Do Nuclear Star Clusters and Supermassive Black Holes Follow the Same Host-Galaxy Correlations?

Peter Erwin
MPE Garching

With: Dimitri Gadotti (ESO)

No.

(Thanks for listening!)

(Well, at least not for spirals…)

Compact, Massive Objects in the Centers of Galaxies: Are NCs Analogs of Supermassive Black Holes?

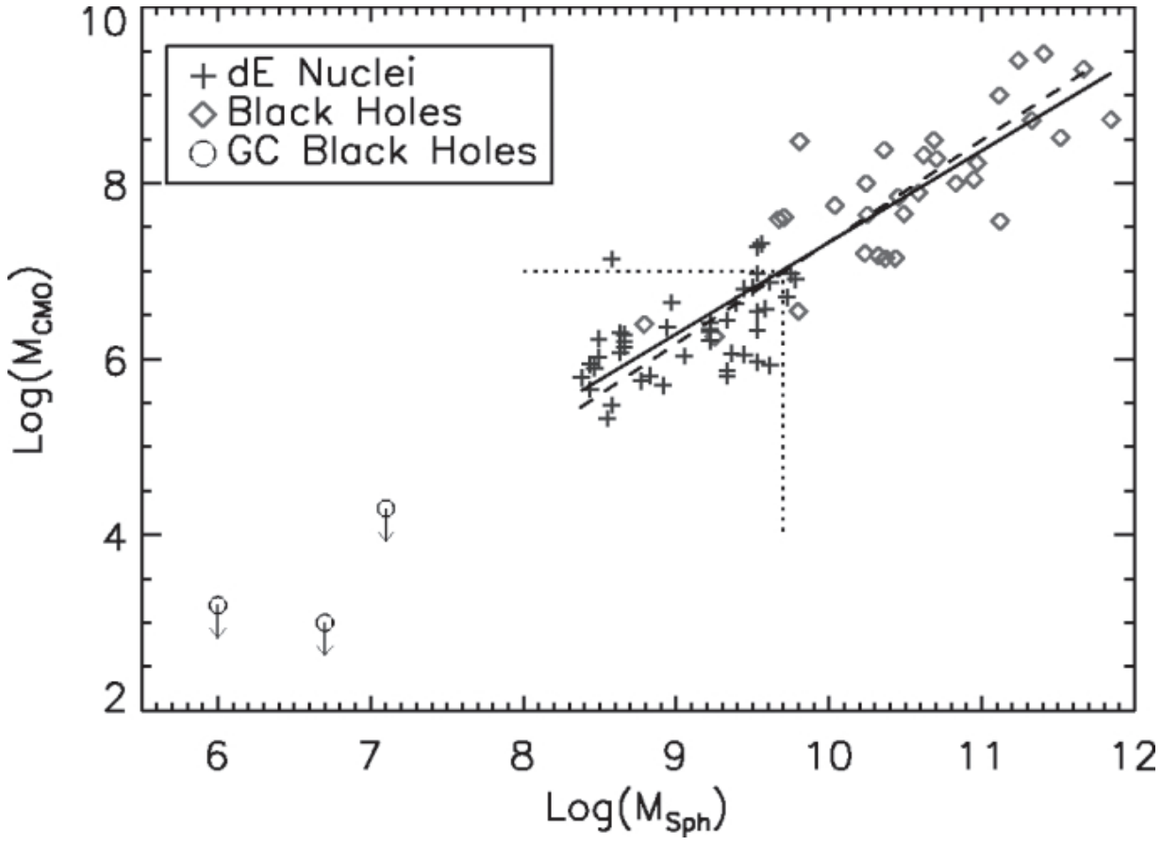
- **A recent suggestion: Just like SMBHs, NC *mass* scales with *spheroid* mass**

- **Wehner & Harris 2006; Ferrarese+2006; Côté +2006; Rossa+2006; Balcells+2007**

- **NCs are somehow an *extension* of SMBHs to low-mass galaxies; they are both "Central Massive Objects" (CMOs)**

- **Common formation mechanism ...?**

Wehner & Harris (2006)



Caveats

- **Main studies arguing this (Ferrarese+2006; Wehner & Harris 2006) used only early-type galaxies (dE and E; some S0)**

- **Nuclear cluster masses: mostly based on using colors to estimate optical-band M/L (or even assuming a single M/L for clusters)**

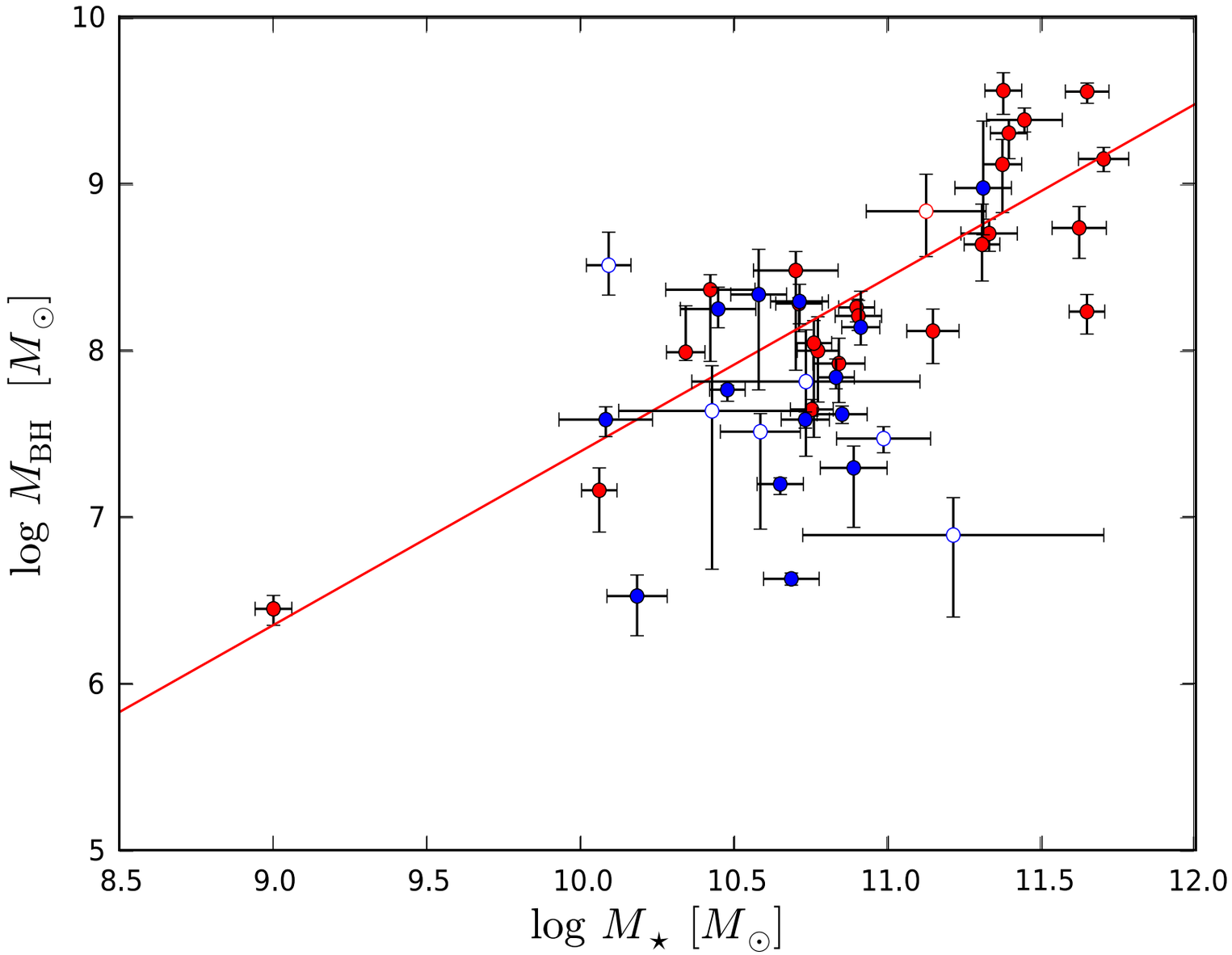
- **So is this still true for galaxies with little or no bulge, with more accurate cluster masses?**

