A torus+jet model for Sgr A*

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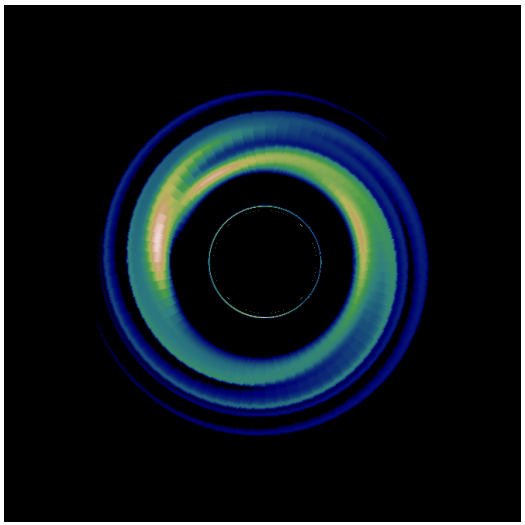
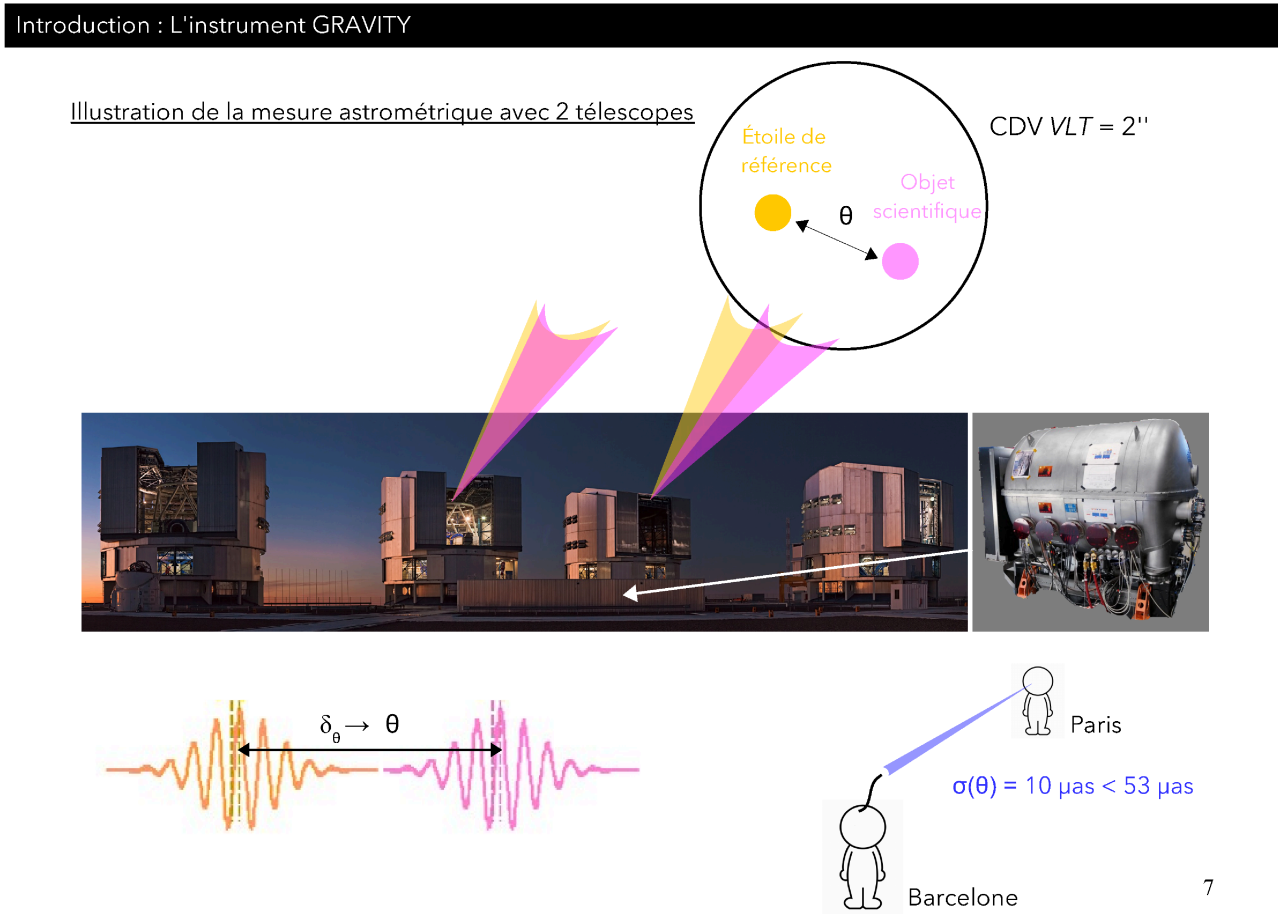
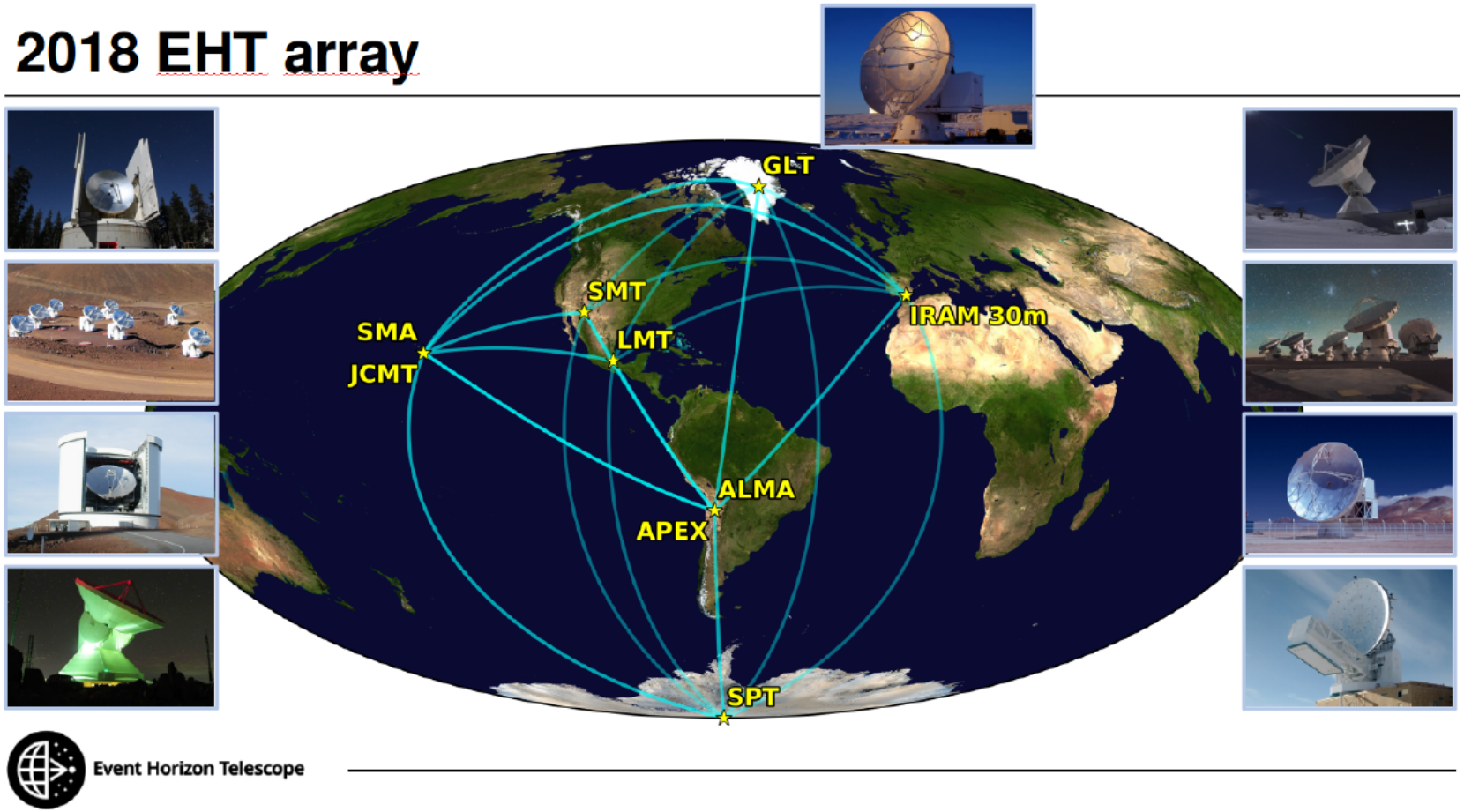




