A Bridge from Sgr A* to LLAGN: A 300ks Simultaneous Multi-λ Campaign on M81* with the *Chandra HETGS*

Sera Markoff (MIT)

C. Canizares (MIT), G. Bower (UC Berkeley), P. Chandra (TIFR), T. Cheung (KIPAC), S. Gallagher (UCLA), S. Heinz (MIT), M. Jiminez-Garate (MIT), H. Marshall (MIT), M. Muno (UCLA), M. Nowak (MIT), A. Peck (CfA/SMA), G. Petitpa (CfA/SMA), A. Ray (TIFR), R. Schödel (U Köln), A. Young (MIT)

Motivation

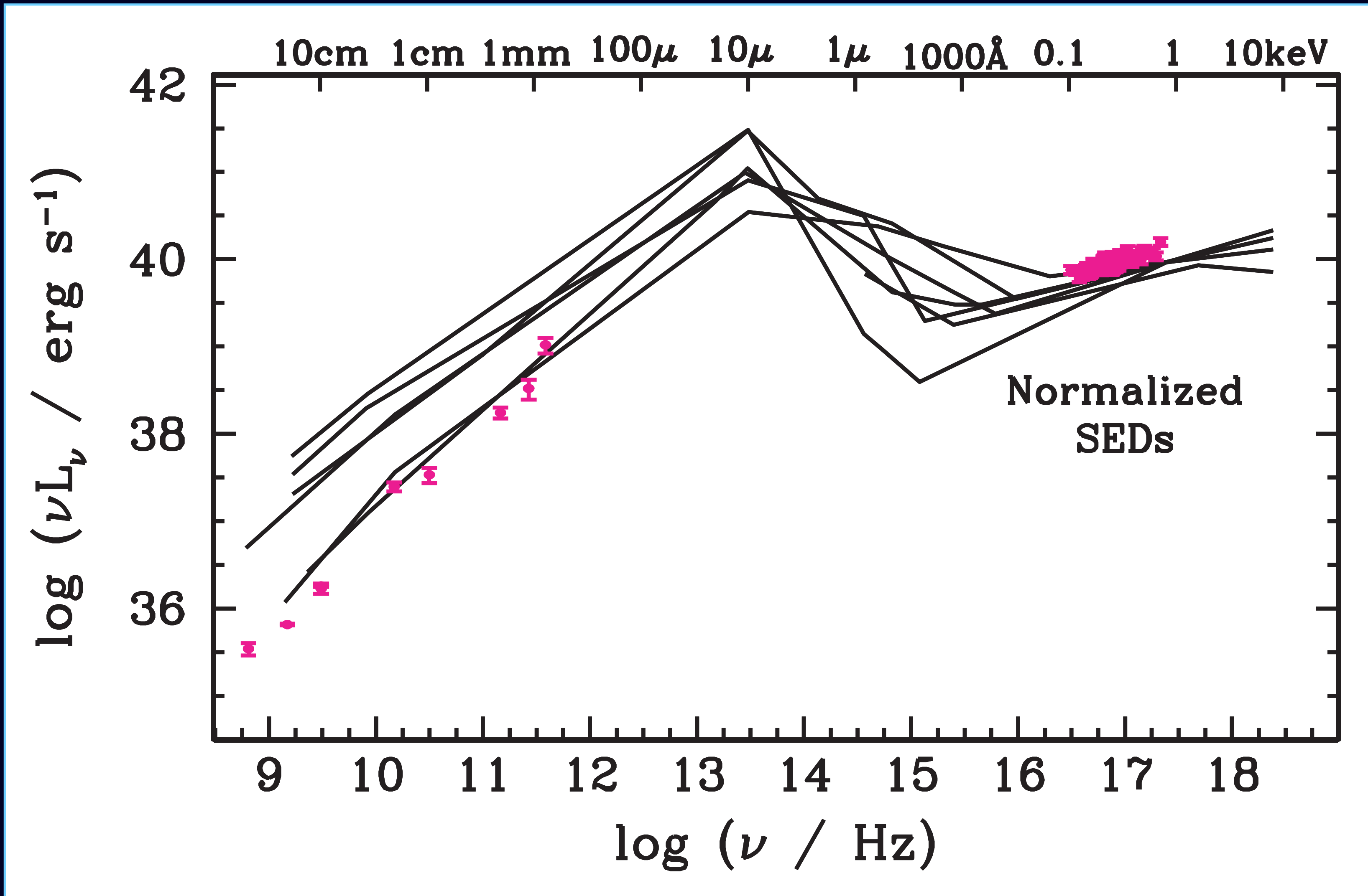
1. **Study accretion flow of a low-lum SMBH in detail**
   - isolate accretion flow ➠ Chandra (1”), nearby source (selects low-luminosity)
   - obtain high-res lines from nuclear region ➠ HETGS
   - nearby LLAGN are bright ➠ HETGS (avoid pileup)
2. **Useful comparison to Sgr A***
   - Sgr A* is weird, and we know a lot about how weird it is, but not *why*. Need a candidate LLAGN with enough similarities to make a useful comparison of: spectrum, variability, accretion processes

Why M81?

1. Nearest active nucleus in spiral (Sb) w/ reliable M & D, can resolve inner 17pc (~5×10^6 R_g) with *Chandra*!

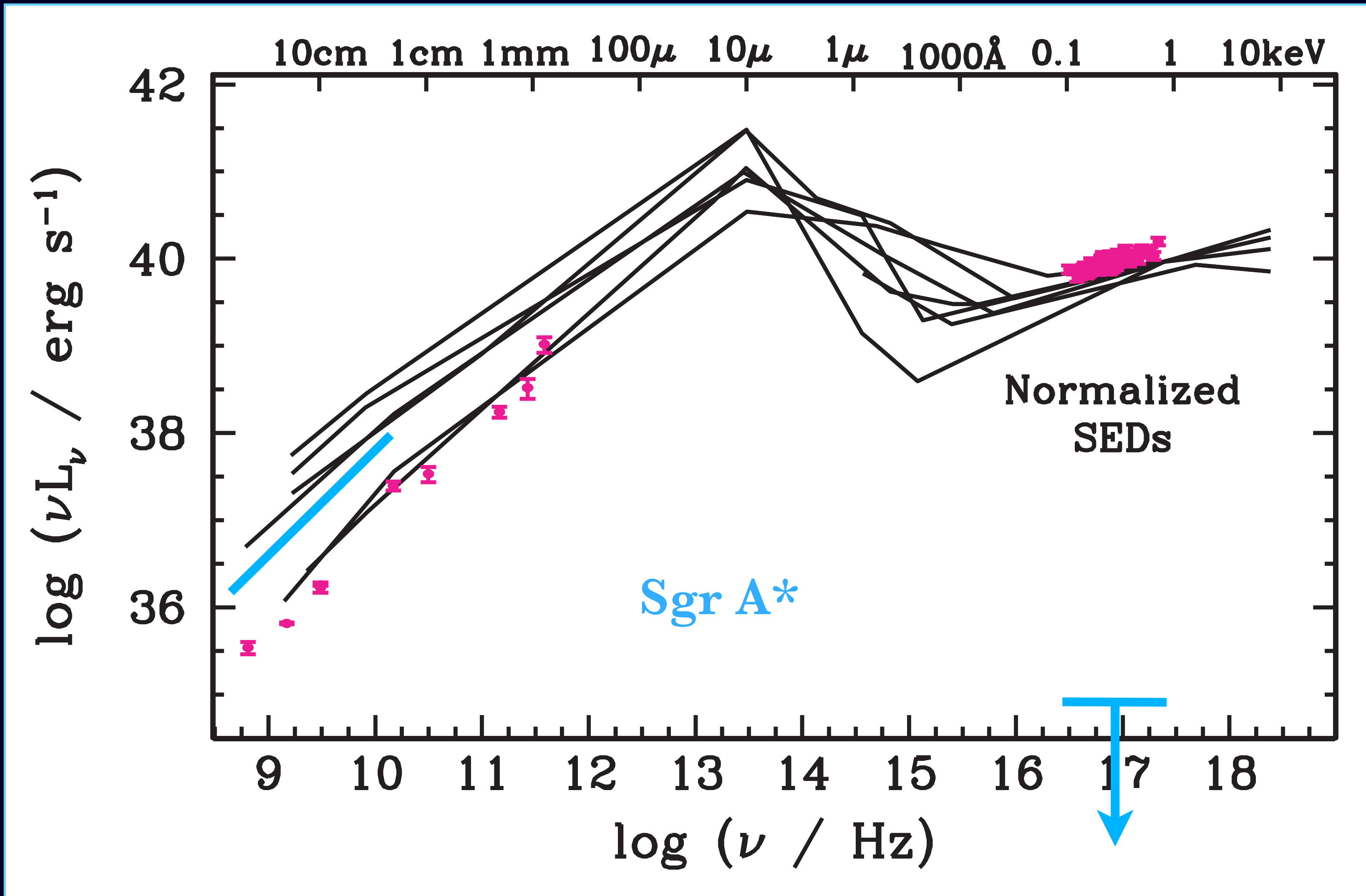
2. Classic LLAGN (LINER/Seyfert 1), no blue bump

M81* is a classic LLAGN



adapted from Ho (1999)

M81* vs. LLAGN



adapted from Ho (1999)

Why M81?

