

Na LGS

height profiles at Teide Observatory
... and future plans



Julio Castro-Almazán

Instituto de Astrofísica de Canarias
Sky Quality Team



In collaboration with :



Instituto de Astrofísica de Canarias:

Ángel Alonso
Marcos Reyes García-Talavera
Iciar Montilla



Durham University:

Matthew J. Townson
James Osborn



European Southern Observatory:

Domenico Bonaccini Calia



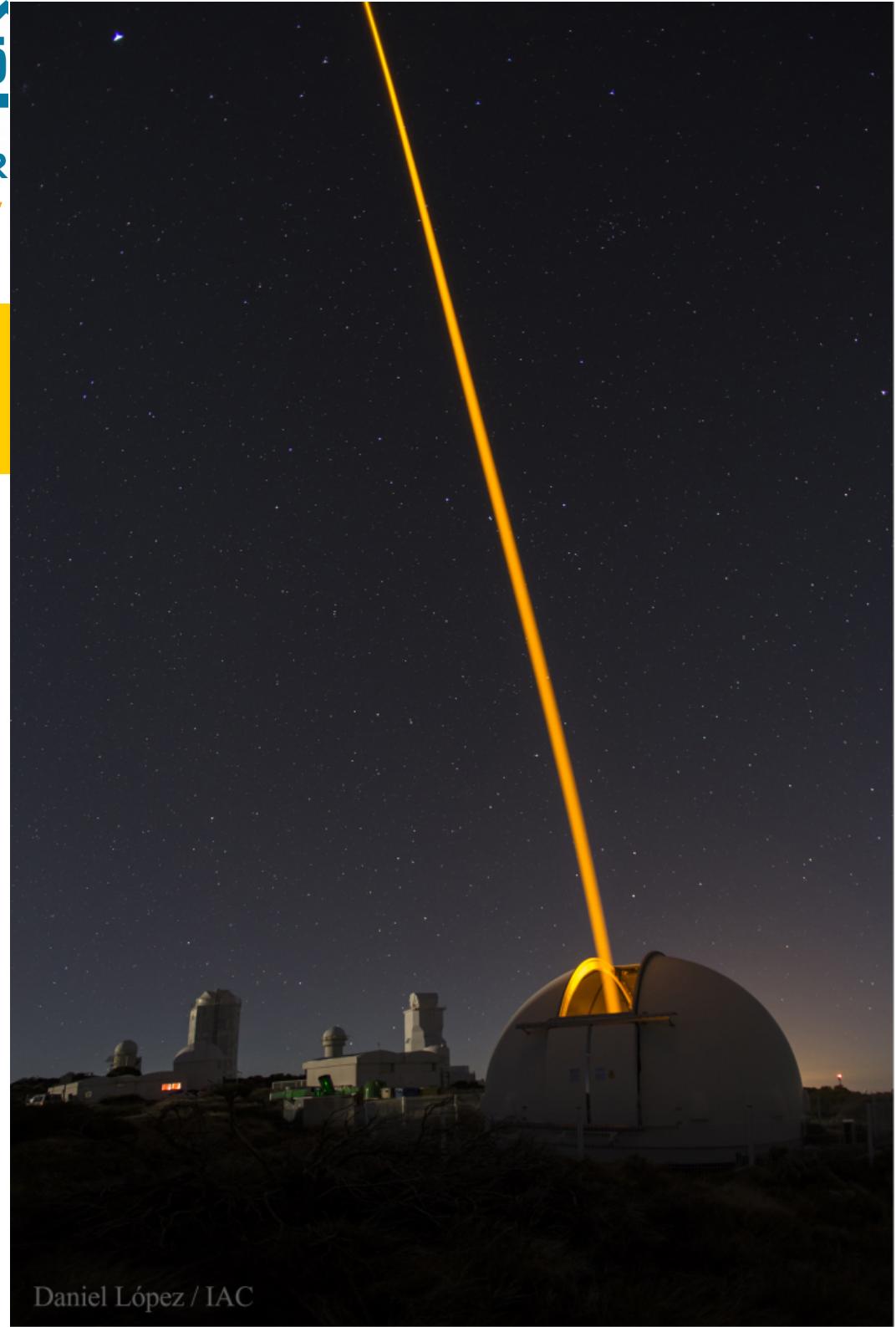
INAF-Osservatorio Astronomico di Roma:

Mauro Centrone



Gran Telescopio Canarias:

Gianluca Lombardi

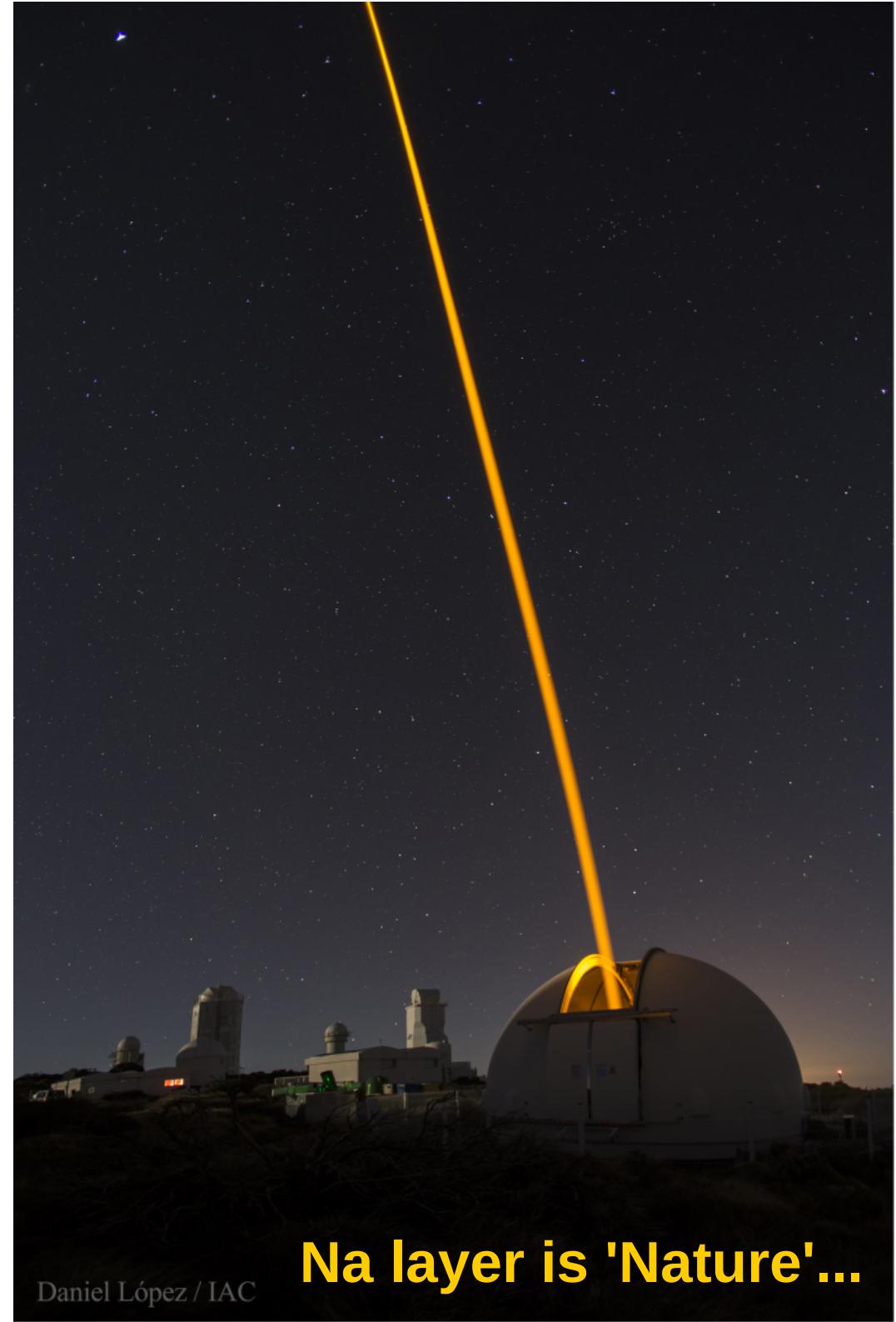


Daniel López / IAC

Na LGS

height profiles at OT... and plans

retrieving *absolute*
Na height profiles



Daniel López / IAC

Na layer is 'Nature'...

Na LGS

height profiles at OT... and plans

retrieving *absolute* Na height profiles

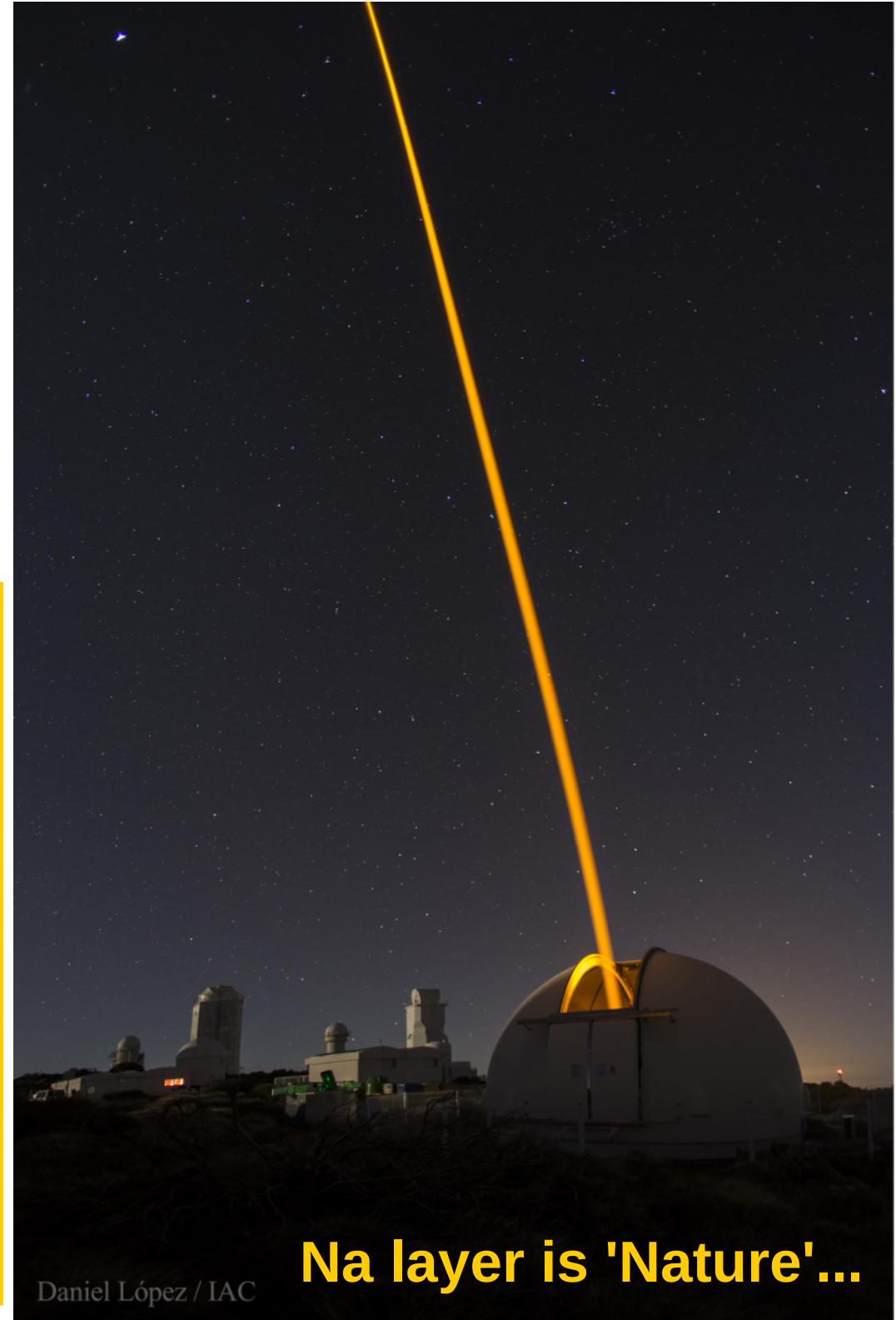
why?

