Black Holes in Globular Clusters

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KITP 05 Aug '13

Why?

Massive Black Holes: Birth, Growth and Impact

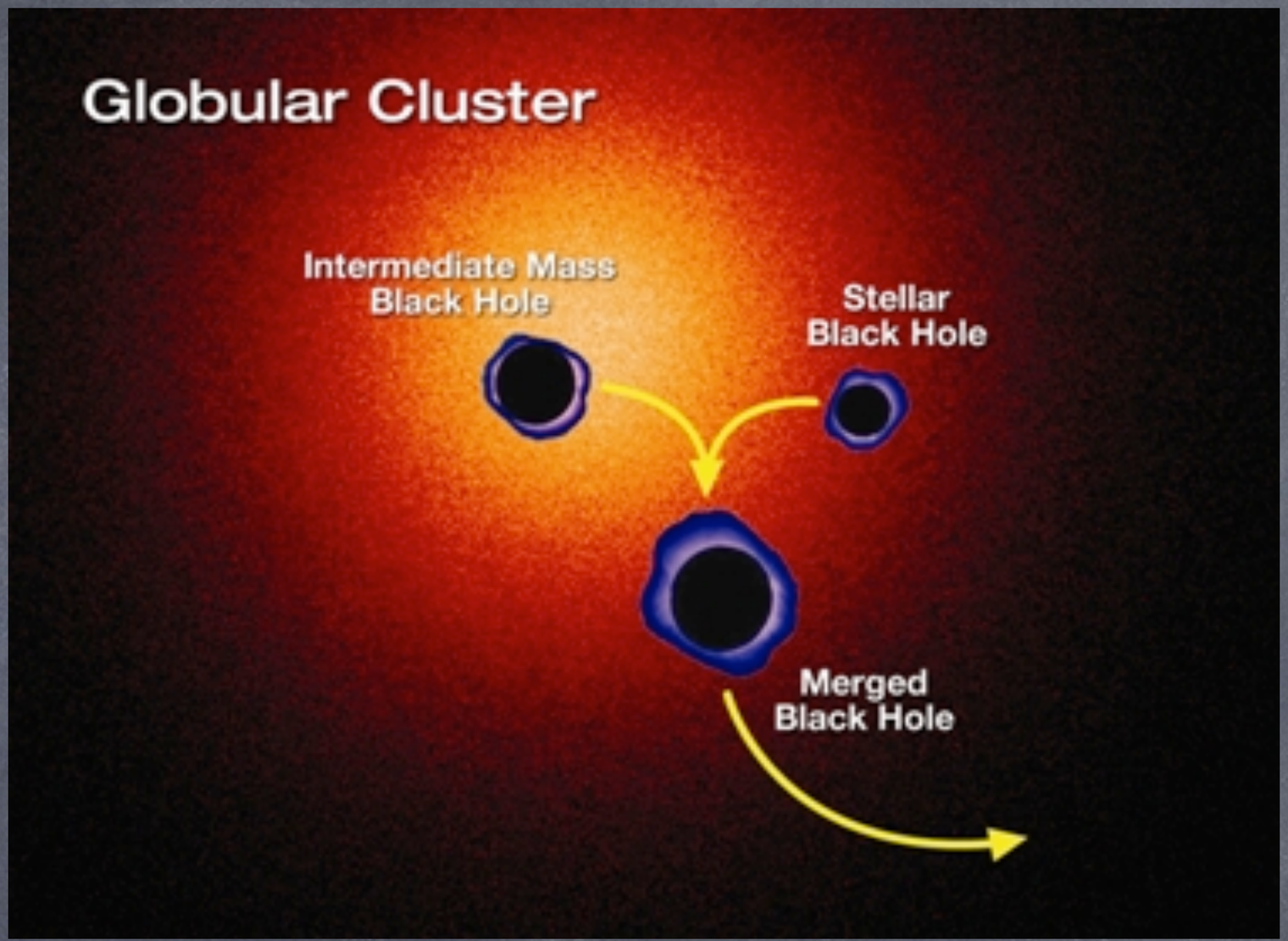
Session: Formation and early growth of supermassive and intermediate mass black holes

- Probes BH formation at high z
- maybe some insight into seeds
  - M_{halo}-M_{BH} - how low does it go?
- really need to understand dynamical evolution of small clumps of BH over 10+ Gyrs...
- good bet, a priori, for IMBH hunts

BH formation and kicks

- Expect BH formation in GCs
  - 100-1,000 BH within ~10^8 y
  - dynamical evolution
    - retention incl. natal kick
- cf Nova Sco - Brandt et al 1995
- Evidence for mass independent BH kicks Repetto et al 2012

"Black Hole Interaction"
Bintley's $E=mc^2$ Birmingham Royal Ballet



K. H-B. Vanderbilt (2008)

Are there BH in GC?