1. Nearest active nucleus also in spiral (Sb) w/ reliable M & D, can resolve inner 17pc (~$5\mathrm{x}10^6$ R_g) with *Chandra*!

2. Classic LLAGN (LINER/Seyfert 1), no blue bump

3. X-ray bright (L~10^{41} erg/s), significant variability (30% intraday has been observed), flares?

4. *XMM-Newton* observed neutral/ionized Fe, possibly redshifted, *ASCA* & *BeppoSAX* saw highly ionized Fe

5. Most similar LLAGN to Sgr A* in the radio: spectrum and polarization (CP > LP in cm range)

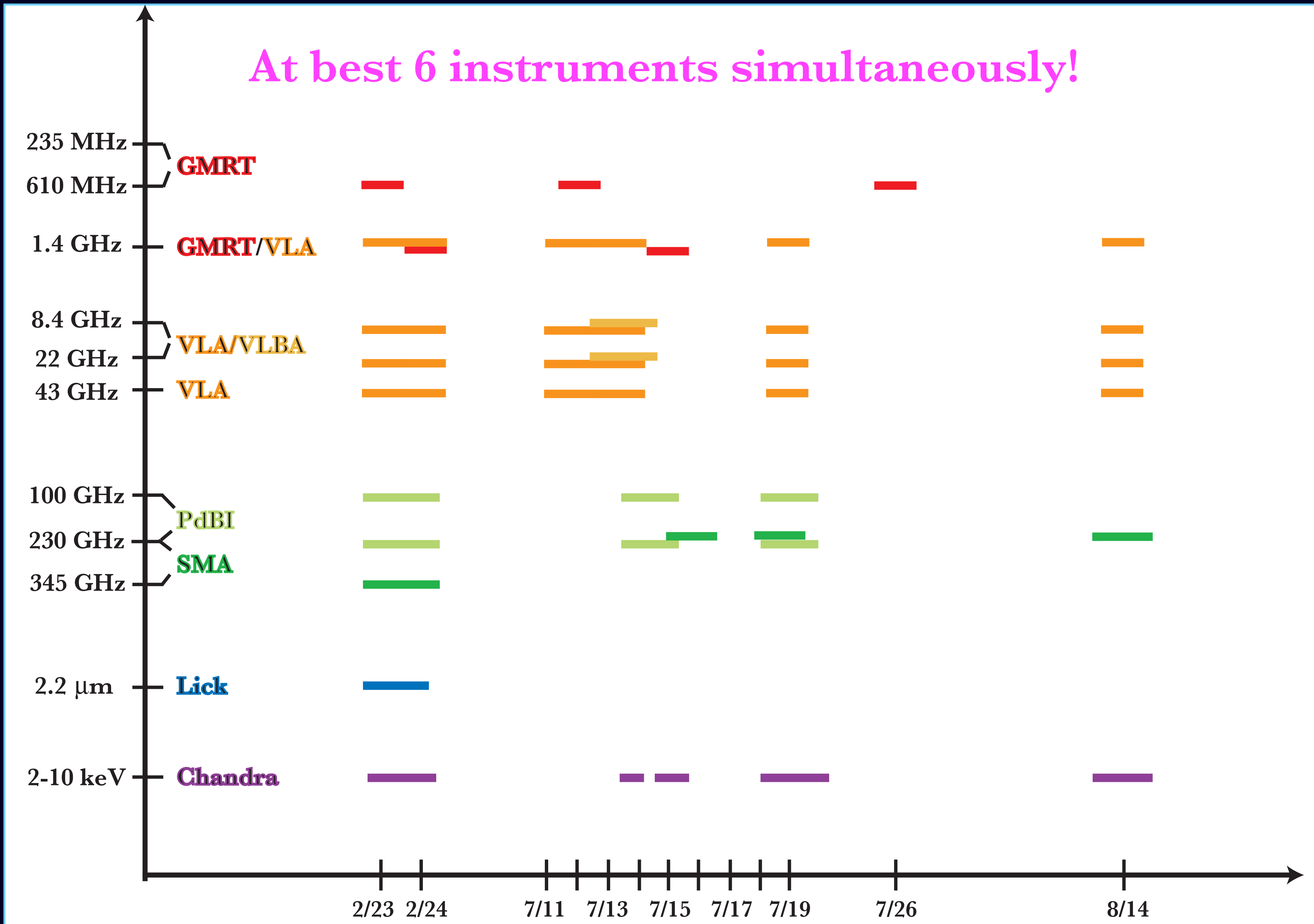
Why GTO?

- To get good statistics, needed ~300ks: expensive!

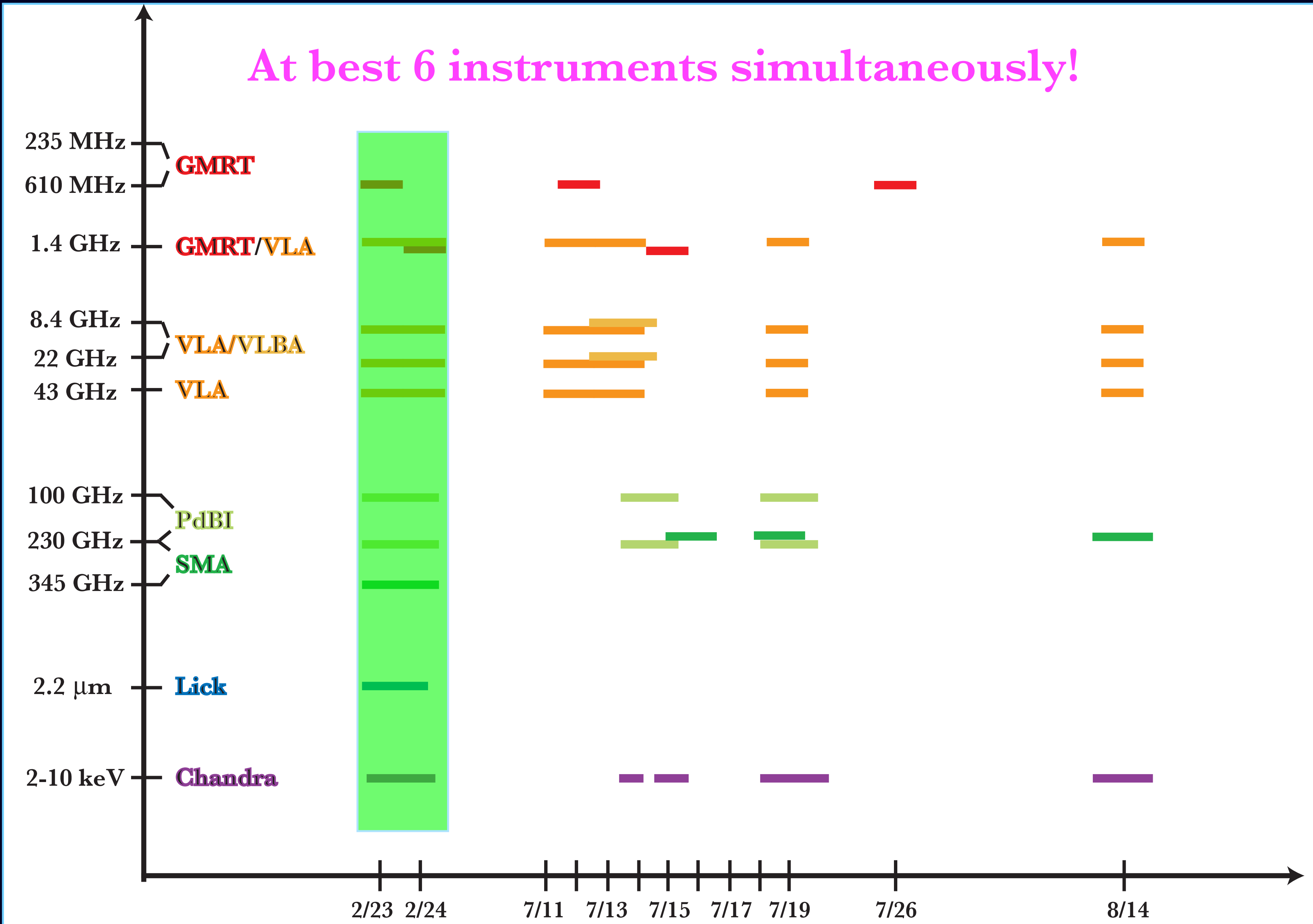
  Soap Box: The following results would not have been achievable with less time.

  They will also not be possible with upcoming X-ray missions...