Real time feedback for AO
with elongated LGS:

- Total flux calibration in WFS
- Laser waist/focus adjust
- WFS focus adjust

Na layer site characterization:

- AO simulations
- Design specifications



NaLGS

height profiles at OT... and plans

The method

A solution based on
the Bistatic Configuration and the Cartesian Geometry

**2 telescopes:
observer and launcher**

Separated by a constant baseline

line-plane intersection

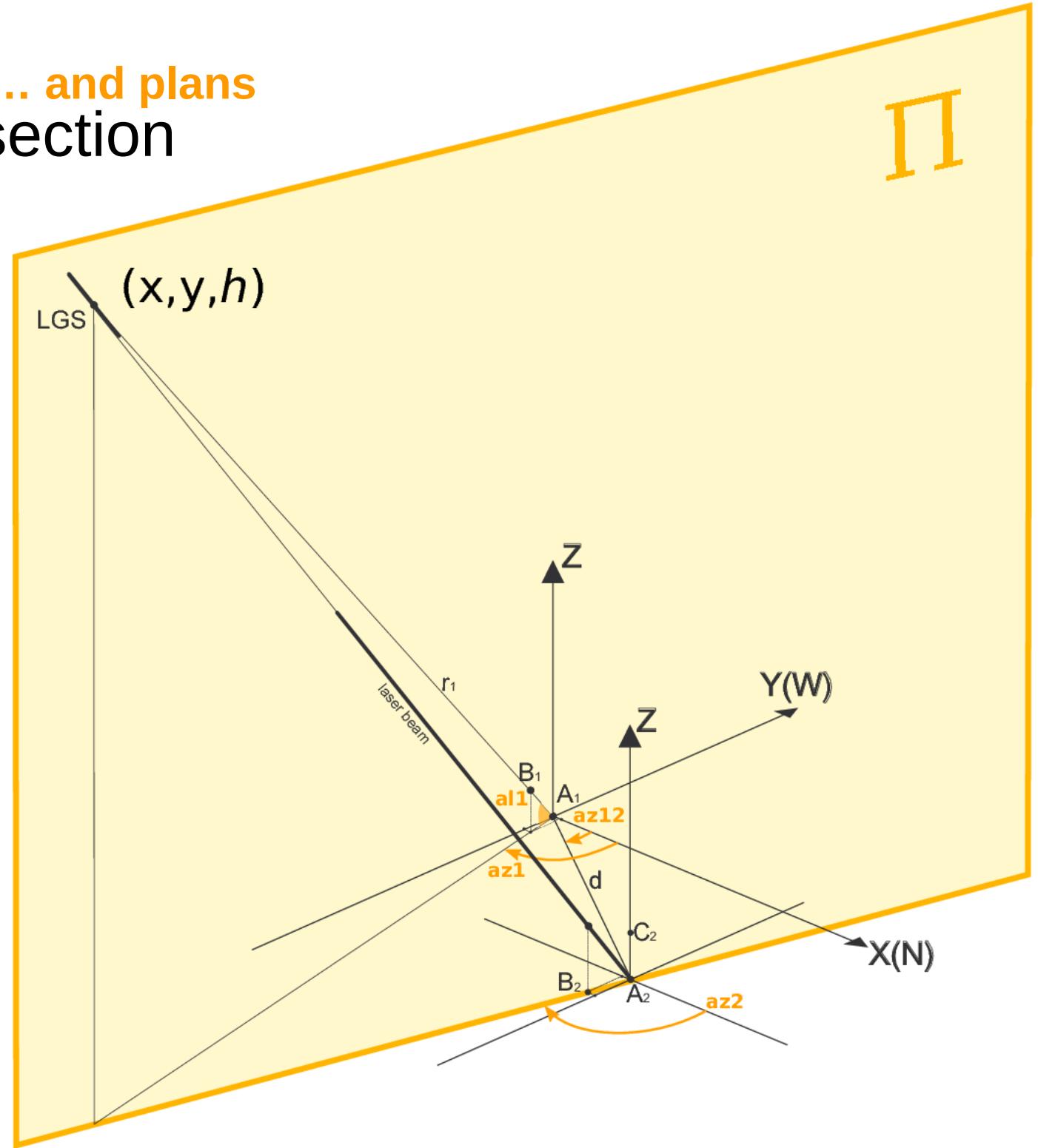
The intersection of the **Line of View** and
the **PLANE of Launching** defines
an unique point in the space (x, y, H)

Na LGS

height profiles at OT... and plans
line-plane intersection

The method

Π



Na LGS

height profiles at OT... and plans
line-plane intersection

Π

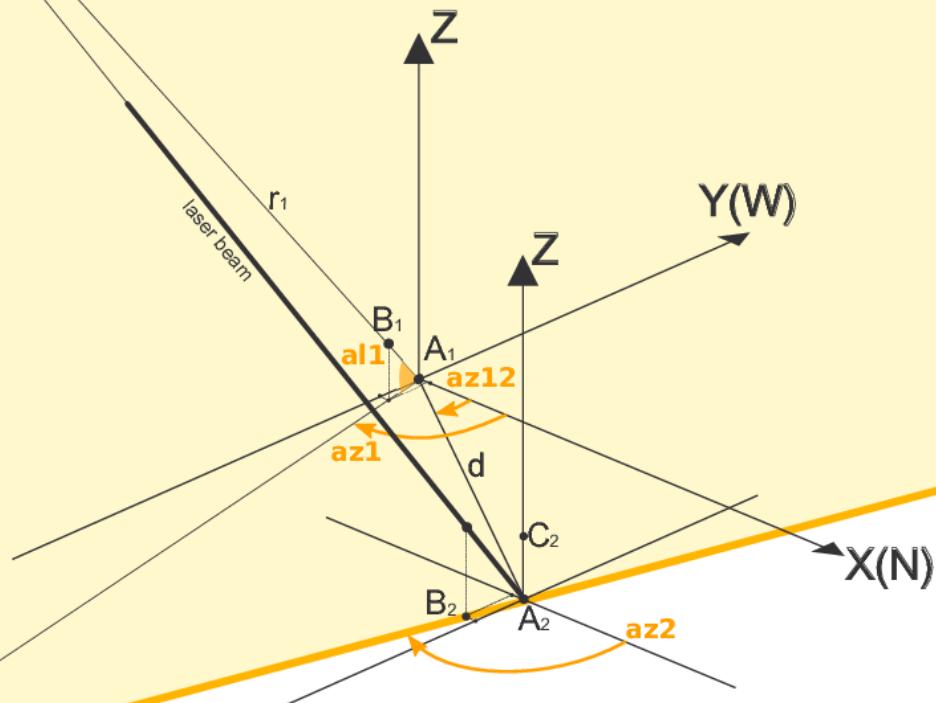
The method

LGS
(x, y, h)

$$h = d \cdot \tan al_1 \frac{\tan az_2 \cos az_{12} - \sin az_{12}}{\tan az_2 \cos az_1 - \sin az_1}$$

$$\begin{aligned} A_1 &= (0, 0, 0) \\ B_1 &= (\cos al_1 \cdot \cos az_1, \cos al_1 \cdot \sin az_1, \sin al_1) \end{aligned}$$

$$\begin{aligned} A_2 &= (d \cdot \cos az_{12}, d \cdot \sin az_{12}, 0) \\ B_2 &= (d \cdot \cos az_{12} + \cos az_2, d \cdot \sin az_{12} + \sin az_2, 0) \\ C_2 &= (d \cdot \cos az_{12}, d \cdot \sin az_{12}, 1) \end{aligned}$$



Na LGS

height profiles at OT... and plans
line-plane intersection

The method

inputs:

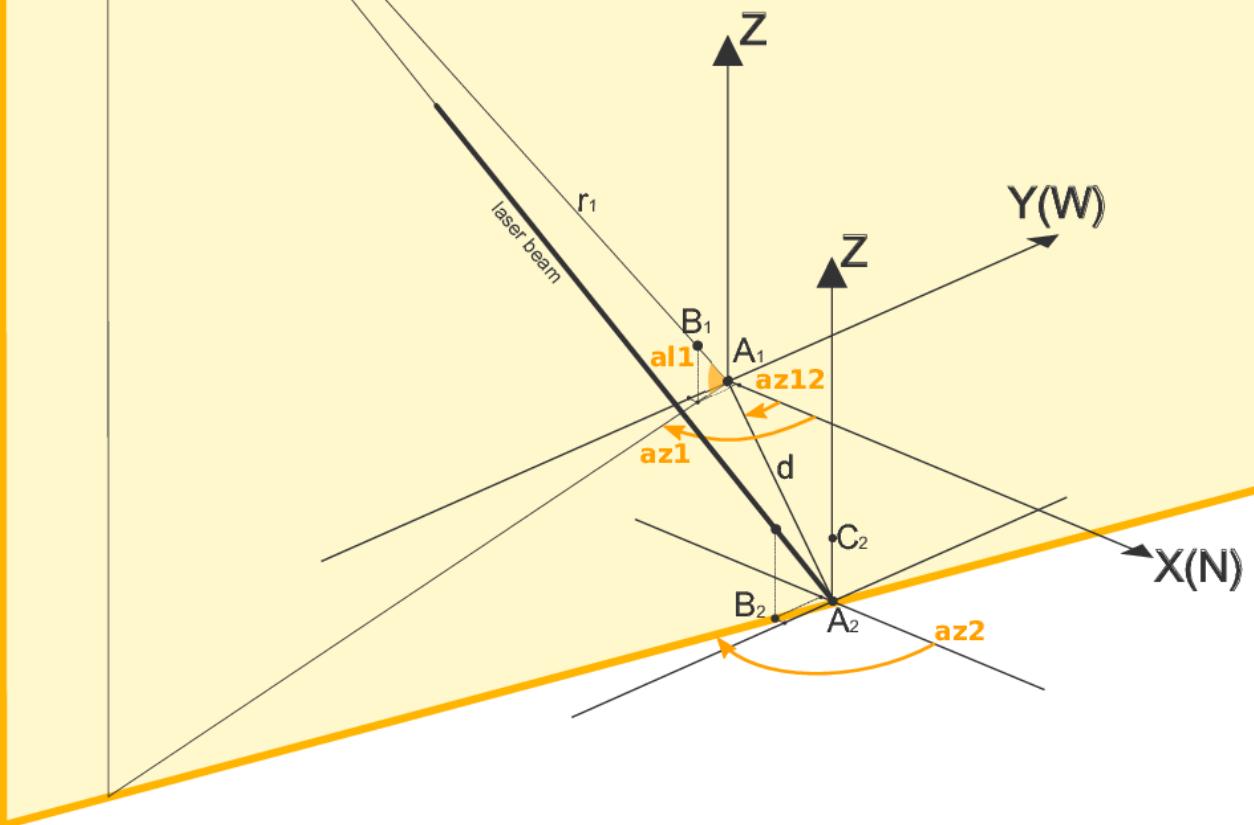
al_1 az_1 az_2

observer azimuth
observer elevation
launcher azimuth

Π

(x, y, h)

$$h = d \cdot \tan al_1 \frac{\tan az_2 \cos az_{12} - \sin az_{12}}{\tan az_2 \cos az_1 - \sin az_1}$$



Na LGS

height profiles at OT... and plans
line-plane intersection

The method

inputs:



observer azimuth
observer elevation
launcher azimuth

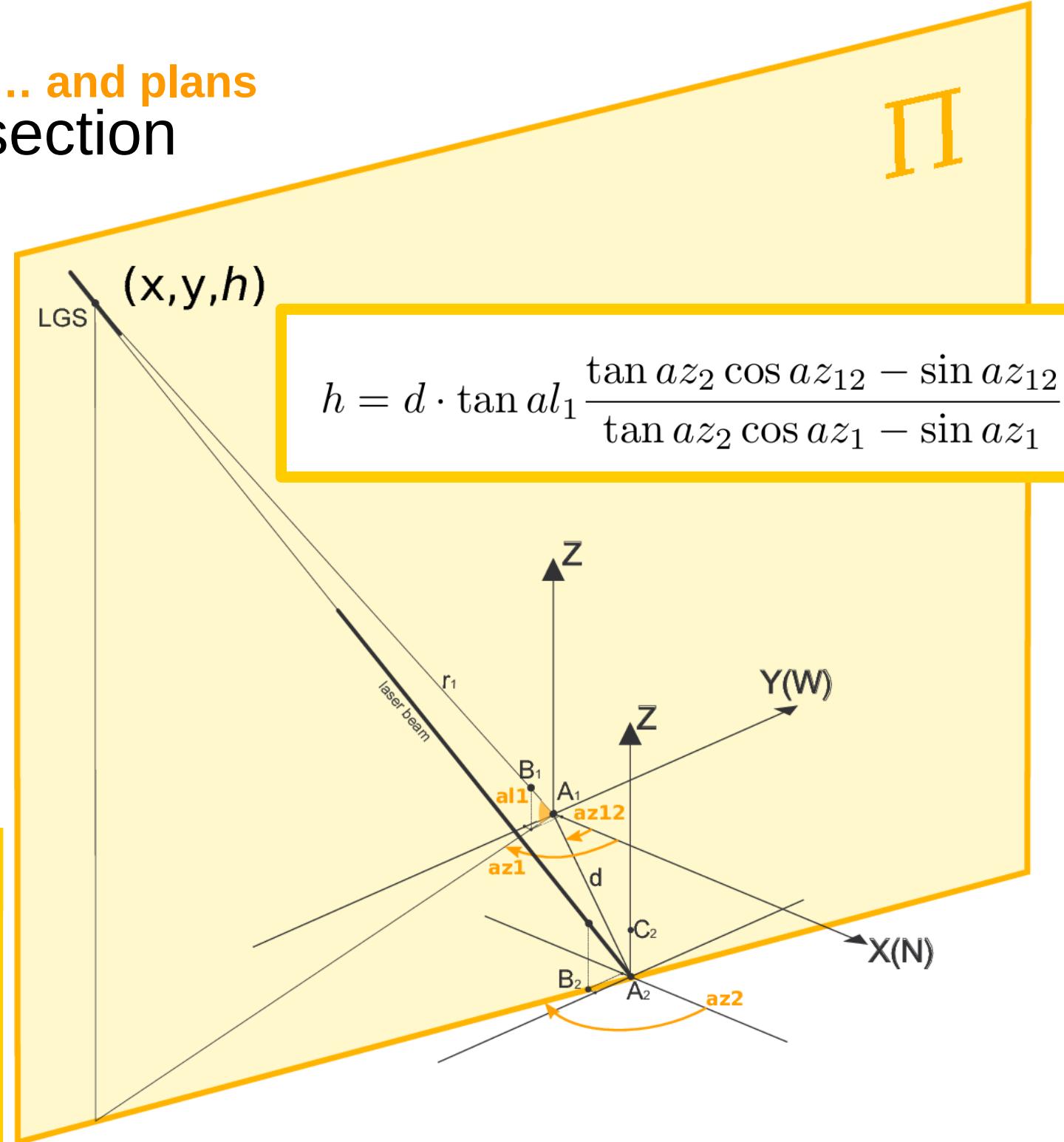
↓
NO launcher al

↓
NO refraction effect

No influence of the
differences in
topographic height
between launcher
and observer

Π

$$h = d \cdot \tan al_1 \frac{\tan az_2 \cos az_{12} - \sin az_{12}}{\tan az_2 \cos az_1 - \sin az_1}$$



Na LGS
height profiles at OT... and plans
line-plane intersection

$$h = d \cdot \tan al_1 \frac{\tan az_2 \cos az_{12} - \sin az_{12}}{\tan az_2 \cos az_1 - \sin az_1}$$

The method

but...

small angles
↓
fast error propagation
↓
accurate input coordinates required



observer:

launcher:

Na LGS

height profiles at OT... and plans
line-plane intersection

$$h = d \cdot \tan al_1 \frac{\tan az_2 \cos az_{12} - \sin az_{12}}{\tan az_2 \cos az_1 - \sin az_1}$$

