WATCHING A BLACK HOLE WIND GROW

Chandra and Hubble reveal different stages of quasar feedback

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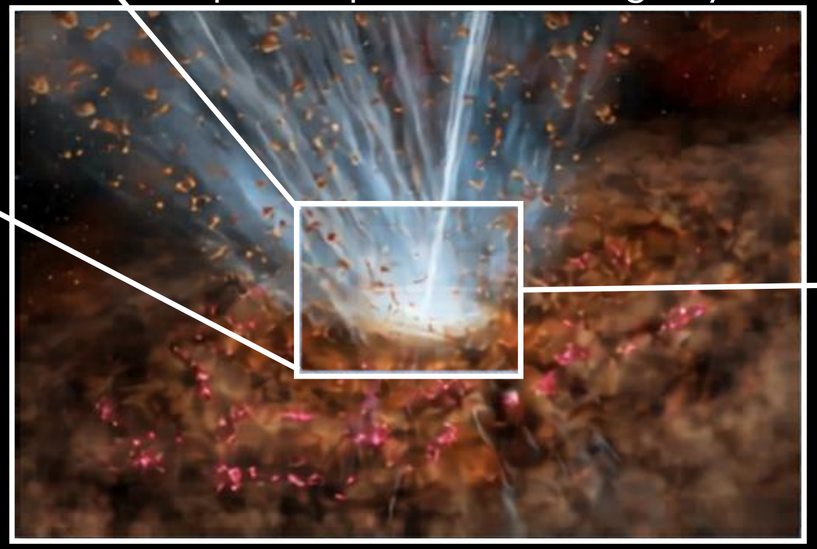
ACTIVE BLACK HOLES CAN RESHAPE ENTIRE GALAXIES

a <1 pc (<3 light-years)

FEEDBACK

b 1 pc – 1 kpc (3 - 3,000 light-years)



c >10 kpc (> 30,000 light-years)

a The central engine: gas accretes onto a supermassive black hole.

b Nuclear outflow: powerful winds blow gas and dust out of the central region.

c Galaxy-scale impact: the wind carries energy thousands of light-years, heating gas, removing it from the galaxy, and suppressing star formation.