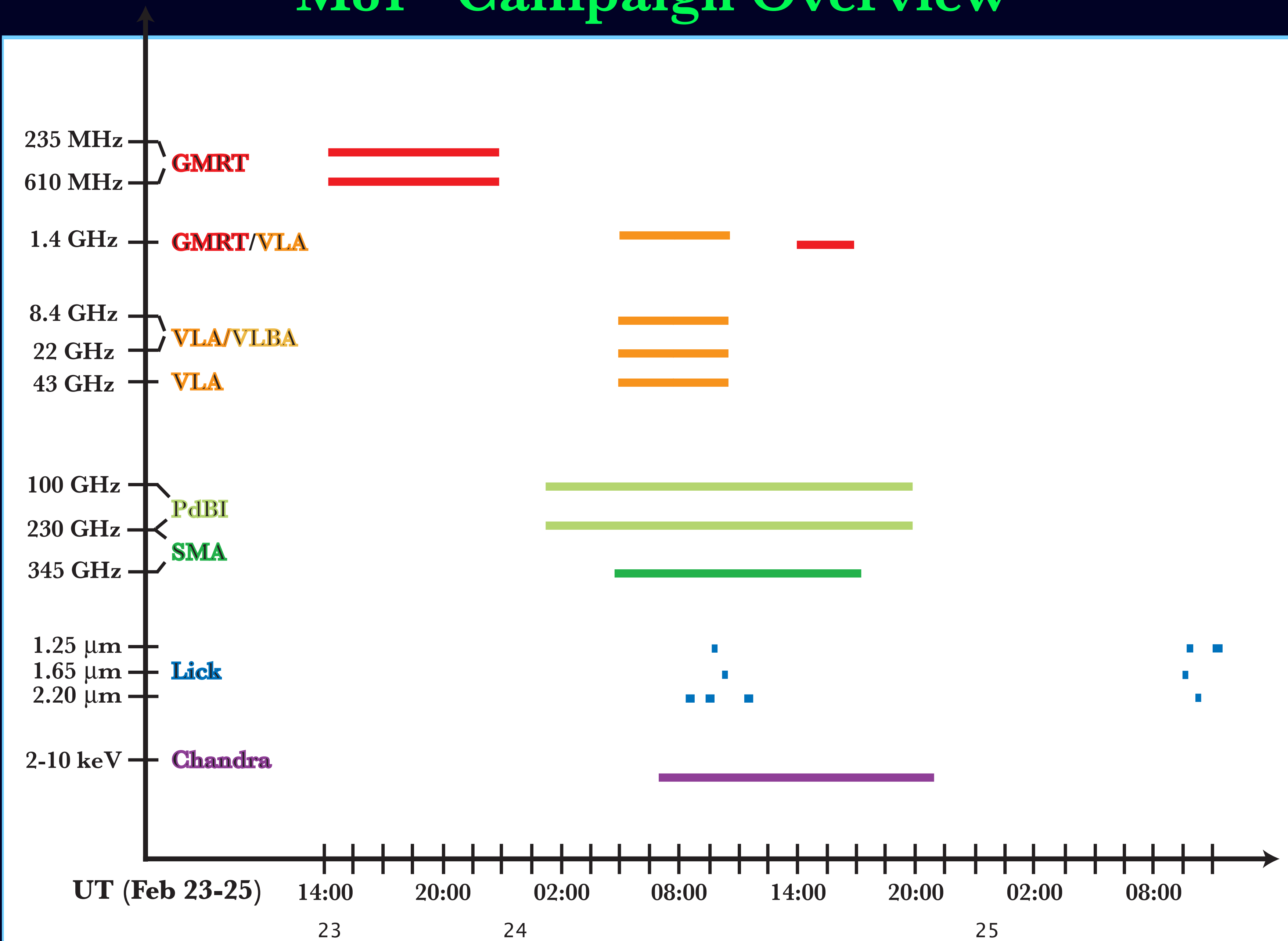
M81* Campaign Overview



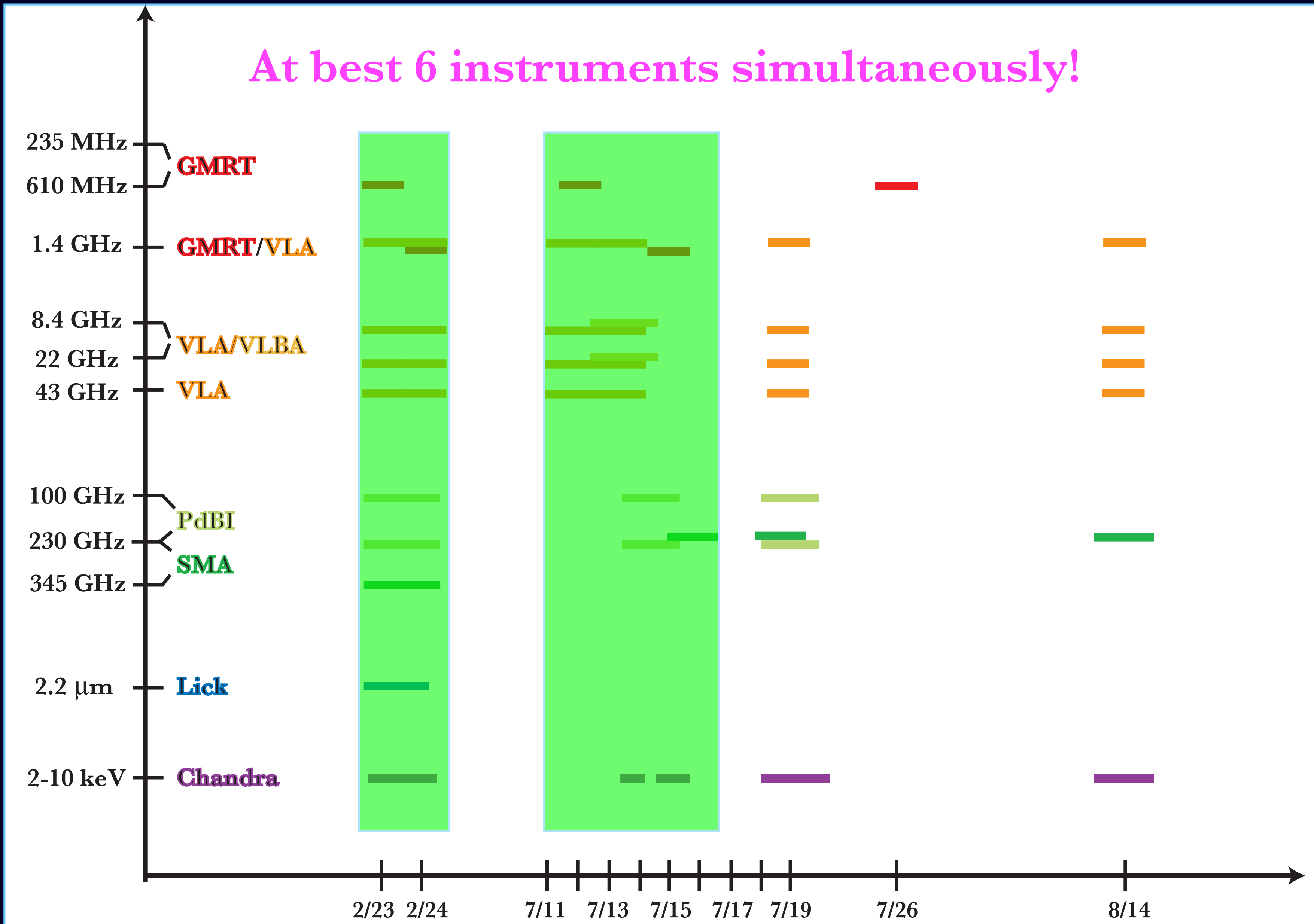
M81* Campaign Overview



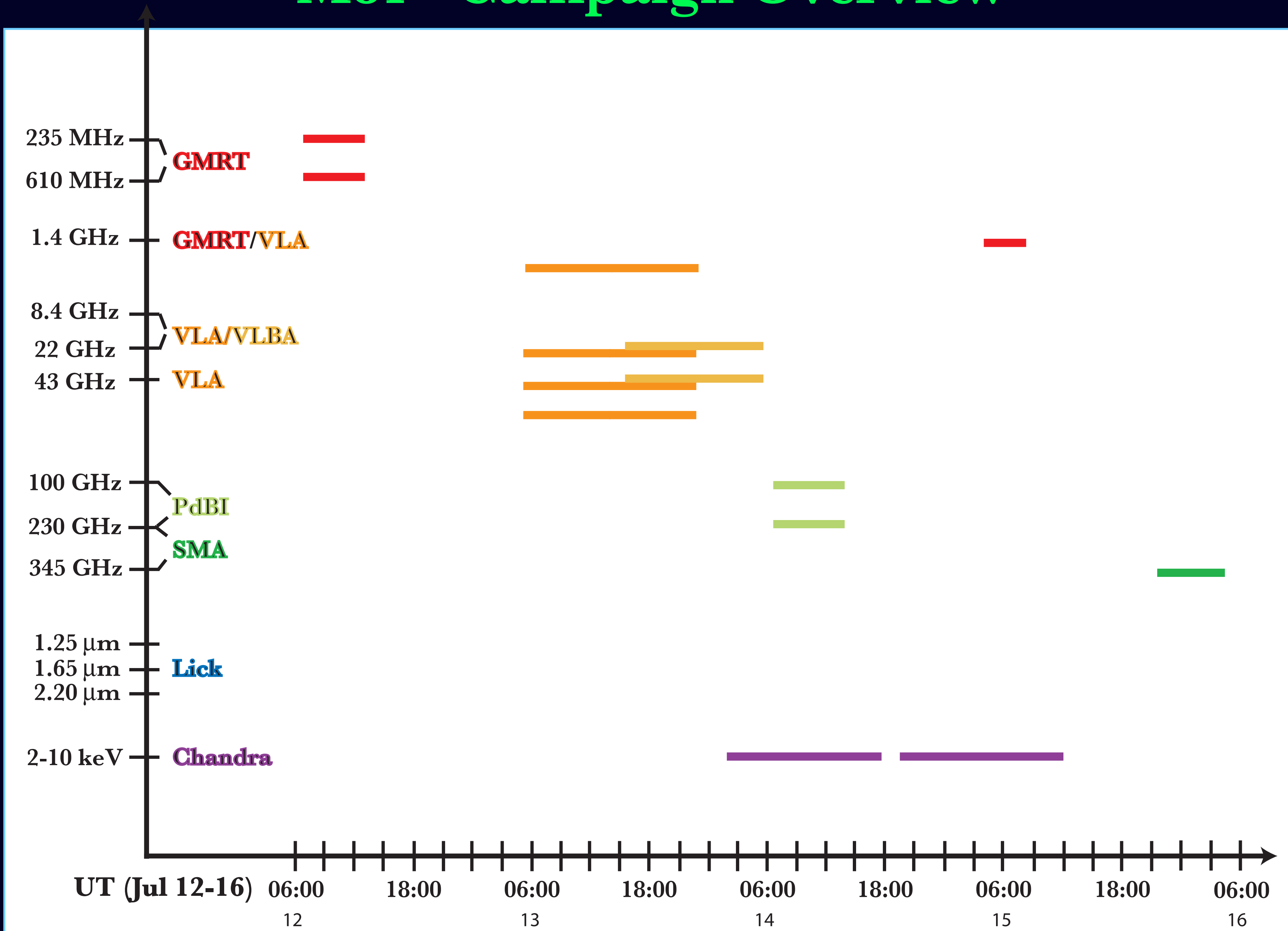
M81* Campaign Overview



M81* Campaign Overview



