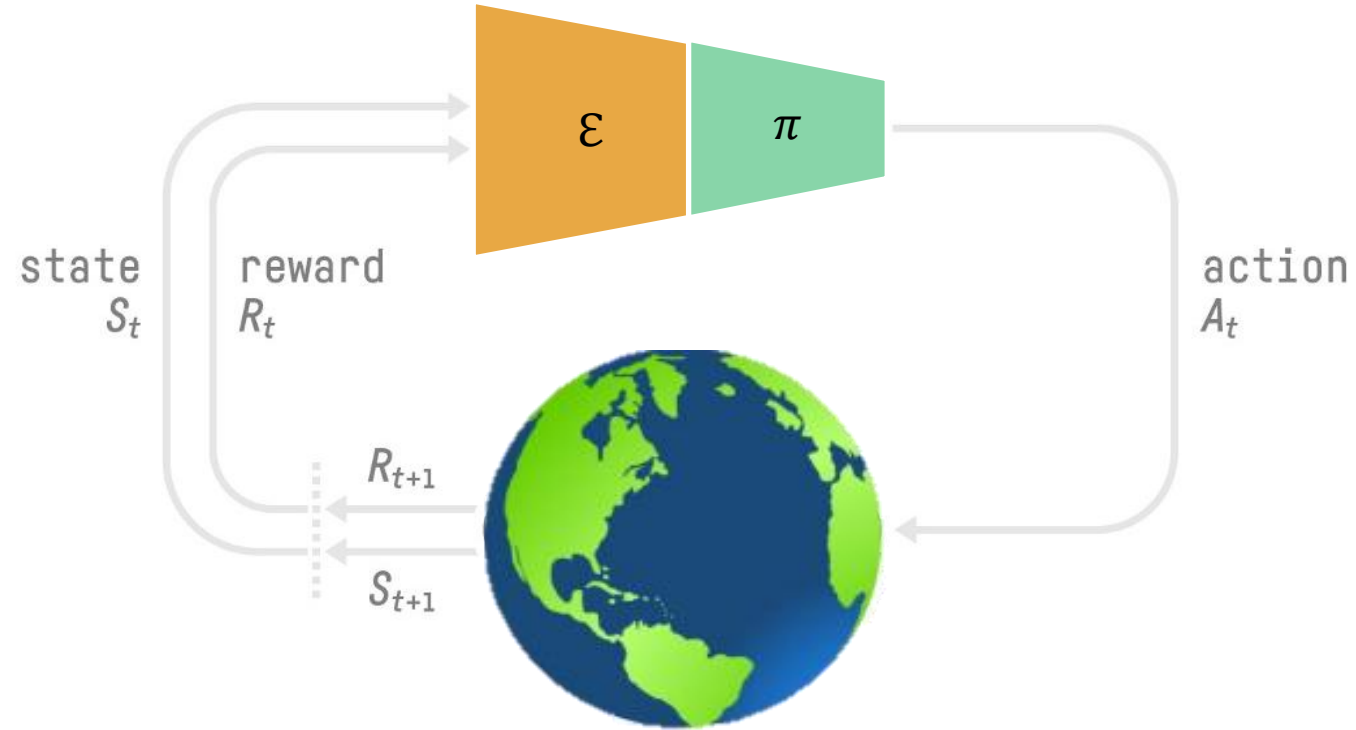
By **Parag Dutta**, Mohd Ayyoob, Shalabh Bhatnagar and Ambedkar Dukkipati



