# Spectacular Shells in the Host Galaxy of the QSO MC2 1635+119

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# The Nature of QSO Host Galaxies

Majority of luminous low-redshift QSOs in ellipticals
(e.g. Disney et al. 1995; Bahcall et al. 1997; Floyd et al. 2004)

M_bulge – M_BH relation (e.g. Magorrian et al. 1998):
QSOs with most massive BHs in galaxies with most massive bulges

What mechanisms trigger activity? Galaxy interactions/mergers?
steep evolution of QSO activity with redshift:
accretion onto BH more common, triggering mechanism more common

ULIRGs: close connection between mergers and QSO activity
(e.g. Canalizo & Stockton 2001)

Most QSOs: begin life as mergers (e.g. Sanders et al. 1988)?
reside in old ellipticals (e.g. Dunlop et al. 2003)?

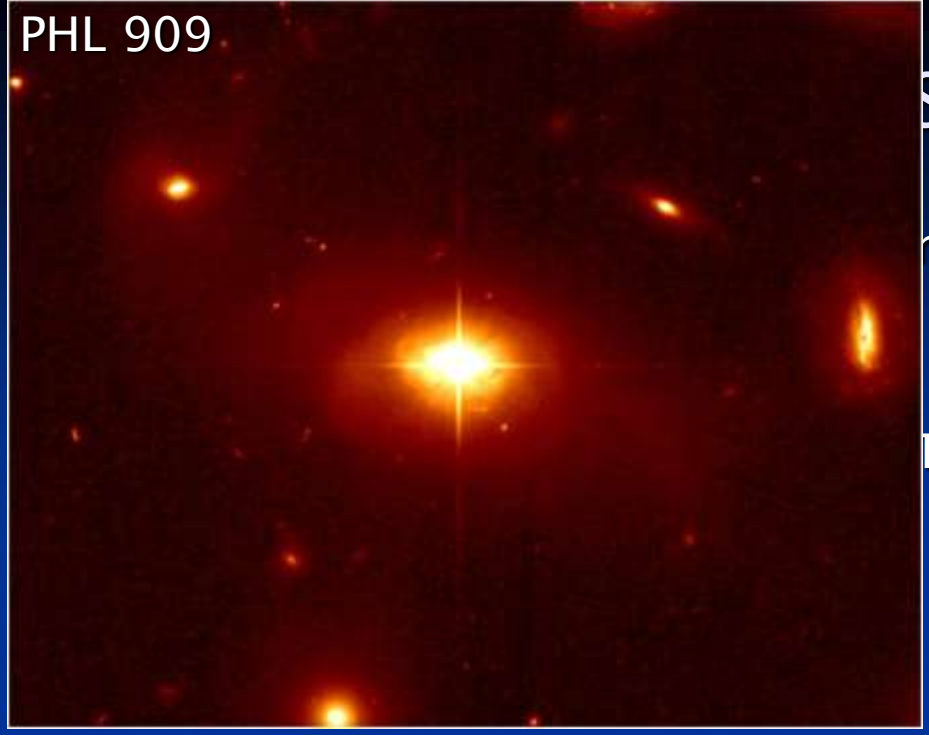
# The Nature of QSO Host Galaxies

Dunlop et al. (2003): 33 AGNs (RQQs, RLQs, RGs, $0.1<z<0.25$)
hosts are massive ellipticals
„indistinguishable from quiescent, evolved, low-redshift ellipticals at comparable mass“

Elliptical galaxies formed through mergers given enough time?
(e.g. Toomre & Toomre 1972)
QSO activity triggered by merger, activity can outlast the signs of interactions?

Keck spectroscopy of 14 QSO host galaxies from Dunlop et al. (2003):
starburst component in all but one of the hosts
major starburst episodes (> 10% of mass) with ages 0.6-2.2 Gyr
(Canalizo et al. 2006)

