

Pop-III feedback on Pop-II  
solving the Cosmic Lithium Problem

***Dorottya Szécsi***

Associate Professor & OPUS group leader  
*Nicolaus Copernicus University*

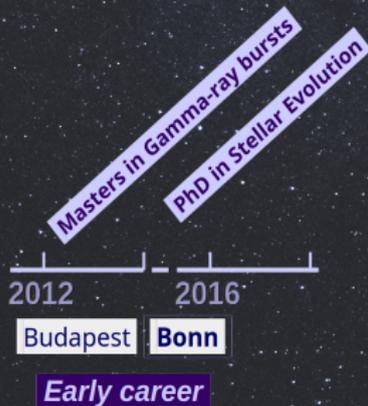
Kiel, 4th April 2025



*Dr. rer. nat. habil. Dorottya Szécsi, prof. UMK*

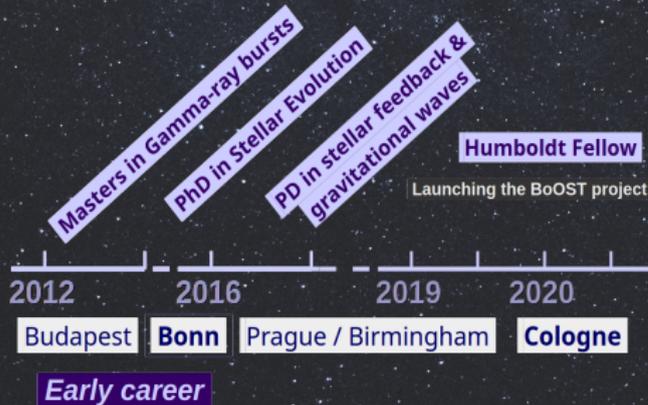
Associate Prof. &

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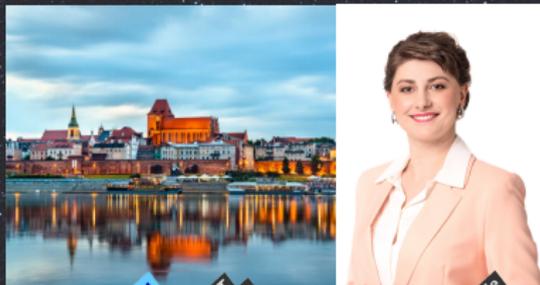
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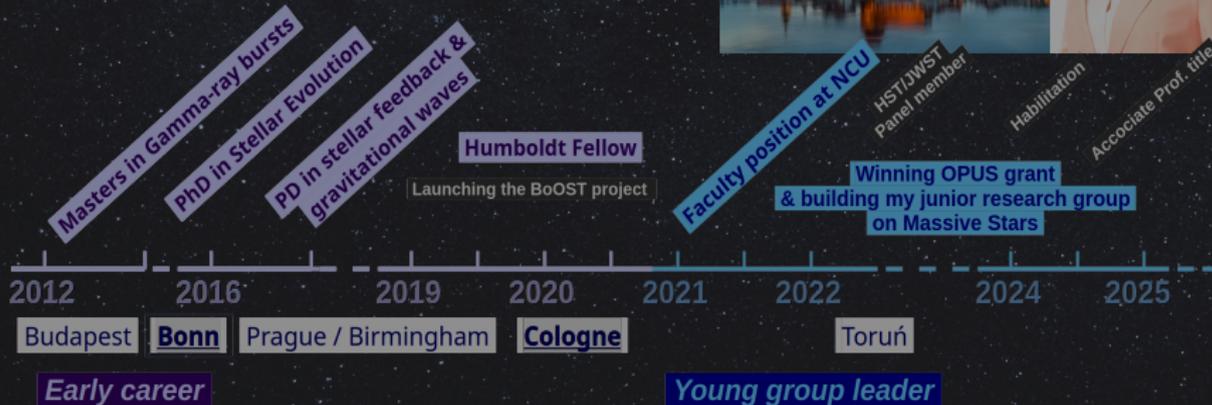
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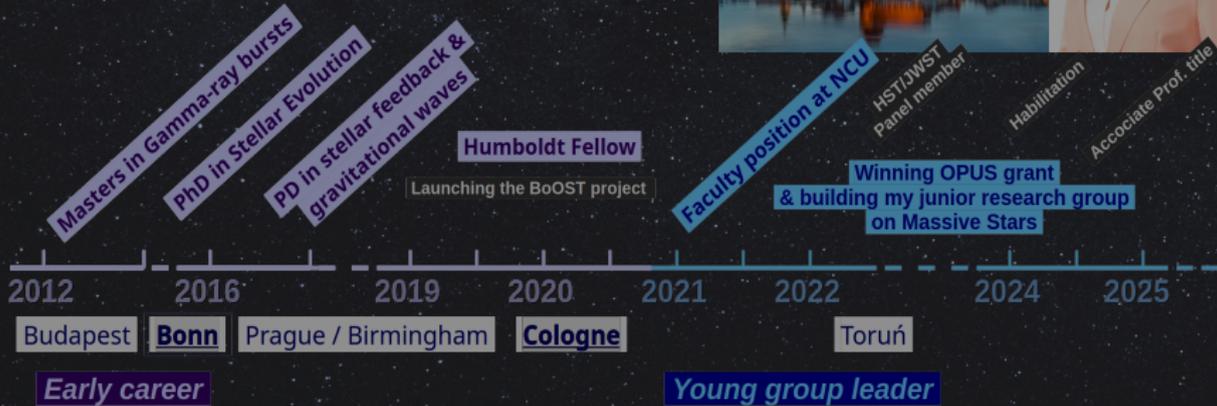
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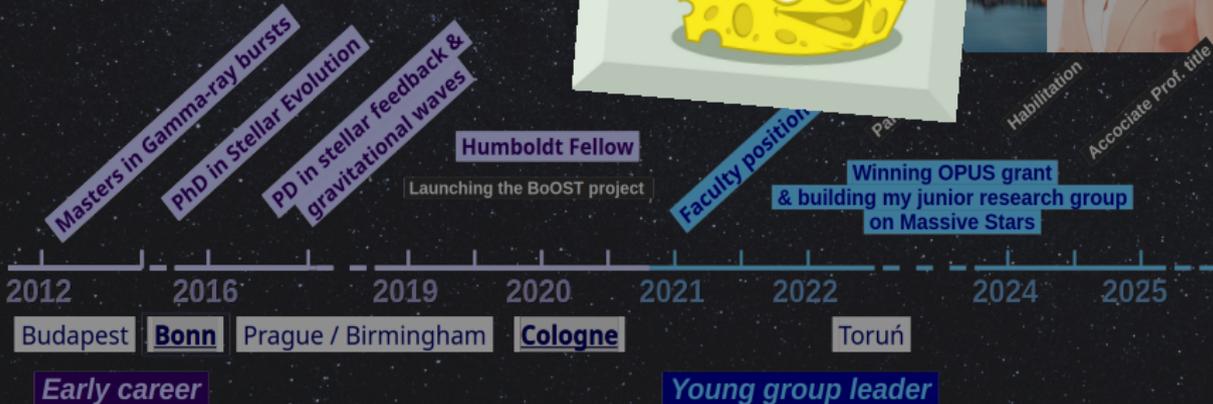
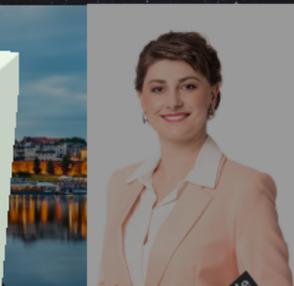
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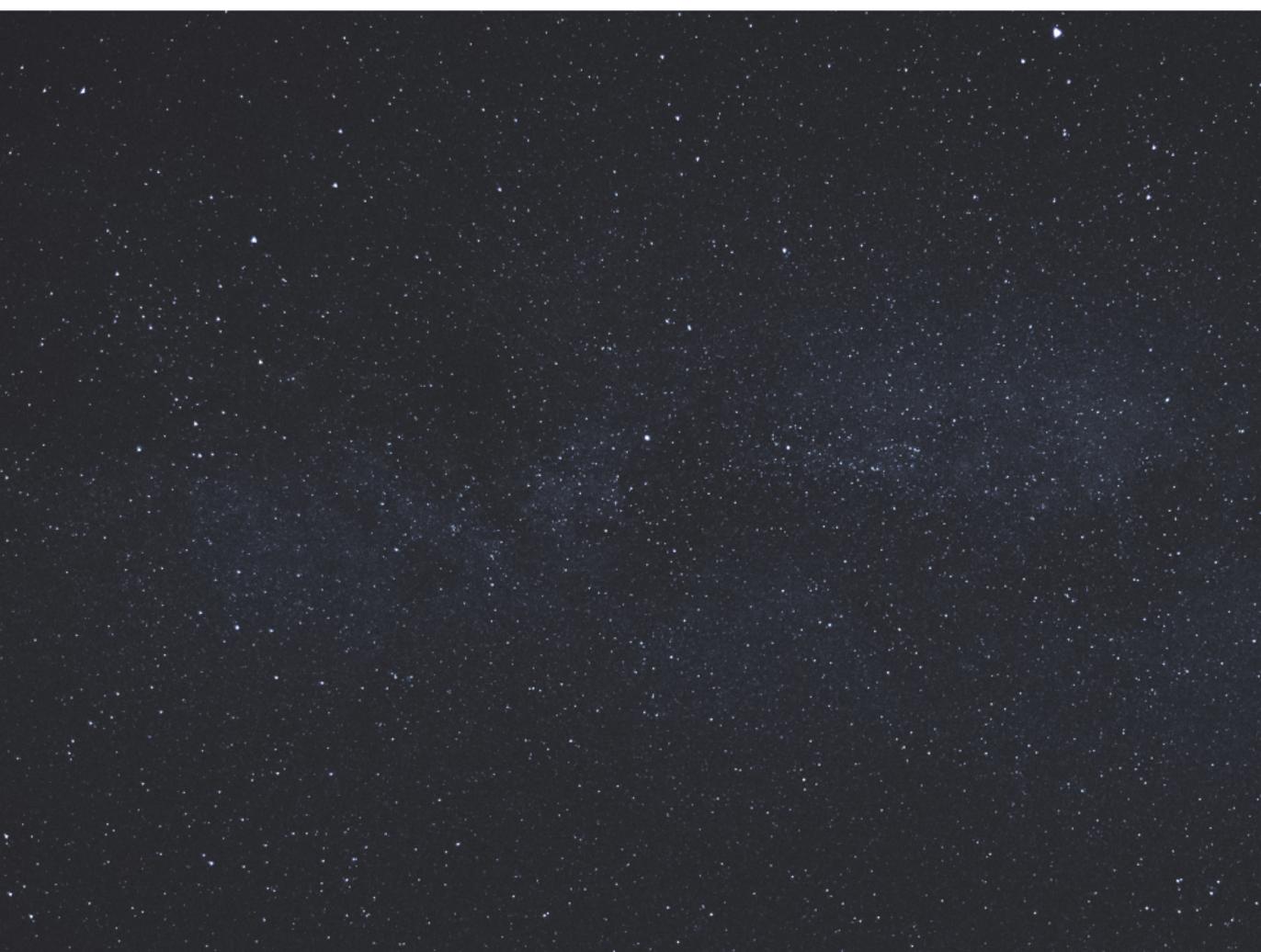


