Black holes and neutron stars: an astronomical view

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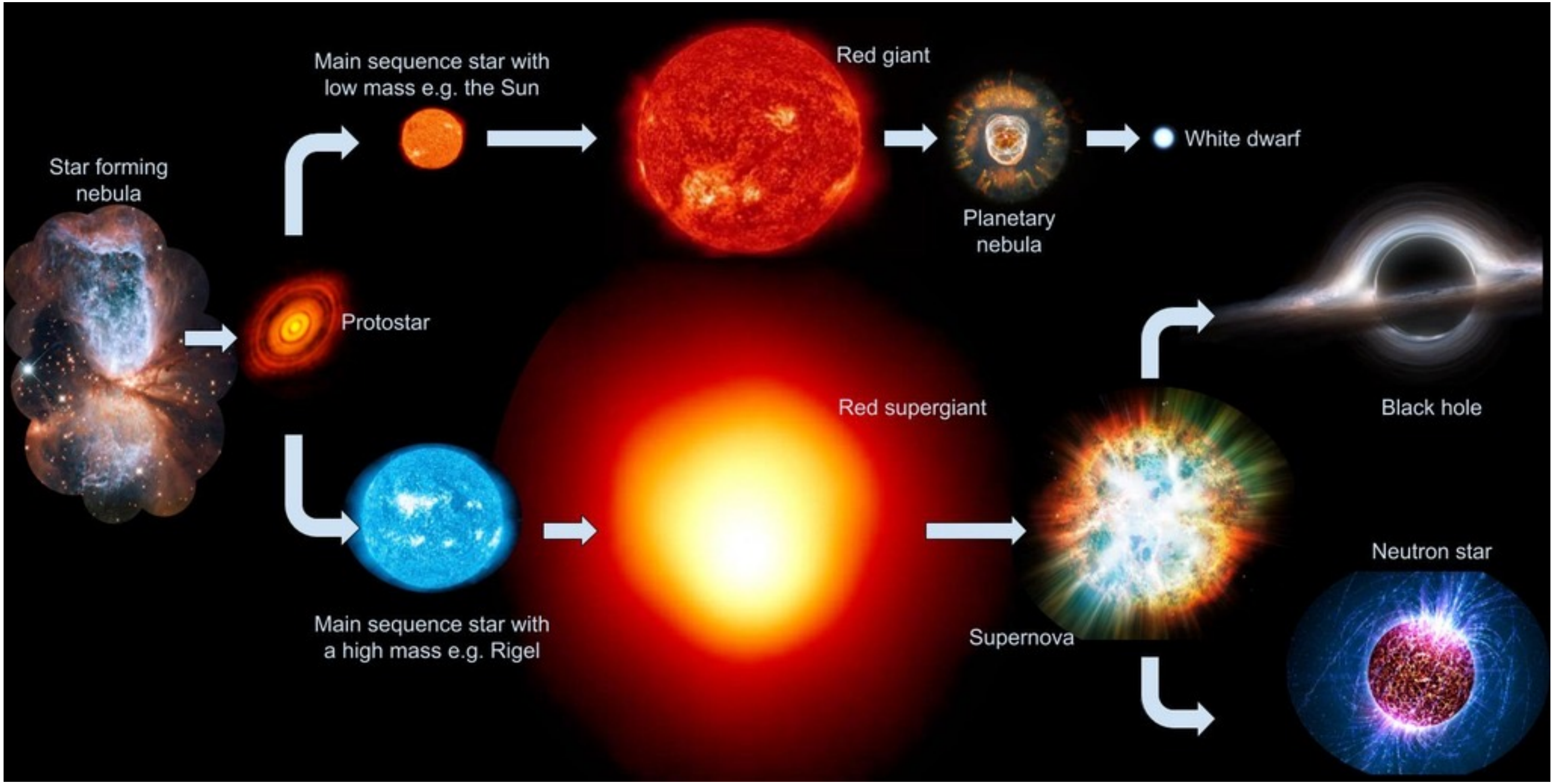
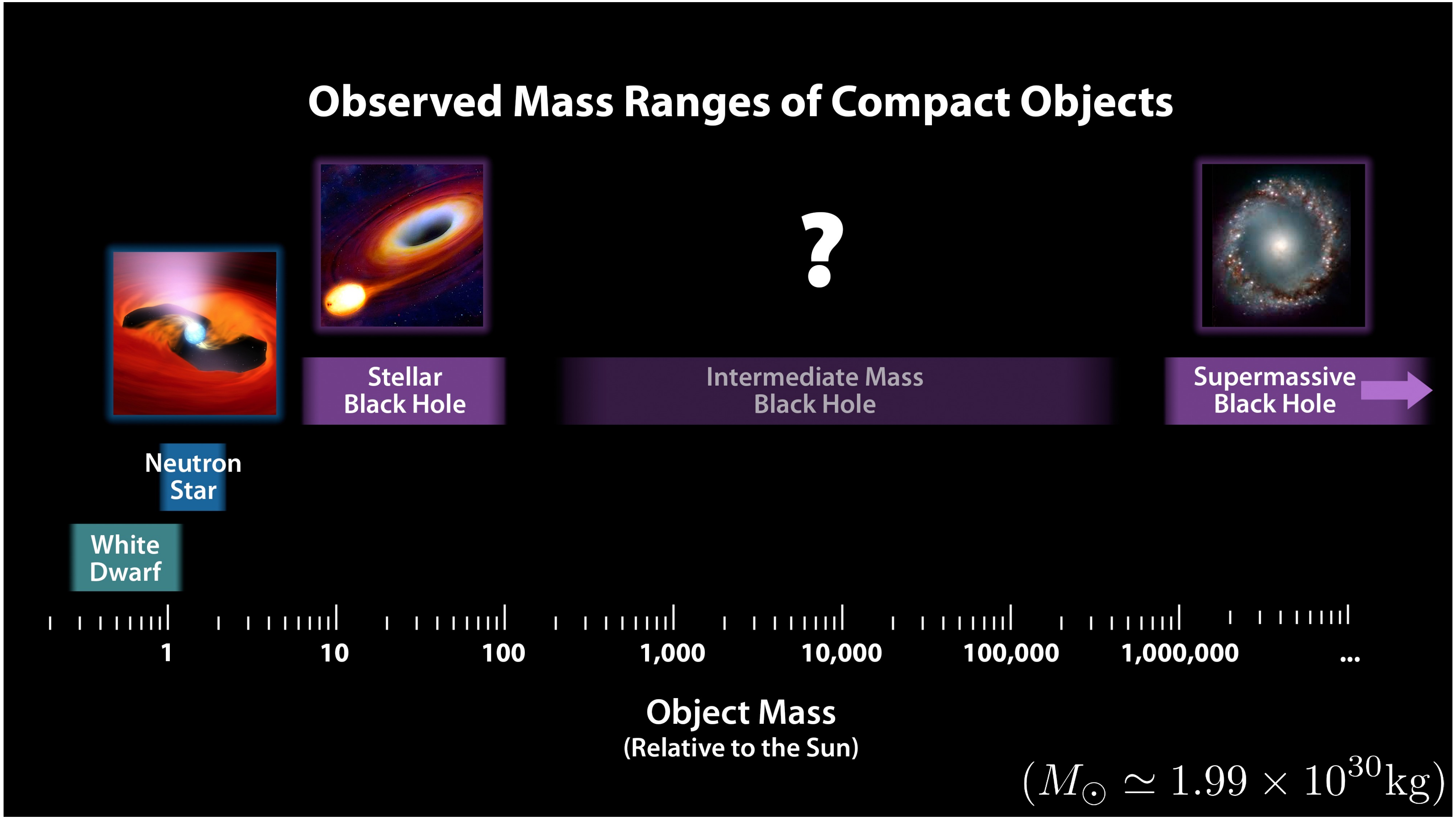
A day in the life (and death) of a star



