

An IMBH in the core of NGC 6388? New constraints from the radial velocity of individual stars

BARBARA LANZONI

Physics & Astronomy Department – University of Bologna

(Italy)







- ✤ 5-year project
- + Advanced Research Grant funded by the European Research Council (ERC)
- ✦ PI: Francesco R. Ferraro (Dip. of Physics & Astronomy Bologna University)
- AIM: to understand the complex interplay between dynamics & stellar evolution
- + HOW: using **globular clusters** as cosmic laboratories and

Blue Straggler Stars Millisecond Pulsars Intermediate-mass Black Holes

as probe-particles





Intermediate-mass BHs (IMBHs): 10²-10⁵ M_☉



SMBHs (10⁶ - 10⁹ M_o)







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Why interesting?

- seeds of SMBHs observed in all galaxies
 → galaxy formation & co-evolution with AGNs
- strong sources of gravitational waves detectable by the next generation detectors (e.g., Miller & Colbert 2004)
- at the origin of **ultraluminous X-ray sources (ULX)** detected in nearby galaxies (e.g., Zezas & Fabiano 2002; Kong et al. 2004)
- role in dynamical evolution & stability of globular clusters (e.g., Hut et al. 1992)

...but do they exist ??





They are expected (especially in GCs)

• Extrapolation of the "Magorrian relation" to GC mass scales







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- Extrapolation of the "Magorrian relation" to GC mass scales
- **Plausible formation scenarios in GCs** (runaway collisions of massive MS stars, gas accretion; e.g. Portegies Zwart +02; Freitag +07; Vesperini+10)

✓ IMBH FINGERPRINTS in GCs

(e.g., Baumgardt +05; Miocchi 2007; Heggie +07; Trenti +07, +10; Dukier & Bailyn +03; Maccarone 2004; Gill +08; Vesperini & Trenti 2010; Umbreti+12)

- 1) shallow density cusp in the centre
- 2) cuspy velocity dispersion profile
- 3) presence of **high-velocity stars** (even *v* ~ 100 km/s)
- 4) quenching of mass segregation
- 5) X-ray and radio emission from accreting gas





...however no solid detection yet

see talks at SnowPac 2013 "BH fingerprints", March 17-23 2013, Utah: http://www.physics.utah.edu/snowpac/index.php/snowpac-2013

Why?

- challenging observations (sub-arcsec BH sphere of influence)
- uncertainties on expected X-ray and radio emission
- controversial theoretical predictions (e.g., density cusp)
- controversial observational results... e.g., NGC 6388







- one of the most massive Galactic GCs: M ~ 2.6 $10^6 M_{\odot}$
- metal-rich: [Fe/H]=-0.44 (Carretta et al. 2007)
- HB with extended blue tail (Rich et al. 1997)
- multiple populations (Bellini et al. 2013)







high-resolution (HST: ACS-HRC, ACS-WFC, WFPC2)

+ wide-field (ESO-WFI) observations

(Lanzoni et al. 2007, ApJ 668, L139)







+ self-consistent, multi-mass, King models with central BH
 → IMBH of ~ 6000 M_☉

(Lanzoni et al. 2007, ApJ 668, L139)





• X-ray and radio observations: $M_{BH} < 600 M_{\odot}$



(Nucita et al. 2008; Cseh et al. 2010; Bozzo et al. 2011)

Lützgendorf et al. 2011 (L11):

 cuspy velocity dispersion profile, σ₀~23-25 km/s (from the line broadening of integrated-light spectra)

• IMBH of ~1.7 $10^4~M_{\odot}$

(from spherical Jeans models with constant M/L)







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Velocity dispersion from the radial velocities of individual stars

(Lanzoni et al. 2013, ApJ 769, 107)

 • ESO-VLT/SINFONI: AO-assisted IFU spectrograph, R=4000, K-band grating (1.95-2.45 μm), spatial resolution=0.1", FoV=3.2"x3.2"
 → central σ(r)

• ESO-VLT/FLAMES-GIRAFFE in MEDUSA mode: multi-object spectrograph (132 fibres), high spectral resolution (R>10,000), optical (Ca triplet, Fe, ..), FoV of 25' in diameter

\rightarrow external $\sigma(r)$





SINFONI (central) sample

- cross-correlation between SINFONI and HST/HRC
- spectrum extracted from central spaxel only
- excluded low-quality spectra & blended sources
- V_r mainly from CO band-heads



www.cosmic-lab.eu

CO

FLAMES (external) sample

Velocity dispersion profile

Velocity dispersion profile

Velocity dispersion profile

Insufficient shot-noise correction?

Insufficient shot-noise correction?

Comparison with models: IMBH mass

Solution of the spherical **Jeans equation** with density given by the observed one plus a variable central point mass (as in L11)

NO IMBH (or $M_{BH} \leq 2000 M_{\odot}$)

Conclusions

• velocity dispersion profile of NGC 6388 from V_r of individual stars:

52 stars at r<2" (ESO-VLT/SINFONI) 276 stars at 18"<r<600" (ESO-VLT/FLAMES)

- central velocity dispersion: $\sigma_0 = 13-14$ km/s
- NO IMBH or $M_{\rm BH}$ $\leq 2000~M_{\odot}$

- inconsistent with the results obtained from integrated light spectra
- integrated light spectra likely biased by the dominant contribution of a few bright giants

• results about IMBH fin GCs from integrated-light spectroscopy (Noyola+2010; Lutzgendorf +11,12) could be ALL biased

ω Centauri:

σ(r) from integrated-light spectra in disagreement with proper motion results (Noyola +08, 10 *vs.* Anderson & van der Marel 10)

Let's keep searching:

ongoing spectroscopic campaign to measure individual V_r with SINFONI, KMOS, FLAMES/GIRAFFE @VLT (NGC 6624, NGC6752, NGC 2808, NGC 1851) ...

Thank you for your attention!

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