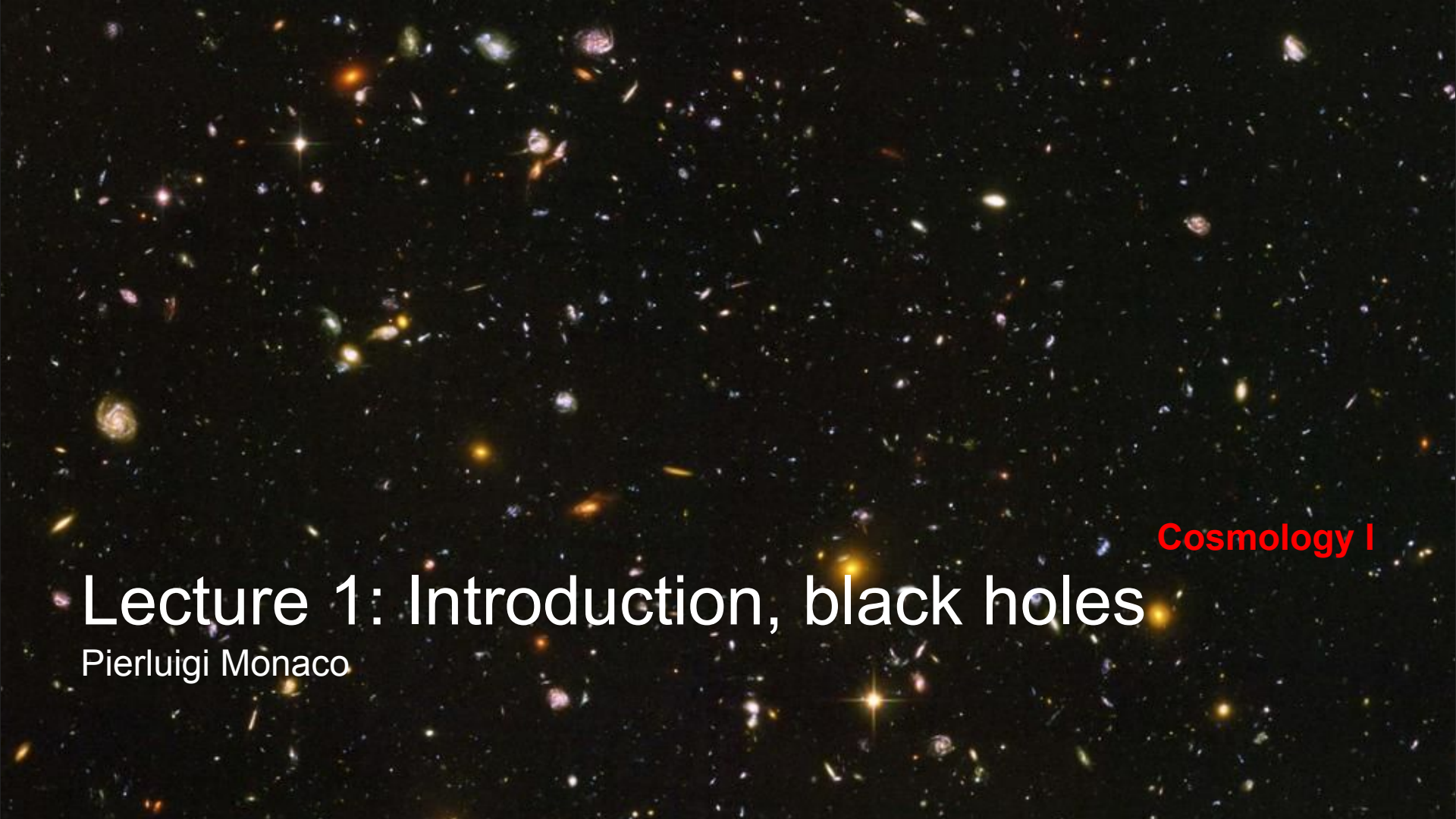
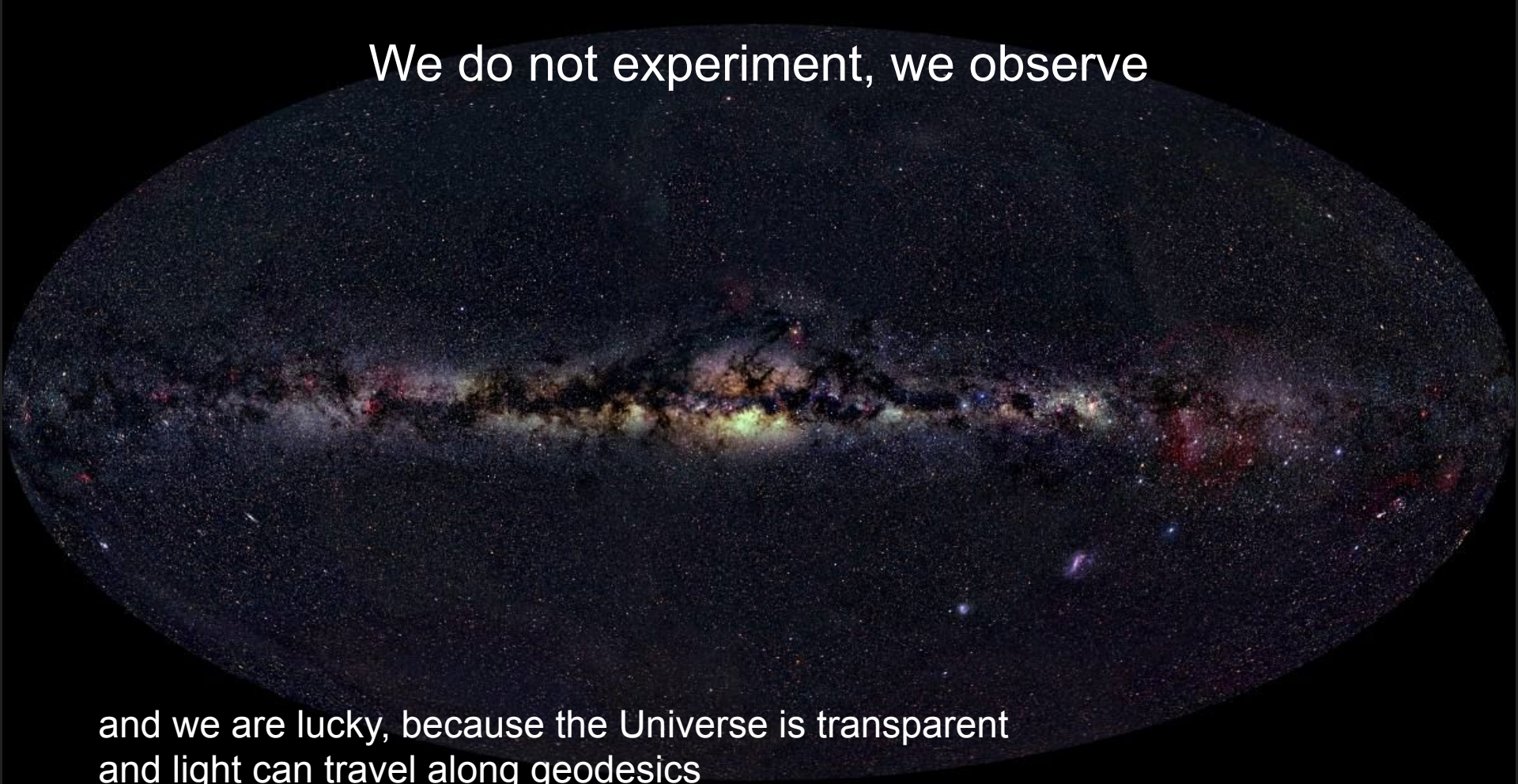


