Metal-poor massive stars

Linking gravitational waves, star-formation and the dawn of the Universe

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Warsaw, 8th December 2021

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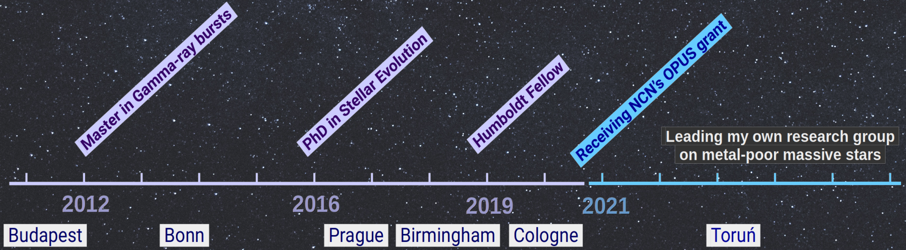

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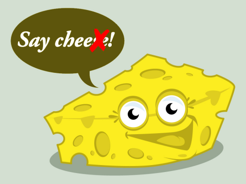
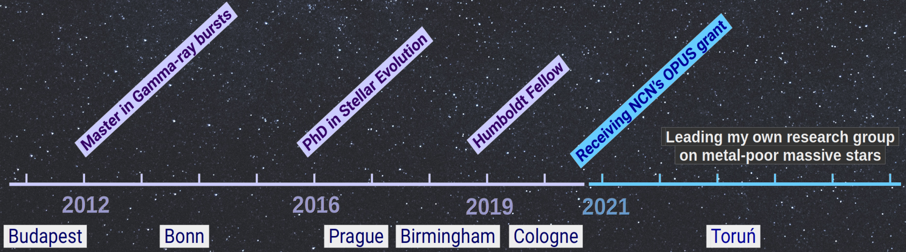
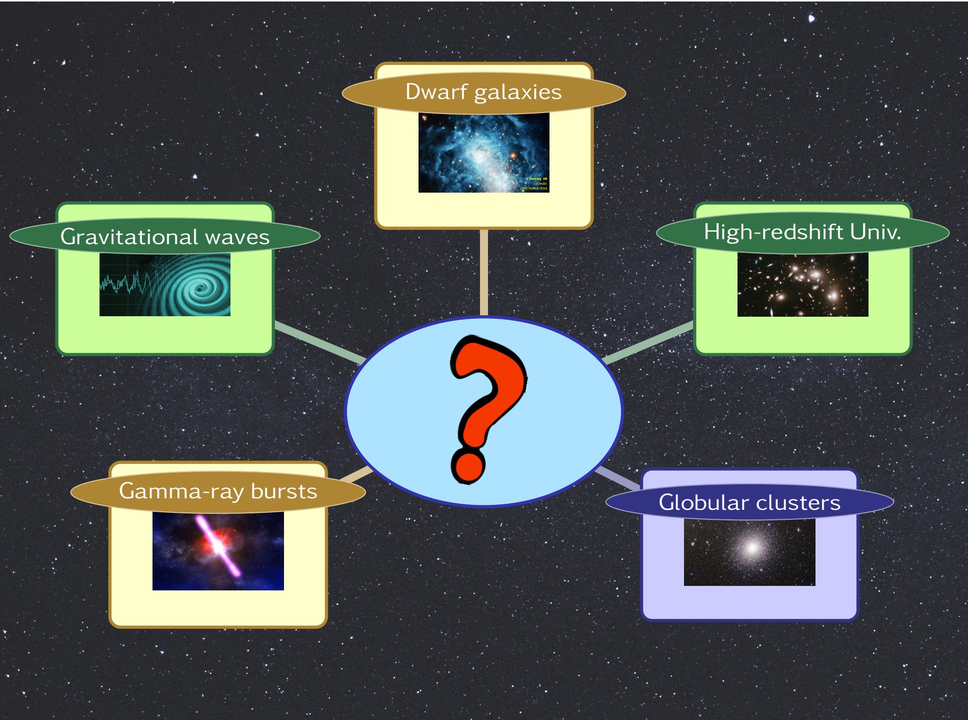
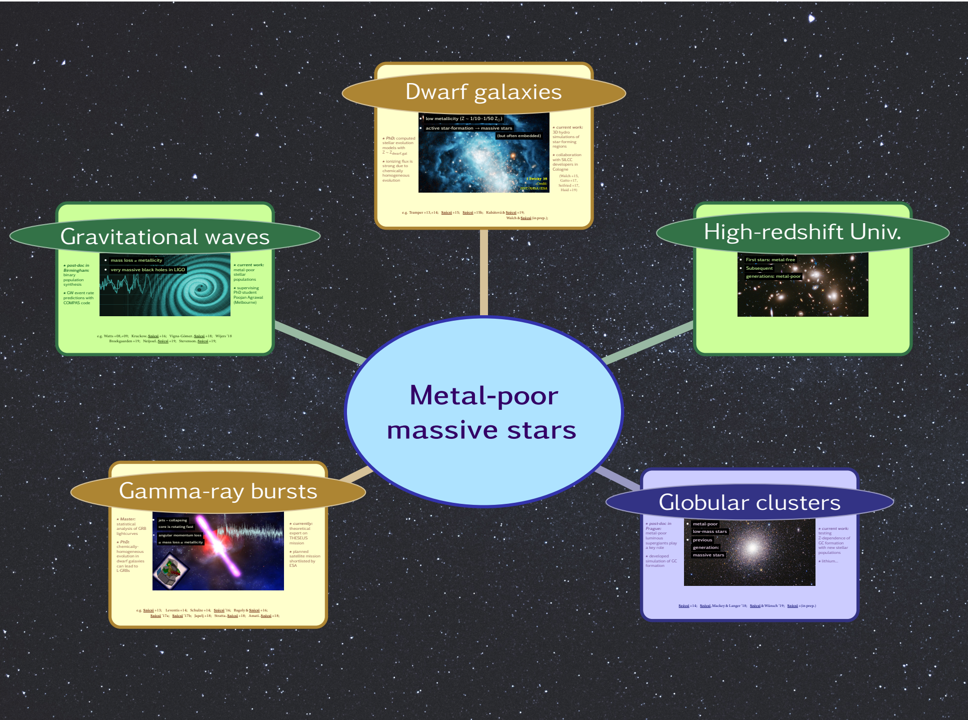