Revisiting the Black Hole–Bulge Correlations

Erwin & Gadotti (2010, in prep)

- **Updated list of high-quality SMBH detections**
- **Careful accounting of errors, including distance errors**
  - **Focus on galaxies with well-determined distances (Cepheids, SBF, etc.)**
- **2D bulge-disk-bar decompositions of disk galaxies (updated version of BUDDA code [de Souza et al. 2004], including bars and nuclear point sources)**
  - **Testing effect on B/T ratio of including bar component**
  - **Does relative mass or size of bar affect SMBH correlations?**
- **Calculation of galaxy and bulge stellar masses: 2MASS *K*-band luminosity + M/L ratios from Bell et al. 2003**

SMBHs & Total Stellar Mass

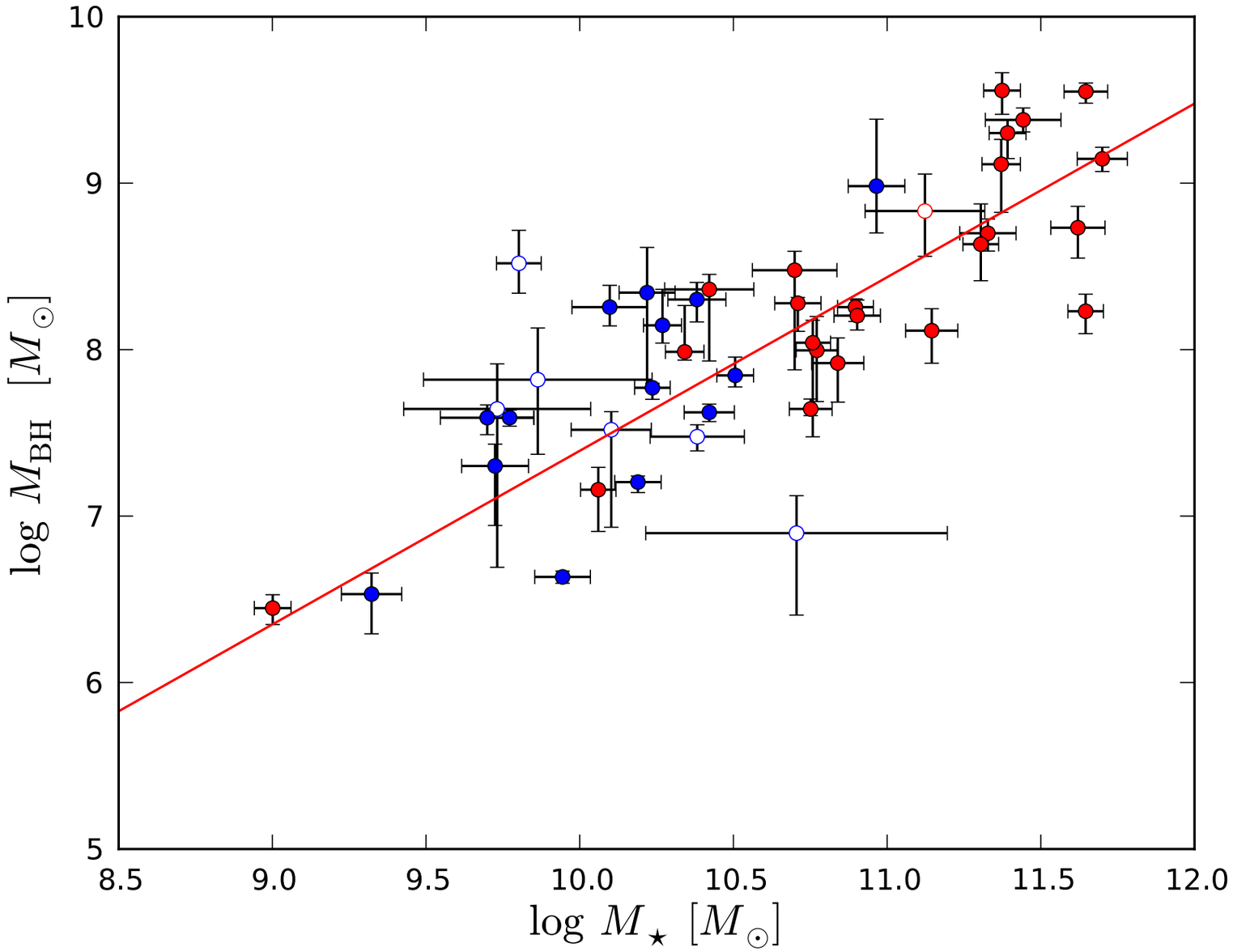


Line = fit to elliptical galaxies [red] only

Poor correlation for disk galaxies:

$r_S = 0.30$ $(P = 0.29)$

SMBHs & *Bulge* Stellar Mass



Much better correlation for disk galaxies:

$r_S = 0.71$ $(P = 0.0047)$

So SMBHs correlate with bulge mass, not total mass (cf. Kormendy & Richstone 1995, etc.)

So — Do NCs really correlate with *bulge* stellar mass (like SBMHs), or with *total* stellar mass?

(E.g., evidence that NC luminosity scales with *galaxy* luminosity — Carollo+1998; Lotz+2004; etc.)