Cosmology I

Lecture 1: Introduction, black holes

Pierluigi Monaco

We do not experiment, we observe



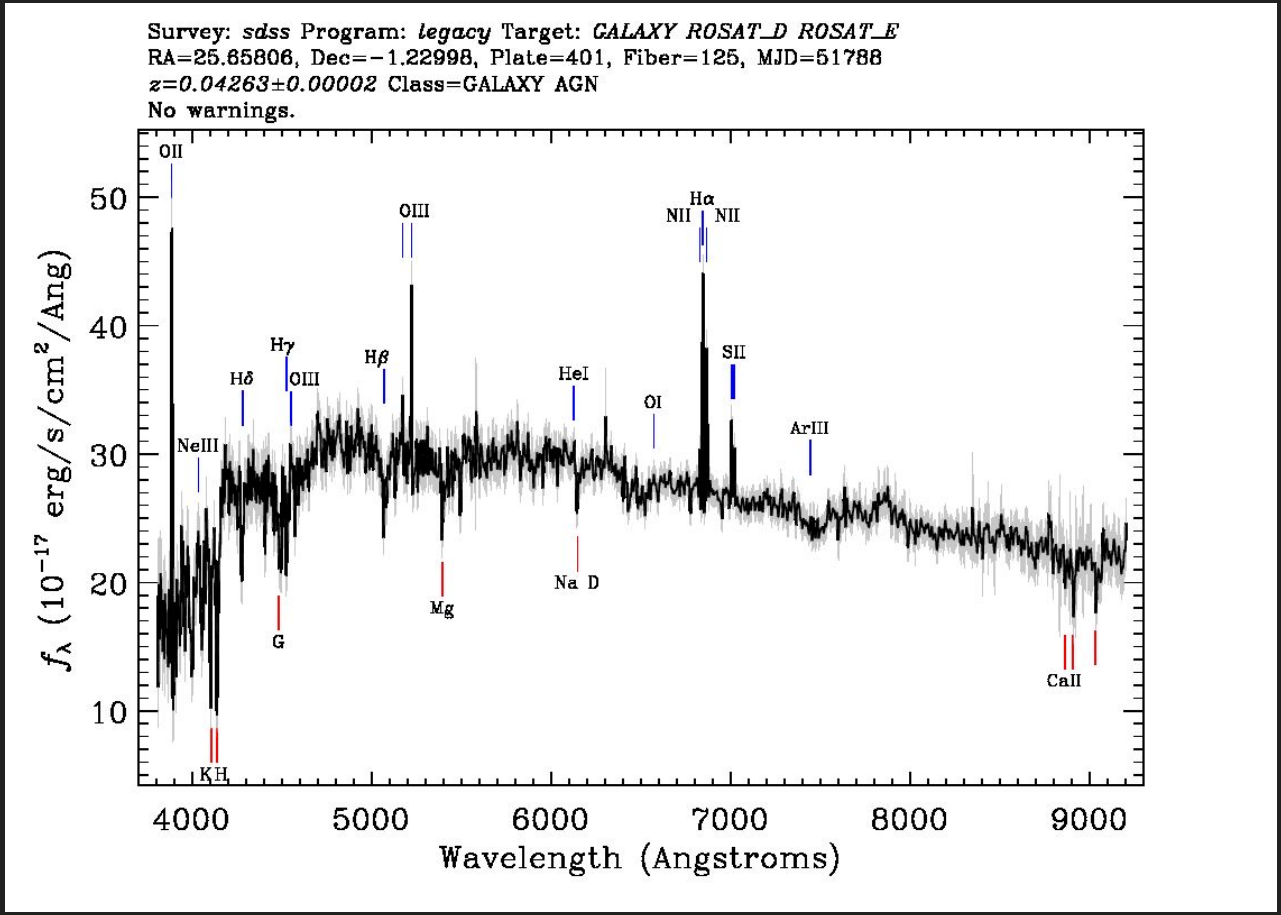
and we are lucky, because the Universe is transparent
and light can travel along geodesics