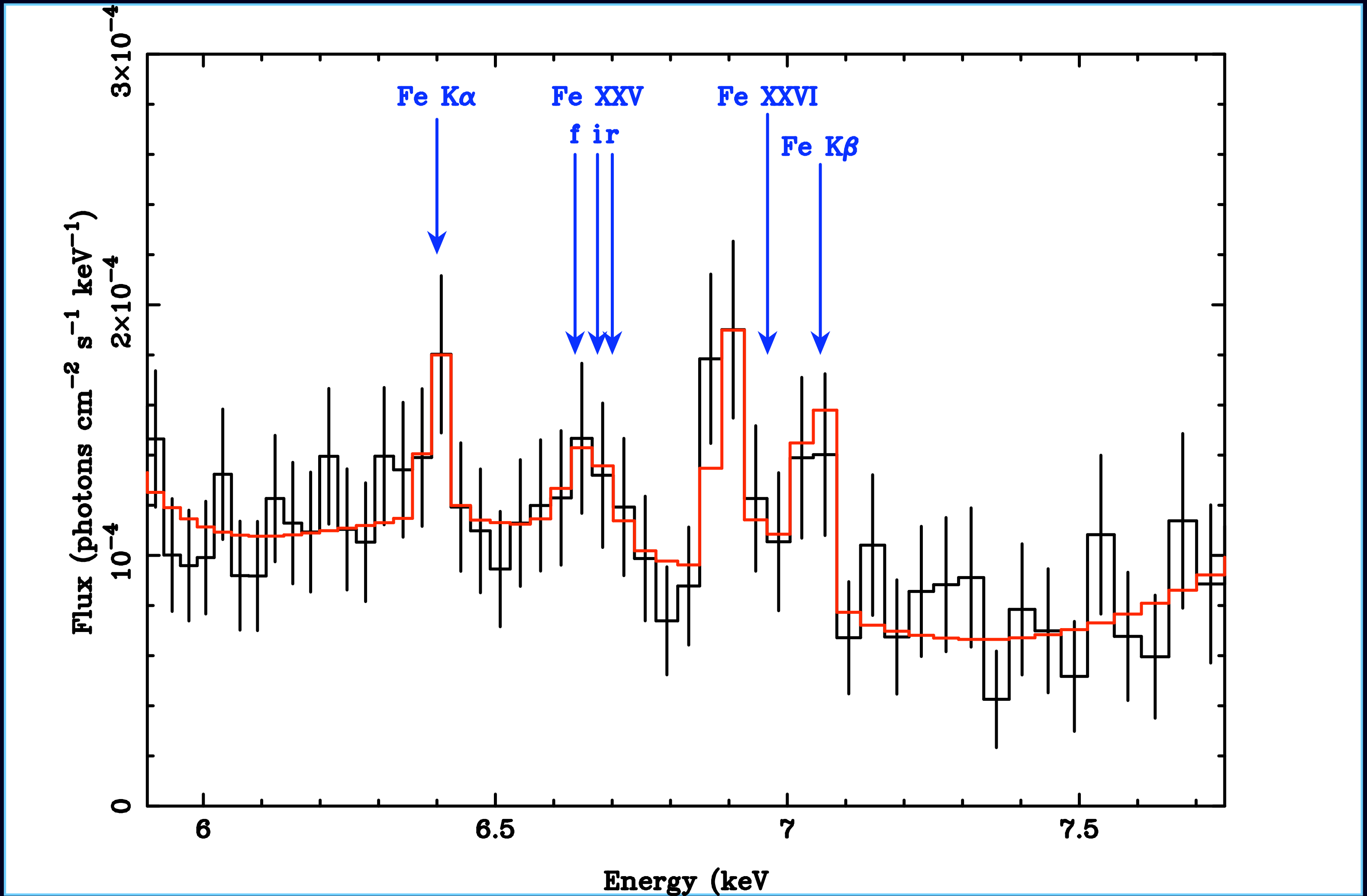
M81* Campaign Overview



Results I: Emission Lines from Accretion Flow

(See poster 1.24 by A. Young et al.)

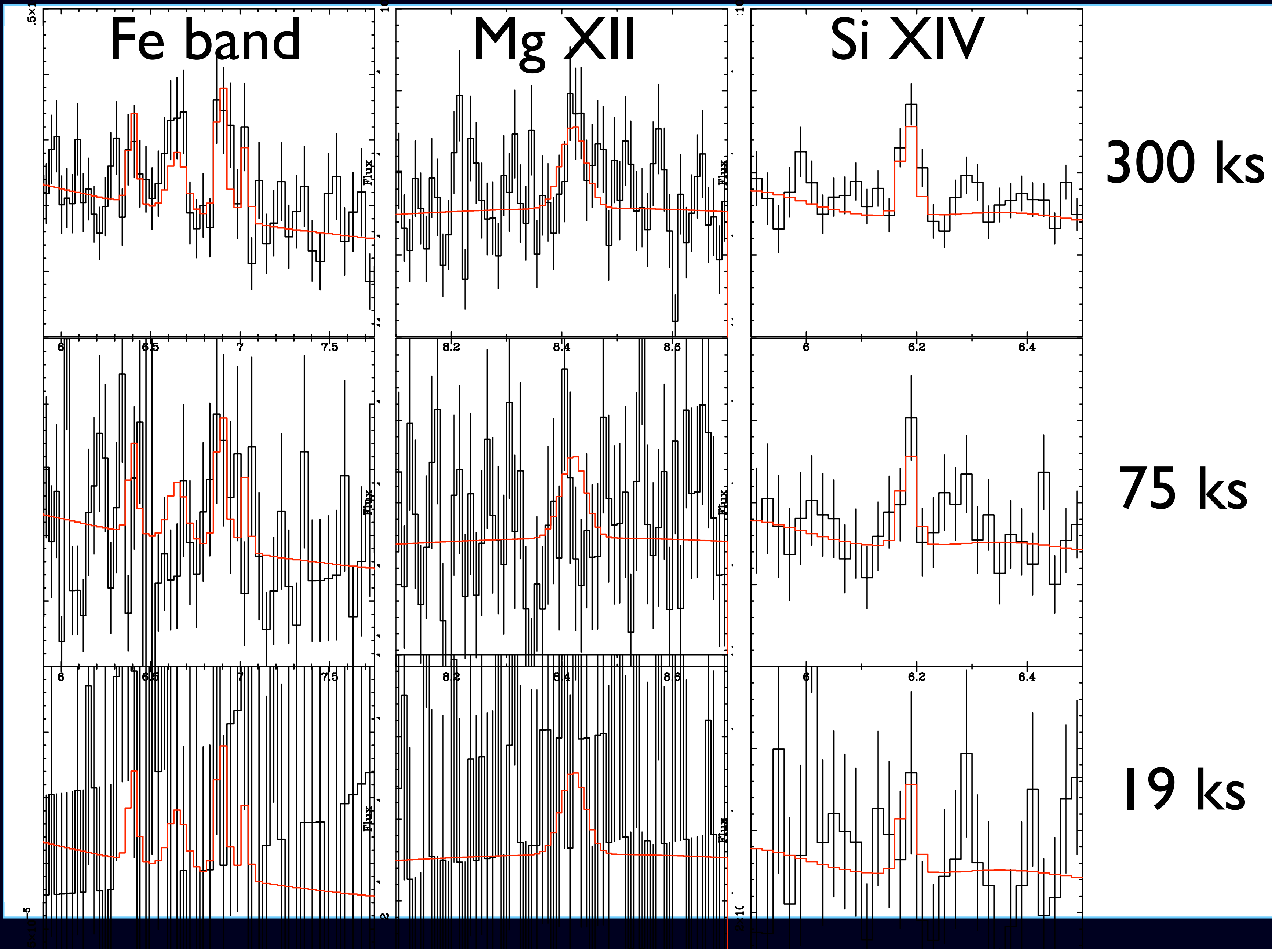
- Iron lines observed from w/in 17pc!



