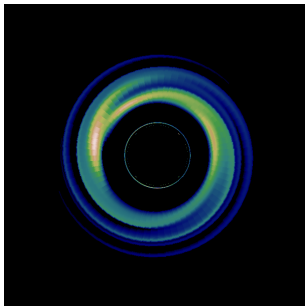


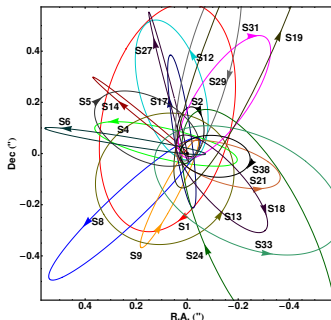
Imaging a boson star at Sgr A*

Frédéric VINCENT¹

Z. Meliani, P. Grandclément, E. Gourgoulhon, O. Straub

¹Observatoire de Paris/LESIA

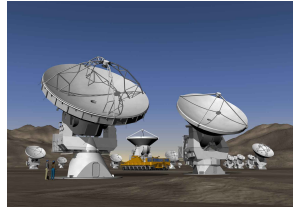
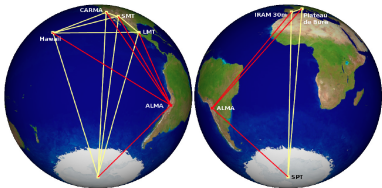




S-stars cluster (Gillessen+09): size = $1'' \approx 0.05 \text{ pc}$

Sgr A*: big mass in small region, SMBH

- Astrometric measurements of close stars \rightarrow central mass
- Sgr A* mass is $4.3 \cdot 10^6 M_{\odot}$,
S2 at pericenter at **100 AU** from Sgr A*,
 \rightarrow black hole? $\theta_{\text{BH}} \approx 50 \mu\text{as}$
- Check whether Sgr A* is a black hole: make a **picture**

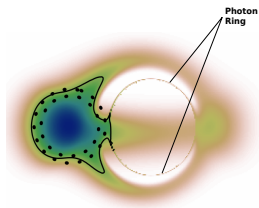
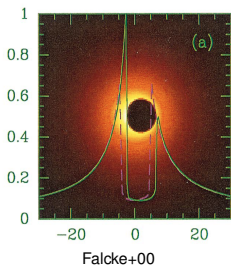


Event Horizon Telescope (2008-2020)

Making a picture of Sgr A*

- EHT: **15 μas** resolution (mm; synchrotron peak)
- Compared to $\theta_{\text{BH}} \approx$ **50 μas**

→ Doeleman+08, *Nature*, 455, 78; Doeleman+09, *Astro2010 White Paper*



Smoking gun for an event horizon

- **Shadow:** central dark region of strong-field images
 - **Photon ring:** contour of the shadow
-
- **Compact object with no event horizon: boson star**
 - No shadow? No photon ring?

Boson star

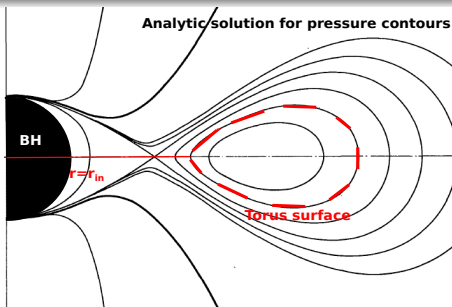
- Distribution of spin-0 bosons
- Modeled by a scalar field $\Phi(\vec{r}, t)$

Parameters of a boson star

- $\Phi = \phi(r, \theta) \times \exp(i(\omega t - k\varphi))$, $0 \leq \omega \leq 1$, k int.
 ω smaller, more relativistic, "stronger" scalar field
 k bigger, higher boson star angular momentum
- Solution for $\Phi \rightarrow$ **KADATH** library (P. Grandclément)
- One solution: one pair (k, ω)

