The theory linking gravitational waves, star-formation and the dawn of the Universe

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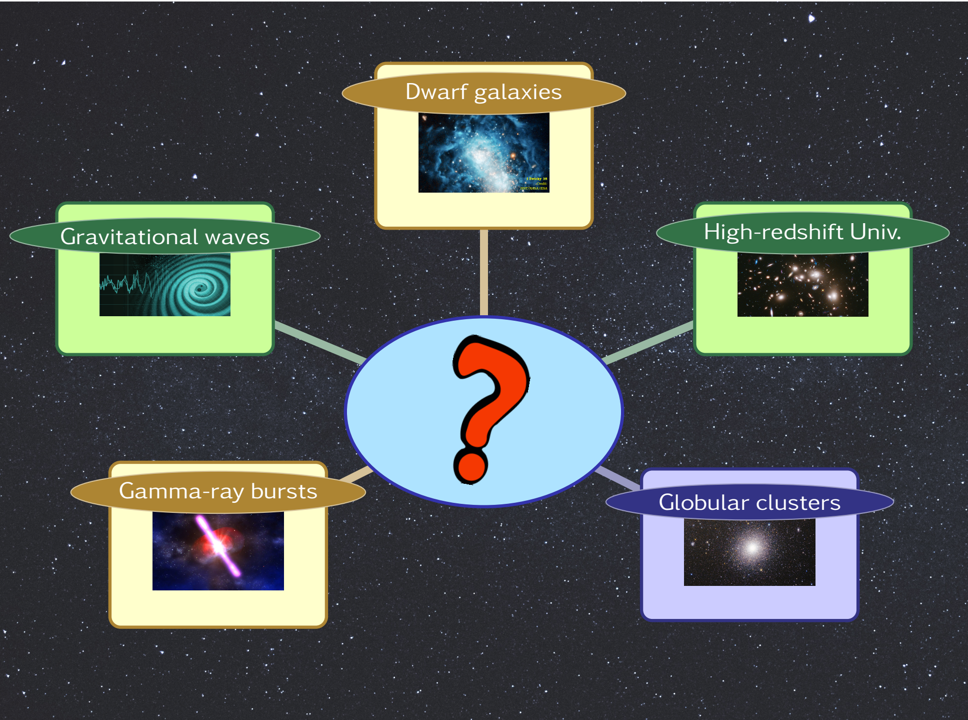
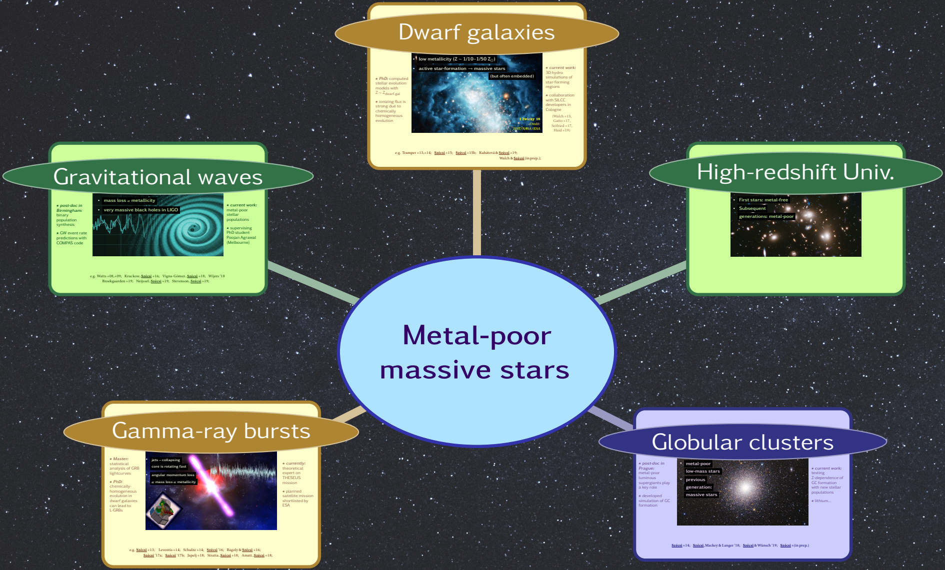
Alexander von Humboldt
Stiftung/Foundation


Dwarf galaxies
Gravitational waves
High-redshift Univ.
Gamma-ray bursts
Globular clusters