# THE REINFORCEMENT LEARNING FRAMEWORK



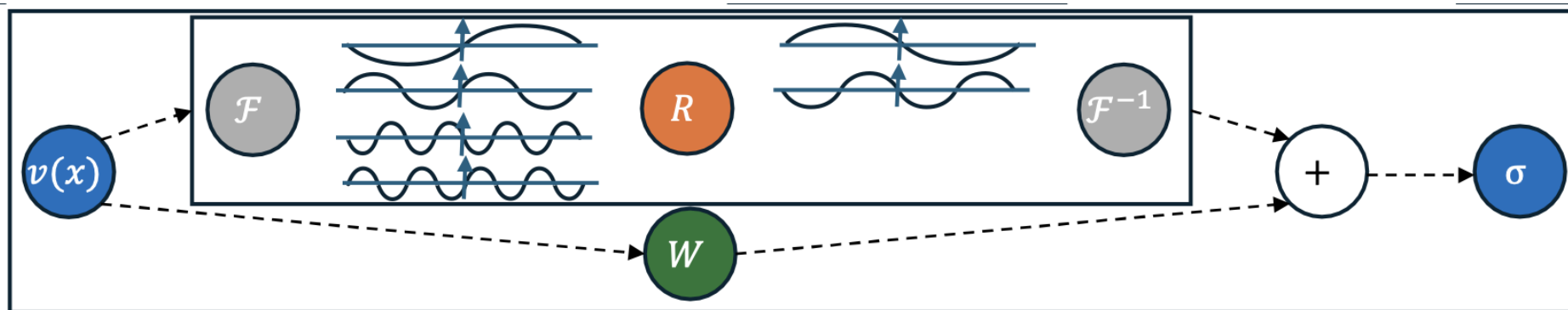
# THE REINFORCEMENT LEARNING FRAMEWORK



# CHALLENGES WITH EXISTING ENCODER ARCHITECTURES

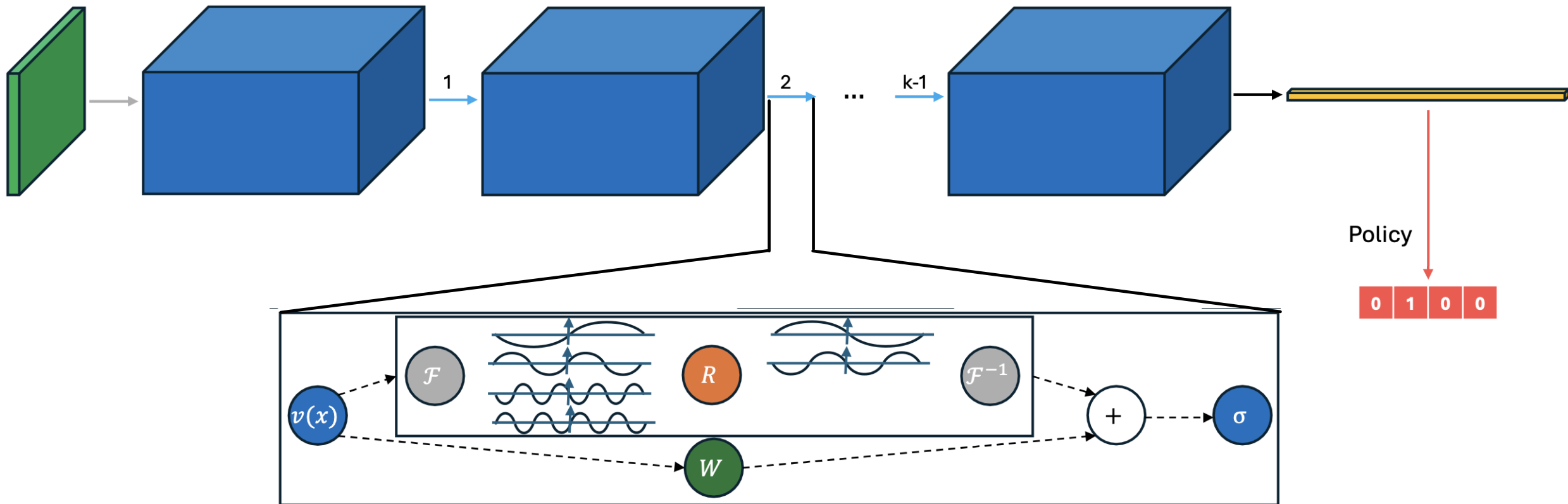
- Requirement of Hyper-parameter tuning with each modification
- Not much performance gain with after modification
- Highly sensitive to Training Domain

