Catch me if you can:

is there a 'runaway-mass' black hole in the Orion Nebula Cluster?

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Star cluster dynamics

- two-body relaxation (cluster evolution) on time-scale

$$t_{\rm relax} \approx \frac{v^3}{8\pi\, G^2 m^2 n\, \ln\Lambda}$$

- mass segregation
- gas expulsion due to radiation from massive OB stars $\longrightarrow$ weakening of the mean gravitatinal potential $\longrightarrow$ cluster expansion (or even dissolution)
- primordial binaries: carry substantial fraction of the cluster energy
- three-body interactions: acceleration of stars to high velocities, shrinking of tight binaries
- "physical" stellar collisions — $R_\star \approx R_\odot (M_\star/M_\odot)^{0.6}$
- stellar evolution

Orion nebula cluster

Observations:

- $D \approx 400\,\mathrm{pc}$
- age $\lesssim 2.5\,\mathrm{Myr}$
- $M_\mathrm{c} \approx 1800\,M_\odot$
- $M_\mathrm{gas} \lesssim 100\,M_\odot$
- $r_\mathrm{h} \lesssim 0.8\,\mathrm{pc}$
- $t_\mathrm{relax} \gtrsim 10\,\mathrm{Myr}$
- $N_\mathrm{OB} \approx 15$
- $\sigma \approx 2.5\,\mathrm{km\,s^{-1}}$
- $\sigma_\mathrm{core} \gtrsim 4\,\mathrm{km\,s^{-1}}$

HST image $\approx 3.5 \times 3.5\,\mathrm{pc}$

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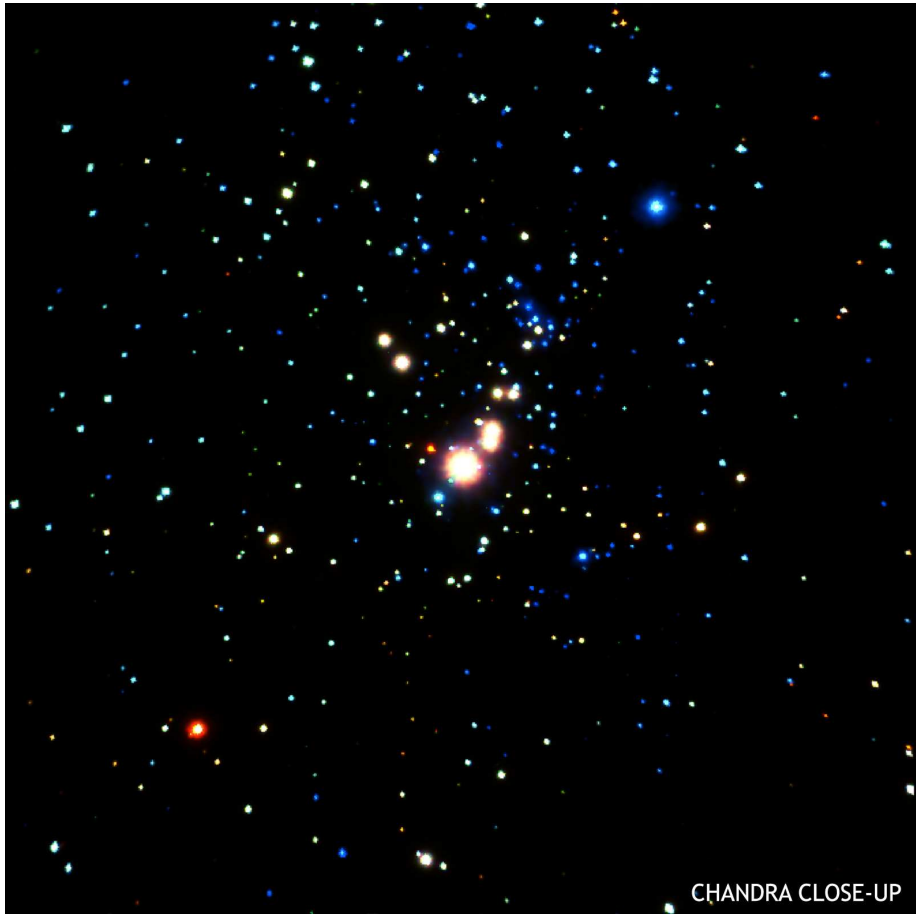