Dwarf galaxies
low metallicity (Z ~ 1/10–1/50 Z⊙)
active star-formation → massive stars
(but often embedded)
I Zwicky 18
Credit: HST/NASA/ESA
⋆ PhD: computed stellar evolution models with Z ~ Z dwarf.gal
⋆ ionizing flux is strong due to chemically homogeneous evolution
⋆ current work: 3D hydro simulations of star-forming regions
⋆ collaboration with SILCC developers in Cologne
(Walch +15, Gatto +17, Seifried +17, Haid +19)
e.g. Tramper +13,+14; Szécsi +15; Szécsi +15b; Kubátová & Szécsi +19; Walch & Szécsi (in prep.);
Gravitational waves
mass loss ∝ metallicity
very massive black holes in LIGO
⋆ post-doc in Birmingham: binary population synthesis
⋆ GW event rate predictions with COMPAS code
⋆ current work: metal-poor stellar populations
⋆ supervising PhD student Poojan Agrawal (Melbourne)
e.g. Watts +08,+09; Kruckow..Szécsi +16; Vigna-Gómez..Szécsi +18; Wijers '18
Broekgaarden +19; Neijssel..Szécsi +19; Stevenson..Szécsi +19;
High-redshift Univ.
First stars: metal-free
Subsequent generations: metal-poor
Metal-poor massive stars
Gamma-ray bursts
jets – collapsing core is rotating fast
angular momentum loss ∝ mass loss ∝ metallicity
⋆ Master: statistical analysis of GRB lightcurves
⋆ PhD: chemically-homogeneous evolution in dwarf galaxies can lead to L-GRBs
⋆ currently: theoretical expert on THESEUS mission
⋆ planned satellite mission shortlisted by ESA
e.g. Szécsi +13; Leventis +14; Schulze +14; Szécsi '16; Bagoly & Szécsi +16;
Szécsi '17a; Szécsi '17b; Japelj +18; Stratta..Szécsi +18; Amati..Szécsi +18;
Globular clusters
metal-poor low-mass stars
previous generation: massive stars
⋆ post-doc in Prague: metal-poor luminous supergiants play a key role
⋆ developed simulation of GC formation
⋆ current work: testing Z-dependence of GC formation with new stellar populations
⋆ lithium...
Szécsi +14; Szécsi, Mackey & Langer '18; Szécsi & Wünsch '19; Szécsi +(in prep.)


What is a star?

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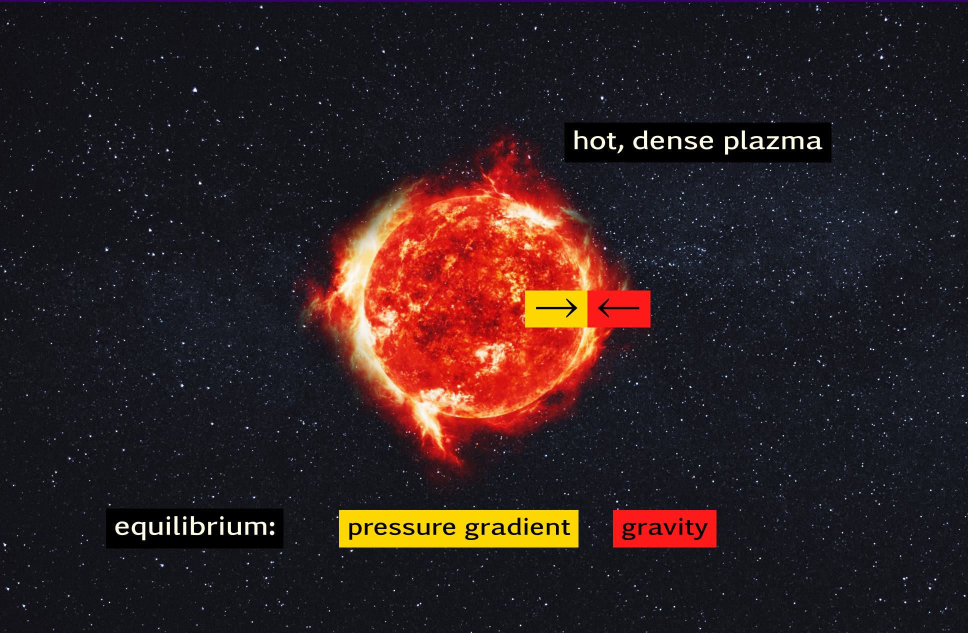
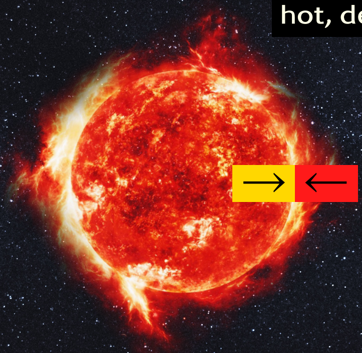


What is a star?