Nuclear Cluster Masses

- **Main Sample: dynamical mass measurements in spirals (16 galaxies)**
- **Sources of NC masses (almost all in late-type spirals!):**
  - **Walcher+2005: 9 galaxies (mostly Scd–Sd); Ho & Filippenko 1996: NGC 1705 ("S0"/BCD); Böker+1999: IC 342 (Scd); Matthews+1999 and Gebhardt+2001: M33 (Scd); Barth+2009: NGC 3621 (Sd); Milky Way (Launhardt+2002); NGC 4303 (L. Colina); M31 (Kormendy & Bender 1999)**
  - **Median Hubble type = Scd**
- **Secondary Sample: *Spectroscopic* masses from Rossa+2006: 15 galaxies (Sa–Sm; median = Sbc)**

Galaxy and Bulge Stellar Masses

As for SMBH study:

- **2MASS *K*-band photometry (Malhotra+1996 for M31 & M33)**

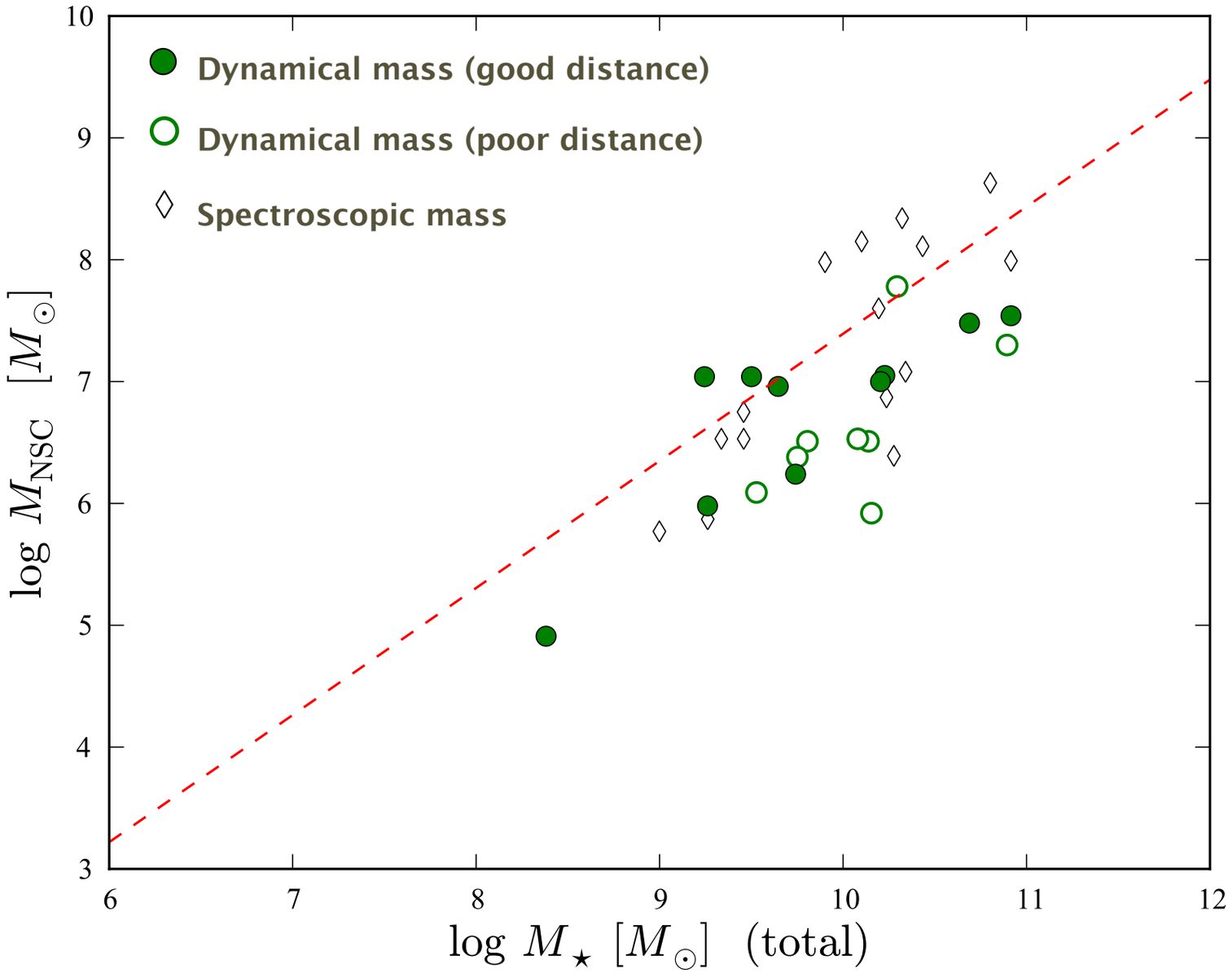
- **Optical colors → M/L ratios (Bell & de Jong 2001; Bell +2003 *or* Zibetti+2009)**

Bulge/disk decompositions from 1-D profiles, now adding 2D decompositions

(Also 2D decompositions from Laurikainen+2004, Barth+2009)

Note that at least some of these "bulges" are clearly *not* classical spheroids (e.g. disky pseudobulges; bars)

NC Mass & Total Stellar Mass



Line = elliptical SMBH fit

Excellent correlation

Dynamical masses:

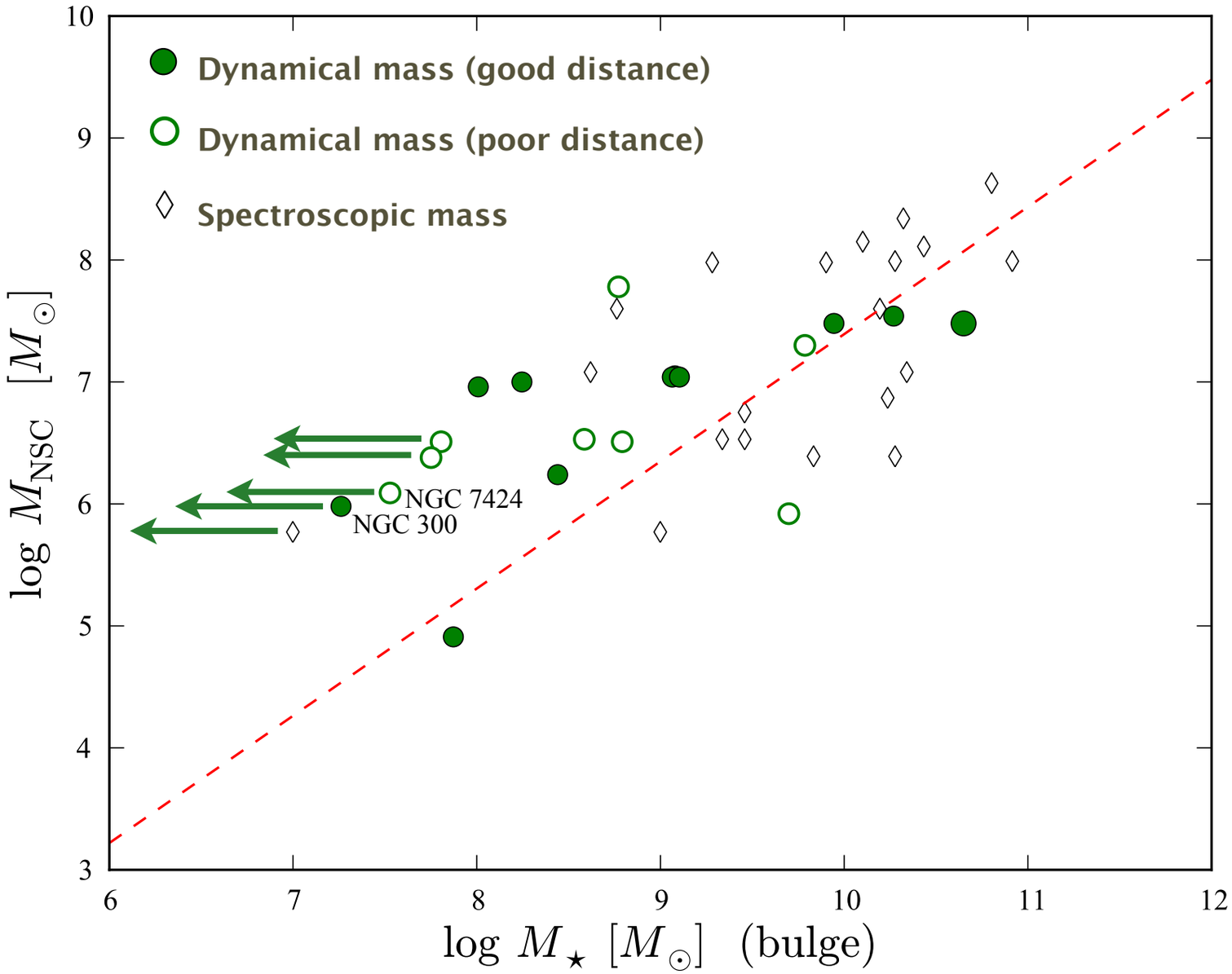
$r_s = 0.82$ $(P = 9 \times 10^{-5})$

All clusters:

$r_s = 0.74$ $(P = 2 \times 10^{-6})$

(Slightly *better* than SMBH–bulge correlation for disk galaxies)

NC Mass & Bulge Stellar Mass



Line = elliptical SMBH fit

Much weaker correlation!

Dynamical masses:

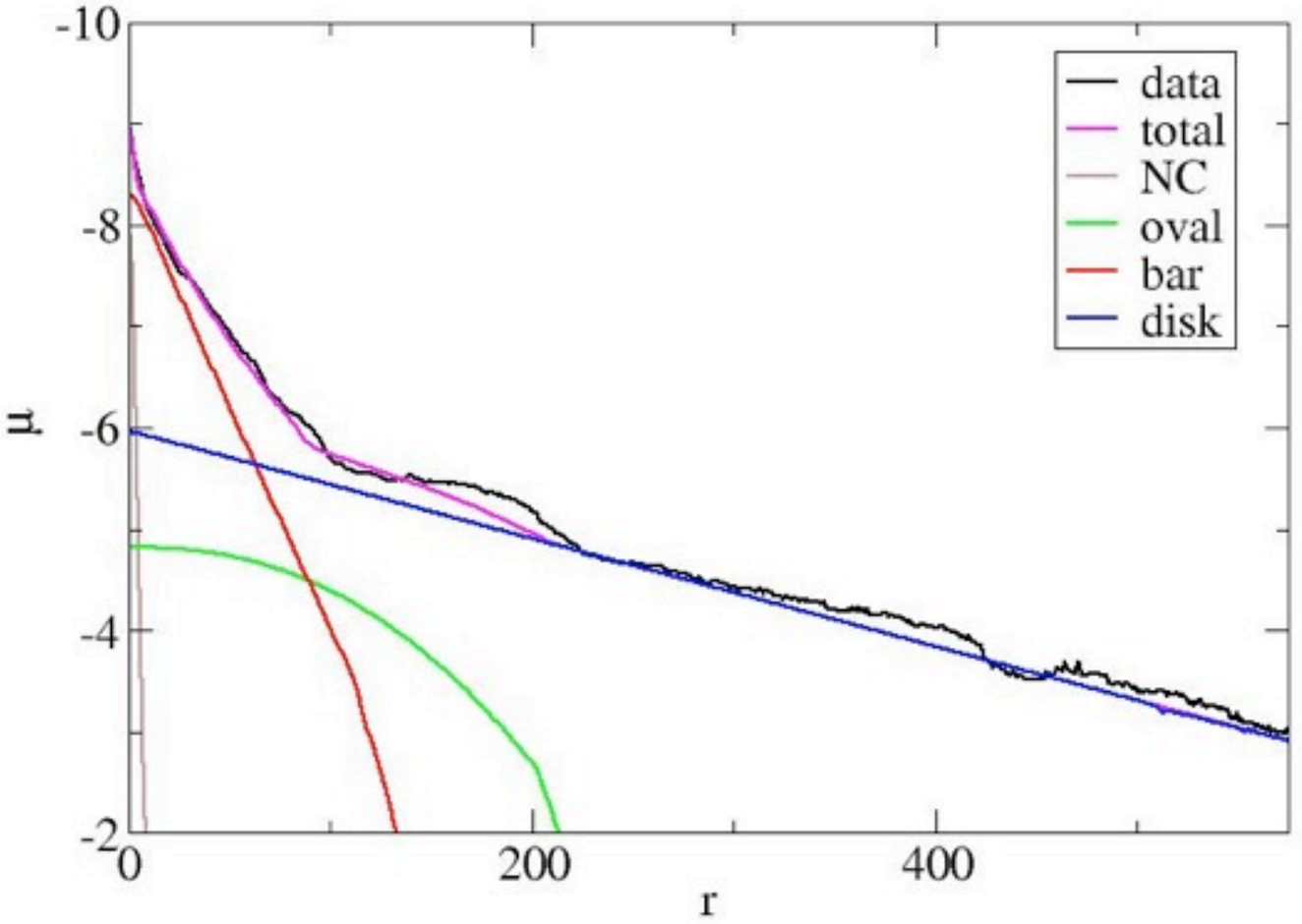
$$r_s = 0.55 \ (P = 0.03)$$

All clusters:

$$r_s = 0.62 \ (P = 0.002)$$

(Actually, it's *worse*, because of bulgeless galaxies...)