Chandra image $\approx 2.5 \times 2.5\,\mathrm{pc}$

Orion nebula cluster – model

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Model – initial conditions:

- $M_\mathrm{c} = 2700\,M_\odot$
- $M_\mathrm{gas} = 2700\,M_\odot$
- $r_\mathrm{h} \approx 0.1\,\mathrm{pc}$
- $t_\mathrm{relax} < 1\,\mathrm{Myr}$
- $N_\mathrm{OB} = 50$

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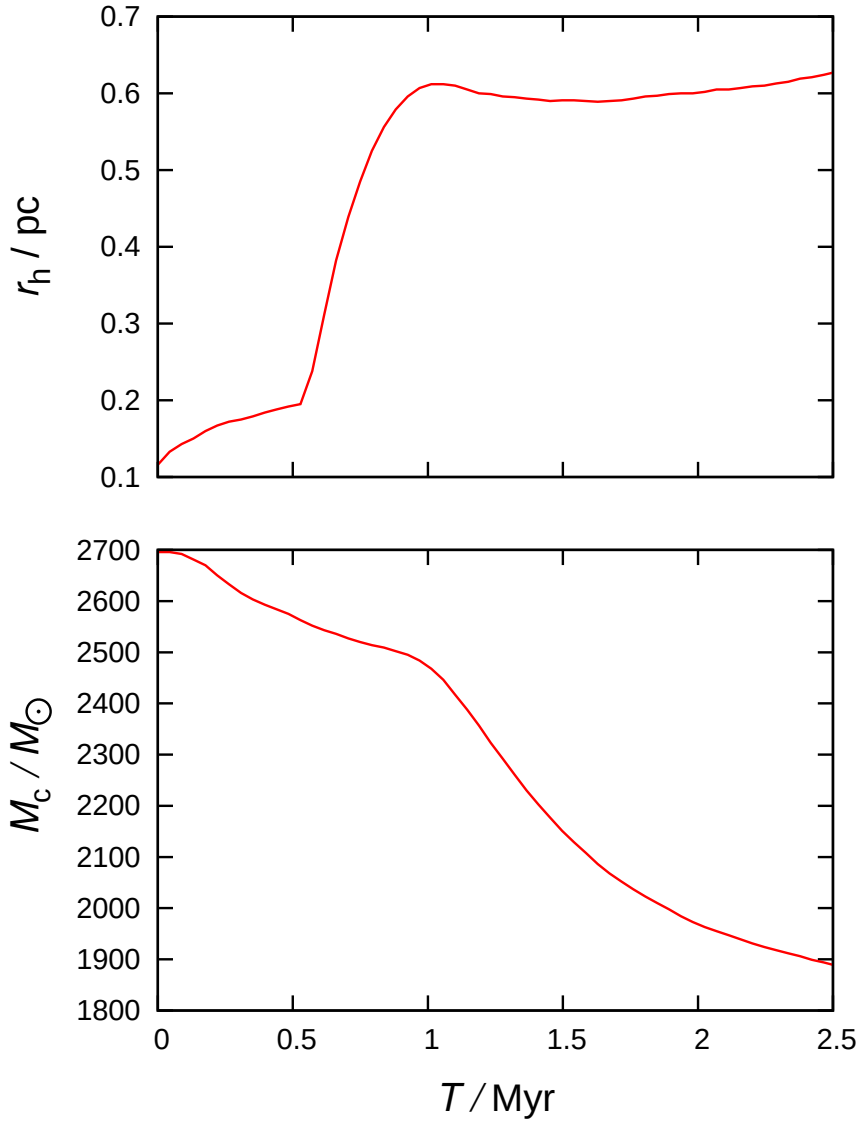