Dwarf galaxies
Gravitational waves
High-redshift Univ.
Gamma-ray bursts
Globular clusters


Metal-poor massive stars
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
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.)

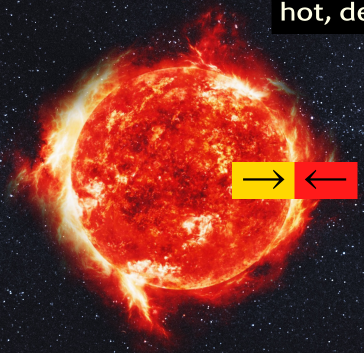
What is a star?

What is a star?

What is a star?

What is a star?

hot, dense plazma

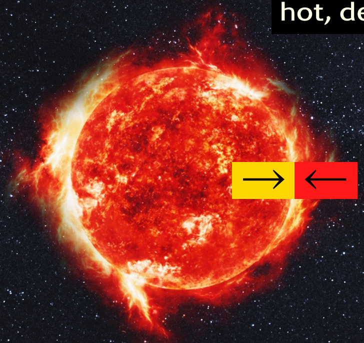


equilibrium: pressure gradient gravity

What is a star?

surface?

hot, dense plazma

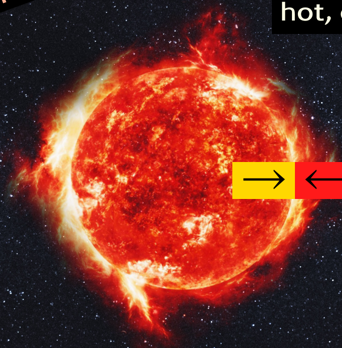


equilibrium: pressure gradient gravity

What is a star?

surface?
→ photons escape
"photosphere"

hot, dense plazma



→ ←

equilibrium: pressure gradient gravity

What is a star?

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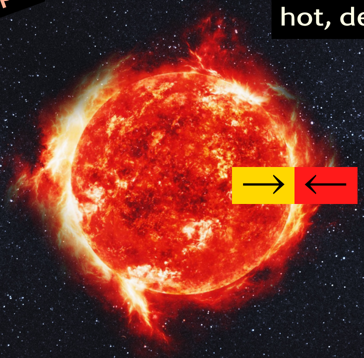

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What is a star?

surface?
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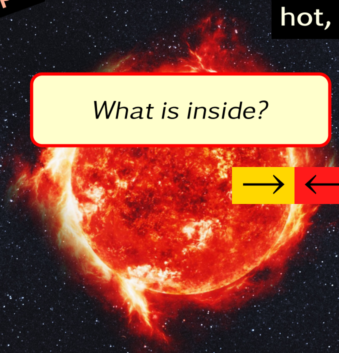


What is inside?

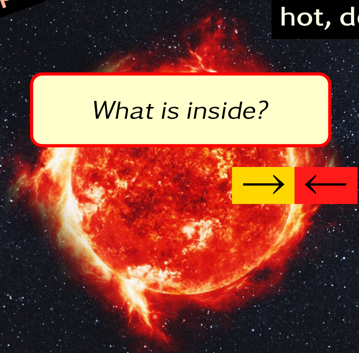
→ ←

equilibrium: pressure gradient gravity

What is a star?

surface?
→ photons escape
"photosphere"

hot, dense plazma



What is inside?

