MAX-PLANCK-INSTITUT FÜR PLASMAPHYSIK

ITER Divertor flow monitor - Reflection supression

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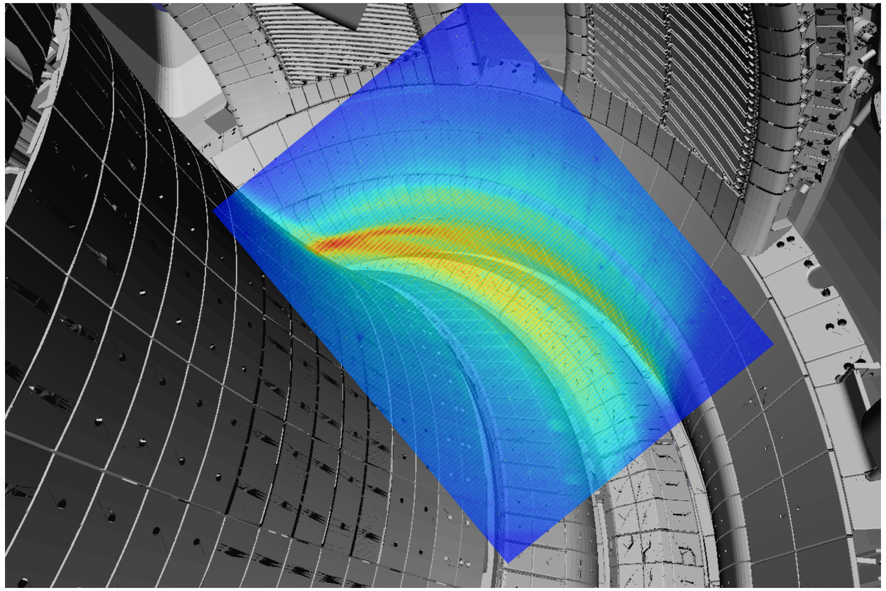
M. Kocan - ITER-IO

ITPA Topical Group Diagnostics, October 2021

iter
china eu india japan korea russia usa

Reflections in CIS

- Many successful existing coherence imaging spectroscopy (CIS) systems (TEXTOR, MAST, D3D, W7X...)
- Only AUG so far with metal wall --> Effect of reflections significant in some image areas.



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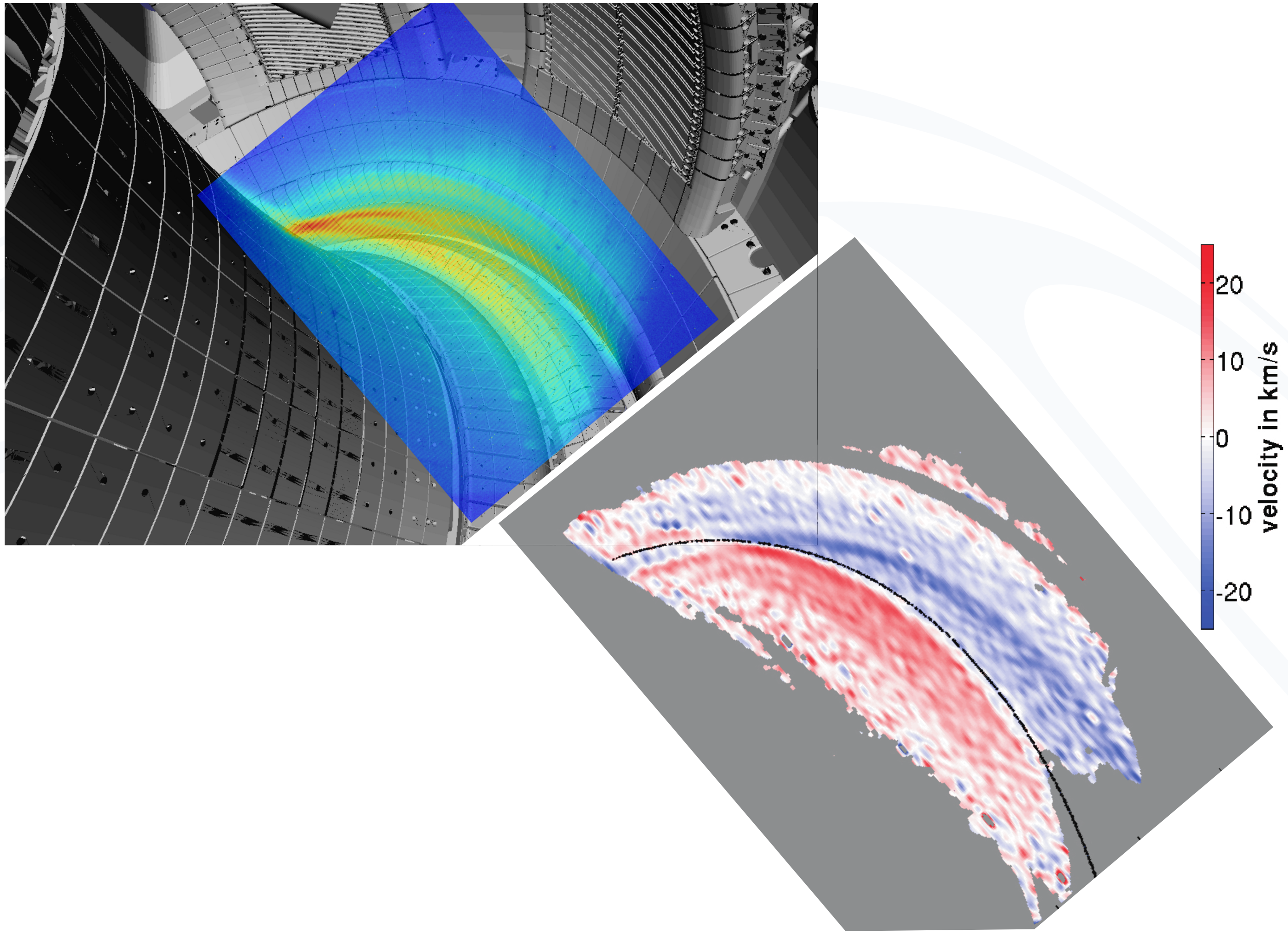

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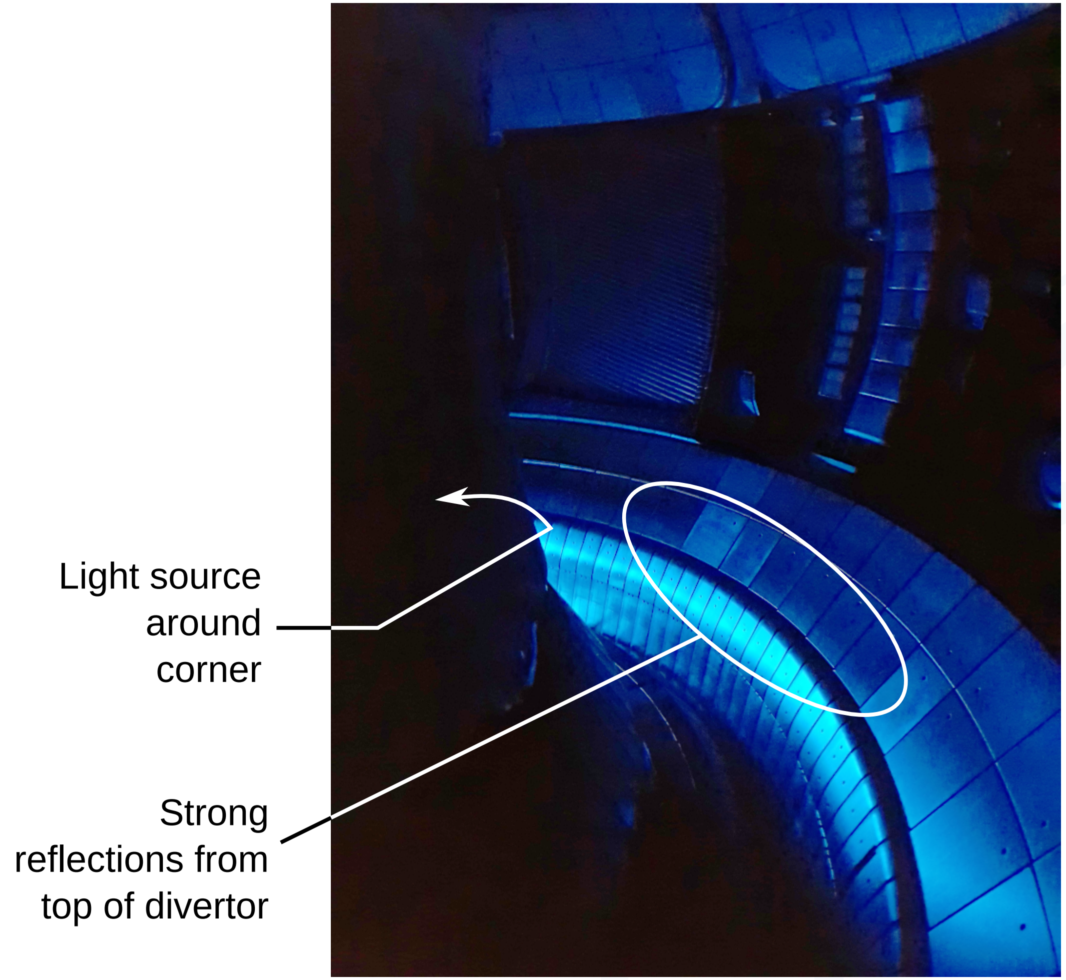