When we look deep we see galaxies

We can measure:

- position on the sky
- energy flux in a band => magnitude
- monochromatic flux in a range of λ => spectrum
  - continuum => main emission mechanism
  - absorption / emission lines => composition, ionization state...
  - Doppler shift of lines => radial velocity
- distances...

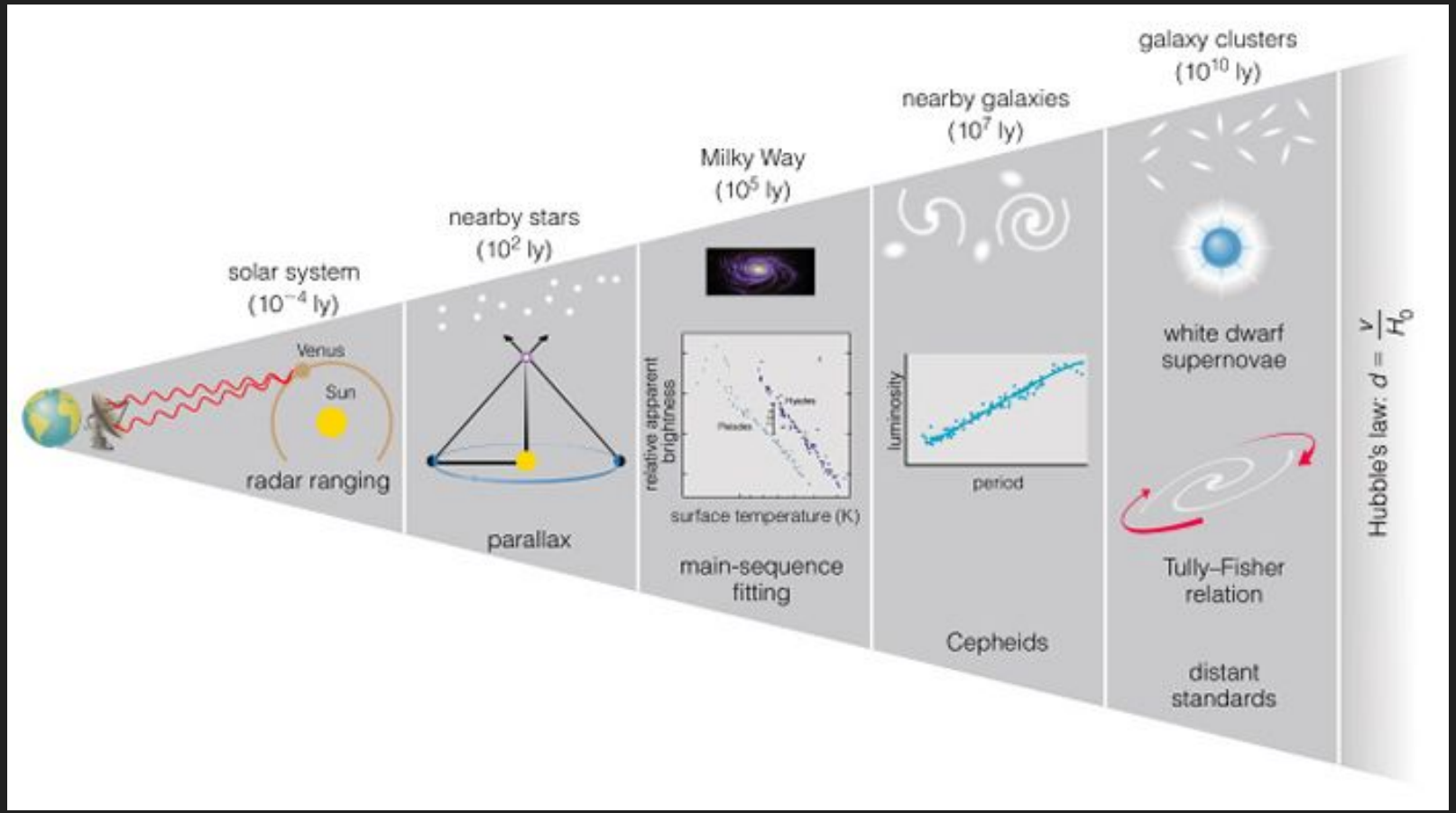
A galaxy spectrum