The method

but...

small angles



fast error propagation



accurate input coordinates required



observer:

ASTROMETRY
in the FOV

XparallaX J.J.Sanabria (IAC)

launcher:

Na LGS
height profiles at OT... and plans
line-plane intersection

The method

$$h = d \cdot \tan al_1 \frac{\tan az_2 \cos az_{12} - \sin az_{12}}{\tan az_2 \cos az_1 - \sin az_1}$$

but...

small angles
↓
fast error propagation
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observer:
ASTROMETRY
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XparallaX J.J.Sanabria (IAC)

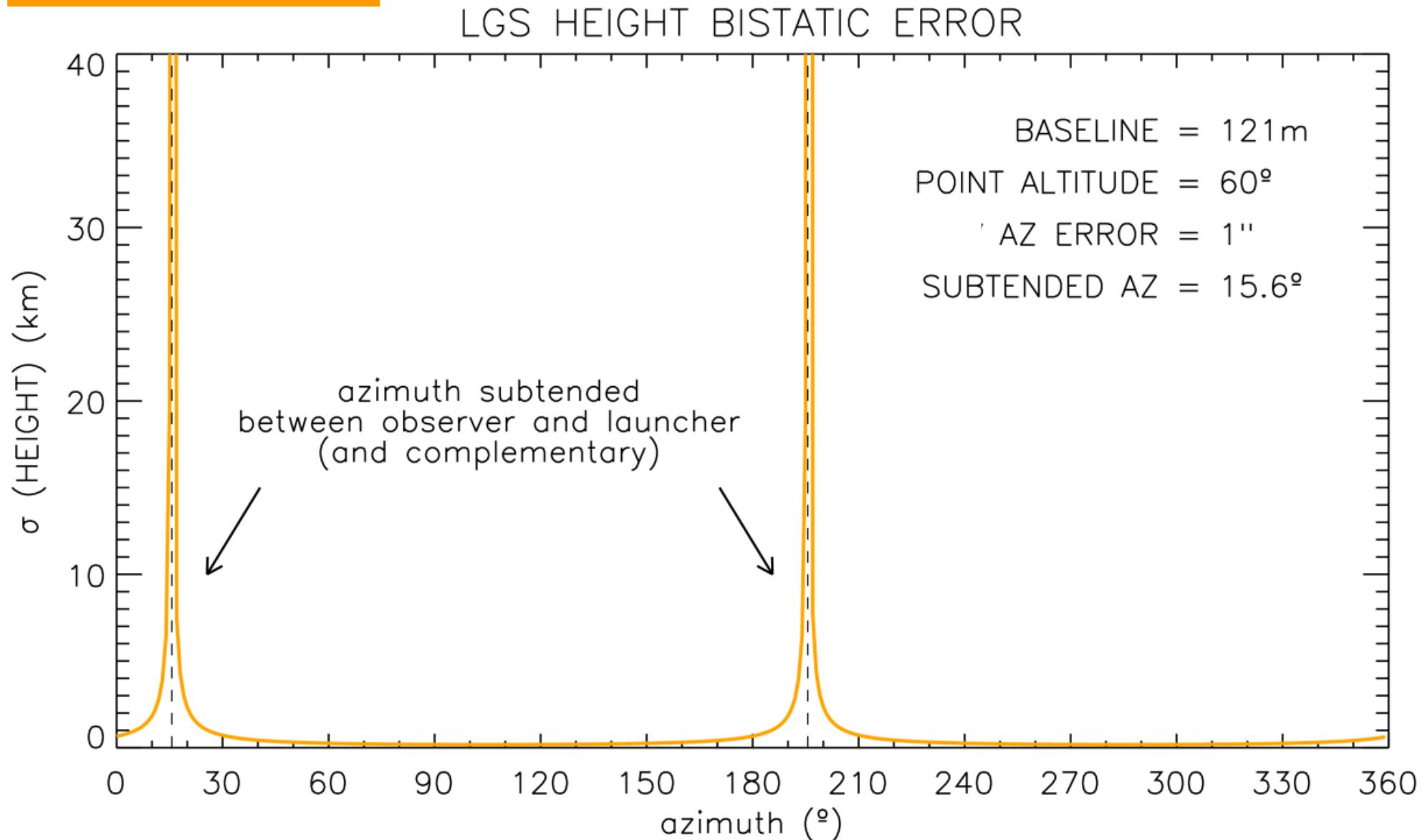
launcher:
Montecarlo
simulation for
error propagation

Na LGS

height profiles at OT... and plans

montecarlo simulation - error propagation

The method

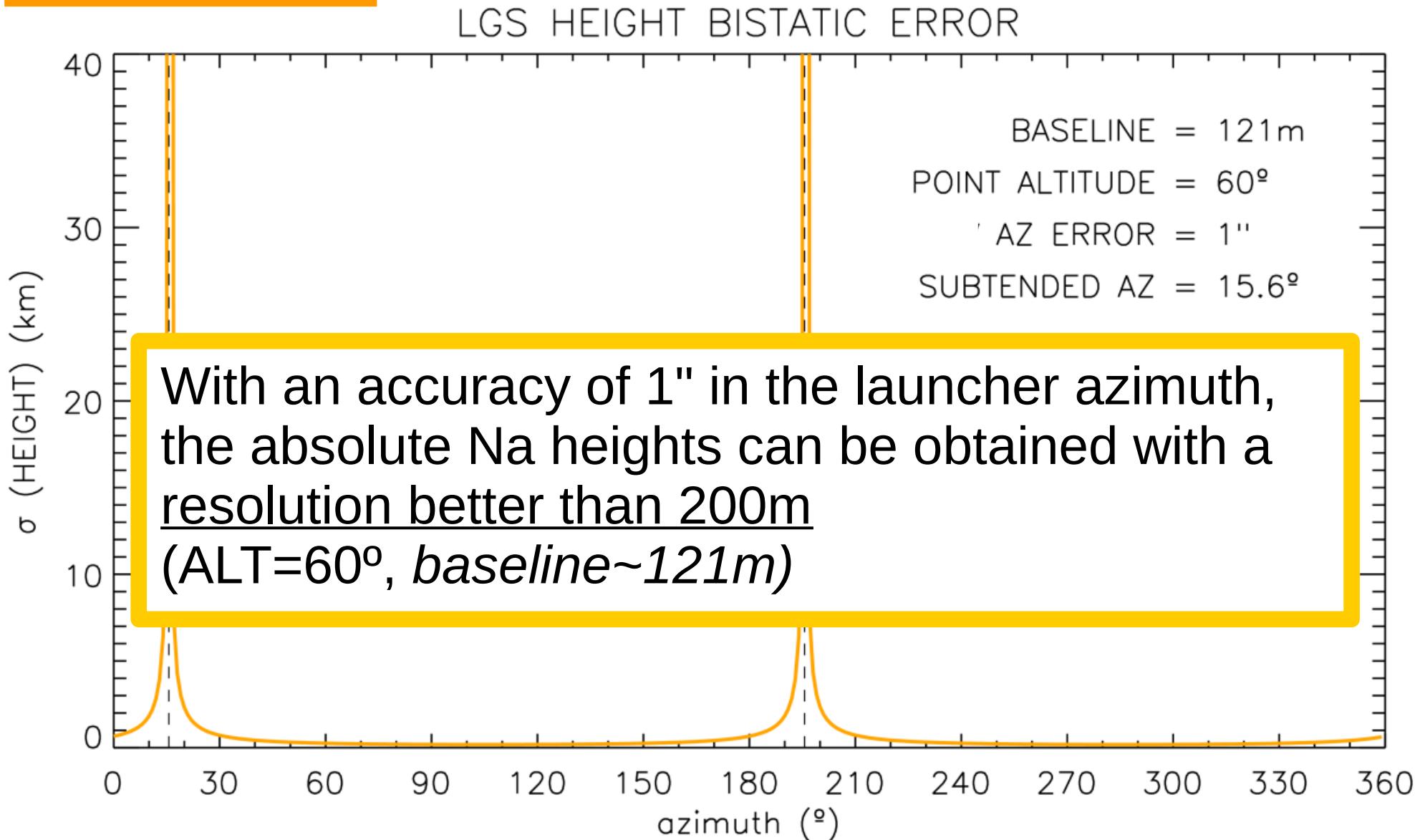


Na LGS

height profiles at OT... and plans

montecarlo simulation - error propagation

The method



Na LGS

height profiles at OT... and plans

The method

launcher azimuth accuracy:

- accurate telescope pointing models...
- tracking + autoguiding...
- also astrometry...



(A)

absolute mode

accurate az_2 from
launcher pointing data

Na LGS

height profiles at OT... and plans

The method

launcher azimuth accuracy:

- accurate telescope pointing models...
- tracking + autoguiding...
- also astrometry...



(A)

absolute mode

accurate az_2 from
launcher pointing data

(B)

relative mode

ad hoc
LGS peak = 90km
and estimate az_2

ESO Wendelstein LGS Unit (WLGSU)
@Teide Obsv. (OT)

2015-2016

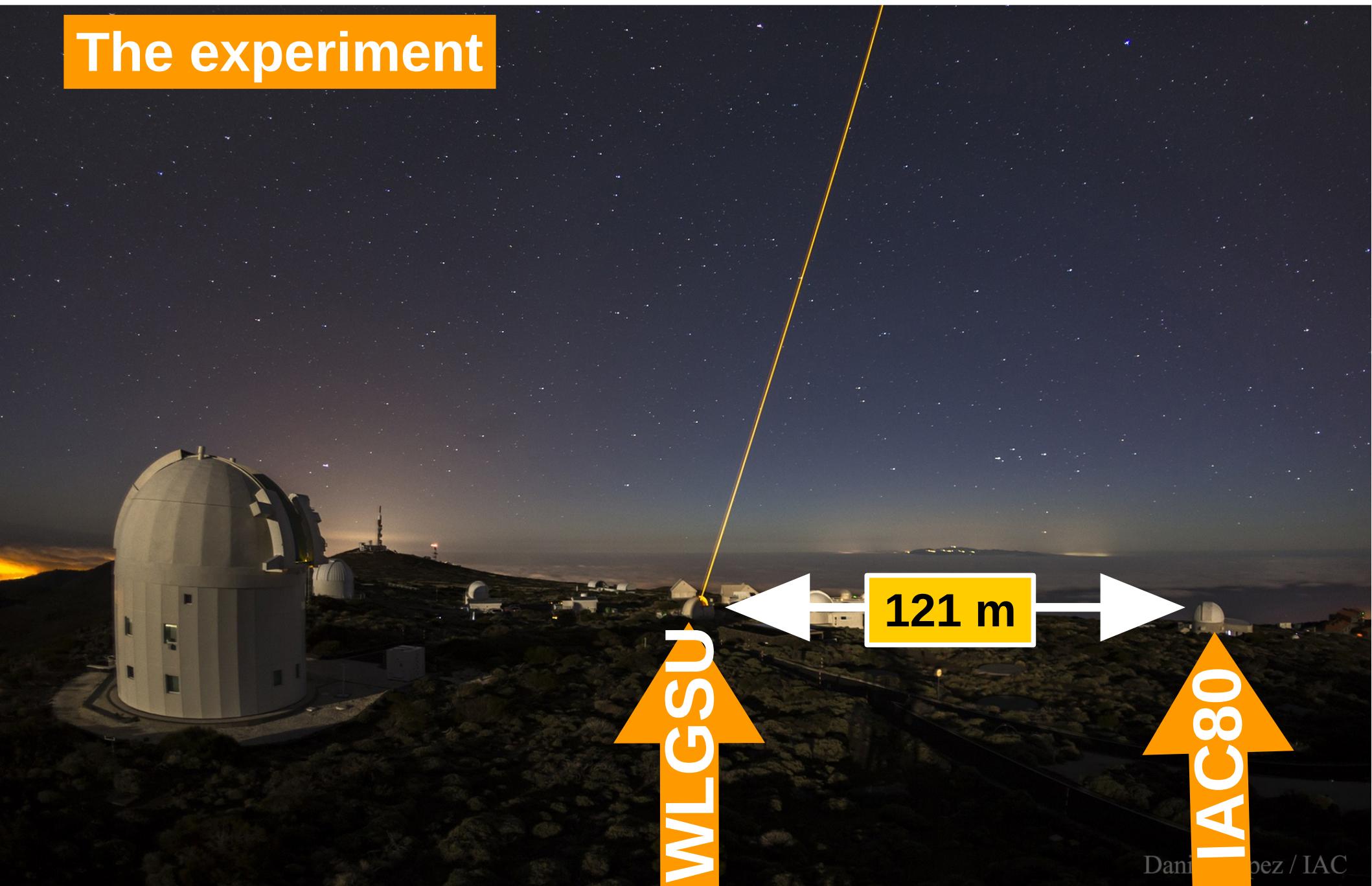
The experiment



ESO Wendelstein LGS Unit (WLGSU) @Teide Obsv. (OT)

2015-2016

The experiment



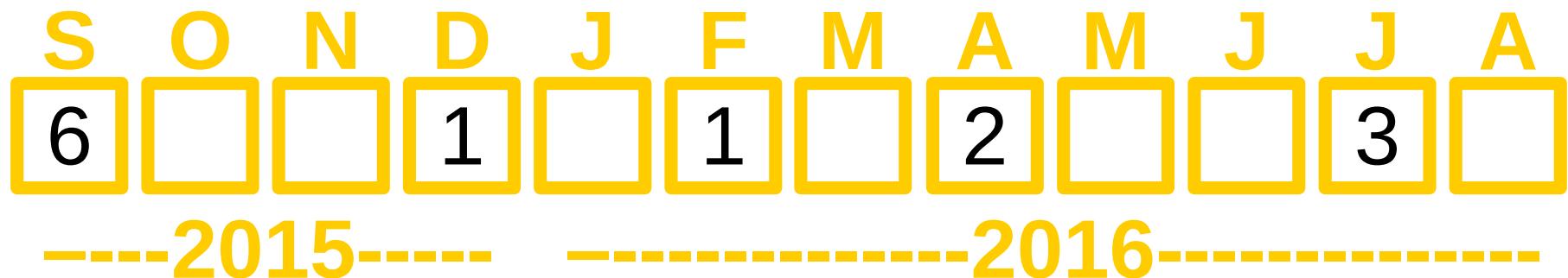
Na LGS

height profiles at OT... and plans

The experiment

campaign summary

~3000 profiles
13 nights



Na LGS

height profiles at OT... and plans

Some results

note: relative heights mode (**B**)