→ ←

theoretical modelling of the stellar structure

equilibrium: pressure gradient gravity

Theoretical modelling of the stellar structure

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

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

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

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

Guilera+ 11

Theoretical modelling of the stellar structure

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

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Guilera+ 11

Theoretical modelling of the stellar structure

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$$\frac{\partial P}{\partial m_r} = -\frac{G m_r}{4\pi r^4}$$ momentum conservation (2)

$$\frac{\partial L_r}{\partial m_r} = \epsilon_{\rm pl} - T\frac{\partial S}{\partial t}$$ energy conservation (3)

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

Guilera+ 11

Theoretical modelling of the stellar structure

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mass conservation

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transport of energy

Guilera+ 11

Theoretical modelling of the stellar structure

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$$\frac{\partial P}{\partial m_r} = -\frac{G m_r}{4\pi r^4} \qquad (2)$$

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transport of energy

Guilera+ 11

composition change due to nuclear burning:

Theoretical modelling of the stellar structure

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

energy conservation

$$\frac{\partial T}{\partial m_r} = -\frac{G m_r T}{4\pi r^4 P}\nabla \qquad (4)$$

transport of energy

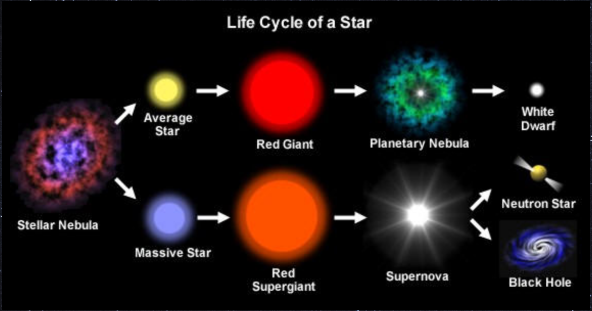
Guilera+ 11

composition change due to nuclear burning:

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

Massive vs. low-mass stars

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



Massive vs. low-mass stars

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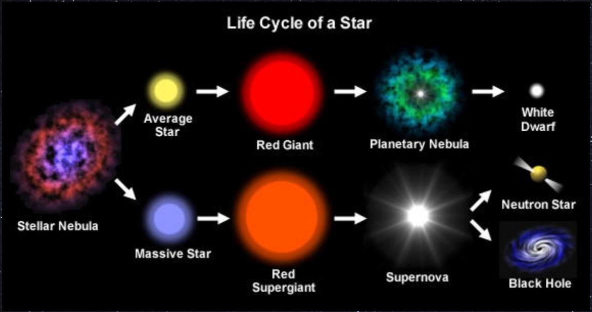
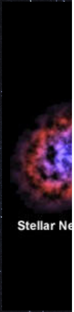
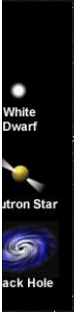


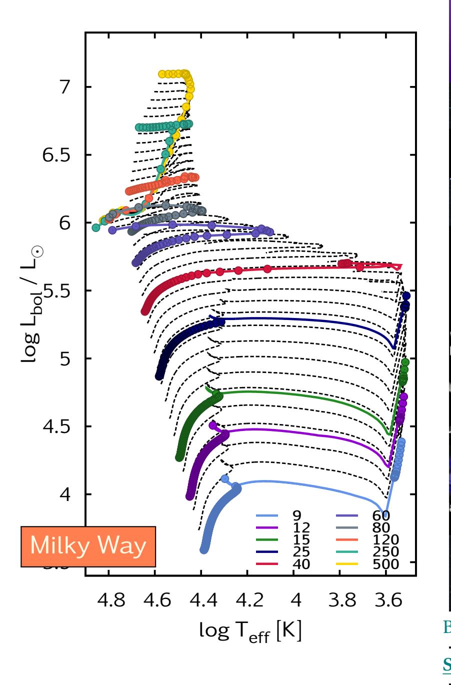
- Metallicity
- Rotation
- Binarity

Massive vs

Massi... 9 $M_\odot$)







- Metallicity
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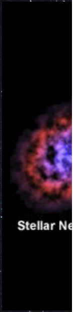
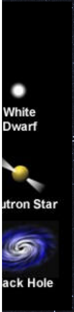
Brott+ 11 ($< 60\,M_\odot$),

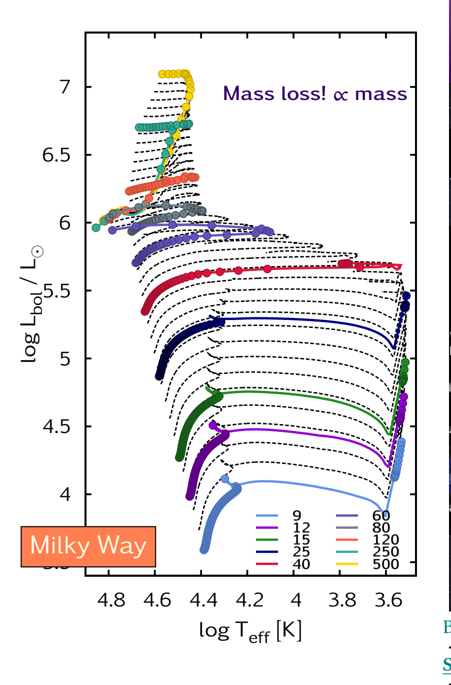
Szécsi+ 20 ($> 60\,M_\odot$ & interpol.)