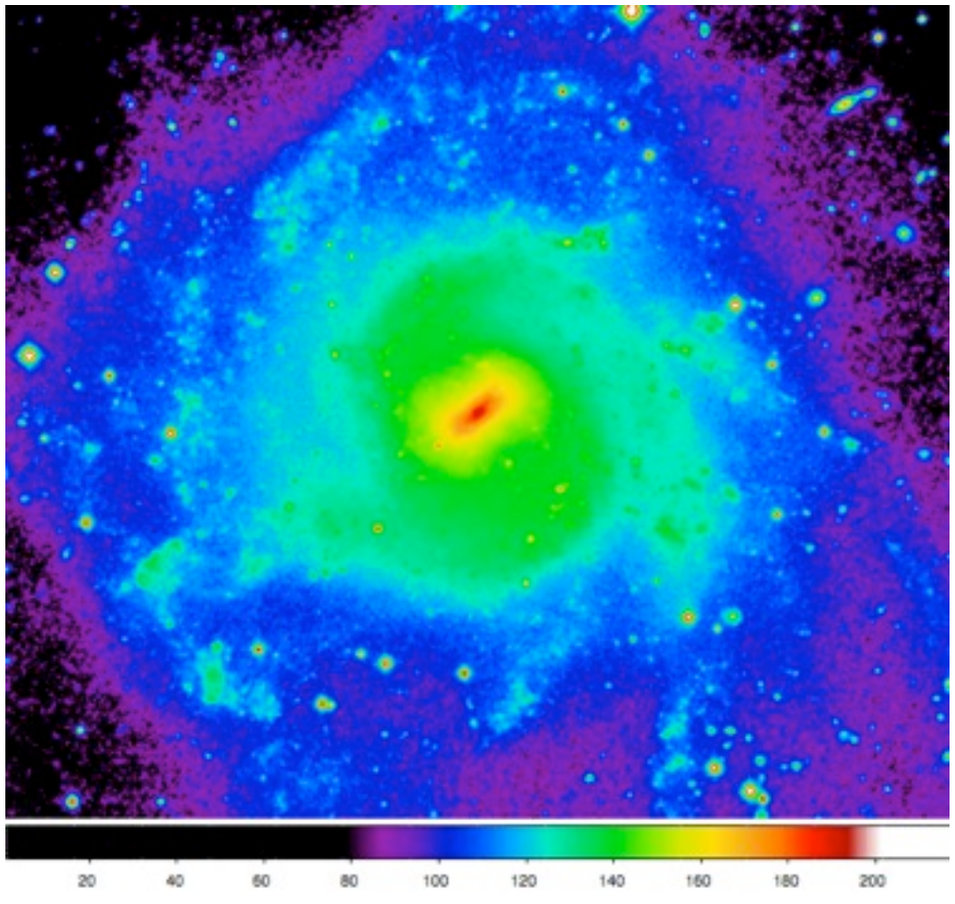
NGC 7424: "Bulge" is really the Bar



NC mass ~ 1.2 x 10^6

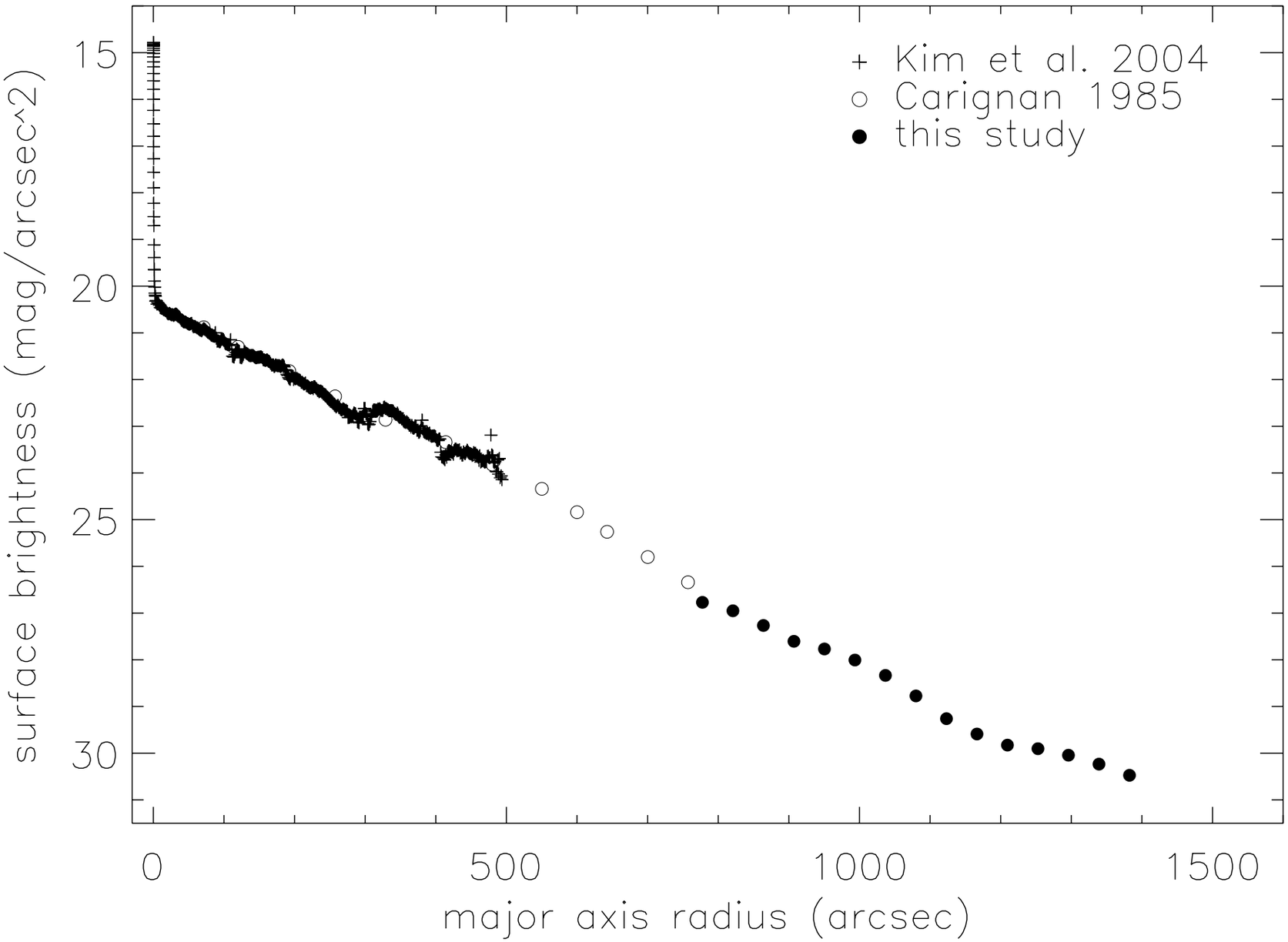
Apparent bulge in 1-D profile...

But it's really a bar!