(we still have to go deeper with the *az* accuracy)

...focused on features
impacting AO

Na LGS

height profiles at OT... and plans



Na LGS

height profiles at OT... and plans

Some results



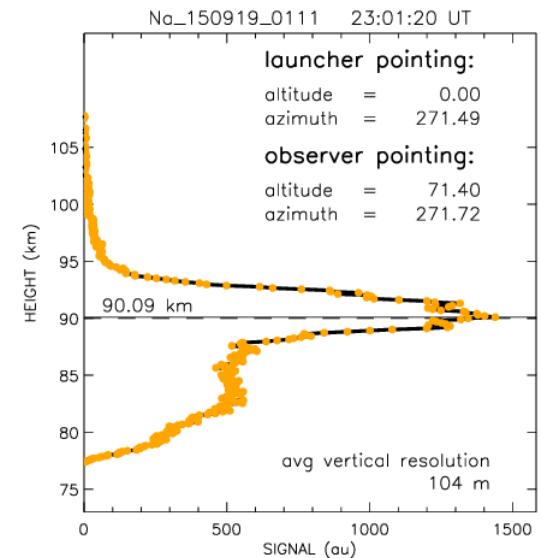
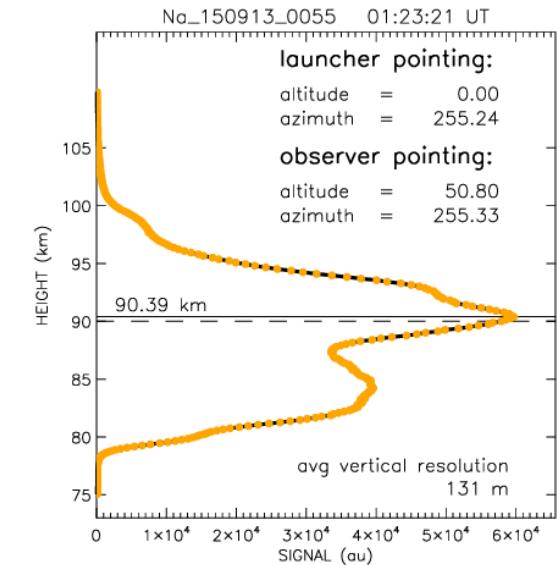
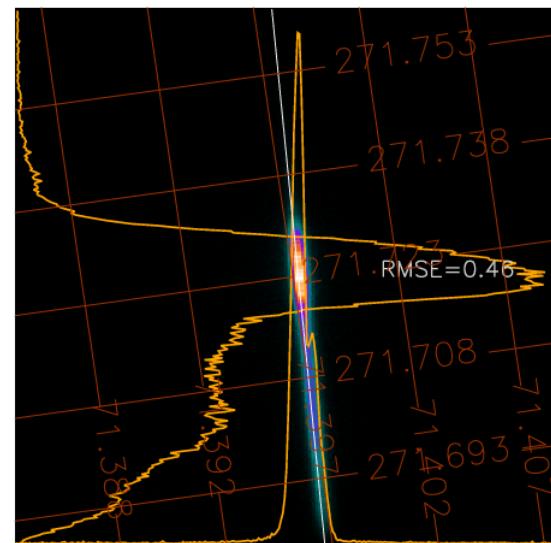
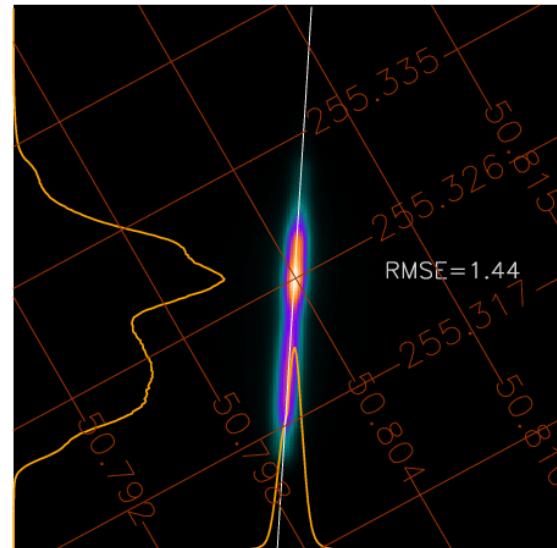
Na LGS

height profiles at OT... and plans

Some results

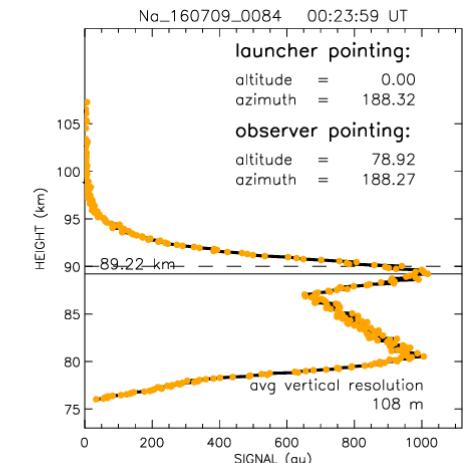
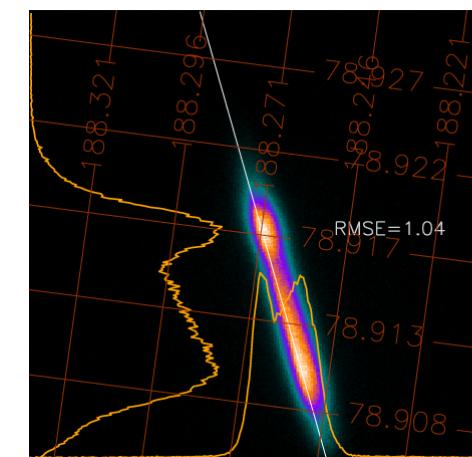
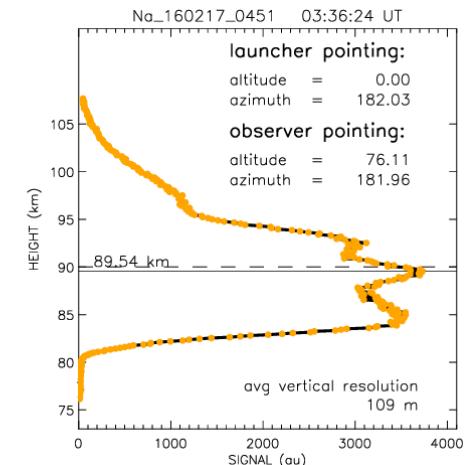
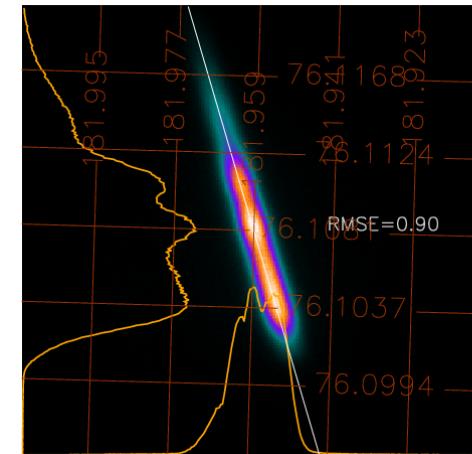
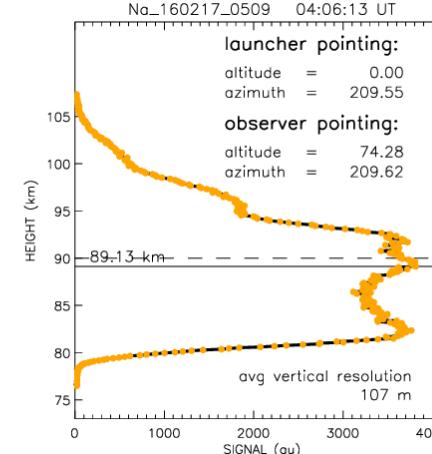
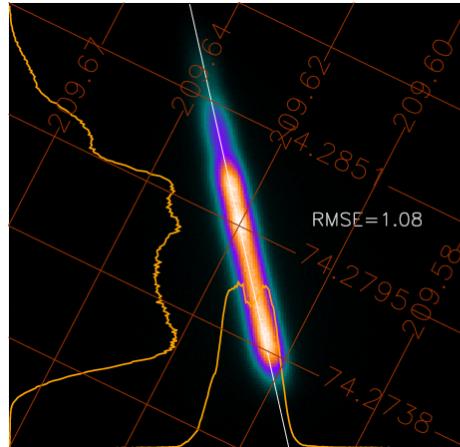
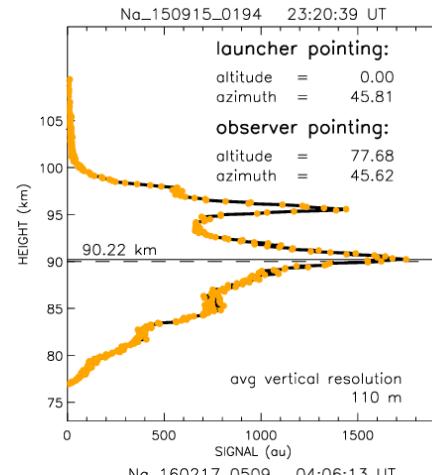
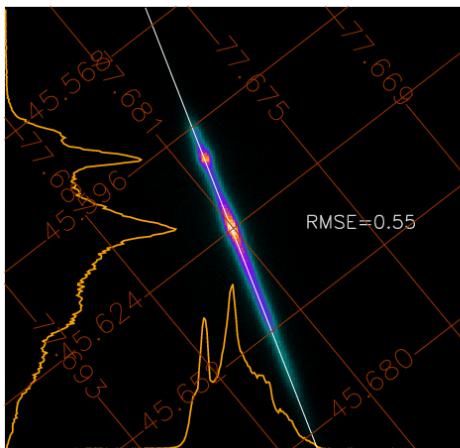


