# Question 2 - behavioral cloning

## Question 2.2 - BC performance against expert

### Archtecture of the neurual net

- Normalization of inputs (aka Z-score) (rmk: std+=1e-6 to avoid divide by 0)
- 2 `Dense` hidden layer, `tanh` activation
- `Dense` output layer
- `Adam` optimizer, `batch_size=256`, `validation_split=10%`, `verbose=2`
- `Adam` hyperparams to be learnt and the default value `learning_rate=0.001`, `epochs=10` (this part for question 2.3)
- for each expert, `num_rollouts=20`
- for the neurual net, `num_rollouts=20`
- each rollout stop until `max_steps = env.spec.timestep_limit`

### behavioral cloning performance across all agent

| | | | | | | | --- | --- | --- | --- | --- | --- | | # | expert name | expert mean reward | expert std reward | BC mean reward | BC std reward | | 0 | Ant-v2 | 4814.0965474080385 | 108.80632605584692 | 4406.201751455288 | 573.3854836162683 | | 1 | HalfCheetah-v2 | 4127.516970772937 | 104.15206994425873 | 3513.893690862605 | 508.35242034980627 | | 2 | Hopper-v2 | 3777.979019335801 | 3.7795498677440458 | 348.8571445834208 | 5.574347555130938 | | 3 | Humanoid-v2 | 10398.817690139582 | 46.76945115242351 | 1398.7654248744934 | 662.1544824968952 | | 4 | Reacher-v2 | -3.882463098485824 | 1.5836904717634293 | -10.895058170778515 | 4.211804026505475 | | 5 | Walker2d-v2 | 5518.253465989686 | 45.763351643271314 | 5231.149197823615 | 1010.5542993232773 |

### comparable performance with expert

Ant-v2 | expert | imitation -----------------|-------------|------------ mean reward | 4823 | 4776 std reward | 87 | 92 pct full rollout | 100% | 100%

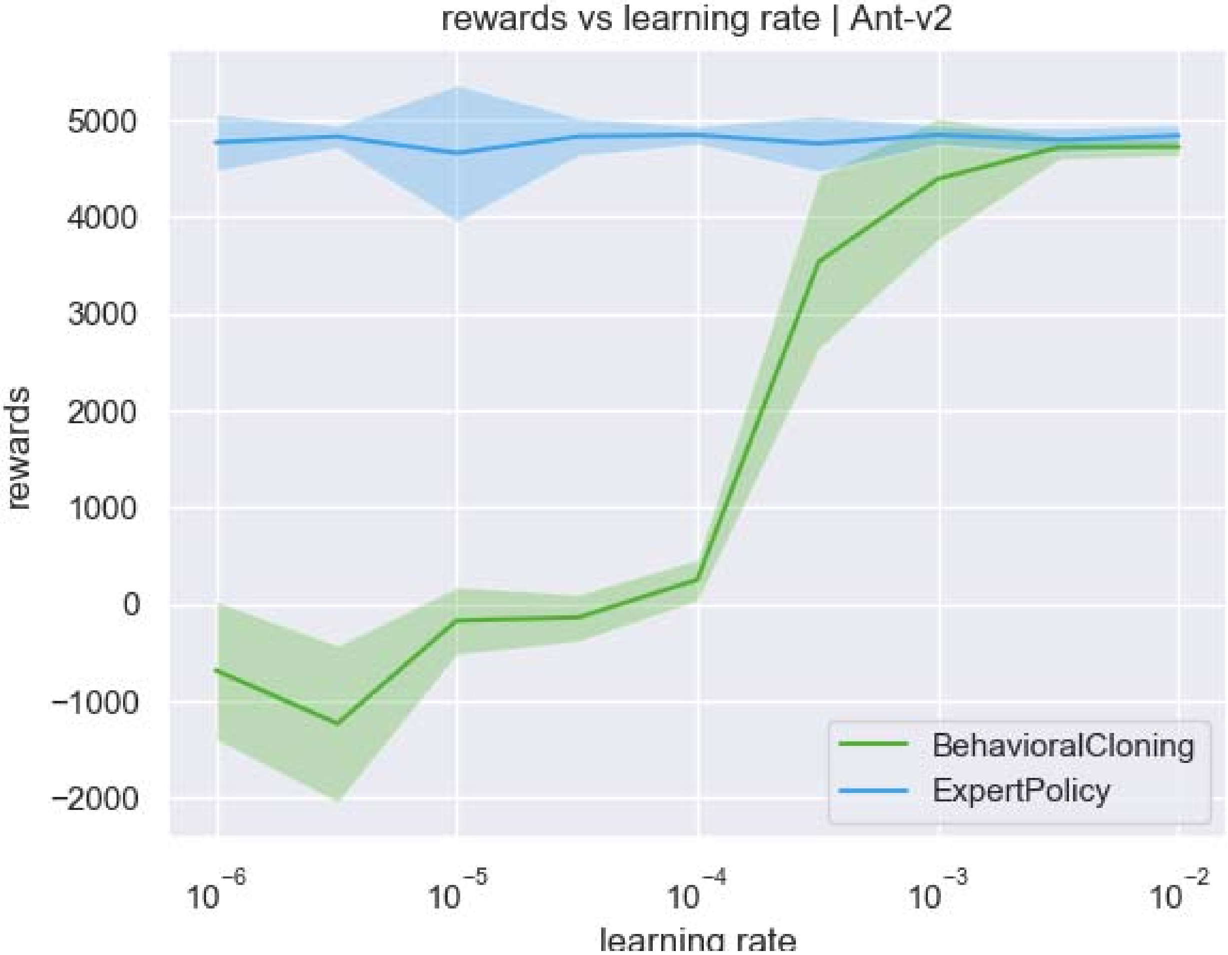
### significant deviation from expert performance

Reacher-v2 | expert | imitation -----------------|-------------|------------ mean reward | -4.39 | -10.06 std reward | 2.00 | 4.62 pct full rollout | 100% | 100%

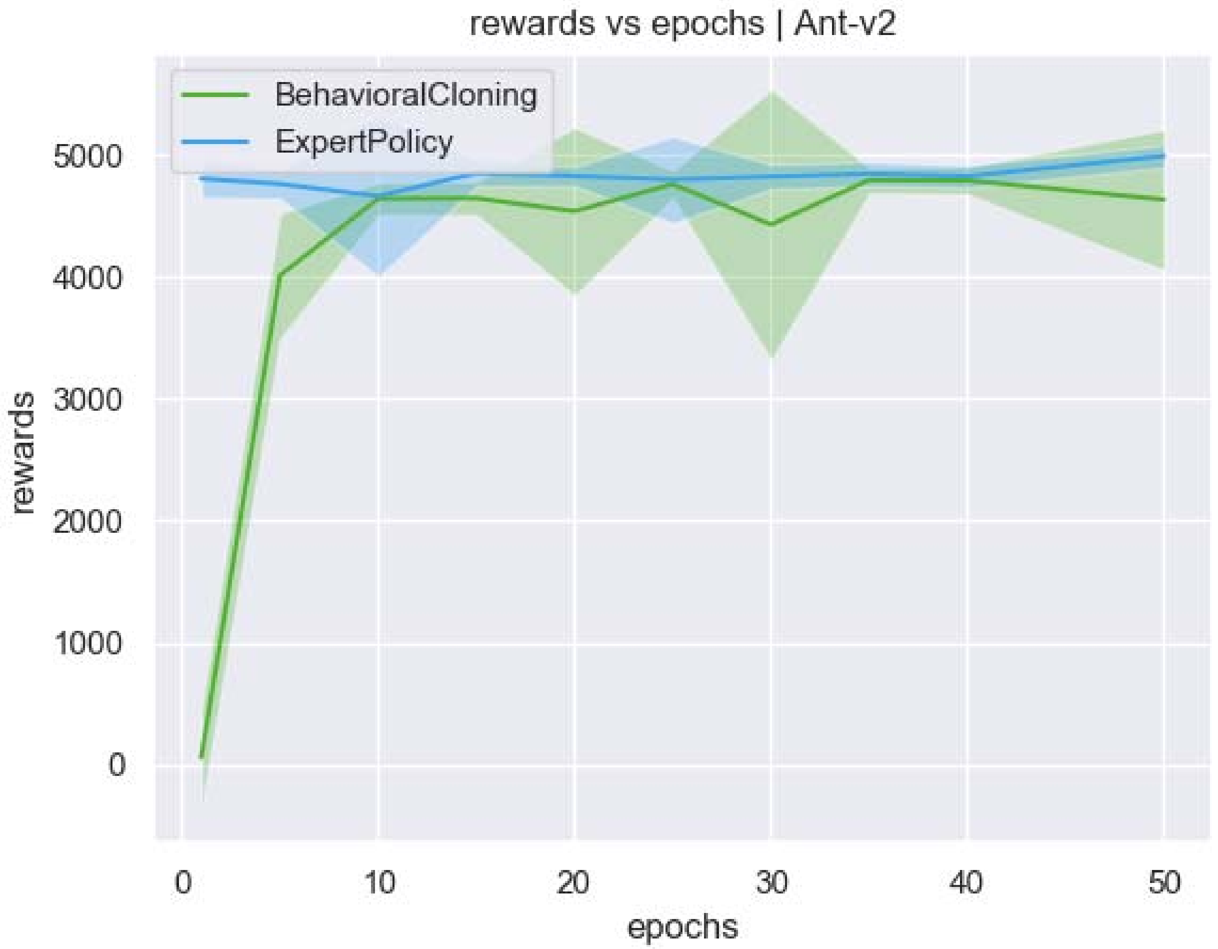
## Question 2.3 - BC sensitivity analysis to hyperparameters