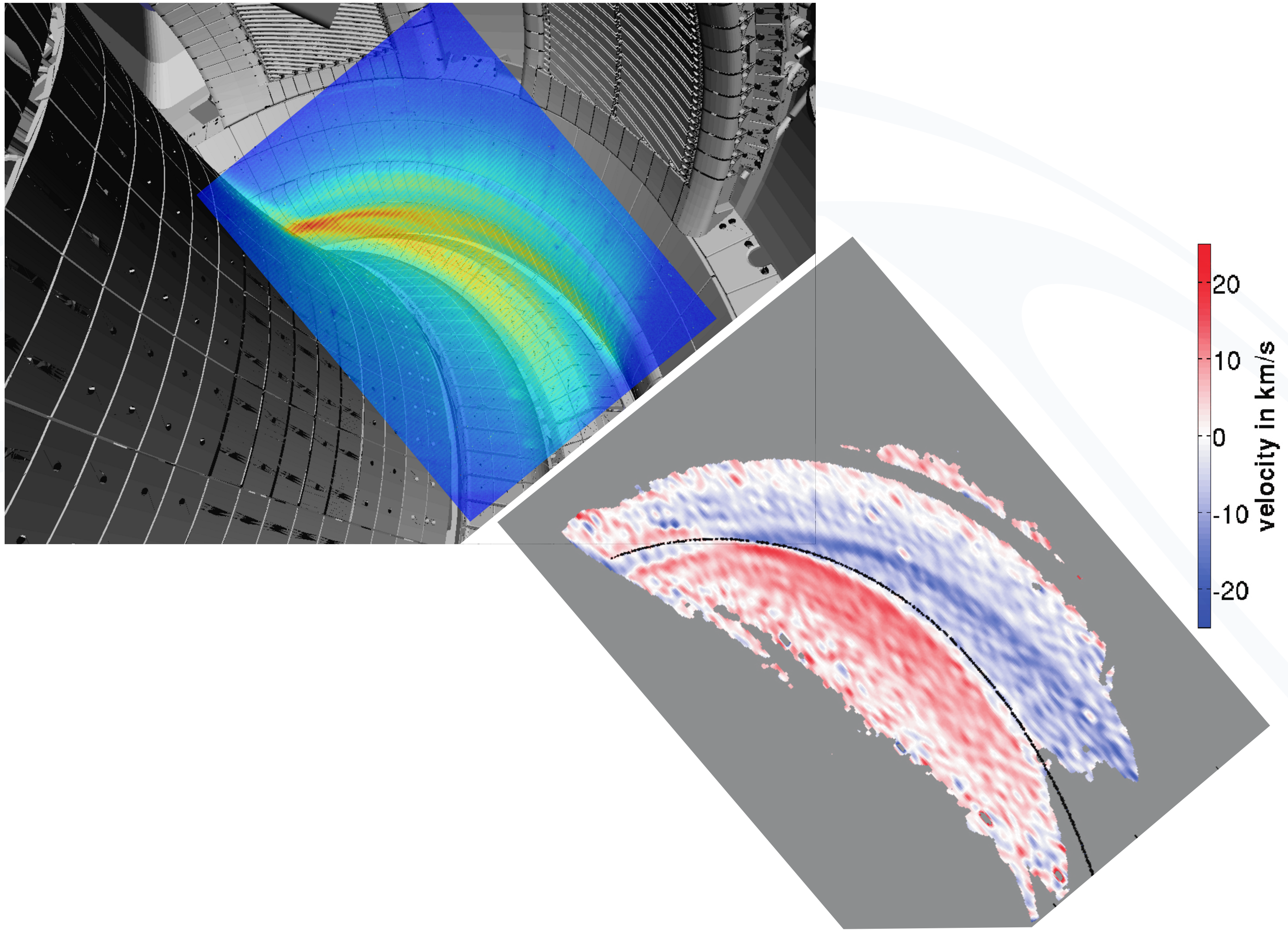

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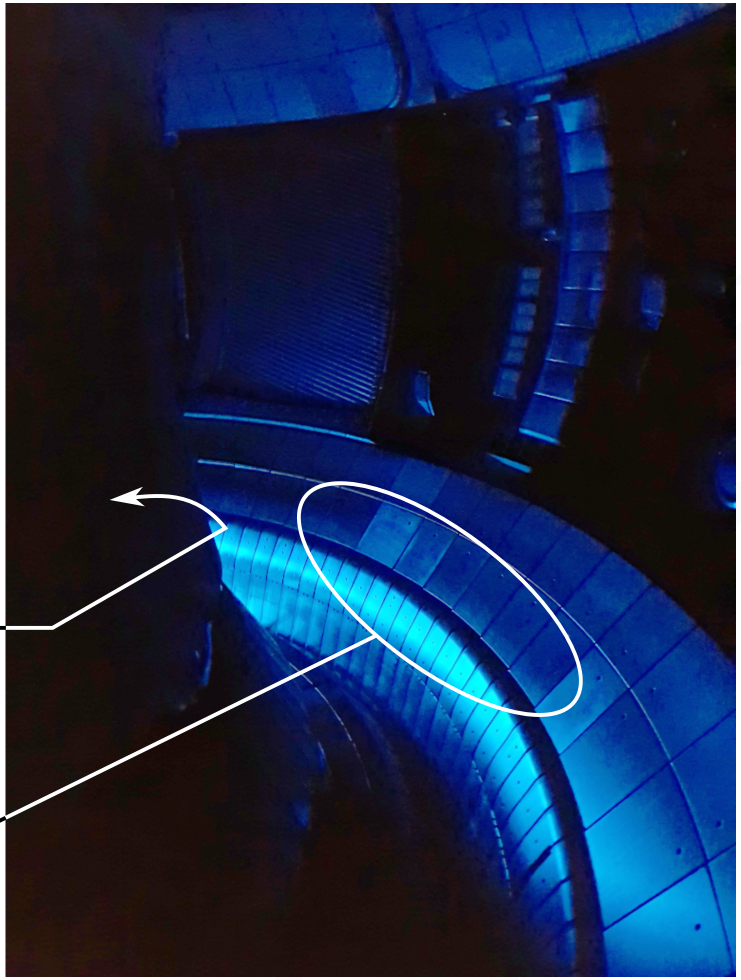
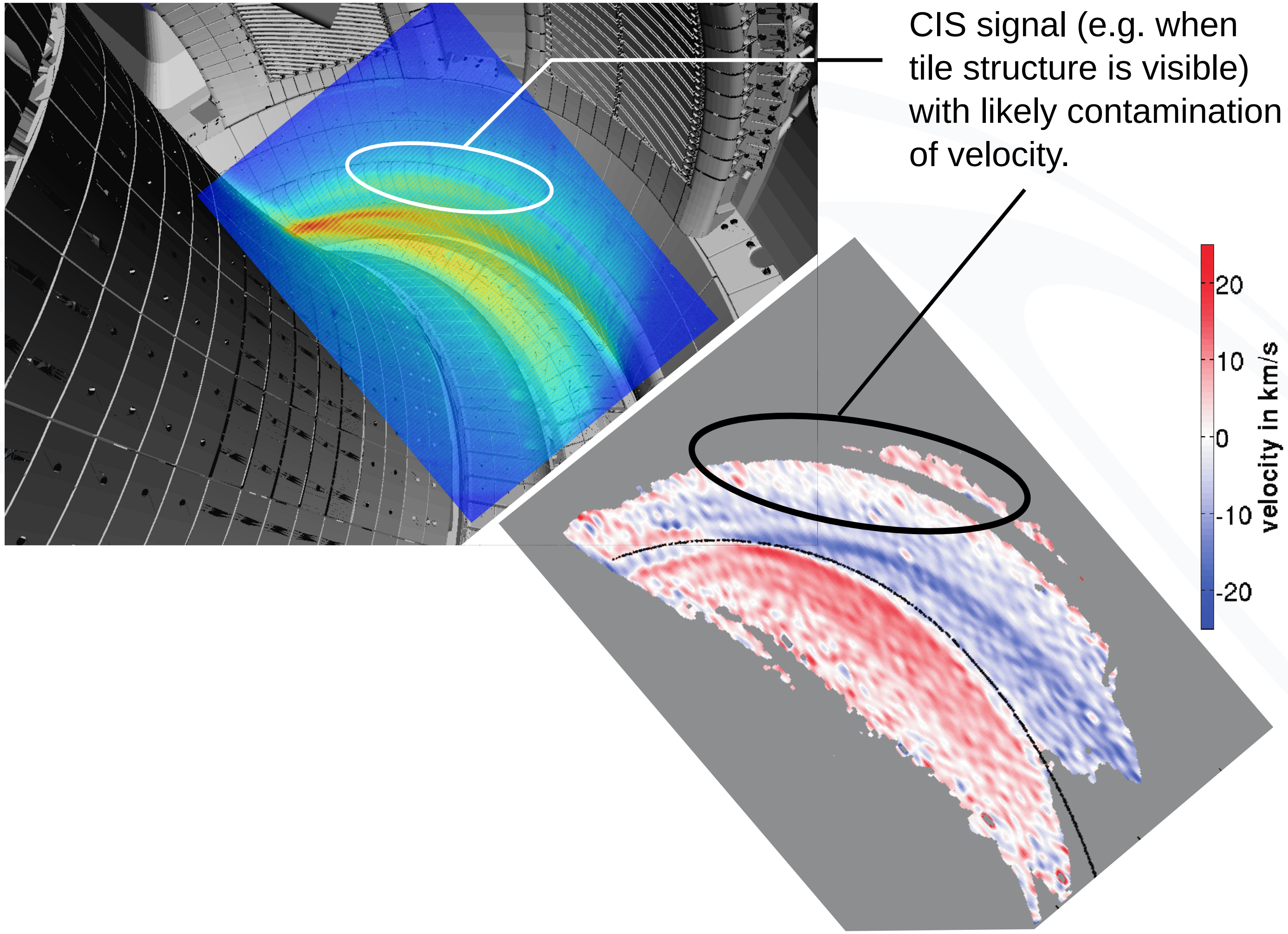
Light source around corner

Strong reflections from top of divertor