Different from a black hole

No horizon, no singularity; no hard surface



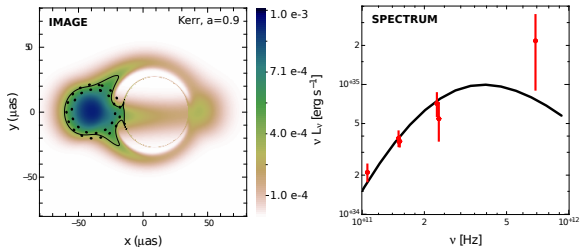
From Abramowicz+78

Accretion flow model: ion torus

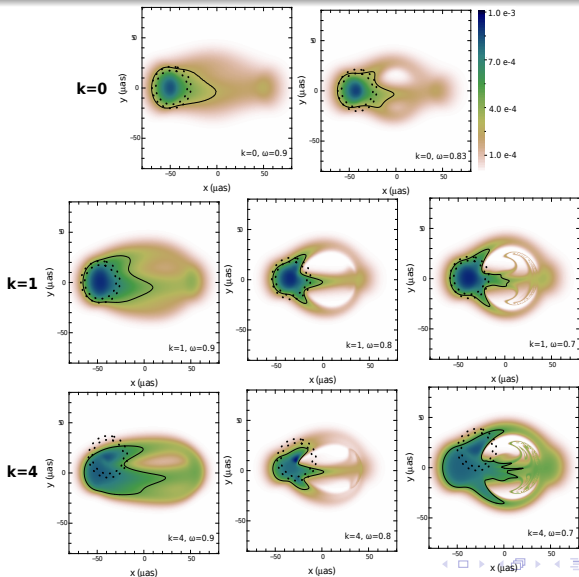
- Constant angular momentum: $\ell = -\frac{u_\varphi}{u_t} = \text{cst}$
- Polytropic, circularly orbiting perfect gas
- Synchrotron emitting
- Compute an image: **GYOTO** ray-tracing code
- Model parameters: $(k, \omega, i, \ell, k_{\text{polytrope}}, r_{in}, T_c, \rho_c, \beta)$

Setting the physics from Kerr

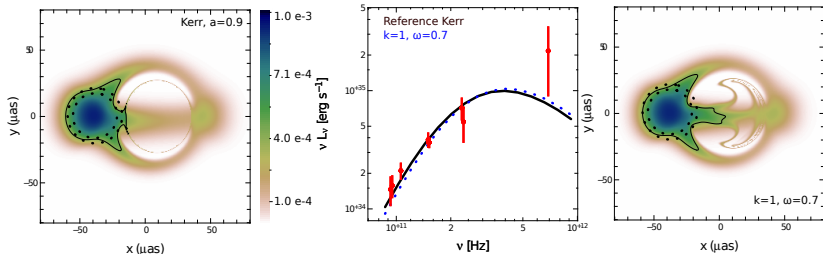
$(a = 0.9, i = 85^\circ, \ell = 3.2 M, k = 5/3, r_{\text{in}} = 4.2 M,$
 $T_c = 5.3 \cdot 10^{10} K, n_c = 6.3 \cdot 10^6 \text{ cm}^{-3}, \beta = 0.1)$



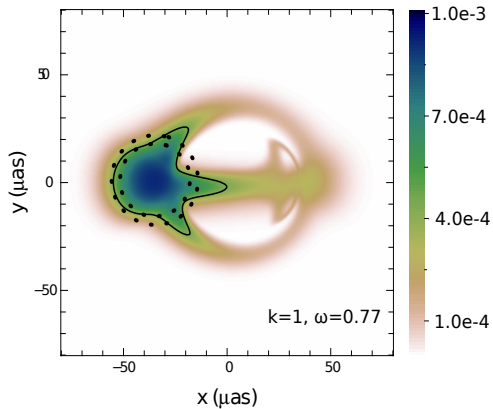
Imaging boson stars



A really similar case



An example with no stability issue



Conclusion

- Picture of an object with no horizon/singularity/surface?
- **BS can have shadow, sharp edges, just like Kerr**
- Tell the presence of an event horizon at Sgr A*??

- **Caveats:** more realistic flow / BS self-interaction / will a BH form? / no matter-boson interaction

→ Vincent, Meliani, Grandclément, Gourgoulhon, Straub,
submitted to CQG [**1510.04170**]