Compact objects



$(M_\odot \simeq 1.99 \times 10^{30}\text{kg})$

[NASA/JPL-Caltech]

Compact objects

Black holes

$$M_{BH}/M_\odot \simeq 3 \div 10^{10}$$

$$R_S = 2\ r_g = 2\ GM/c^2 \simeq 3\ (M/M_\odot)\ \text{km}$$

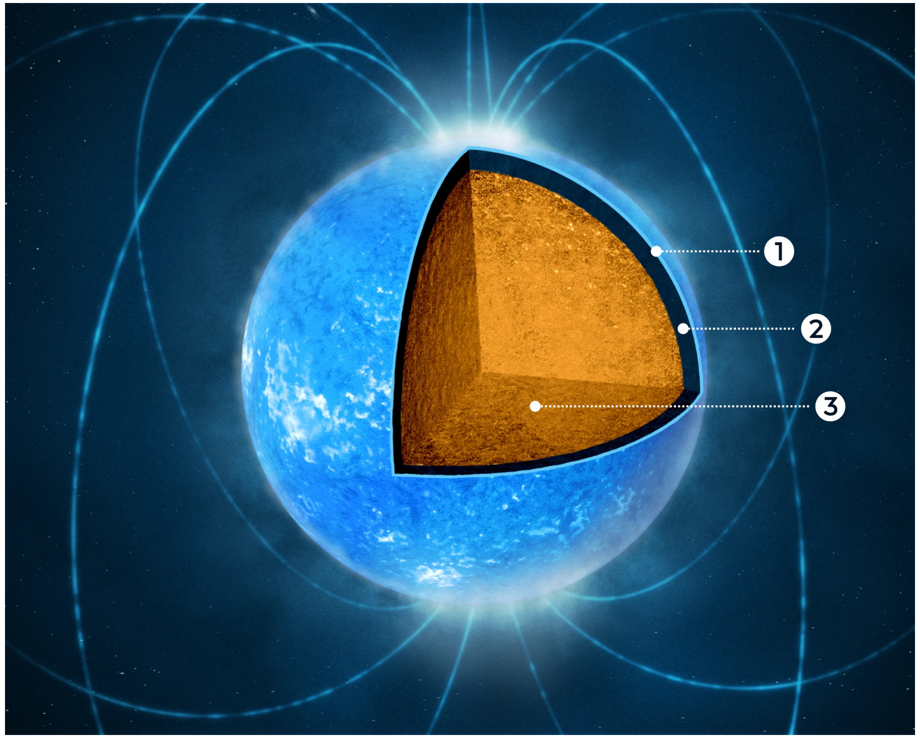
[EHT collaboration, 2017]

Neutron stars

$$M_{NS}/M_\odot \simeq 1.4 \div 2.7$$

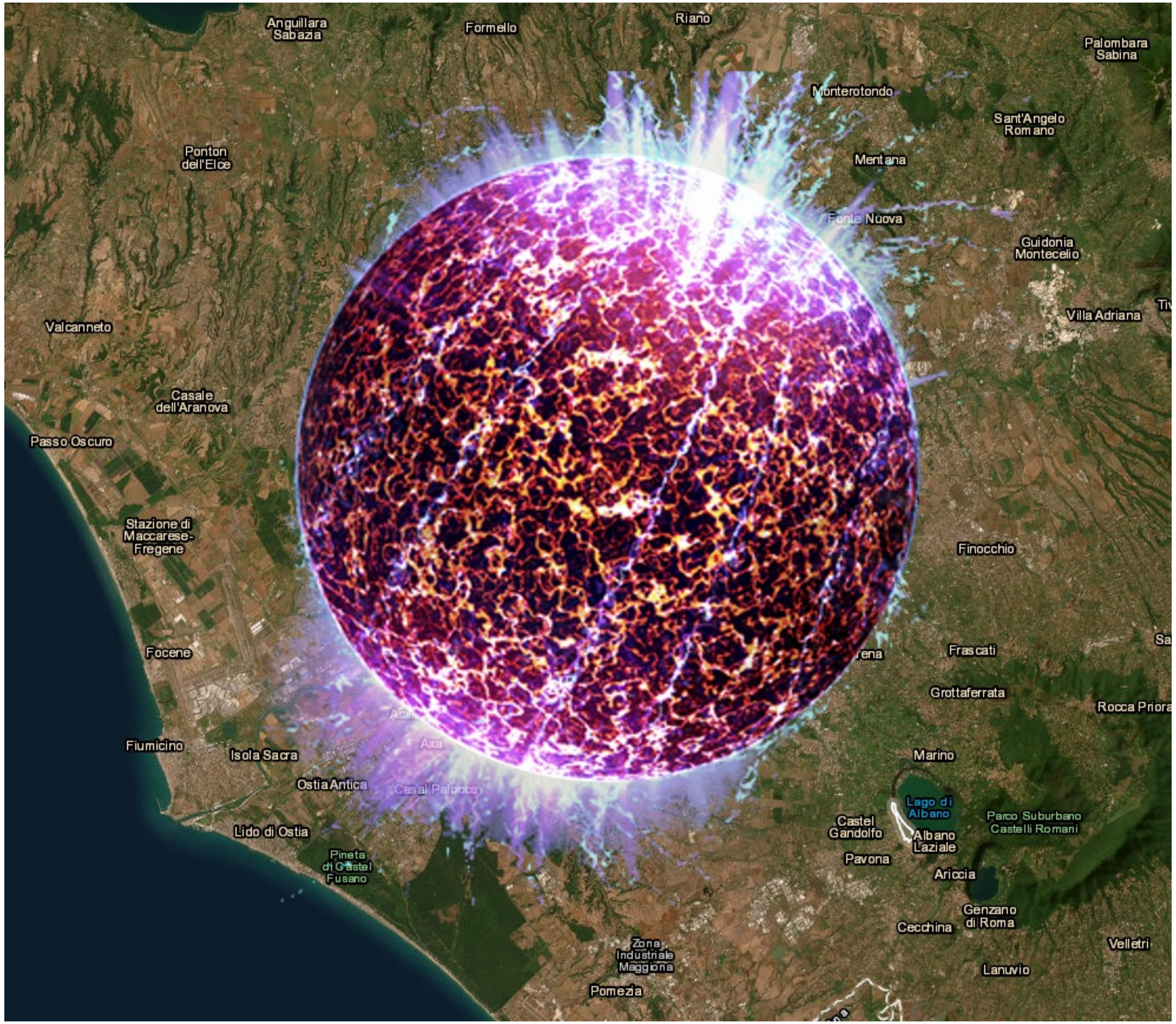
$$R_{NS} \sim (10 \div 20)\ \text{km} \sim 6\ r_g$$