Reflections seen in raw CIS signal (e.g. when tile structure is visible) with likely contamination of velocity.



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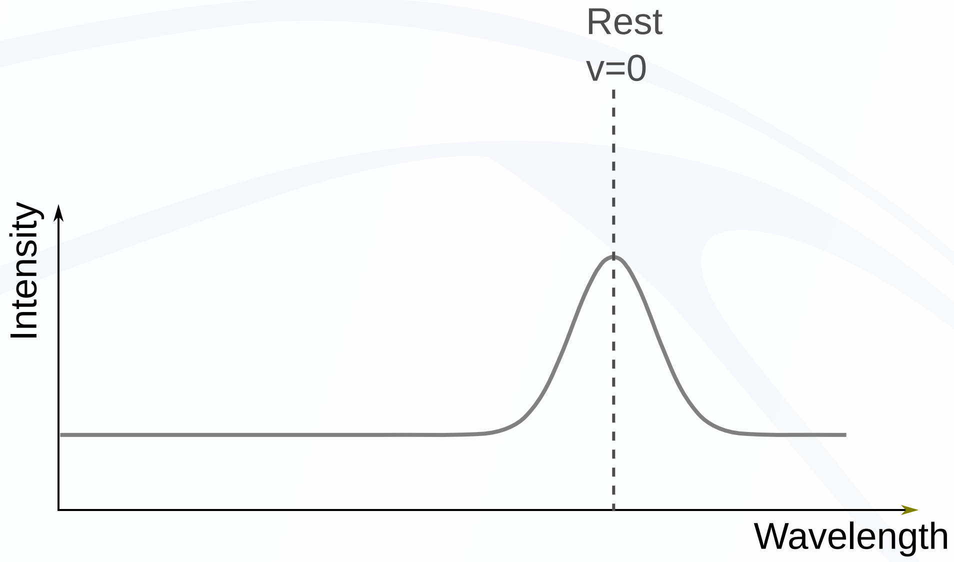

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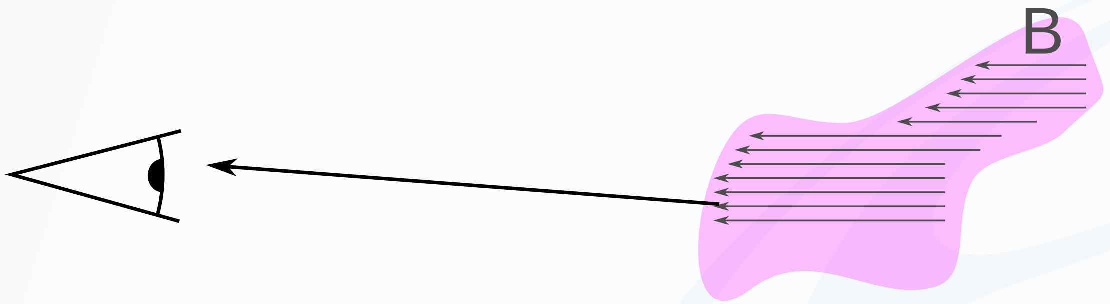

