SPHERE upgrade

XAO perspective

The goals

- Going closer to the optical axis
  → < 150 mas
- Going deeper
  → Gain of 1 to 2 order of mag in contrast
- Going fainter
  → Improve the limit mag (or improve the XAO performance without degrading the limit mag)
- A couple of science cases :
  - Prox B mais pas que …
  - Coupling of SPHERE and ESPRESSO
  - Benifit for other cases (IR observation)

From the SAXO perspective

→ Reduce the impact of the residual halo

⇒Temporal

⇒Noise

⇒Chromatic effects

→ Close to the optical axis

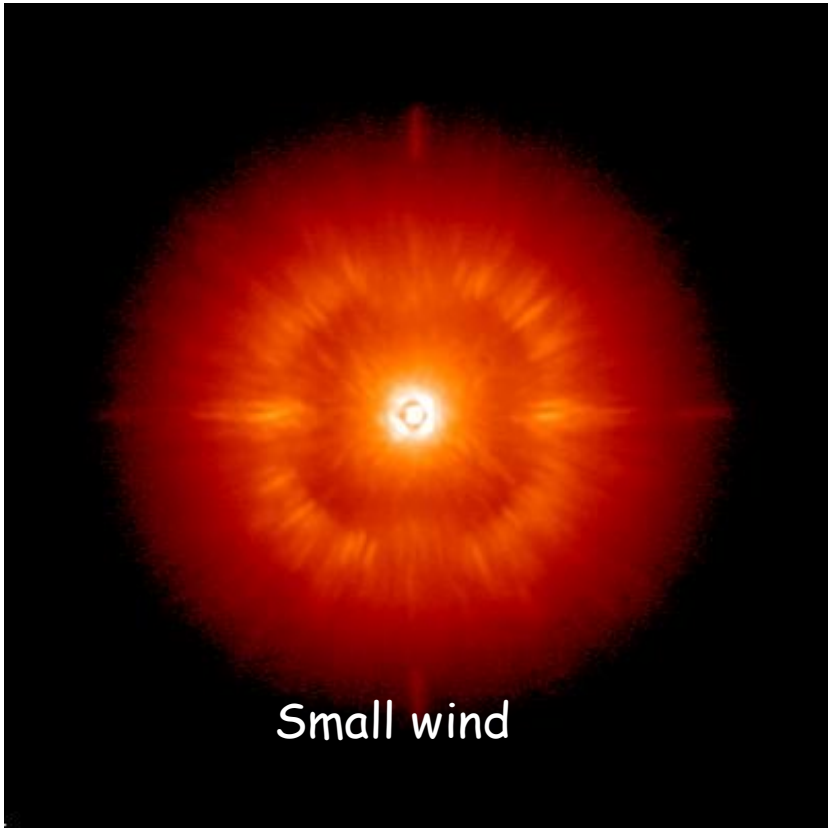
⇒aliasing → Close to the correction radius