# (Ant-v2 as example in this report)

## learning rate



## training epochs



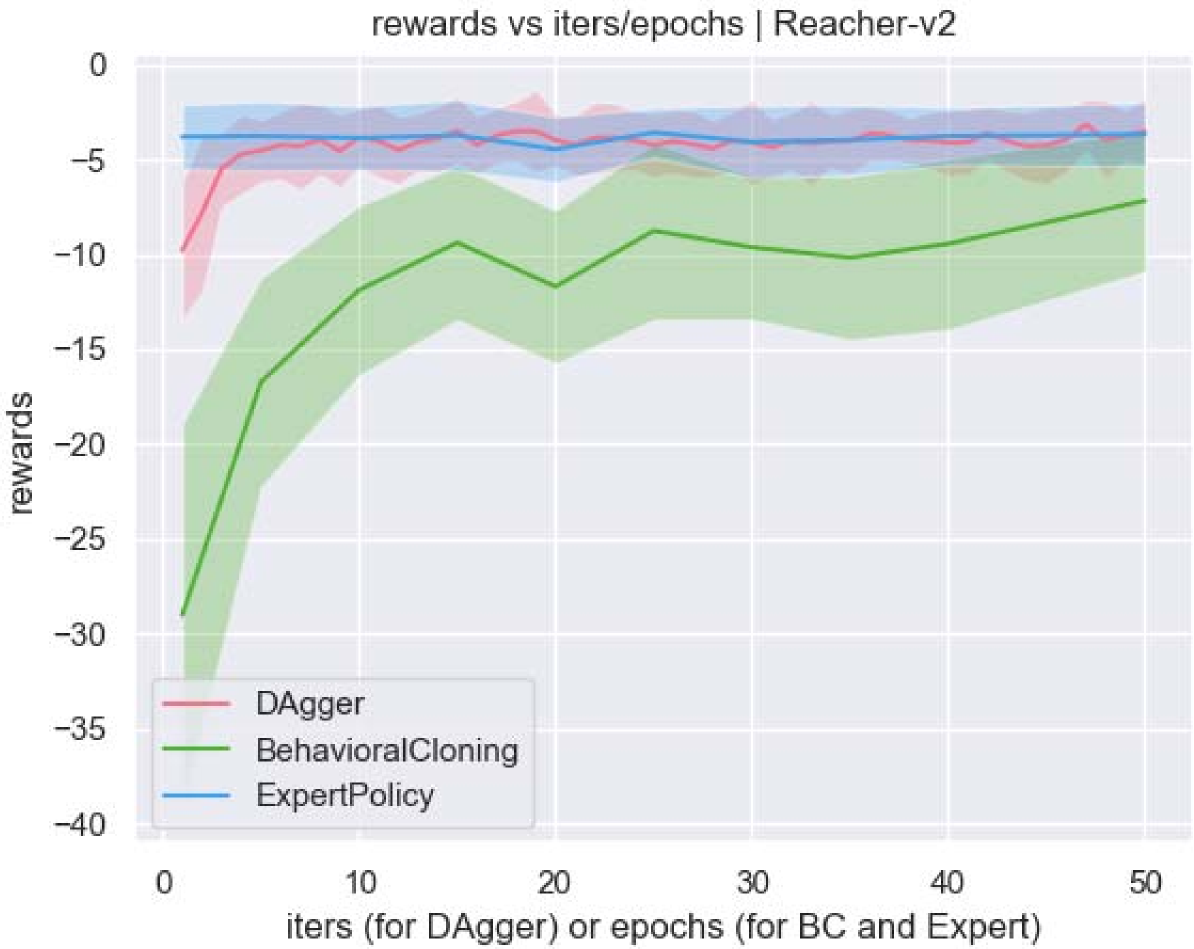
# Question 3 - DAgger

## Question 3.2 - DAgger performance against behavioral cloning (Reacher-v2 as example in this report)

### Architecture of the neural net

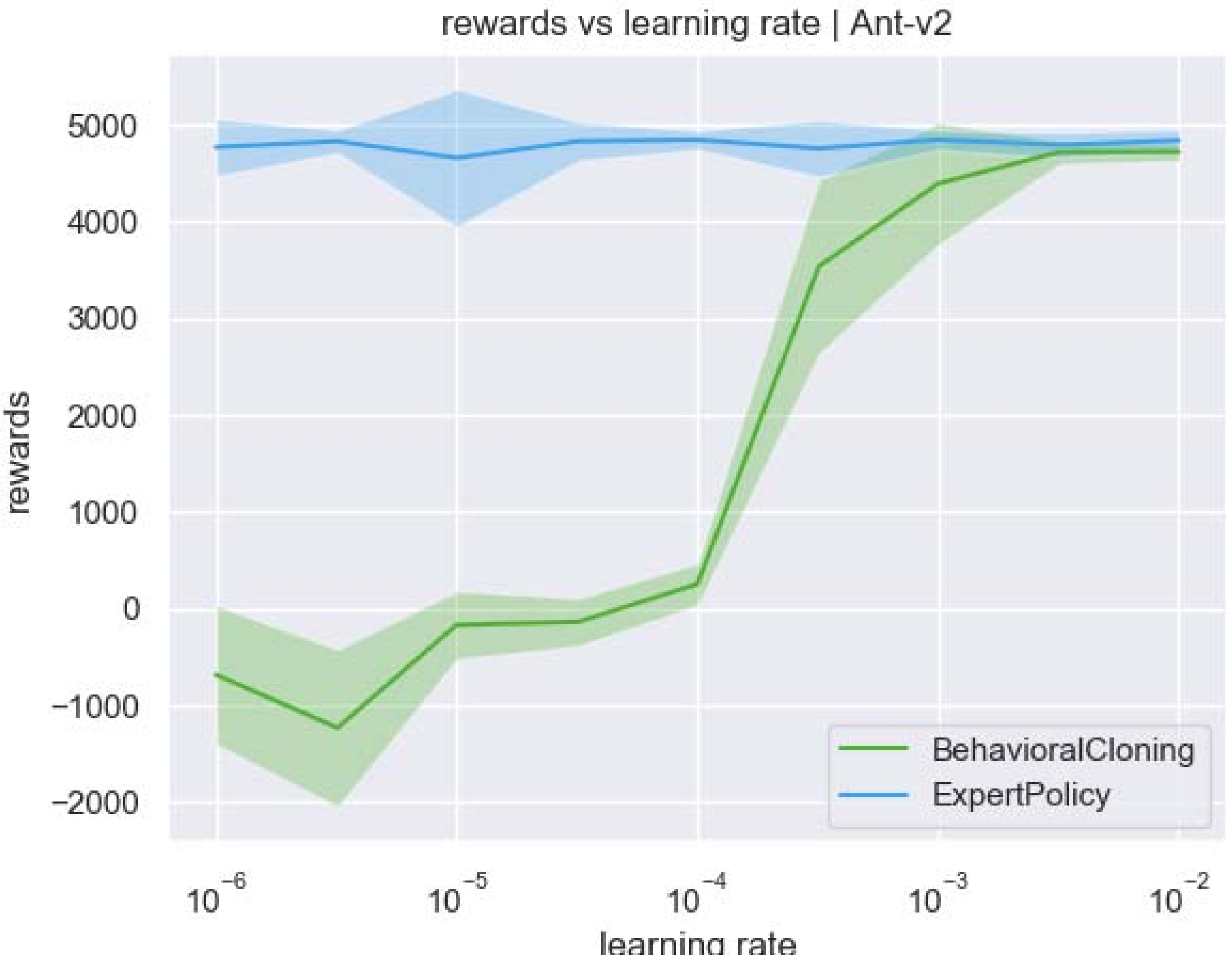
- Normalization of inputs (aka Z-score) (rmk: std+=1e-6 to avoid divide by 0)
- 2 `Dense` hidden layer, `tanh` activation
- `Dense` output layer
- `Adam` optimizer, `batch_size=256`, `validation_split=10%`, `verbose=2`, `learning_rate=0.001`, `epochs=10`
- for each expert, `num_rollouts=20`
- for the neurual net, `num_rollouts=20`
- each rollout stop until `max_steps = env.spec.timestep_limit`
- for the ietrations of DAgger, `iters=10`

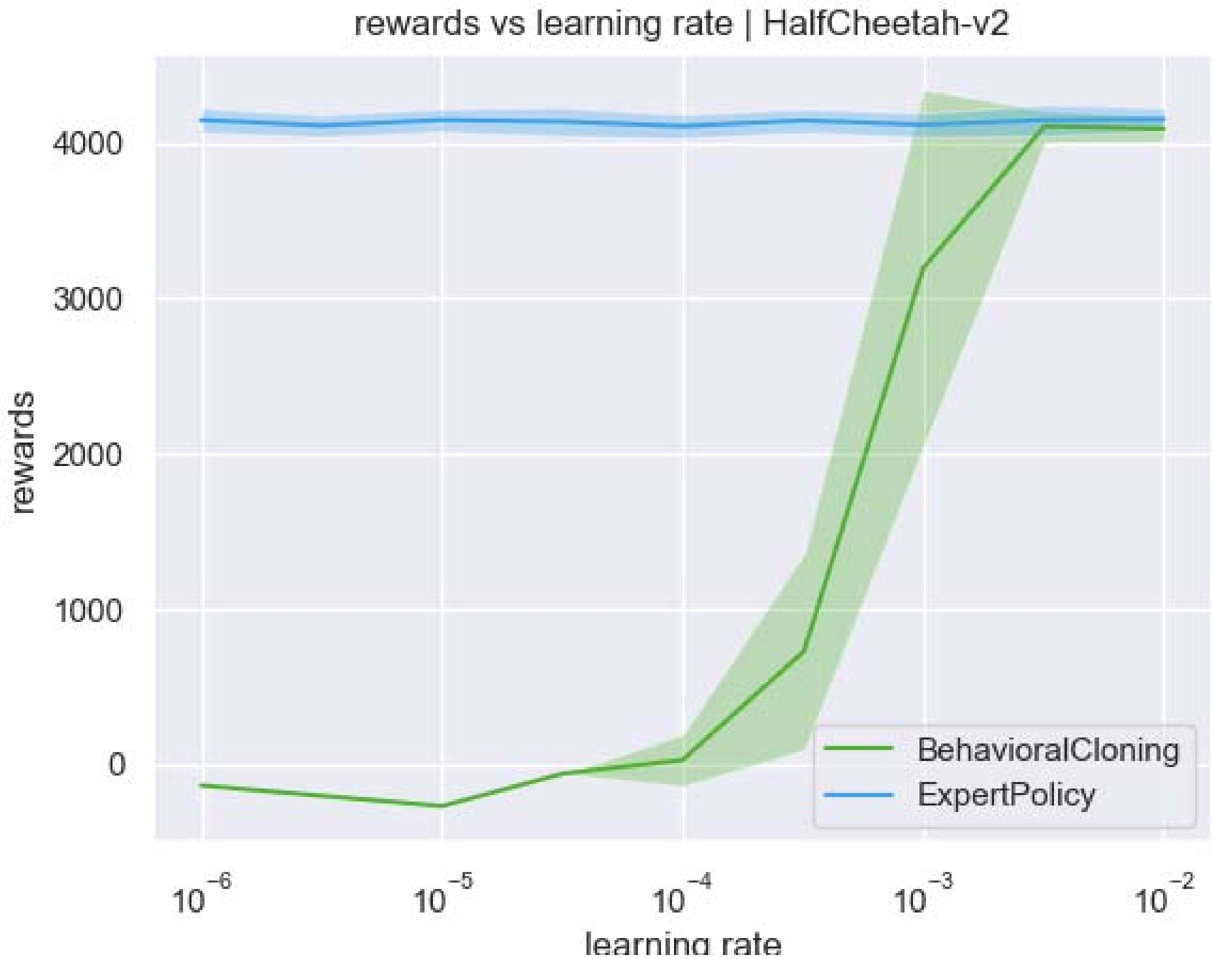
### DAgger performs better than behavioral cloning