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Dwarf galaxies



Gravitational waves



High-redshift Univ.



Gamma-ray bursts



Globular clusters



## Dwarf galaxies

**Low metallicity ( $Z \sim 10^{-3} - 10^{-2} Z_{\odot}$ )**

- Active star formation  $\rightarrow$  massive stars (that often explode)



**High-redshift Univ.**

- First stars, earliest time
- Unsupervised
- gravitational waves
- metal-poor massive stars

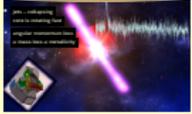
**Gravitational waves**

- mass loss  $\rightarrow$  variability
- many massive black holes in LIGO



**Gamma-ray bursts**

- observed
- observed
- observed
- observed



**Globular clusters**

- metal-poor
- low-mass stars
- gravitational
- massive stars



## Gravitational waves

**High-redshift Univ.**

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## High-redshift Univ.

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# Metal-poor massive stars

## Gamma-ray bursts

**Gravitational waves**

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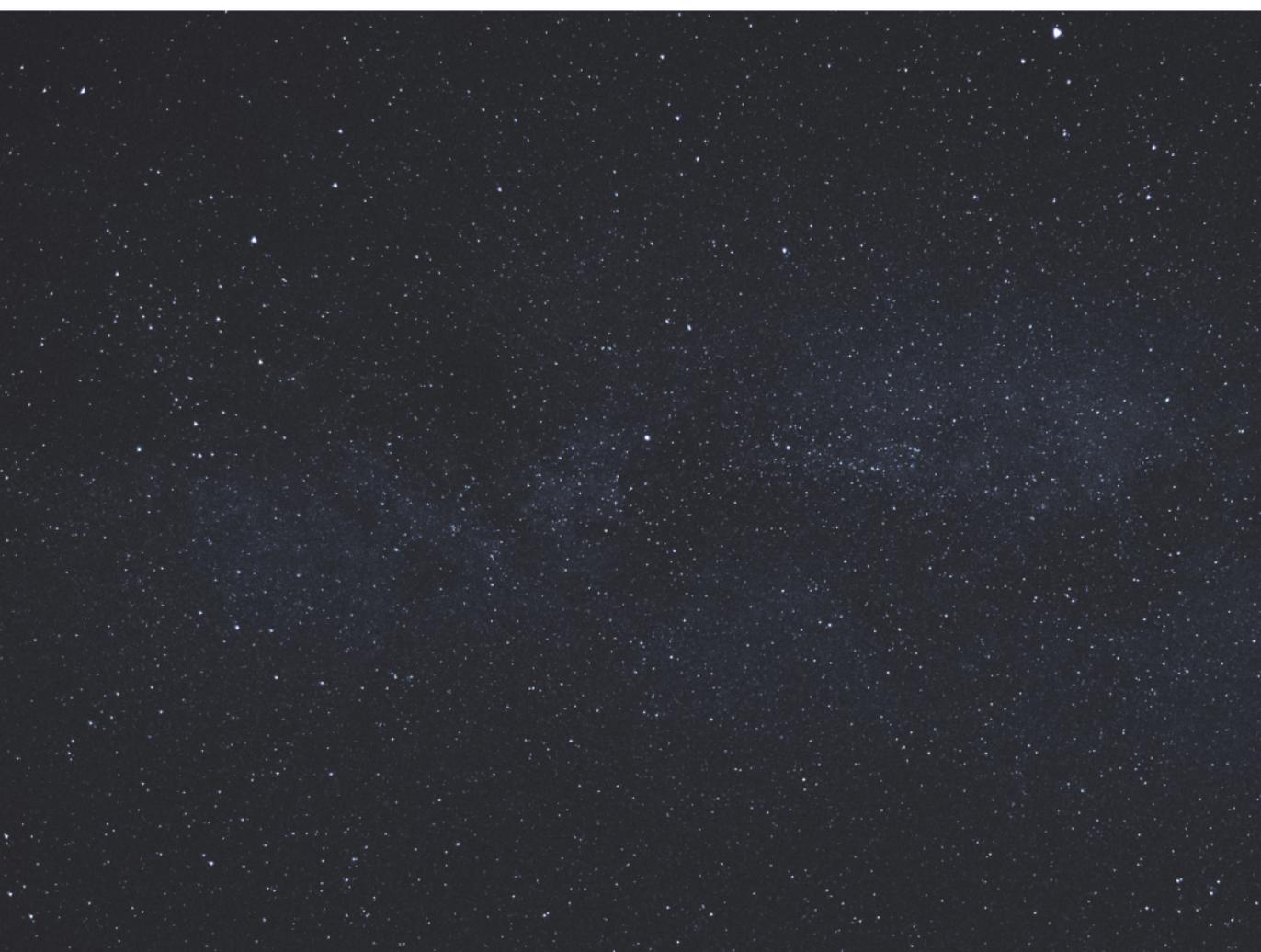


## Globular clusters

**High-redshift Univ.**

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What is a star?

What is a star?



