

# Knowledge-grounded Natural Language Recommendation Explanation

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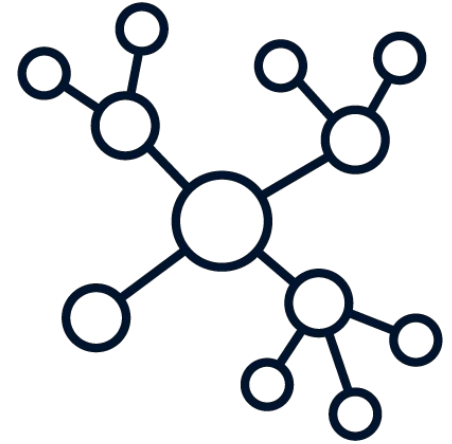


**BOSCH**

# Problem

Knowledge Graph Rec Systems introduce background knowledge for reasoning and structural explanations

- Helps solve cold start problem and provides additional context clues for explanation



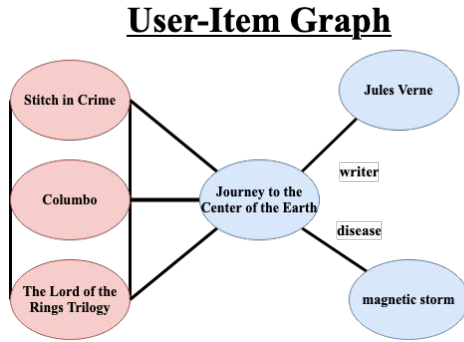
Natural Language Recommendation Explanation

- Generate a natural language explanation, for a user/item pair which justifies why the item is being recommended.



# Research Question

Can we leverage Knowledge Graphs to narrate such features in order to provide fact-grounded natural language explanations for recommendations?



## Ground Truth Explanation (Description)

Jules Verne's Professor Lindenbrook leads a trip through monsters, mushrooms, and a magnetic storm.

**Rating: 4.0**

## Generated Explanation (Personalized)

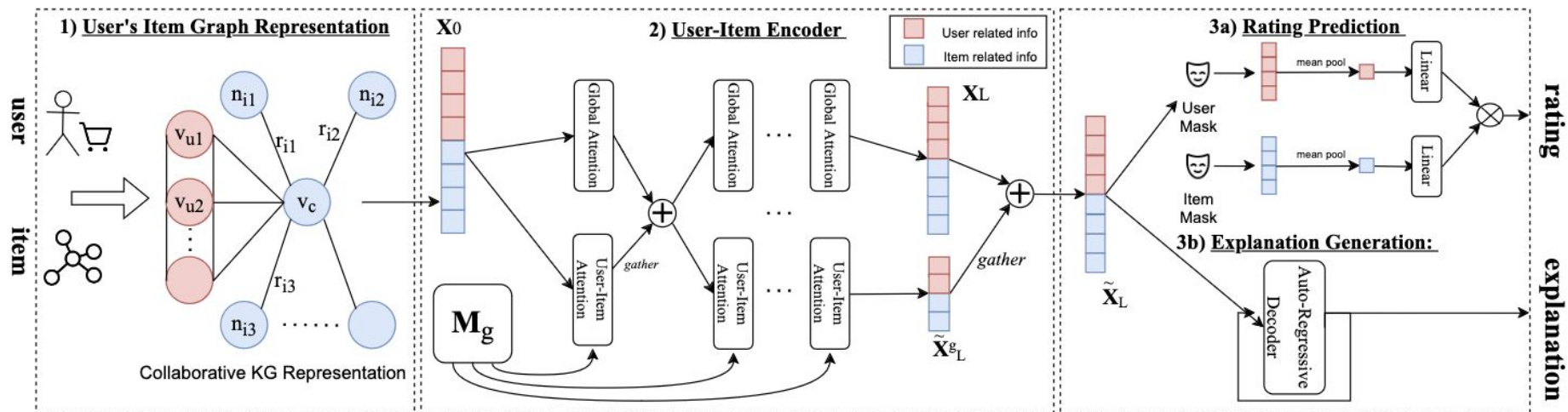
A scientist (Jules Verne) **investigates** a magnetic storm that sends a **mysterious beam of light** from earth to the center of the earth.