$$B_{NS} \sim (10^8 \div 10^{15})\ \text{G}$$

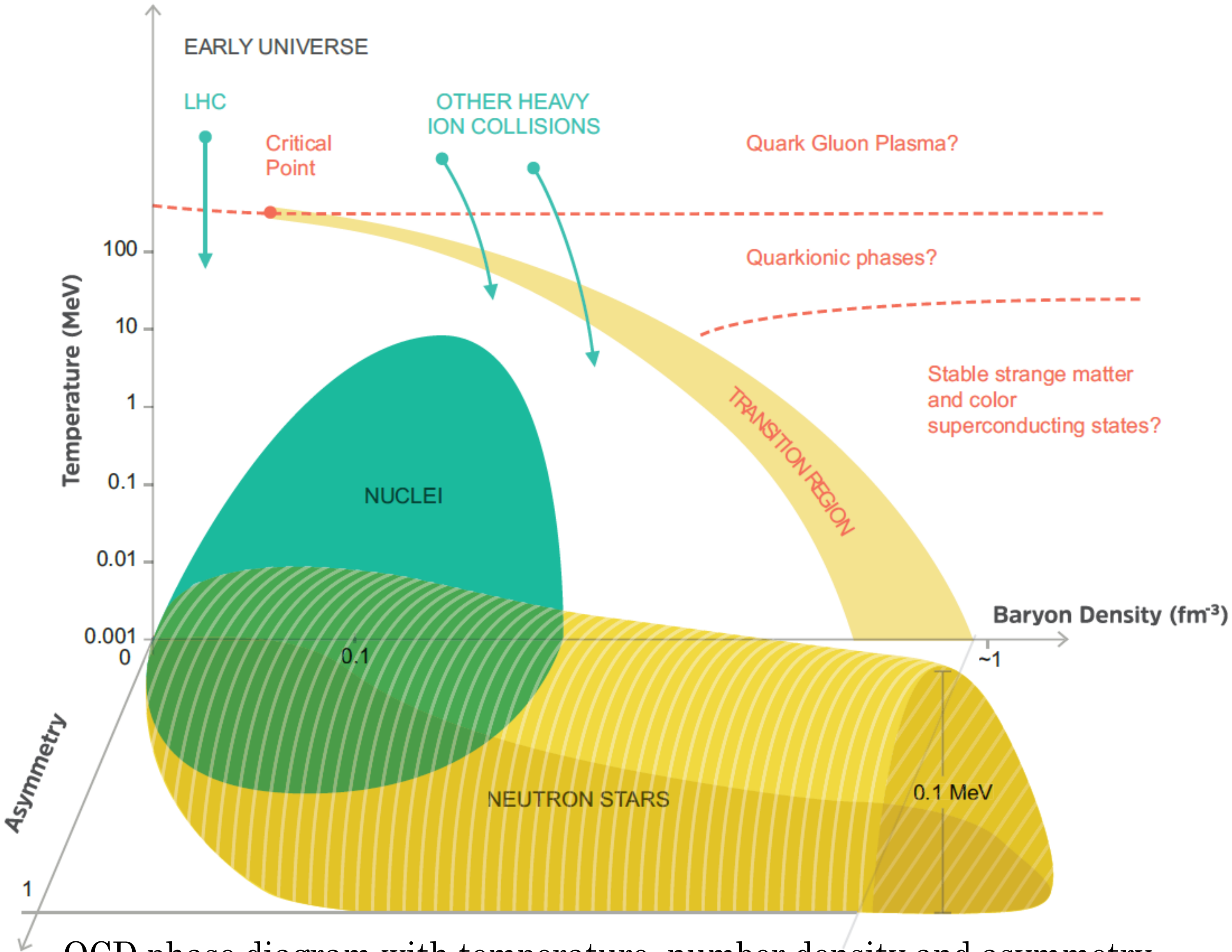


[Watts et al., 2016]

Compact objects



Neutron stars and ultradense matter



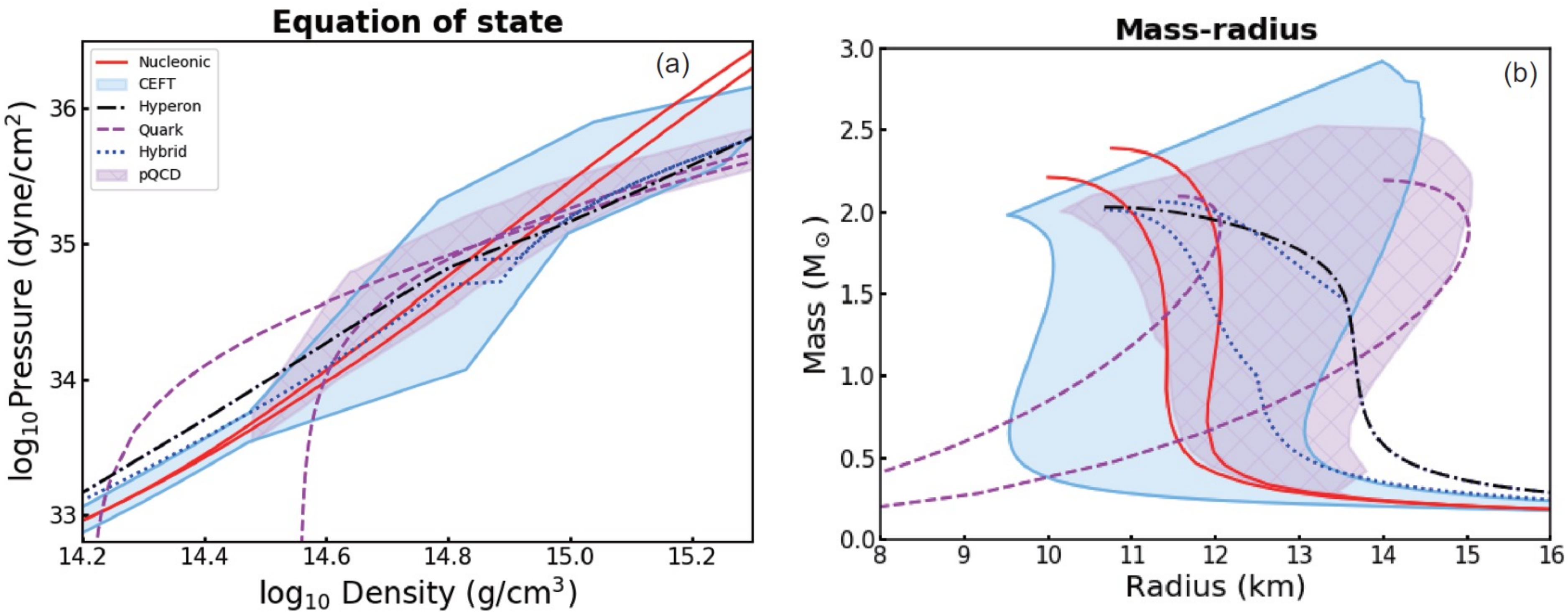
QCD phase diagram with temperature, number density and asymmetry *[Watts et al., 2019]*