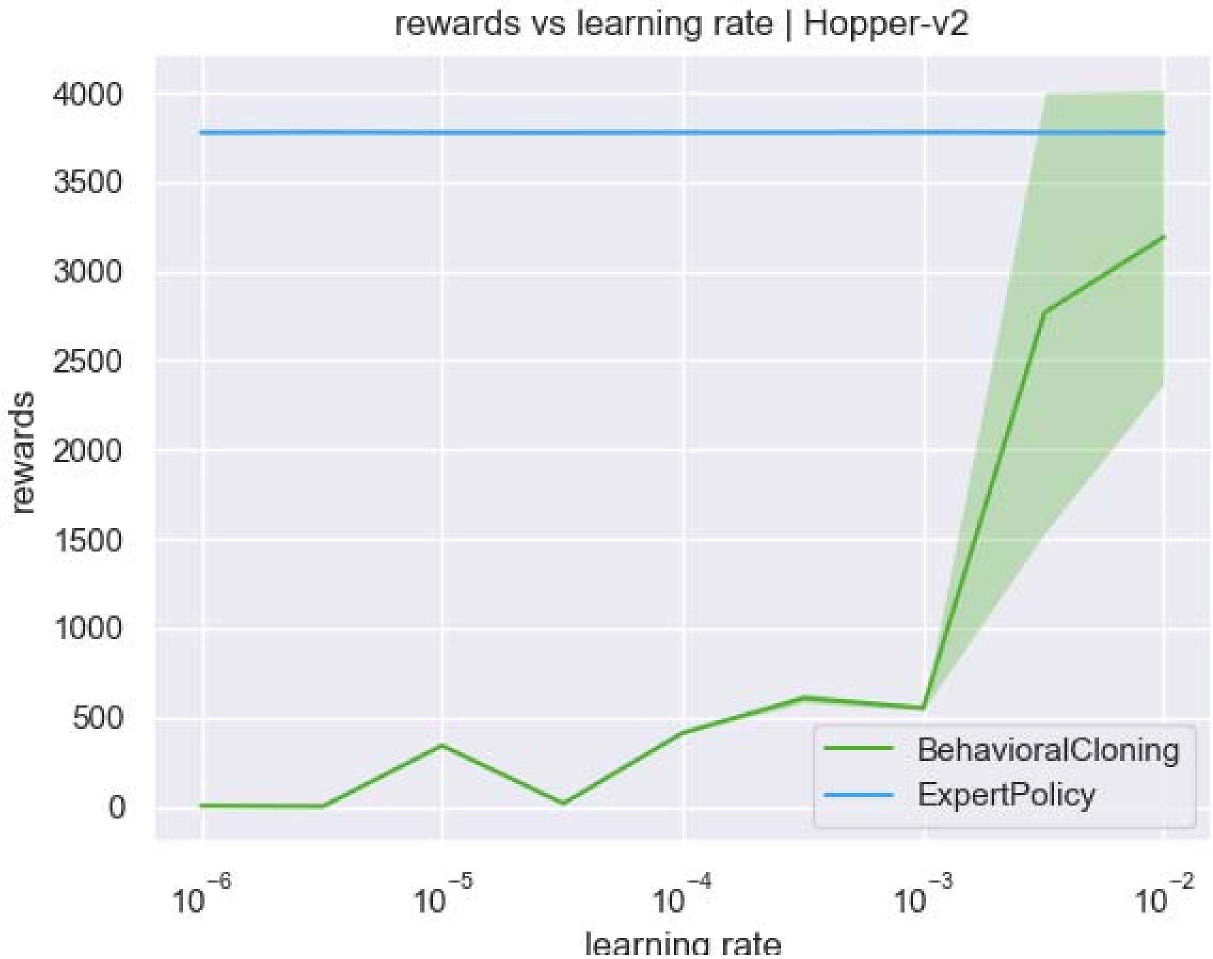


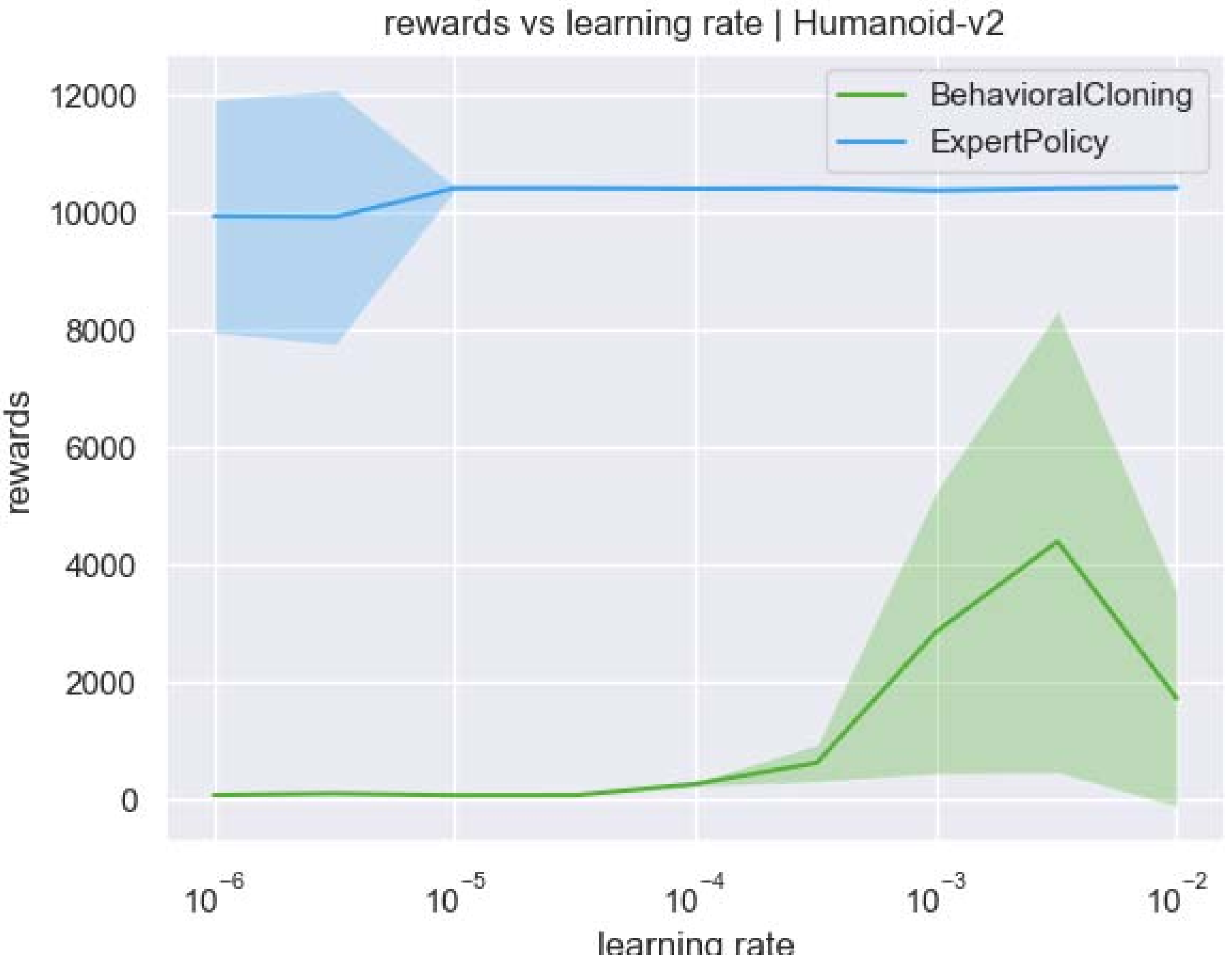
# Appendix

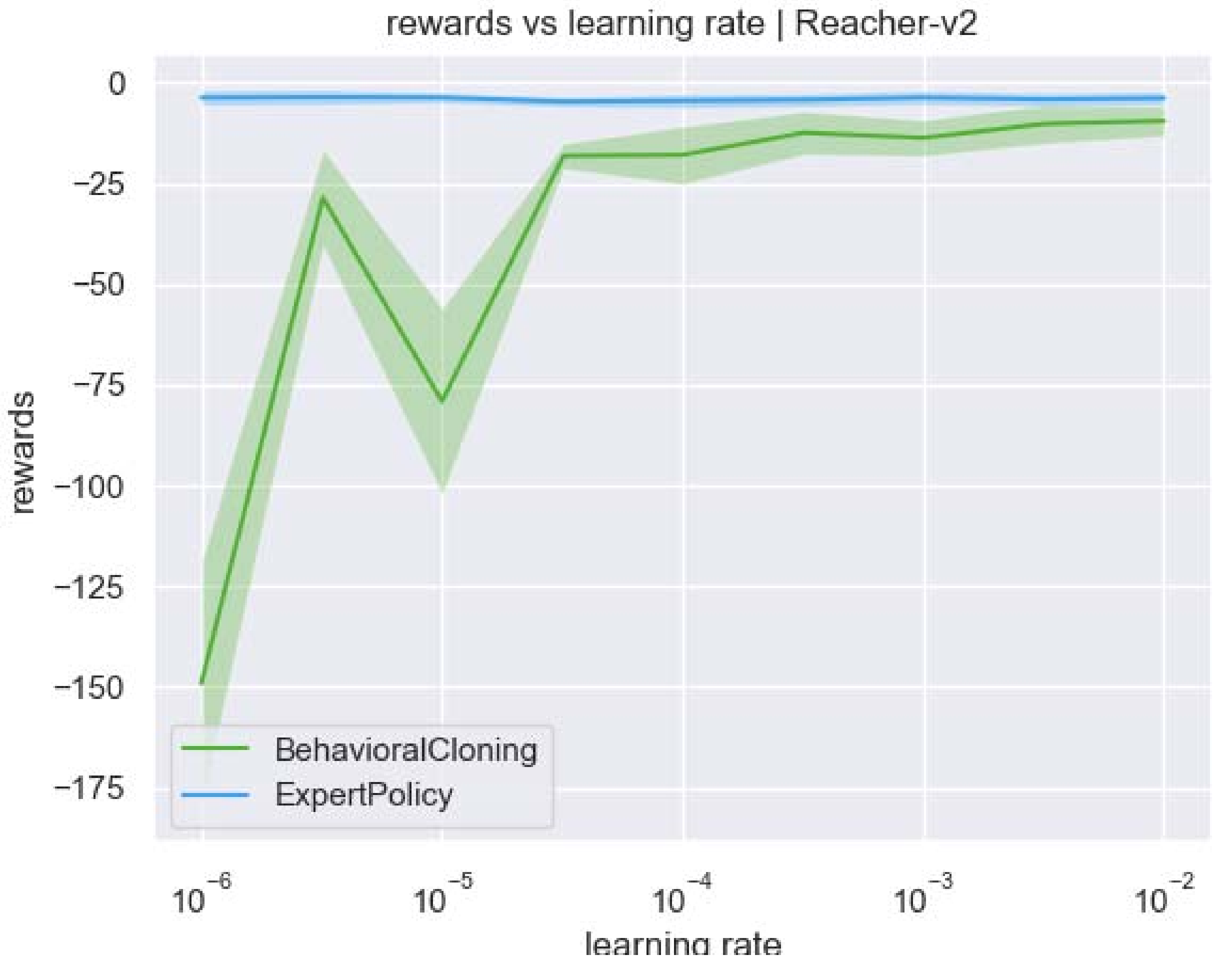
### BC hyperparams -- rewards vs learning rate

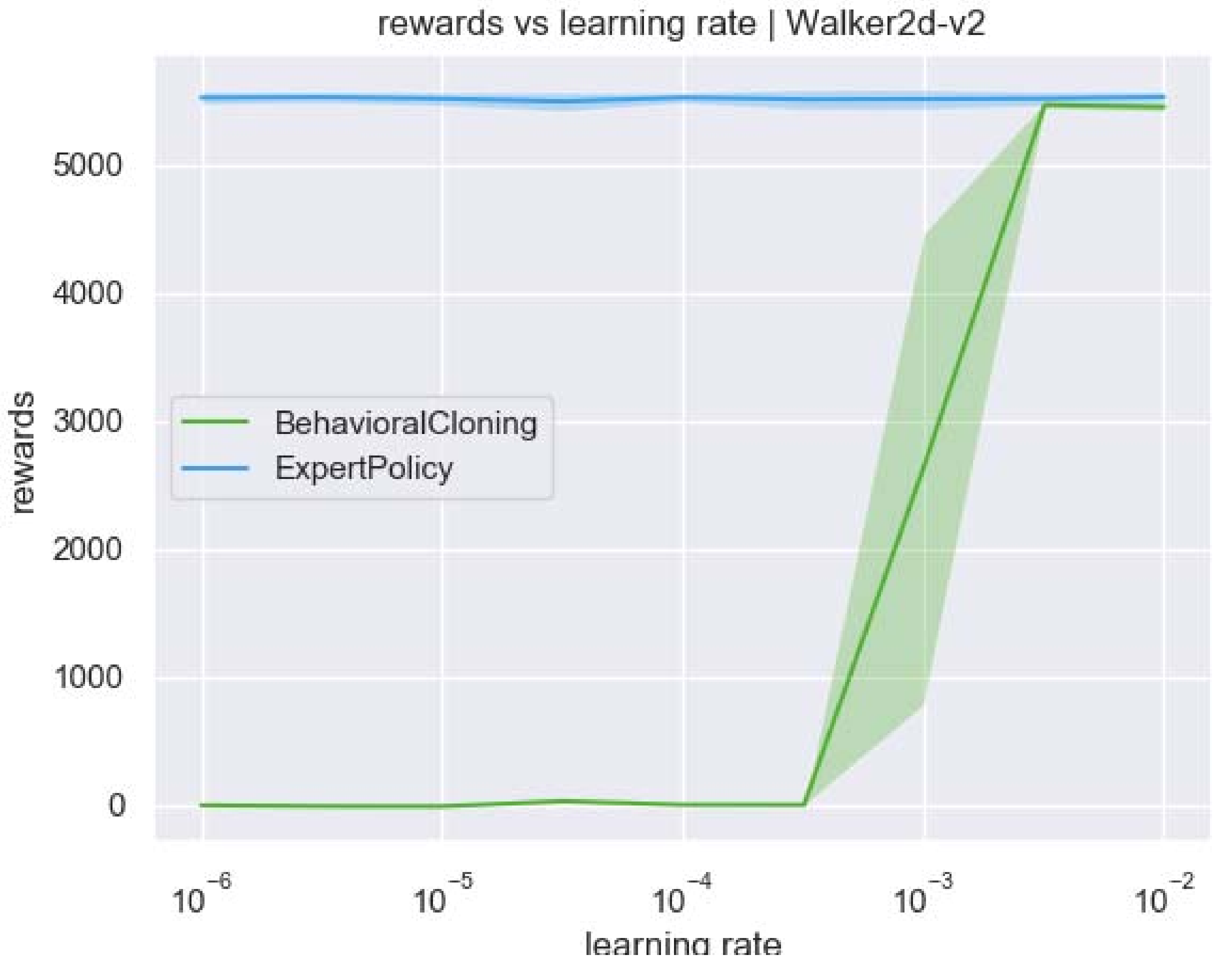

rewards vs learning rate | Ant-v2
rewards
5000
4000
3000
2000
1000
0
−1000
−2000
$10^{-6}$
$10^{-5}$
$10^{-4}$
$10^{-3}$
$10^{-2}$
learning rate
BehavioralCloning
ExpertPolicy