**Rating: 4.2**

Current work:

- Fact-grounded? **✗** (Based on user reviews)
- Knowledge Graph? **✗** (Features extracted from reviews)

# Our Approach (KnowRec)

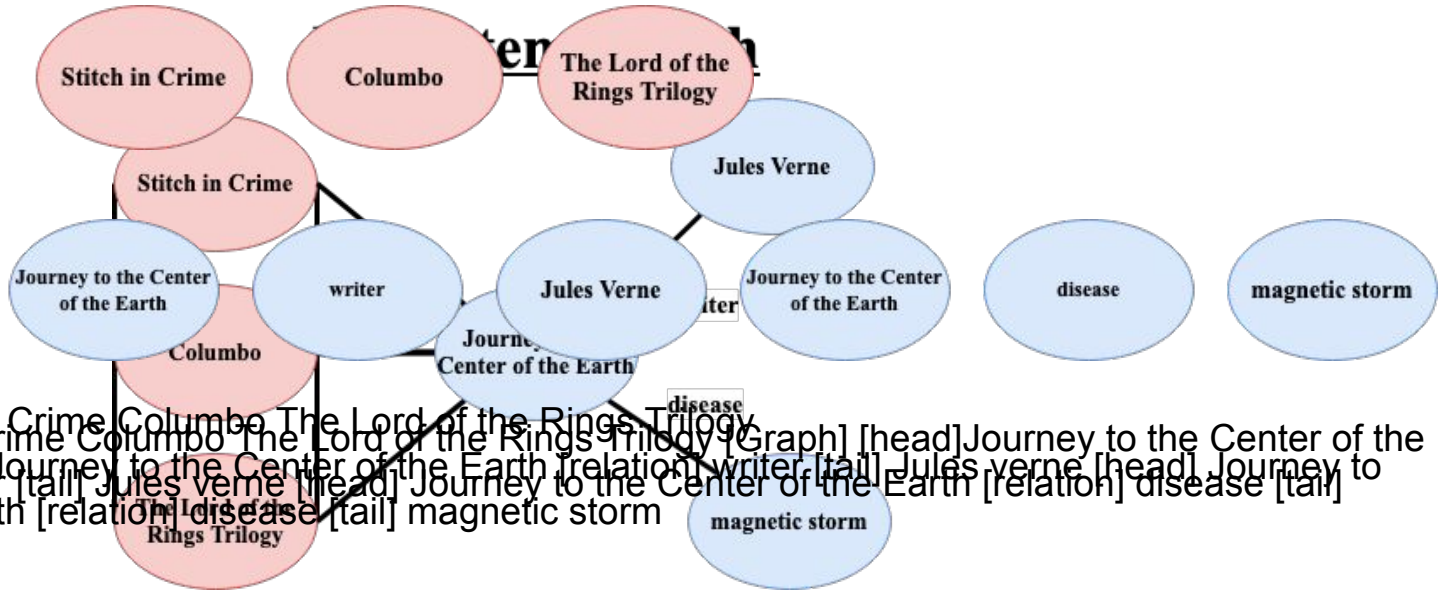


# Model (Input)

- **User  $u$ :** purchase history
- **Item  $v$ :** item KG graph

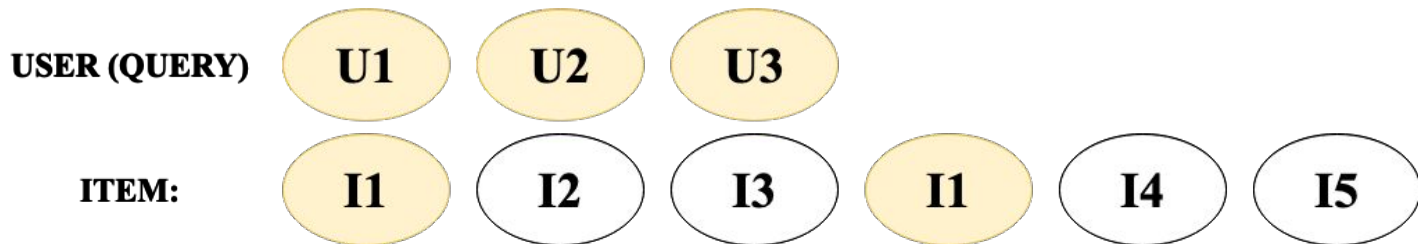
**USER (QUERY)**

**ITEM:**



User: [User] Stitch in Crime Columbus The Lord of the Rings Trilogy  
 X0: [User] Stitch in Crime Columbus The Lord of the Rings Trilogy [Graph] [head] Journey to the Center of the Earth [relation] writer [tail] Jules verne [head] Journey to the Center of the Earth [relation] writer [tail] Jules verne [head] Journey to the Center of the Earth [relation] disease [tail] magnetic storm