I-band image from Larsen+1999

NGC 300: *Really* Bulgeless Spiral



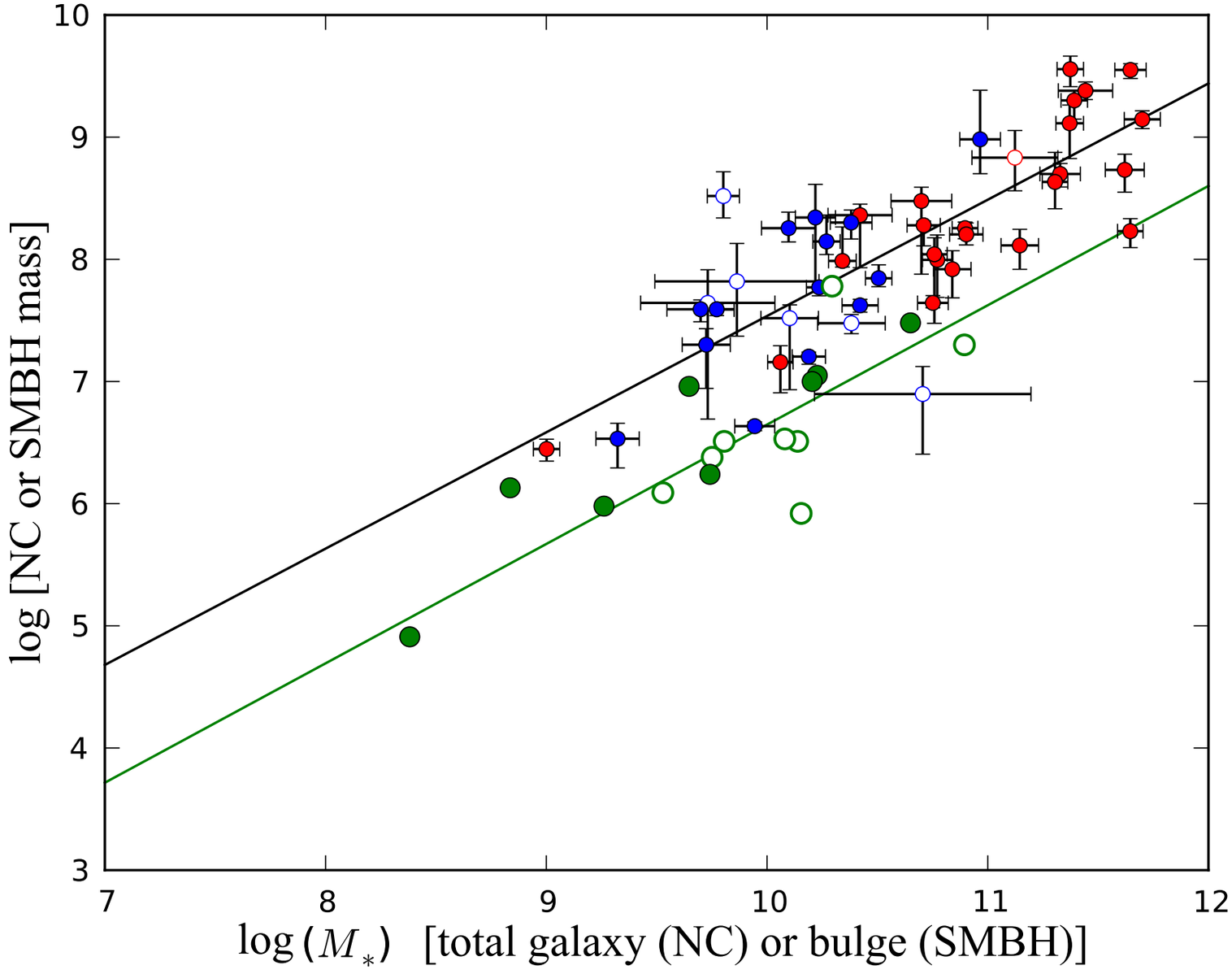
from Bland-Hawthorn+2005

NC mass ~ 1 x 10^6

No bulge (classical or pseudo-)

So — Nuclear clusters in spirals correlate with *total* stellar mass, *not* with bulge mass

Comparing the Relations



Fit for dynamical NC masses:

$$\log(M_{\rm NC}) = 7.65 + 0.99\,\log(M_\star/10^{11})$$

with intrinsic scatter = 0.27 dex

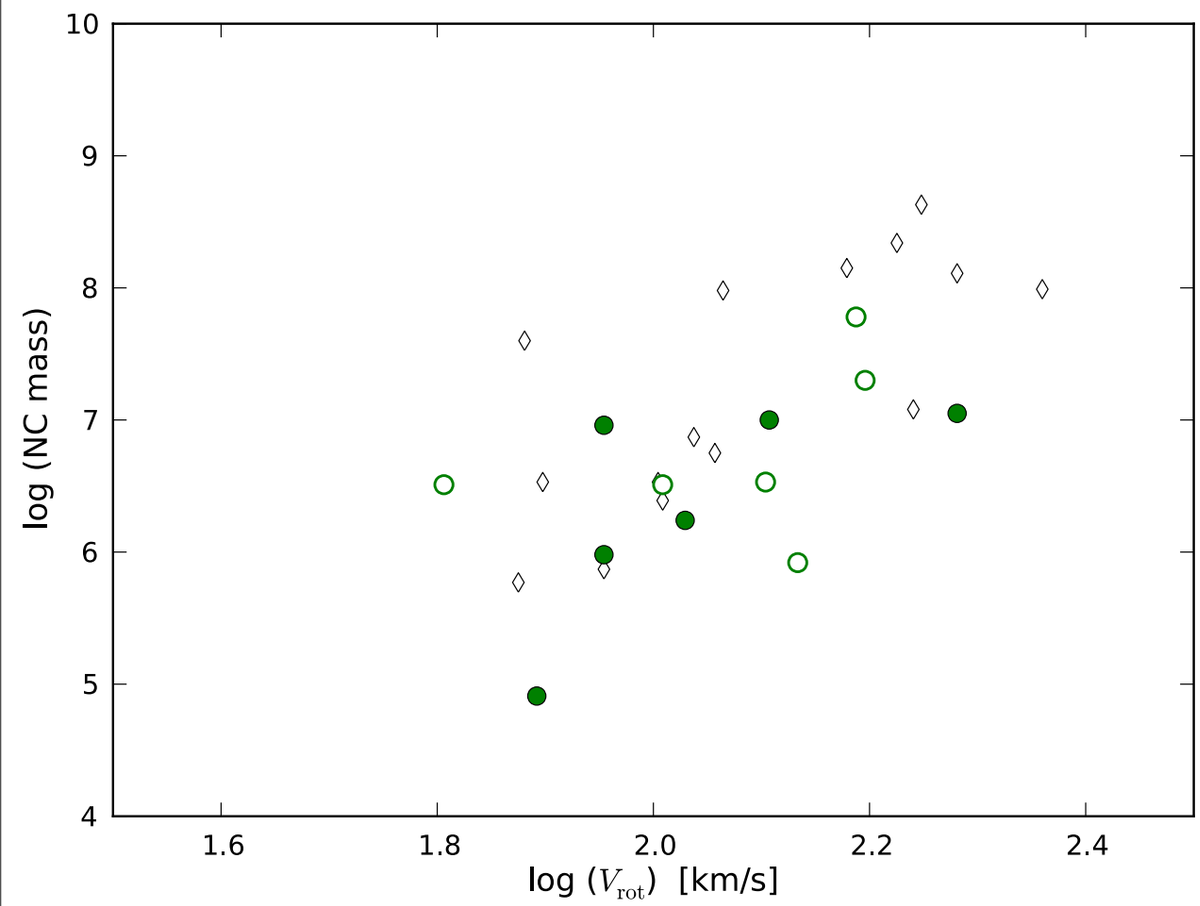
Slope is ~ same as SMBH slope, but zero point is lower by ~ 3-sigma.