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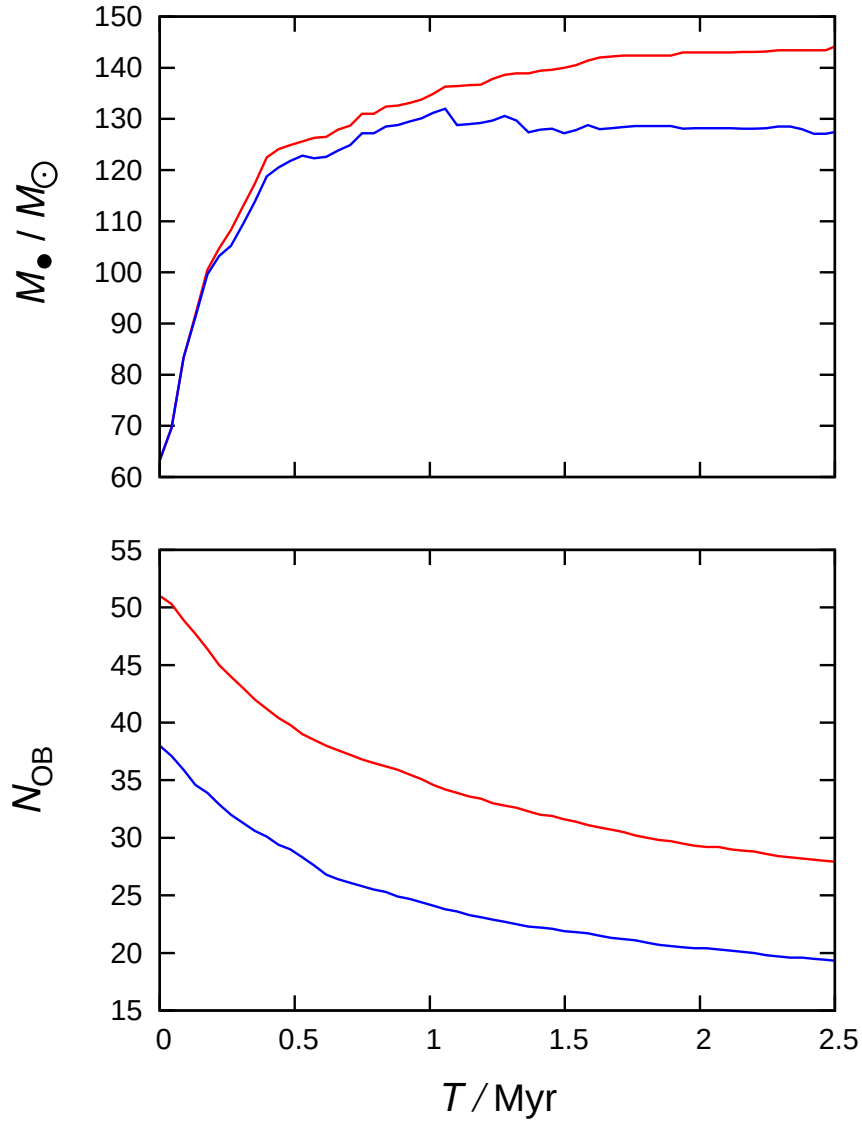