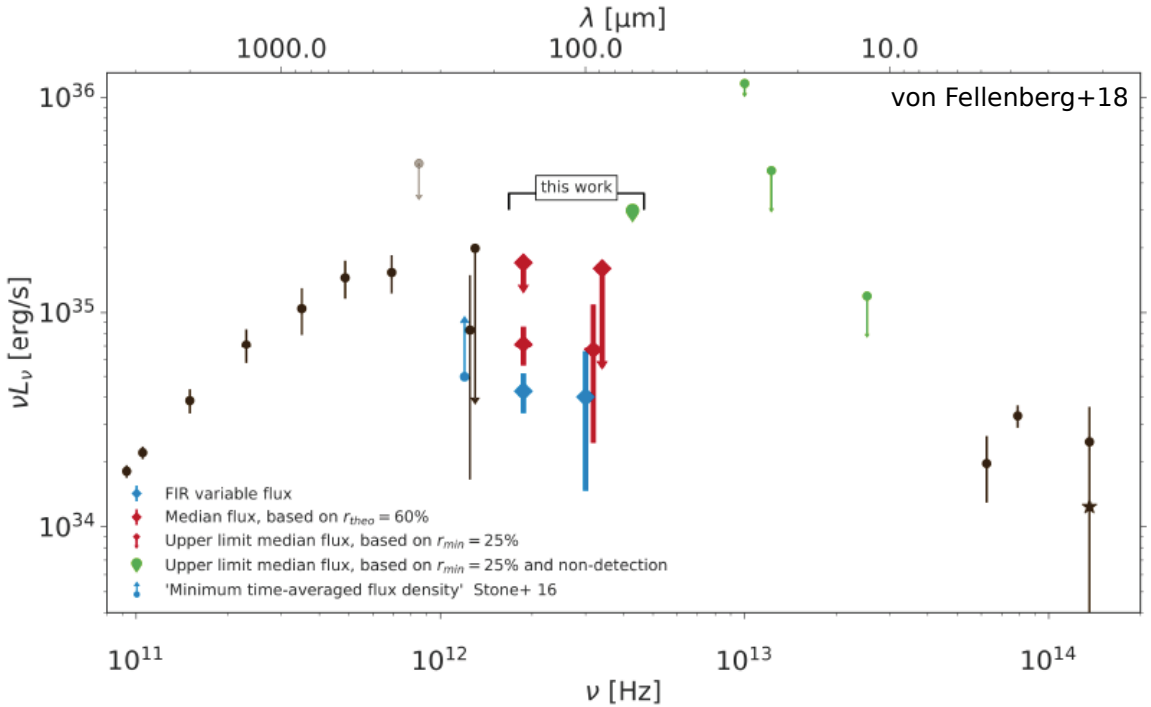
Motivation: GRAVITY

- Flares of Sgr A* $\rightarrow$ understand accretion flow



Motivation: EHT

- Image of Sgr A* $\rightarrow$ understand accretion flow

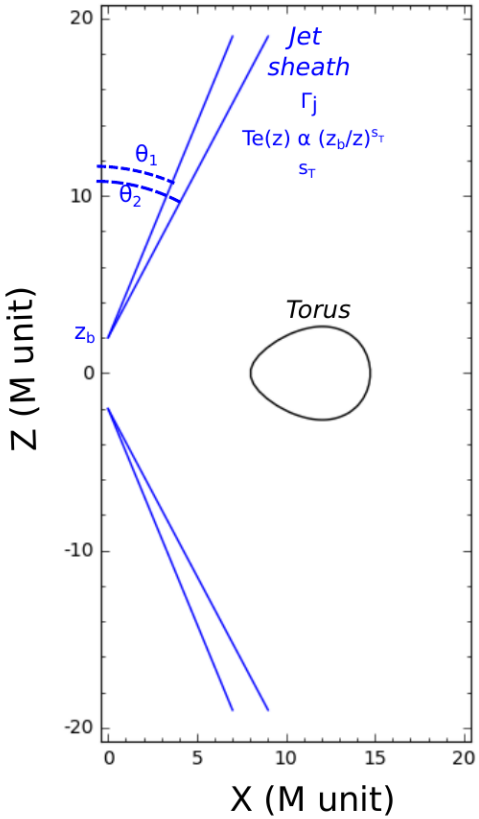


Motivation: spectral data

- Recent far-infrared spectral data

Aim

- Simple analytic model of Sgr A* accretion flow emission (synchrotron radiation → density, temperature, B field)



Torus+Jet

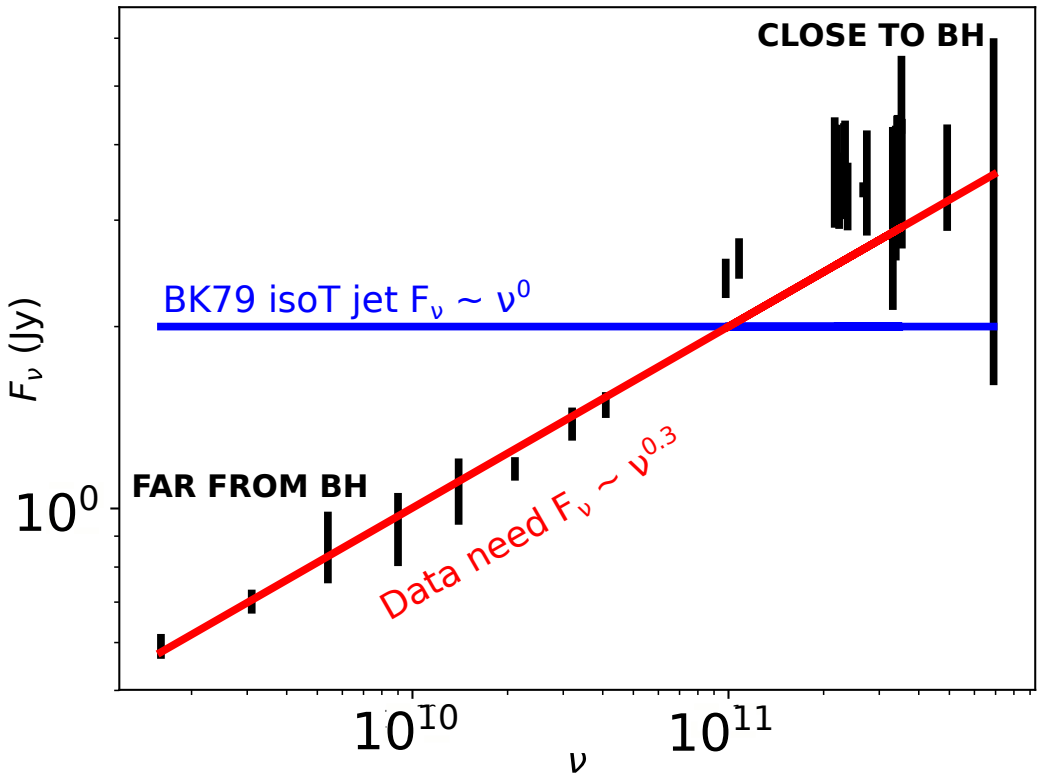
- Torus: “standard” ion-torus model (Straub+12, Vincent+15)
- Adding a simple jet model
- Aim: simplest physically meaningful setup

Jet model

- Moscibrodzka+13: jet sheath is emitting

  $\rightarrow z_{\rm base}, \theta_{\rm in}, \theta_{\rm out}$
- Constant Lorentz Γ_j
- Mass conservation: $n_e \propto r_{\rm cyl}^{-2}$
- Approximate equipartition: $B^2 \propto n_e$
- Power-law temperature

  $\rightarrow T_e(z) = T_e(z_{\rm base}) \left(\frac{z_{\rm base}}{z}\right)^s$
- Synchrotron from κ-distribution electrons (following Davelaar+18)
- Ray tracing in Kerr metric



Flat radio spectrum

- $F_\nu \propto \nu^{0.3} \rightarrow$ more flux closer, less flux further
- Power-law temperature:

  $\rightarrow T_e(z) = T_e(z_{\rm base}) \left(\frac{z_{\rm base}}{z}\right)^s$

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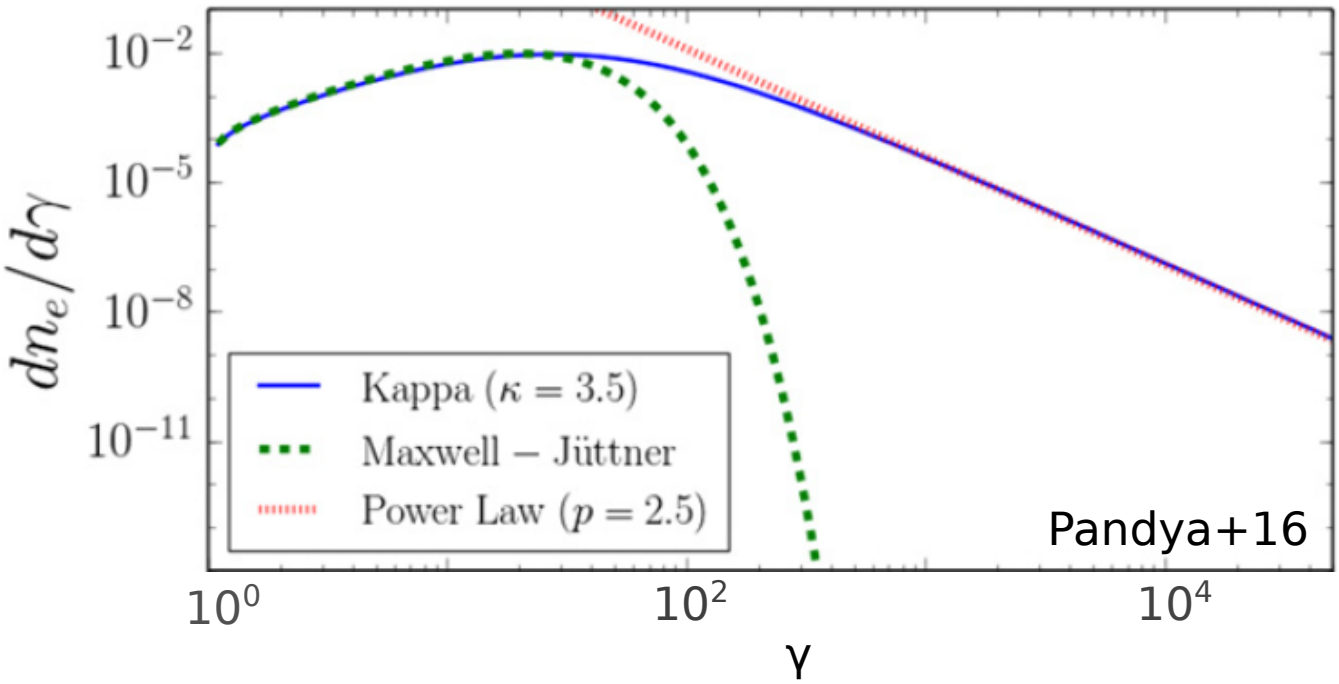

κ-distribution

- $\frac{dn_e}{d\gamma} = N\gamma\sqrt{\gamma^2-1}\left(1+\frac{\gamma-1}{\kappa\theta_e}\right)^{-(\kappa+1)}$
- Matches thermal at low γ and PL at high γ ($\kappa = p+1$)
- Synchrotron emission/absorption from Pandya et al. (2016)