-> host galaxies not purely ancient stellar populations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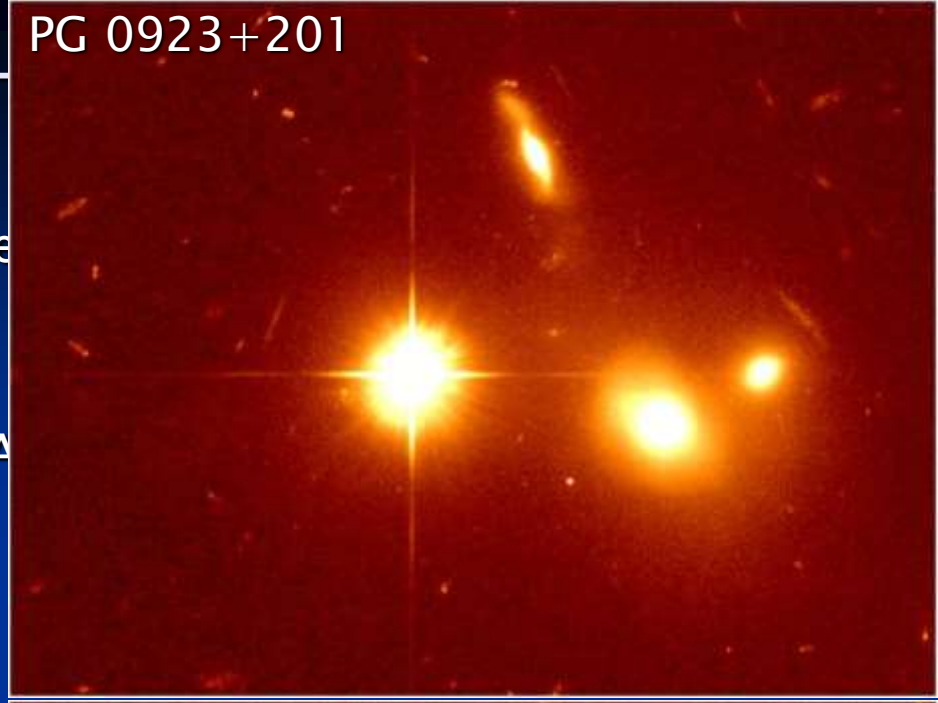
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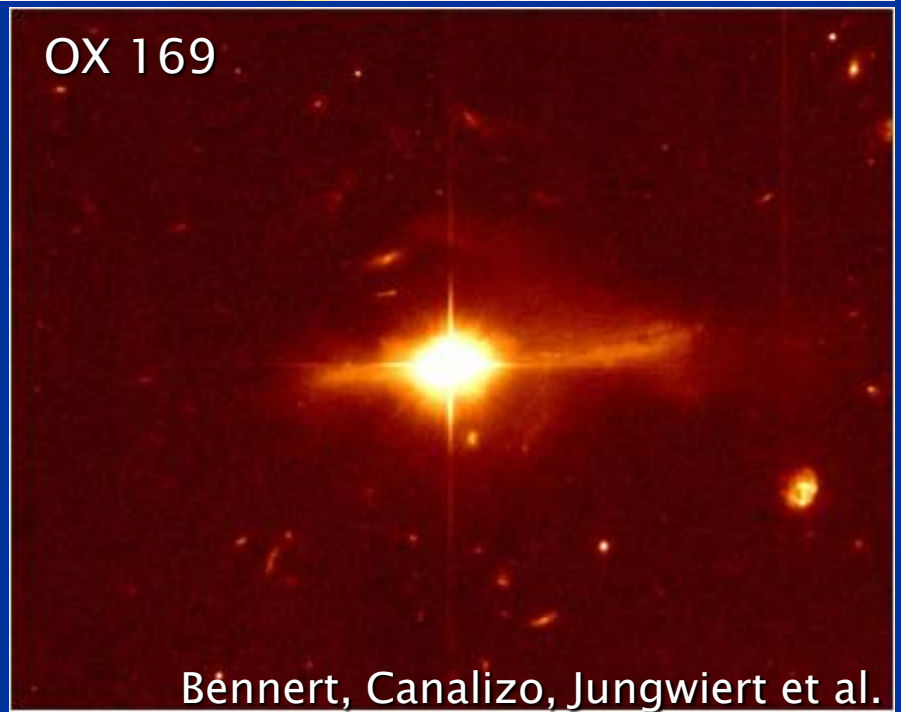
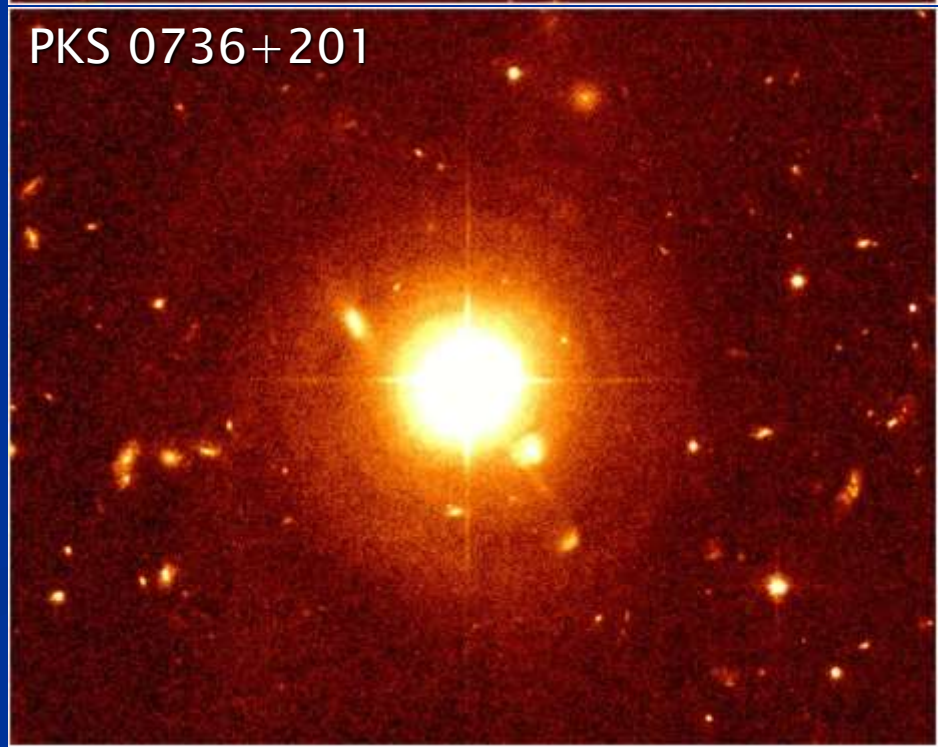