*structure, width > 20km,
temporal and spatial
instability,...*



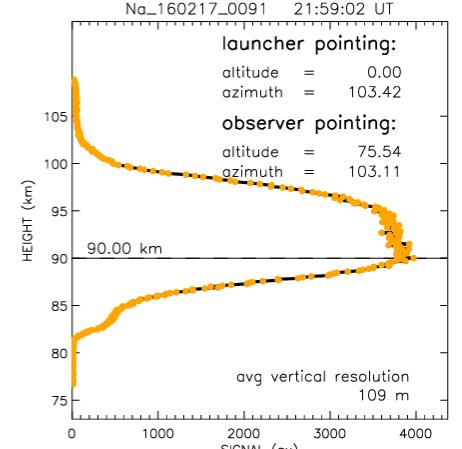
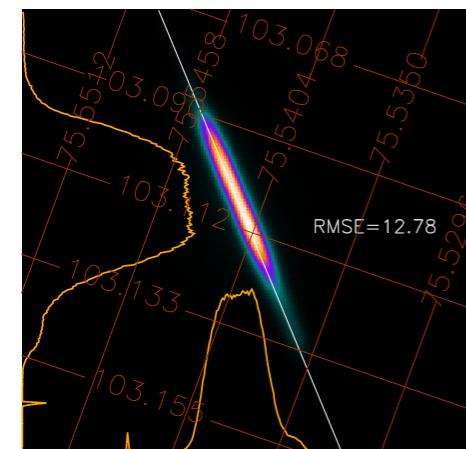
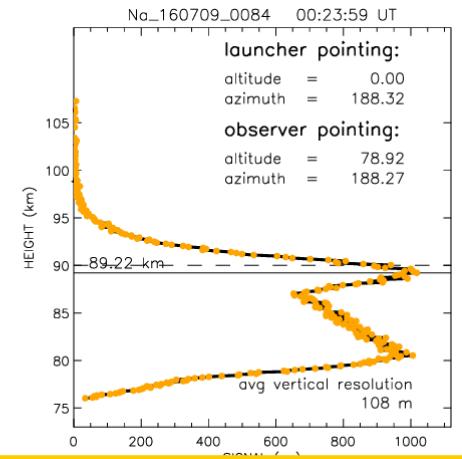
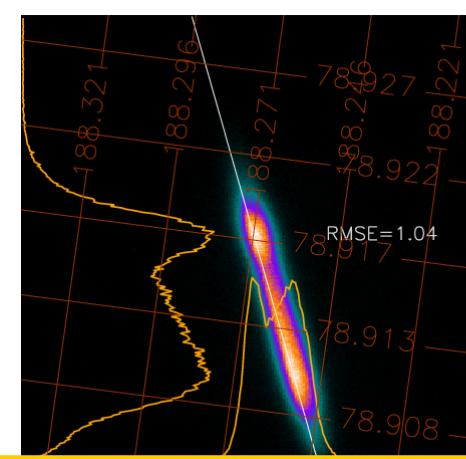
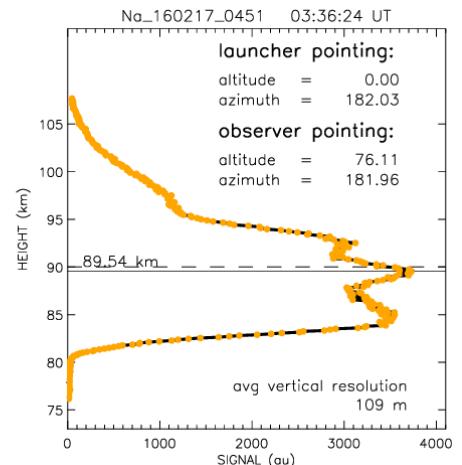
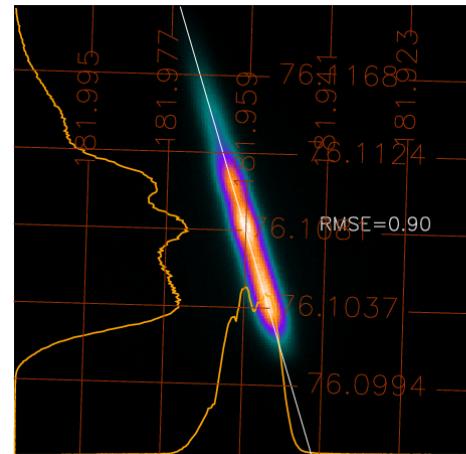
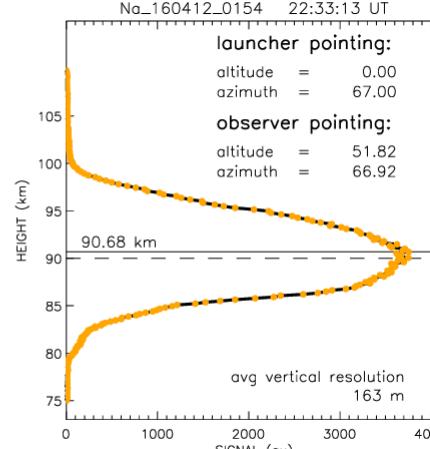
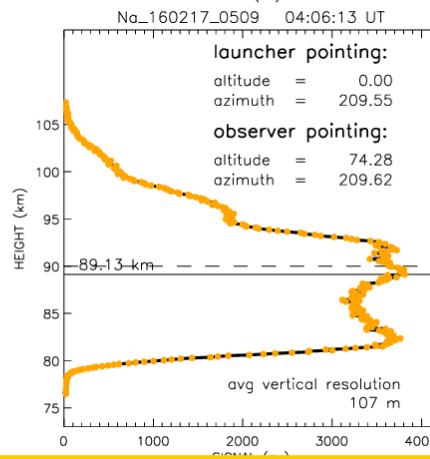
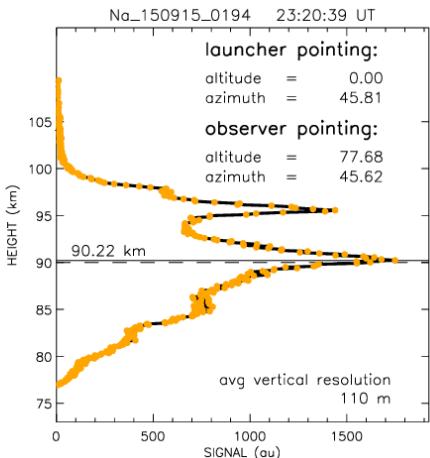
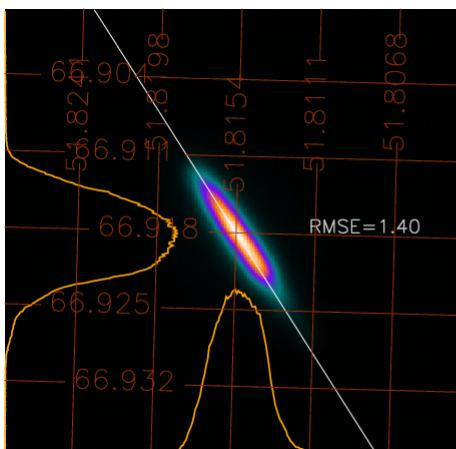
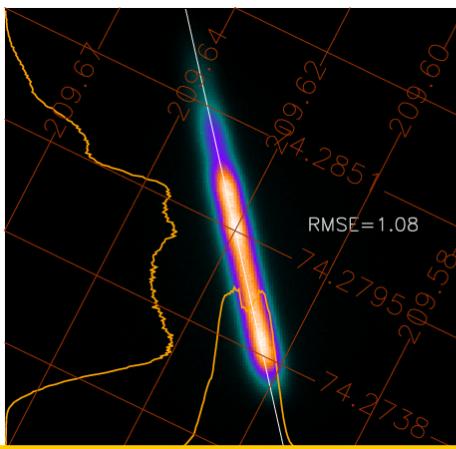
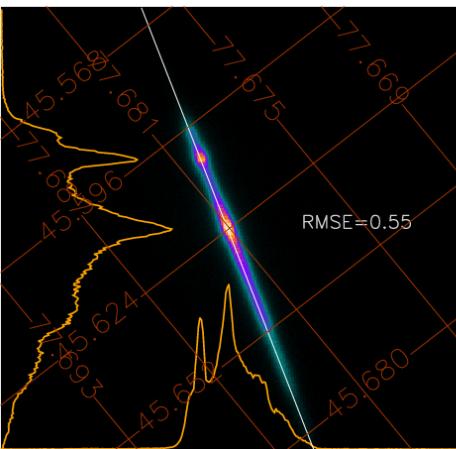
Na LGS height profiles at OT... and plans

multiple sporadic layers,....

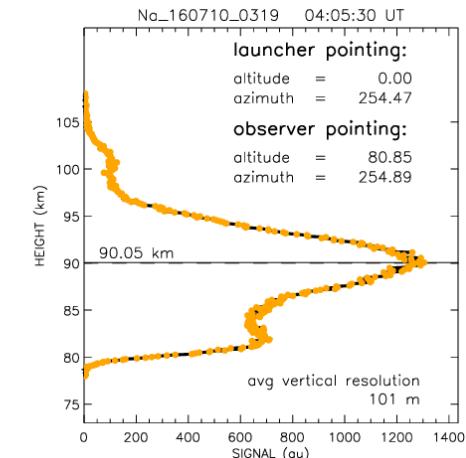
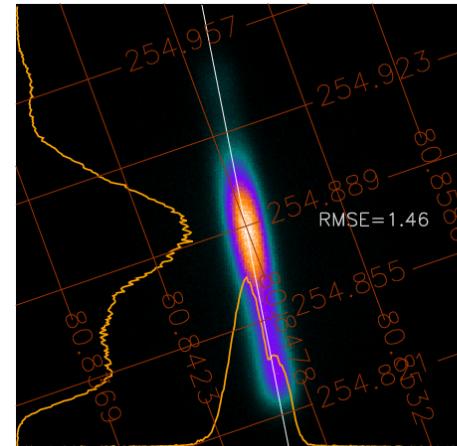
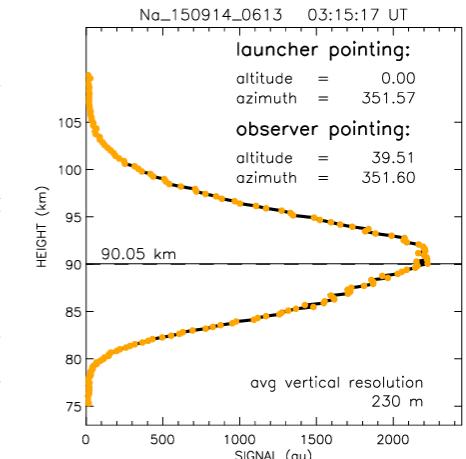
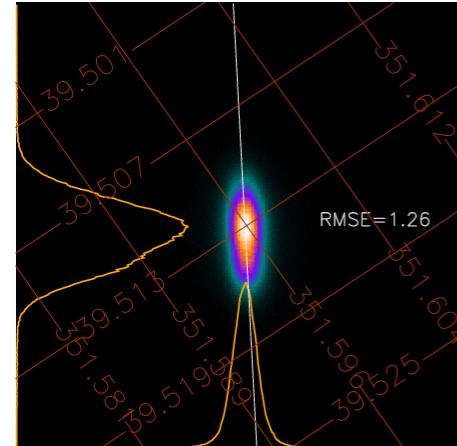
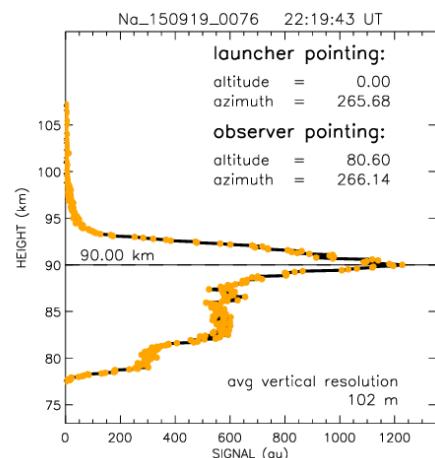
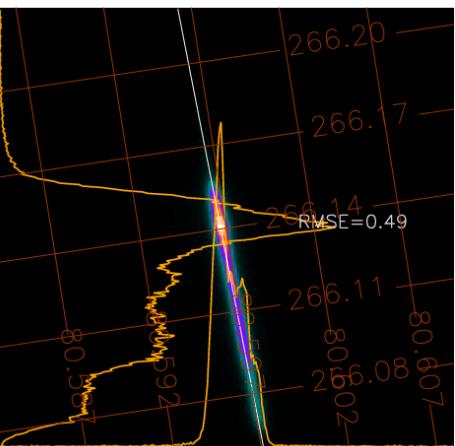
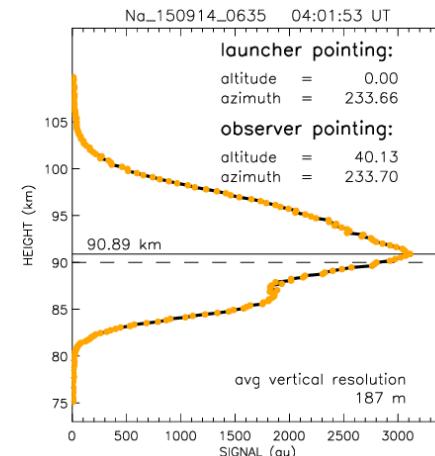
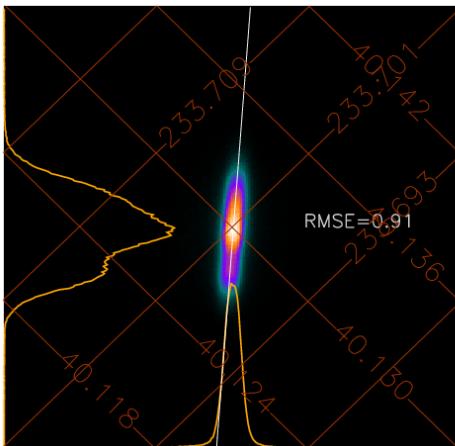


Na LGS height profiles at OT... and plans

but still “gaussian” many times,...



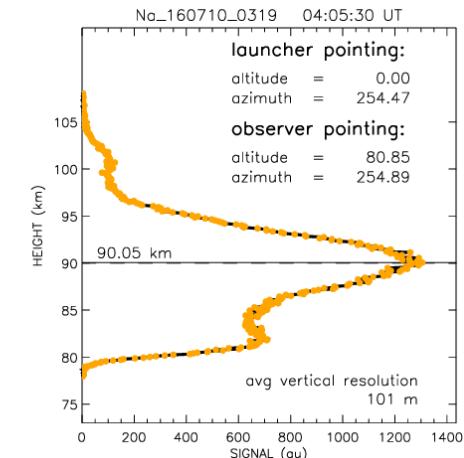
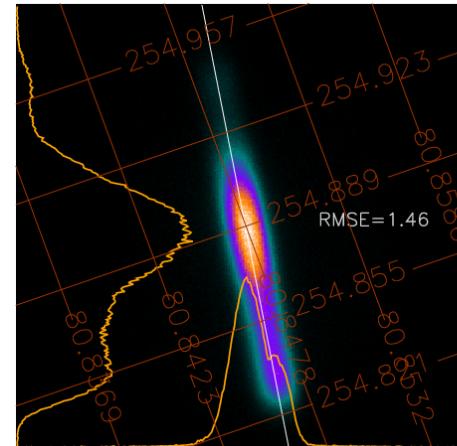
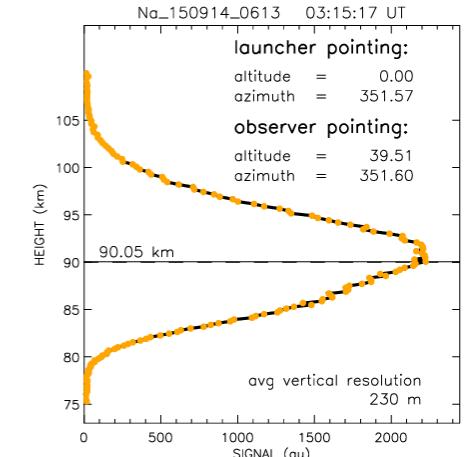
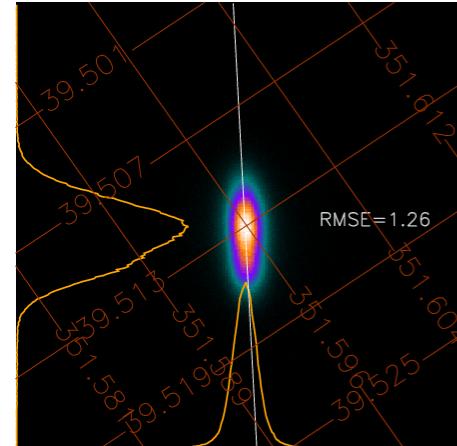
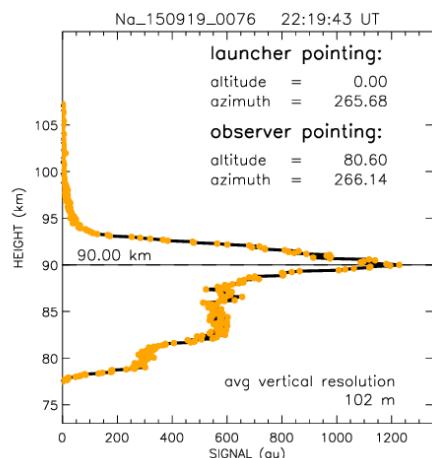
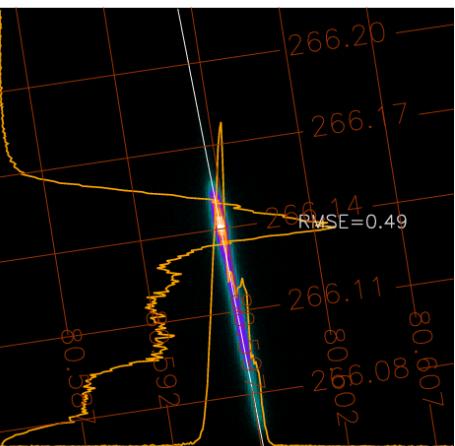
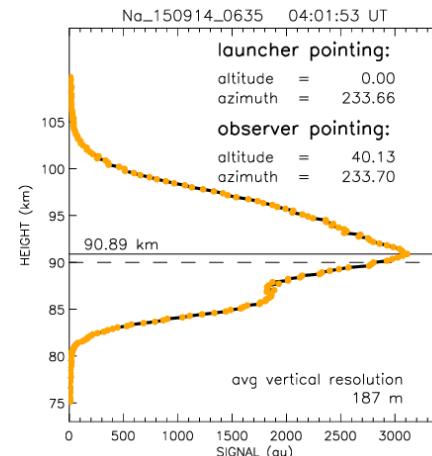
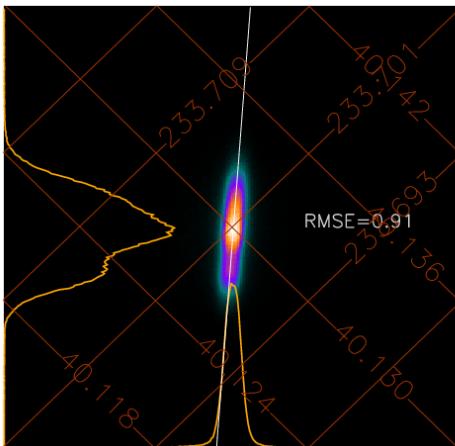
Na LGS height profiles at OT... and plans



horizon vs zenith

horizon lost of resolution, but still resolvable
and not impacting the layer width...