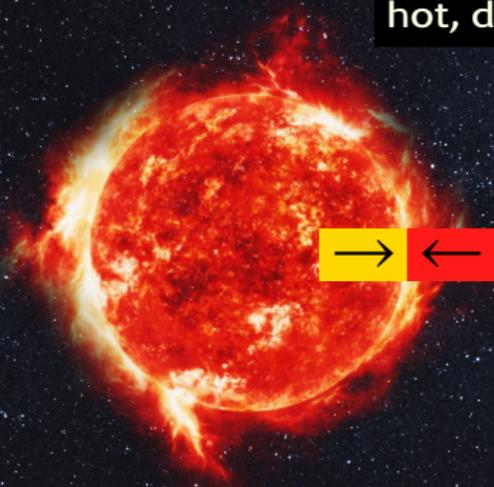
What is a star?



hot, dense plazma

# What is a star?

hot, dense plasma

A central image of a glowing orange and red star with a turbulent, fiery surface. The star is set against a dark background filled with numerous small white stars. Two arrows are positioned horizontally across the middle of the star: a yellow arrow pointing to the right and a red arrow pointing to the left, representing opposing forces.

equilibrium:

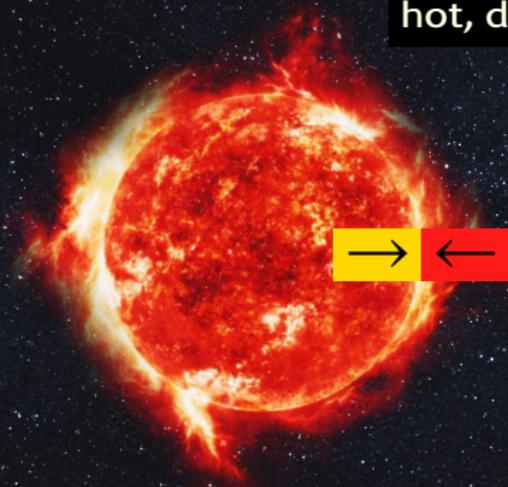
pressure gradient

gravity

# What is a star?

surface?

hot, dense plazma



equilibrium:

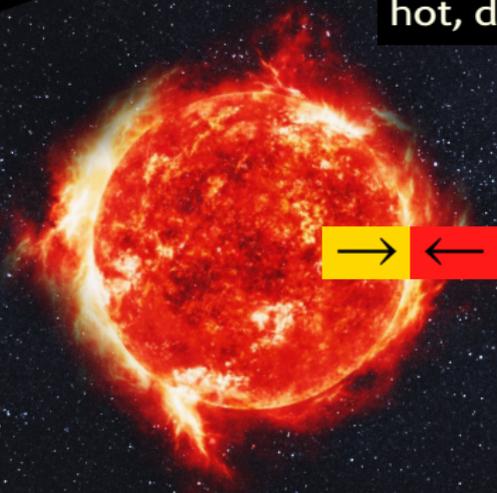
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surface?  
→ photons escape  
"photosphere"

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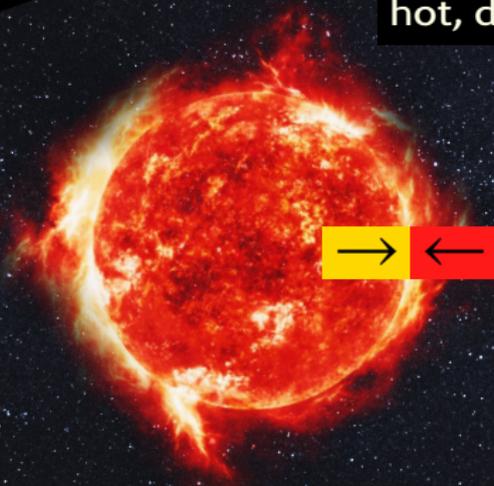
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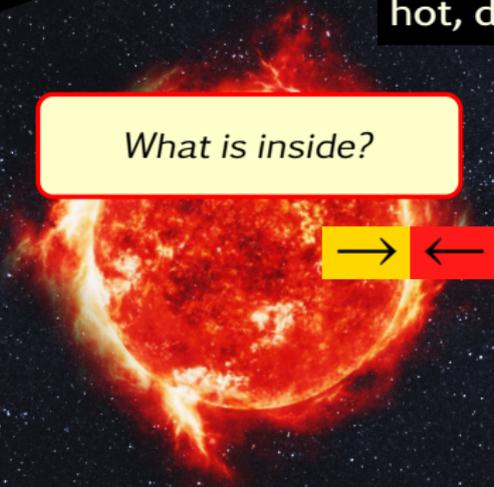
What is inside?



equilibrium:

pressure gradient

gravity



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What is inside?

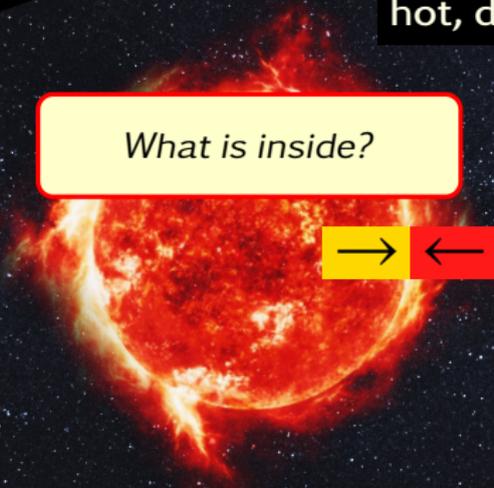


equilibrium:

pressure gradient

gravity

theoretical  
modelling  
of the stellar  
structure



# Theoretical modelling of the stellar structure

$$\frac{\partial r}{\partial m_r} = \frac{1}{4\pi r^2 \rho} \quad \text{equation of definition of mass} \quad (1)$$

$$\frac{\partial P}{\partial m_r} = -\frac{Gm_r}{4\pi r^4} \quad \text{equation of hydrostatic equilibrium} \quad (2)$$

$$\frac{\partial L_r}{\partial m_r} = \epsilon_{\text{pl}} - T \frac{\partial S}{\partial t} \quad \text{equation of energetic balance} \quad (3)$$

$$\frac{\partial T}{\partial m_r} = -\frac{Gm_r T}{4\pi r^4 P} \nabla \quad \text{equation of energy transport,} \quad (4)$$

# Theoretical modelling of the stellar structure

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# Theoretical modelling of the stellar structure

$$\frac{\partial r}{\partial m_r} = \frac{1}{4\pi r^2 \rho} \quad \text{equation (1) mass conservation} \quad (1)$$

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$$\frac{\partial T}{\partial m_r} = -\frac{Gm_r T}{4\pi r^4 P} \nabla \quad \text{equation (4) transport of energy} \quad (4)$$

Guilera+ 11

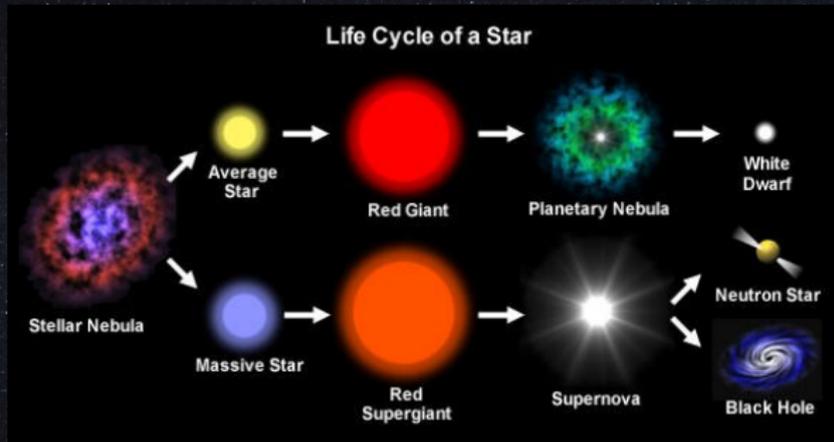
composition change due to nuclear burning:

$$\frac{\partial X_i}{\partial t} = \frac{A_i m_u}{\rho} (-\sum_{j,k} r_{i,j,k} + \sum_{k,l} r_{k,l,i}) \quad (5)$$

dsa  
'evolution'

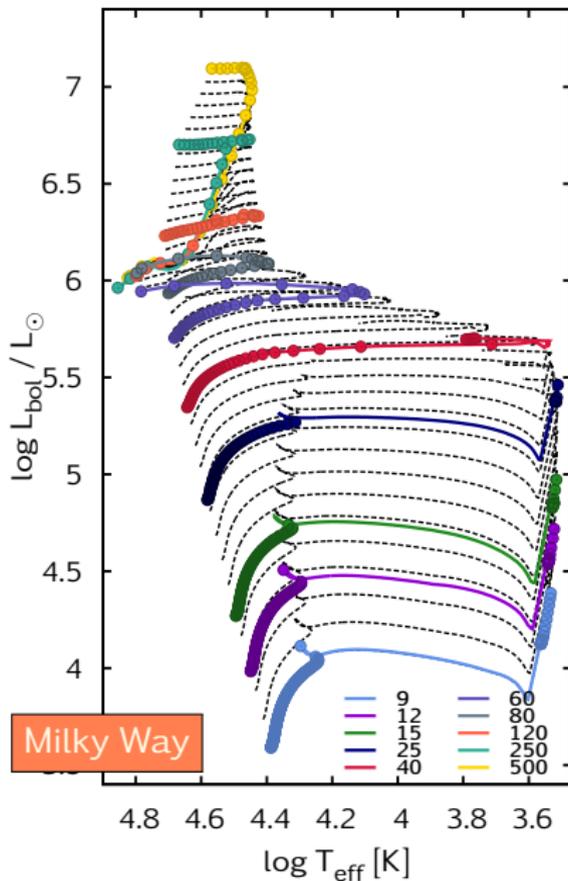
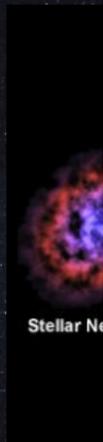
# Massive vs. low-mass stars