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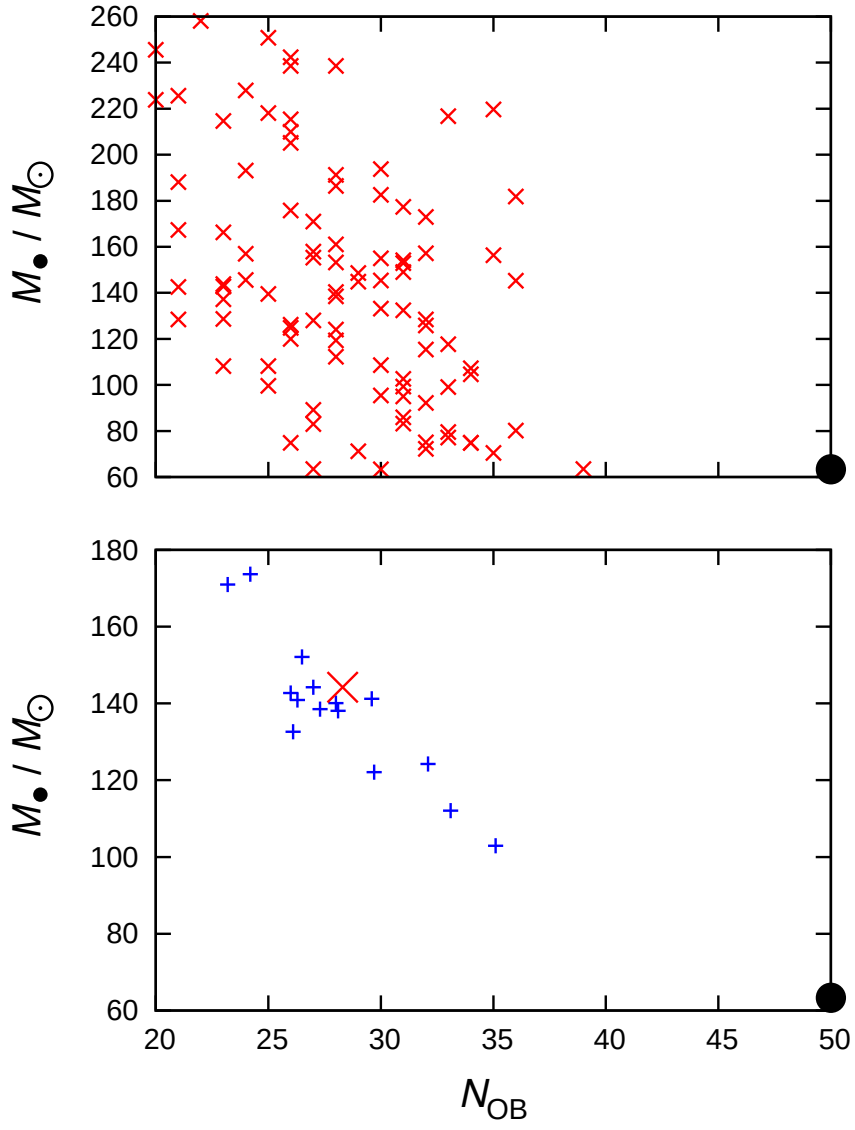