CHANDRA AND HUBBLE REVEAL THE WIND

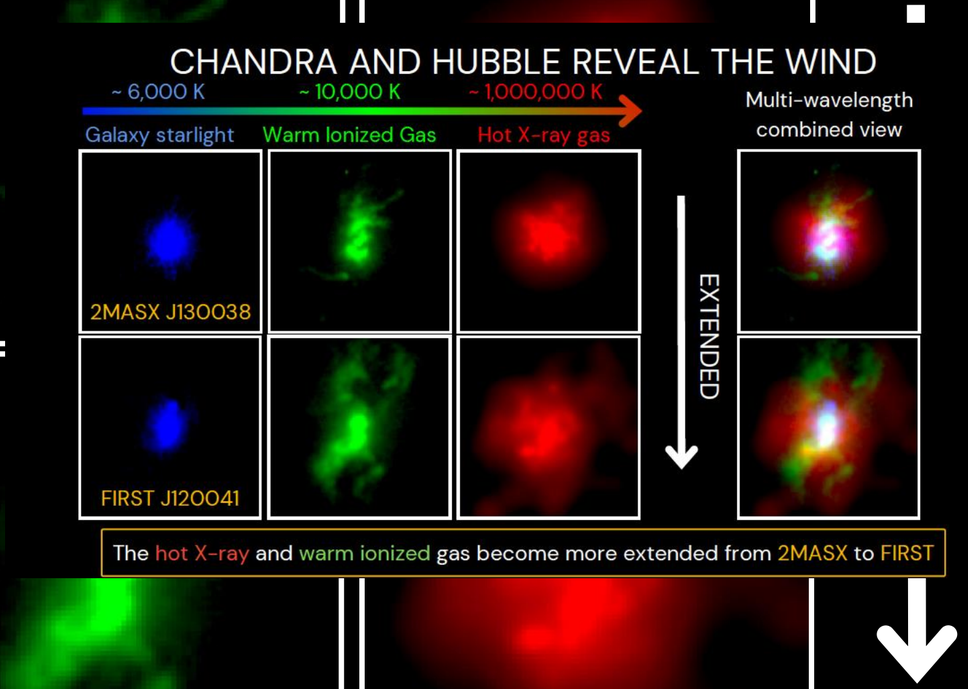
~ 6,000 K ~ 10,000 K ~ 1,000,000 K

Galaxy starlight Warm Ionized Gas Hot X-ray gas

Multi-wavelength combined view

2MASX J130038

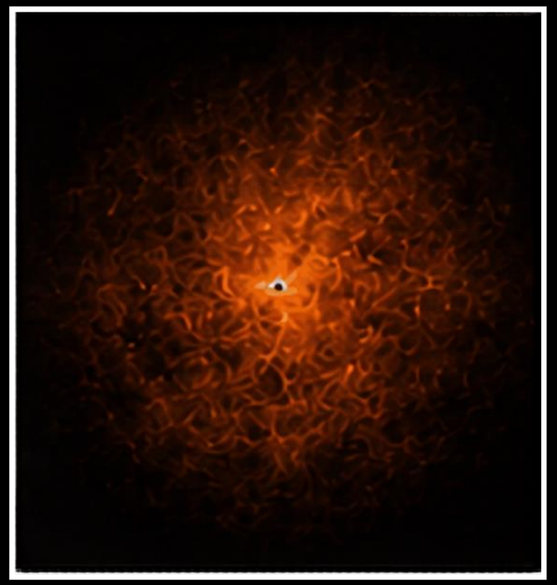
FIRST J120041



The hot X-ray and warm ionized gas become more extended from 2MASX to FIRST

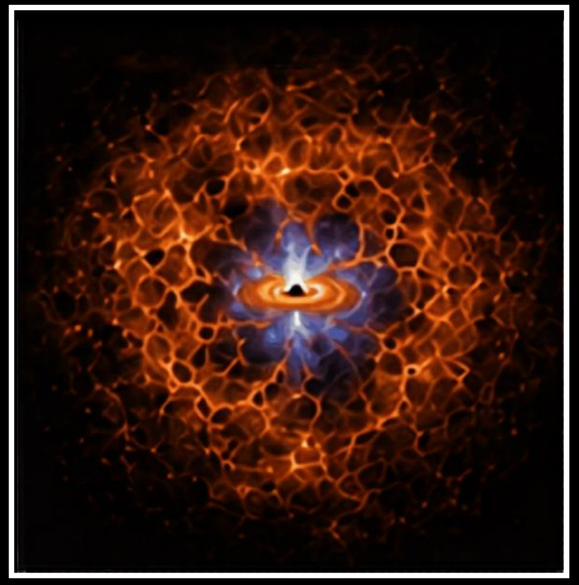
A BLACK HOLE WIND FEEDBACK SEQUENCE

STAGE 1
PRE-BLOWOUT



Compact wind
Compact morphology

STAGE 2
BLOWOUT

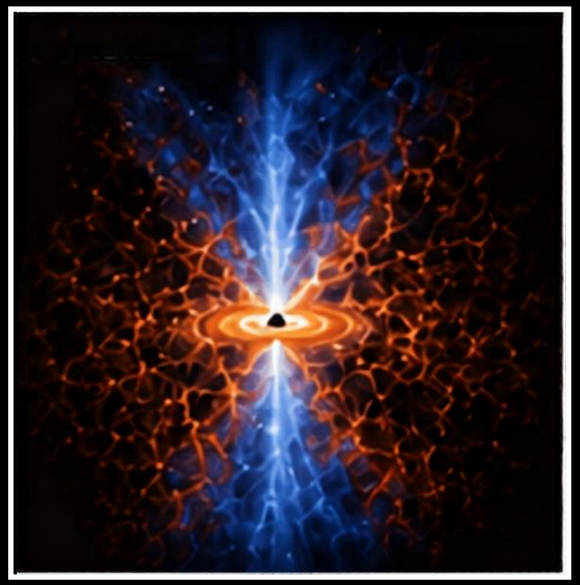


Wind emerging
Extended and disturbed gas

STAGE 3
EARLY POST-BLOWOUT

Wind expanding
Expanding outflows

STAGE 4
LATE POST-BLOWOUT

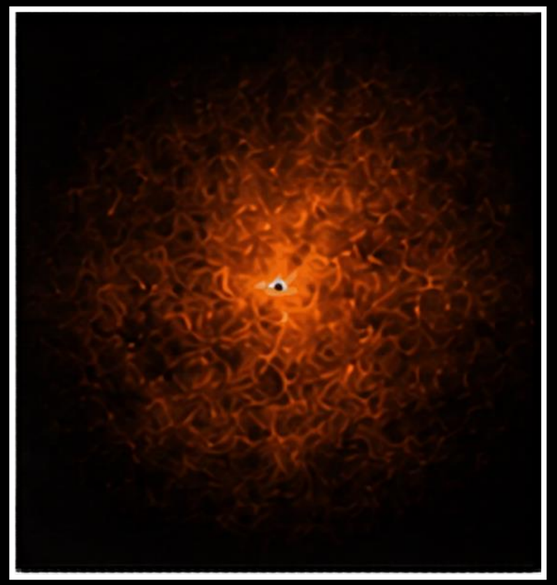


Galaxy-scale wind
Circumnuclear torus

TIME

A BLACK HOLE WIND FEEDBACK SEQUENCE

STAGE 1
PRE-BLOWOUT



Compact wind
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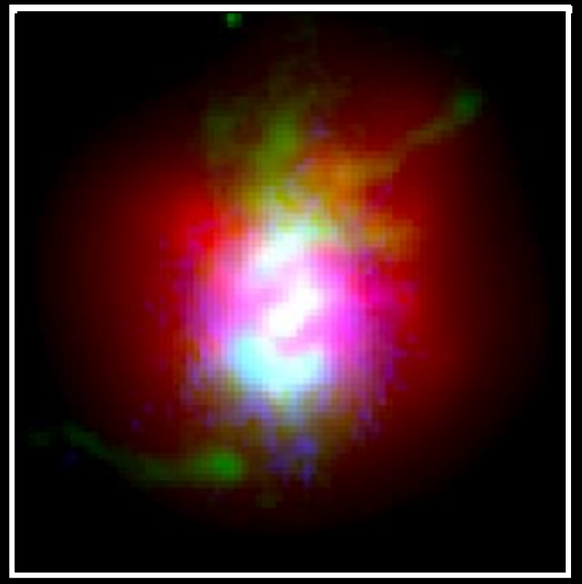
STAGE 2