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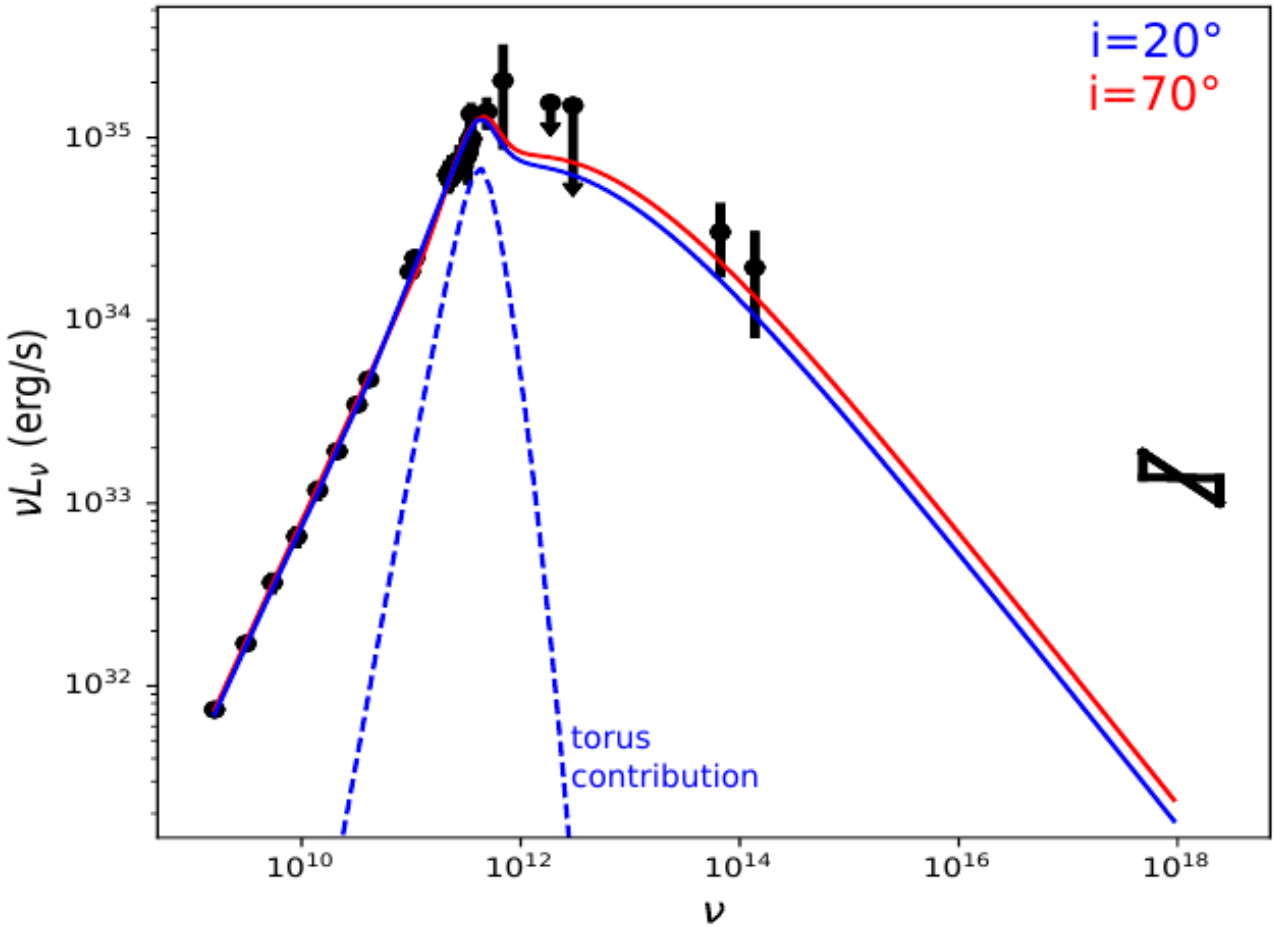
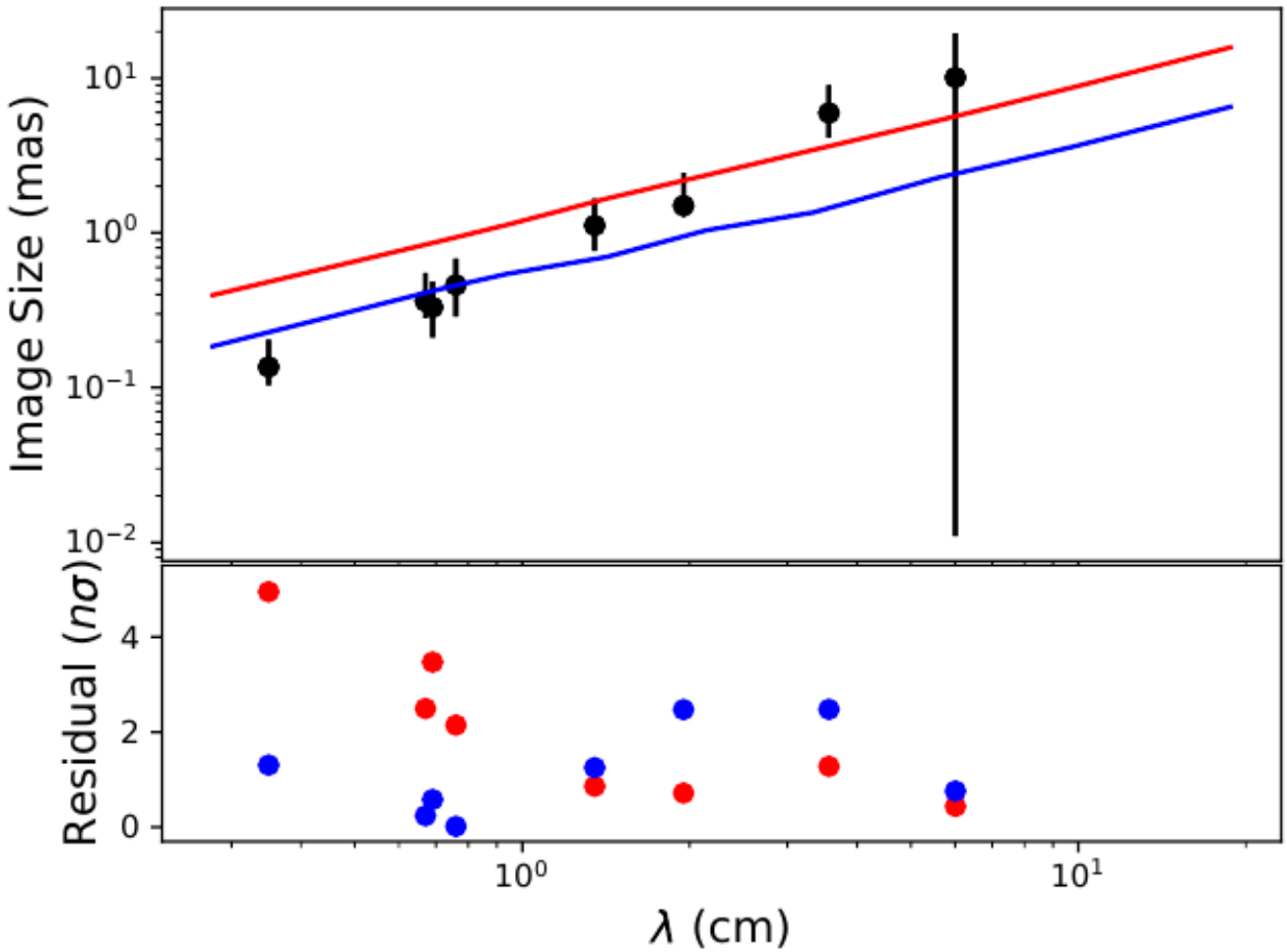