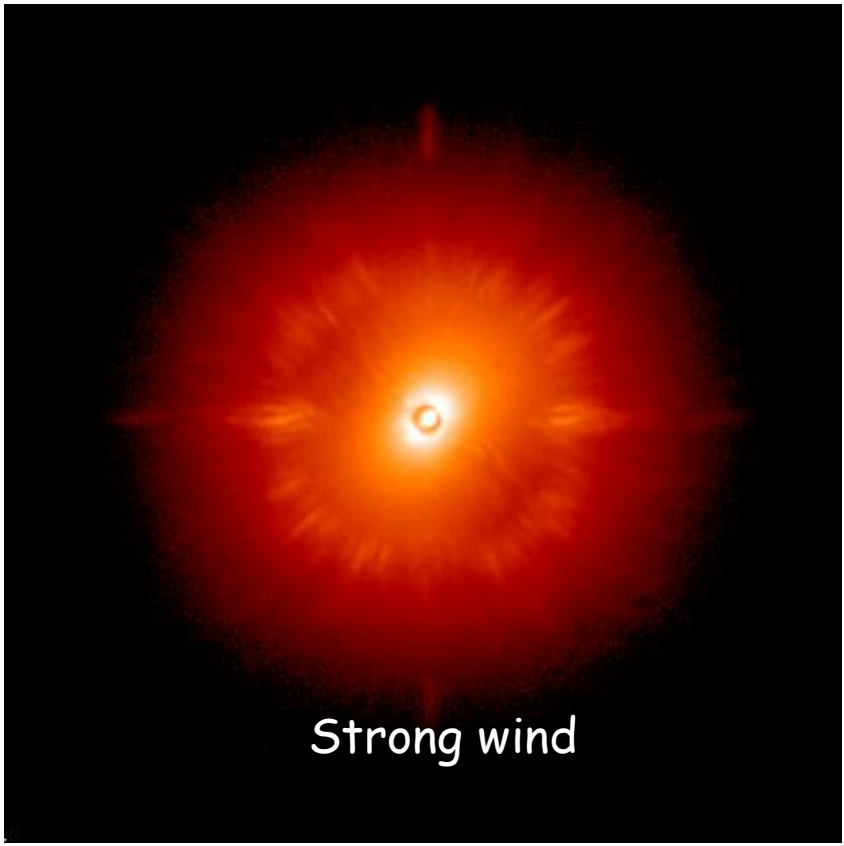
→ Reduce the contribution of static speckles

⇒ Dark-hole calibration => Coffee

⇒ Dark-hole stabilisation => Zelda

XAO halo





Seeing (DIMM) = 0.9 ± 0.03″

SR = 85 ± 1 %

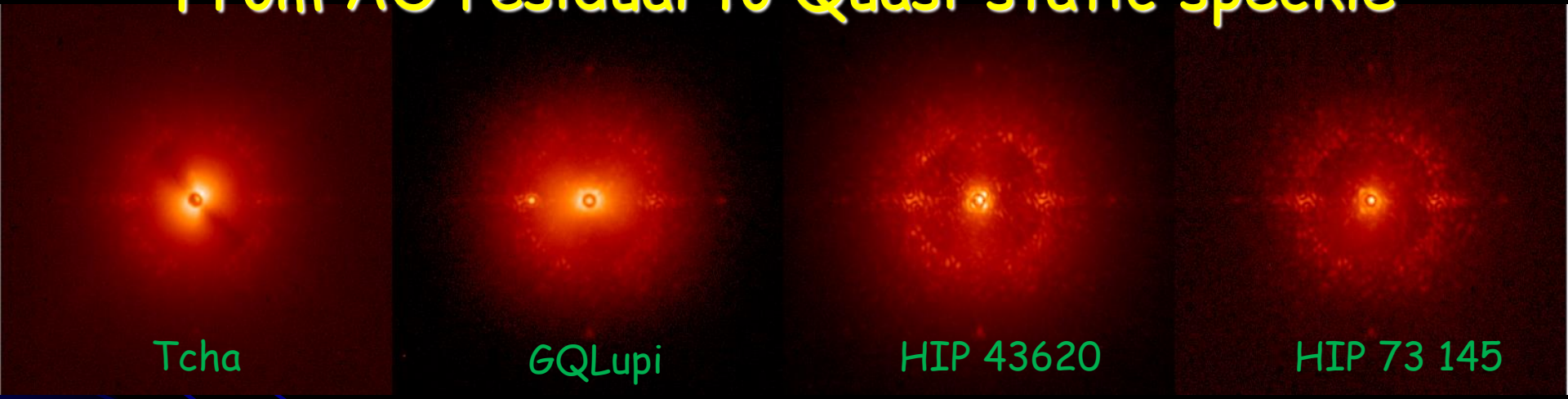
Seeing(DIMM) = 1.0 ± 0.3″

SR = 57 ± 8 %

ESO SPARTA RTC ; very low latency (80 μs)

SPHERE

SPHERE main limitation:
From AO residual to Quasi-static speckle



Wind speed

Limited by AO residual

Limited by QS residuals

2 solutions

- Simple and limited : post-processing & coronagraphic PSF estimation
  - Use of RTC data – No HW implementation
  - « simple PSF substraction » to improve final data
  - Potential gain in detectivity BUT
  - Limitation = Photon noise !