**Massive stars:  $\gtrsim 9$  times the Sun ( $\gtrsim 9 M_{\odot}$ )**



Massive vs

Massive



9  $M_{\odot}$

White Dwarf

Neutron Star

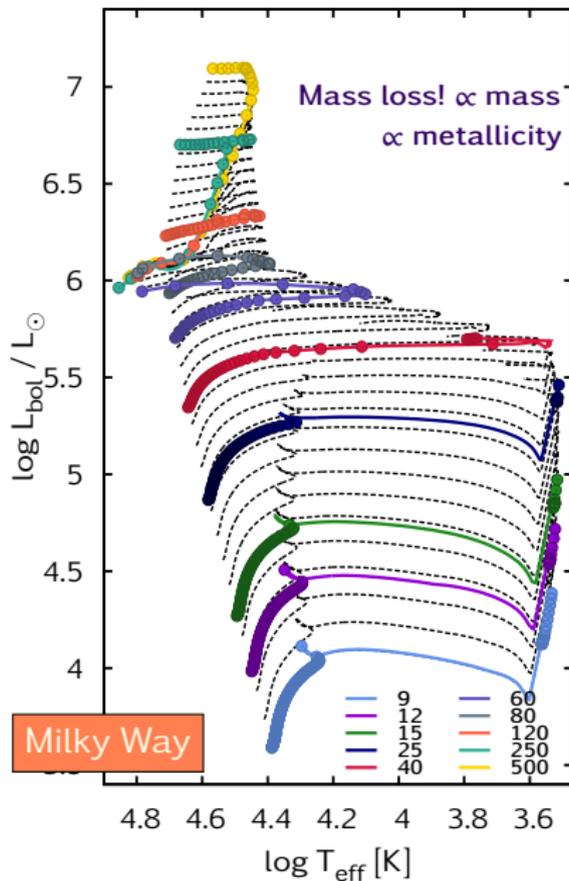
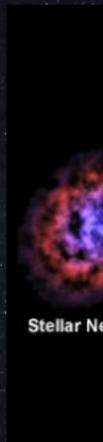
Black Hole

Brott+11 ( $< 60 M_{\odot}$ ),

Szécsi+22 ( $> 60 M_{\odot}$  & interpol.)

Massive vs

Massive



9  $M_{\odot}$

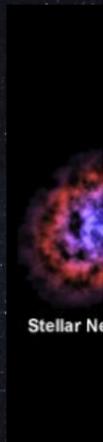


Brott+11 ( $< 60 M_{\odot}$ ),

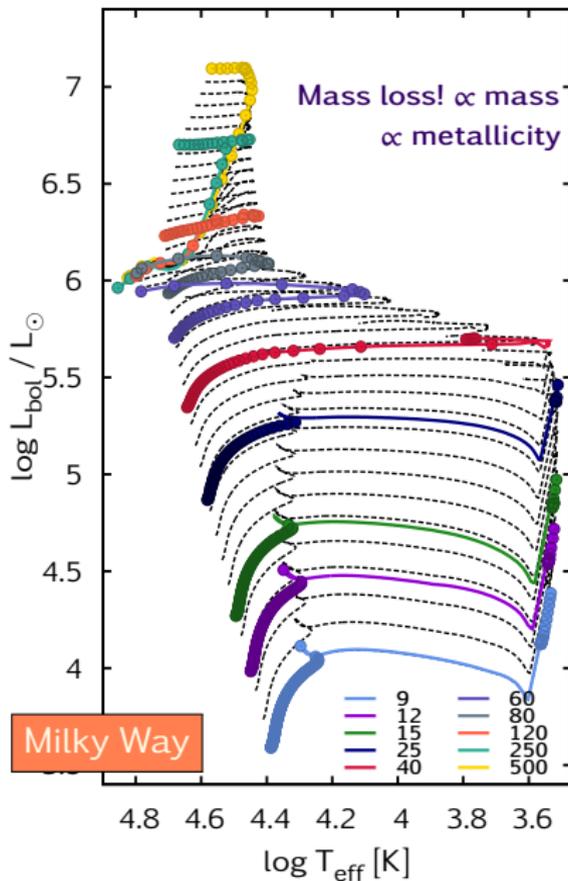
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# Massive vs

Massive



- Metallicity
- Rotation
- Binaricity



9  $M_{\odot}$

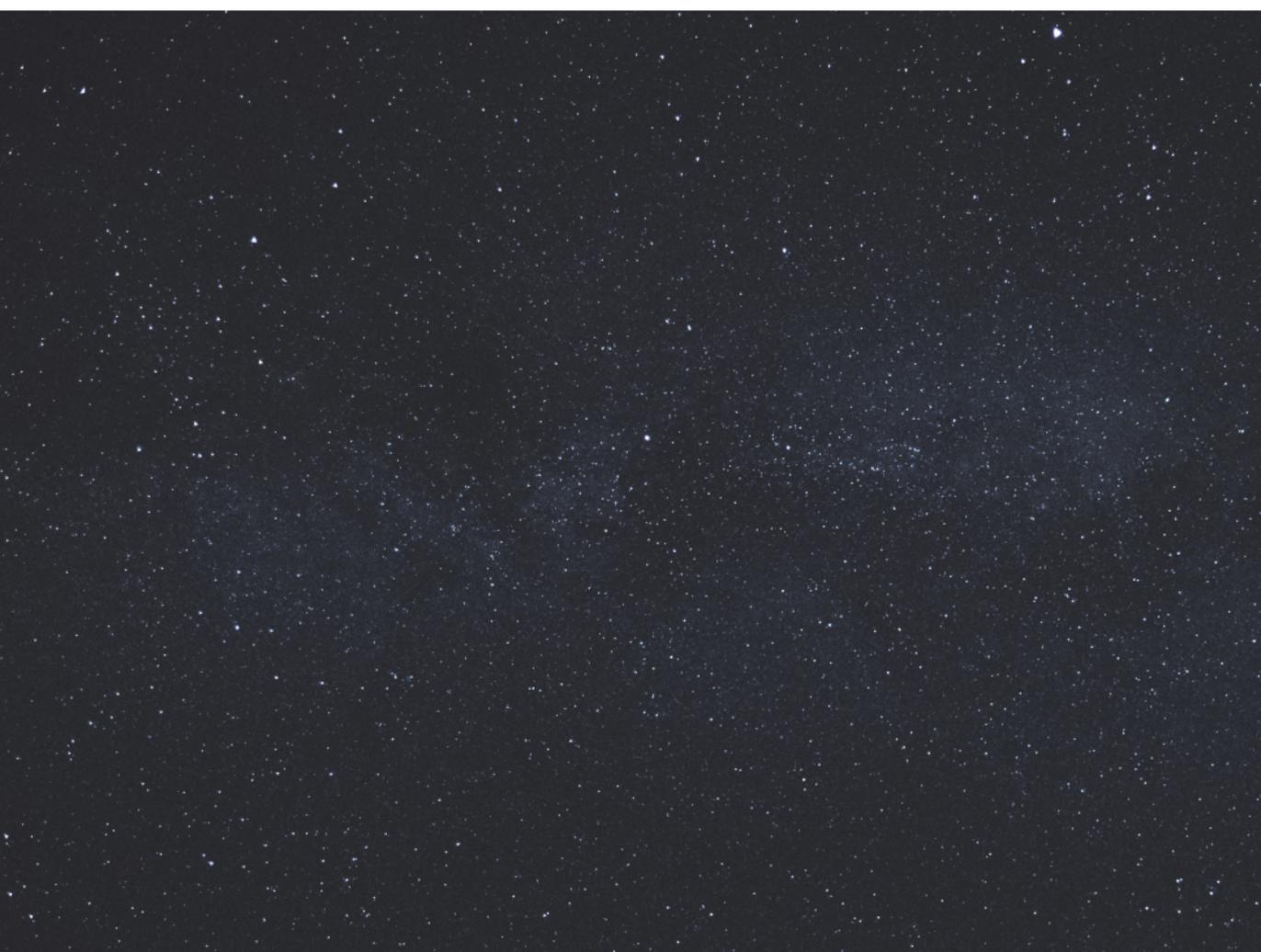
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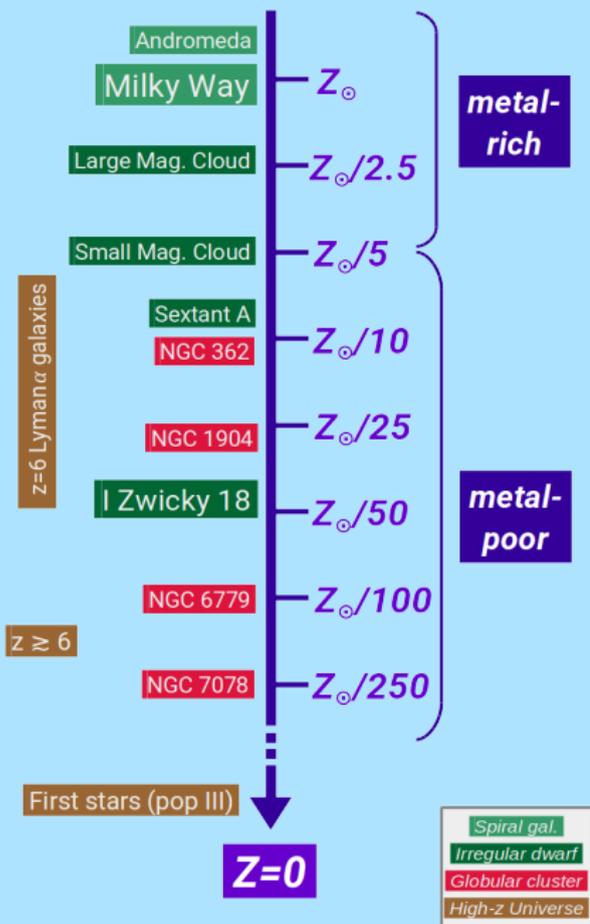
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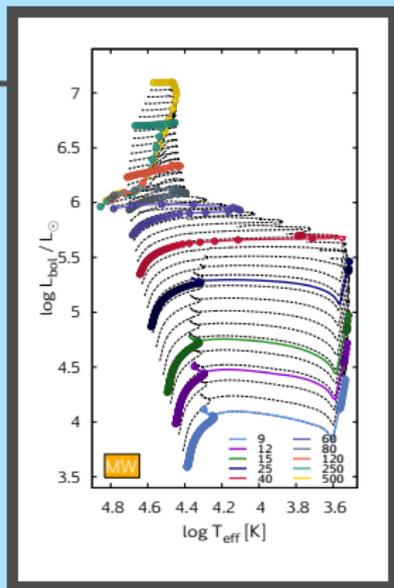
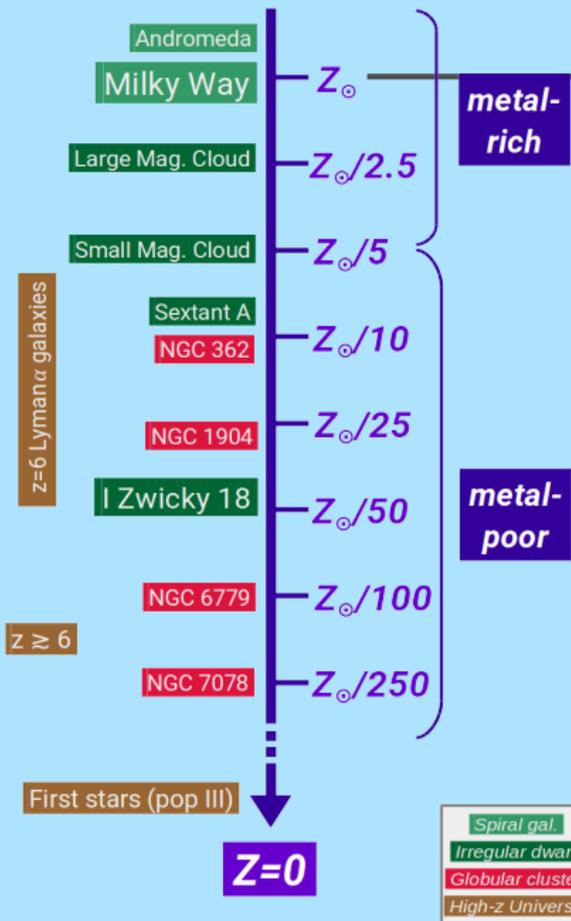