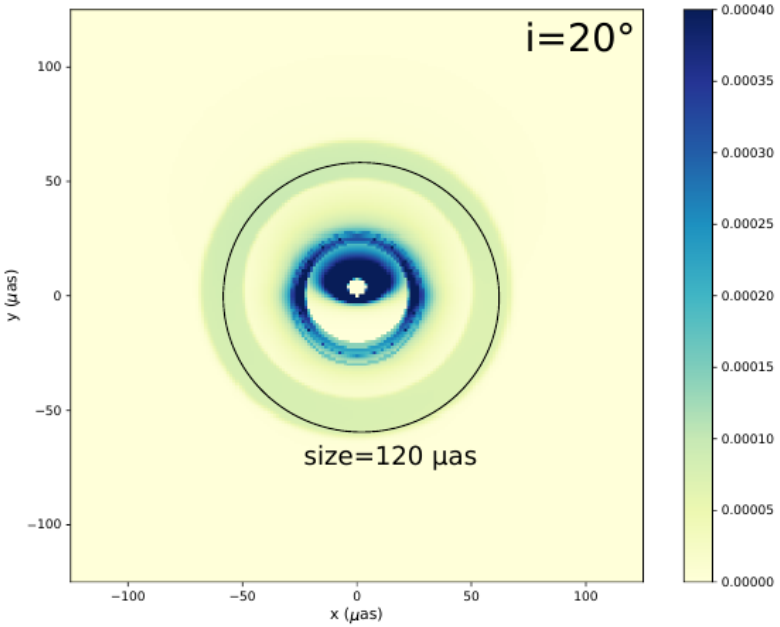
Spectral best fit

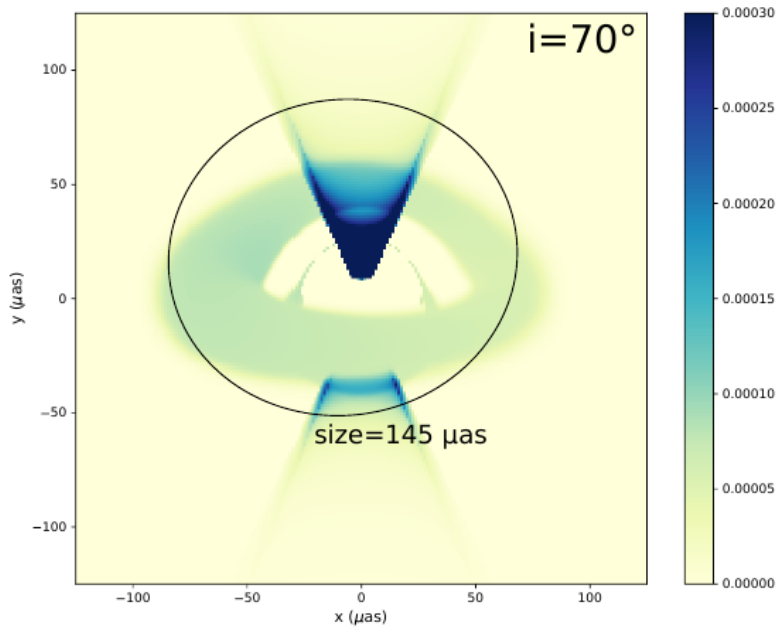
- Our model: $n_e = 5 \times 10^7 \mathrm{cm}^{-3}$, $T_e = 3 \times 10^{10}$ K
- Davelaar+18: $n_e = 2.9 \times 10^7 \mathrm{cm}^{-3}$, $T_e = 1.2 \times 10^{11}$ K



Spectral best fit size

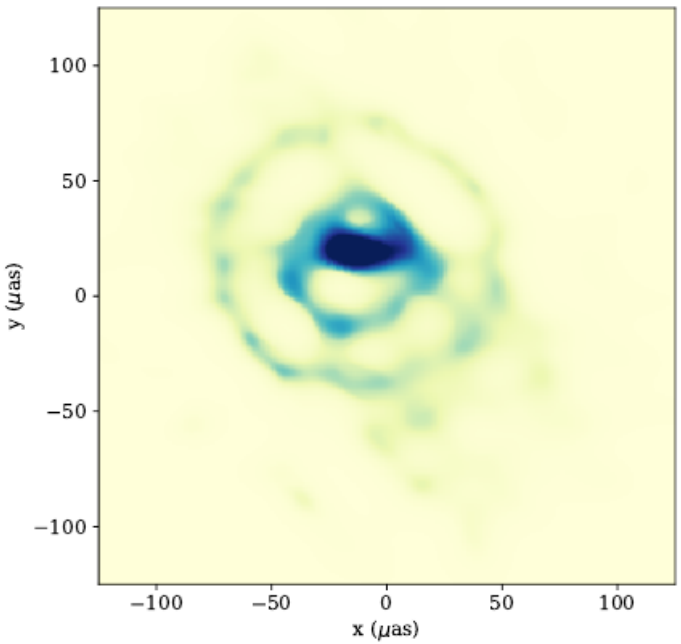
- Image major axis compared to Bower+06 constraints