# FOURIER NEURAL OPERATORS



Reference: Fourier Neural Operator for Parametric Partial Differential Equations,  
ICLR 2021 - <https://openreview.net/forum?id=c8P9NQVtmnO>

# OUR PROPOSED ENCODER



# WHY FNO?

- Our Encoder exploits the underlying PDEs that govern the transition dynamics
- The conventional CNN encoder can be replaced with FNOs for all major classes of model-free RL algorithms, i.e.:
  1. Policy gradient
  2. Actor-Critic
  3. Q-Learning
- No need for any additional hyper-parameter search after replacing CNN with FNO
- FNOs enable zero-shot domain adaptation from low-resolution training images to high-resolution inference images without any additional fine-tuning.



# EXPERIMENTS



## ATARI GAMES (ONLINE Q-LEARNING)

Game	Rainbow	Efficient Rainbow	CURL	Rainbow FNO (Ours)
Breakout	1.74	0.69	11.1	<b>42.7</b>
Freeway	0.0	94.26	90.20	<b>101.01</b>
Pong	0.28	3.97	11.90	<b>36.83</b>
Qbert	-0.30	7.44	6.61	<b>18.44</b>
Seaquest	0.15	0.68	<b>0.75</b>	<b>0.75</b>

Average rewards obtained across 3 runs on **Atari100K** benchmark.

Our Encoder outperforms the CNN encoder in Efficient Rainbow in **20/26** games

We achieve median **26.1% HNS** compared to 16.1% HNS in CURL

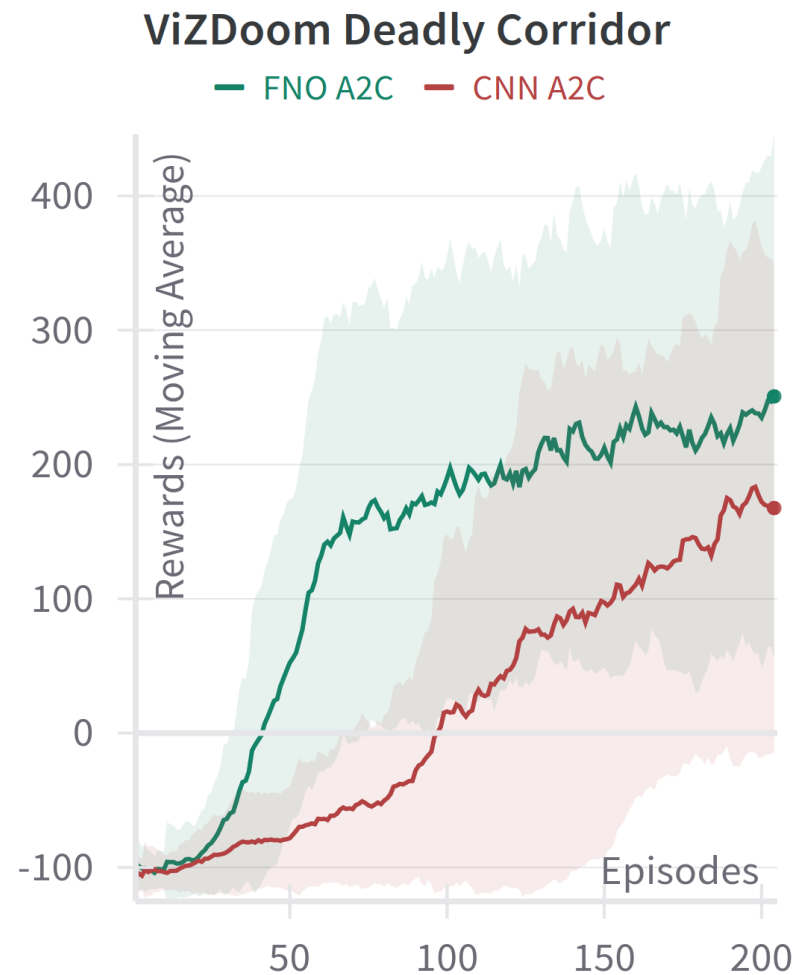
## ATARI GAMES (OFFLINE)

Game	BC	QR-DQN	CQL	DT	R-BVE	Ours
Breakout	138.9	17.1	211.1	267.5	110.5	<b>555.1</b>
Pong	85.2	18.0	111.9	106.1	92.6	<b>112.8</b>
Qbert	17.3	0.0	104.2	15.4	72.7	<b>110.7</b>
Seaquest	2.1	0.4	1.7	2.5	2.3	<b>3.1</b>

Average rewards obtained across 3 runs on **OfflineAtari1%** benchmark.

