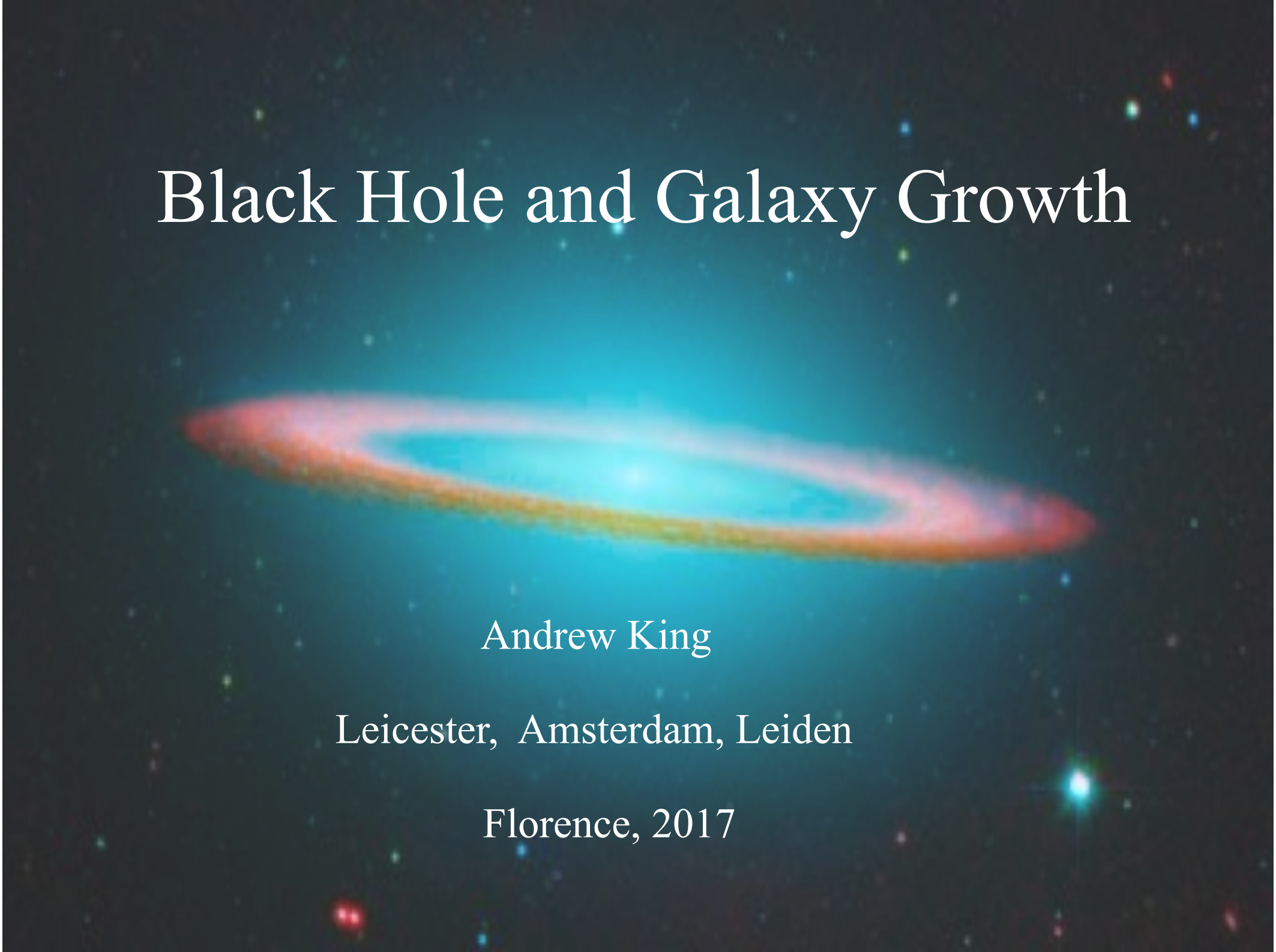
Black Hole and Galaxy Growth



Andrew King

Leicester, Amsterdam, Leiden

Florence, 2017

1. how do SMBH grow?

Soltan => gas accretion (low z)

disc formation is unavoidable

all accreting gas has enough angular momentum to orbit the hole, so a disc always forms

large disc mass => fragmentation, star formation, mass loss....

disc probably never in steady state: Bondi is not a good estimate

2. disc accretion is slow

Σ spreads on *viscous timescale*

$$t_{\rm visc} = \frac{R^2}{\nu} = \frac{1}{\alpha}\left(\frac{R}{H}\right)^2 t_{\rm dyn}$$

where $t_{\rm dyn}$ is the *dynamical timescale* $R/v_K = (R^3/GM)^{1/2}$

this is *long*: $t_{\rm visc} \simeq 10^{10}$ yr for $R \sim 1$ pc

can we get gas closer in - cancel angular momentum?

either borrow some a.m. from SMBH (via Lense-Thirring) to cancel gas a.m. (`disc tearing'),

or use radial SMBH feedback to give energy but not a.m. => eccentric => collisions….