Core density of neutron stars $\varrho_{NS} > \varrho_{atomic}$

$T_{eff} \sim 0$ K due to complete degeneracy of the nucleons

Protons only $1 \div 10\%$ of the nucleons within the core regions

Neutron stars and ultradense matter

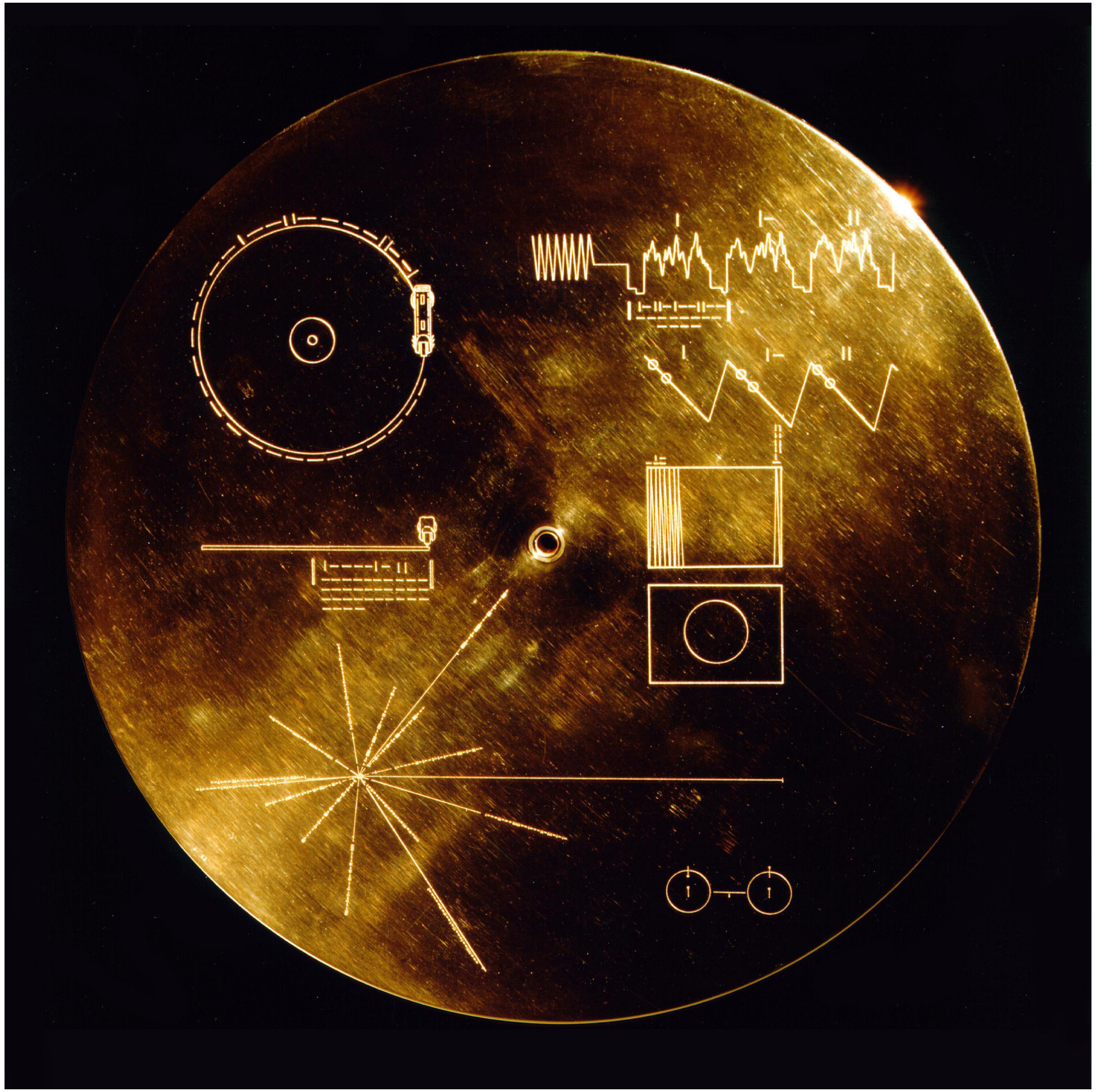


[Watts et al., 2019]

The measurement of neutron star **masses** and **radii** let us derive **constraints on their equation of state**

A **precision of a few percent** required to discern among similar EoS models

Pulsars: our cosmic clocks



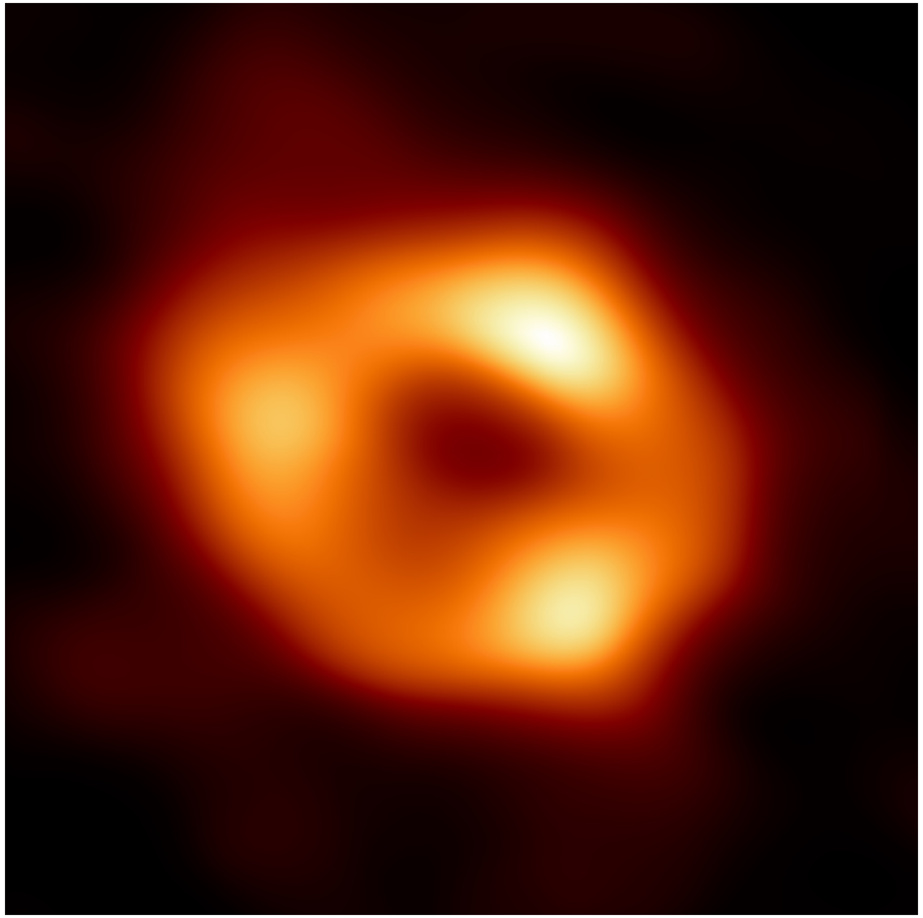
Now more than 3000!