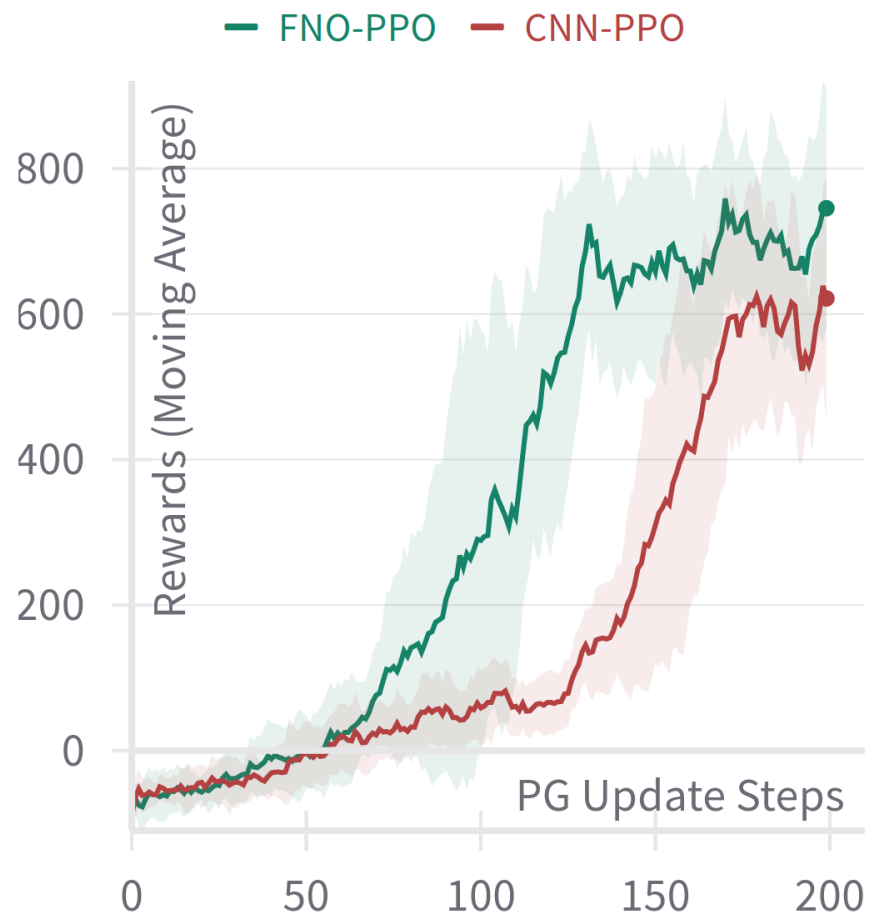
We achieve 2.9x HNS compared to SOTA transformer based models.