# Encoder Details



## Global Attention

$$\mathbf{X}_l = \text{Attn}(\mathbf{Q}, \mathbf{K}, \mathbf{V}) = \text{softmax}\left(\frac{\mathbf{Q}\mathbf{K}^\top}{\sqrt{d_k}}\right) \mathbf{V}$$

$$\mathbf{Q} = \mathbf{X}_{l-1} \mathbf{W}_l^Q, \mathbf{K} = \mathbf{X}_{l-1} \mathbf{W}_l^K,$$

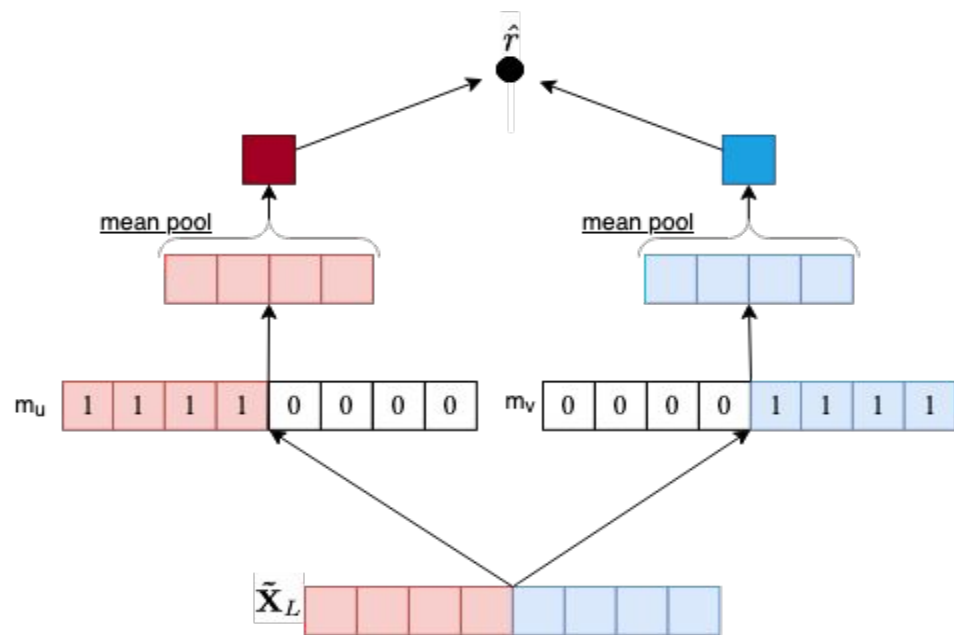
$$\mathbf{V} = \mathbf{X}_{l-1} \mathbf{W}_l^V$$

## User-Item Attention

$$\tilde{\mathbf{X}}_l^g = \text{Attn}_M(Q, K, V) = \text{softmax}\left(\frac{QK^\top}{\sqrt{d_k}} + M_g\right) V.$$

	U1	U2	U3	I1	I2	I3	I4	I5
U1								
U2								
U3								
I1								
I2								
I3								
I4								
I5								

# Model (Rating Prediction)



$$\tilde{\mathbf{x}}_u = \text{pool}_{\text{mean}}(\tilde{\mathbf{X}}_L + \mathbf{m}_u) \mathbf{W}^u$$

$$\tilde{\mathbf{x}}_v = \text{pool}_{\text{mean}}(\tilde{\mathbf{X}}_L + \mathbf{m}_v) \mathbf{W}^v$$