OX 169
Bennert, Canalizo, Jungwiert et al.


PKS 0736+201

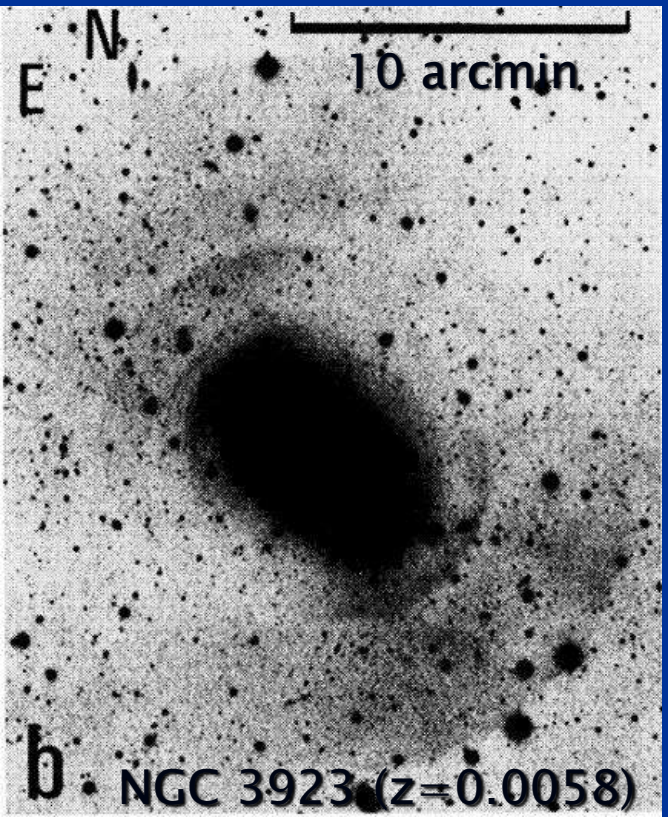
# Spectacular shells in MC2 1635+119

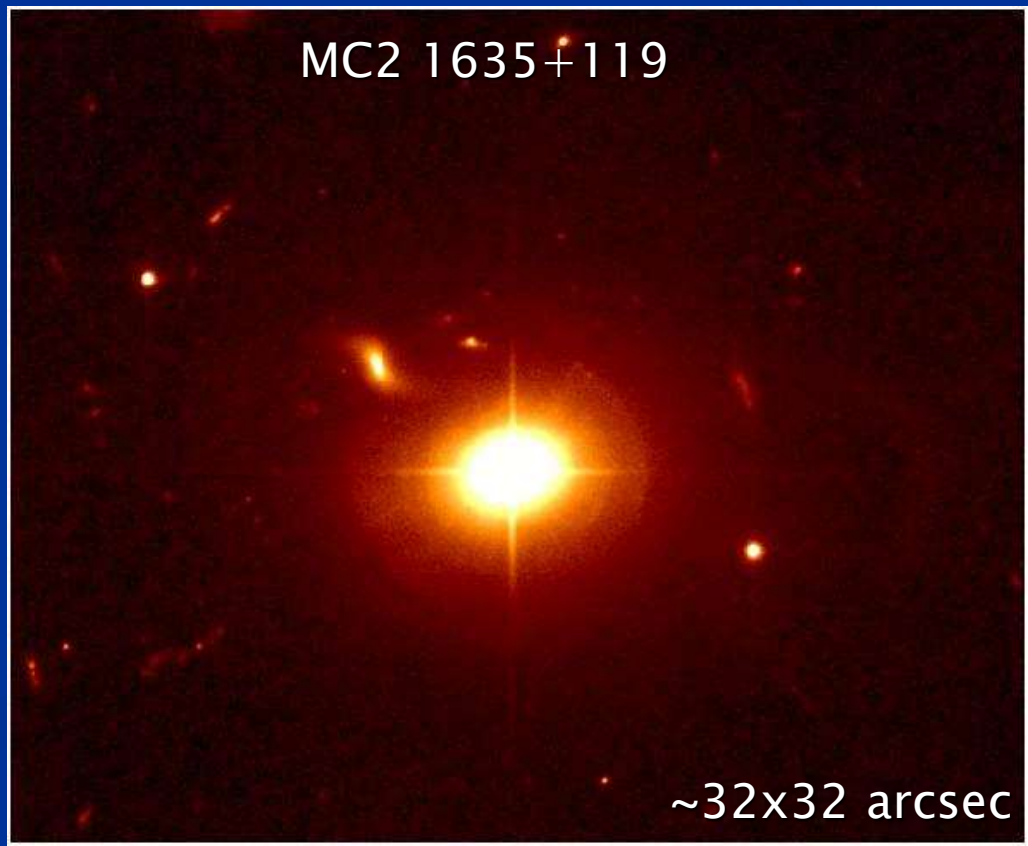
V-mag = 16.5; z=0.146; 1 arcsec ~ 2.5 kpc; radio-quiet

M_BH = 1-7x10^8 M_sun (e.g. McLure & Dunlop 2001, Dunlop et al. 2003)

Host galaxy: elliptical with r_e = 5.75 kpc (Dunlop et al. 2003)

Like NGC 3923, best example of ellipticals with shells (Malin & Carter 1983)