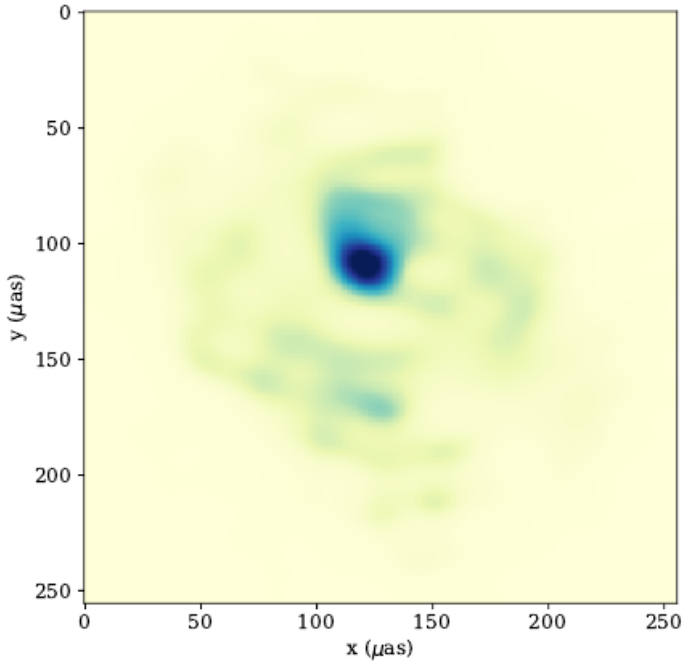




1.3mm image

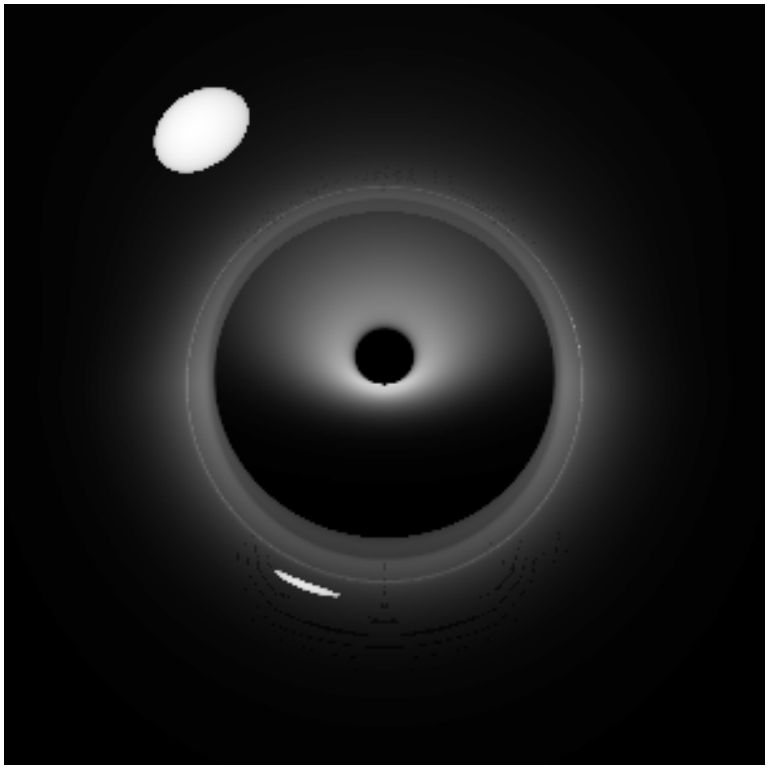
- EHT 2008: intrinsic size for circ Gaussian = 37^{+16}_{-10} μas
  size increases to $\approx 80\mu$as for thick-ring model
- Our size bigger, but strong $\approx 40\mu$as features present
- In good agreement with GRMHD results of Davelaar+18





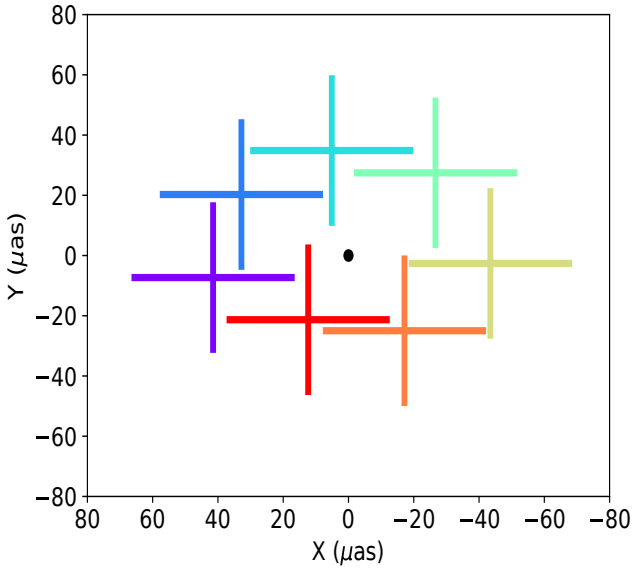
EHT-simulated image

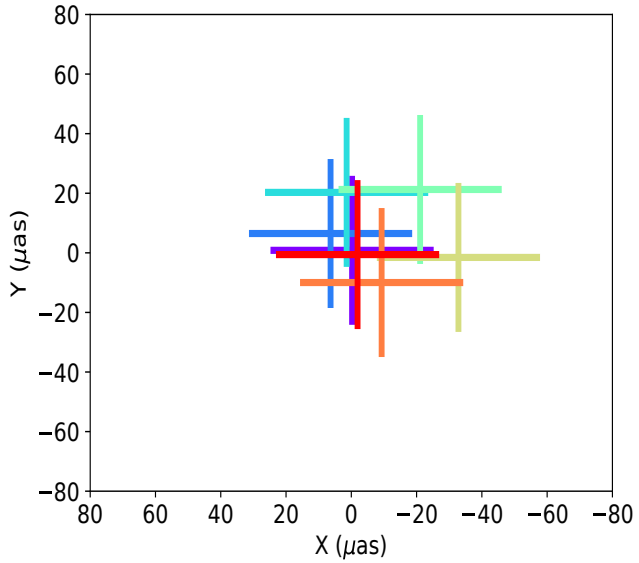
- Torus and jet contributions well visible for face-on
- Rather clear difference with inclination
- EHT Sgr A* image: strong constraint on accretion flow



Simple flare model

- Adding an orbiting blob
- Hotspot n_e, $T_e \propto 1.3 \times$ quiescent $\times$ Gaussian(t)
- Compute centroid evolution





Simple flare model

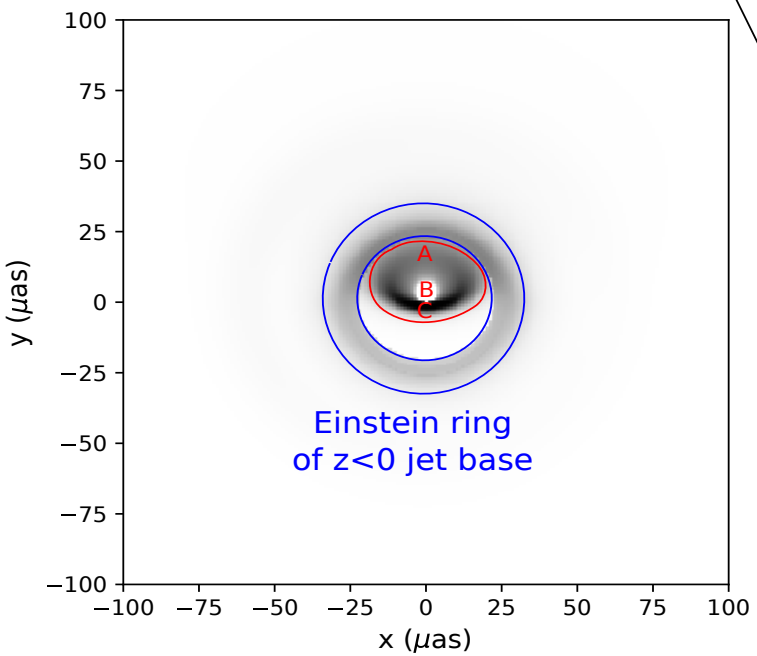
- Quiescent centroid influence:

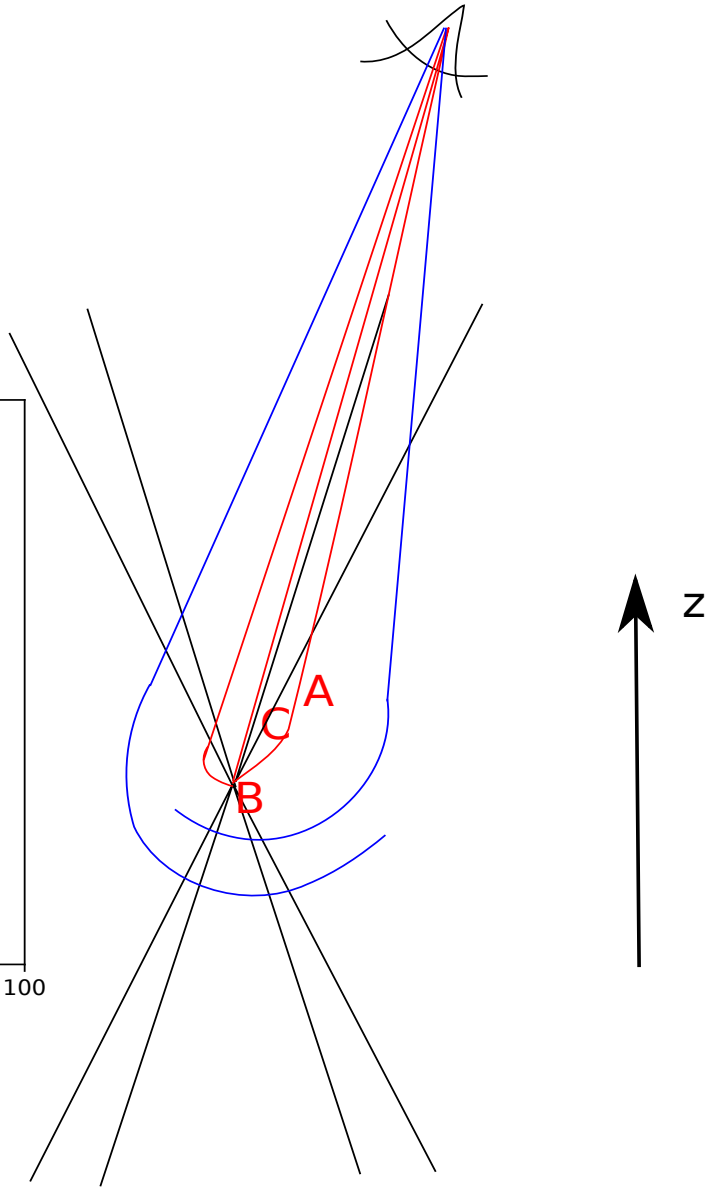
  smaller orbit + not centered on $(0, 0)$

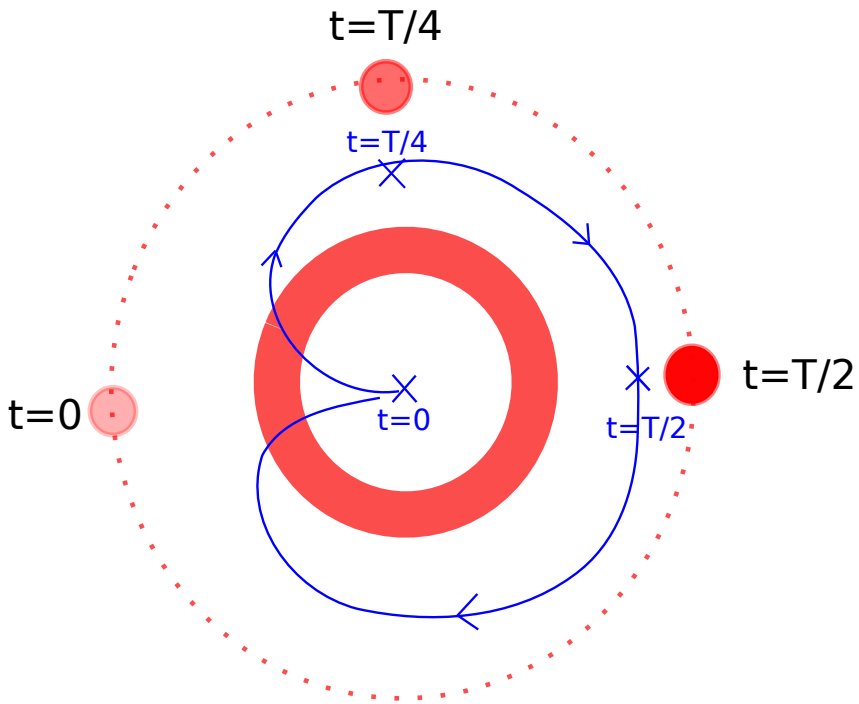
  because centroid converges to $\approx (0, 0)$ at quiescence

Conclusion

- Accurate simple (fast) analytical model
- In reasonable agreement with observed constraints and other similar results
- So far quiescent state only (EHT image)
- Under way: flaring state (GRAVITY astrometry)


100
75
50
25
0
−25
−50
−75
−100
y (μas)
−100 −75 −50 −25 0 25 50 75 100
x (μas)
A
B
C
Einstein ring
of z<0 jet base


A
C
B
z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t=T/4
t=0
t=0
t=T/2
t=T/2