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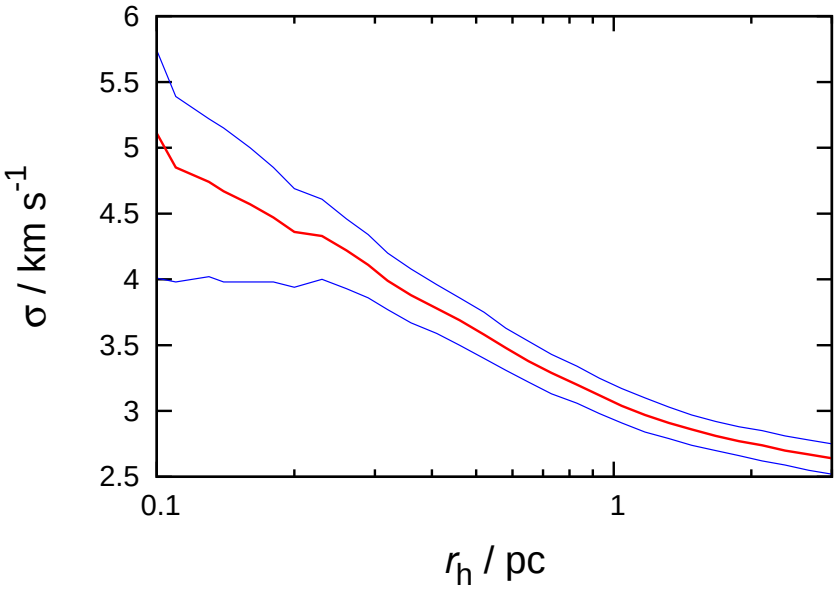
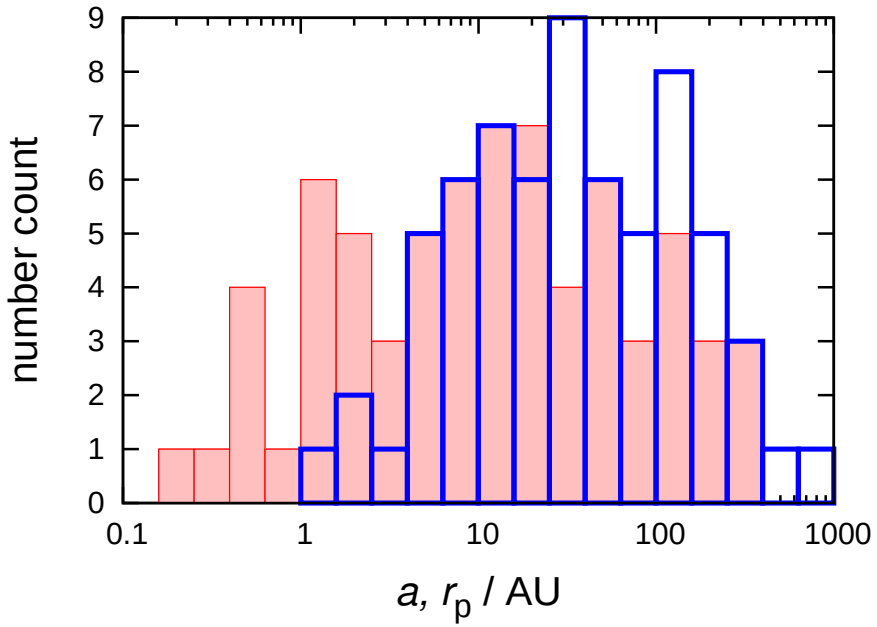


Runaway-mass star or black hole?

No evidence for a runaway-mass star in the ONC $\longrightarrow$ direct collapse to an IMBH?

- possible detection through:
- secondary star with $v_{\rm orb} \gtrsim 10\,{\rm km\,s^{-1}}$ ($\approx 70\%$ probability)
- episodic accretion of stellar wind from a secondary O star ($\approx 50\%$ probability)



For comparison: Cyg-X1: $M_{\rm BH} \approx 10\,M_\odot$, $M_{\rm s} \approx 25\,M_\odot$, $a \approx r_{\rm p} \approx 0.2\,{\rm AU}$, $L \approx 2 \times 10^{37}{\rm erg\,s^{-1}}$