Massive vs

Massi… 9 $M_\odot$)







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

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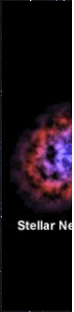
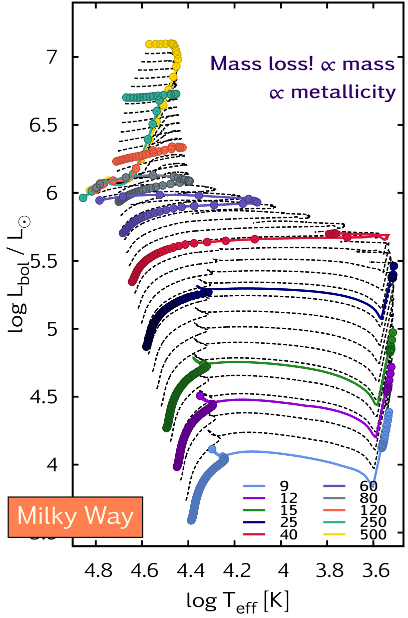
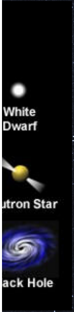
Massive vs

Massi… 9 $M_\odot$)







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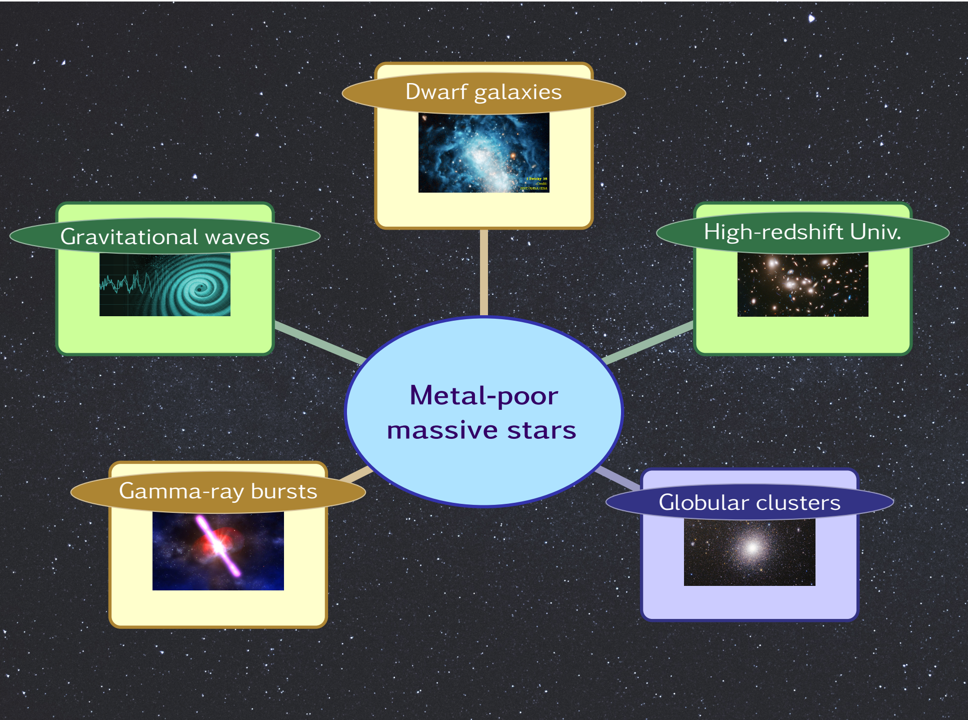
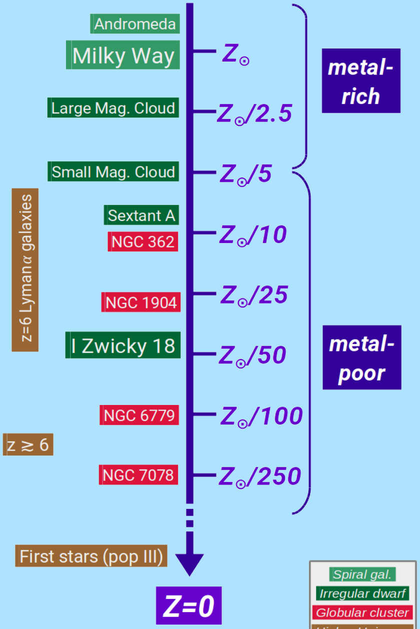
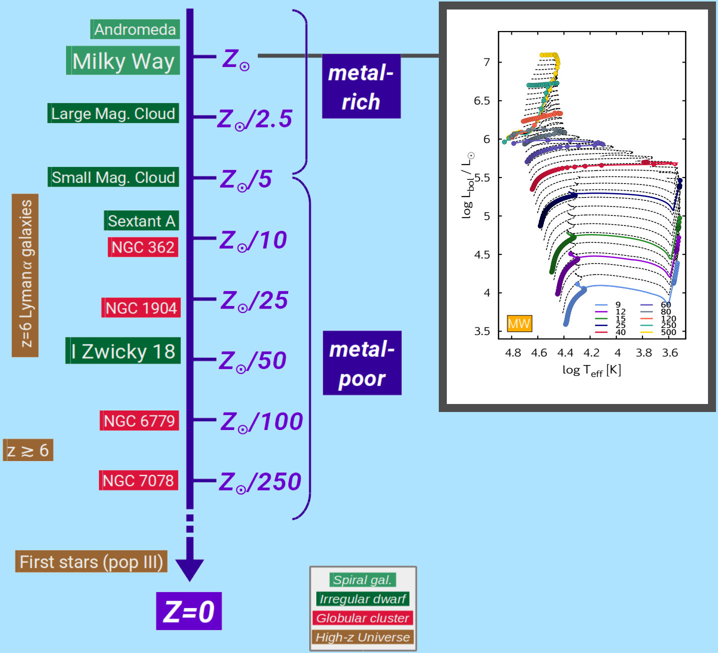
Brott+ 11 (< 60 $M_\odot$),