rewards vs learning rate | HalfCheetah-v2
rewards
4000
3000
2000
1000
0
learning rate
$10^{-6}$
$10^{-5}$
$10^{-4}$
$10^{-3}$
$10^{-2}$
BehavioralCloning
ExpertPolicy

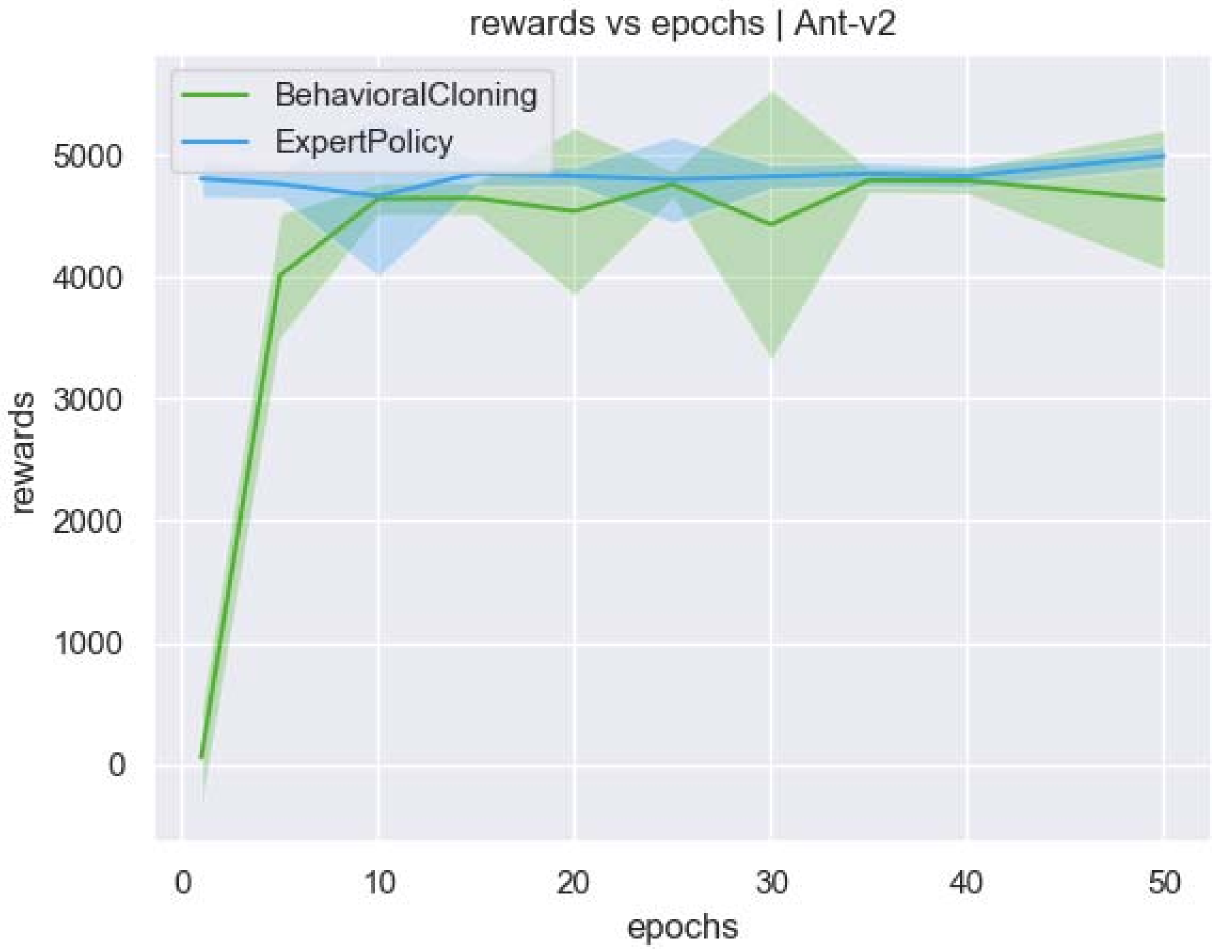

rewards vs learning rate | Hopper-v2
rewards
4000
3500
3000
2500
2000
1500
1000
500
0
$10^{-6}$
$10^{-5}$
$10^{-4}$
$10^{-3}$
$10^{-2}$
learning rate
BehavioralCloning
ExpertPolicy