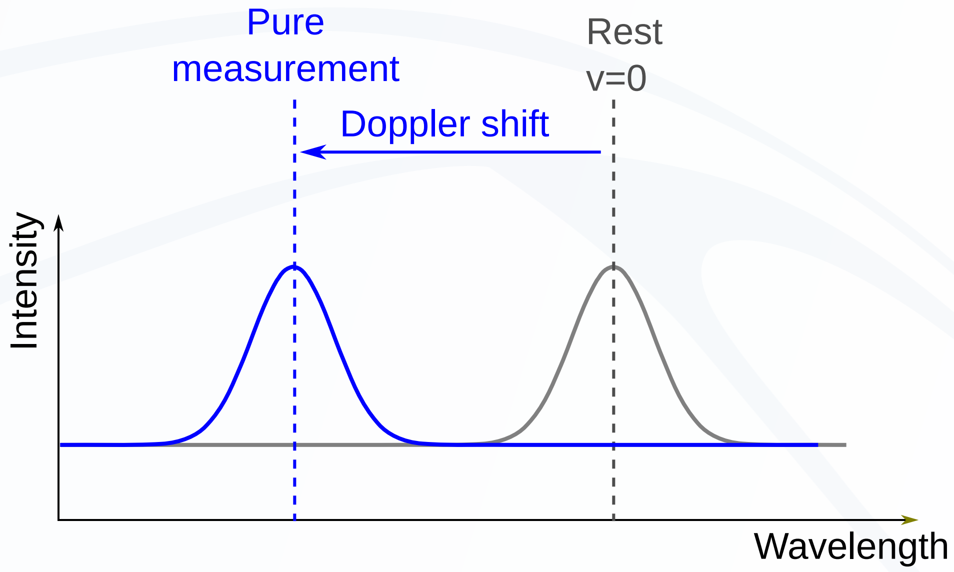

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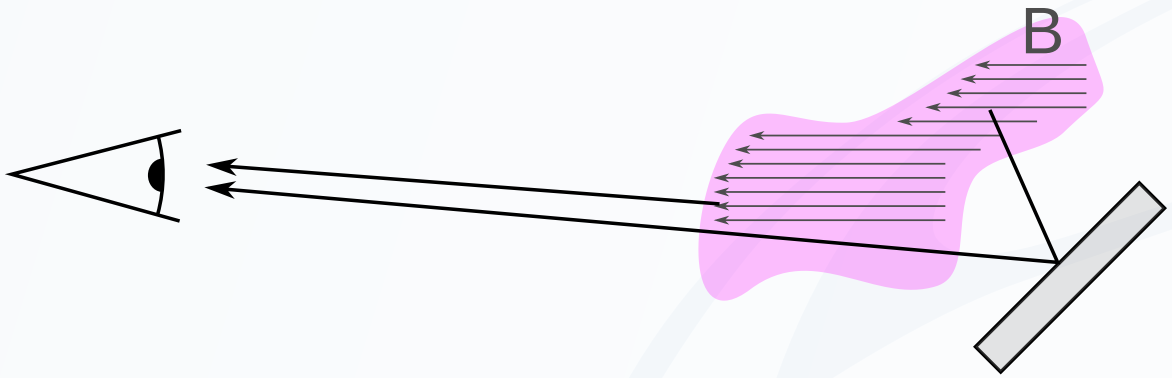
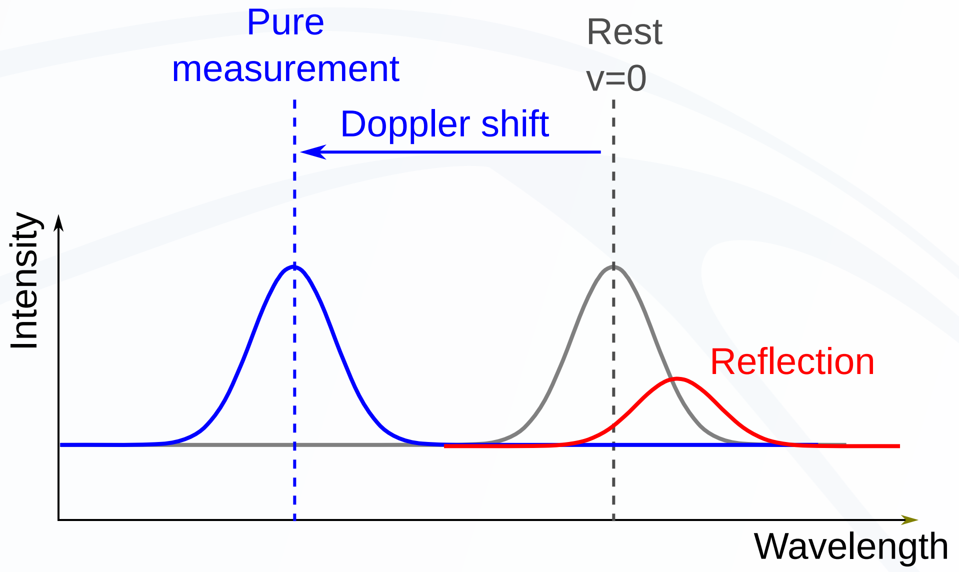
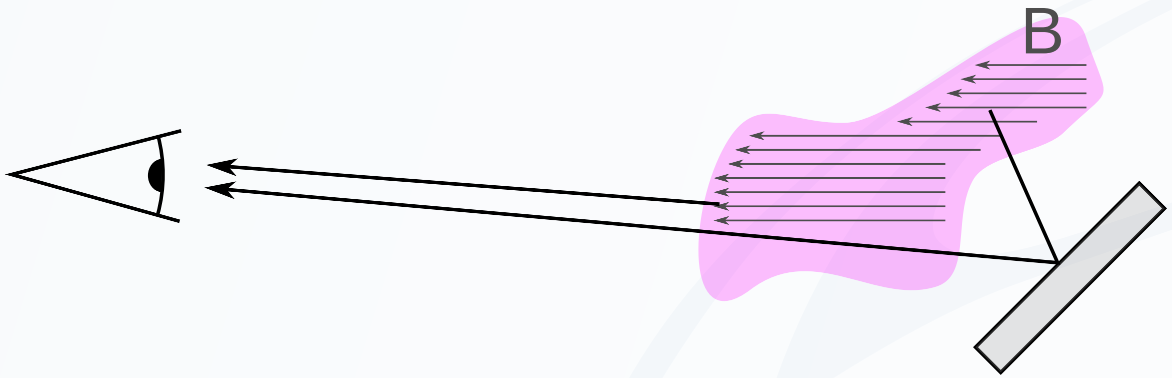


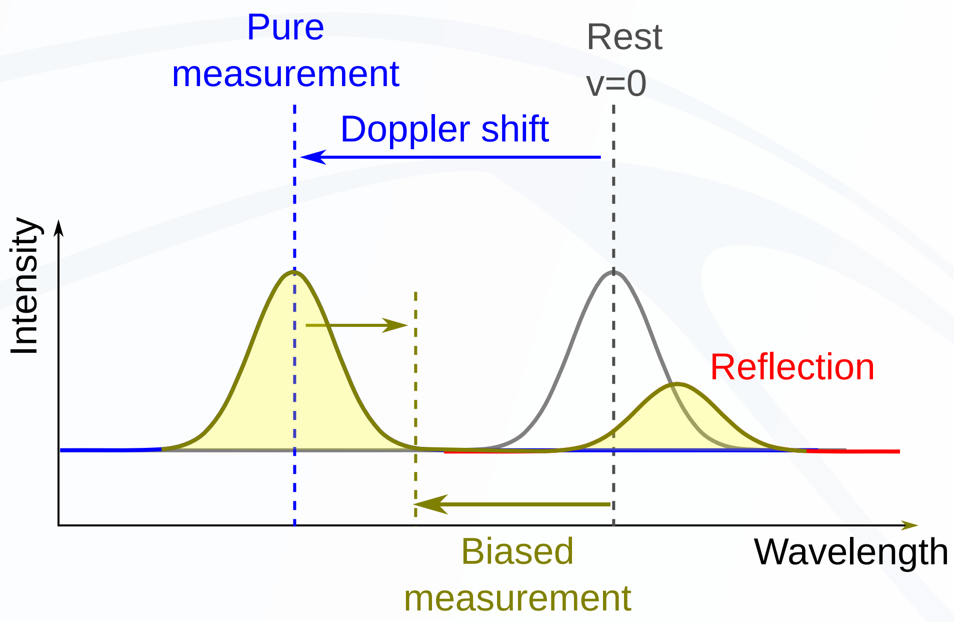


Reflections in CIS

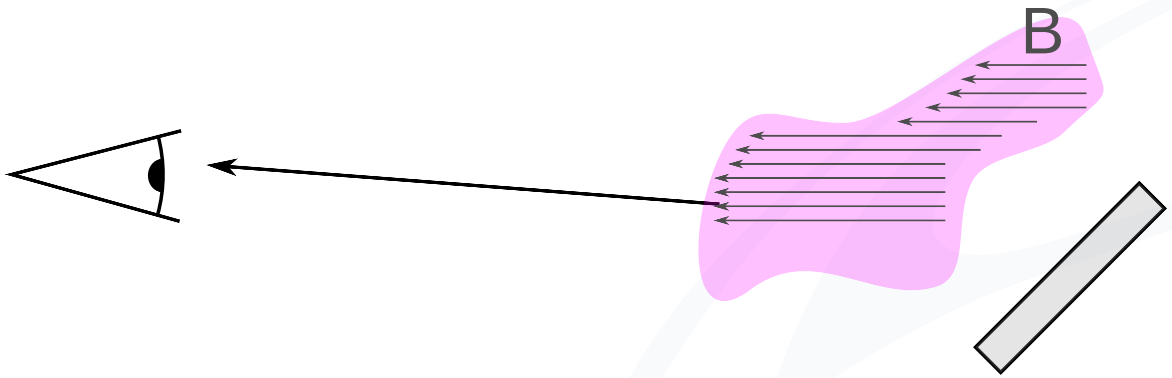
- CIS measures velocity from average Doppler shift of captured light.
- Reflection has wrong Doppler shift and biases measurement.



