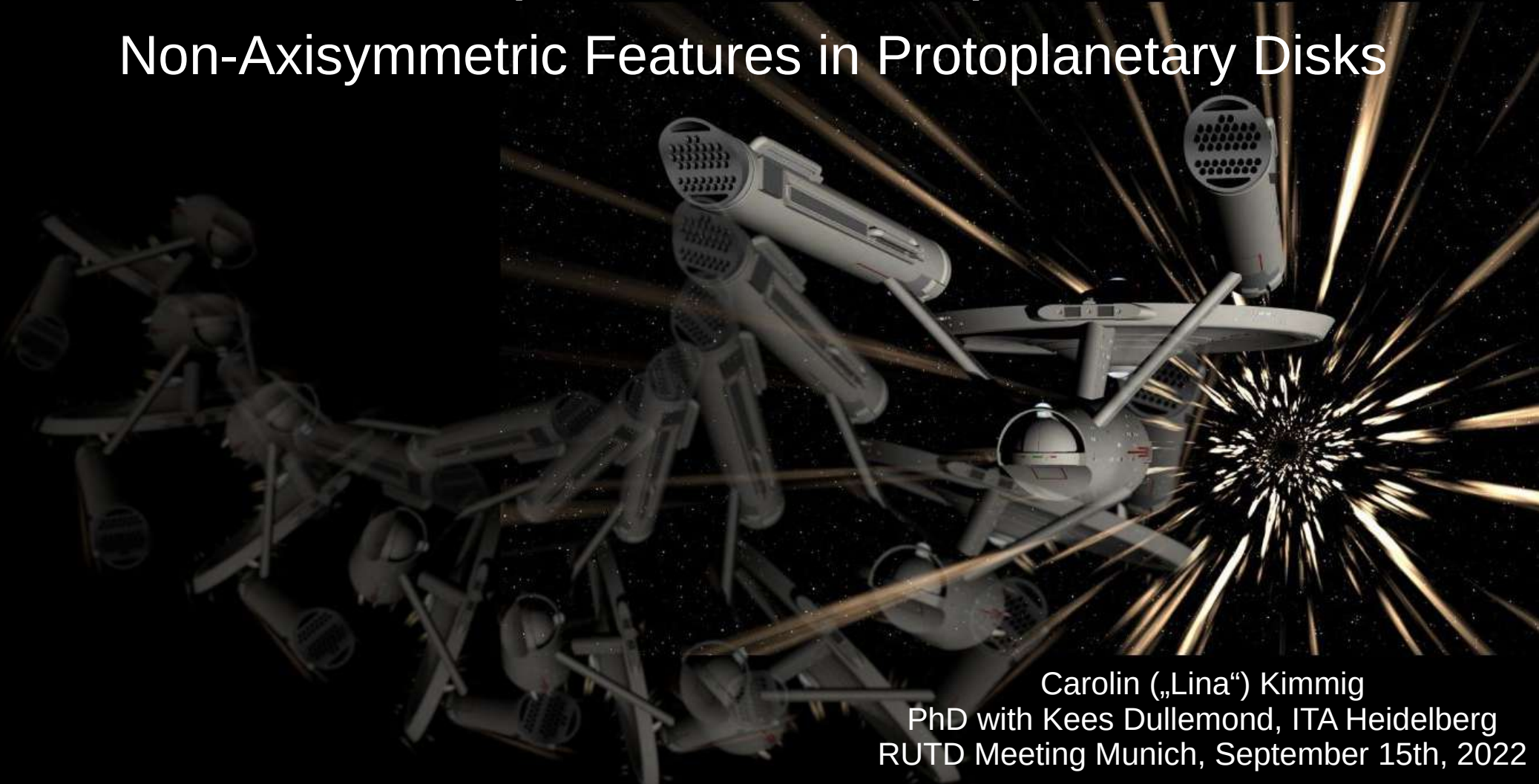


# Spirals and Warps

## Non-Axisymmetric Features in Protoplanetary Disks



Carolin („Lina“) Kimmig

PhD with Kees Dullemond, ITA Heidelberg  
RUTD Meeting Munich, September 15th, 2022