Szécsi+ 20 (> 60 $M_\odot$ & interpol.)


Dwarf galaxies
Gravitational waves
High-redshift Univ.
Metal-poor
massive stars
Gamma-ray bursts
Globular clusters


Metal-poor
massive stars


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)
$Z_\odot$
$Z_\odot/2.5$
$Z_\odot/5$
$Z_\odot/10$
$Z_\odot/25$
$Z_\odot/50$
$Z_\odot/100$
$Z_\odot/250$
Z=0
metal-rich
metal-poor
Spiral gal.
Irregular dwarf
Globular cluster
High-z Universe



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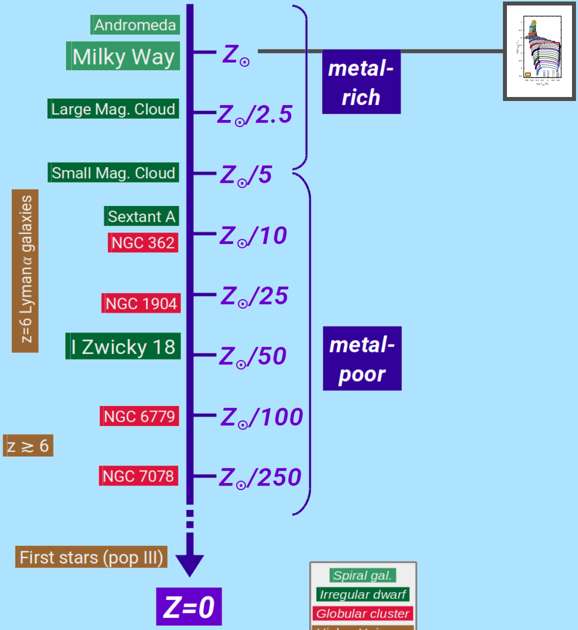
$Z_\odot/100$
$Z_\odot/250$
Z=0
metal-rich
metal-poor
log L_{bol} / $L_\odot$
log T_{eff} [K]
MW
9
12
15
25
40
60
80
120
250
500
Spiral gal.
Irregular dwarf
Globular cluster
