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Formation of Supermassive **Black Holes**





Alexander Heger (Monash) Tyrone Woods (Monash) Lionel Haemmerle (Geneva) Ralf Klessen (Heidelberg) Ken Chen (NOAJ, AASIA) Dan Whalen (Portsmouth)



The many Pathways to make massive black holes

massive black hole (Rees 1984)

The Forge of **Big Stars:** Then and Now





Formation Environment of the First Stars

(Hirano et al. 2013)

The Most Massive Stars Today



R136

- young massive star cluster
- Age around 1.5 Myr
- Star "a1": maybe 200 M_o initial mass
- (Crother et al. 2010)

Eta Car – a really big star in our galaxy today

Evolution of Center for Different Initial Masses



The Death of the Stars







Supermassive Stars







The Centre of our Galaxy

The Cosmic Frontier: Monster Supermassive Black Holes at the Cosmic Dawn

SDSS J0100+2802 Z=6.3 SDSS J1148+5251 z=6.4 ULAS J1120+0641 Z=7.1



• $M_{BH} \sim 1.2 \times 10^{12} M_{\odot}$

(Wu+2015)

(from Yuexing Li 2017)

- L_{bol} ~10¹⁴ L_☉
 (Barth+03)
- M_{BH} ~3x10⁹ M_☉ (Willot+03)

- $L_{bol} \sim 6.3 \times 10^{13} L_{\odot}$ (Mortlock+2011)
- M_{BH} ~2x10⁹ M_☉ (Mortlock+2011, Matson+2011)

"Really" Big Stars?

- We observe quasars at high redshift z > 6
- Requires supermassive black holes M ~ 10⁹ solar masses
- Accretion would need to be very efficient to make these
- Other possibility: Make dense cluster for very big primordial cloud, runaway star merging
- Or make big stars with WIMPs...
- We only need a very few of them...

Form Inside Proto-Galaxies?



Proto-Galaxy at z=15 in LW background.

(Whalen et al. 2013)



Primordial Supermassive Stars



(Woods+ 2017, in prep.)

Primordial Supermassive Stars: Collapse or Shine?



rp-process at Collapse?



Rotation as Barrier for Building Stars



- Accretion from a disk can spin up star quickly
- To build big stars, significant angular momentum transport is needed.
- For supermassive stars the effective specific angular momentum accreted needs to be less than 1% of surface keplerian

Formation of Supermassive Stars by Rapid Accretion





Accreting Supermassive Stars



(Woods+ 2017)

Accreting Supermassive Stars





Accreting Supermassive **Stars** in the HRD

Depending on accretion rate, they can be quite bright in ionising photons.

. and a slightly less

supermassive star





Lightcurve of 55kM_o Star



Supermassive Stars

