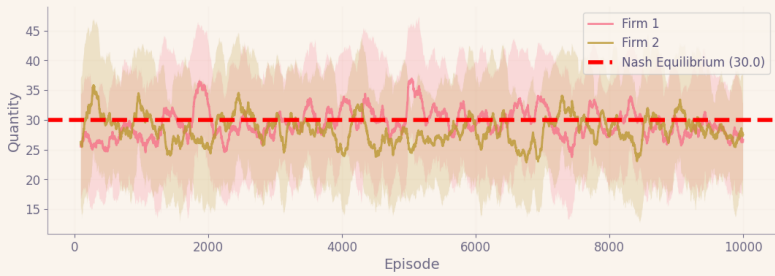# ULTIMATE MARL CONVERGENCE VISUALIZATION
Multi-Agent Reinforcement Learning Discovers Nash Equilibria
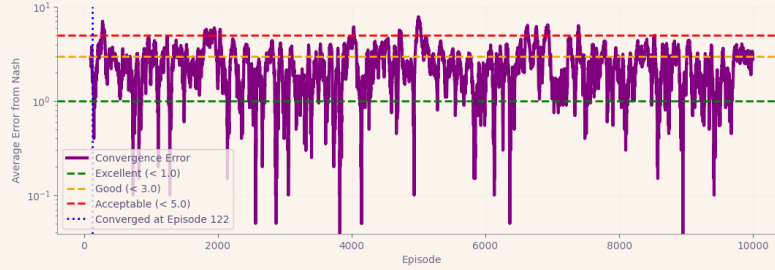
QUANTITY CONVERGENCE
Agents Learning Nash Strategies

- Firm 1
- Firm 2
- Nash Equilibrium (30.0)

Quantity / Episode

LEARNING PROGRESS
Convergence Speed & Quality

- Convergence Error
- Excellent (< 1.0)
- Good (< 3.0)
- Acceptable (< 5.0)
- Converged at Episode 122

Average Error from Nash / Episode

MARKET PRICE CONVERGENCE
Economic Outcomes

- Market Price
- Nash Price (40.0)

Price / Episode

PROFIT CONVERGENCE
Firm Performance

- Firm 1
- Firm 2
- Nash Profit (900.0)

Profit / Episode

STRATEGY EVOLUTION HEATMAP
How Agents Learn Over Time

Action (Quantity) / Learning Phase (Episodes)

Action Frequency
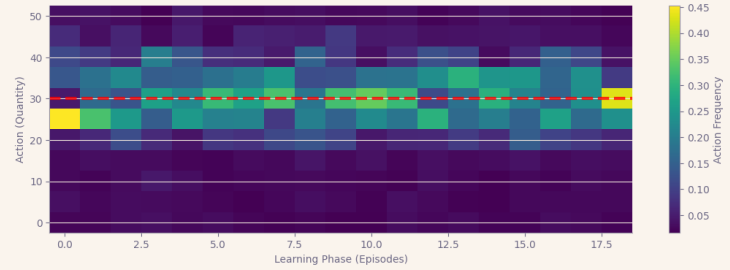
CONVERGENCE SUMMARY
Quantitative Assessment

```
 CONVERGENCE SUMMARY

 Final Performance:
• Learned Quantities: 27.2, 26.9
• Nash Quantities:    30.0, 30.0
• Quantity Errors:     2.8, 3.1

 Market Outcomes:
• Learned Price:       45.8
• Nash Price:          40.0
• Price Error:         5.8

 Overall Assessment:
• Average Error:       3.88
• Assessment:          ⚠ MODERATE convergence - could be improved
```

ECONOMIC INSIGHTS
Learned vs Nash Market Outcomes

- Learned Strategies
- Nash Equilibrium

Economic Metrics	Learned Strategies	Nash Equilibrium
Total Quantity	54.2	60.0
Consumer Surplus	1467.5	1800.0
Producer Surplus	1940.8	1800.0
Total Welfare	3408.3	3600.0

Value / Economic Metrics