Periods from 1 ms to ~ 10 s

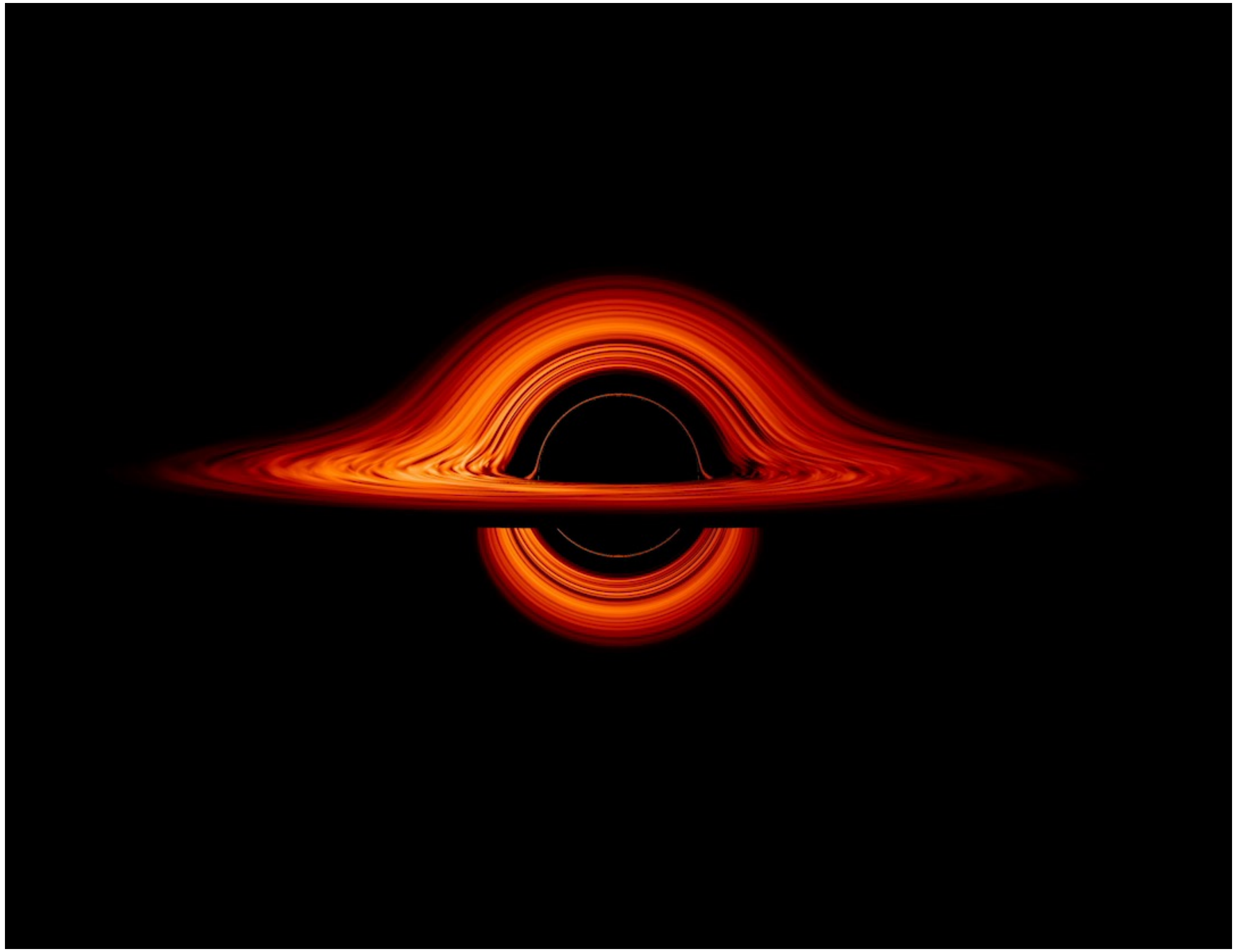
Among the most precise GR testing benches

Can be used for navigation

Black holes

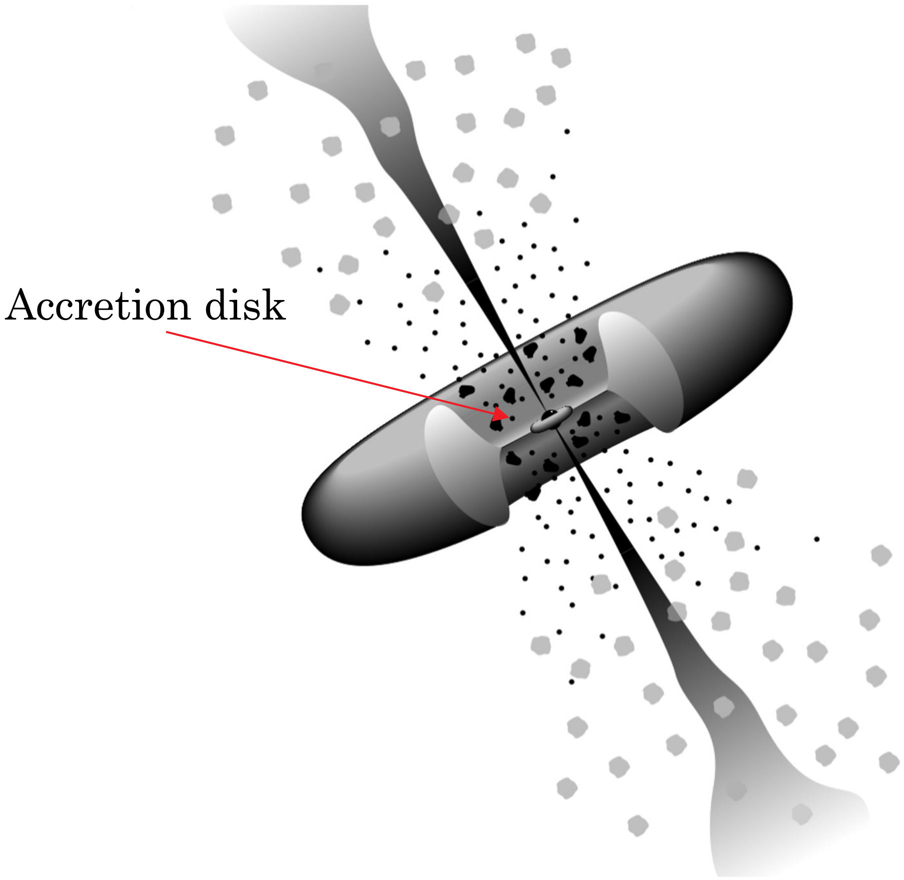


[EHT collaboration, 2022]

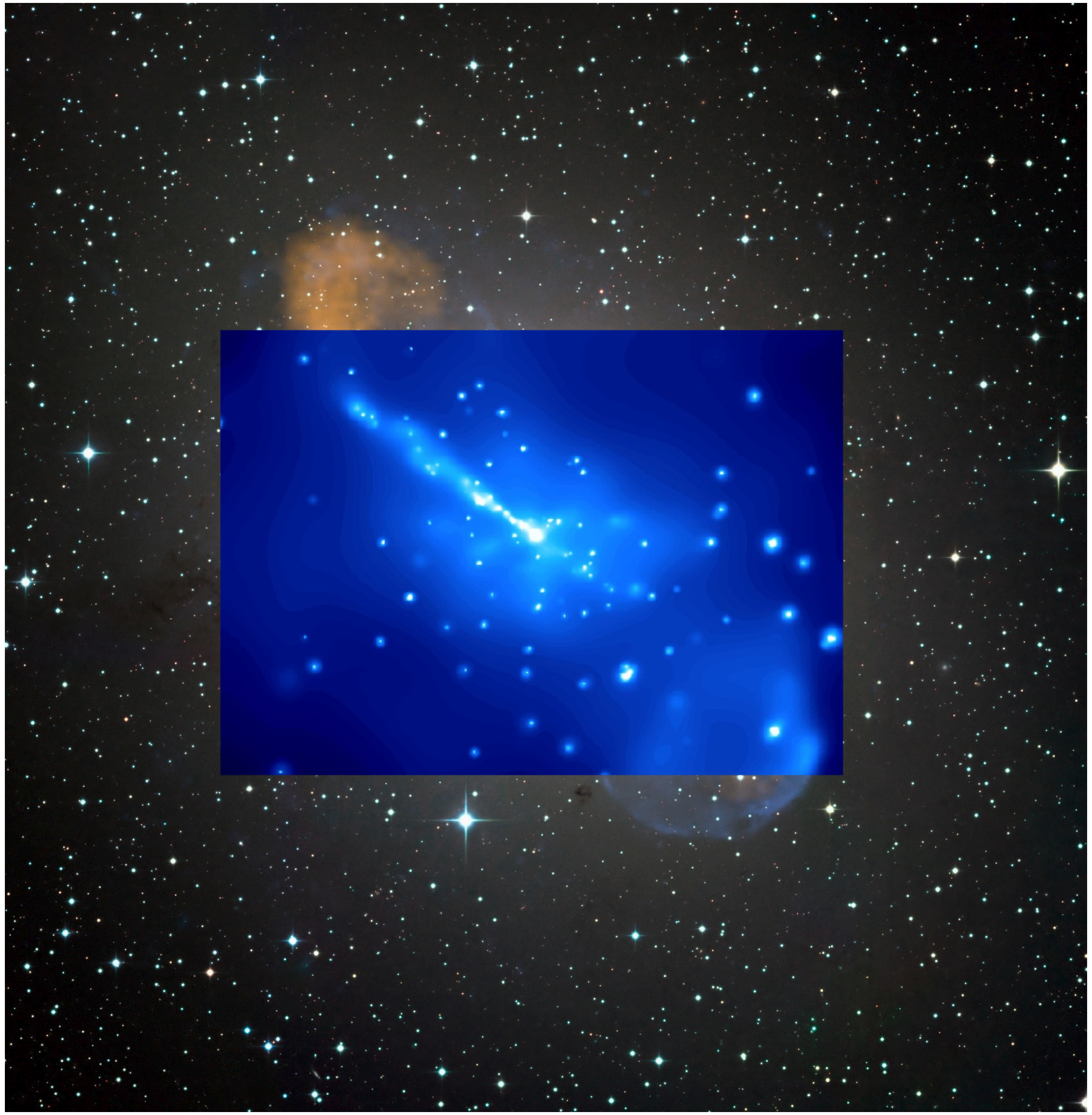


[Schnittman, 2019]