(Moderate angle specular reflection)



- Flow monitor proposes to isolate reflections from signal using different polatisation states of Zeeman-split emission:



Reflection discrimination

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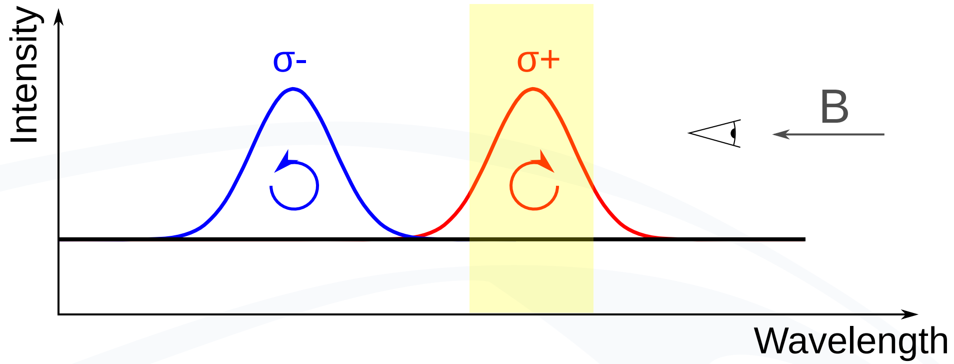
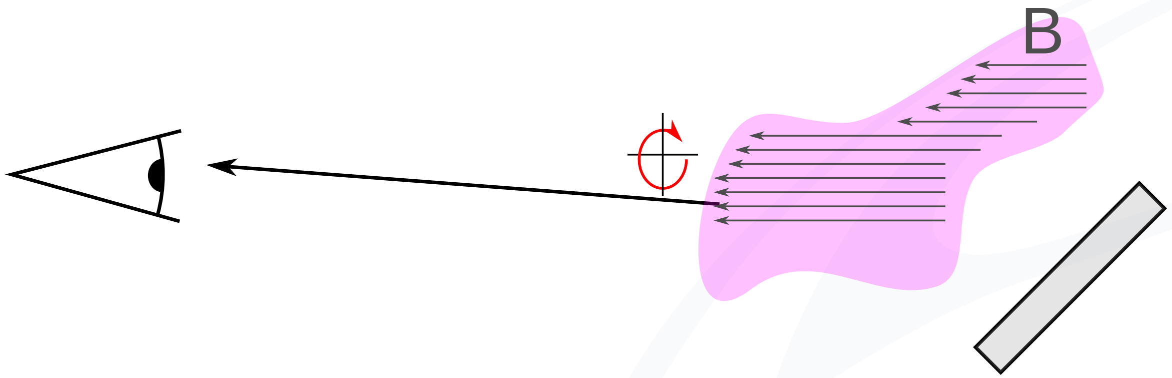
Assume:

- Emission along field mostly circularly polarised σ±





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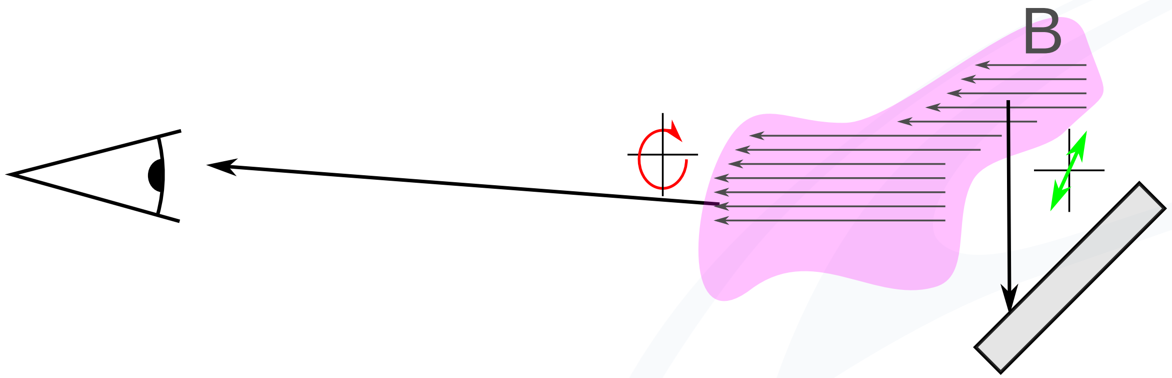

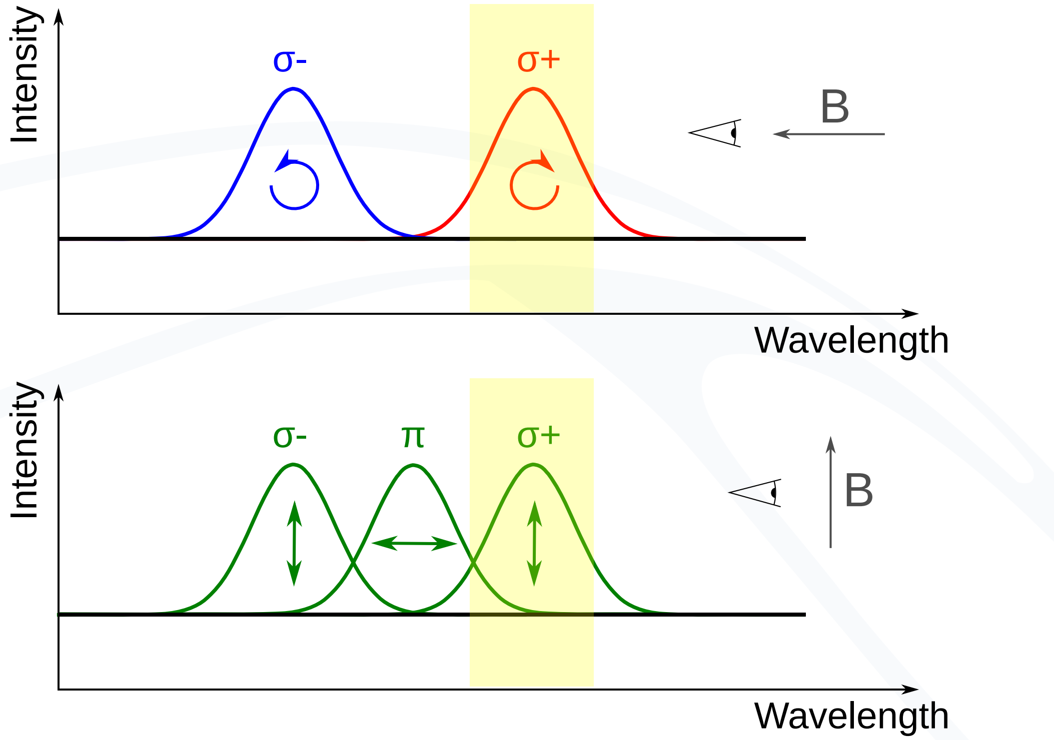

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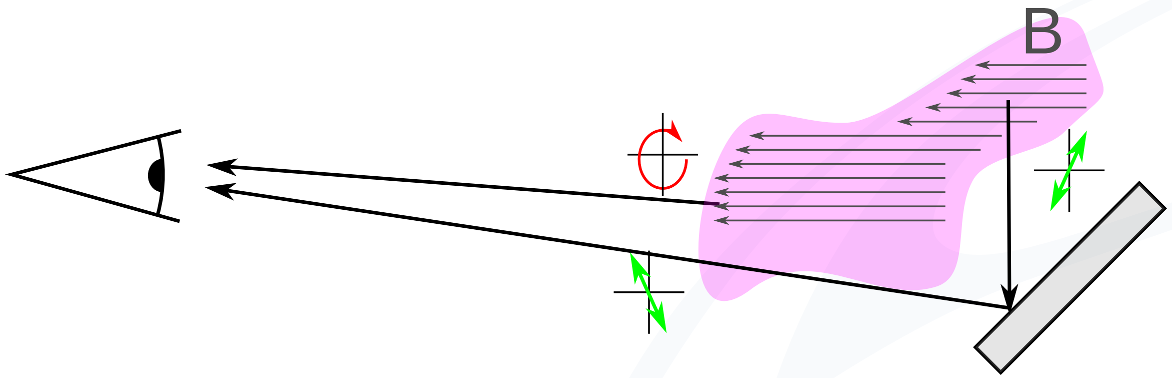