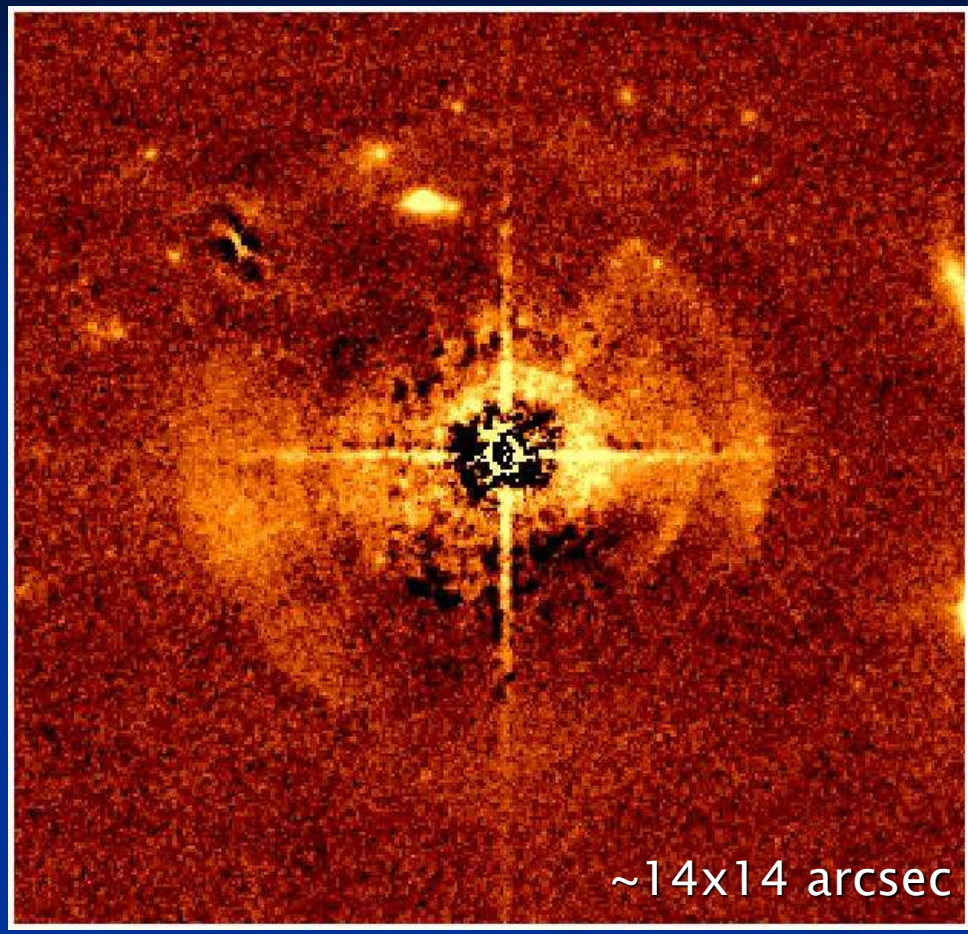


# Spectacular shells in MC2 1635+119

Use GALFIT (Peng et al. 2002):

- PSF star (star at same position)
  - outmask saturated center
  - fit to wings only
- Fit host galaxy (1–3 Sersic profiles)
- Background
- Outmask surrounding objects
- Fit bright neighbor galaxy