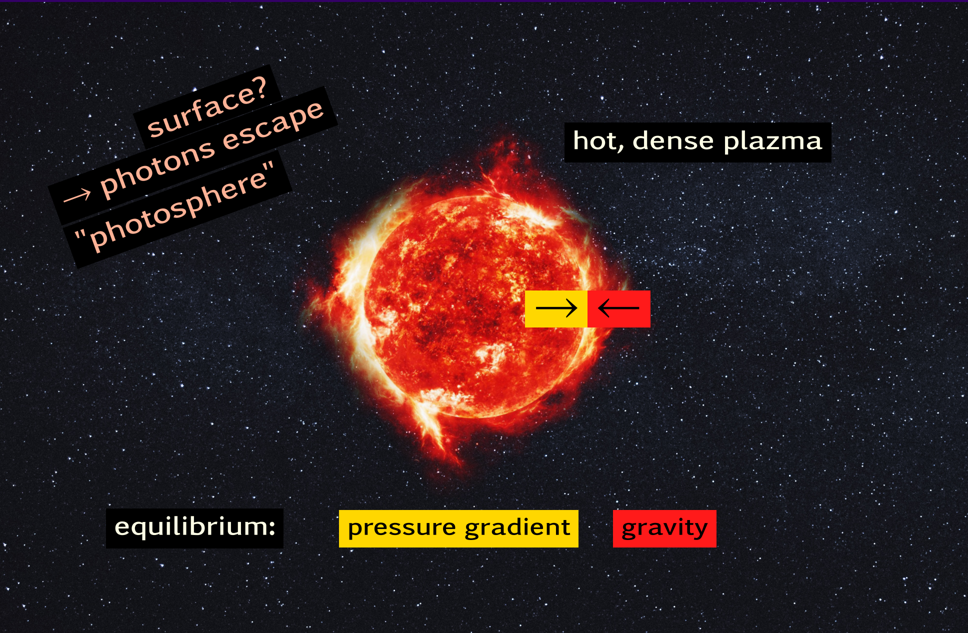
surface?

hot, dense plazma



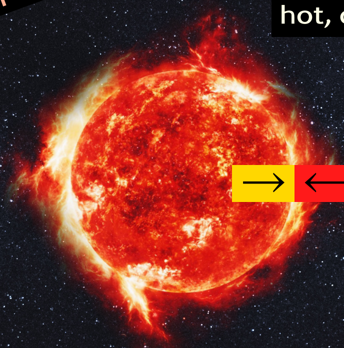
equilibrium: pressure gradient gravity

What is a star?



What is a star?

surface?
→ photons escape
"photosphere"



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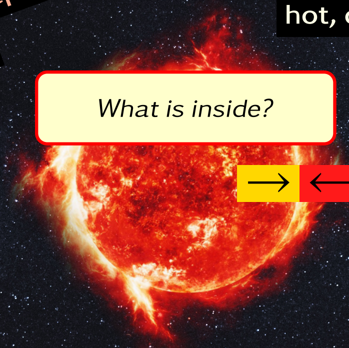

What is inside?