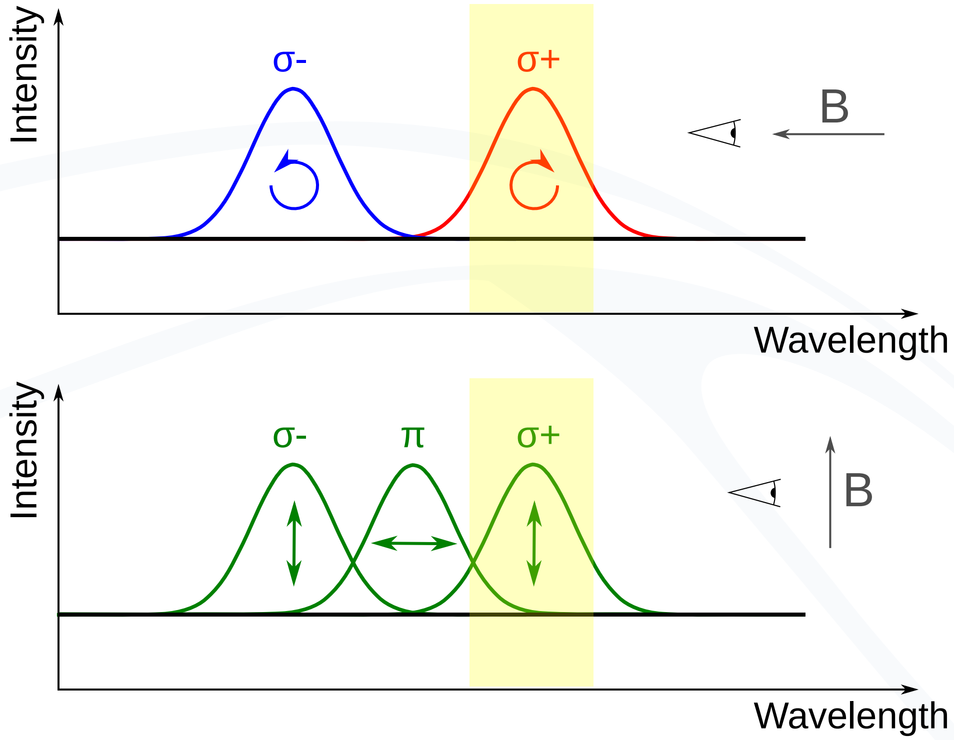

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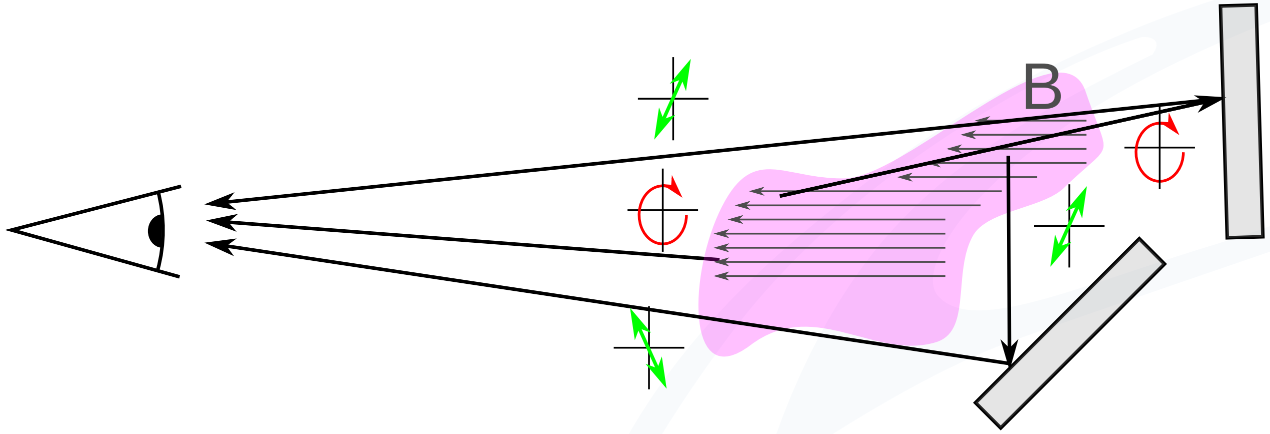