# Structure

1. Motivation: asymmetrical features

2. Warped disks

- Formation
- 1D model
- Evolution

3. Current PhD project(s)



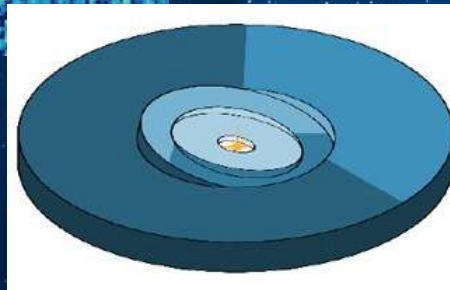
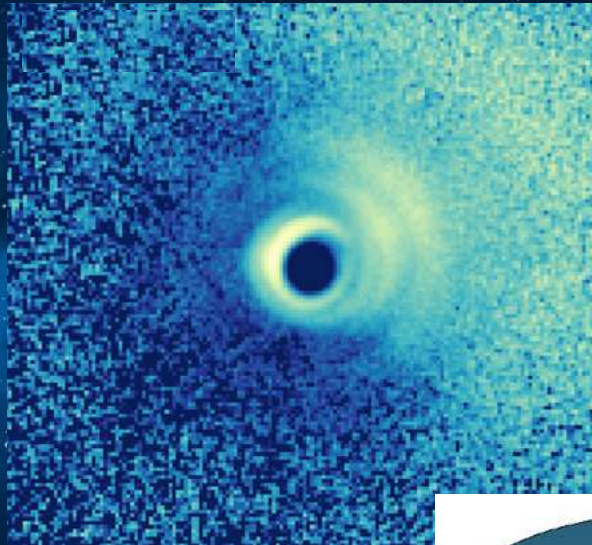
# Asymmetrical features in protoplanetary disks

## Structure

- 1 Motivation
- 2 Warped disks
  - Formation
  - 1D model
  - Evolution
- 3 PhD project(s)
- 4 Summary

HD 139614

Muro-Arena et al. 2020

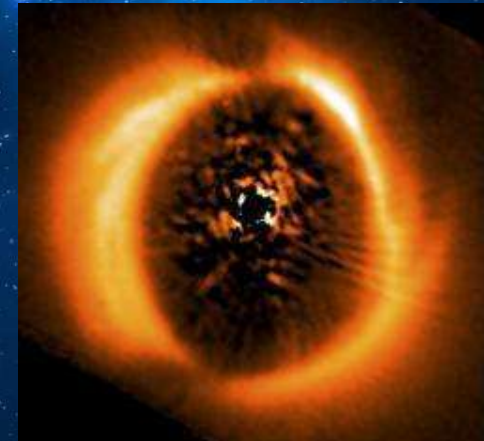


HD 135344B

ESO, T. Stolker et al.

HD 142527

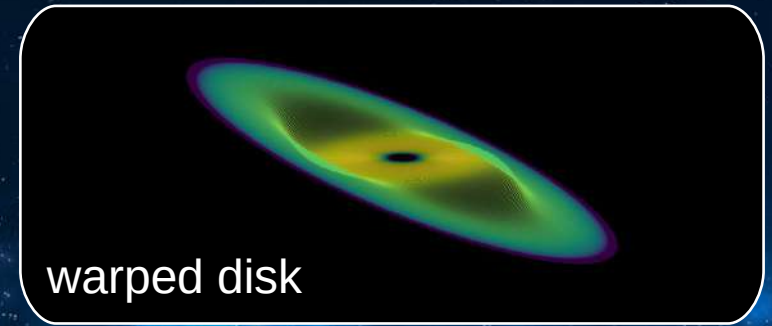
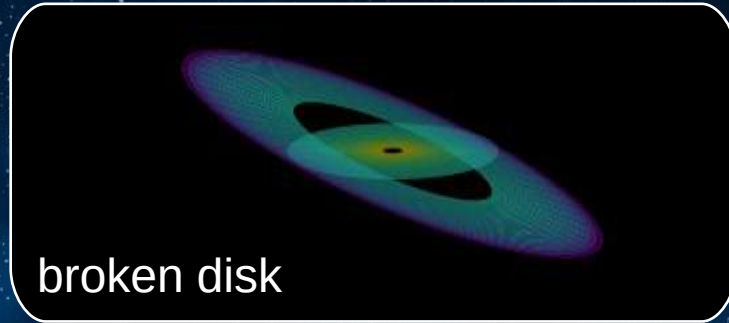
Marino et al. 2015



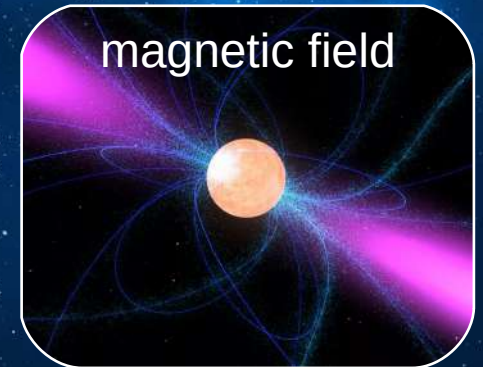
# Misaligned disks – formation

## Structure

- 1 Motivation
- 2 Warped disks
  - Formation
  - 1D model
  - Evolution
- 3 PhD project(s)
- 4 Summary



misalignment is the key!