Black holes

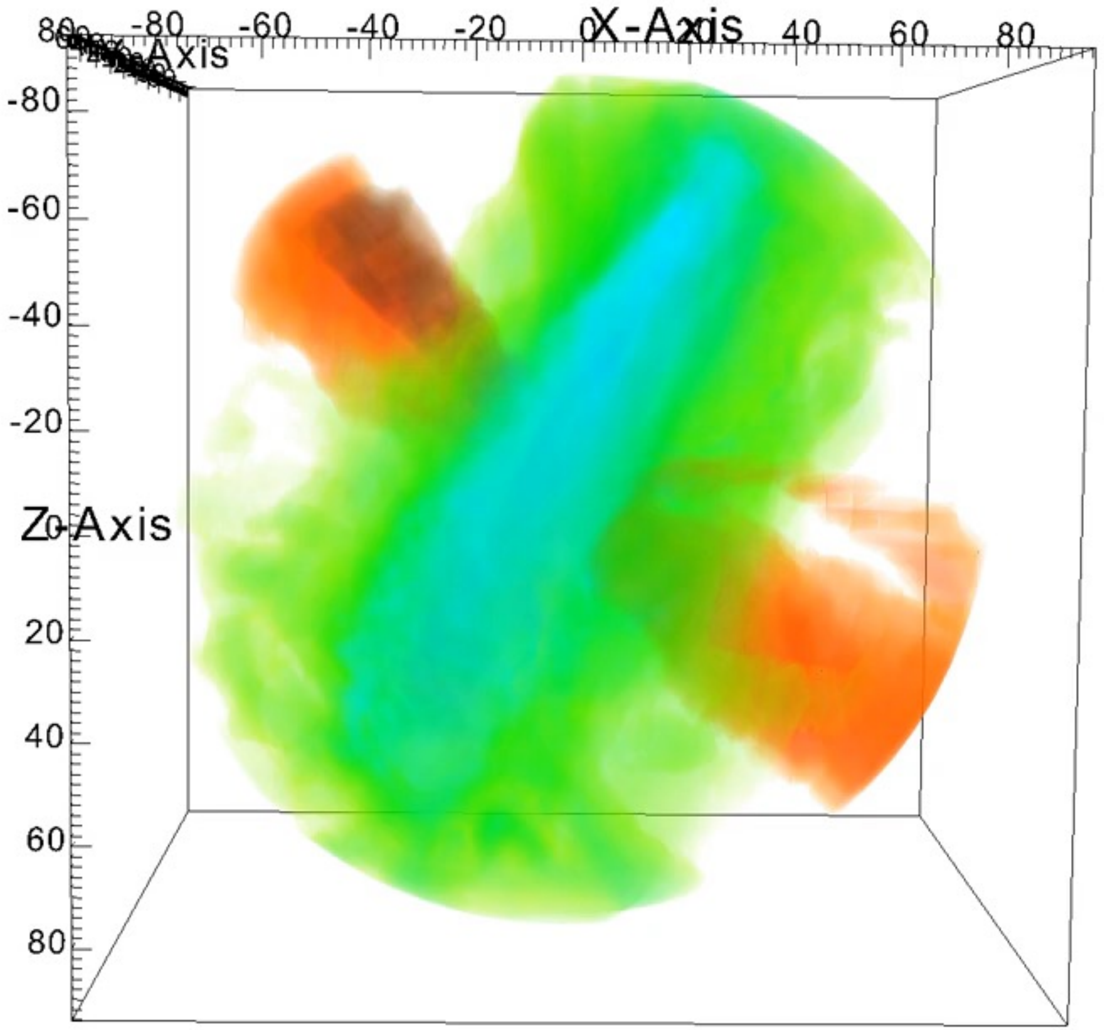


[Padovani, 1997]

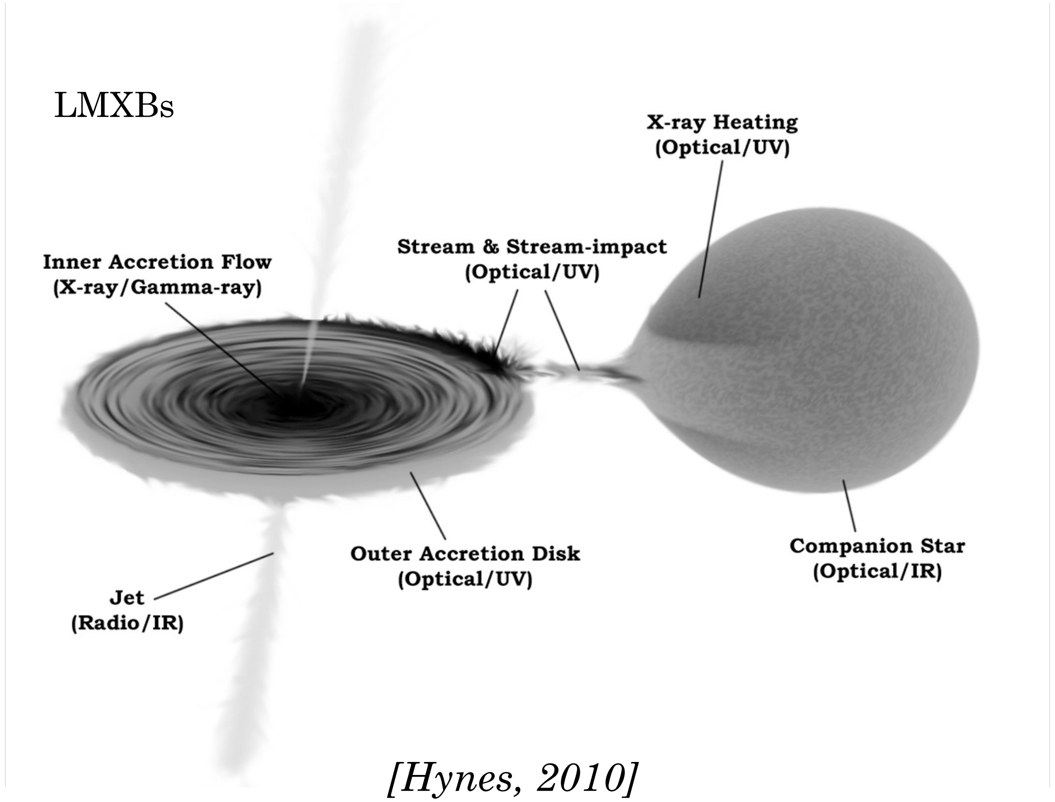


[ESO/NASA]