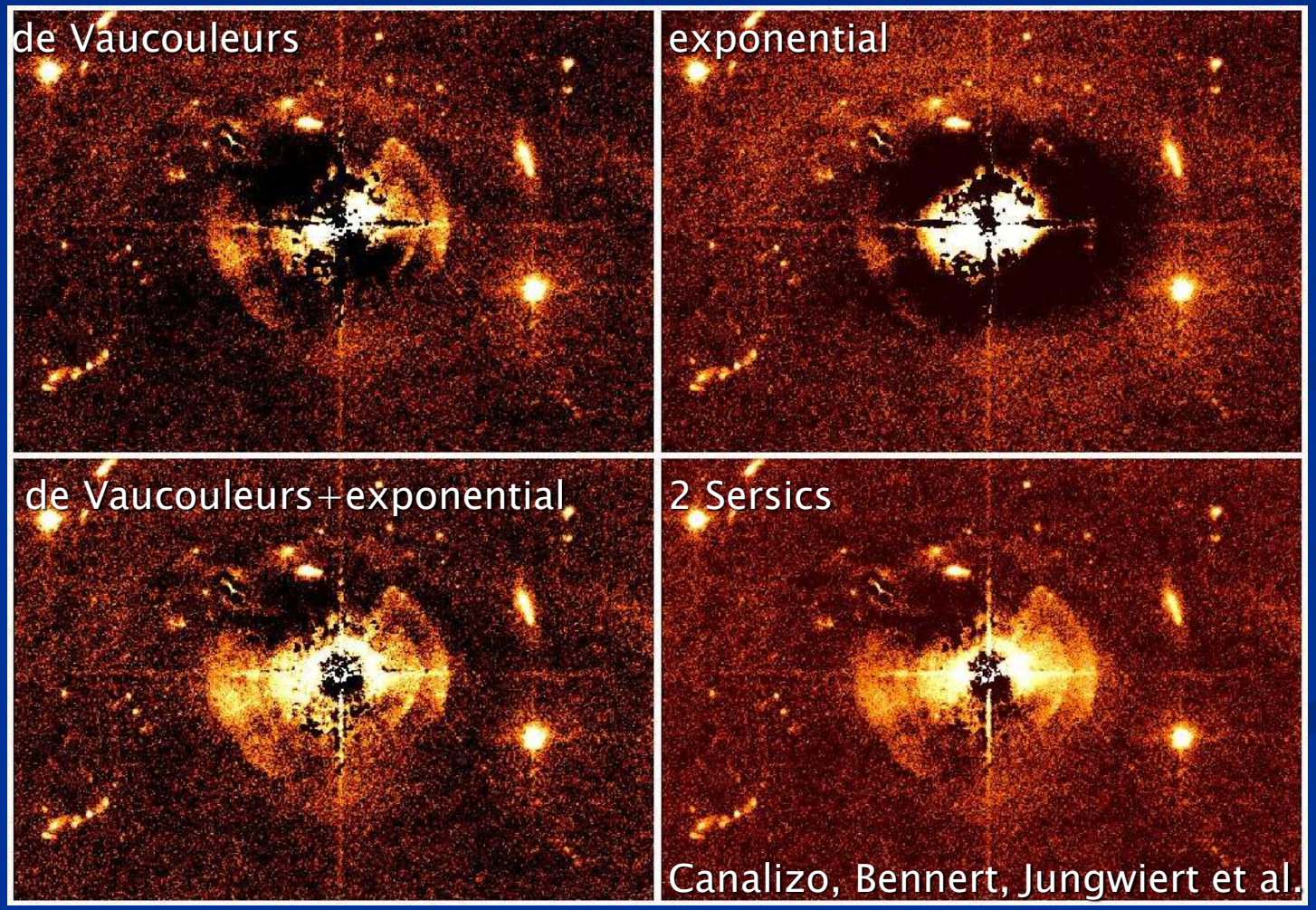

Shells at radii of 5–12 kpc, width of 1–2.5 kpc

Interleaved (shells appear on alternate sides of nucleus as *r* increases)
5 shells?

# Spectacular shells in MC2 1635+119

De Vaucouleurs profile: similar results to Dunlop et al. (2003) but not good fit

2 Sersic profiles: 1 close to de Vauc. (R_e ~ 3kpc), 1 close to exp. (R_e ~ 16kpc)



# Comparison with numerical simulations

Shells known from local giant ellipticals
(e.g. Schweizer 1980, 1983, Malin & Carter 1983)

N-body simulations: minor merger
radial collition of dwarf elliptical/spiral with large elliptical
(e.g. Quinn 1982, 1984; Dupraz & Combes 1986; Hernquist & Quinn 1988, 1989)

Shells: outward moving density wave composed of stars from accreted material