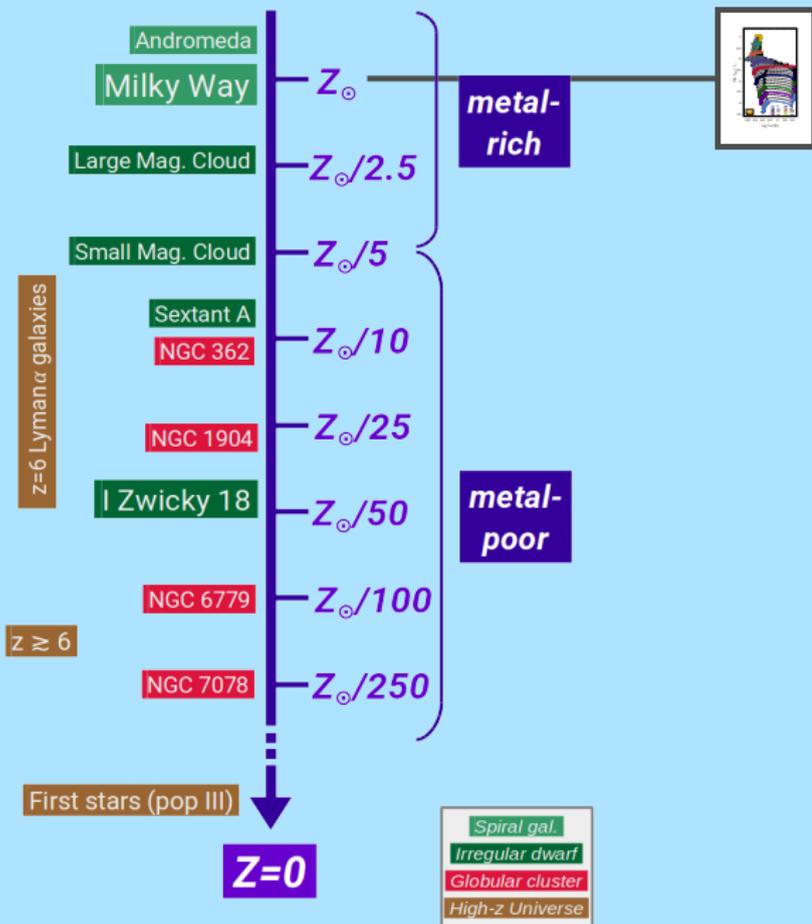


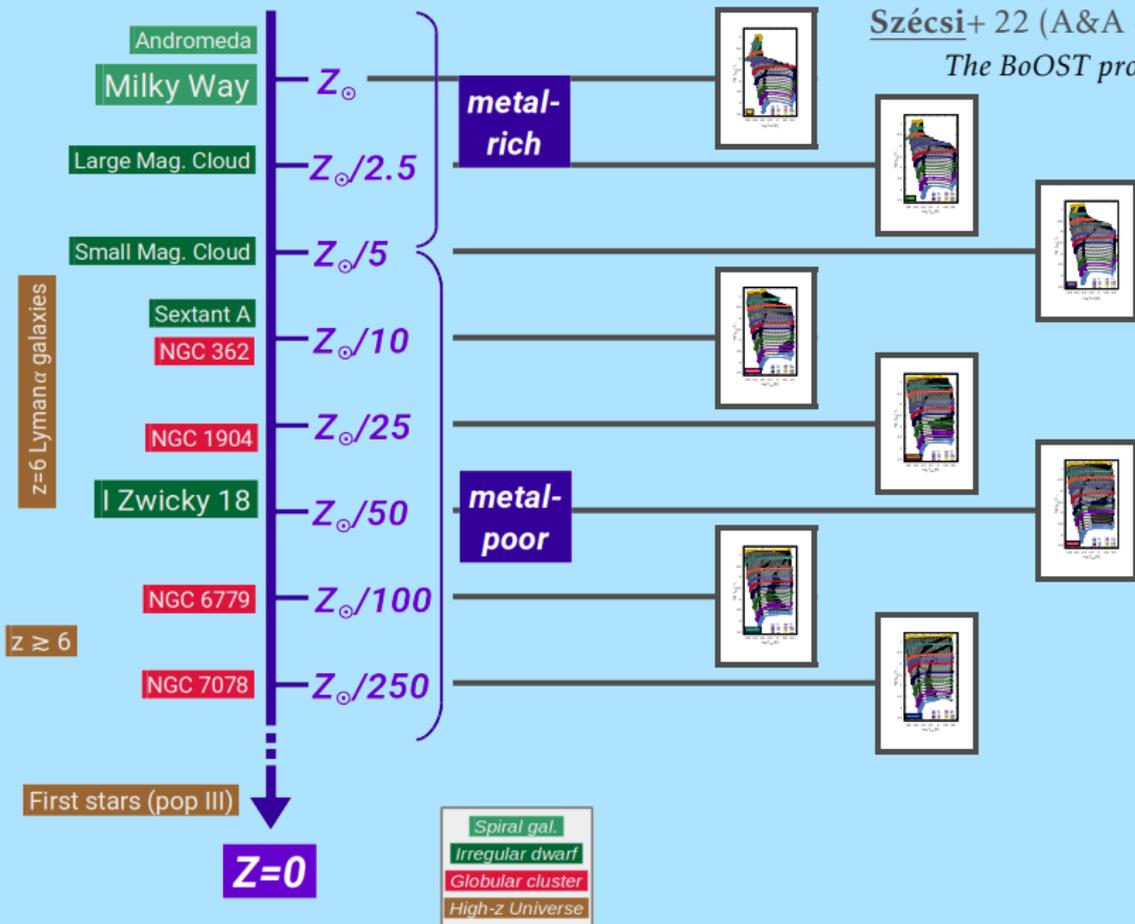


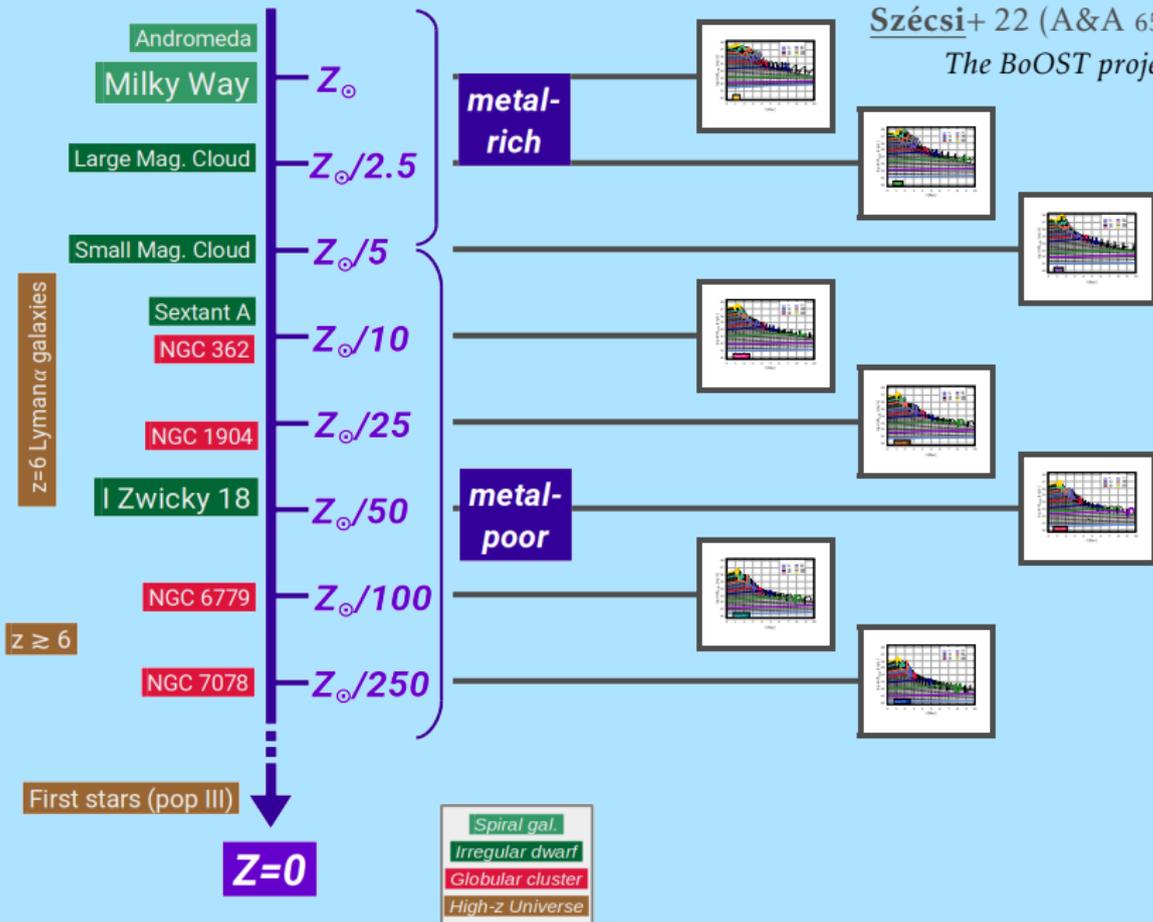
**Metal-poor  
massive stars**

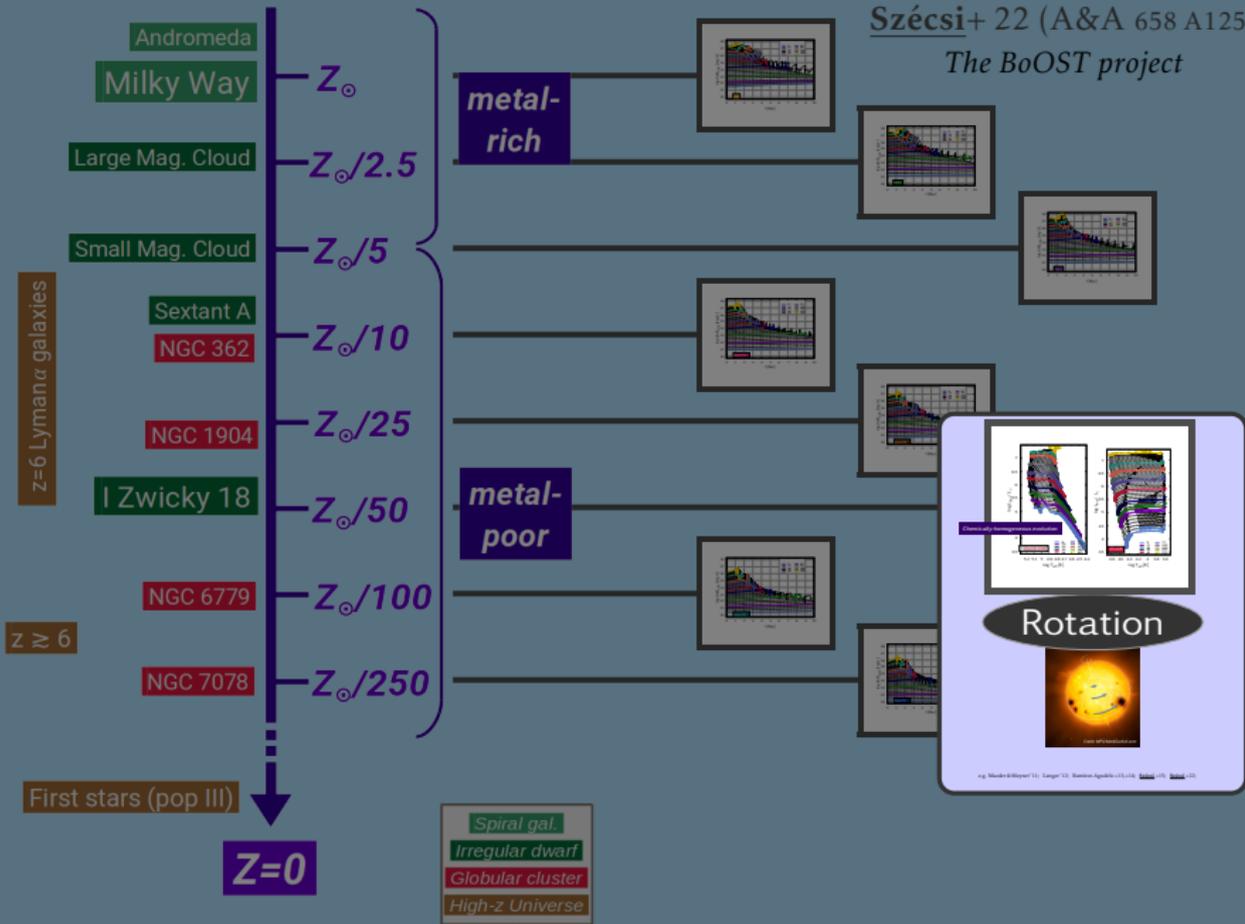


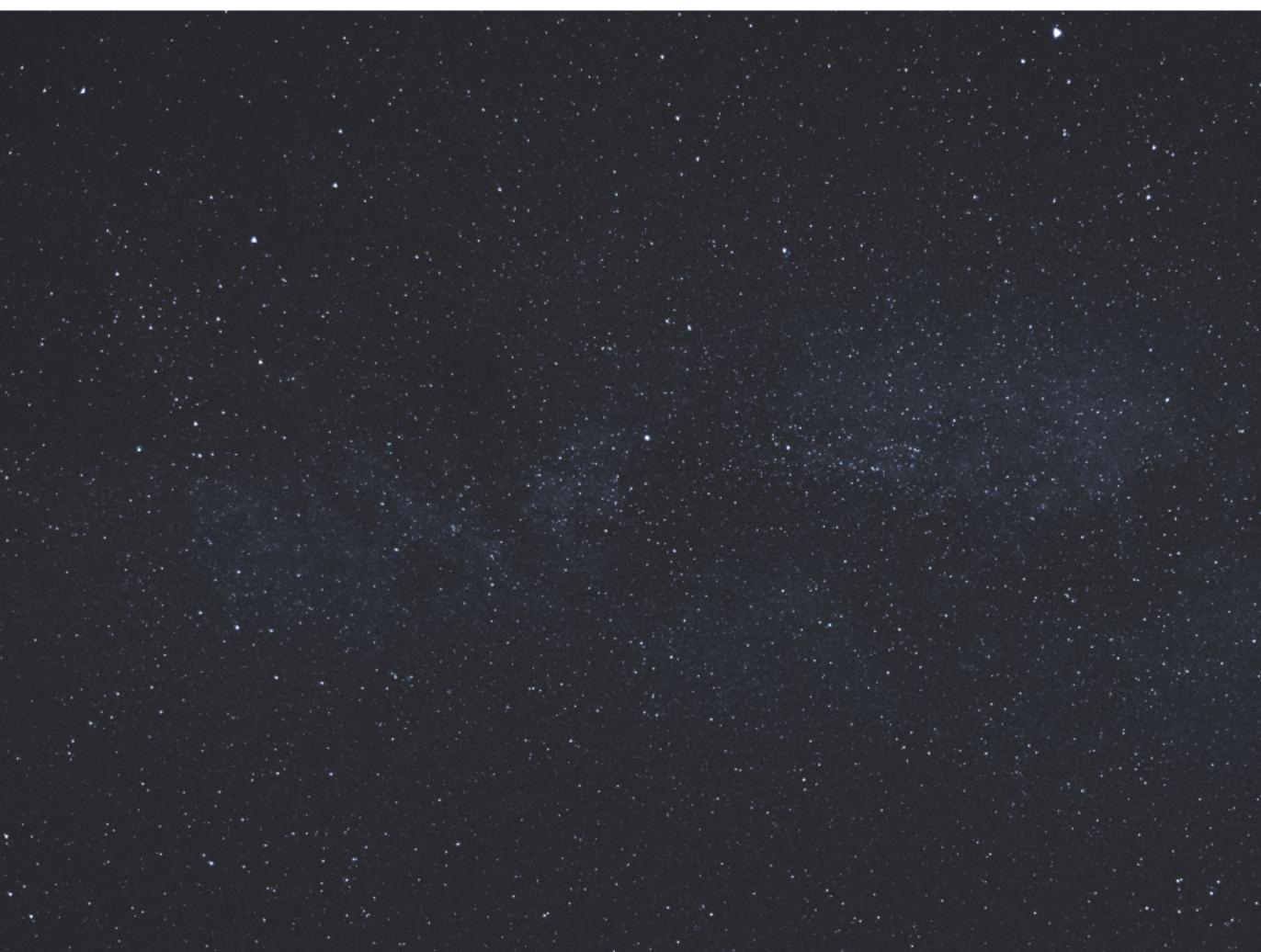














What is above a star?

...around? a star

What is above a star?

...around? a star

Stellar atmosphere  
(and stellar wind)

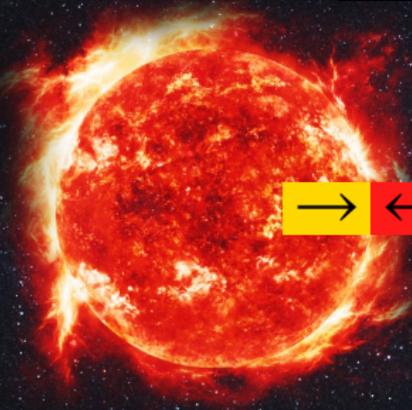
# Stellar atmosphere & stellar wind



# Stellar atmosphere & stellar wind

surface?  