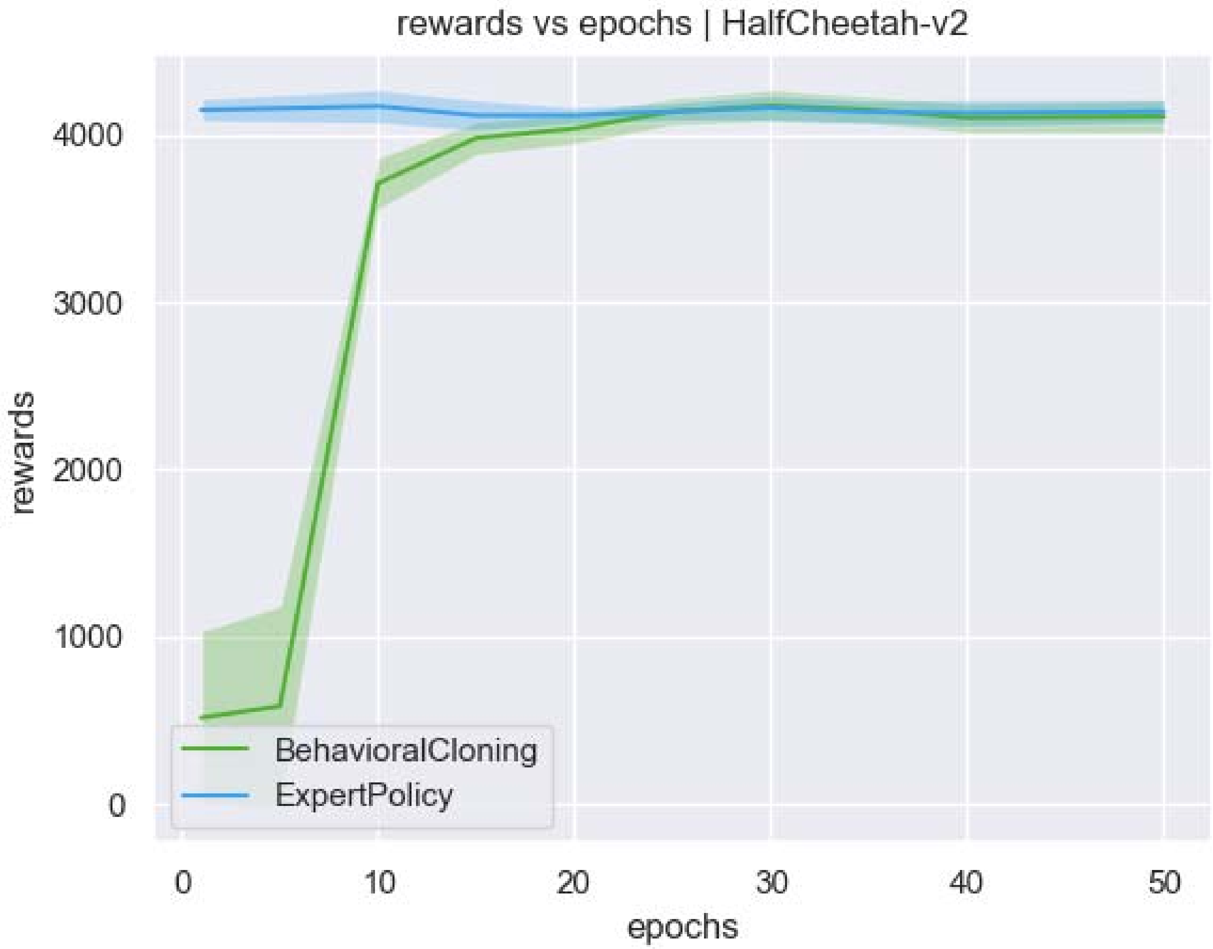

rewards vs learning rate | Humanoid-v2
BehavioralCloning
ExpertPolicy
rewards
12000
10000
8000
6000
4000
2000
0
$10^{-6}$
$10^{-5}$
$10^{-4}$
$10^{-3}$
$10^{-2}$
learning rate

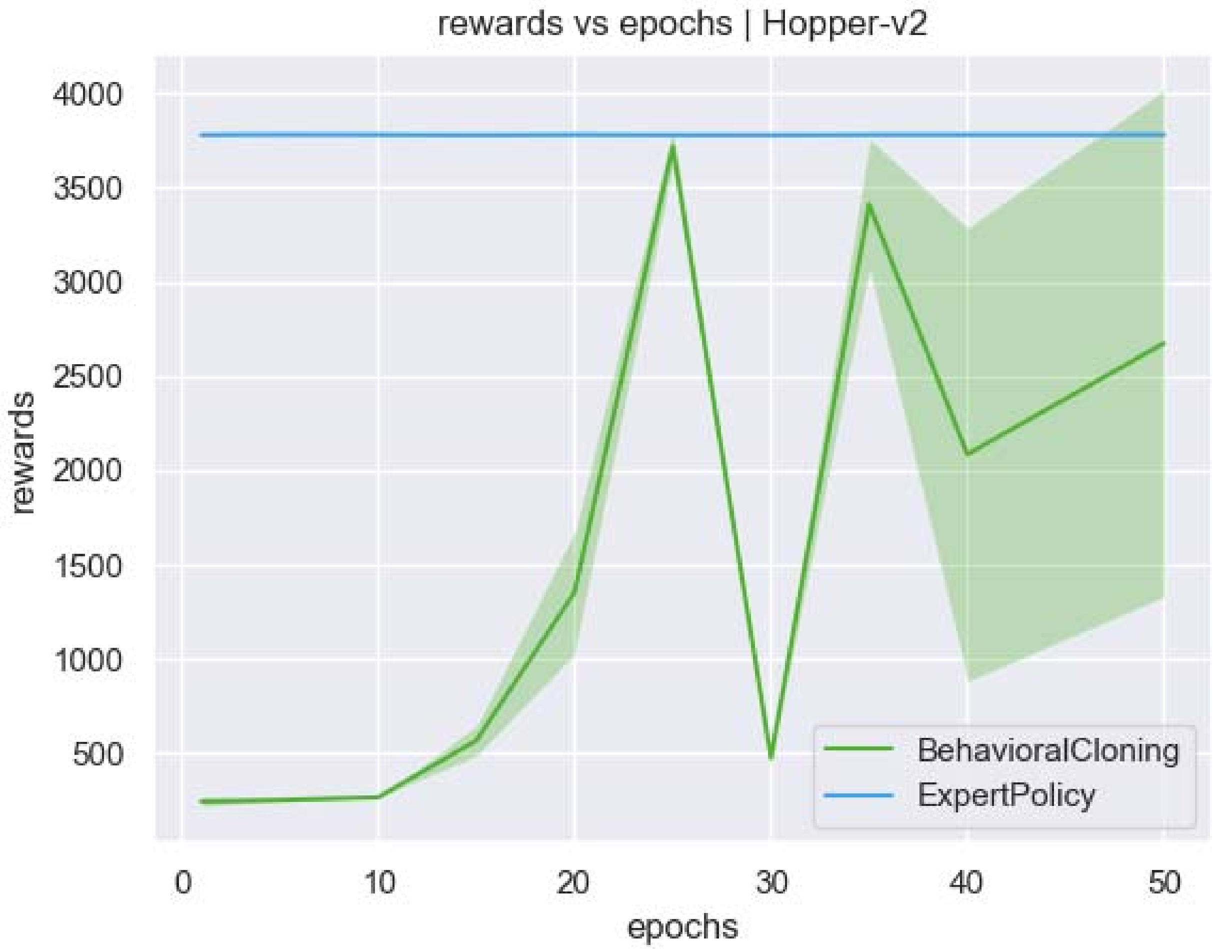

rewards vs learning rate | Reacher-v2
rewards
learning rate
0
−25
−50
−75
−100
−125
−150
−175
$10^{-6}$
$10^{-5}$
$10^{-4}$
$10^{-3}$
$10^{-2}$
BehavioralCloning
ExpertPolicy