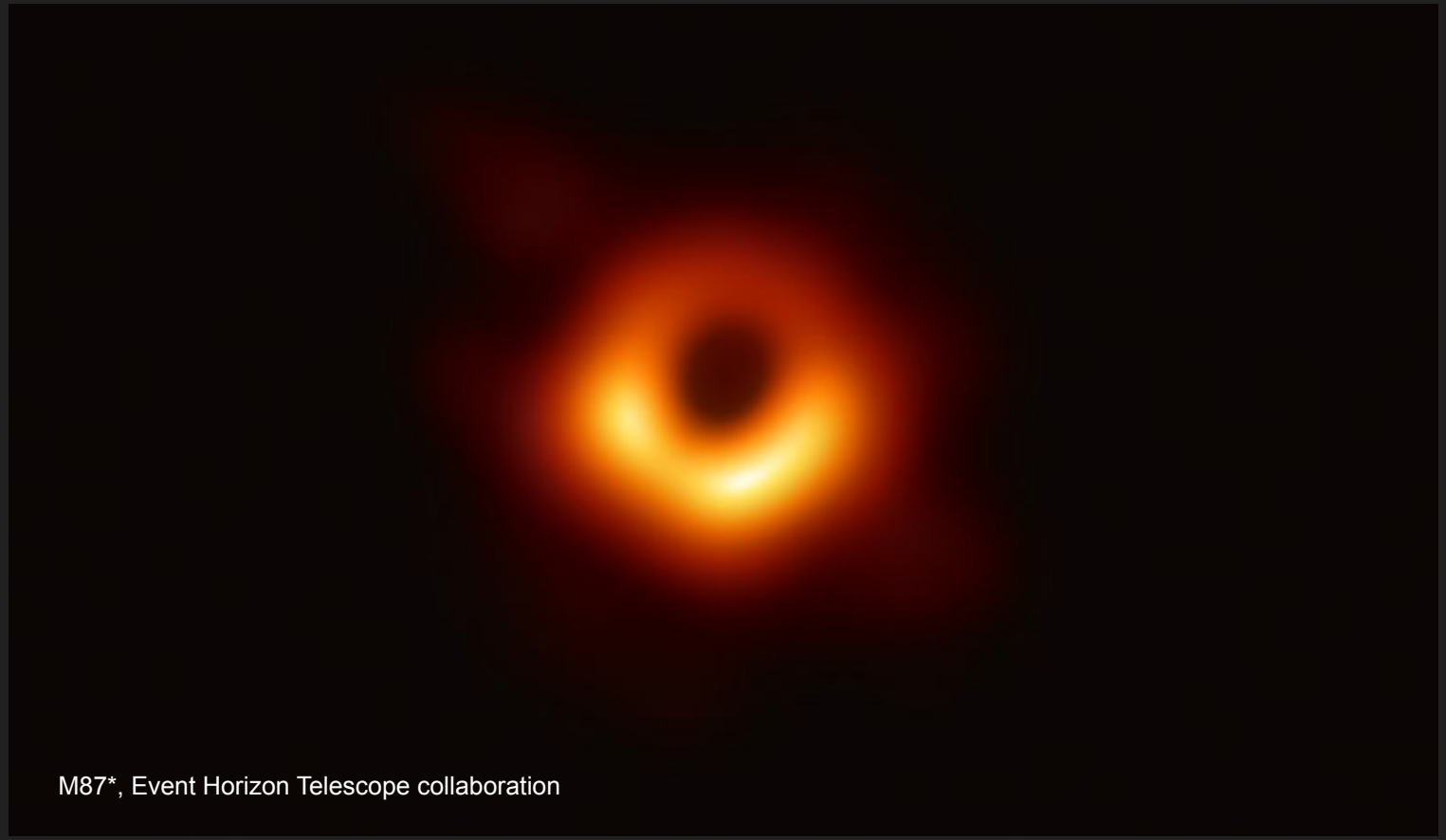
redshift:
$z = (\lambda_{obs} - \lambda_{em})/\lambda_{em}$

Doppler redshift:
$v \approx cz$, $v \ll c$

Distances require a “ladder” of methods



A first cosmological application of GR: black holes



M87*, Event Horizon Telescope collaboration

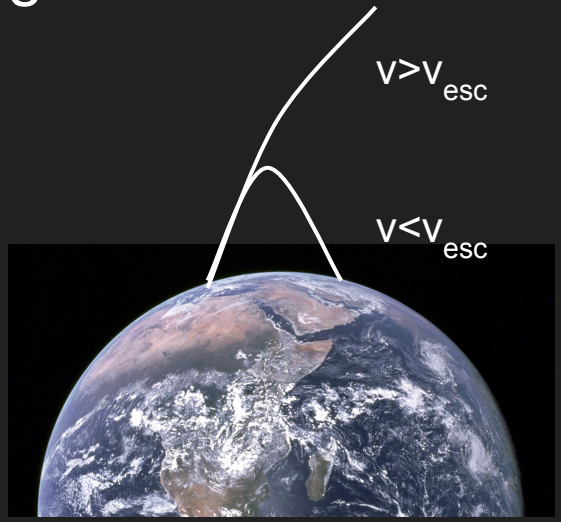
Dark stars

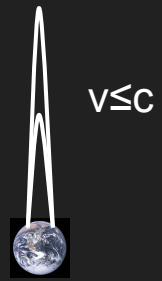
Mitchell and Laplace (ca 1784):