on primarily radial orbits in potential of elliptical

Outermost shell: stars captured during first passage
Travel through giant galaxy, turn at R_turn, sweep back through center,
Form shell at other side R_shell ~ R_turn
-> have travelled 3 x R_turn since first passage through galaxy

t_dyn = dynamical time, center to turning point
Age of shell: t_shell ~ 3 x t_dyn (R_shell)

# Comparison with numerical simulations

Assume: Merger of giant elliptical + dwarf elliptical on nearly radial orbit

Dwarf is completely disrupted during first passage

No outer shell dissolved so far

No outer shell missed due to low S/N

R_shell = 12 kpc

t_dyn: depends on surface brightness profile of giant elliptical

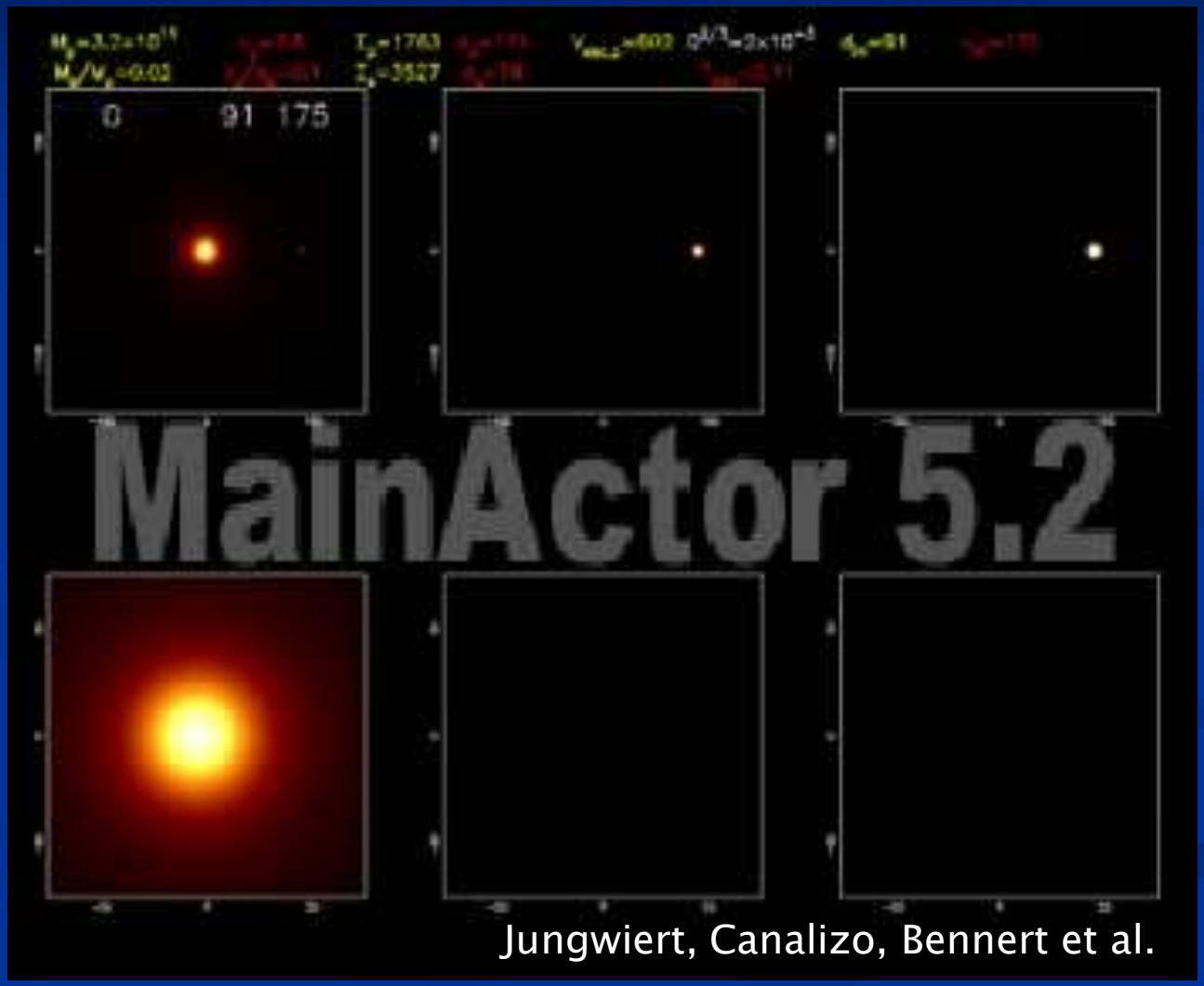
Assume: Plummer sphere and de Vaucouleurs