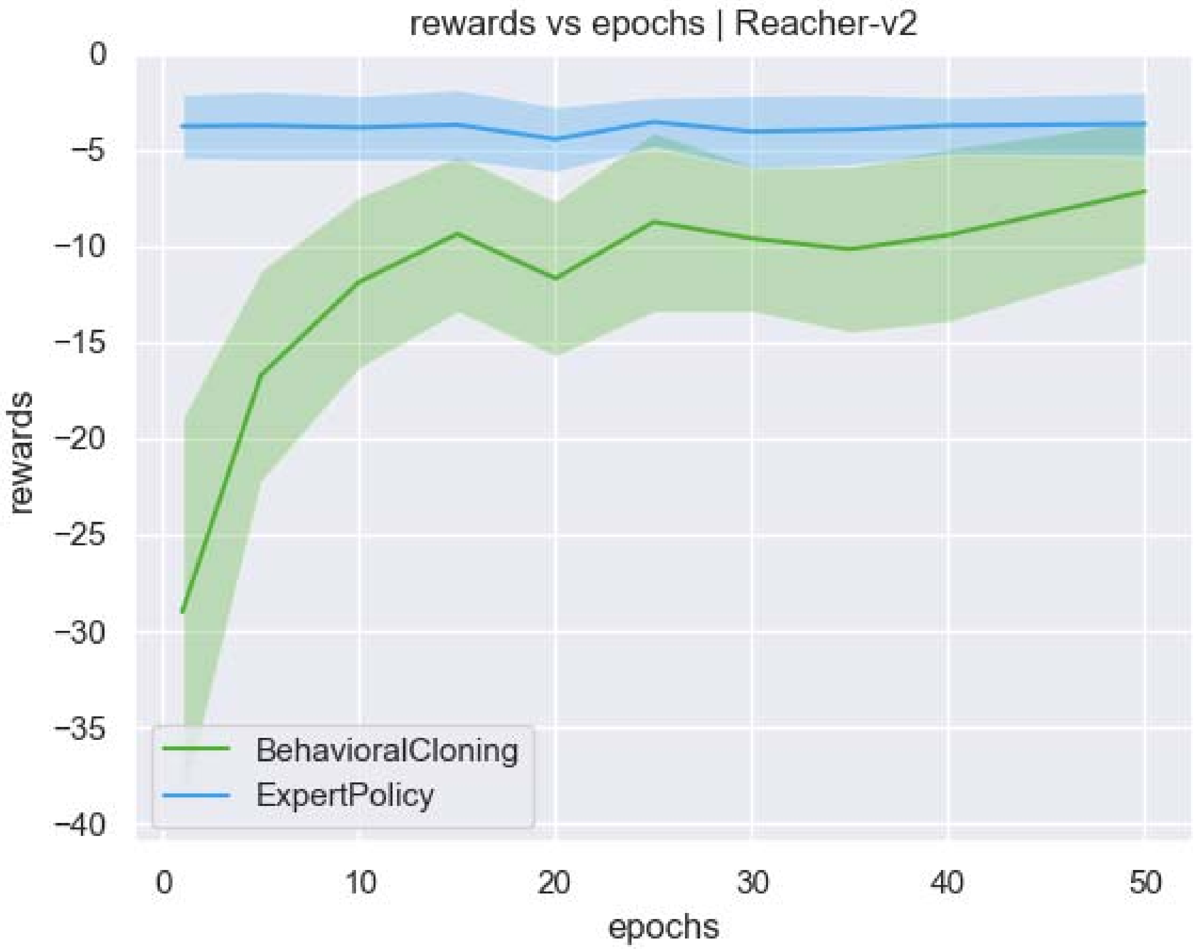


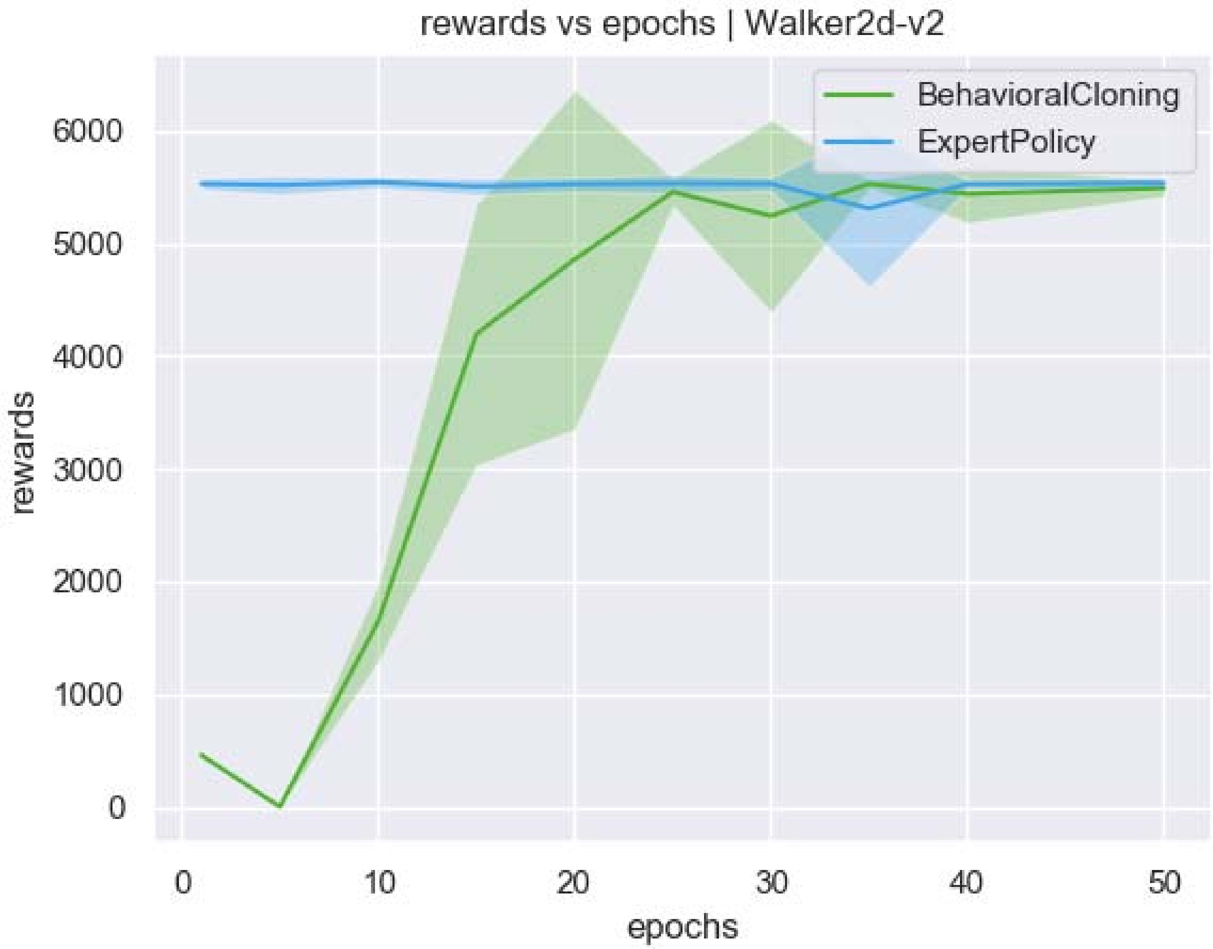
### BC hyperparams -- rewards vs epochs


rewards vs epochs | Ant-v2
BehavioralCloning
ExpertPolicy
5000
4000
3000
2000
1000
0
rewards
0
10
20
30
40
50
epochs

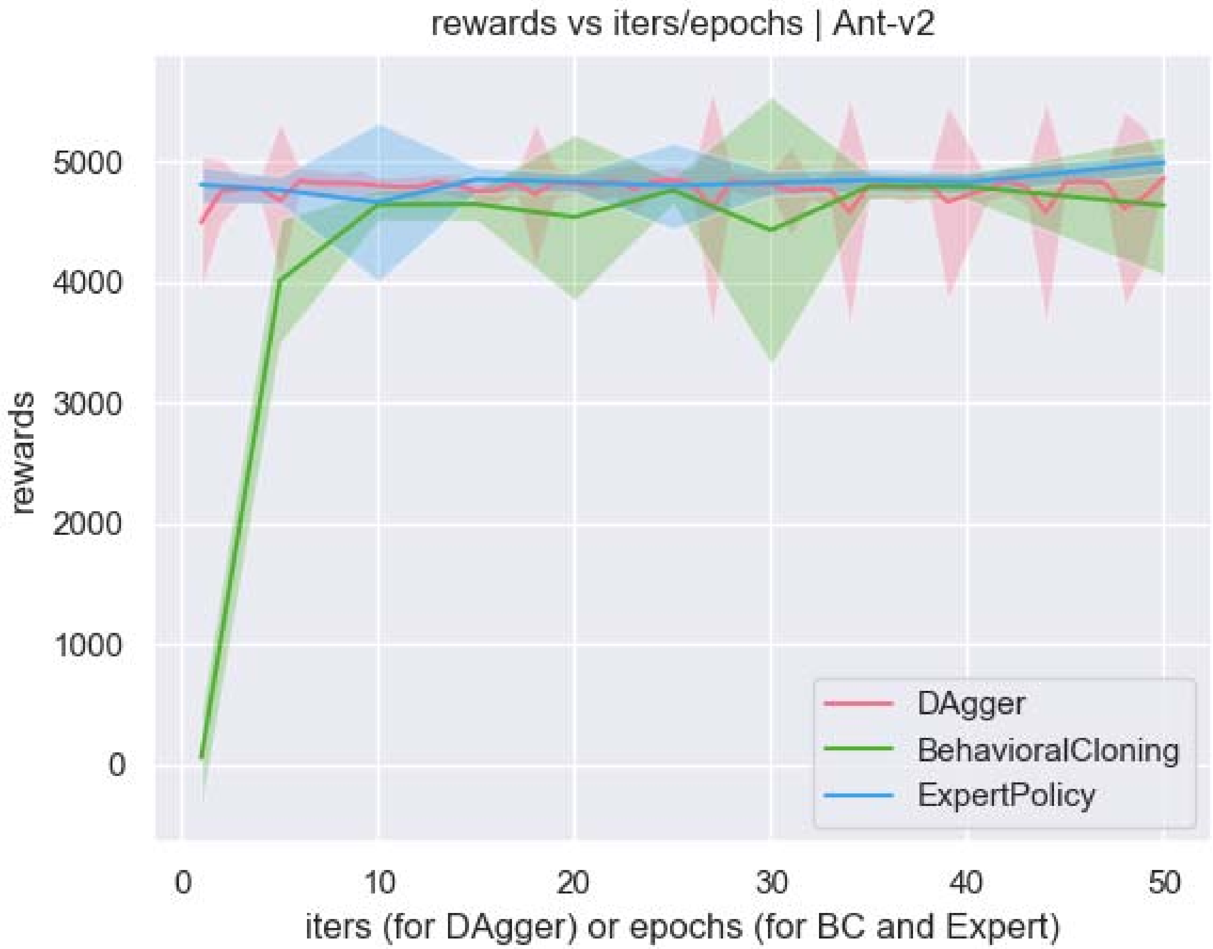

rewards vs epochs | HalfCheetah-v2
rewards
4000
3000
2000
1000
0
epochs
0
10
20
30
40
50
BehavioralCloning
ExpertPolicy