# How does a warped disk evolve?

## Structure

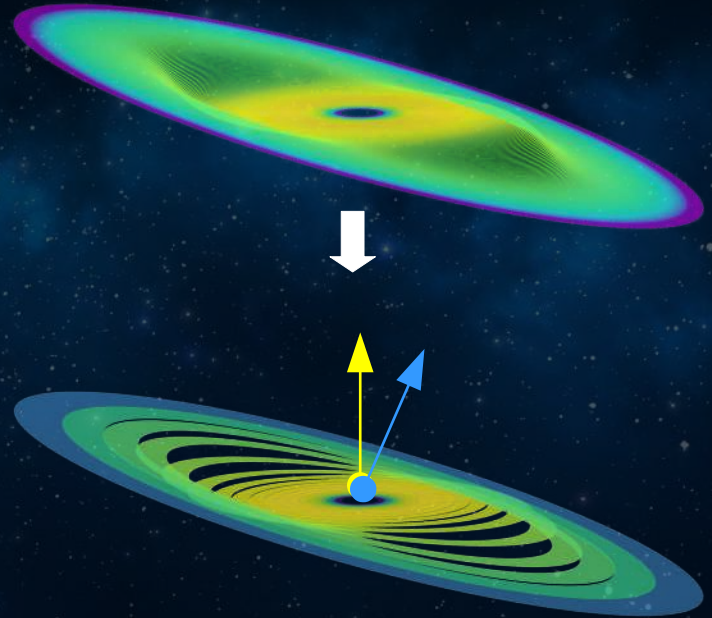
- 1 Motivation
- 2 Warped disks
  - Formation
  - 1D model
  - Evolution
- 3 PhD project(s)
- 4 Summary



1 dimension for  
a 3D object  
???

## 1-dimensional model

break up the disk into annuli



# How does a warped disk evolve?

## Structure

- 1 Motivation
- 2 Warped disks
  - Formation
  - 1D model
  - Evolution
- 3 PhD project(s)
- 4 Summary



1 dimension for  
a 3D object  
???

## 1-dimensional model

dwarpy

disk warps in python



other ring codes by  
J. Pringle,  
R. Nealon,  
D. Price,  
G. Ogilvie...