→ ←

equilibrium: pressure gradient gravity

What is a star?

surface?
→ photons escape
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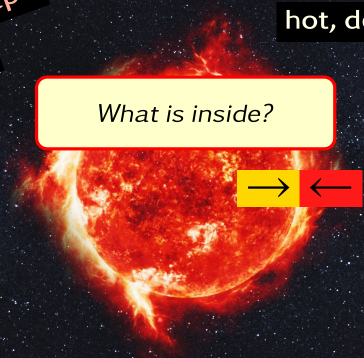
hot, dense plazma

What is inside?



theoretical modelling of the stellar structure

equilibrium: pressure gradient gravity

Theoretical modelling of the stellar structure

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

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

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

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

Guilera+ 11

Theoretical modelling of the stellar structure

$$\frac{\partial r}{\partial m_r} = \frac{1}{4\pi r^2 \rho} \qquad (1)$$

ec mass conservation

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transport of energy

Guilera+ 11

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transport of energy

Guilera+ 11

composition change due to nuclear burning:

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transport of energy

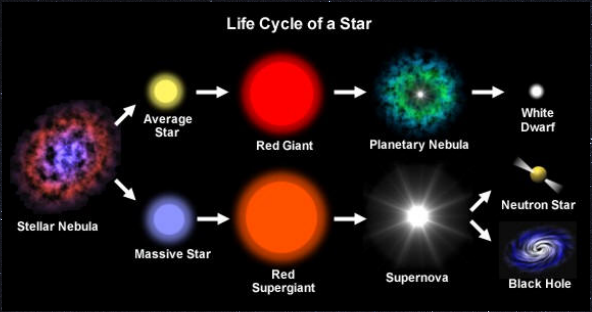
Guilera+ 11

composition change due to nuclear burning:

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

Massive vs. low-mass stars

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



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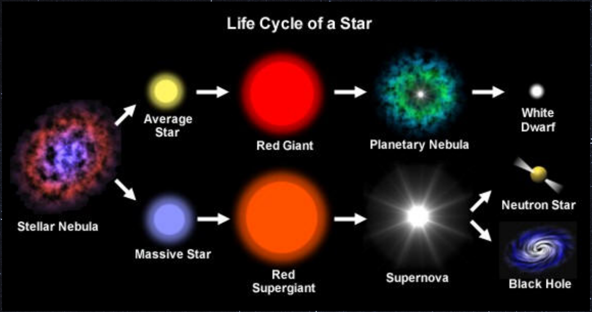

- Metallicity
- Rotation
- Binarity

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The BoOST project

Bonn Optimized Stellar Tracks

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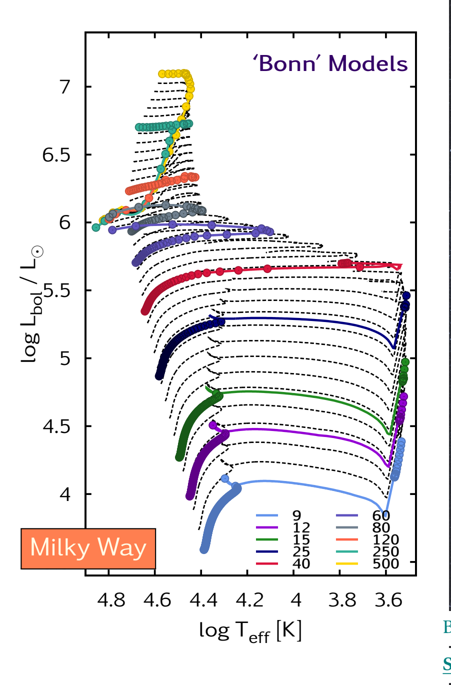

Brott+ 11 ($< 60\,M_\odot$), Köhler+ 15

Szécsi+ 15,20 ($> 60\,M_\odot$ & interp

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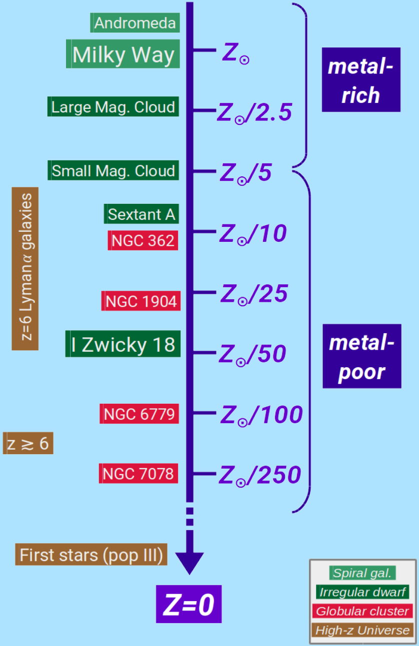
Bonn Optimized Stellar Tracks