$v_{esc} = \sqrt{(2\,GM / R)} > c$
if
$R = 2\,GM / c^2$

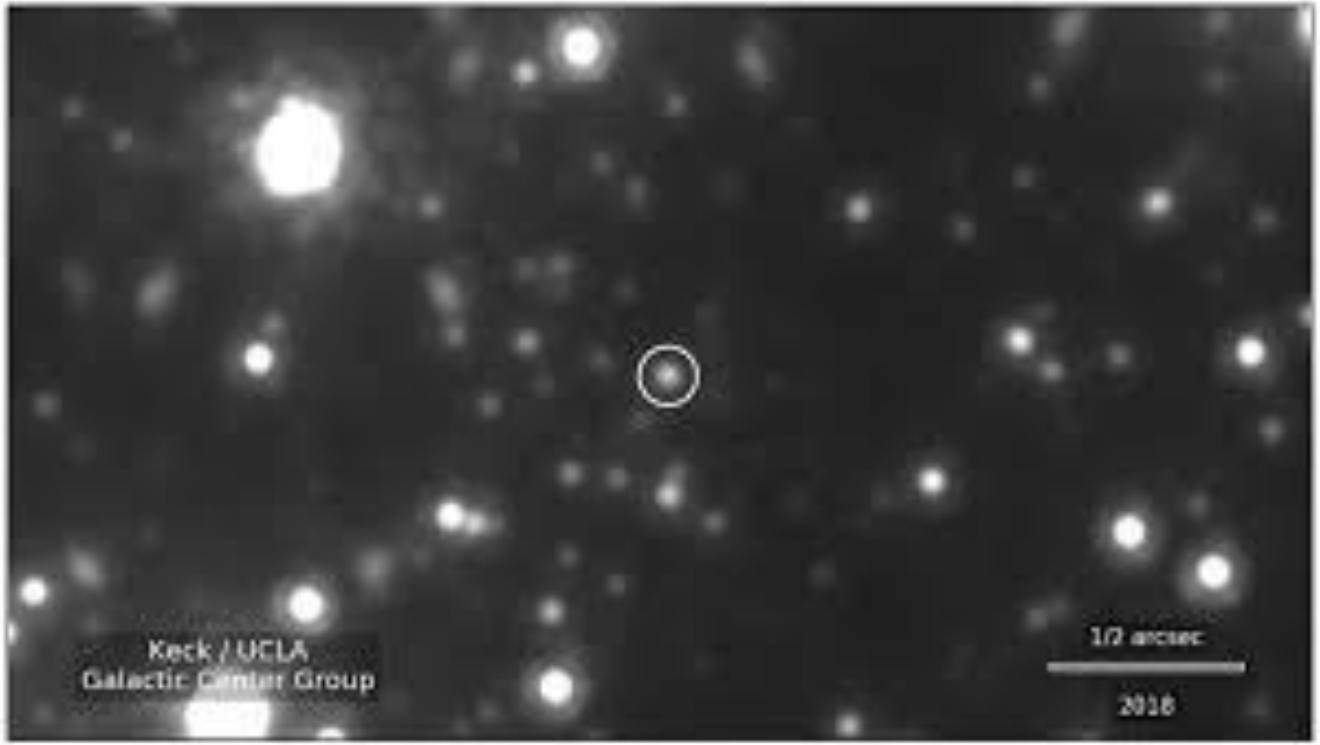
Earth:
R = 8 mm!