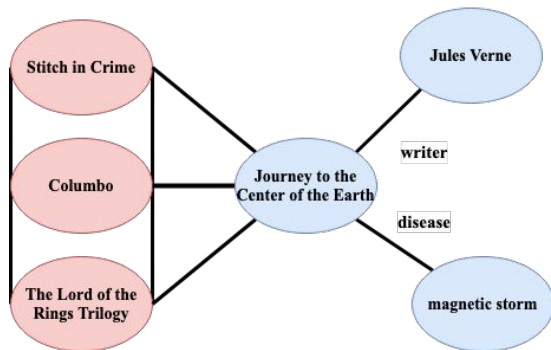
$$\hat{r}_{u,v} = \text{dot}(\tilde{\mathbf{x}}_u, \tilde{\mathbf{x}}_v),$$

# Joint Learning

Recommendation and Explanation

$$\mathcal{L} = \lambda_r \mathcal{L}_r + \lambda_e \mathcal{L}_e$$

## User-Item Graph



### Ground Truth Explanation (Description)

Jules Verne's Professor Lindenbrook leads a trip through monsters, mushrooms, and a magnetic storm.

**Rating: 4.0**

### Generated Explanation (Personalized)

A scientist (**Jules Verne**) **investigates** a magnetic storm that sends a **mysterious beam of light** from earth to the center of the earth.

**Rating: 4.2**

Mean Square Error (MSE):

$$\mathcal{L}_r = \frac{1}{|\mathcal{U}||\mathcal{I}|} \sum_{u \in \mathcal{U} \wedge v \in \mathcal{I}} (r_{u,v} - \hat{r}_{u,v})^2$$

Negative Log-Likelihood (NLL)

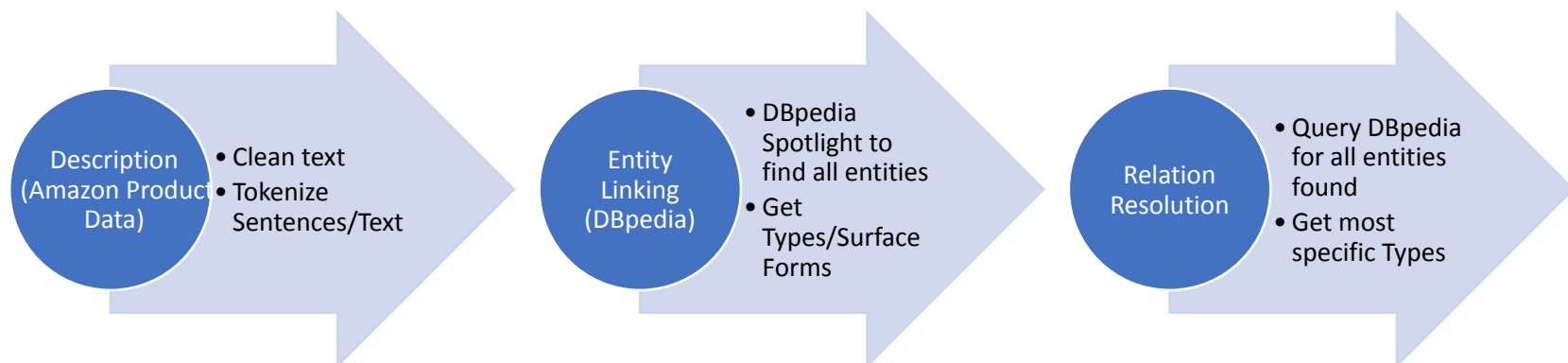
$$\mathcal{L}_e = \frac{1}{|\mathcal{U}||\mathcal{I}|} \sum_{u \in \mathcal{U} \wedge v \in \mathcal{I}} \frac{1}{|E_{u,v}|} \sum_{t=1}^{|E_{u,v}|} -\log p_t^{e_t}$$

$$\text{MSE: } (4 - 4.2)^2 = 0.04$$

$$\text{NLL: } -\log(\text{Jules}) = -\log(0.60) = 0.30$$



# Review Datasets Augmented with KGs



Name	#Users	#Items	#Interactions	KG	#Es	#Rs	#Triples	EC	Desc.	Words/Sample
<i>Book KG-Exp</i>	396,114	95,733	2,318,107	Yes	195,110	392	745,699	71.45	Yes	99.96
<i>Movie KG-Exp</i>	131,375	18,107	788,957	Yes	59,036	363	146,772	71.32	Yes	96.35