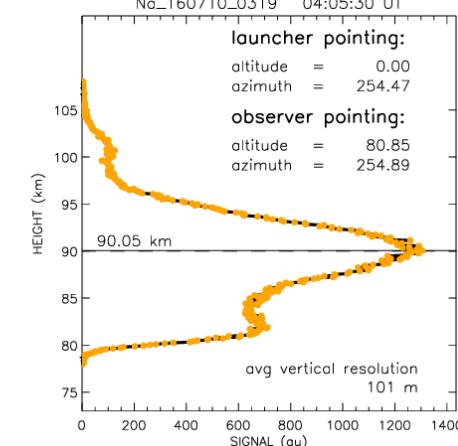
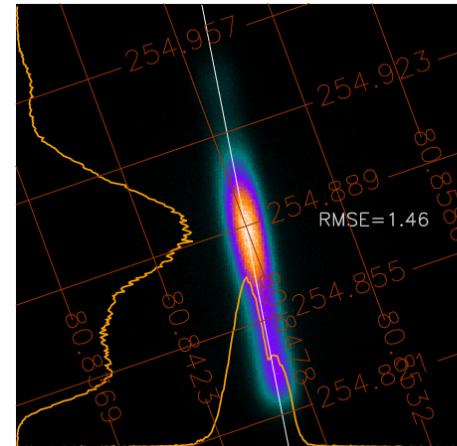
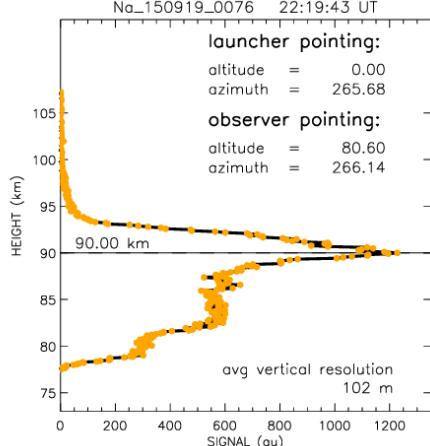
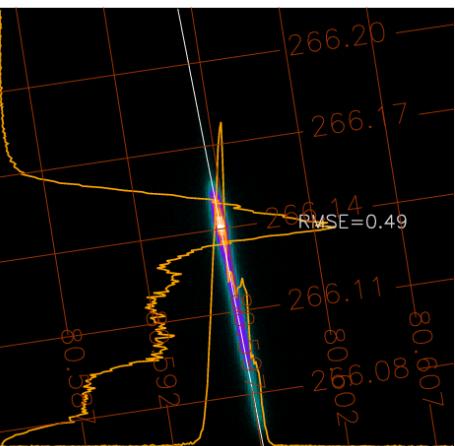
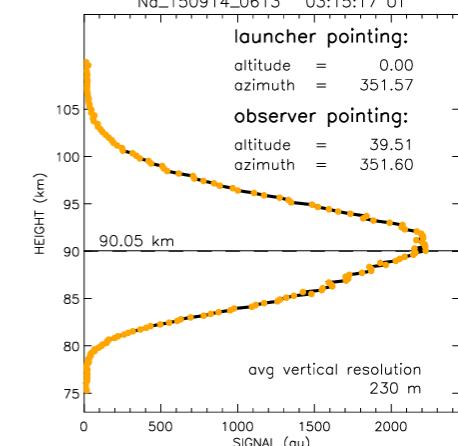
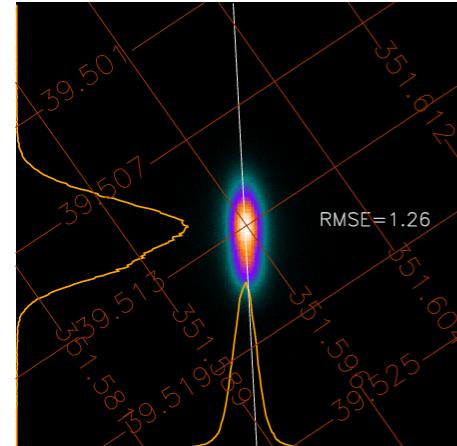
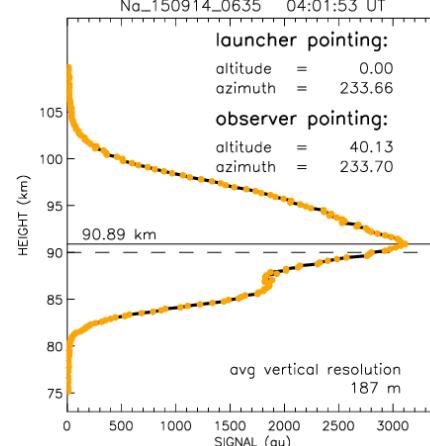
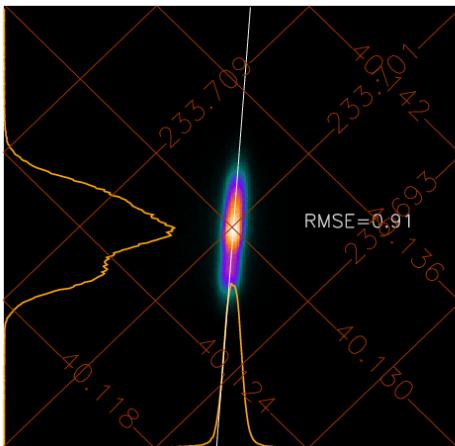
Na LGS height profiles at OT... and plans



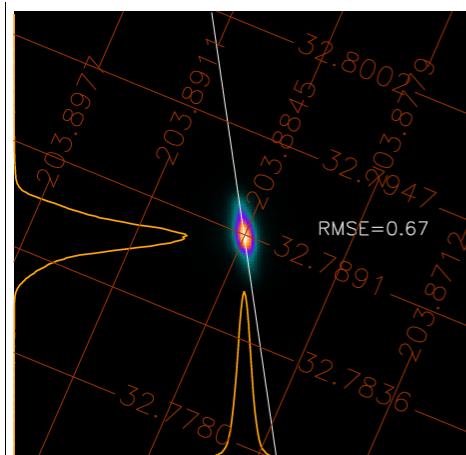
horizon vs zenith
for AO ...
horizon
wins!

horizon *lost of resolution, but still resolvable*
and not impacting the layer width...

Na LGS height profiles at OT... and plans

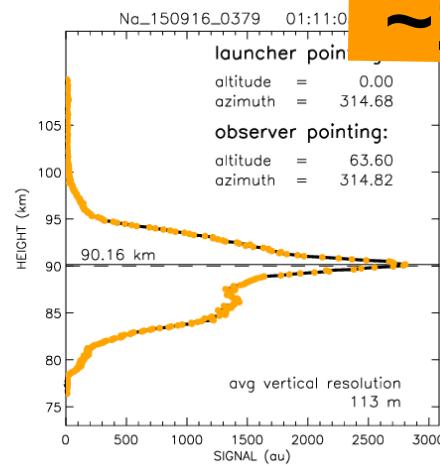
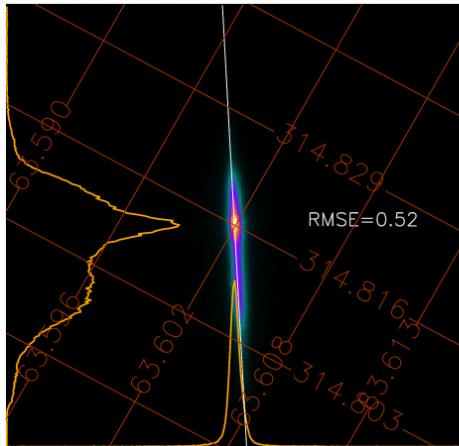


horizon vs zenith
for AO ...
**horizon
wins!**

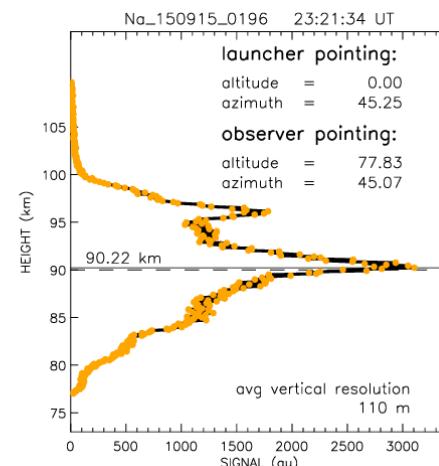
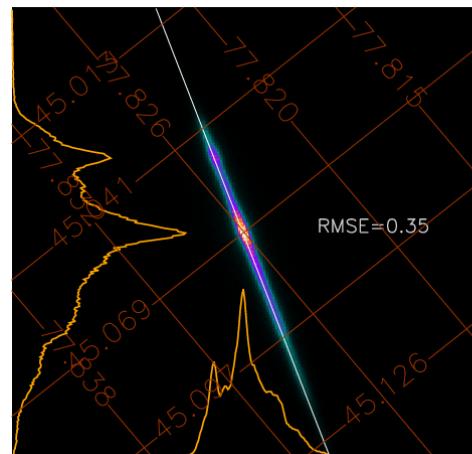
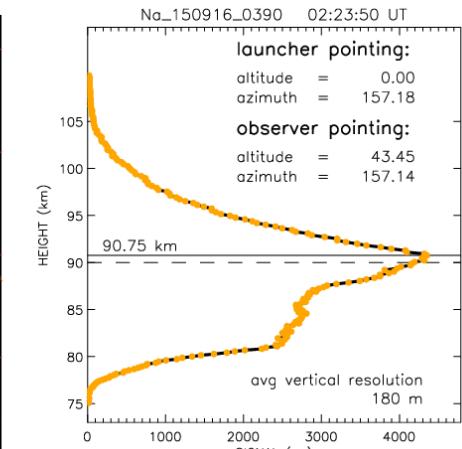
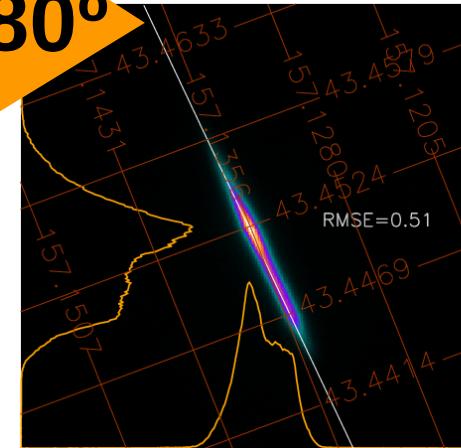


pointing to the
Galactic Center

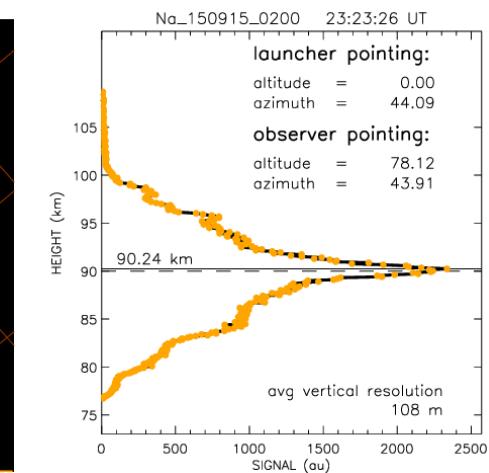
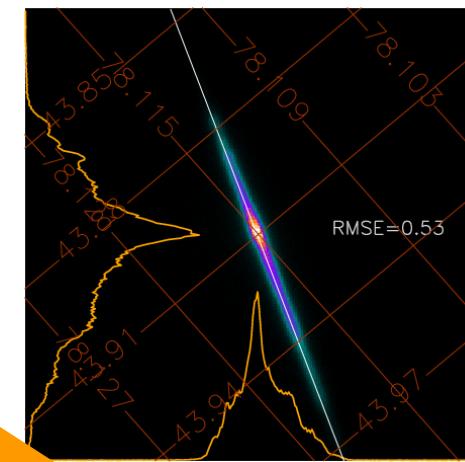
Na LGS height profiles at OT... and plans