- Yes.
- Most **may** be ejected:
  - Newtonian recoil in 3-body encounters
  - radiation recoil in mergers
    - BH-BH mergers
    - BH-NS merger radiation recoil?!
- Some may persist in globulars. Many?

BH survival

- Spitzer instability & runaway:
  - Kulkarni et al '93, Sigurdsson & Hernquist '93
- Or not:
  - Mackey et al '08, Morscher et al '13, Sippel & Hurley '13
  - no equipartition? (Trenti & van der Marel 2013)
- Mass spectrum; IMBH?
  - cf Miller & Hamilton '02

Do we see BH in GC?

- Emission line object in NGC1399 - Irwin et al '10
  - see also Clausen et al. 2012
- Object in RZ2109 in NGC4472 - Maccarone et al '11
- Assorted UXB and IMBH candidates...
  - caveat young clusters vs GCs
- M22 - Strader et al '12
- M62 - Chomiuk et al '13

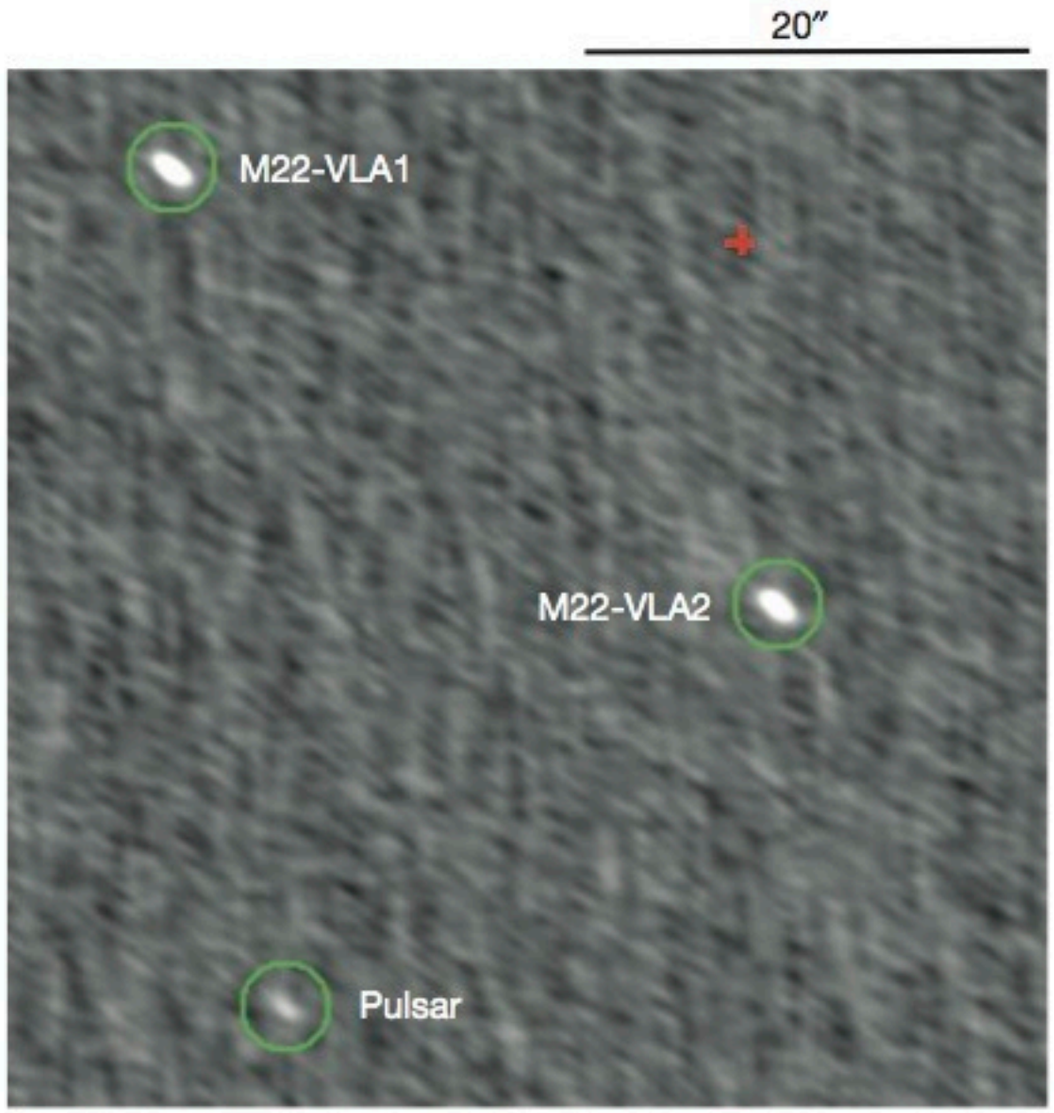


Figure 1 | VLA radio continuum image of the core of the globular cluster M22. The two bright circled objects are the sources identified as stellar-mass black holes, M22-VLA1 and M22-VLA2. These sources have flux densities of

From Strader et al '12

or maybe they are just
z ~ 10 proto AGN...

...but
what about M62?

implies many more
equipartition?!?!

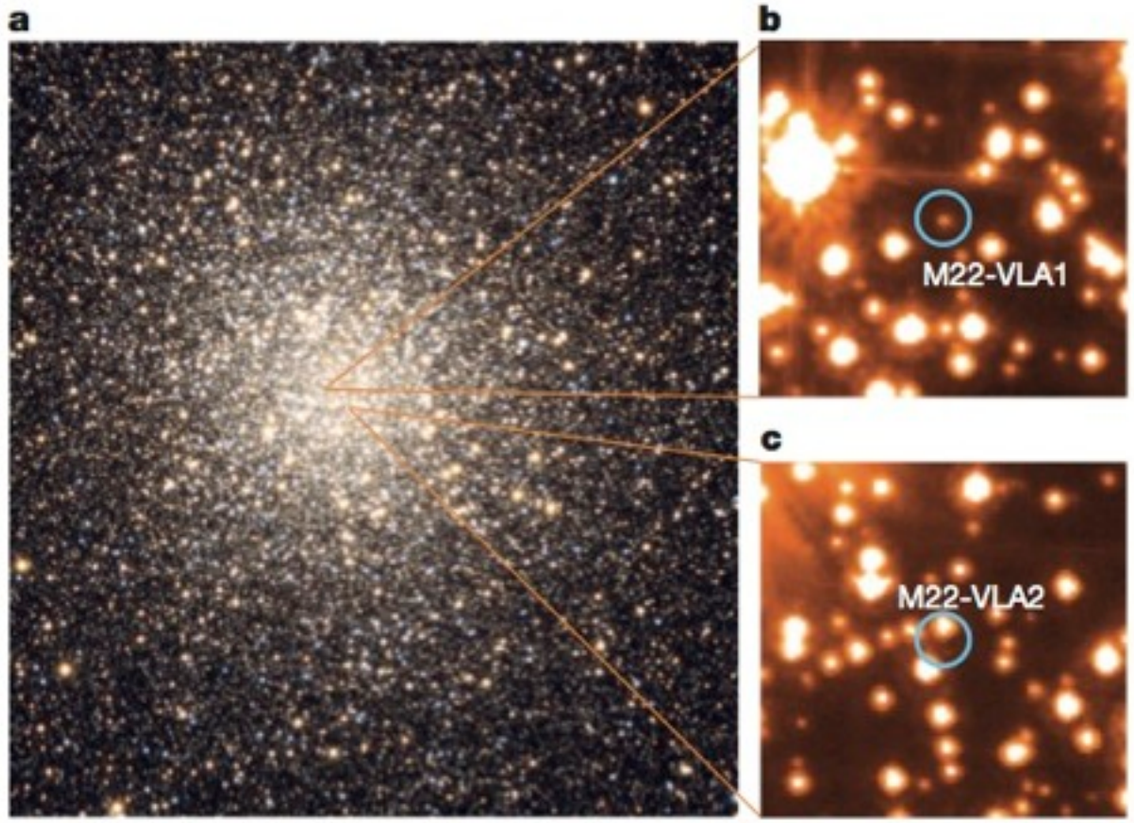


Figure 2 | Optical images of M22 and the candidate companion stars to the radio sources. a, Ground-based image that shows the approximate location of

GC dichotomy?