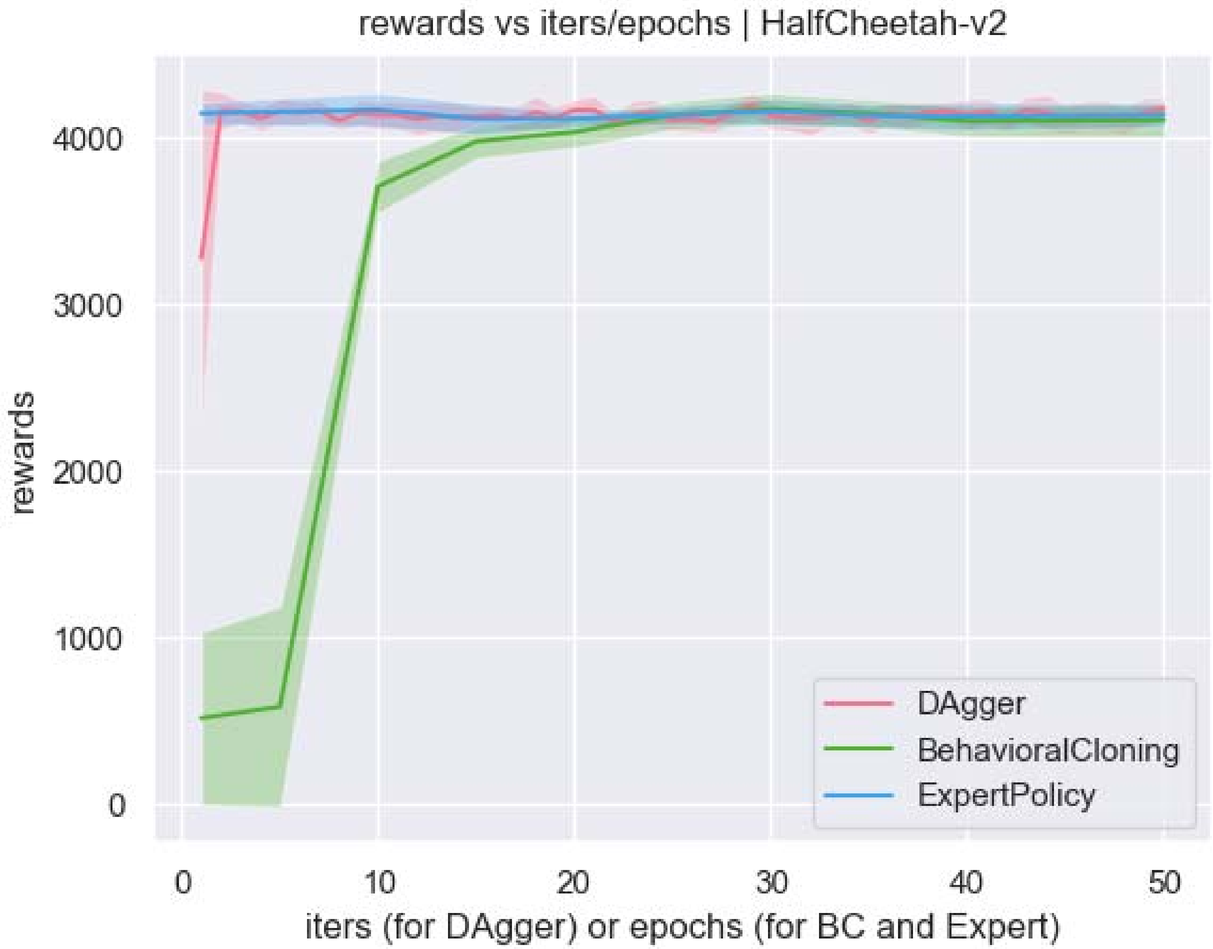

rewards vs epochs | Hopper-v2
rewards
4000
3500
3000
2500
2000
1500
1000
500
0
10
20
30
40
50
epochs
BehavioralCloning
ExpertPolicy

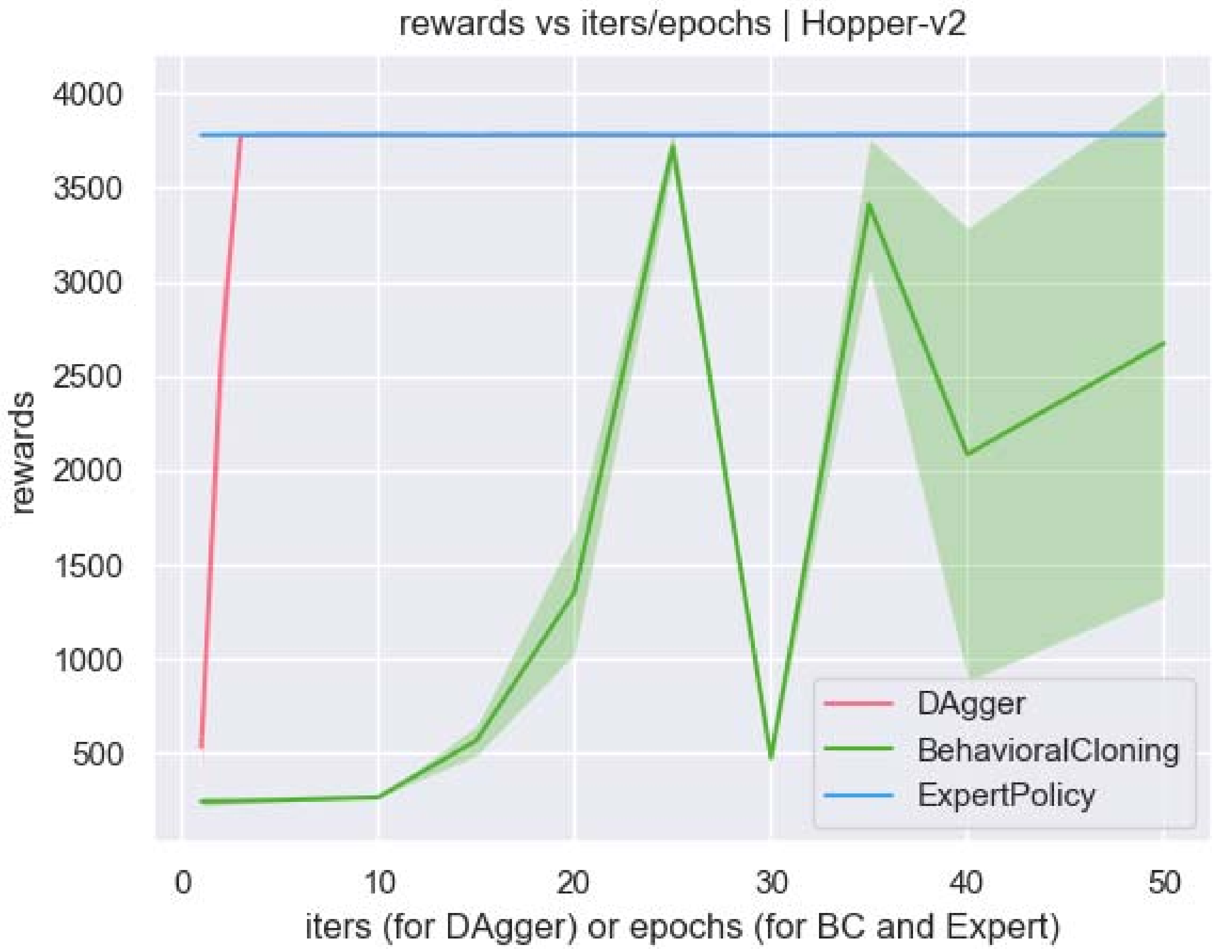

rewards vs epochs | Reacher-v2
0
−5
−10
−15
−20
−25
−30
−35
−40
rewards
0
10
20
30
40
50
epochs
BehavioralCloning
ExpertPolicy