→ photons escape  
"photosphere"

hot, dense plasma



equilibrium:

internal pressure

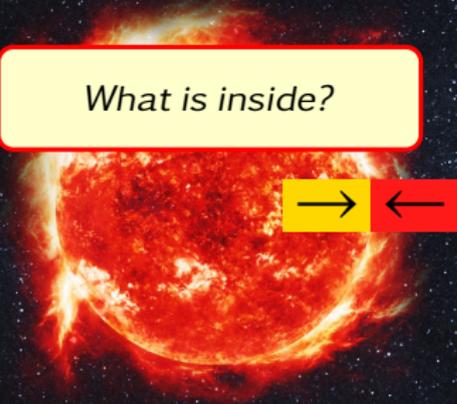
gravity

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What is inside?



theoretical  
modelling  
of the stellar  
structure

equilibrium:

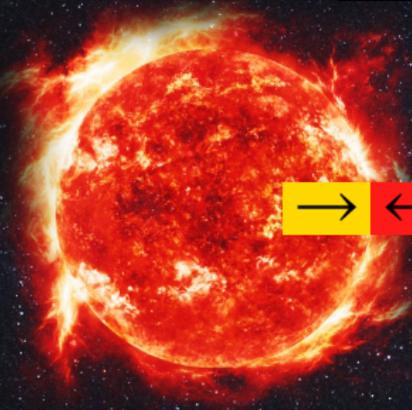
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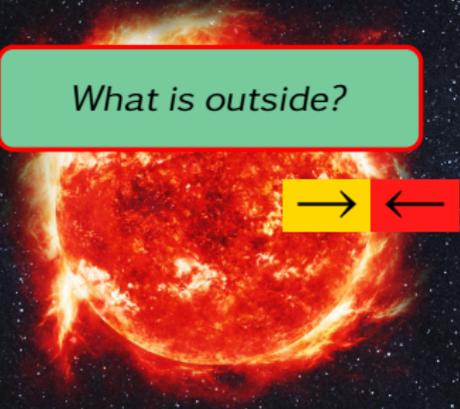
gravity