# Evaluation

## Explanation Performance

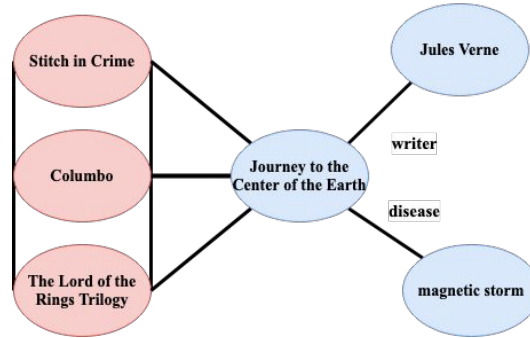
- NLG Metrics
  - BLEU
  - ROGUE
- Unique Sentence Ratio (USR)
- Entity Coverage (EC):

$$\frac{\#KG \text{ entities found in output}}{\#KG \text{ entities}}$$

## Recommendation Performance

- Root Mean Square Error (R)
- Mean Absolute Error (M)

## User-Item Graph



### Ground Truth Explanation (Description)

Jules Verne's Professor Lindenbrook leads a trip through monsters, mushrooms, and a magnetic storm.

**Rating: 4.0**

### Generated Explanation (Personalized)

A scientist (Jules Verne) investigates a magnetic storm that sends a mysterious beam of light from earth to the center of the earth.

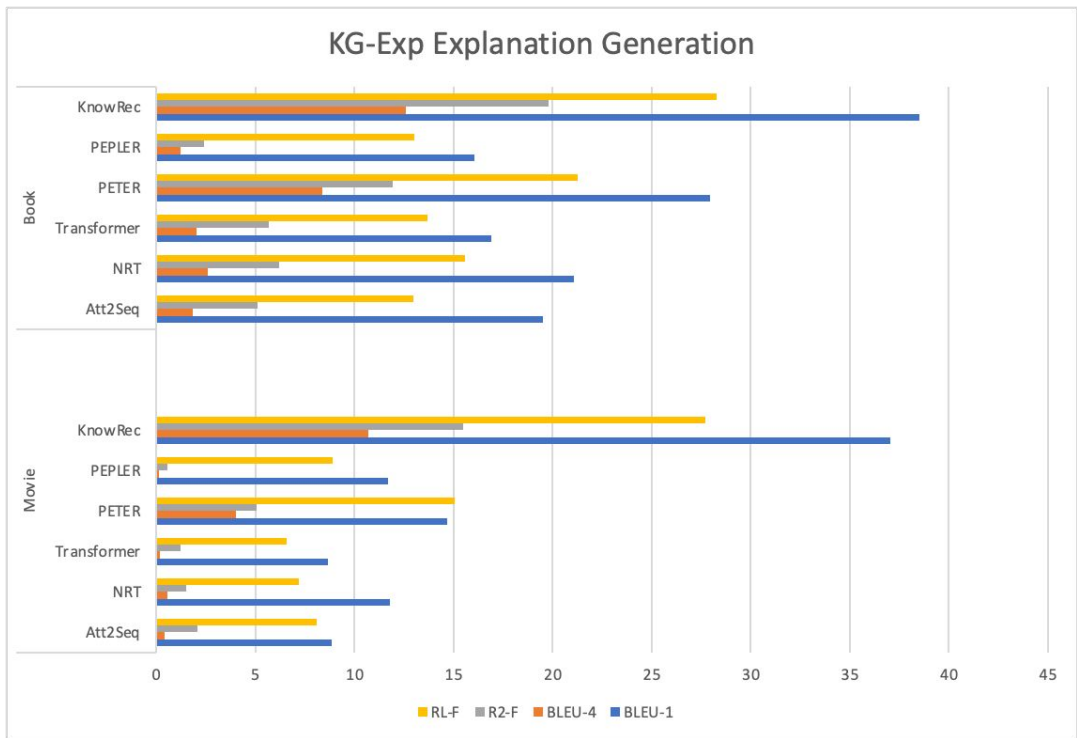
**Rating: 4.2**

#KG entities found in output = 2

#KG entities = 3

$$EC = \frac{2}{3}$$

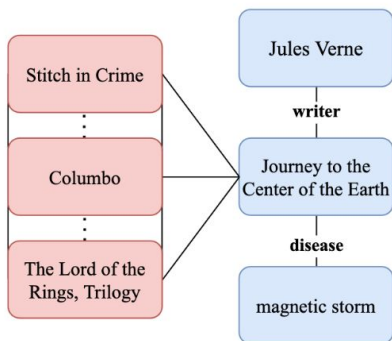
# Results



- KnowRec consistently outperforms all baselines
- Baselines inadequate on longer, more objective explanations
- KnowRec produces entity-centric tokens
- KnowRec produces more diverse/personalized sentences
- *Similar trend results in few-shot setting*