Sun:
R = 3 km

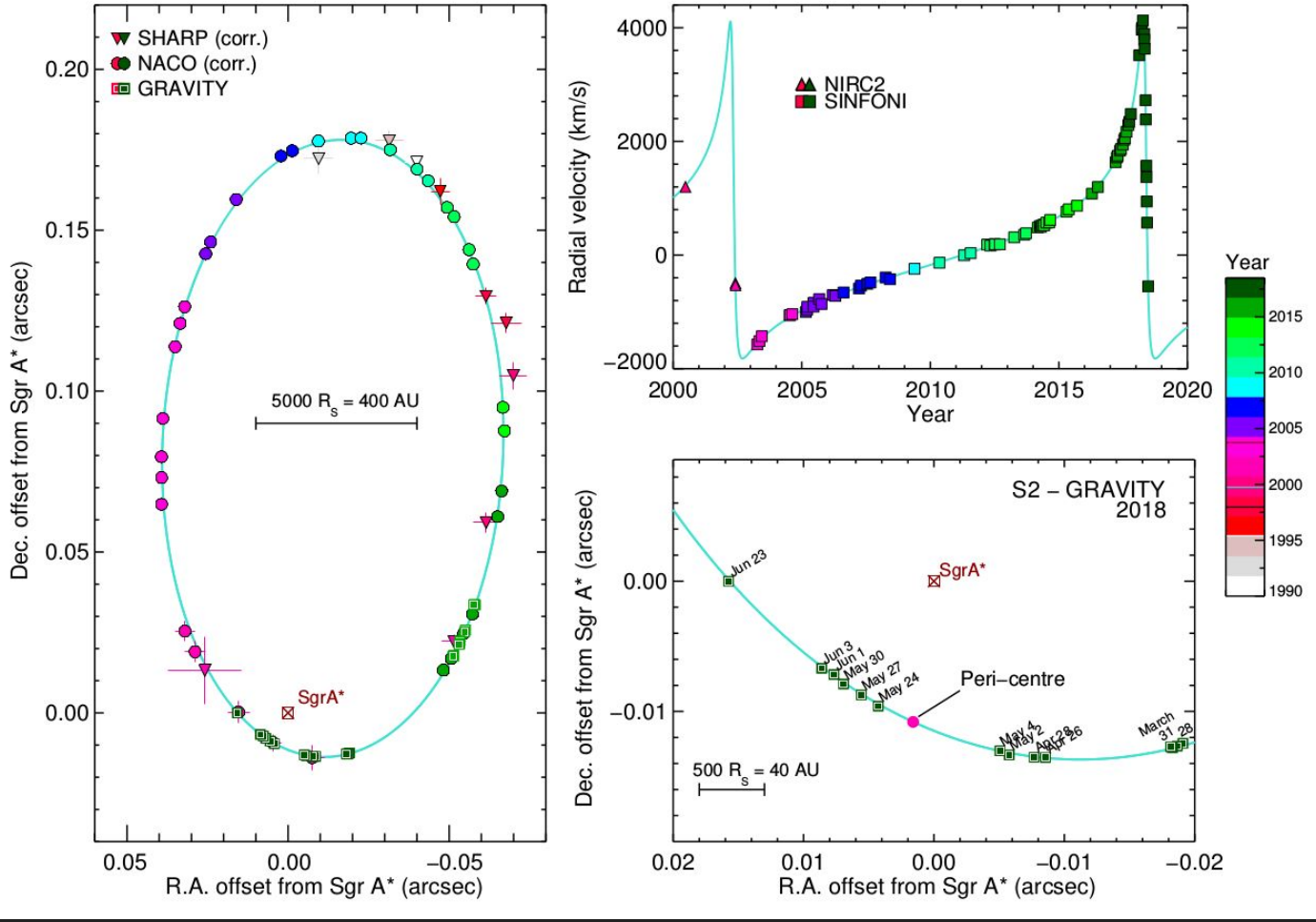




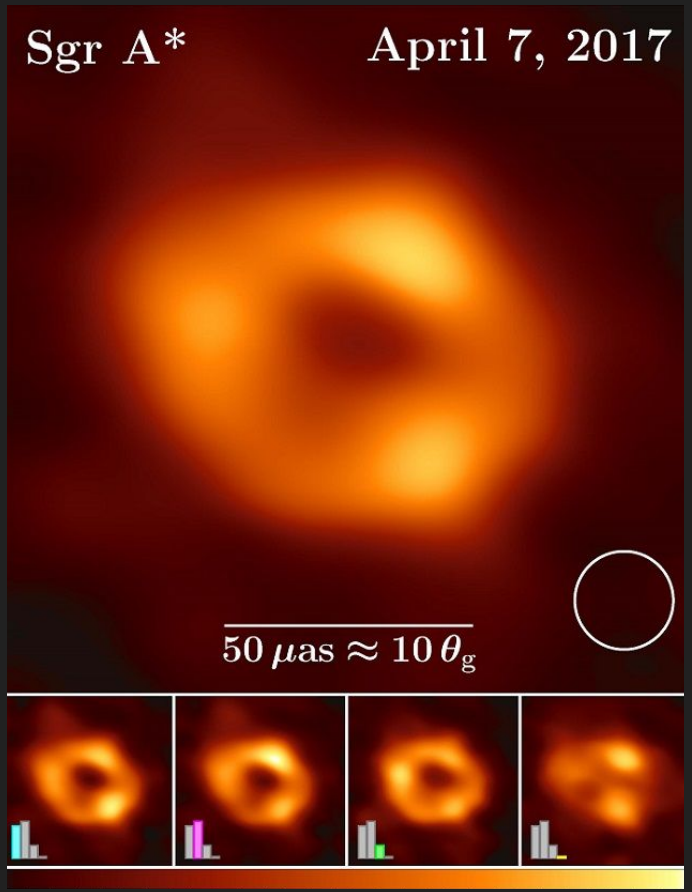

2012.85
2961820.60 km/h
0.231% of speed of light


Keck / UCLA
Galactic Center Group
1/2 arcsec
2018

GRAVITY collaboration 2018, A&A 615, L15

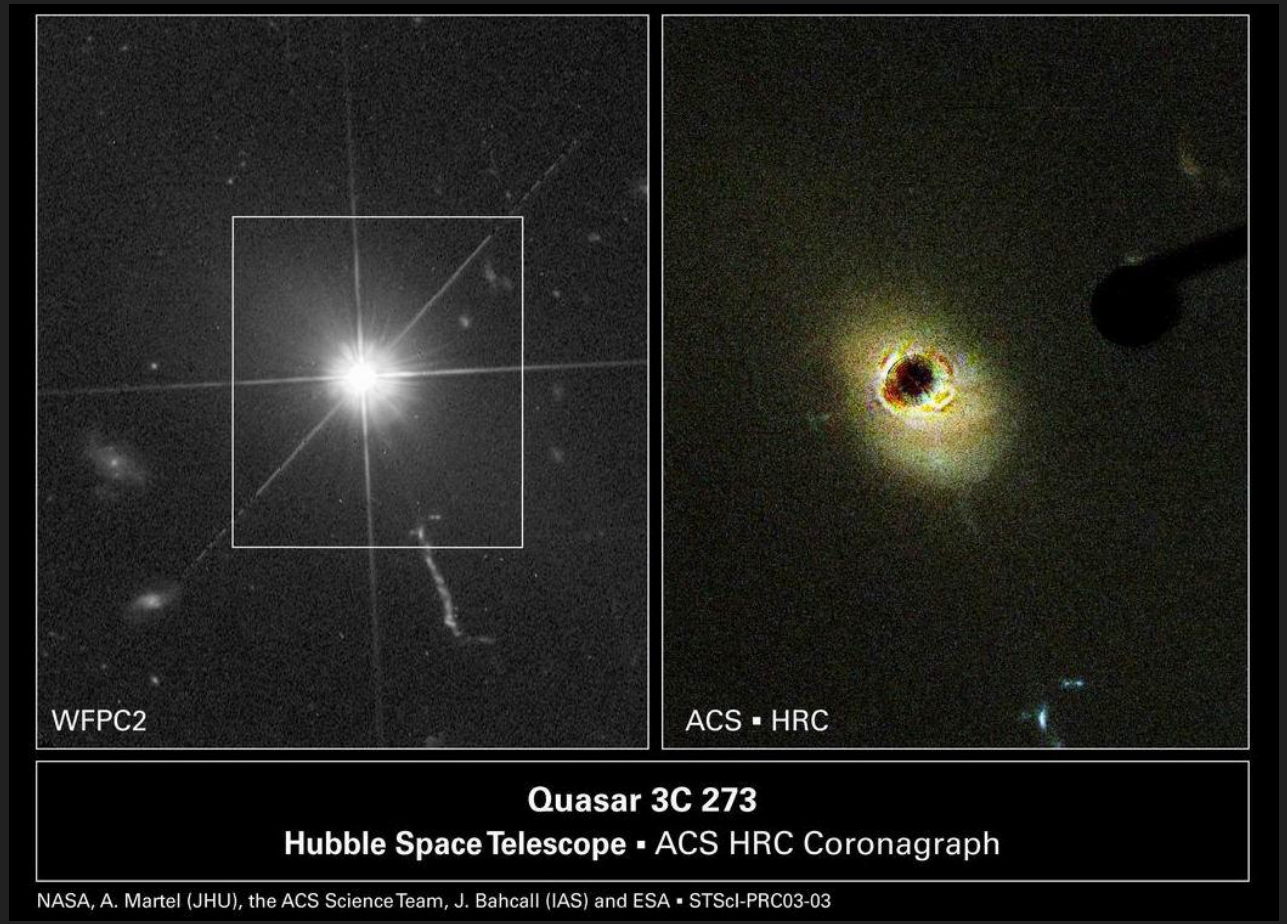


Imaging of the event horizon of Sgr A*

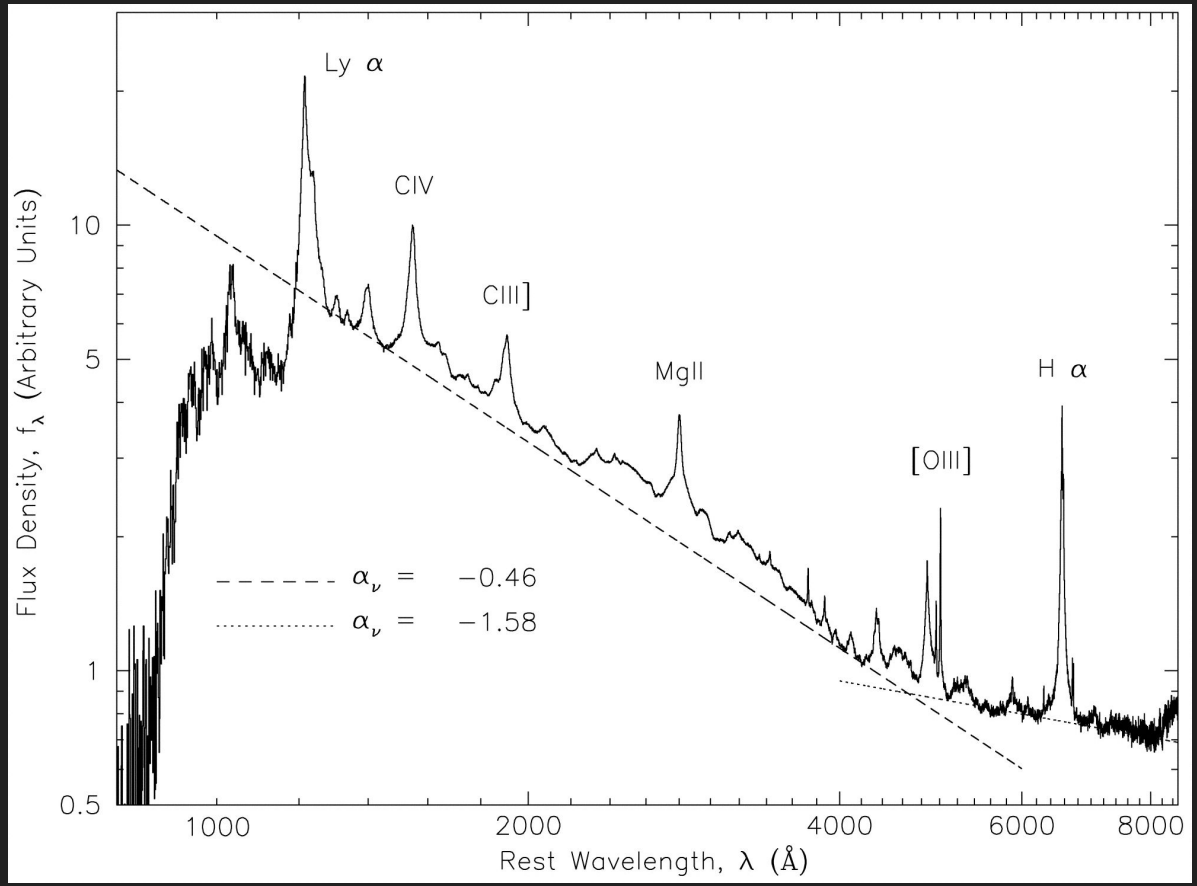