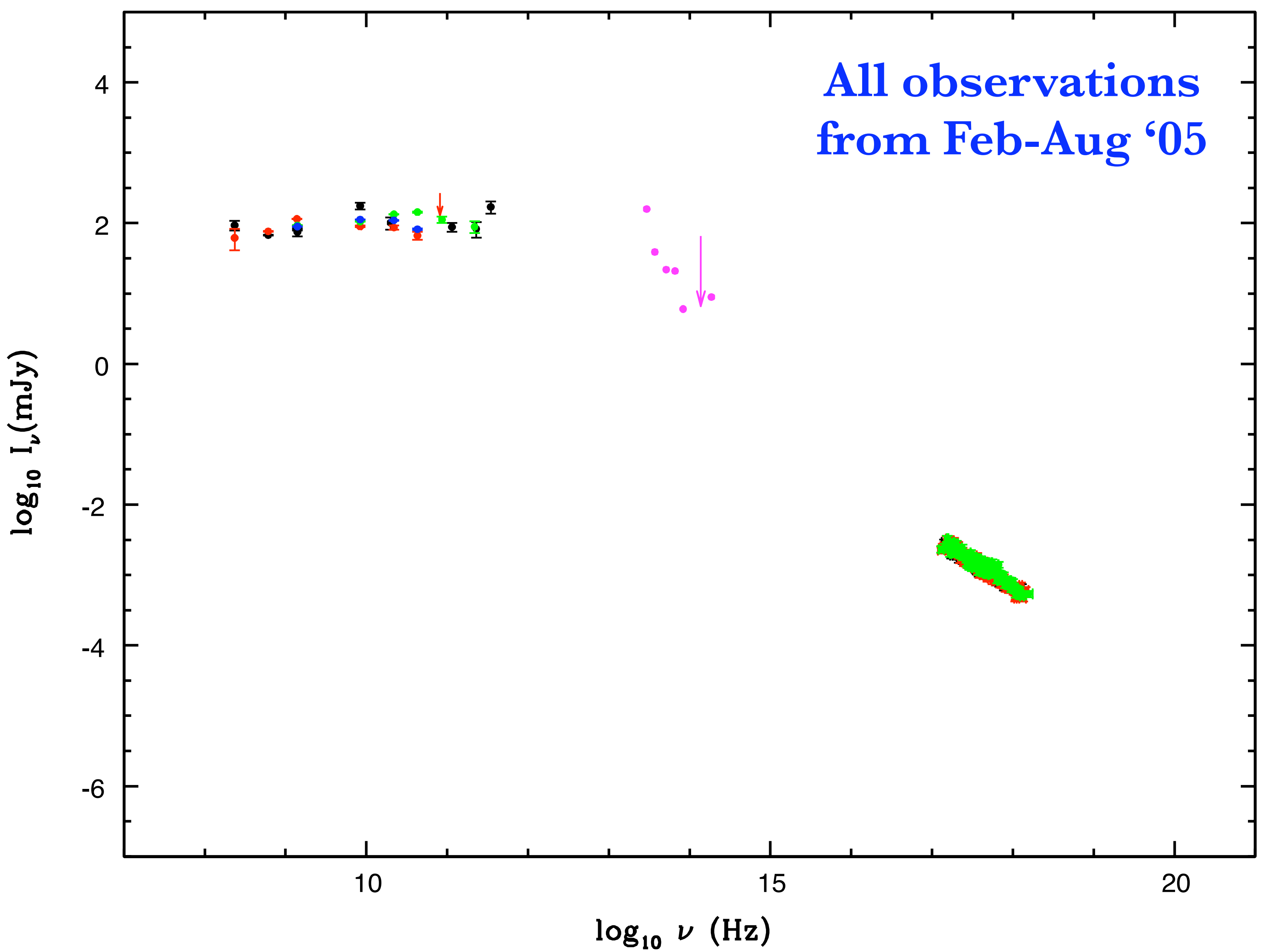
Results I: Emission Lines from Accretion Flow

- Iron lines observed from w/in 17pc! (>99%)
  - Fe K_α fluorescent line ⇒ cooler material
  - Fe XXV, XXVI (He, H-like) ⇒ hotter material
  - Fe XXVI either double peaked or redshifted w/ velocity ~3000 km/s. *XMM lines were nuclear!*
    - heated atmosphere above disk or hot, inner (radiatively inefficient?) flow, $R_k \sim 10^4\ R_g$ (consist. w/some scenarios)
  - Broadened lines from low-Z elements: Mg, Si, S, O. A first for LLAGN!! Plasma diagnostics for accretion flow (T, density ➠ η)