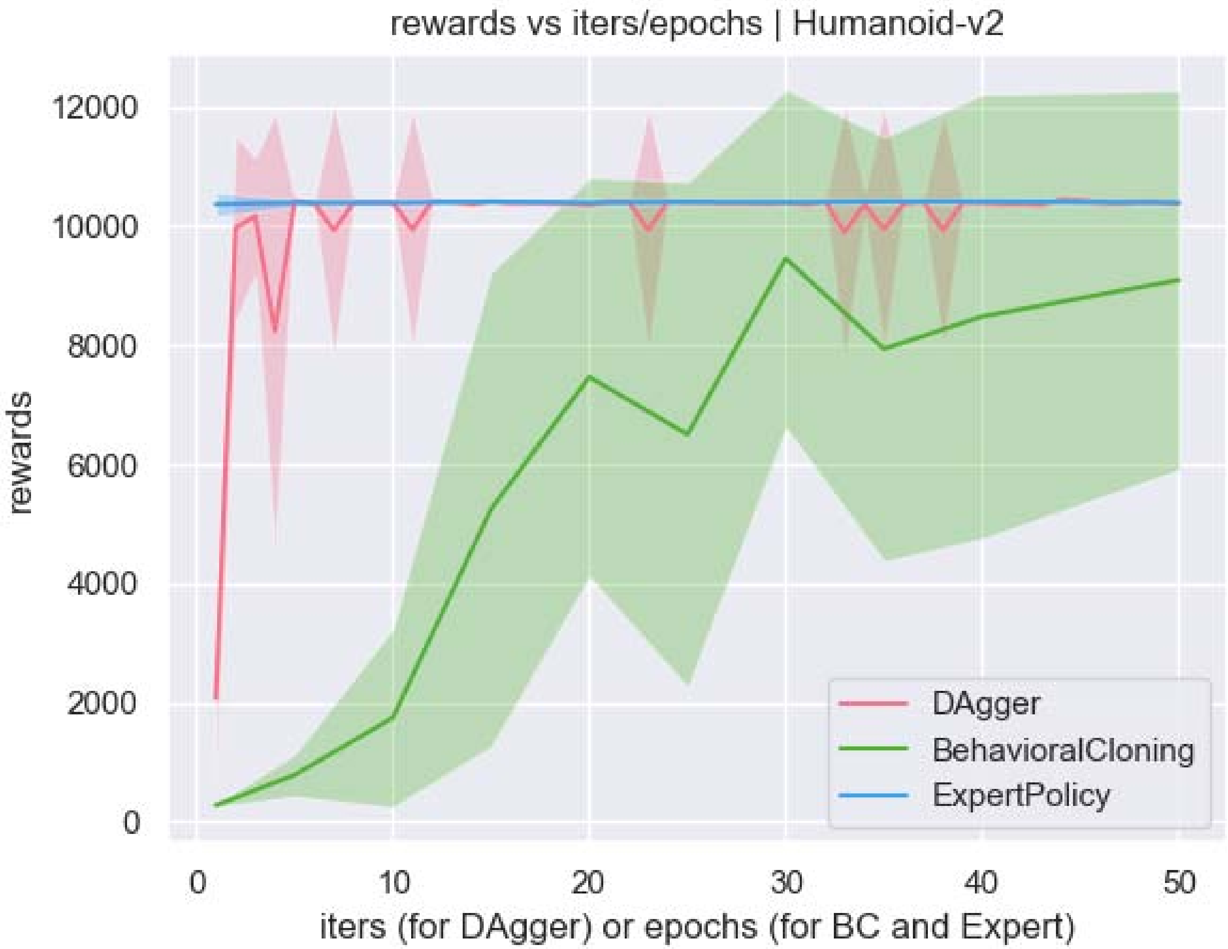


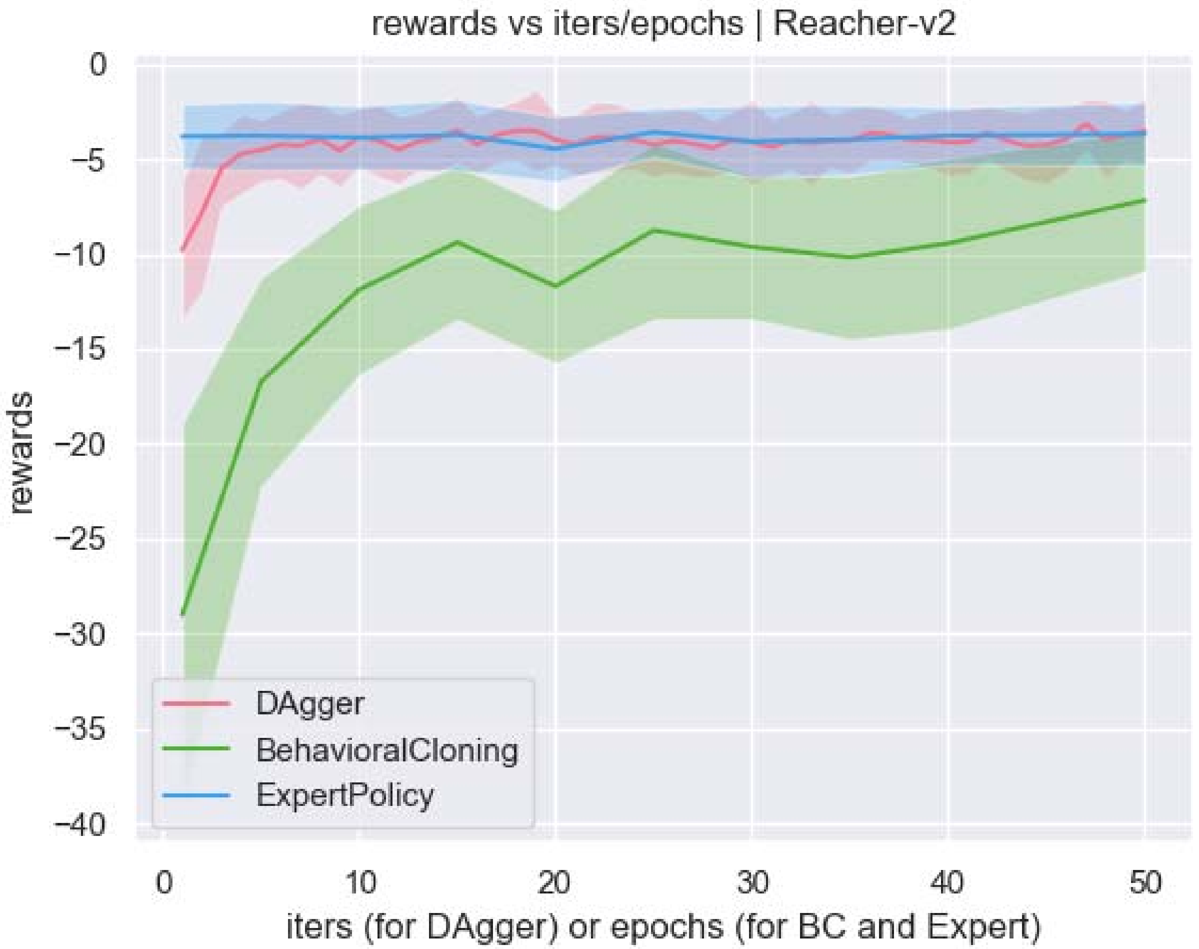
## Expert vs BC vs DAgger -- rewards vs iters --

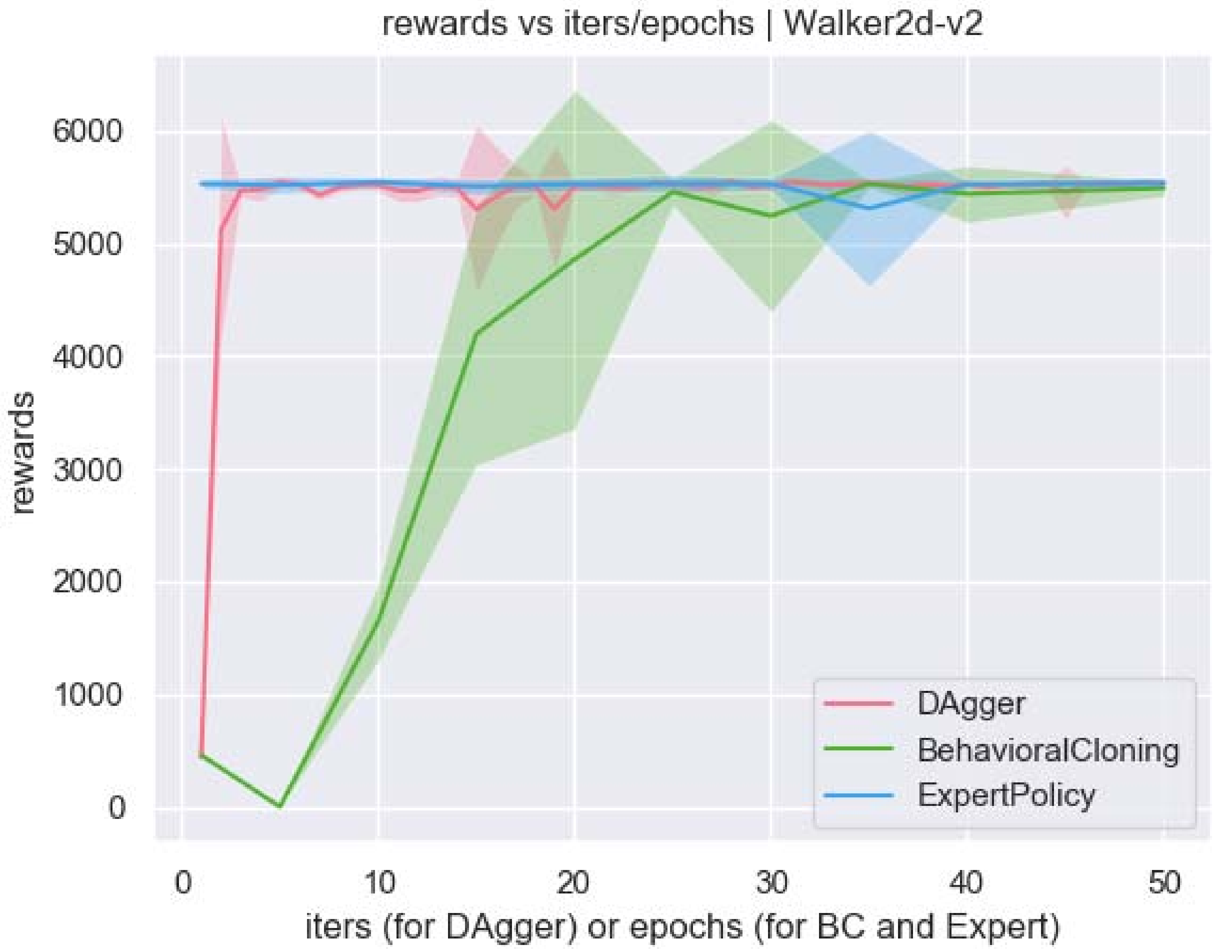

rewards vs iters/epochs | Ant-v2
rewards
5000
4000
3000
2000
1000
0
0
10
20
30
40
50
iters (for DAgger) or epochs (for BC and Expert)
DAgger
BehavioralCloning
ExpertPolicy


rewards vs iters/epochs | HalfCheetah-v2
rewards
0
1000
2000
3000
4000
0
10
20
30
40
50
iters (for DAgger) or epochs (for BC and Expert)
DAgger
BehavioralCloning
ExpertPolicy


rewards vs iters/epochs | Hopper-v2
rewards
4000
3500
3000
2500
2000
1500
1000
500
0
10
20
30
40
50
iters (for DAgger) or epochs (for BC and Expert)
DAgger
BehavioralCloning
ExpertPolicy


rewards vs iters/epochs | Humanoid-v2
rewards
12000
10000
8000
6000
4000
2000
0
0
10
20
30
40
50
iters (for DAgger) or epochs (for BC and Expert)
DAgger
BehavioralCloning
ExpertPolicy


rewards vs iters/epochs | Reacher-v2
rewards
0
−5
−10
−15
−20
−25
−30
−35
−40
0
10
20
30
40
50
iters (for DAgger) or epochs (for BC and Expert)
DAgger
BehavioralCloning
ExpertPolicy


rewards vs iters/epochs | Walker2d-v2
rewards
6000
5000
4000
3000
2000
1000
0
0
10
20
30
40
50
iters (for DAgger) or epochs (for BC and Expert)
DAgger
BehavioralCloning
ExpertPolicy