accretion rate limited by Eddington (radiation pressure) limit:

$$\eta c^2 \dot{M}_{\rm acc} \leq L_{\rm Edd} = \frac{4\pi G M c}{\kappa}$$

and some of rest–mass energy goes into radiation, i.e.

$$\dot{M} = (1-\eta)\dot{M}_{\rm acc}$$

$$=> \dot{M} \leq \frac{1-\eta}{\eta}\frac{M}{t_{\rm Edd}}$$

where

$$t_{\rm Edd} = \frac{\kappa c}{4\pi G} = 4.5 \times 10^8 \text{ yr}$$

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holes with low spin can grow *much* faster –
(and are easier to retain if they coalesce)

`chaotic' accretion can keep spin low, grow SMBH to $M \gtrsim 10^9 M_\odot$
by $z \gtrsim 6$ from initial *stellar* masses

3. does stellar bulge grow with SMBH?

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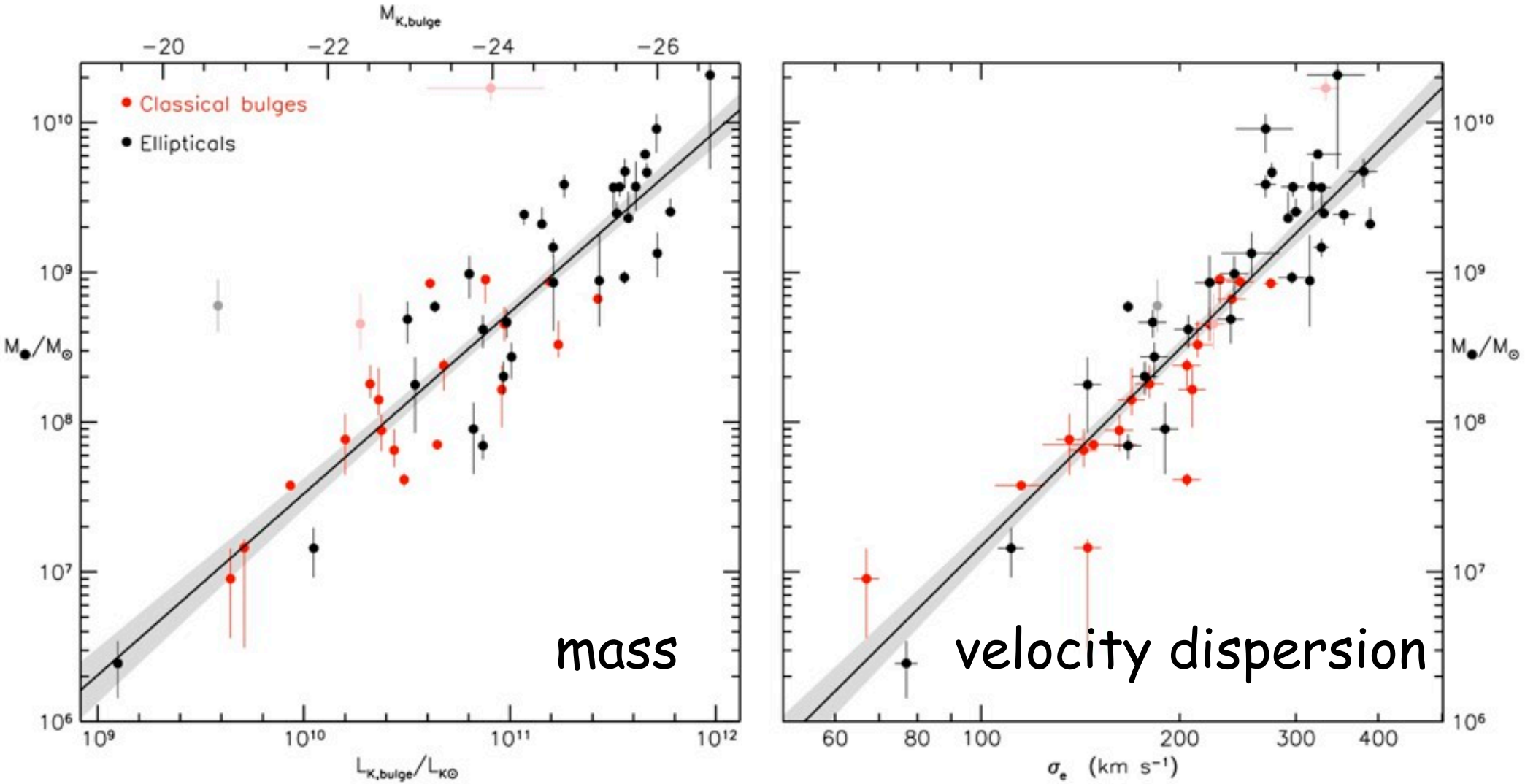
at low z, galaxy knows about central SMBH



galaxy bulge ⟶

Kormendy & Ho, 2013

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(`tertium quid')

- SMBH grow through disc accretion
- disc accretion is slow - need to make discs small - *chaotic accretion?*
- then rapid SMBH growth possible, as SMBH spin stays low
- and SMBH growth even from stellar masses viable
- $M \propto \sigma^4$ and $M_b \propto \sigma^4$ result separately from (BH, stellar) feedback
- $M - M_b$ `relation' is two parallel relations