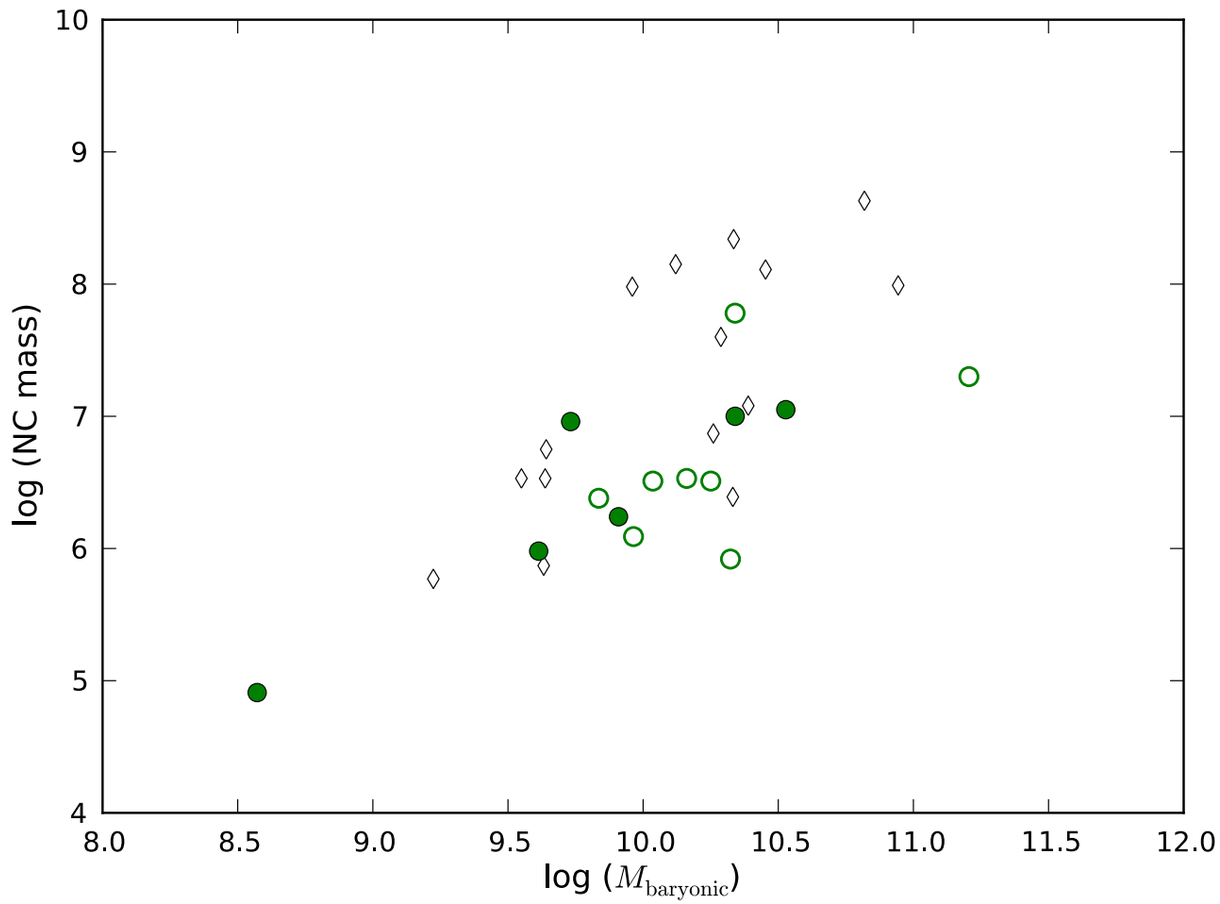
Given an elliptical and a (late-type) spiral of the same total stellar mass, the elliptical will have an SMBH with mass ~ 10 times the spiral's NC

Parallel relations, perhaps — but not the *same* relation!

Does NC Mass Correlate with Anything Else?

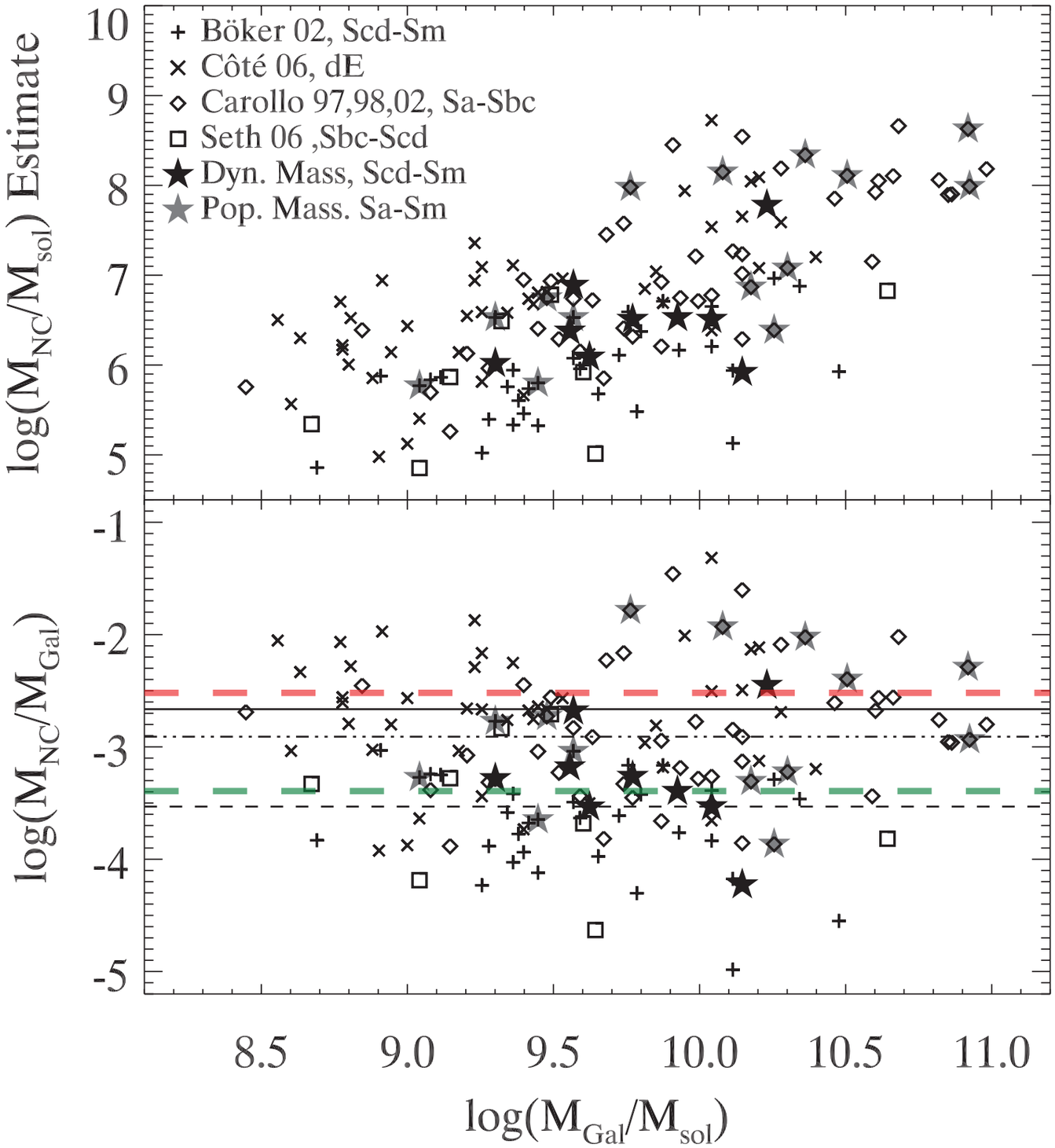
- **NC mass correlates with V_{rot} as well — but not as strongly as with M_{star}**
- **Similarly, correlation with $M_{baryonic}$ exists, but is not as strong as correlation with M_{star}**