Event Horizon Telescope collaboration

Active galactic nuclei (AGN): quasars



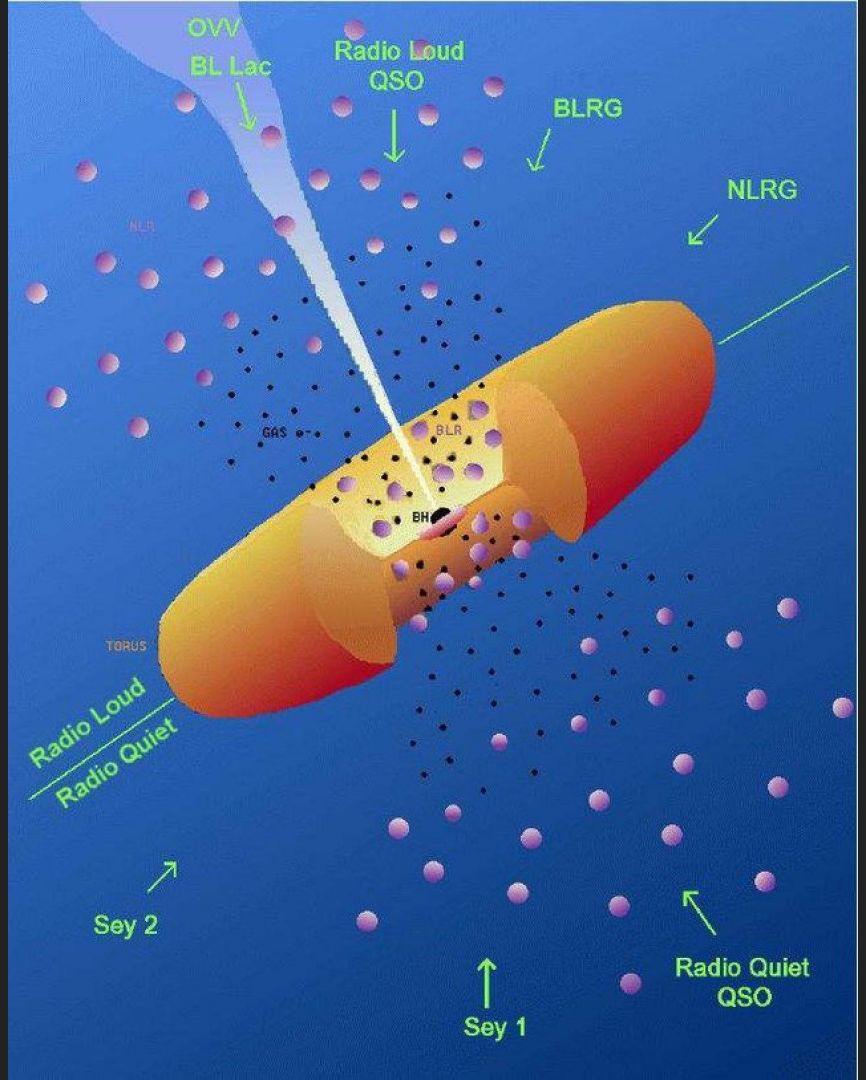
Active galactic nuclei: quasars



Active galactic nuclei: classification

	optical			radio		bolometric luminosity	
	blue continuum	broad lines	narrow lines	radio loud	radio quiet	low ($L<10^{44}$ erg/s)	high ($L>10^{44}$ erg/s)
Seyfert 1	✅	✅	✅			✅	
Seyfert 2			✅			✅	
QSO	✅	✅	✅		✅		✅
quasar	✅	✅	✅	✅			✅
radiogalaxy				✅			✅

A unified model for AGN



Program for the first part

- Einstein equations of General Relativity
- conserved quantities
- Schwartzschild metric from Einstein equations
- motion of a massive particle around a black hole
- motion of a photon around a black hole
- gravitational redshift
- photon radius and EHT observations
- first test on black holes