~180°



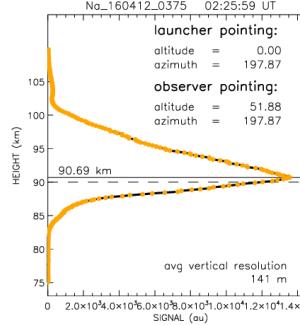
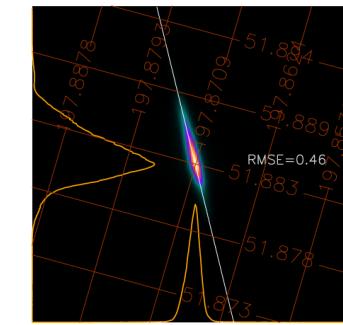
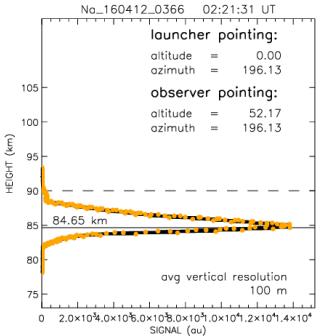
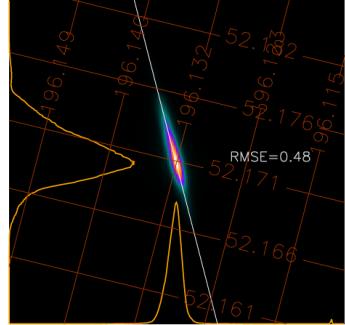
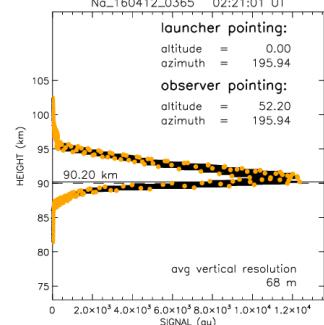
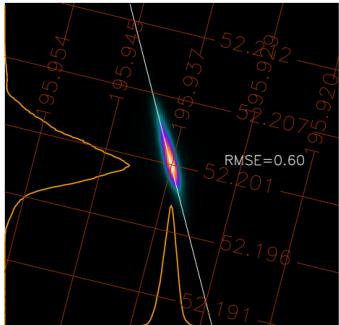
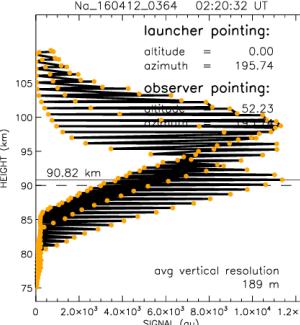
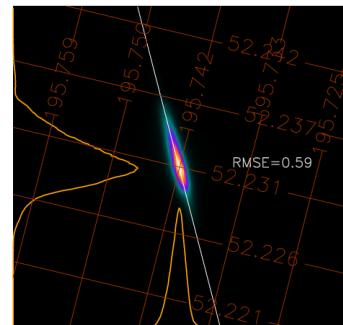
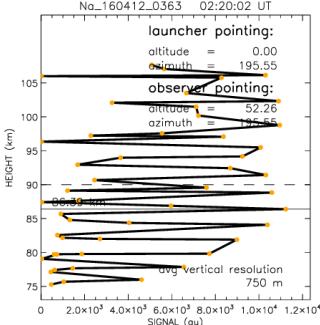
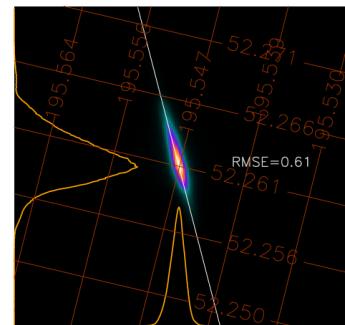
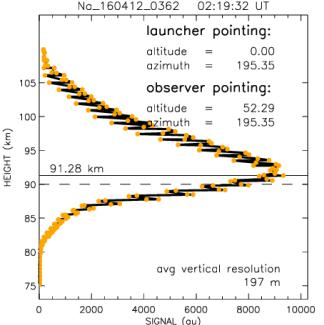
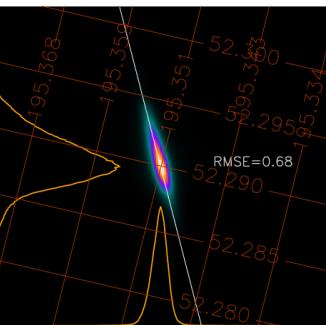
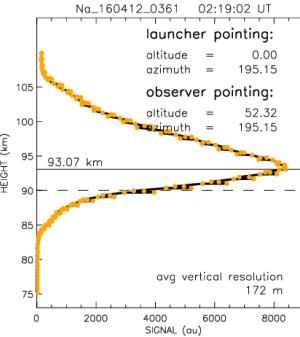
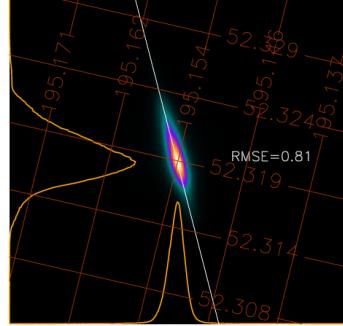
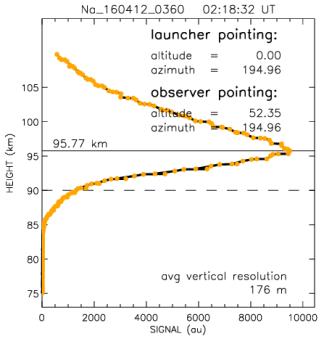
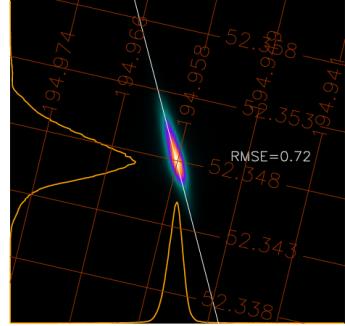
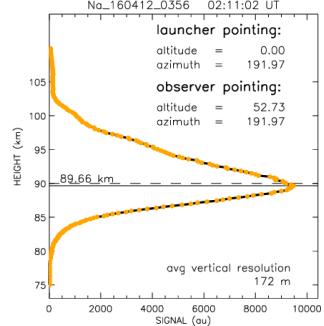
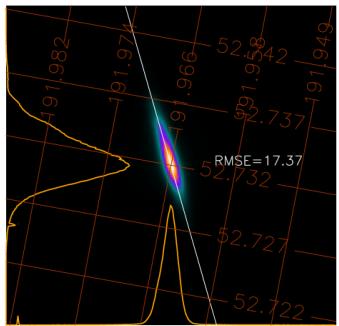
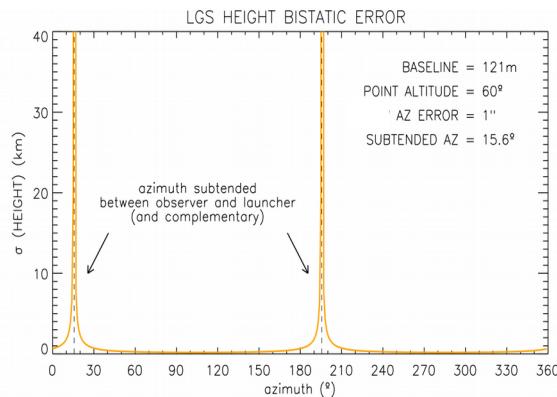
~2min



spatial and temporal instability,...

Na LGS height profiles at OT... and plans

*moving through
the no mathematical domain points*

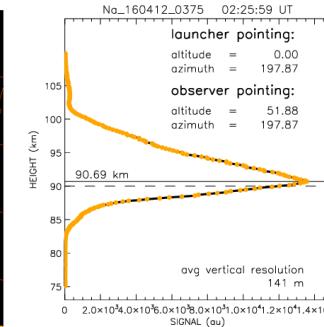
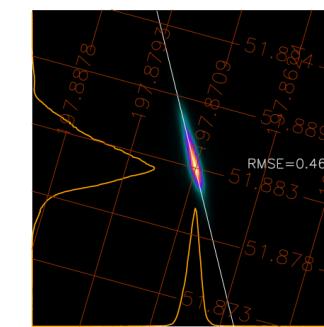
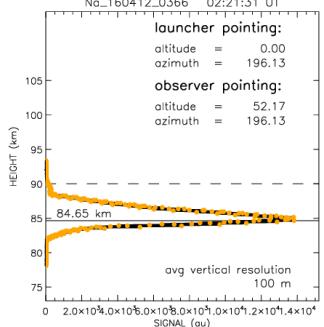
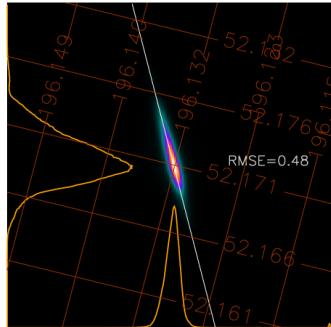
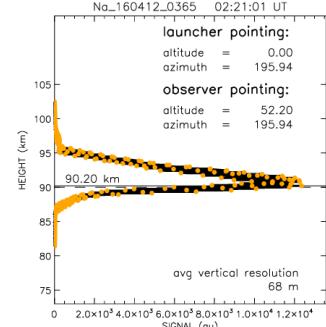
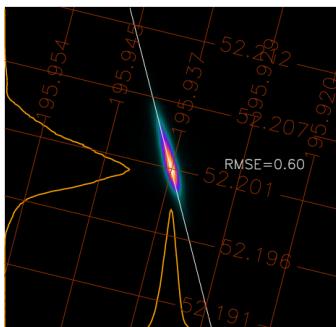
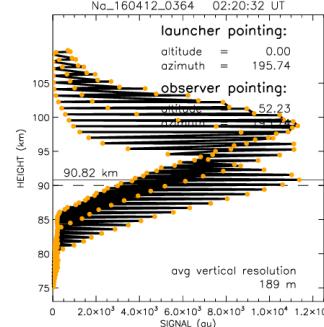
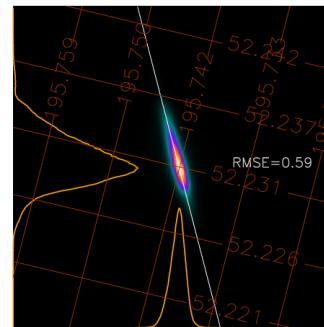
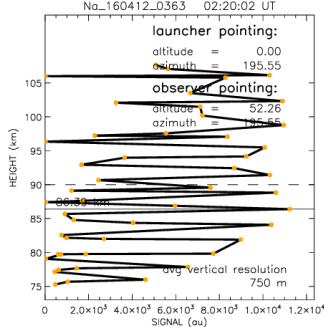
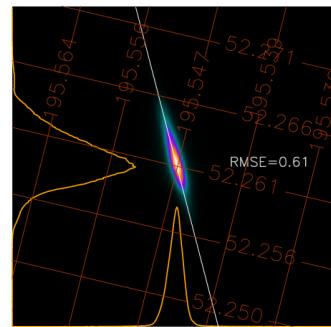
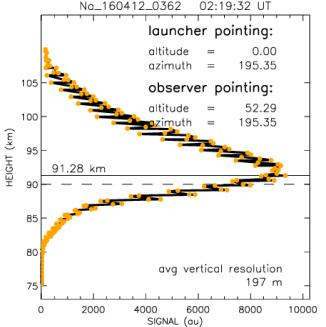
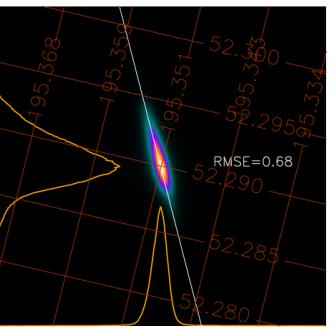
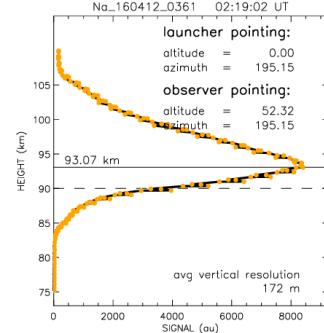
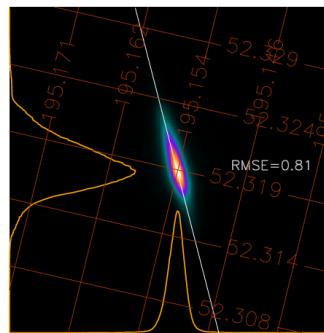
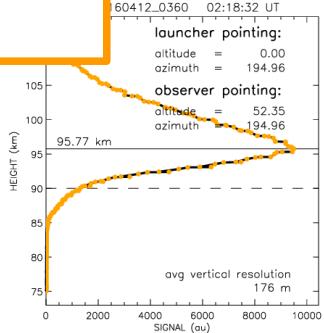
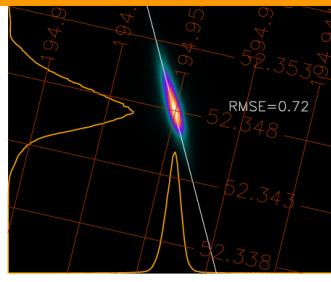
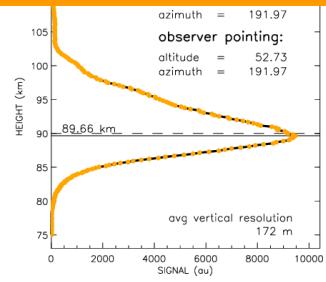
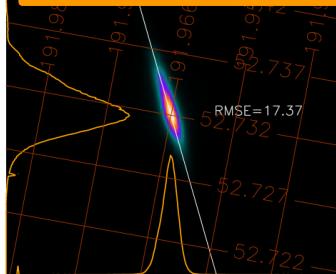
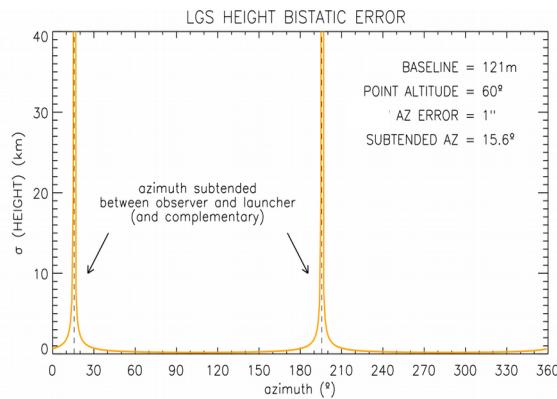


