The design of an adaptive optics telescope : the case of DAG

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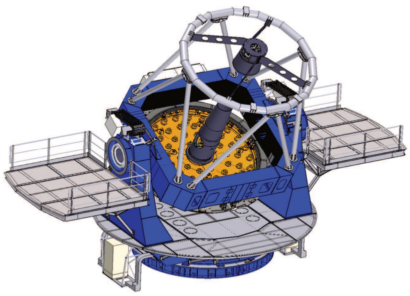
INTRODUCTION

Astronomical observations on modern telescopes benefit now from adaptive optics (AO) correction. Any new telescope should therefore be designed with AO performance as the reference, and not seeing limited observations. It generates stronger constraints on the telescope design. Here we show how we have designed a 4 m telescope (**DAG – Dogu Anadolu Gozlemevi, a new telescope for Turkey**) considering AO constraints.



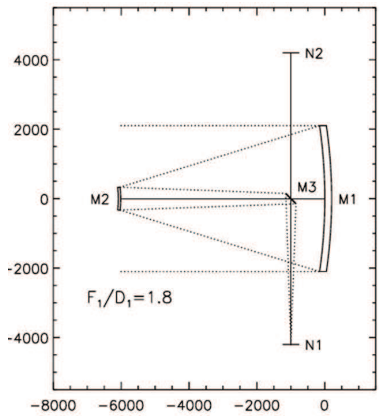
METHODS

OPTICAL DESIGN STEPS / CHOICES

- DAG will be used for high angular resolution science but also wide field seeing limited science
- Both modes to be considered as design constraints
- Ritchey-Chrétien (moderate FoV is acceptable, AO does not need 2 deg FoV)
- Make it short, no need for M1 focus (Gregorian)
- **AO KILLER :** VIBRATIONS & static errors (NCPA)
  So we ruled out Cassegrain : **NASMYTH platforms only** (one for AO, one for seeing limited)
- Focal length : pixel size IR camera 7 mu, Nyquist sampling at 800 nm of an AO, diffraction limited PSF -> 56 m

OPTICAL DESIGN CONCEPT (CONT')

- Single guide star AO : only a few 1"-10"
- Ground layer AO : a few 1'-10'
- Seeing limited : 30' is enough for most objects
- Field curvature correction possibly not needed for on-axis AO, but mandatory for GLAO mode (we need a field correction lens)



OPTICAL WAVEFRONT ERROR BUDGETING

- M1 control with **active optics** (M1 thickness 14 cm, 14 T, instead of 50 cm, 40 T) M2 / M3 control in position
- aO able to control up to equivalent 78 Zernike, i.e same as what foreseen for AO

LOW ORDER WAVEFRONT ERROR

- We want << than Noll distribution if seeing 0.5"
- actually it is the seeing observation that suffers from LO errors : finally LO WFE set to 49 nm

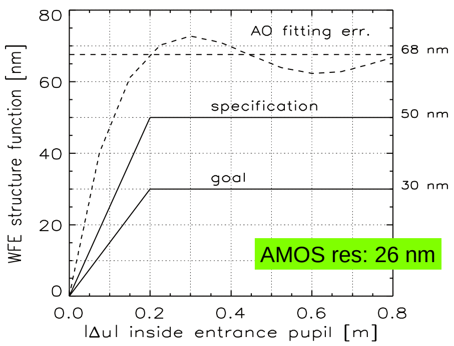
j, n-indexes	$\lvert a_j \rvert$ nm spec.	goal
5-6, 2	25	17
9-10, 3	19	13
11-15, 4	23	9
16-21, 5	19	7
22-28, 6	13	5
quadratic sum a_{29} to a_{78}		
29-78, 7-11	18	8
total error nm	49	26

AMOS res: 45 nm

HIGH ORDER WAVEFRONT ERROR

- AO residual at high frequency is the reference
- We do not want the telescope to degrade the AO
- Mirrors print-through can be a problem
- Zernike not practical for high frequency error
- So we use the **STRUCTURE FUNCTION** approach

$$D_\varphi(\Delta\mathbf{u}) \equiv \left\langle \left[\varphi(\Delta\mathbf{u}+\mathbf{r}) - \varphi(\mathbf{r})\right]^2 \right\rangle_{\mathbf{r}}$$



FINAL DESIGN

OPTIMIZED TELESCOPE SPECIFICATIONS

- Primary mirror optical diameter 3.94 m
- Focal length 56 m
- Central obscuration 19 %
- Ritchey-Chrétien combination
- 2 Nasmyth platforms (no Cassegrain)
  - High angular resolution focus N1
  - Seeing limited observations focus N2
- FoV 14' (30' with some vignetting)
- Active optics (66 actuators, 24 lateral)
- Low order WFE specification Z5 to Z78 : 49 nm
- High order WFE specification : structure function similar to atmospheric fitting error with 0.4 pitch and 50 nm RMS.

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