- Two evolutionary tracks for BH in GCs? ???
- Spitzer instability and collapse for some, but "puffing out" and persistence for others?
- What determines which???
- Some clusters have 0-1 (or 2) BH ?
- some clusters have 10-100 BH ??

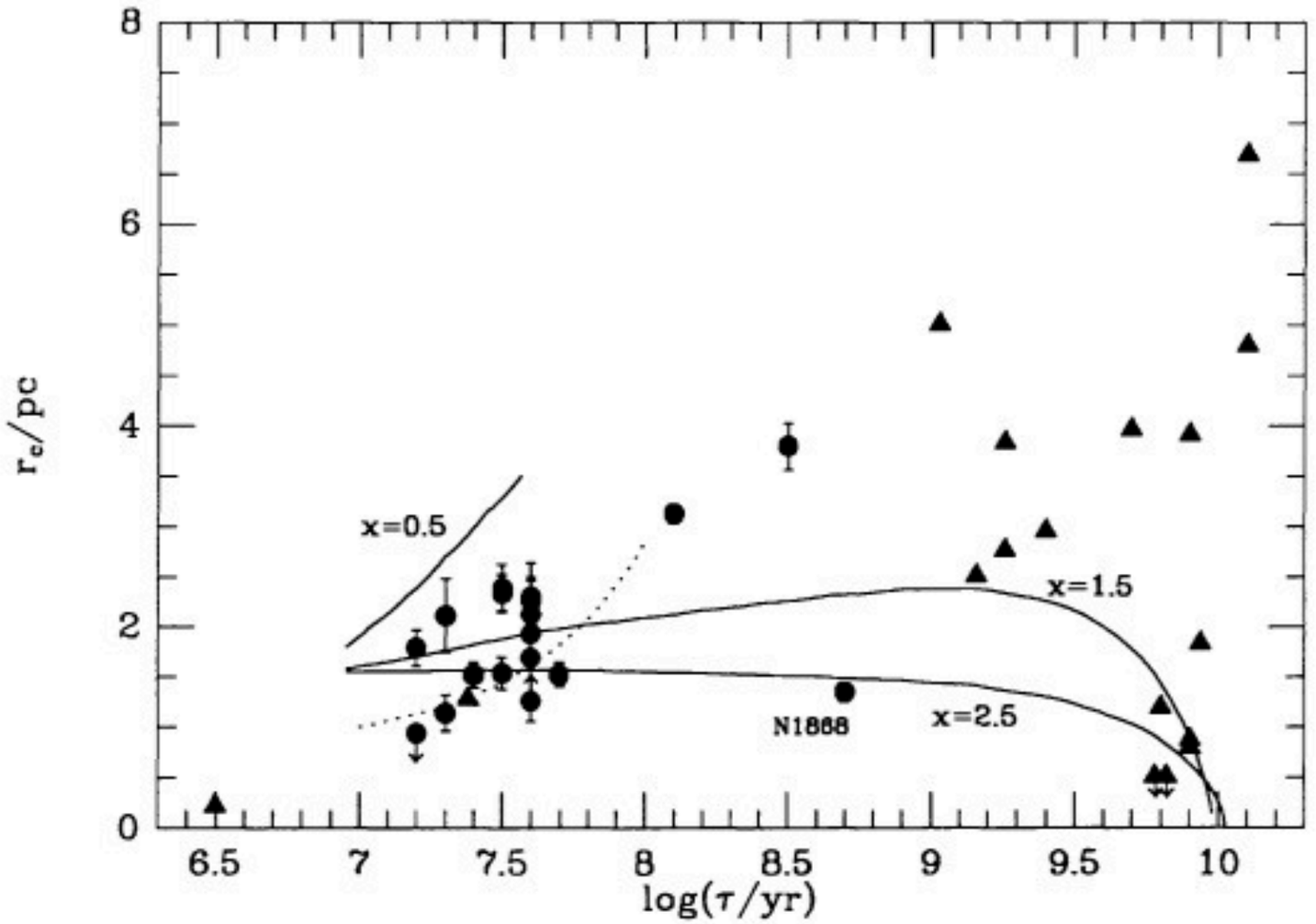


FIG. 11.—Core radius vs. age for the clusters in Table 1 (*circles; r_c* from col. 5), and Table 4 (*triangles*). Solid curves are from Fokker-Planck models of clusters with power-law IMFs with the slopes indicated. (The Salpeter IMF has $x = 1.35$). The dotted curve corresponds to expansion at a constant velocity of 0.02 km s^{-1}.

Structure of LMC clusters vs age from Elson '91

Where is the Hα?

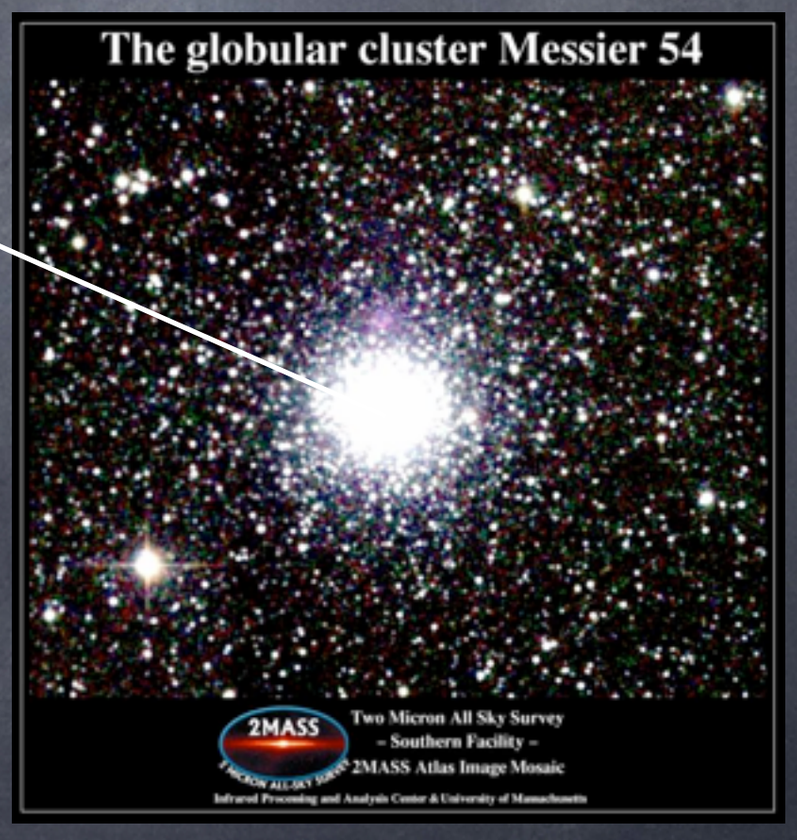
- Hα emission ought not be subtle
- Main sequence interaction cross-section ought to be large and long lasting
- Why don't we see many H emitters?
- Post-main sequence interactions

Theoristing

- Dense clusters ought to hit Spitzer or Quinlan-Shapiro instabilities
- Puffy clusters have "problems" with:
  - BH-NS+WD -> BH-WD +NS (Clausen '13)
- Dense clusters BH-NS merge
  - GW signal! Would be definitive
  - BH-PSR would be nice... (Clausen et al '13)

No equipartition?

- Is naive theory completely misguided?
  - no equipartition - cf Trenti & van der Marel '13
- role of CDM?
  - no dense CDM concentration in GCs
  - embedded in large (>> 100 pc) CDM halos with low density core? (cf Mashchenko et al 2005)
  - **some** GCs definitely dwarf galaxy core clusters
  - all??


The globular cluster Messier 54
2MASS
Two Micron All Sky Survey
– Southern Facility –
2MASS Atlas Image Mosaic
Infrared Processing and Analysis Center & University of Massachusetts

M54

Conclusion

- BH really in GCs
- Still no robust sign of IMBHs in GCs
  - but many tantalising hints
- Theorists bemused - situation normal
- More ~~simulations~~ data needed