High-z Universe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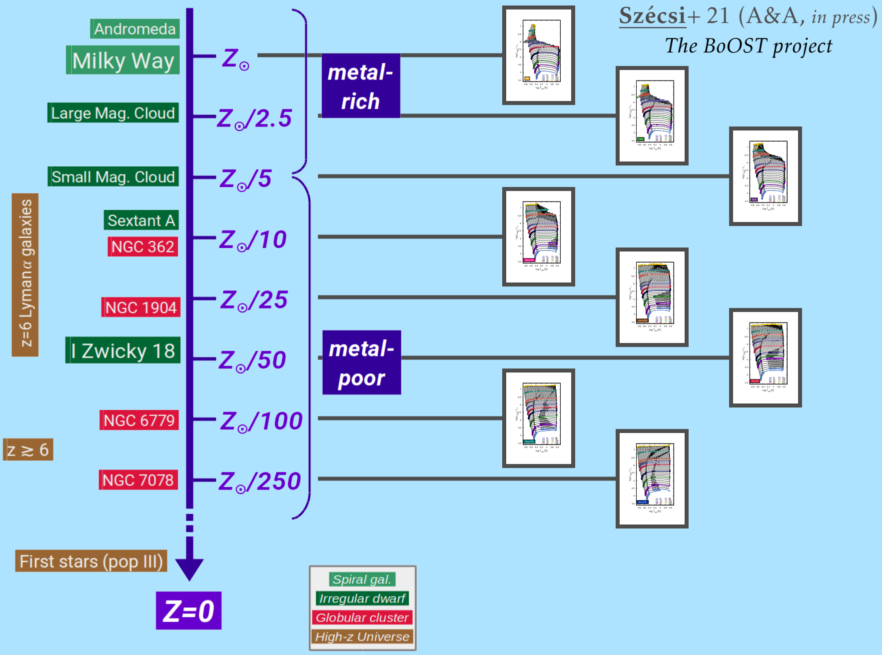
Szécsi+ 21 (A&A, in press)
The BoOST project
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NGC 1904
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Z⊙
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Z⊙/250
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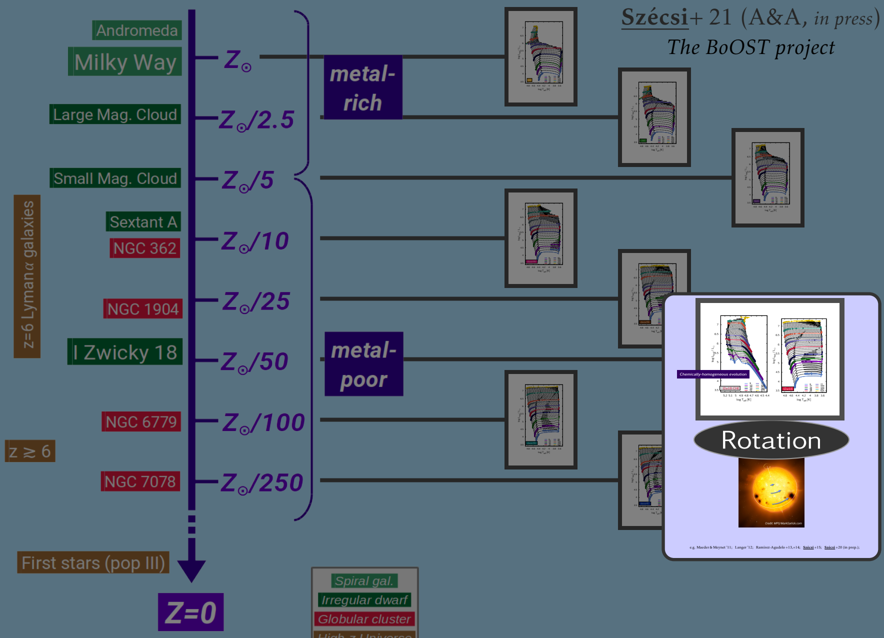
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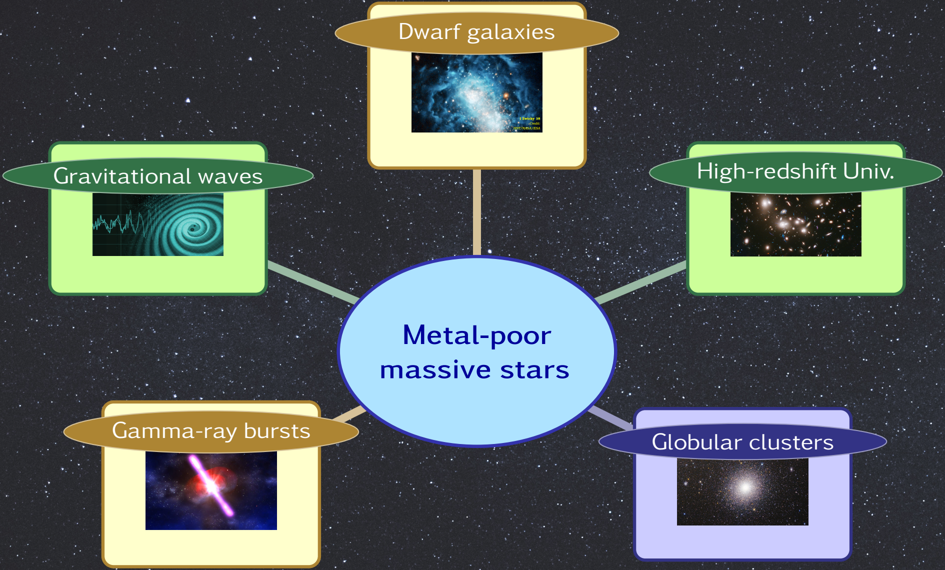
Z=0
metal-rich
metal-poor
Spiral gal.
Irregular dwarf
Globular cluster
High-z Universe
Chemically-homogeneous evolution
Rotation
Credit: MPS/MarkGarlick.com
e.g. Maeder & Meynet '11; Langer '12; Ramirez-Agudelo +13,+14; Szécsi +15; Szécsi +20 (in prep.);