But it probably isn't that simple…

from Seth+2008

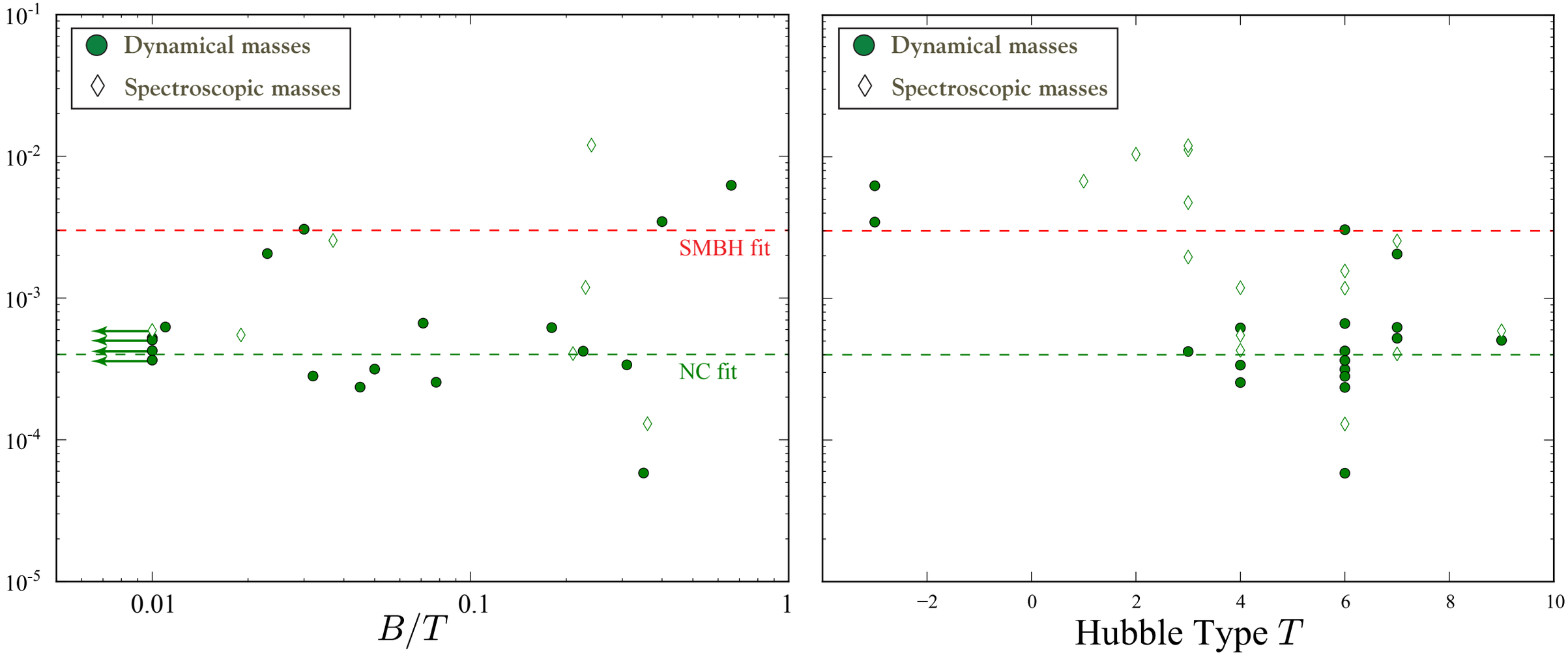


Unless masses of ~ *all* the NC in early-type spirals, S0, dE, etc. are systematically overestimated, it appears that M_{NC} is a *higher* fraction of galaxy mass in earlier Hubble types

SMBH mass fraction

Late-type Spiral NC mass fraction

Does NC Mass Scale with B/T or Hubble Type?



No evidence for a trend with B/T

***Maybe* a hint of a trend with Hubble type — but we're missing accurate NC masses in early-type disks!**

Any Secondary Correlations?

- **Residuals of M_{NC}–M_{star} fit show no clear correlation with:**
  - **Bulge/total ratio**
  - **Hubble type**
  - **V_{rot}**
  - **Gas mass**
  - **M_{gas}/M_{star}**

So M_{NC}–M_{star} correlation seems to be the main story

Possible Implications

- **If we imagine creating a galaxy's worth of stars:**
  - **Elliptical: we end up with SMBH in center, with mass ~ 0.3% of stellar mass**
  - **Late-type spiral: we end up with NC in center, with mass ~ 0.04% of stellar mass (and less than that in SMBH, if any)**
  - **So SMBH growth is more efficient than NC growth, but requires — and scales with — bulge growth**
- **In systems with both SMBH and NC, M_{BH}/M_{NC} ratio might scale with B/T ratio**

Summary

1. **Nuclear star cluster masses (in later-type spirals) correlate with *total* stellar mass of galaxy, *not* with bulge/spheroid mass**

   - ***Different* from SMBHs, which correlate with *bulge* stellar mass**

2. **Slopes of M_{NC}– M_{star} and M_{BH}– $M_{star,bulge}$ relations are similar, but zero points differ:**

   - **$M_{NC} \sim 4 \times 10^{-4}$ of M_{star}**

   - **$M_{BH} \sim 3 \times 10^{-3}$ of bulge M_{star}**

3. **Spiral NCs and SMBHs probably have somewhat different formation channels**

4. **Hints that M_{NC}/M_{star} scales with Hubble type (but *not* with B/T?)**

5. **More dynamical mass measurements of NCs would be very useful (*especially* for early-type spirals & S0's) ...**

Where does SMBH in NGC 3621 lie?

Using possible bulge / pseudobulge from Barth+2009 2D decomposition