Na LGS height profiles at OT... and plans

*moving through
the no mathematical domain points*

proposal:

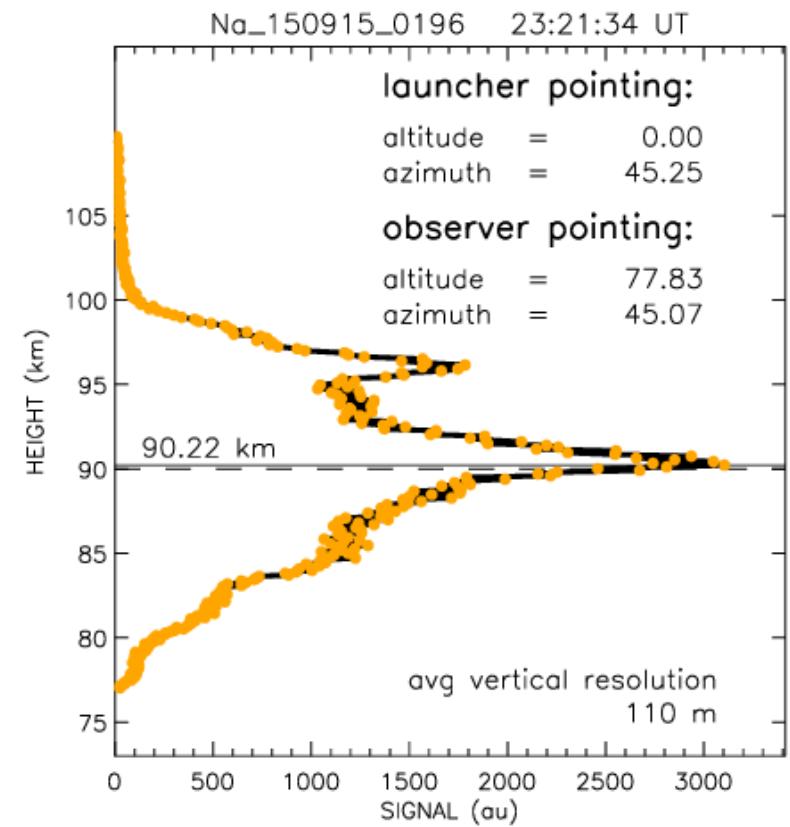
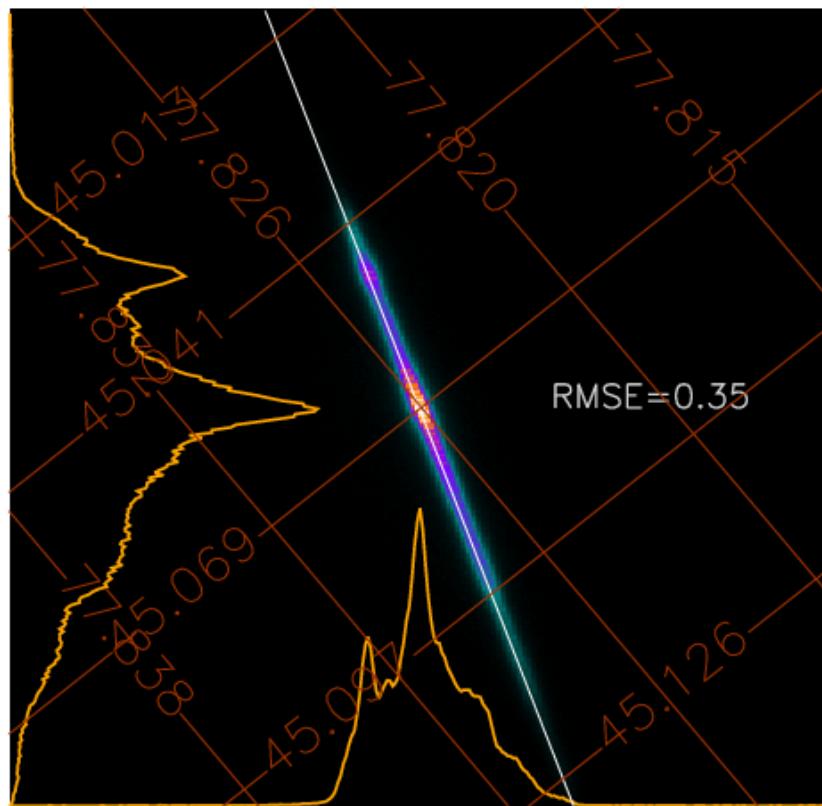
double observer telescope, shifted 90°



Na LGS

height profiles at OT... and plans

getting heights
overcomes the perspective effect



Na LGS

height profiles at OT... and plans

...future (on going) plans

ESO Wendelstein LGS Unit (WLGSU)



@Teide Obsv. (OT)

Daniel López / IAC



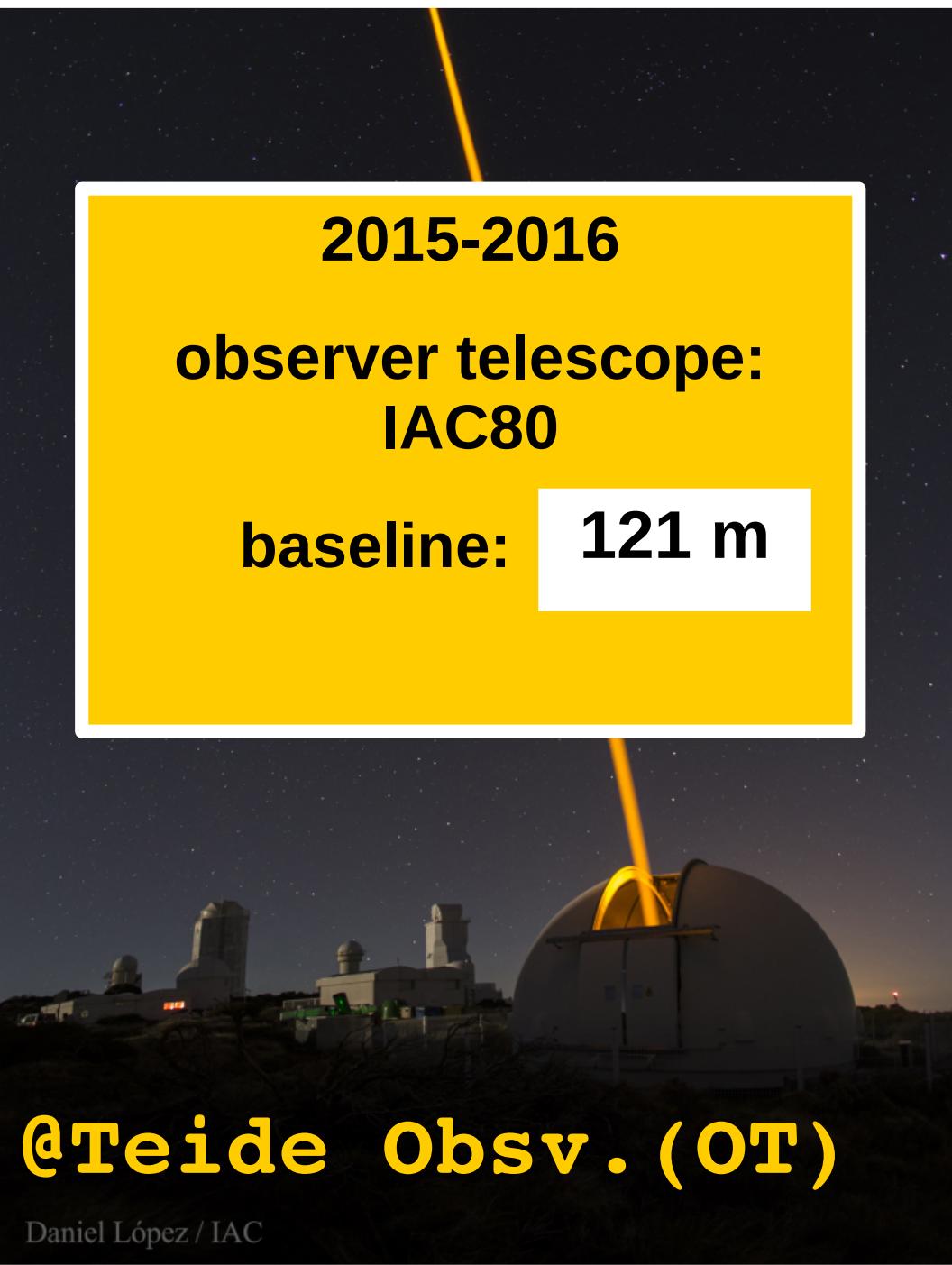
@Roque de los
Muchachos Obsv.
(ORM)

ESO Wendelstein LGS Unit (WLGSU)

2015-2016

observer telescope:
IAC80

baseline: **121 m**



@Teide Obsv. (OT)

Daniel López / IAC

since OCT-2016

telescopes:
WHT (Canary AO demonstrator)

INT (fast LGS profiling)

JKT (height profiling)

baseline: **388 m**



@Roque de los
Muchachos Obsv.
(ORM)

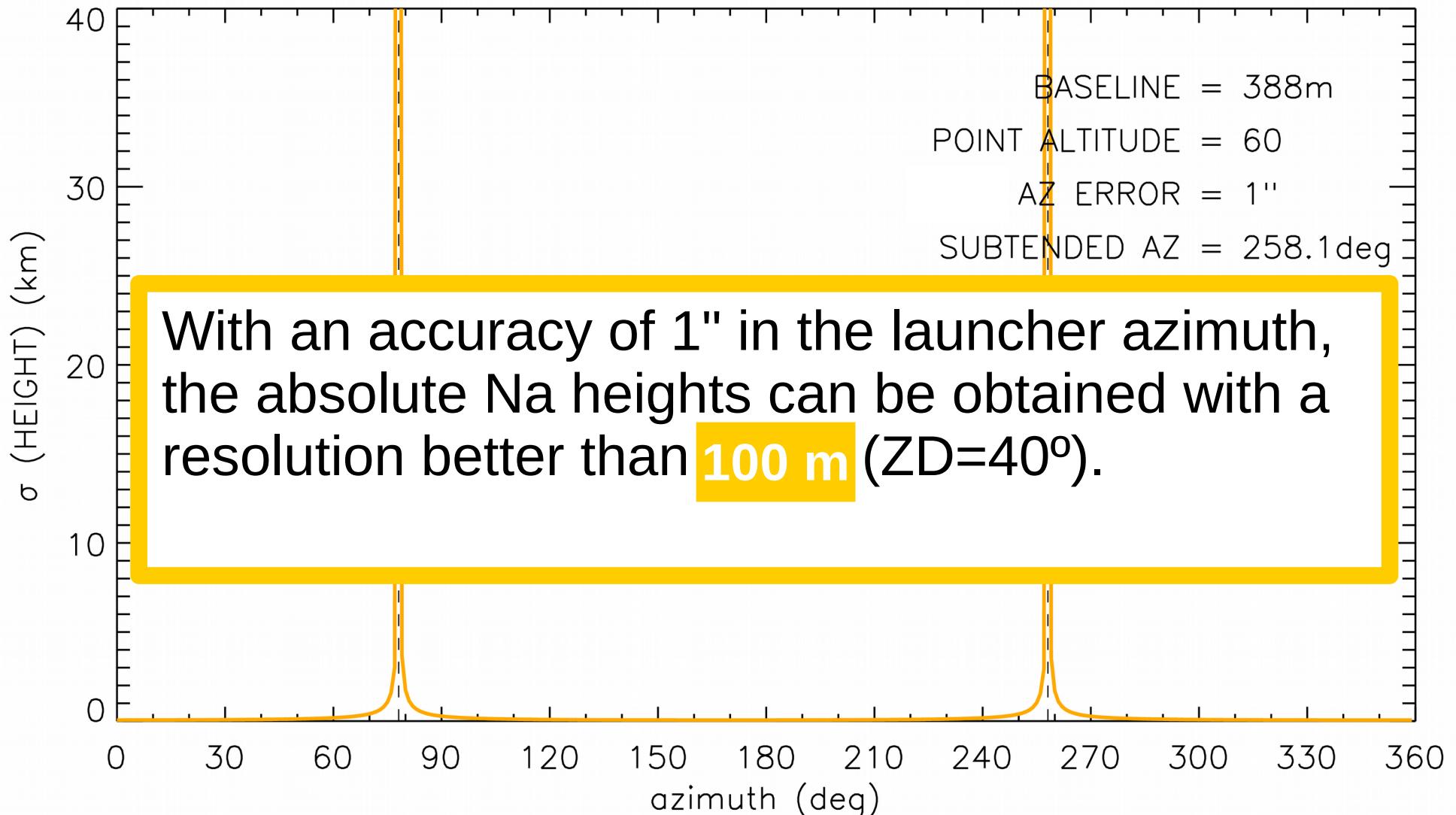
Na LGS

height profiles at OT... and plans

montecarlo simulation - error propagation

@ ORM JKT-WLGSU

LGS HEIGHT BISTATIC ERROR



Na LGS

height profiles at OT... and plans
conclusions

Na layer is “Nature” → measurements and monitoring are important

AO systems benefits from real time Na layer height inputs, either absolutes or relatives
(overcoming the perspective effect)

Our method works retrieving the Na height profile from the AO-LGS → just in FOV (even for extreme pointing positions)

Less altitude is less resolution, but less elongation too.
good for AO!

Future plans are: deeper statistical results, absolute mode on, and work together with the Canary profile-meter (Durham University)

Na LGS

height profiles at OT... and plans



Thank you