  ➔ RDI
- Complex and more performant : Going <u>faster</u> and / or using <u>more efficient control laws</u>
  - Significant potential gain if Fech >> 1.5 kHz
  - Modification / Change of SAXO RTC
  - Significant reduction of SAXO limit mag !

    => needs for a new WFS !!!!!

Going faster – Going fainter

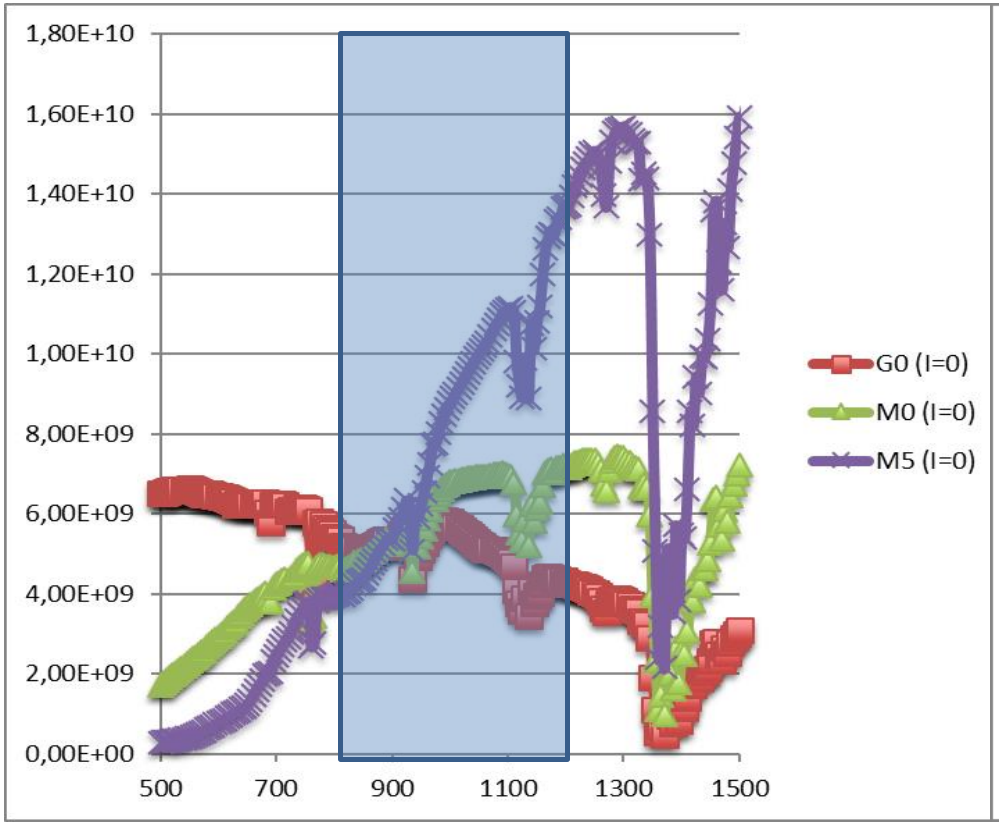
- Coupling new RTC / new control laws and new WFS
- An additional Pyramid WFS in SAXO
  - Real gain if Pyramid works @ high SR
  - Marginal gain for Pyamid @ $\lambda < 700$ nm
  - Benifit from
    - New detectors with exptionnal characteristis (0 RON, no excess noise)
    - GS type (especially for M → M5 types)