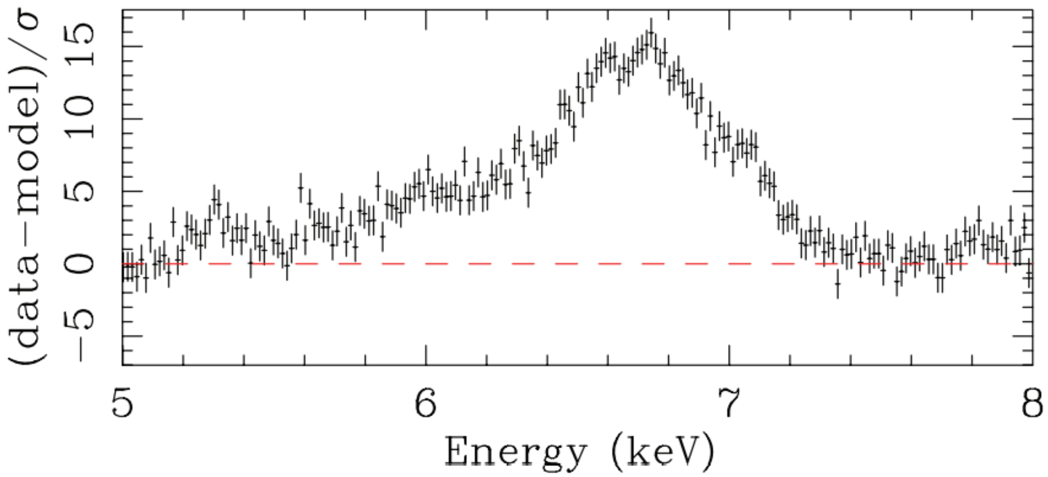
Accretion

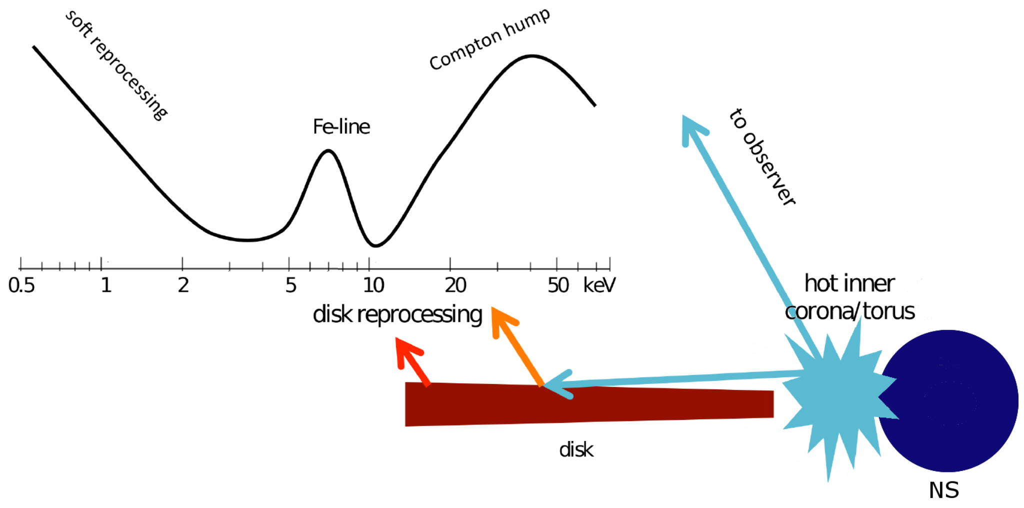


Accretion and X-ray spectroscopy



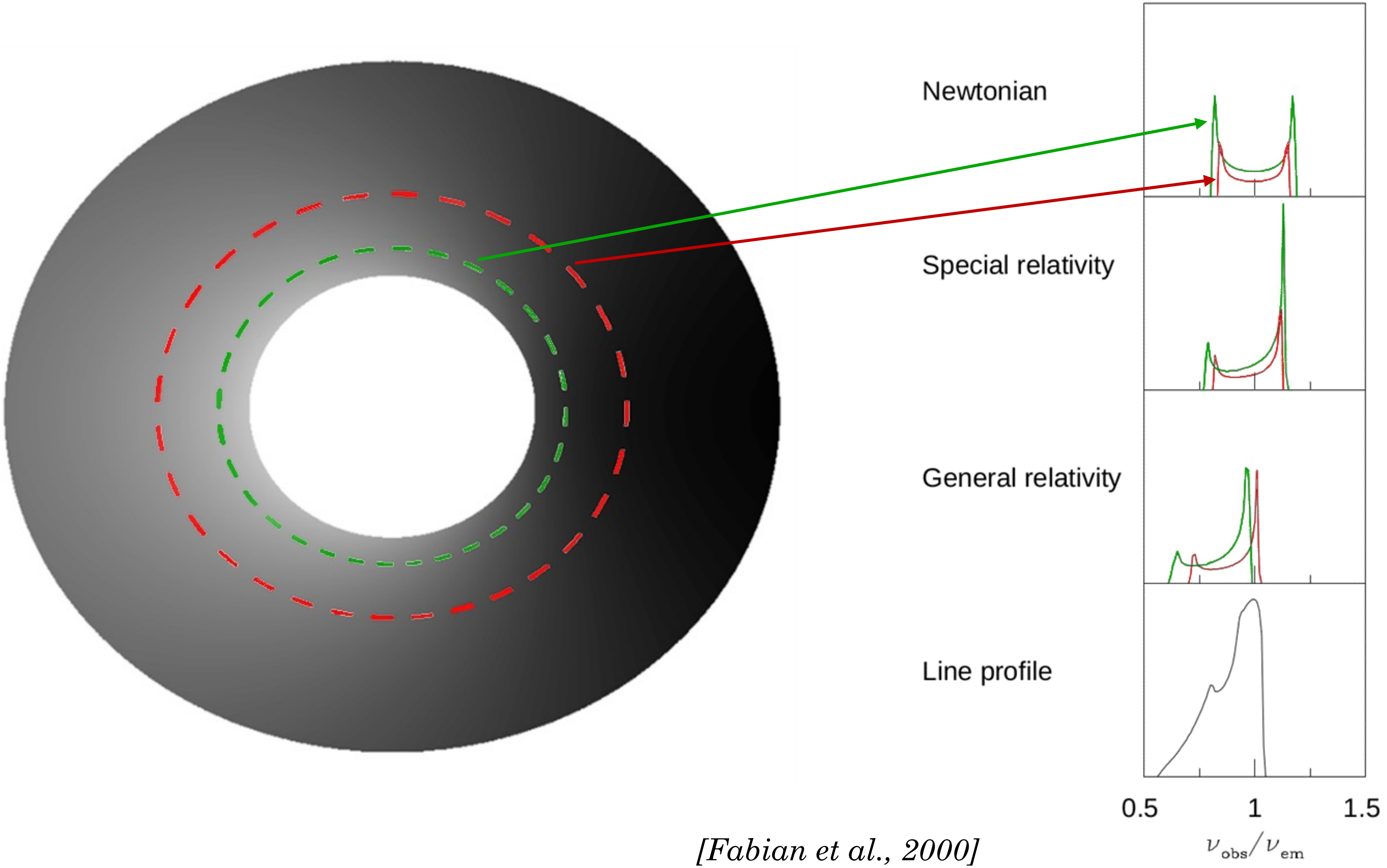
[Hynes, 2010]