Hunting the IMBH

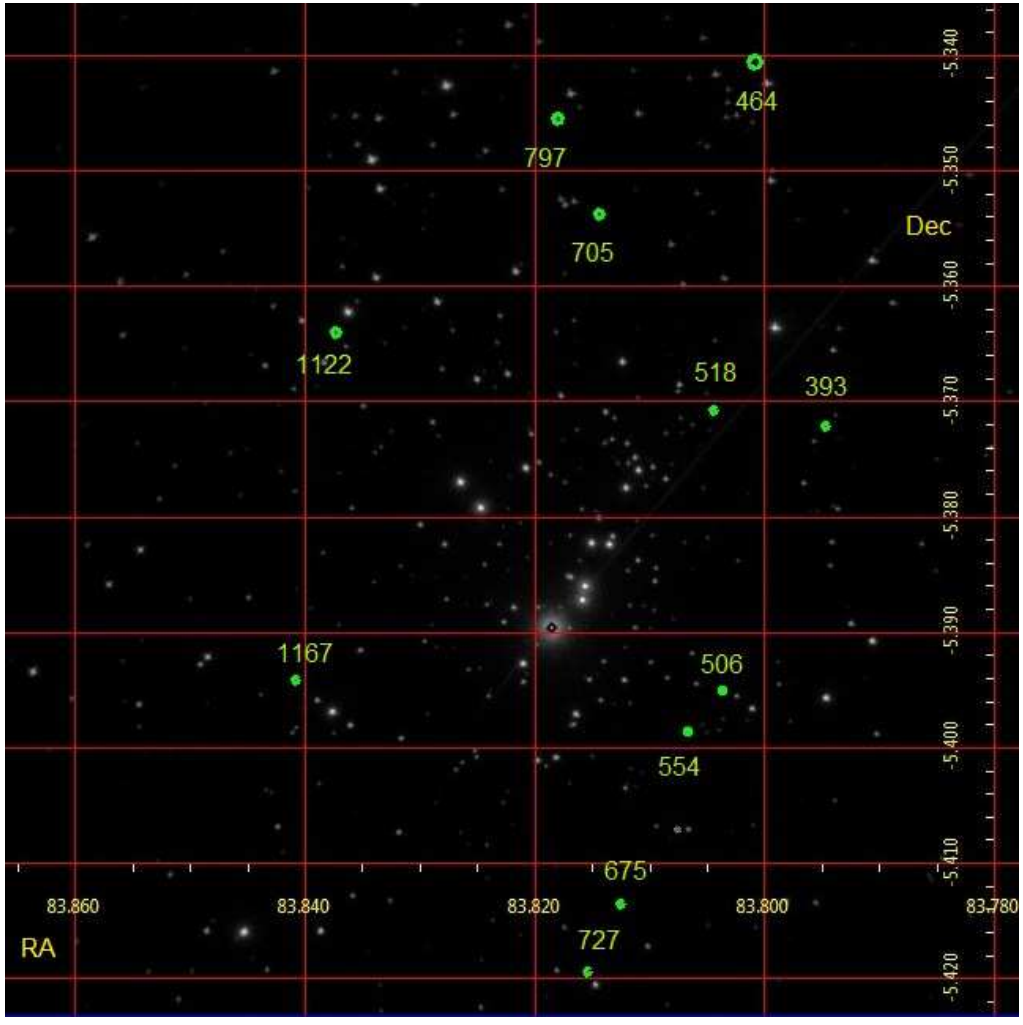
What?

- $\sim 100\,M_\odot$ black hole accreeting a stellar wind from a companion on highly eccentric orbit with period $\gtrsim 10\,\mathrm{yr}$
- X-ray activity, variability

How?

- ESAC trainee project (Aisling Murphy)
- Chandra Orion Ultradeep Project (COUP; 2003; $\approx 800\,\mathrm{ks}$)
- Chandra follow up (2012; $\approx 80\,\mathrm{ks}$)
- source identification, flux determination (in $0.5 - 8\,\mathrm{keV}$)
- cross-identification, variability determination
- candidate selection according to minimal variability

Candidate sources



Conclusions

- viable model of the evolution of the ONC which is able to match all basic observables (mass and size, velocity dispersion, number of the OB stars)
- two modes of removal of OB stars – ejections and collisions – mutually correlated $\Longrightarrow$ low abundance of OB stars indicates presence of the massive merging object
- 22 candidate sources according to high variability in X-rays
  - some of them have been recognised as K/M dwarfs before
  - low significance for most of the others due to worse detection limit in 2012
  - the most promising candidate, COUP ID 554, with variability factor $\approx 95 \pm 47$
- ToDo:
  - revise the source identification
  - study spectral properties of the candidate sources