POSSIBLE RELICS OF FERMI BUBBLES IN ANDROMEDA

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- Introduction : tracing the past activity of the black hole
- Detection of synchrotron emission at 150MHz (LOFAR):
  - no large scale Fermi bubble
  - synchrotron observations of the bulge
- Multiscale and perturbed kinematics
- Outflows, relics?
Co-evolution of SFR and SMBH
(Kormendy & Ho 2013)

AGN feedback: episodic nuclear activity
→ expulse the gas from central parts

ANDROMEDA central kpc:

- SMBH $\sim 1.4 \times 10^8 M_{\text{sol}}$ (Bender et al. 2015)
- Very quiet: $10^{-10} L_{\text{Edd}}$ (Li et al. 2011)
- No activity $> 10^{-4} L_{\text{edd}}$ $\tau > 1000$ yr in the past 100 Myr (Clavel et al. 2017)
- LLAGN (Yang et al. 2017)
- Very close 1 arcsec = 3.8 pc
- Multiwavelength data
- Evidences of no star formation
- LIER (Belfiore et al. 2016)
- Small amount of very clumpy cold gas Melchior & Combes 2011, 2016, 2017
- Synchrotron emission
- Presence of shocks

What’s next?

Mukherjee et al. 2018

See also Williamson et al. 2019
Gamma detections: M31’s disc/bulge: 10 $\sigma$
Excess along the minor axis: 4 $\sigma$
(Ackermann et al. 2017)

- No clear Fermi Bubbles
- Alternatives not satisfactory
  e.g. McDaniel et al. (2019):
  dark matter + MSP + SNR

GAMMA DATA: FERMI BUBBLES IN M31?

Pshirkov et al. 2016

Li et al. 2016

$\rightarrow$ Excess of milli-second pulsars?
Ackermann et al 2017, Eckner et al. 2018
See also Feng et al. 2018, Karwin et al. 2019, Fragione et al. 2019
LOFAR (150 MHz) OBSERVATIONS OF M31

8deg x 8 deg map

(1.4 arcmin, 20arcsec and 5 arcsec resolution)

Good correlation with SF in the 10 kpc ring

Primary beam // disc
No 150 MHz counter-part to the FERMI excess

Very low resolution (1.4 arcmin)  Low resolution (20 arcsec)  High resolution (5 arcsec)
Radio continuum at 1500 MHz

Resolution: 30 arcsec

10 arcsec

2 arcsec

Galvin et al. 2012
CHARACTERISTICS OF SYNCHROTRON EMISSION

• Detection of the 10 kpc star-forming ring
• The bulge (with no SF) is much stronger than the ring
• Different mechanisms are heating both regions.
Resolution: 1.4 arcmin

Resolution: 20 arcsec

Resolution: 5 arcsec

Resolution: 30 arcsec

Resolution: 10 arcsec

Resolution: 2 arcsec
RADIO CONTINUUM EMISSION OF THE CENTRAL KPC

LOFAR 150 MHz

0.5-2keV map – 2MASS K
Xu & Li (2018)

Spectral index

Gießübel & Beck (2014)
X-RAY OUTFLOW

IONISED GAS OUTFLOW

- Kinematic signature in optical ionised gas (Melchior & Combes)
- Gas outflowing from the centre from ionised gas line ratio: low density of electrons in the central arcmin (2 orders of magnitude)  Ciardullo et al 1988

Bogdan & Gilfanov (2008)

See also Li & Wang 2007
PAST AGN?

- **Evidences from XMM-Newton**
  - X-ray lines ratios compatible with AGN excitation 0.5 Myr ago Wang et al. (2019)
  - Evidence of past AGN in radio

Nyland et al. (2018)
THANK YOU!

Comments welcome