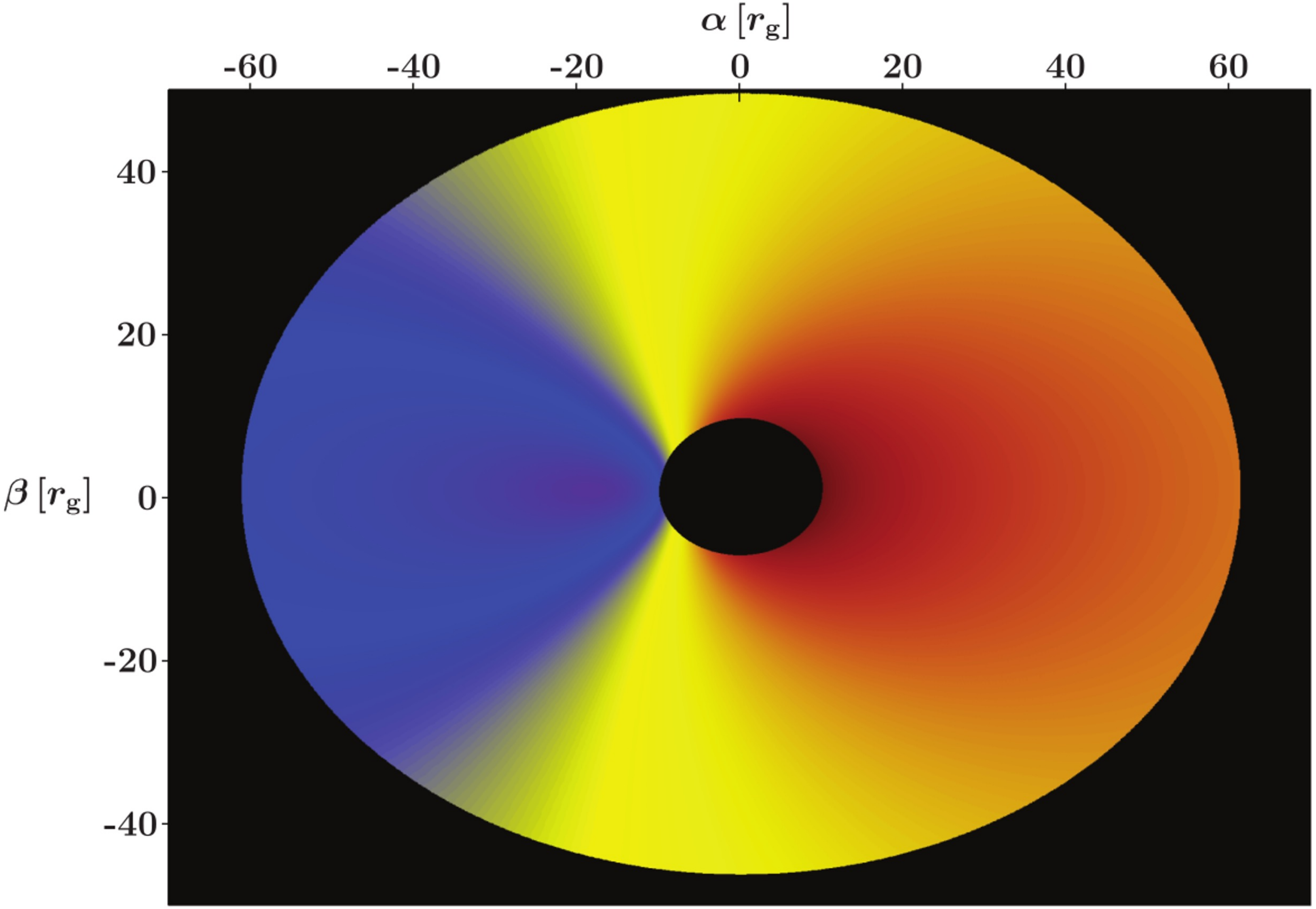
Top – An example of a broadened Iron line emitted by a LMXB (Di Salvo et al, 2009). *Bottom* – Schematic view of the reprocessed emission from an accretion disc.

Iron K-α lines in accretion disks



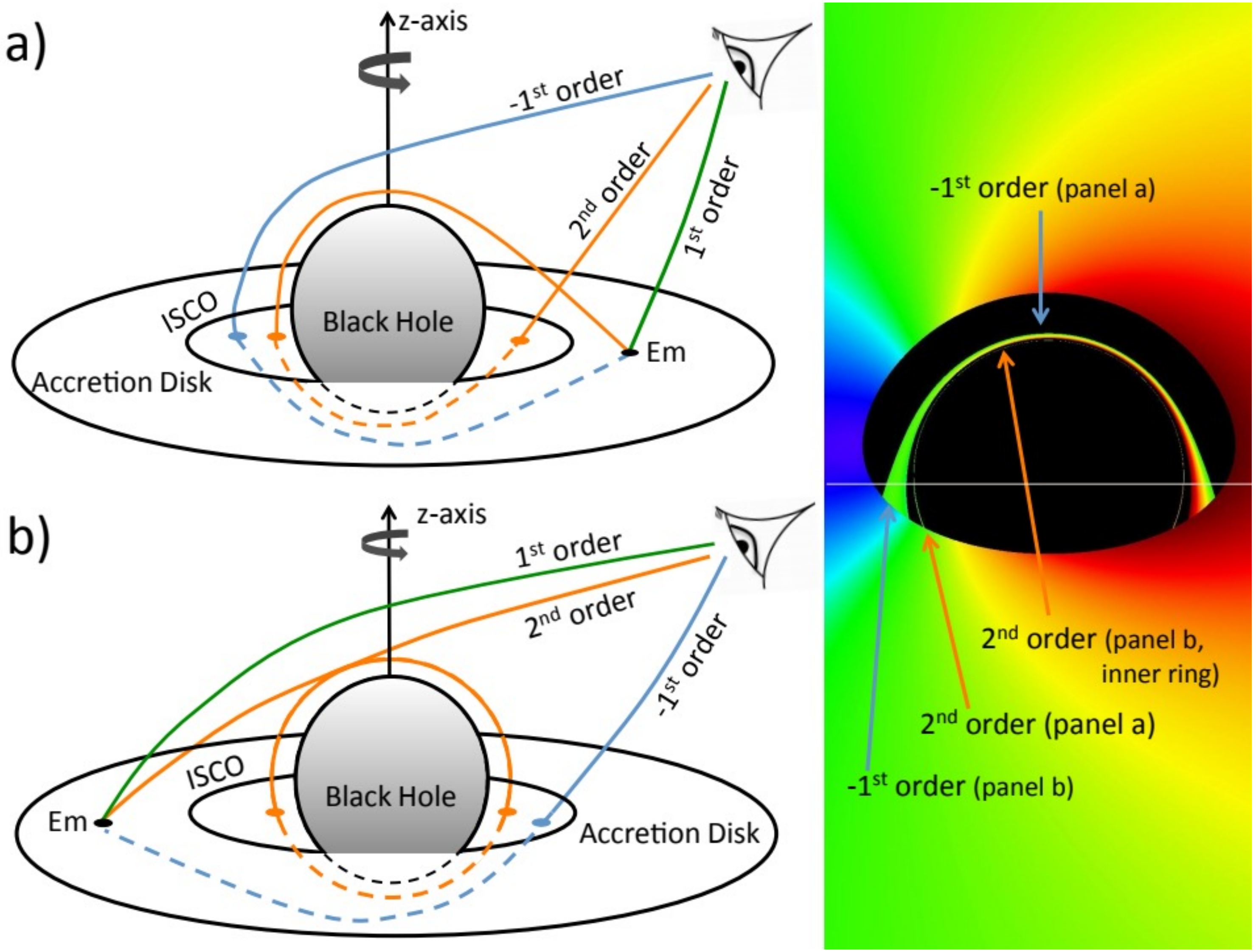
[Fabian et al., 2000]

Higher order images around BHs



[Dauser et al., 2010]

Higher order images around BHs



Too close for NSs

Strongly depends on BH spin and inclination

Full Kerr metric treatment needed