# Case Study (Same Item/Different User)

## Item Graph Representation

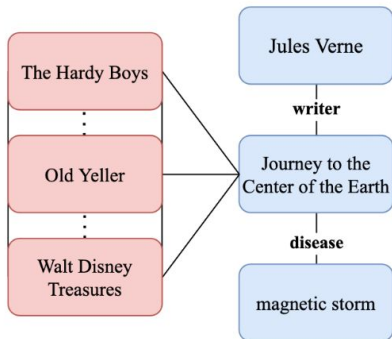


## Generated Explanation

a scientist (**jules verne**) investigates a **magnetic storm** that sends a mysterious beam of light from earth to the center of earth.

## Ground Truth Explanation

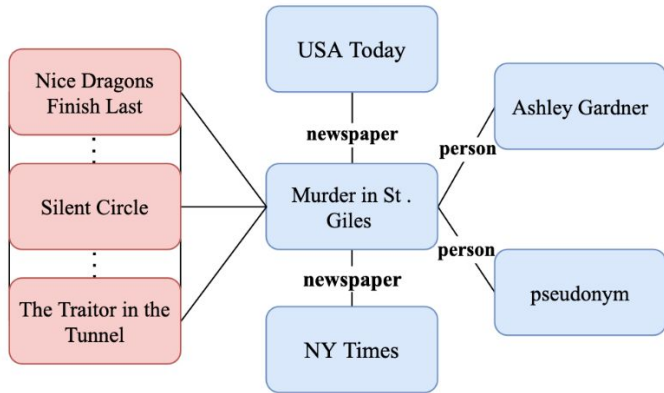
jules verne's professor lindenbrook leads a trip through monsters, mushrooms and a magnetic storm.



a group of scientists, inspired by **jules verne's classic novel**, take a trip to the **magnetic storm** at **the center of the earth.**

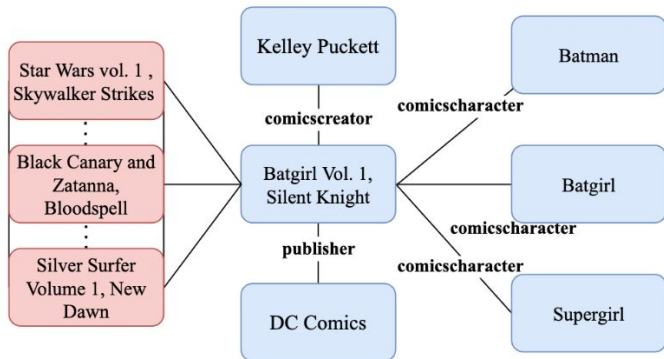
jules verne's professor lindenbrook leads a trip through monsters, mushrooms and a magnetic storm.

# Example Output (Personalized Information)



**ashley gardner** is a **ny times** and **usa today** bestselling author. under the **pseudonym** **jennifer ashley**, she has collectively written more than **70** mystery and historical novels.

usa today bestselling author ashley gardner is pseudonym for ny times bestselling author jennifer ashley.



**kelley puckett** is an american comic book writer best known for his work on **batman** for **dc comics**. he is the author of numerous books for young readers, including **supergirl**, the ultimate guide to character development and **batgirl**, a guide to writing for comics, both published by image.

kelley puckett has been writing comics for far too long, by general consensus. he has worked on such series as batman adventures, batgirl and kinetic and supergirl for dc comics.

# Conclusion

- Novel user-item KG generative model
  - Previous work relies on sparse features
  - Solve item cold-start problem
    - New items
    - No Reviews
- Two datasets to evaluate objective setting for explanation and recommendation
- Outperform SOTA NL explanation recommendation systems

*KnowRec paves way for research focused on detailed, objective, and personal explanations in the realm of explainable recommendation systems.*

Code: <https://github.com/boschresearch/KnowRec>