# Stellar atmosphere & stellar wind

surface?  
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hot, dense plasma

What is outside?



observing/  
modelling  
the atmosphere  
(and wind)

equilibrium:

internal pressure

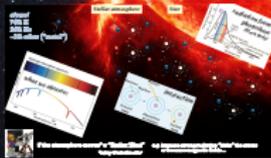
gravity

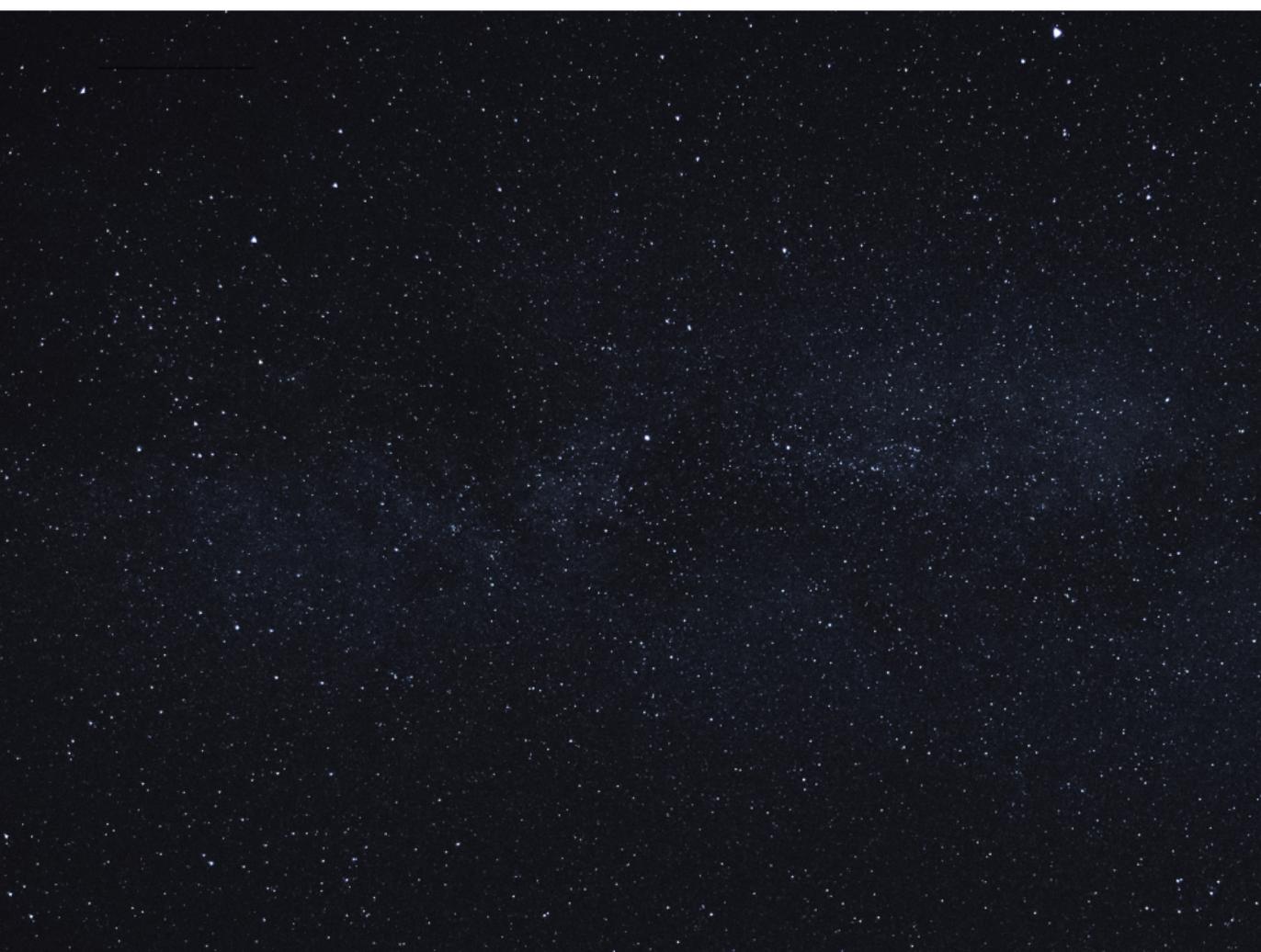
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observing/  
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## Bridging Massive Stars & feedback on SF