# VIZDOOM – DEADLY CORRIDOR – ONLINE ACTOR CRITIC

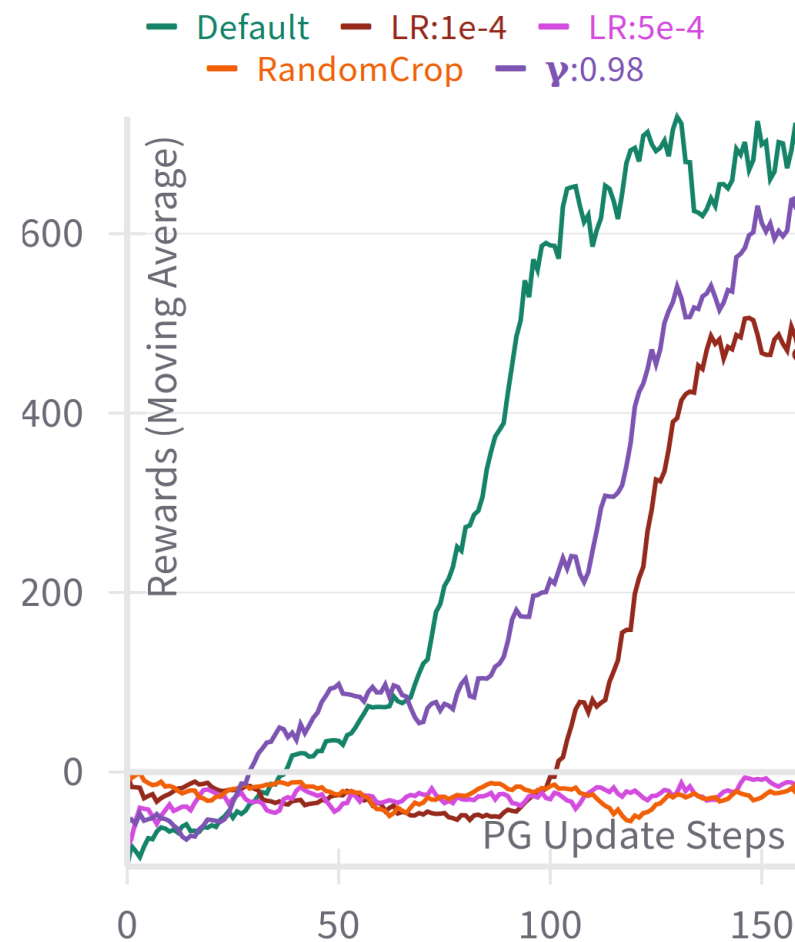


# CARLA AUTONOMOUS DRIVING - ONLINE POLICY GRADIENTS

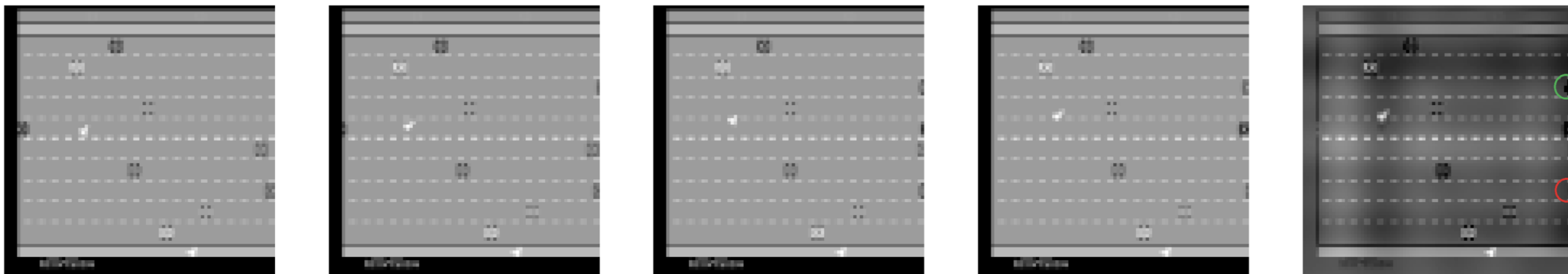
## Carla Lane (Image Observations)



## Carla Lane - Ablation Experiments



# ATARI - ABLATION



- The left 4 images correspond to the 4 sequential images given as input to the model.
- The right image is a weighted combination of the final feature maps, which turns out to be the model's prediction of how the next frame might look like.

# SUMMARY

- We propose a Fourier Neural Operator (FNO) encoder for model-free visual RL.
- We demonstrate that FNOs are superior to CNNs and transformers
- We additionally try to understand the representations learned.
- FNO encoders are invariant to the image input resolution and thus performs zero-shot domain adaptation.
- Code is available at: <https://github.com/paragduttaiisc/FNO-RL>

# Thank You!