Metallicity

Metallicity



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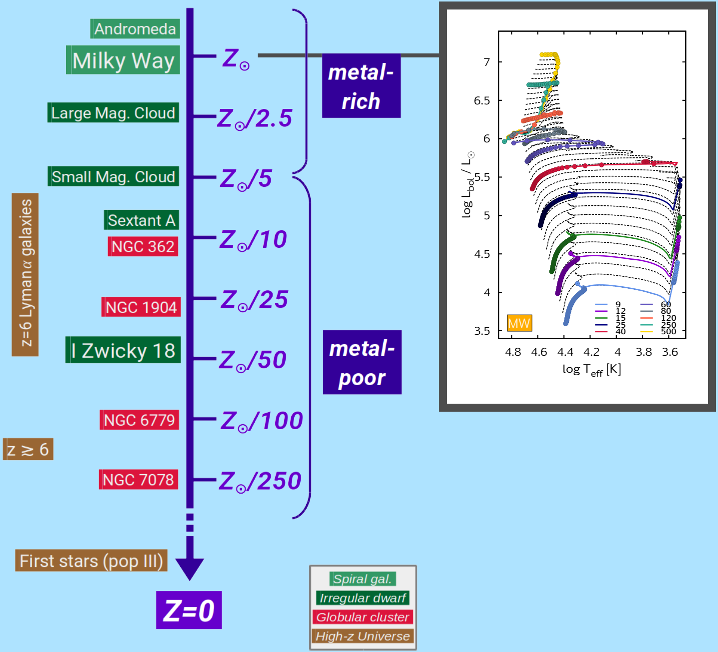

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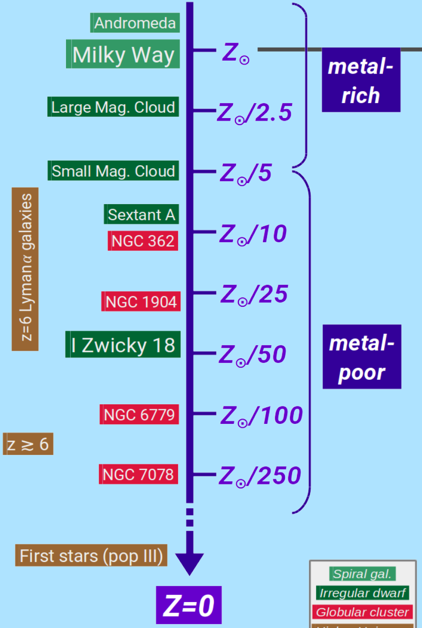

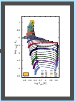

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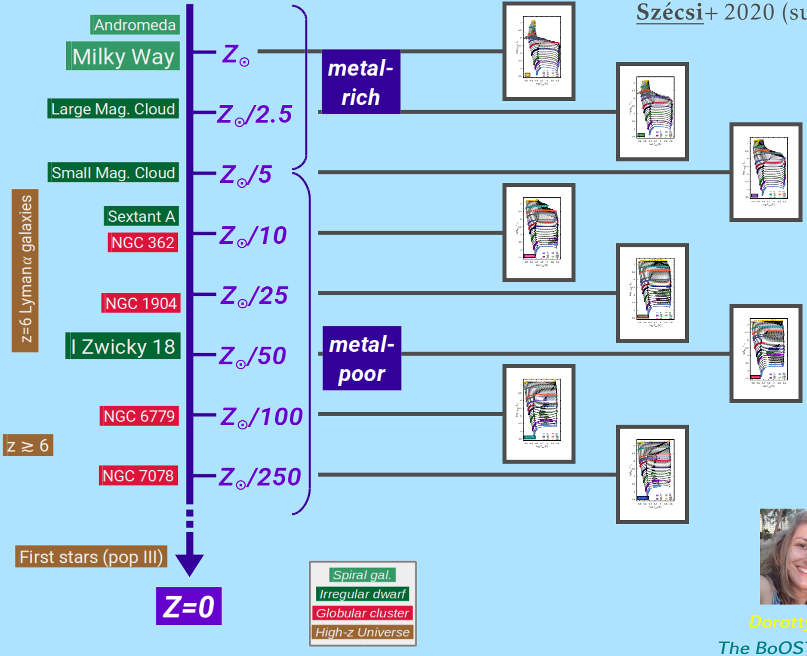
Szécsi+ 2020 (subm.)