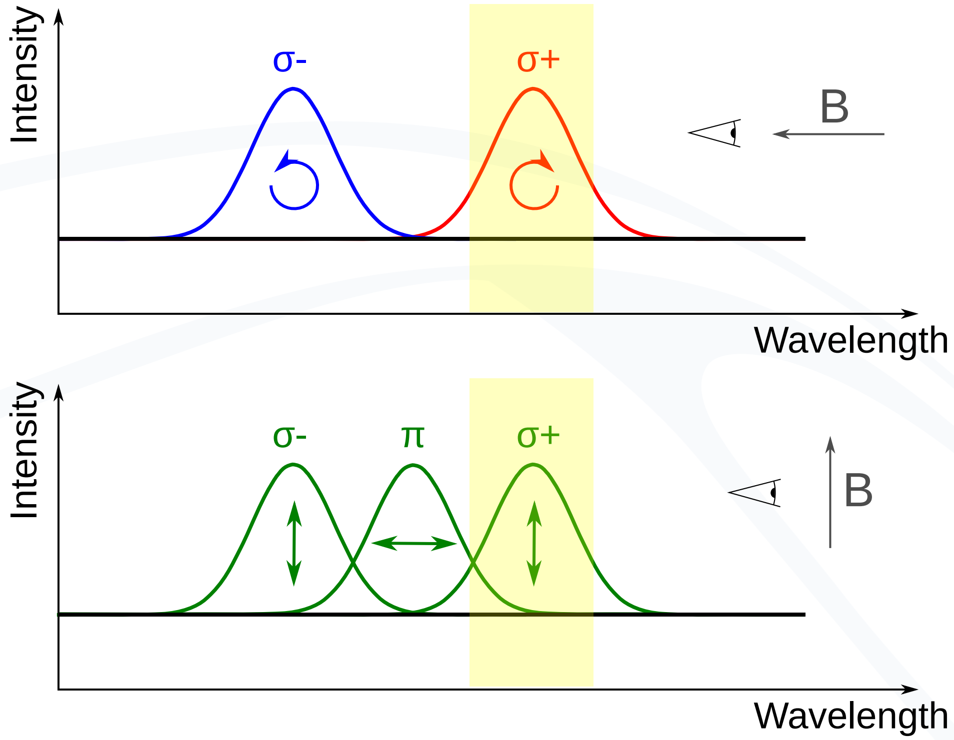

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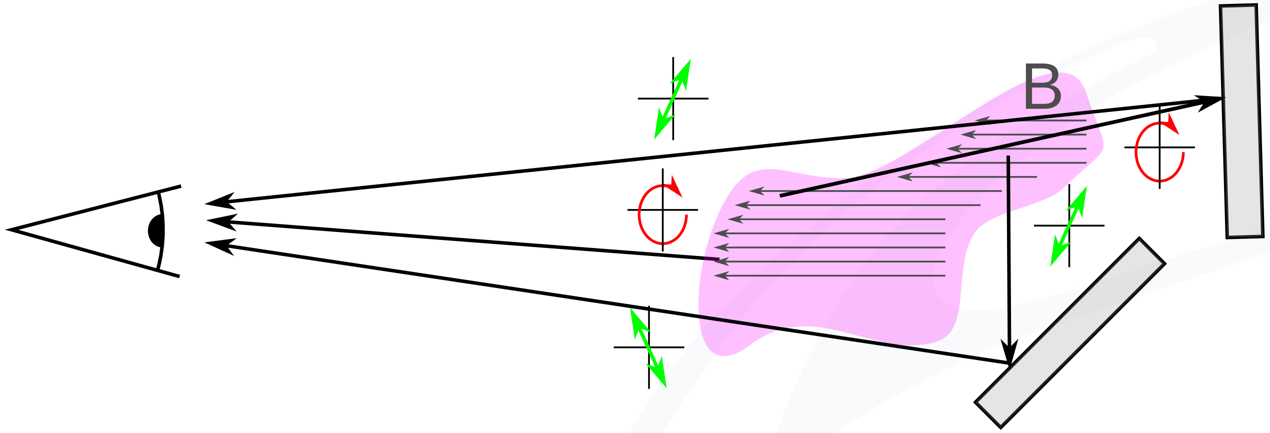

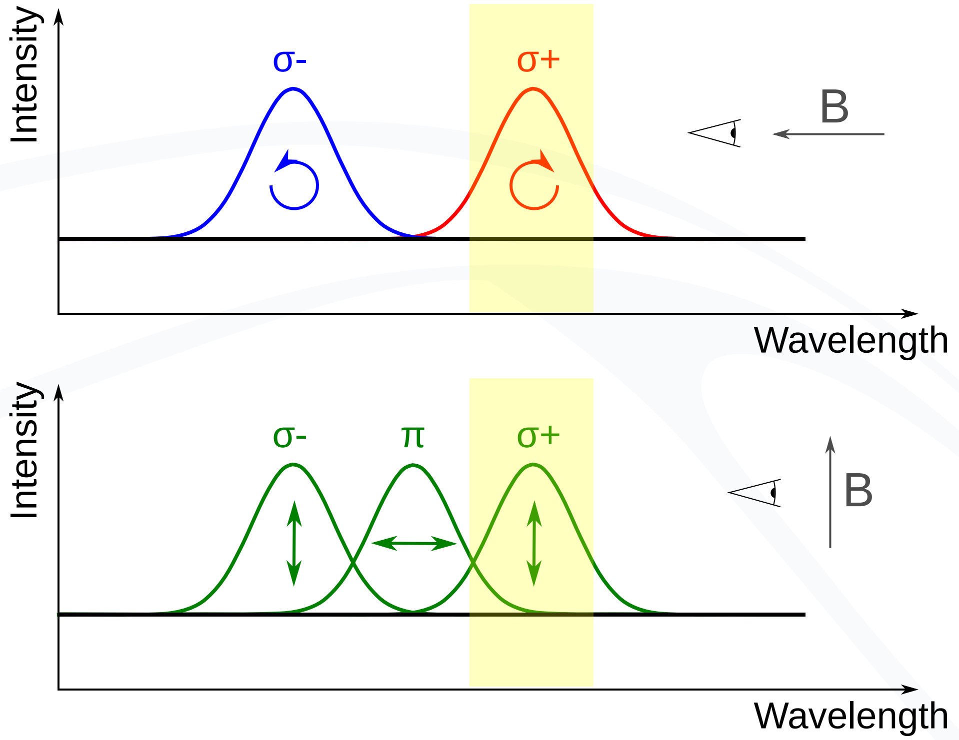

"... because the nett polarized component incident on the wall is dominated by the linearly polarized Stokes components s_1 and s_2 (the emission closest to the wall facet propagates across B), on reflection, it is less likely to interfere with the primarily circularly polarized plasma component s_3 received directly by the camera."

[55.GE Divertor Flow Monitor - The Scientific Basis (YBJ7RW)]

Reflection discrimination - chit 12

Signal is mostly circularly polarised. Reflection is mostly un-/linearly- polarised.
--> Measure polarisation and use it to discriminate and suppress reflections.

- CDR chit #12: **Is this principle valid and applicable for 55.GE view?**

The suppression of reflection is based on the idea that the majority of light reflected by the wall tiles comes from that emitted nearest to it, which necessarily comes perpendicular to the field and is therefore predominantly linearly polarised. This assumes: a) The diffuse reflection is dominant over specular, and b) reflected linear polarisation does not become circularly polarised. This should be shown for at least clean tungsten, but preferably also beryllium coated tungsten if at all possible.

If (a) is not true, specular reflection from lines of sight hitting tiles almost tangentially will contain a strong S3 component from the reflected continuation of that line of sight. If (b) is not true, the diffuse reflection of nearby plasma may be strongly circularly polarised due to phase shifts between the S and P reflected components.

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To resolve:

1: Measure effect on polarisation of relfections from ITER wall materials --> IPP
2: Develop model of realistic reflections in ITER and polarisation mixing --> Luffy.AI
3: Assess probable success of suppression --> IPP

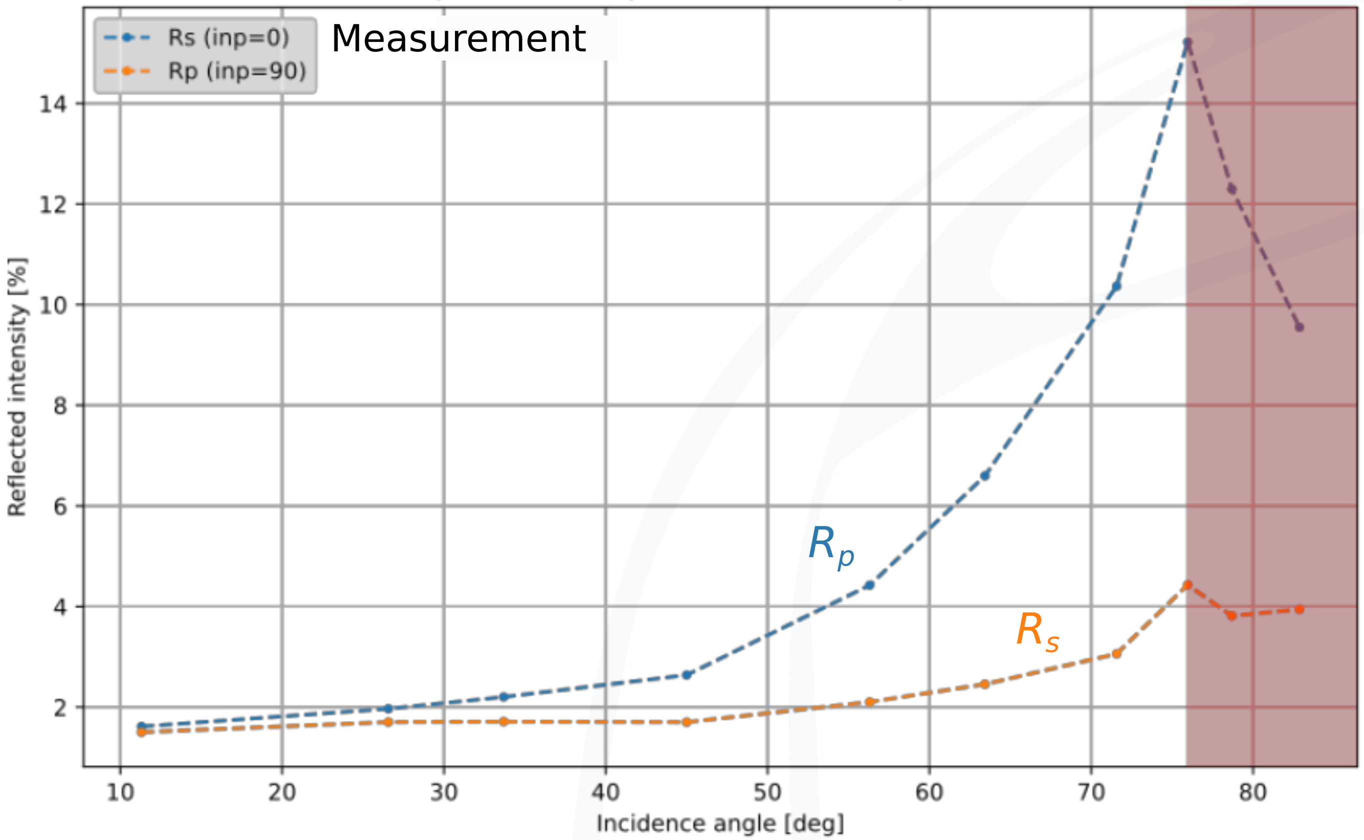
Reflection measurements

Full polarised reflection of several materieals measured at IPP:

Glass, aluminium --> validate Ray-sect polarisation model.