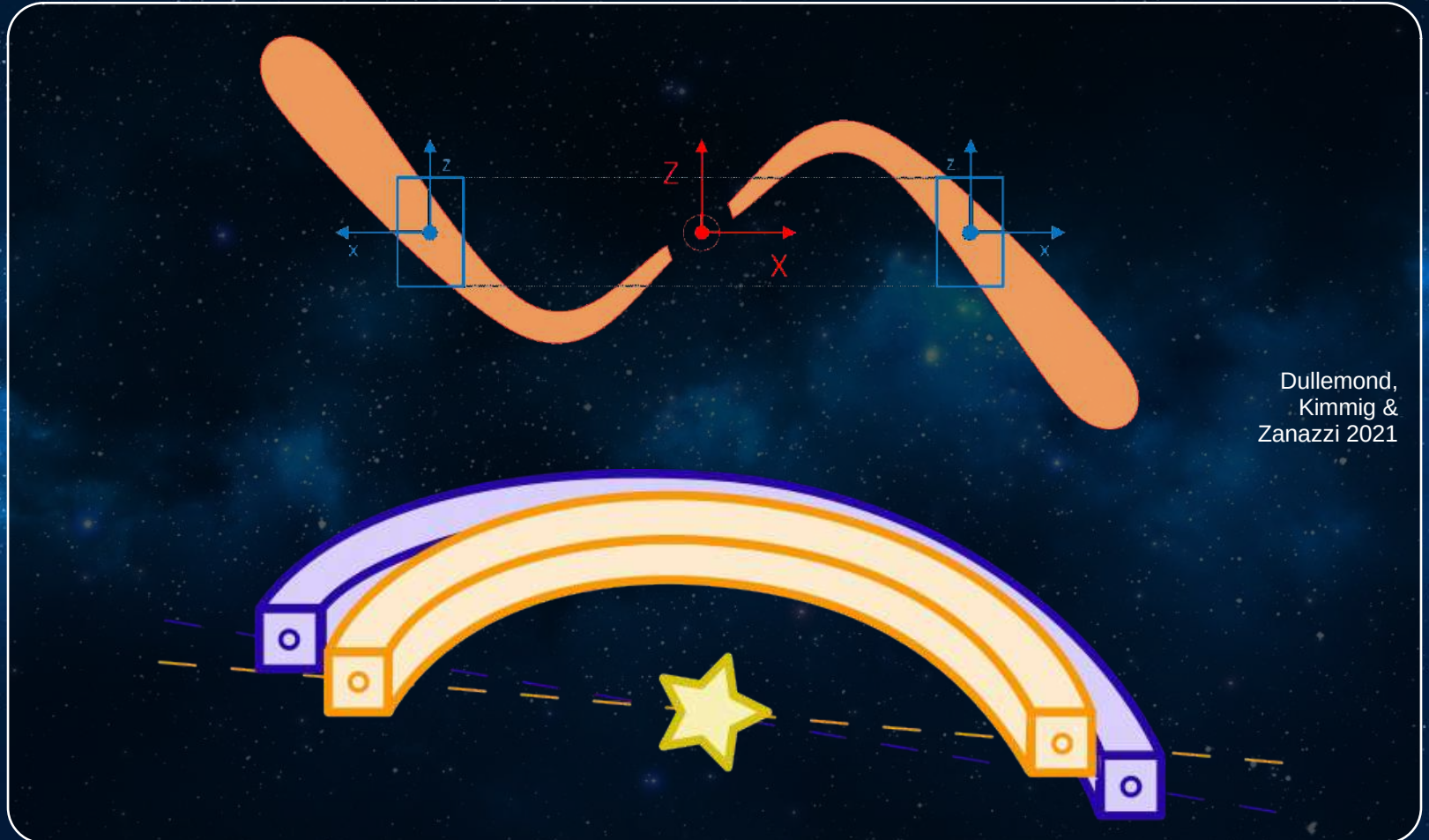
Image Credit: HourglassHero



# Why does a warped disk evolve?

## Structure

- 1 Motivation
- 2 Warped disks
  - Formation
  - 1D model
  - Evolution
- 3 PhD project(s)
- 4 Summary

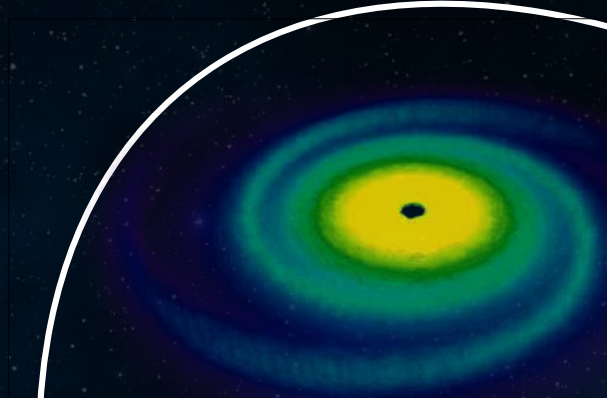


Dullemond,  
Kimmig &  
Zanazzi 2021

# Inclined flyby scenario – FARGO3D

## Structure

- 1 Motivation
- 2 Warped disks
  - Formation
  - 1D model
  - Evolution
- 3 PhD project(s)
- 4 Summary



## Spirals and warps caused by flyby

- How long-lived are spirals?
- How strong is the warp?
  - Rebecca Nealon et al. 2020 (SPH)
- Investigate the kinematics

collab. with Philipp Weber (University of Santiago, Chile)



# Summary

## Structure

1 Motivation

2 Warped disks

- Formation
- 1D model
- Evolution

3 PhD project(s)

4 Summary

- Warped disks are important in the investigation of **non-axisymmetric** features in PPDs
- Dwarpy can be a **powerful tool** to simulate warped disks
- Using RADMC-3D, we are planning to investigate the **shadow evolution** and **kinematics** of warped disks
- We are modeling an inclined **flyby scenario** using FARGO3D



Thank you!

Questions?

contact me anytime  
[c.kimmig@stud.uni-heidelberg.de](mailto:c.kimmig@stud.uni-heidelberg.de)

## Structure

- 1 Motivation
- 2 Warped disks
  - Formation
  - 1D model
  - Evolution
- 3 PhD project(s)
- 4 Summary