Future plans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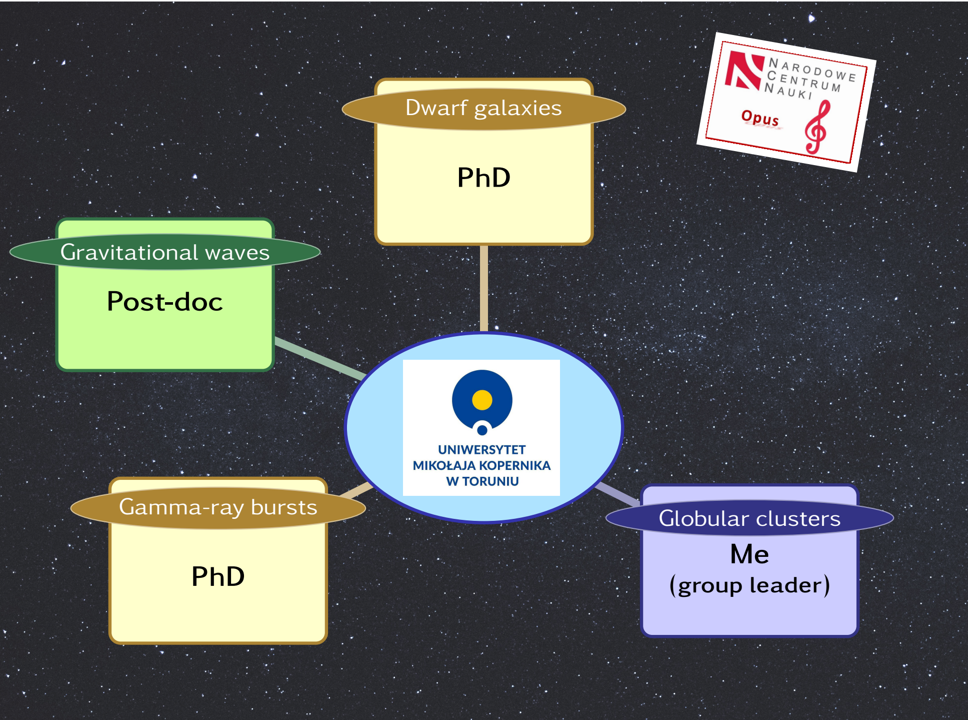
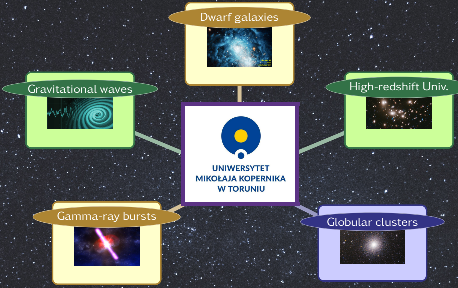


Dwarf galaxies
PhD
Gravitational waves
Post-doc
UNIWERSYTET
MIKOŁAJA KOPERNIKA
W TORUNIU
Gamma-ray bursts
PhD
Globular clusters
Me
(group leader)
NARODOWE
CENTRUM
NAUKI
Opus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MIKOŁAJA KOPERNIKA
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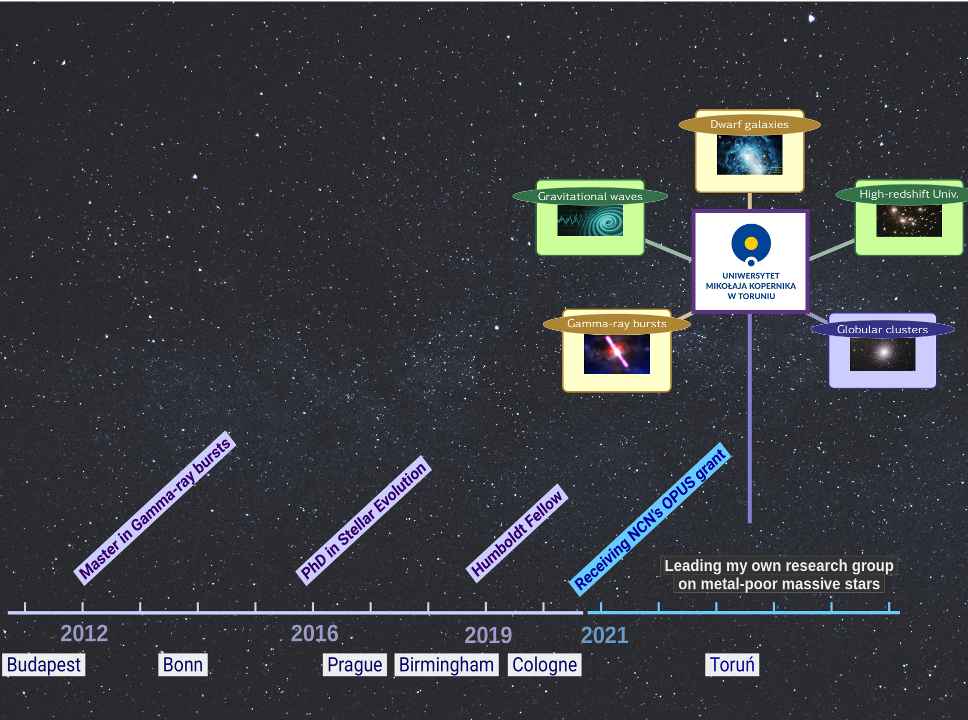

