The inner region of the Galactic Center in X-rays

Roman Krivonos
Space Research Institute (IKI), Moscow, Russia
the closest Galactic nucleus (in quiescence)
Chandra observatory Galactic center region

- Point sources (persistent and transient):
  - active stars
  - bright accreting binary systems
  - cataclysmic variables
  - Sgr A*
- Extended X-ray sources
  - supernova remnants
  - non-thermal filaments
  - pulsar wind nebulae
  - massive star clusters
- Diffuse
  - Warm (kT ~1 keV) and hot (kT ~6.5 keV) thermal plasma
bipolar Sgr A lobes

- width ~10 pc, height ~15 pc
- stronger non-thermal component or hotter thermal emission than the surrounding regions.
- electron density $1-10 \text{ cm}^{-3}$
- 1–3 solar masses, age $\sim 4 \times 10^3$ yr
- thermal energy $9 \times 10^{49}$ erg

Ponti et al., (2015)
bipolar Sgr A lobes

- stellar winds from massive stars collimated by CND
- accretion on to Sgr A*
- magnetar SGR J1745−2900, ∼2pc from Sgr A*
- PWN G359.945−0.044, ∼8’’ from Sgr A*
Radio map

Ponti et al., (2015)
SNR candidates found in X-rays

Ponti et al., (2015)
Warm plasma at high latitudes

most of the high-latitude emission is generated by a thermal radiative process in a warm plasma ~1 keV.
Galactic Center region 10-20 keV (NuSTAR)

Mori et al., (2015)
The Arches stellar cluster

- Massive star cluster 11' from Sgr A*
- Age 1-3 Myr
- ~160 O-type stars
- $3 \times 10^5 \, \text{M}_\odot \, \text{pc}^{-3}$ in the core of ~10”

One of the densest known young clusters in the local group of galaxies

Credit: ESO/P. Espinoza
X-ray emission from the Arches cluster
X-ray emission from the Arches cluster

Non-thermal emission from the cluster surroundings: X-ray reflection or Cosmic Rays?

- Equivalent Width $1.2 \pm 0.2$ keV
- No significant variation of the Fe Kα 6.4 keV line – in contrast to other GC molecular clouds (Muno et al., 2007, Terrier et al., 2010, Ponti et al., 2010, Clavel et al., 2013)
- Tatischeff et al, 2012: The neutral Fe Kα line emission associated with the Arches cluster is likely produced by LECR protons accelerated in the bow shock resulting from the cluster’s proper motion

Clavel et al., (2014),
see also Krivonos et al., (2017) and Chernyshov et al., (2018)
arXiv:1807.00526
NuSTAR morphology of GC is similar to Chandra

Baganoff et al., 2003
Sgr A* extended emission

\[ L_{20-40 \text{ keV}} = 2.4 \times 10^{34} \text{ erg/s} \]

(Perez et al., 2015, Nature)

**Astronomy Magazine**

top 10 discoveries in 2015
Origin of Sgr A* extended emission

• **magnetic filaments**, low surface brightness **PWNs**, or **IC** can account for only a small fraction of CHXE luminosity and cannot reproduce spatial distribution

• low-mass IPs has different latitudinal spatial scale (18’ vs 1’)

• **NS/BH LMXB?** Magnetar discovery near Sgr A* predicts large population of NS in GC, however Swift monitoring results do not support that.

• **ms Pulsars?** Sources identified with Chandra are mostly IPs.

• **Diffuse origin, hadronic and leptonic, cannot explain CHXE** (Chernyshov et al., 2017)

• $10^3$-$10^4$ hot IPs with Mwd $> 0.9$ Msun

• **Density cusp of black holes traced by BH-LMXB** (Hailey et al., 2017, Nature)
Thank you for your attention!