# Comparison with numerical simulations

Plummer; R_e = 7.6 kpc; M=10^11 M_sun

150x150 kpc

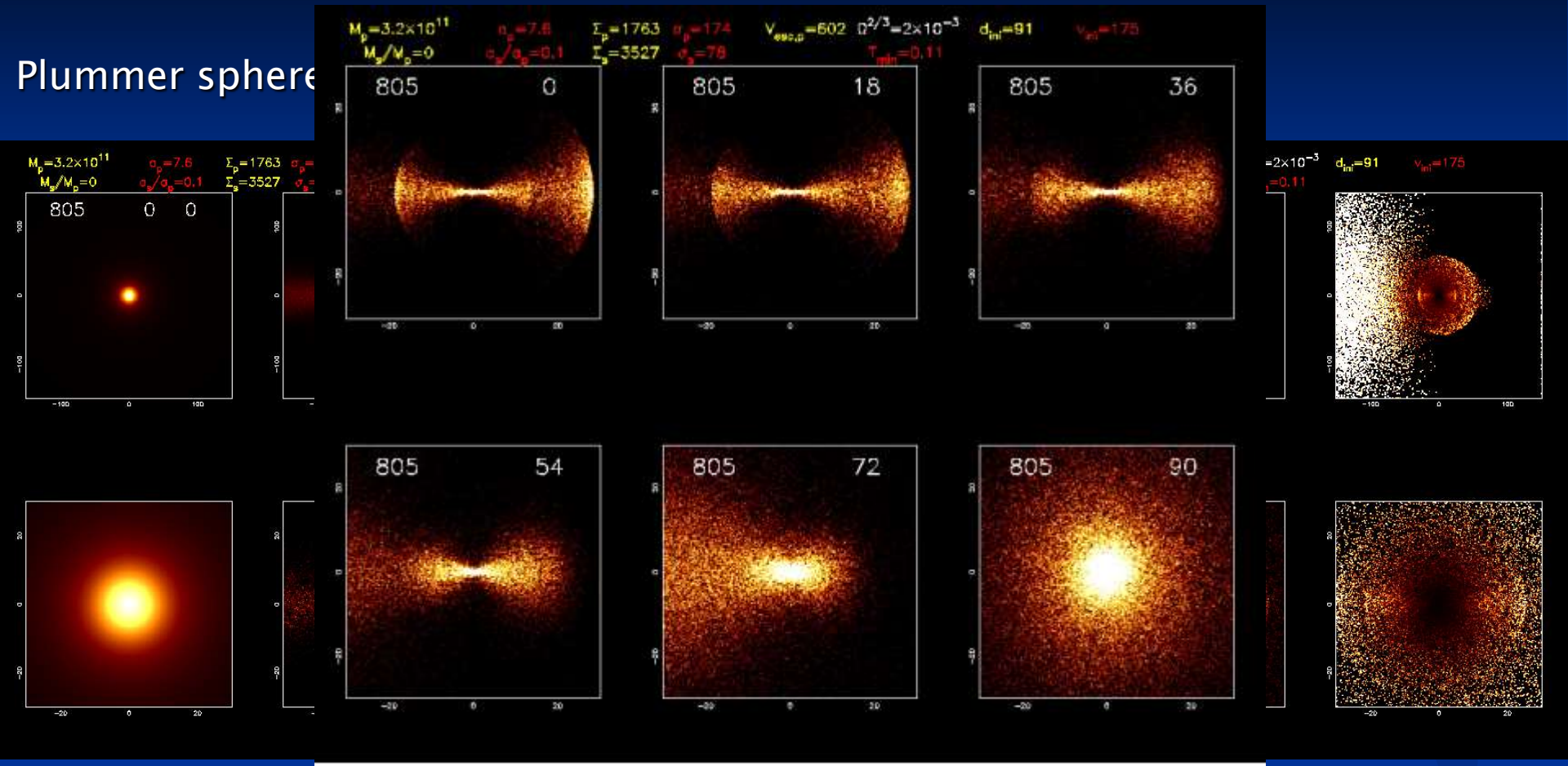
60x60 kpc




Giant elliptical  Dwarf elliptical  dE (unsharp)

# Comparison with numerical simulations

Plummer sphere




Shell structure: highly sensitive to surface-density profile
sensitive to viewing angle; highest contrast if perpendicular

-> results of simplest plausible scenario: merging timescale ~100-700 Myr

# (Preliminary) Conclusions

Very deep HST images:
shells that did not show up in previous HST images!

Host galaxy: not de Vaucouleurs (modeling & simulations)
Younger stellar pop. (1-2 Gyr; see e.g. Kauffmann et al. 2003)

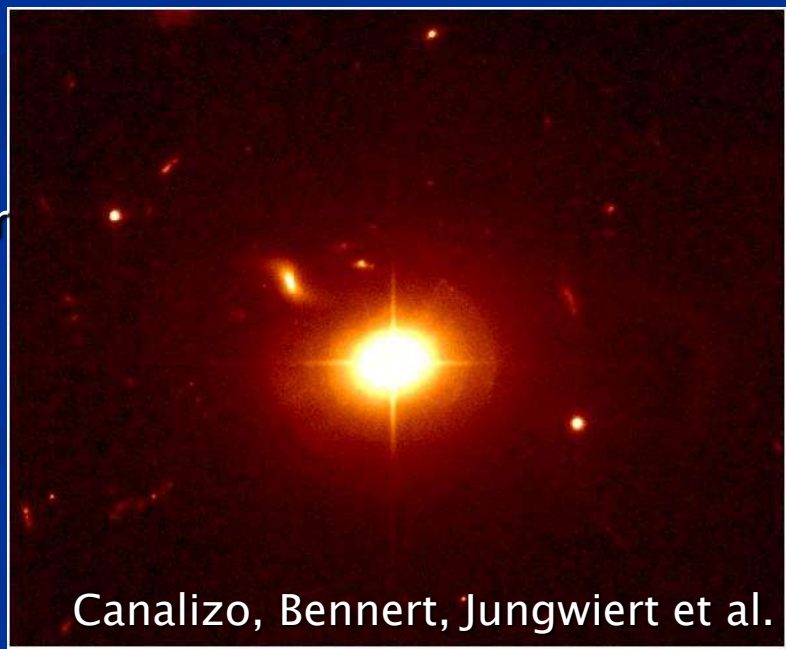
Clear signs of recent minor merger (10-70 x 10^7 yrs), triggered QSO activity?
Comparable to quasar duty cycles (3-13 x 10^7 yrs; Yu & Tremaine 2002)

Shell structure depends on orbit, potential well, viewing angle:
Only small percentage of mergers detectable
-> are very common?

No extended major starburst with minor merger

Outer arc: ~32 kpc radius
Debris from an older merger?

First: collection of gas by major merger
Then: triggering of AGN by minor merger?


Canalizo, Bennert, Jungwiert et al.

# Outlook

Include gas in simulations – so far only stars, but gas important for QSO

Same study for comparison sample of inactive „normal“ ellipticals

- Candidates selected from HST archive
  (deep images in broad filter close to F606W)
- Determine redshift from spectroscopy
- Look for signs of interactions
- Get deep Keck spectra