BLOWOUT



Wind emerging
Extended and disturbed gas
2MASX J130038

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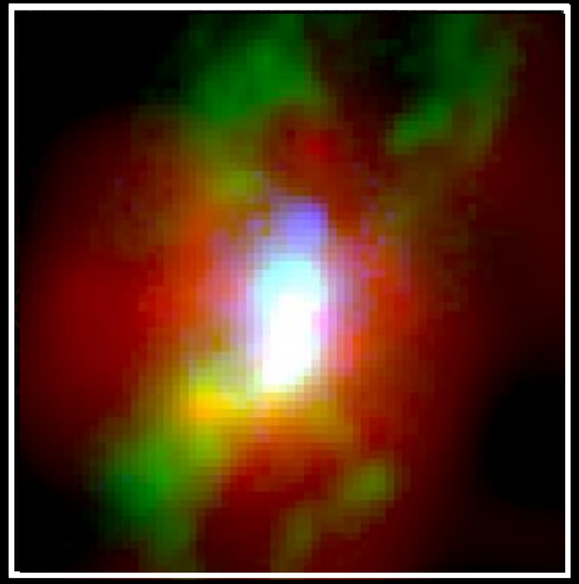

Wind expanding
Expanding outflows
FIRST J120041

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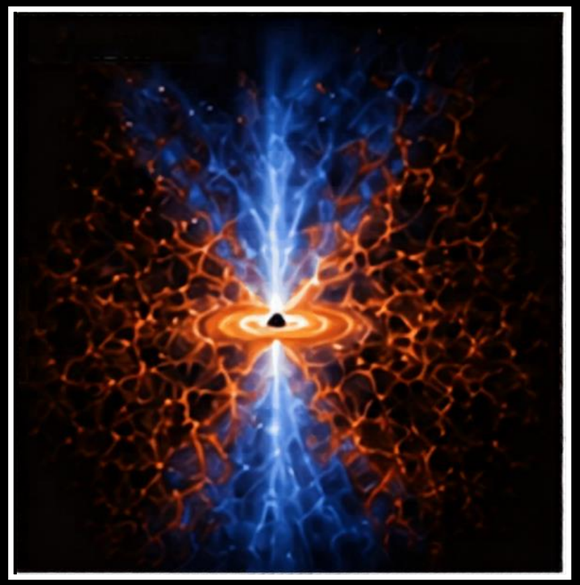

Galaxy-scale wind
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TIME

WHY THIS MATTERS?

Supermassive black holes can influence the evolution of entire galaxies. But one of the major open questions is exactly how that influence begins.

These observations may reveal the early growth phase of that process.

The Chandra + Hubble combination is powerful:

- Chandra shows the hot, energetic gas – *the footprints of the black hole*.
- Hubble shows the warm ionized gas and the stellar structure of the galaxy.

Together, they give us a multi-phase view of black hole feedback in action.

MY RESEARCH

NASA Postdoctoral Program