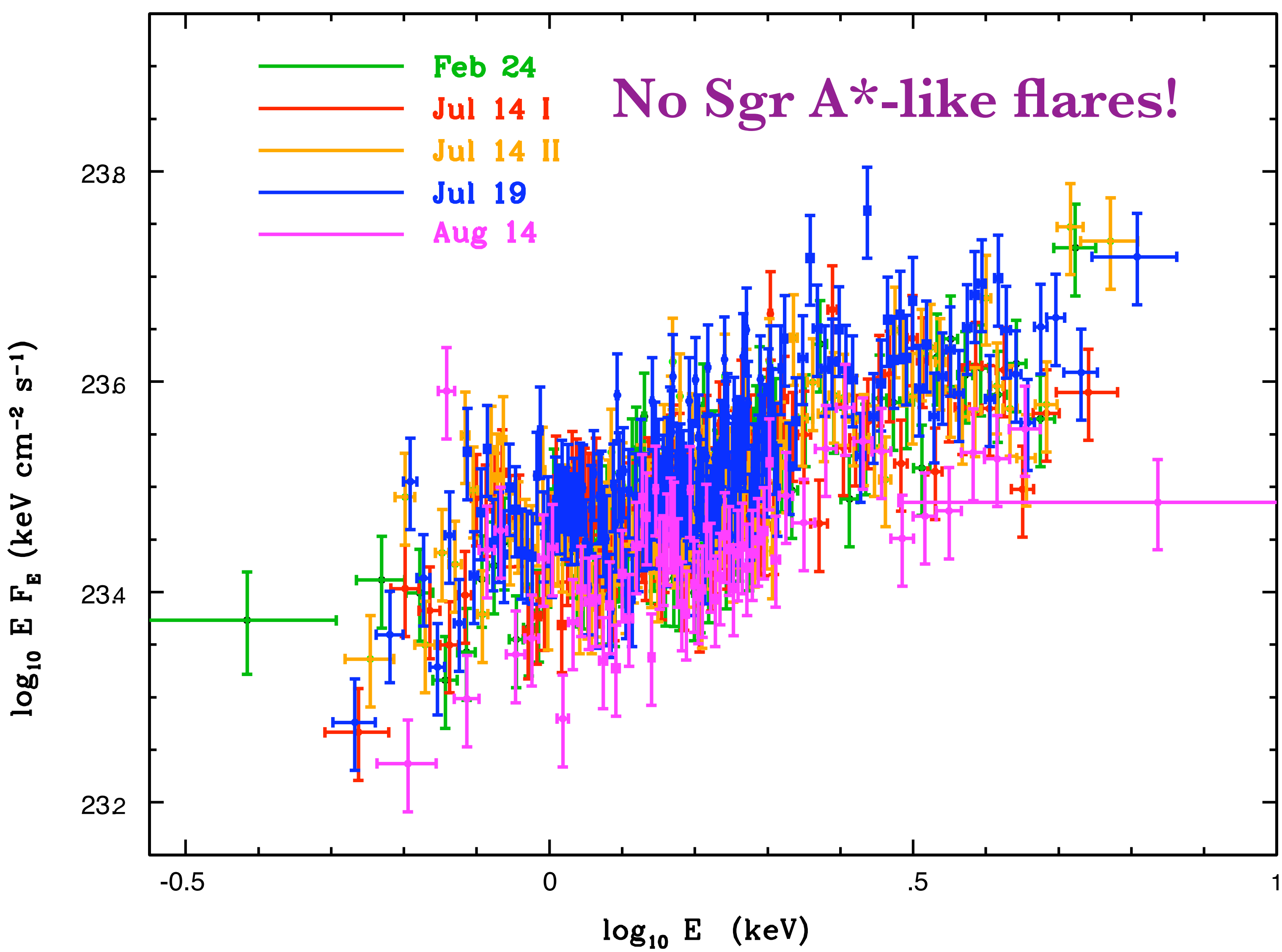
Results I: Long Integration Times



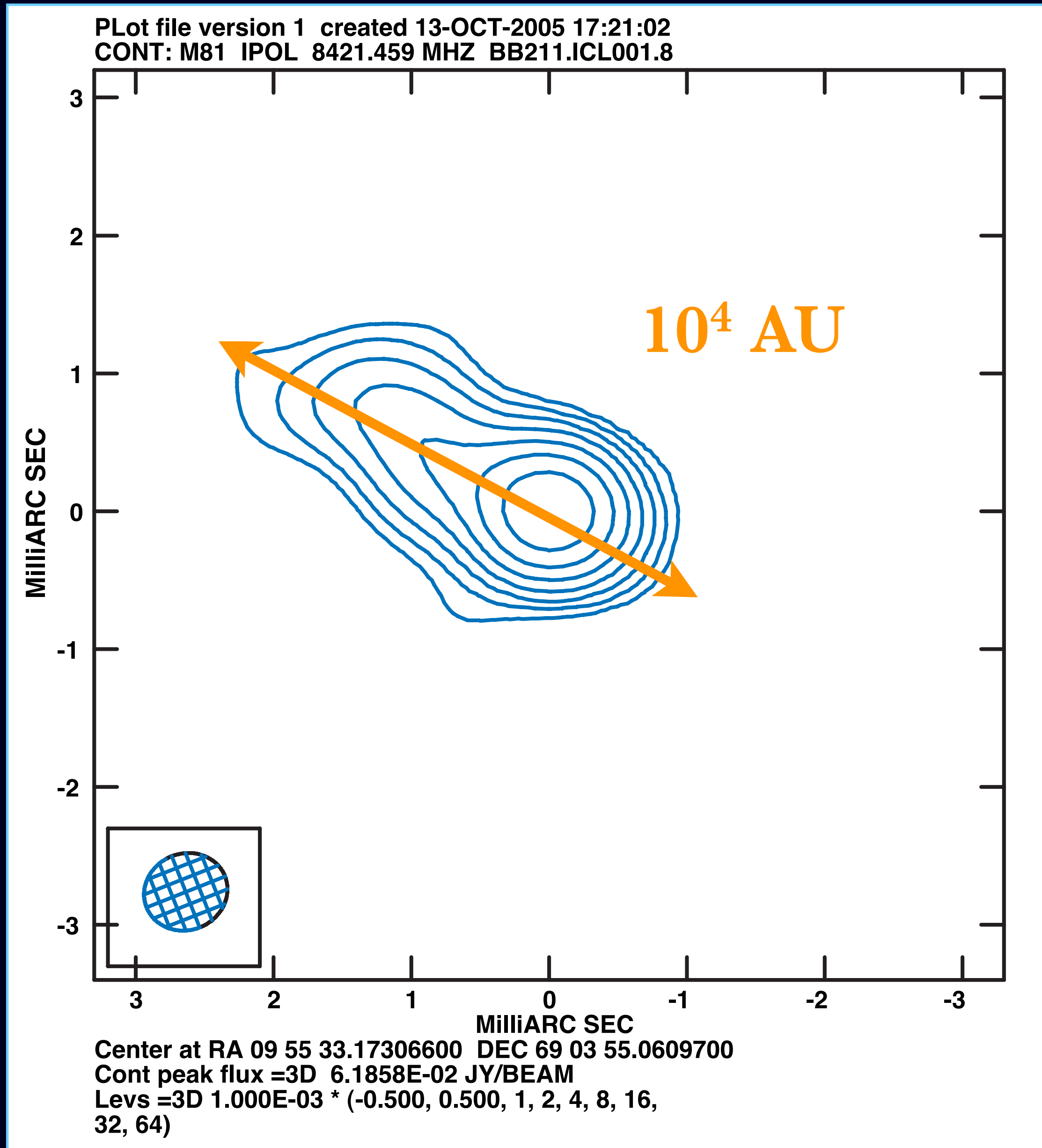
Results II: Continuum Emission



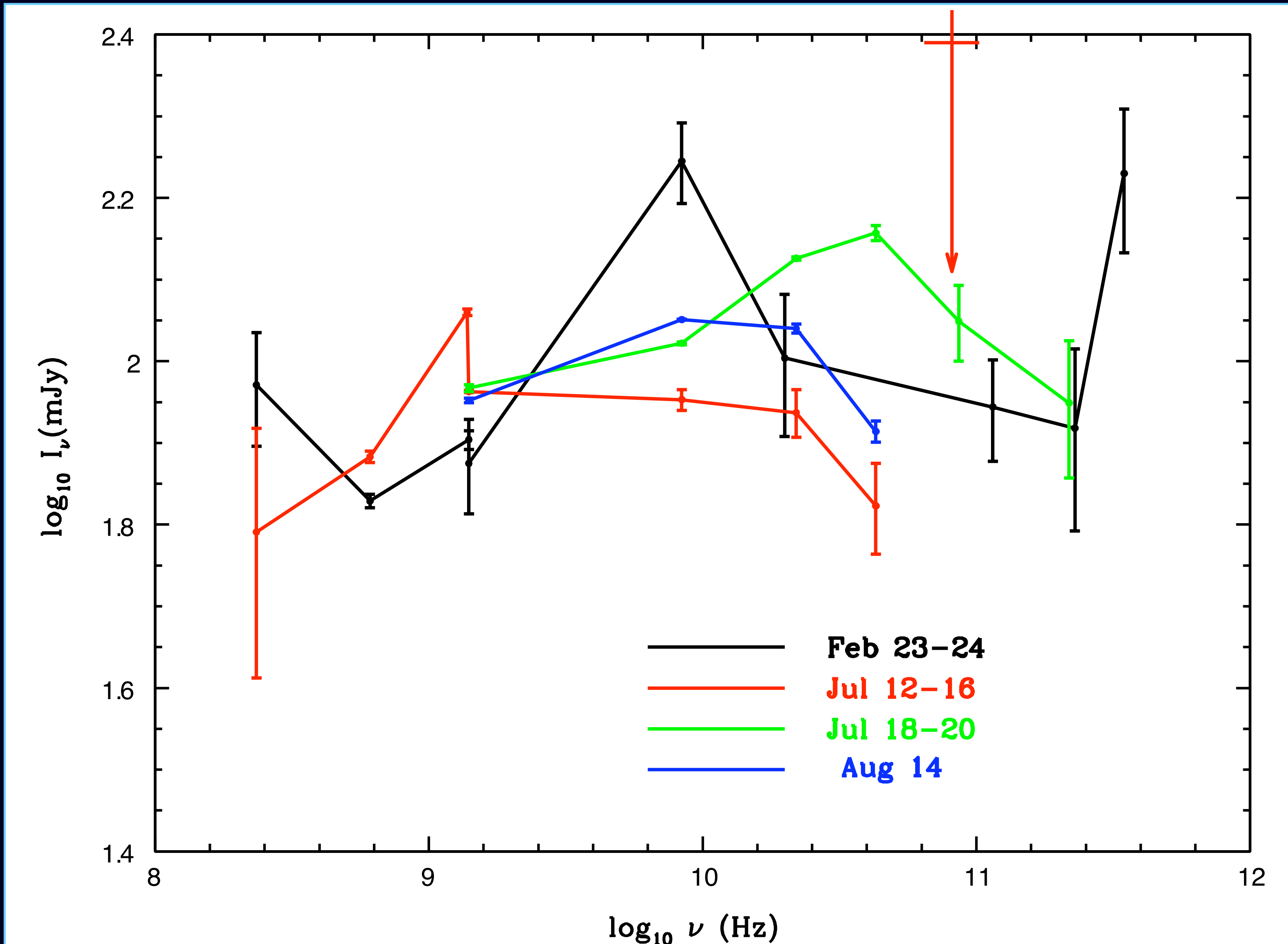
Results II: Continuum Emission



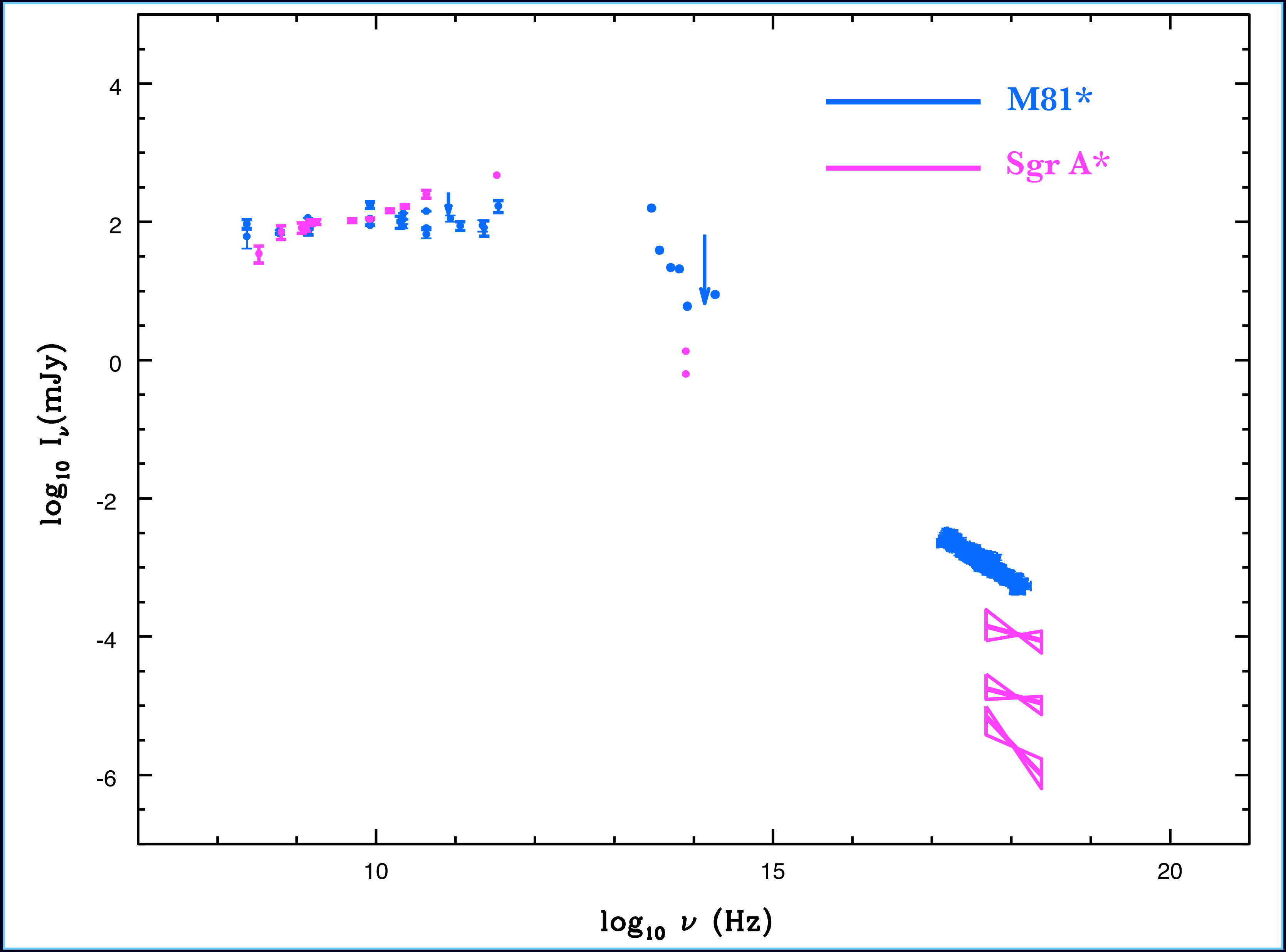
M81* Jet w/VLBA



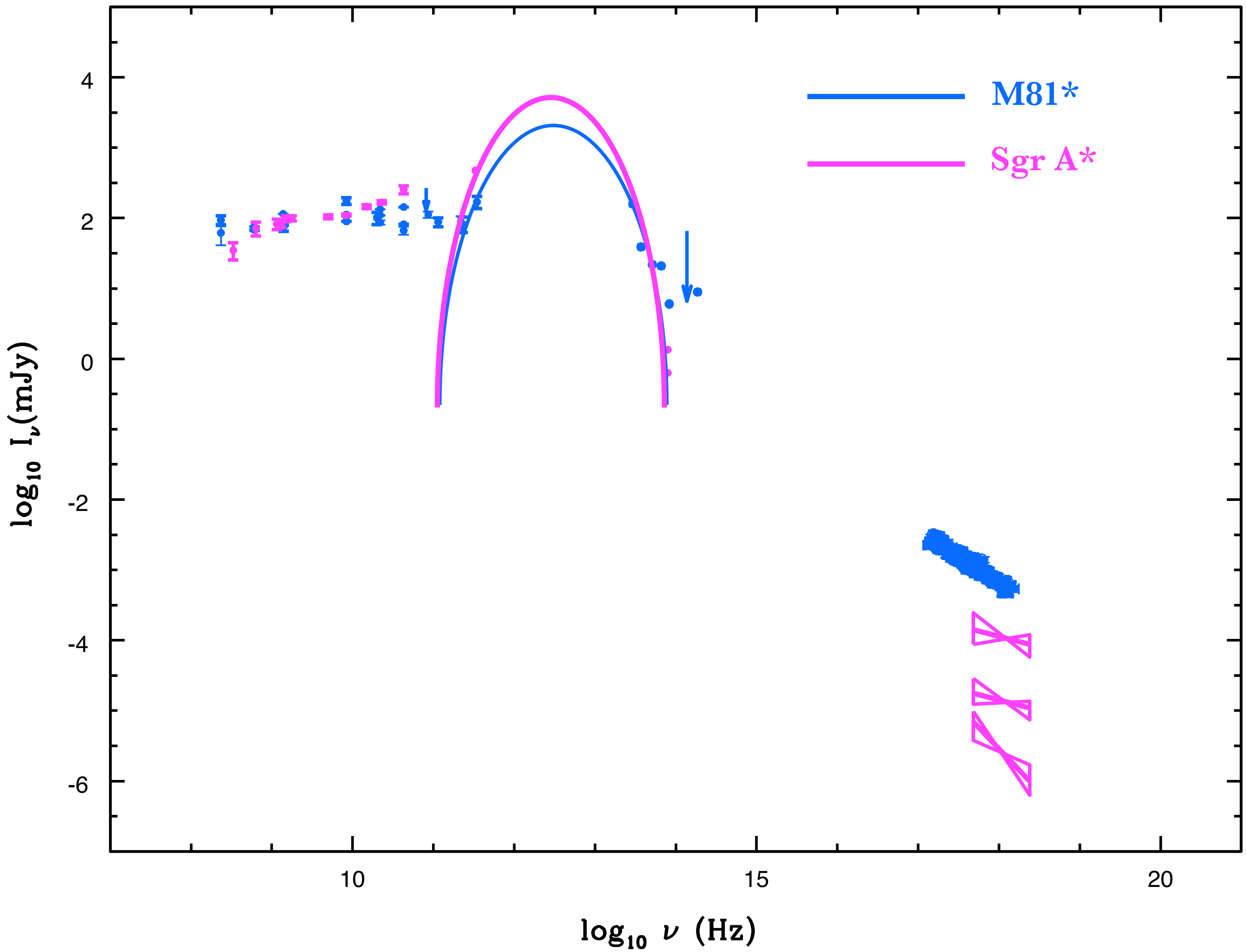
Results II: Continuum Emission



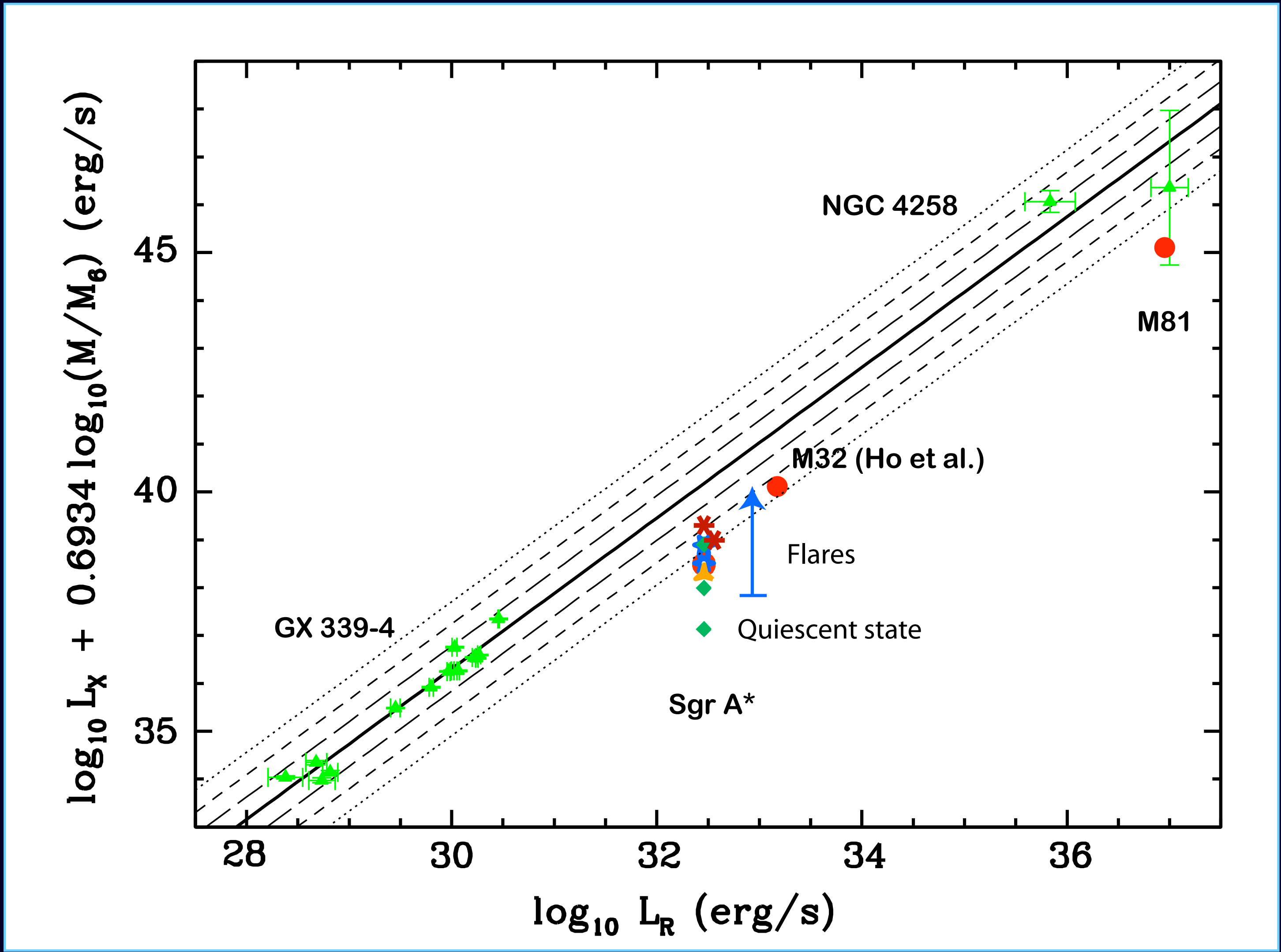
Results II: Continuum Emission



Results II: Continuum Emission