- ★ *Group on world-class massive star research*
- ★ updates in Massive Star physics every day...
- ★ needs to be converted into Feedback data – BoOST project!
- ★ already implemented into SILCC & GRIFFIN
- ★ more to come...



## Bridging Massive Stars & feedback on SF

- ★ *Group on world-class massive star research*
- ★ updates in Massive Star physics every day...
- ★ need *link data –*

### Master Class

self-developed Master Class on  
**Massive Stars –  
from Birth to Death**

full semester lecture covering  
evolution, wind-feedback, explosions,  
final fates as e.g. GW-prog. (3 ECTS)

GRIFFIN



Financed  
from  
OPUS grant

## My people



**Dr. Poojan Agrawal**  
*(ex PhD student,  
now project scientist  
at KU Leuven, Belgium)*

In Toruń:



**Hanno Stinshoff**  
*(PhD student)*



**Dr. Koushik Sen**  
*(ex post-doc)*



**Dr. Áron Szabó**  
*(ex PD fellow)*

open PD position

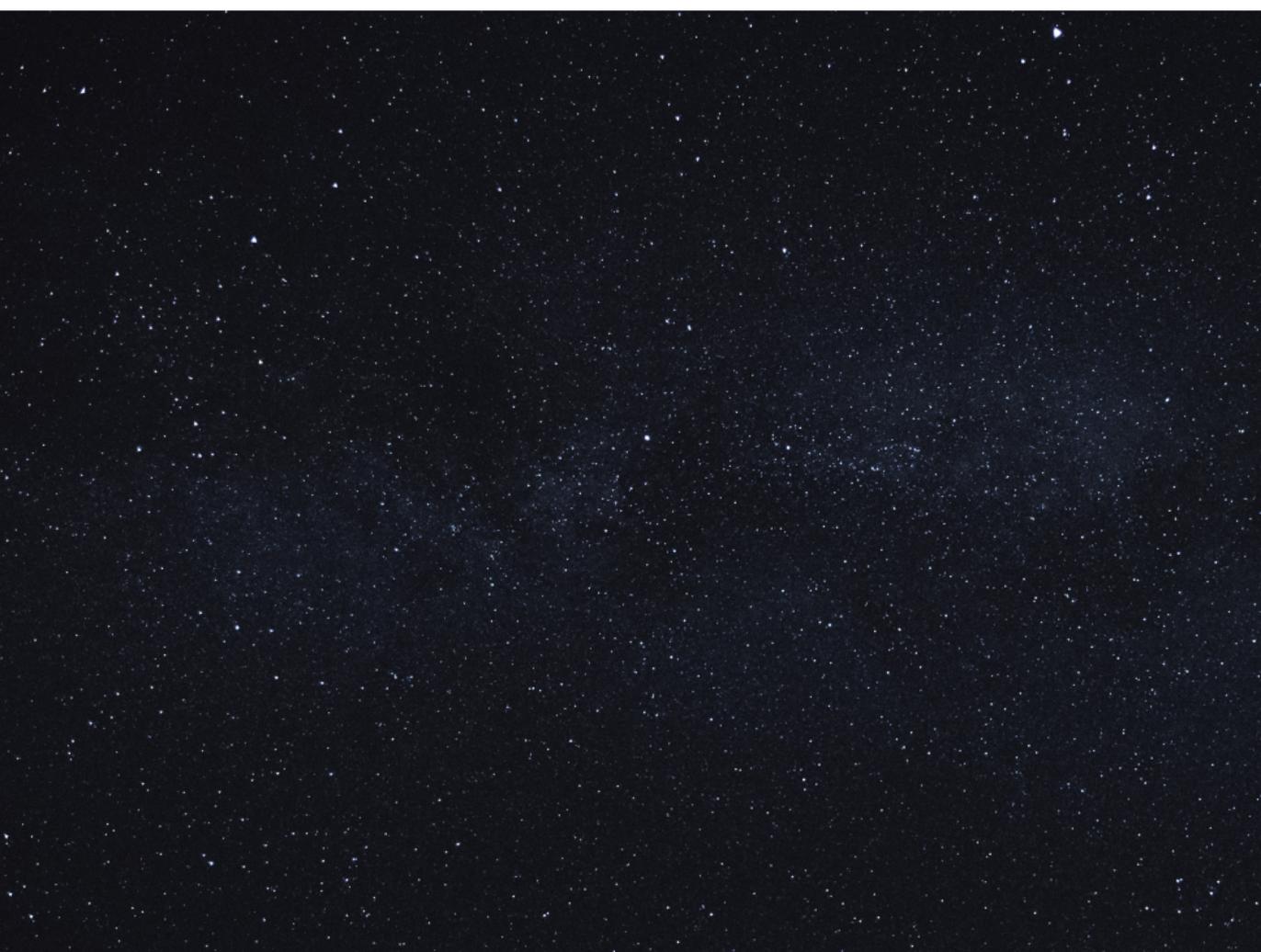
**Rafia Sarwar**  
*(PhD student)*



## My philosophy as a Leader

- ★ supporting and uplifting
- ★ intersectional thinking – excellence may look different in historically underrepresented groups (LGBTQ\*, ethnic minorities etc.)
- ★ promoting a healthy academic culture





## Future plans:

*solving the Cosmic Lithium Problem  
with Pop-III & massive Pop-II feedback on pop-II*

*= metal-poor massive stars*

Dwarf galaxies



Gravitational waves



High-redshift Univ.



Metal-poor  
massive stars

Gamma-ray bursts



Globular clusters



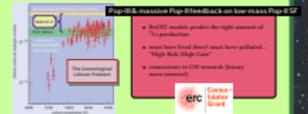
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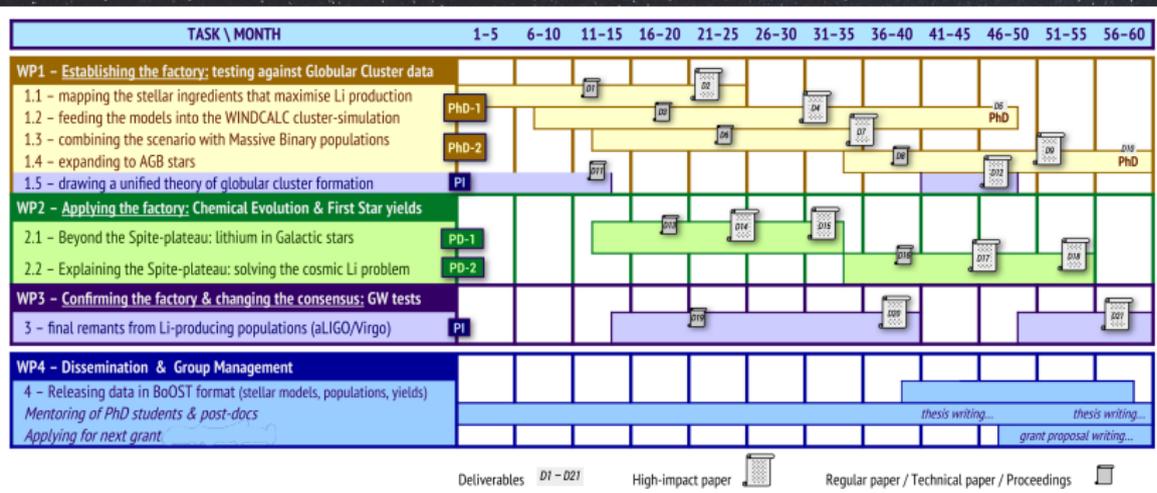
Gamma-ray bursts



Globular clusters



# Project management preparations



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solving the Cosmic Lithium Problem

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Kiel, 4th April 2025