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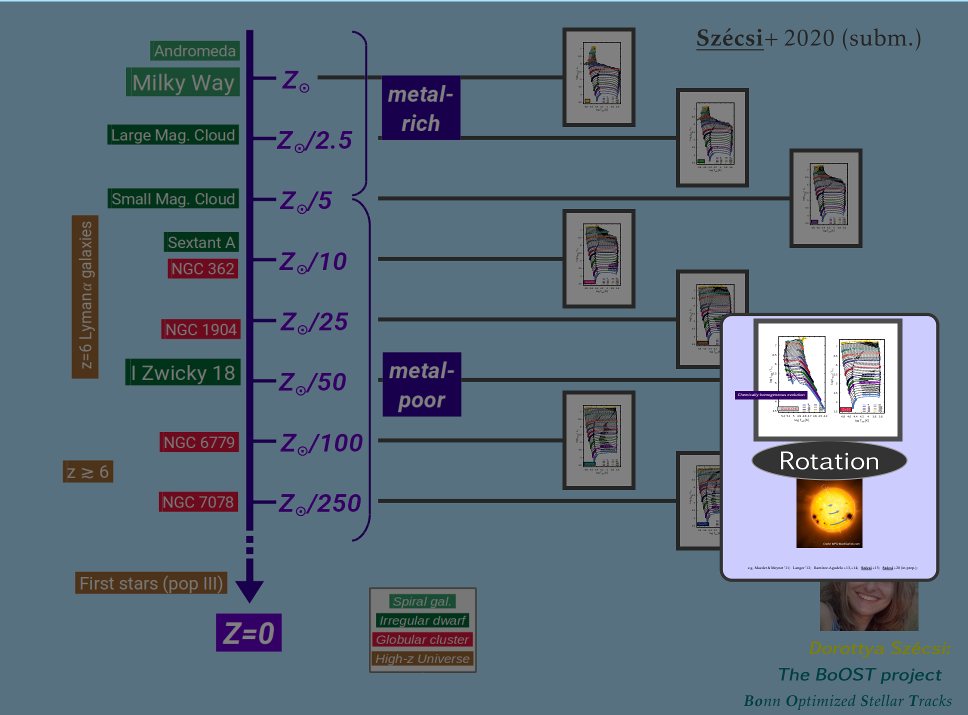
Szécsi+ 2020 (subm.)
Andromeda
Milky Way
Large Mag. Cloud
Small Mag. Cloud
Sextant A
NGC 362
NGC 1904
I Zwicky 18
NGC 6779
NGC 7078
z=6 Lyman α galaxies
z ≳ 6
First stars (pop III)
Z⊙
Z⊙/2.5
Z⊙/5
Z⊙/10
Z⊙/25
Z⊙/50
Z⊙/100
Z⊙/250
Z=0
metal-rich
metal-poor
Chemically-homogeneous evolution
Rotation
e.g. Maeder & Meynet '11; Langer '12; Ramirez-Agudelo +13,+14; Szécsi +15; Szécsi +20 (in prep.);
Spiral gal.
Irregular dwarf
Globular cluster
High-z Universe
Dorottya Szécsi:
The BoOST project
Bonn Optimized Stellar Tracks

Metal-poor massive stars

Dwarf galaxies

⋆ *PhD:* computed stellar evolution models with Z ~ $Z_{dwarf.gal}$

⋆ ionizing flux is strong due to chemically homogeneous evolution

⋆ *current work:* 3D hydro simulations of star-forming regions

⋆ collaboration with SILCC developers in Cologne

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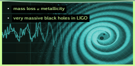
e.g. Tramper +13,+14; **Szécsi** +15; **Szécsi** +15b; Kubátová & **Szécsi** +19; Walch & **Szécsi** (in prep.);

Gravitational waves



⋆ *post-doc in Birmingham:* binary population synthesis

⋆ GW event rate predictions with COMPAS code

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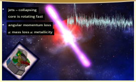
High-redshift Univ.

Gamma-ray bursts



⋆ *Master:* statistical analysis of GRB lightcurves

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Globular clusters

⋆ *post-doc in Prague:* metal-poor luminous supergiants play a key role

⋆ developed simulation of GC formation

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⋆ lithium...

Szécsi +14; **Szécsi**, Mackey & Langer '18; **Szécsi** & Wünsch '19; **Szécsi** +(in prep.)

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