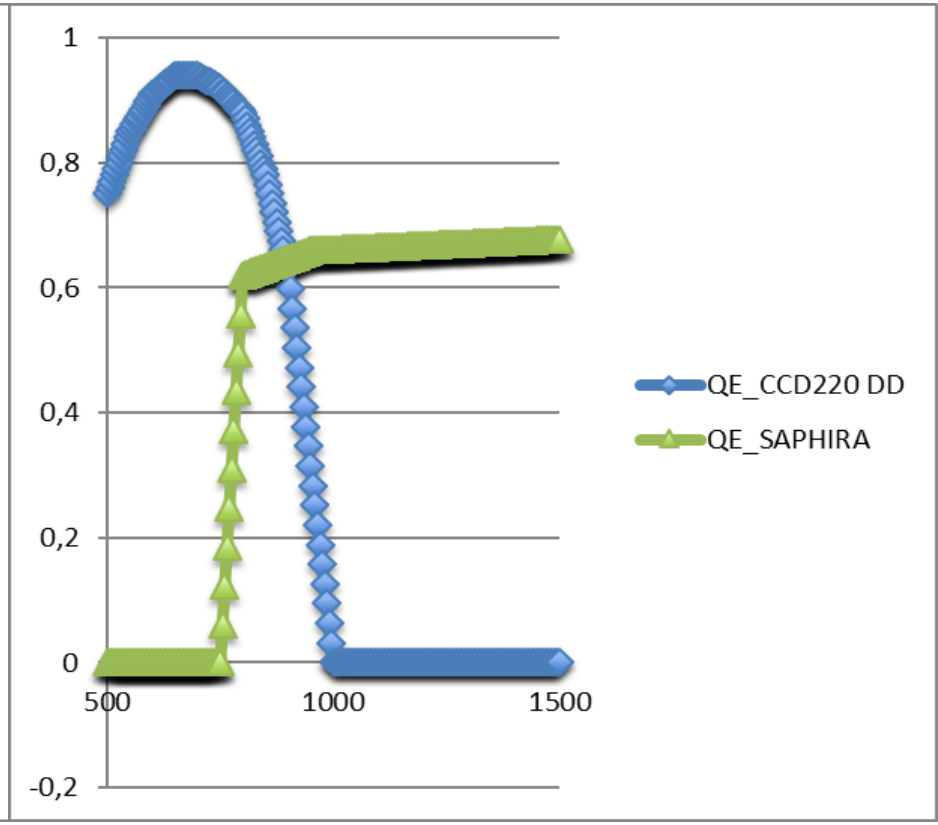
  $\Rightarrow$ Reduce the chromatic errors for IR

  $\Rightarrow$ Improve sensitivity for Zimpol (all vis-light)

  $\Rightarrow$ Best solution for the coupling with Espresso

Photometry





⇒Allow to go faster with the same limit mag

⇒Significant gain in perf for IR-PYR

Interest of an IR-PYR for SPHERE

- Keep SPHERE as it is in its primary mode (VIS F-SH WFS with the SARTA RTC)
- Photometric gain (0.8 – 1.2) :
  - M5 : 3,43E+11 to be compared to VIS : 8,03E+10 Gain **X 9**
  - M0 : 2,50E+11 8,18E+10 **X 6**
  - G0 : 2,05E+11 8,39E+10 **X 5**

  No excess noise Excess noise <=> /2
- Stand alone upgrade
  - IR Pyramid **with its own RTC** (at least for hard real time)
  - No (minimum) interaction between the two modes
  - Pyr high level spec
    - Use existing IR detector : CRed camera (FLI)
    - Bandwidth > 2.5 kHz
    - 60x60 pixel pupil
    - Spectral bandwidth : [800 – 1200 nm] (could be reduced or extented depending on the scientific needs)
    - ADC
    - Modulation ? Probably yes although very limited radius (< 2 λ / D)