Sgr A*/M81* in the fundamental plane



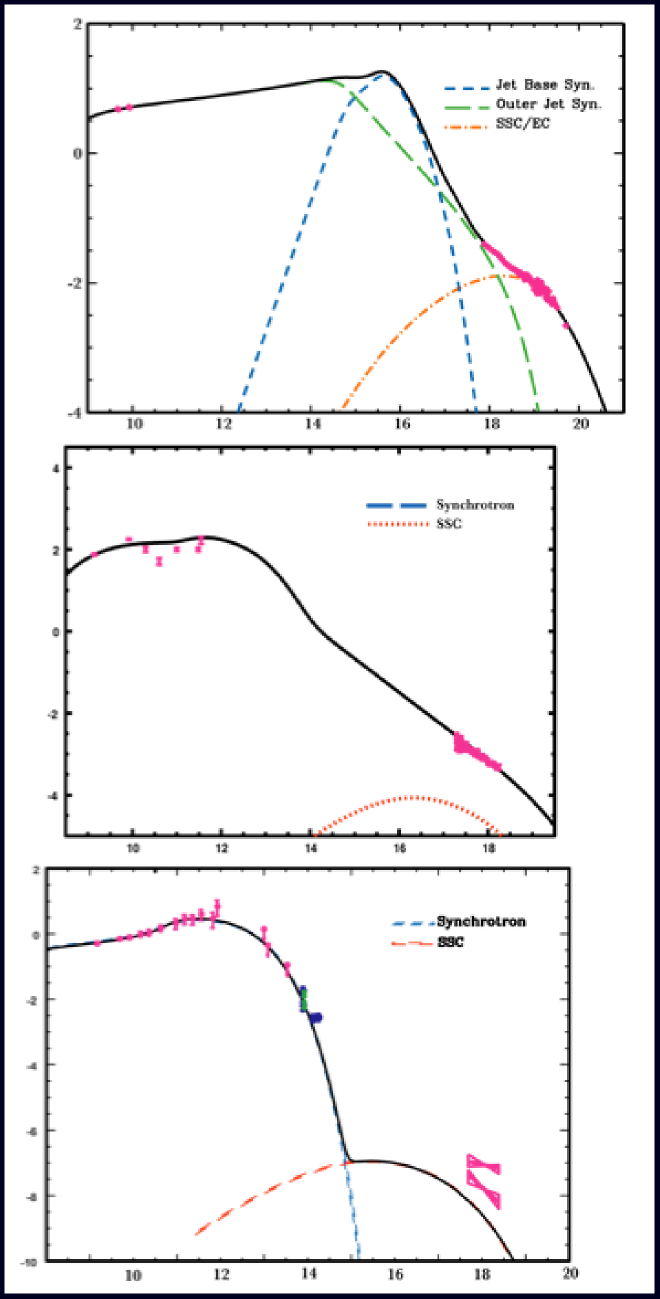
(Markoff 2005)

As above, so below...?

Hard state XRB
(GX 339-4, M=6 M⊙)

Low-lum AGN
(M81*, M=7x10^7 M⊙)

Sgr A*
(M=4x10^6 M⊙)



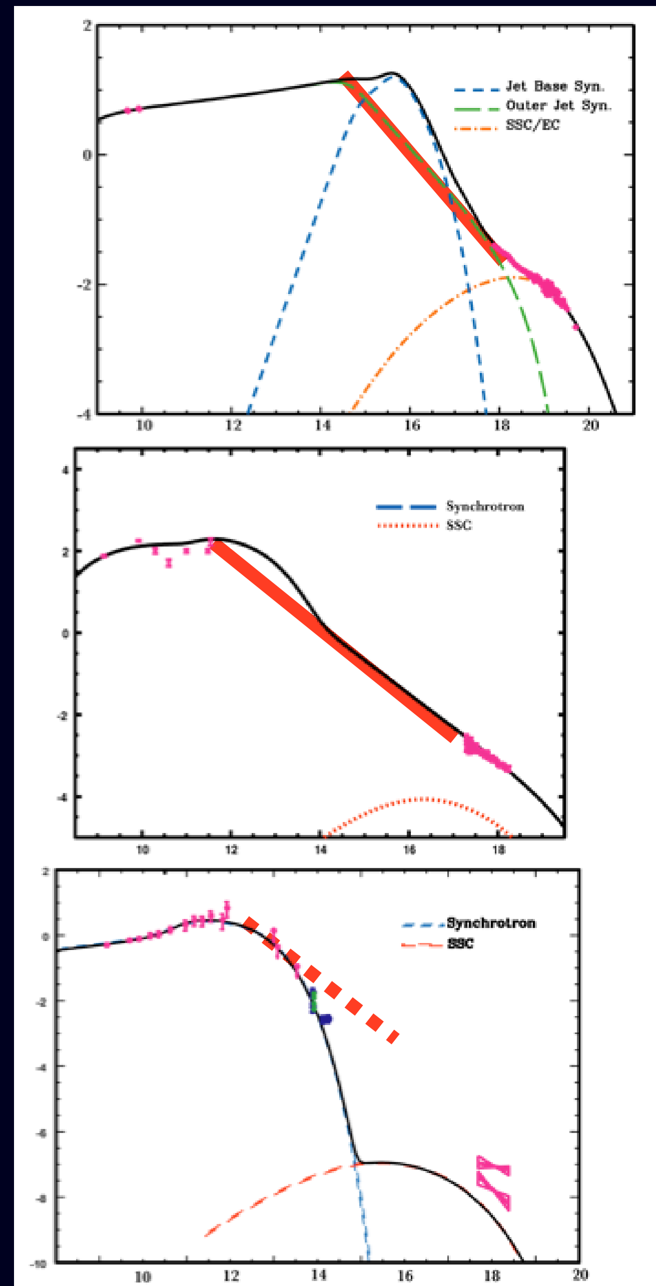
L_{Edd}

As above, so below...?

Hard state XRB
(GX 339-4, M=6 $M_\odot$)

Low-lum AGN
(M81*, M=7×10^7 $M_\odot$)

Sgr A*
(M=4×10^6 $M_\odot$)



L_{Edd}

Summary/Outlook

- Many species of lines observed from near the nucleus, several with indications of high velocities
  - ➡ observing hot/cold phases of flow
  - ➡ 300ks was necessary to resolve most lines
  - ➡ detailed plasma diagnostics to come (Young et al. 2006)
- Radio to submm quite variable, hint of a submm bump similar to Sgr A*
  - ➡ modeling of broadband/comparison to come (Markoff et al. 2006)
- **Upcoming:** followup continuum monitoring with ACIS (PI: J. Miller), along with more simultaneous multiwavelength in radio/submm/IR/opt