Dwarf galaxies
Gravitational waves
High-redshift Univ.
UNIWERSYTET
MIKOŁAJA KOPERNIKA
W TORUNIU
Gamma-ray bursts
Globular clusters
Master in Gamma-ray bursts
PhD in Stellar Evolution
Humboldt Fellow
Receiving NCN's OPUS grant
Leading my own research group
on metal-poor massive stars
2012
2016
2019
2021
Budapest
Bonn
Prague
Birmingham
Cologne
Toruń

Metal-poor massive stars

Linking gravitational waves, star-formation and the dawn of the Universe

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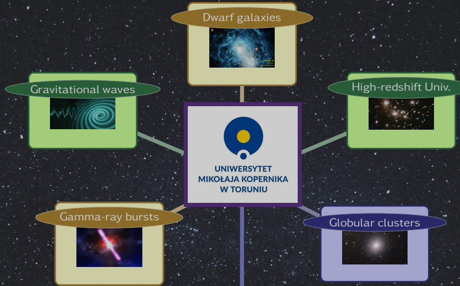
Thank you for your attention!



Master in Gamma-ray bursts

PhD in Stellar Evolution

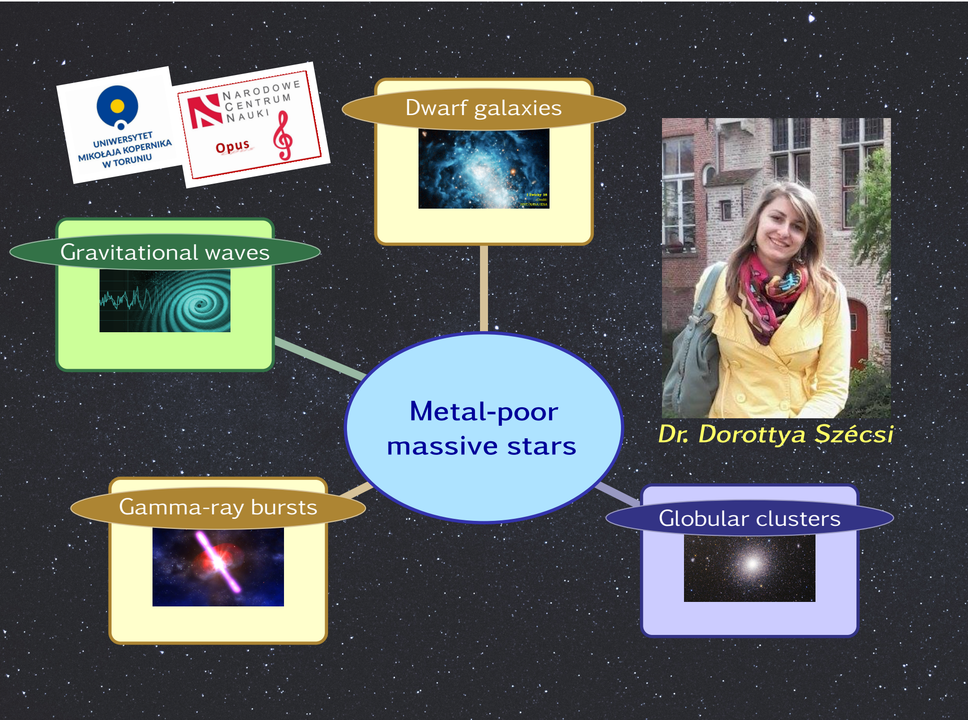
Humboldt Fellow

Receiving NCN's OPUS grant

Leading my own research group on metal-poor massive stars

2012 2016 2019 2021

Budapest Bonn Prague Birmingham Cologne Toruń



UNIWERSYTET MIKOŁAJA KOPERNIKA W TORUNIU
NARODOWE CENTRUM NAUKI
Opus
Dwarf galaxies
Gravitational waves
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