- ASDEX Upgrade Tungsten wall tiles --> Realistic material with diffuse reflection.

Specular reflection:



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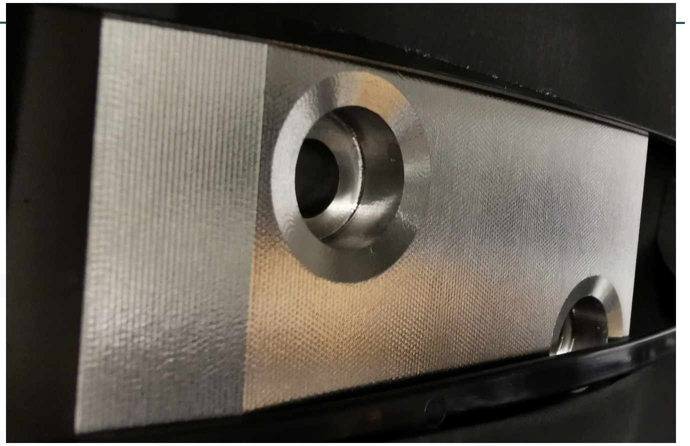

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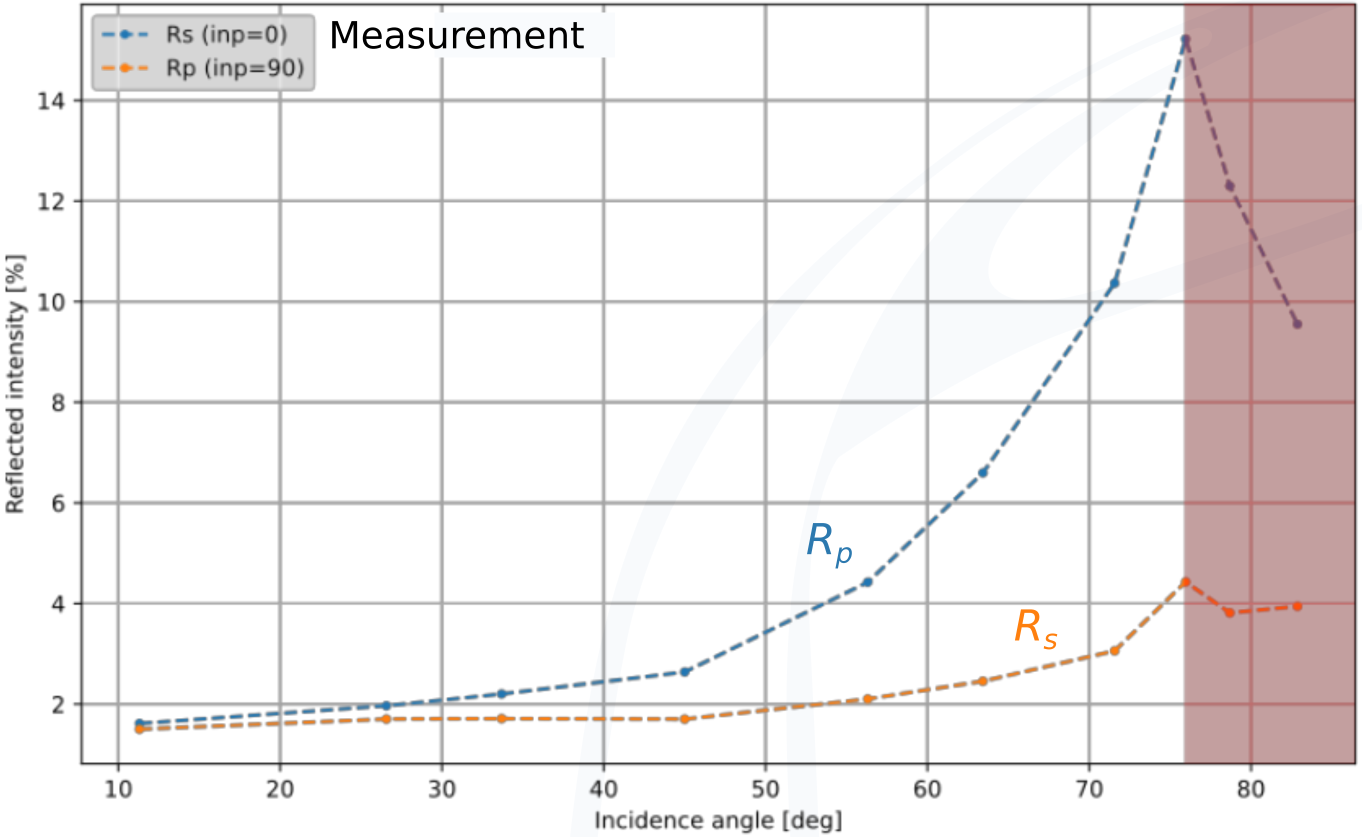

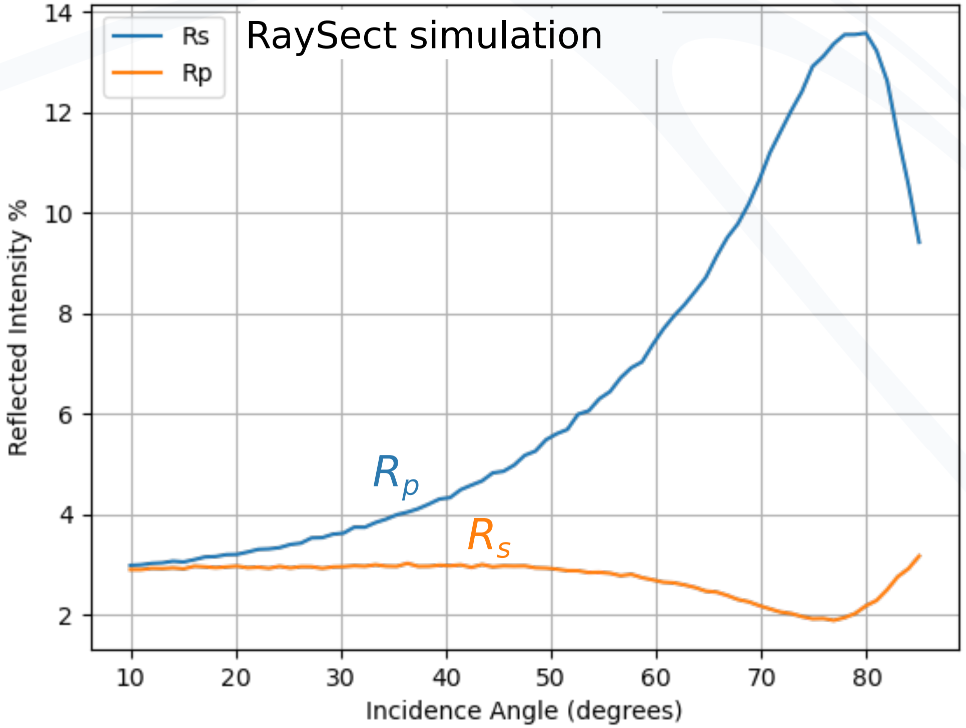

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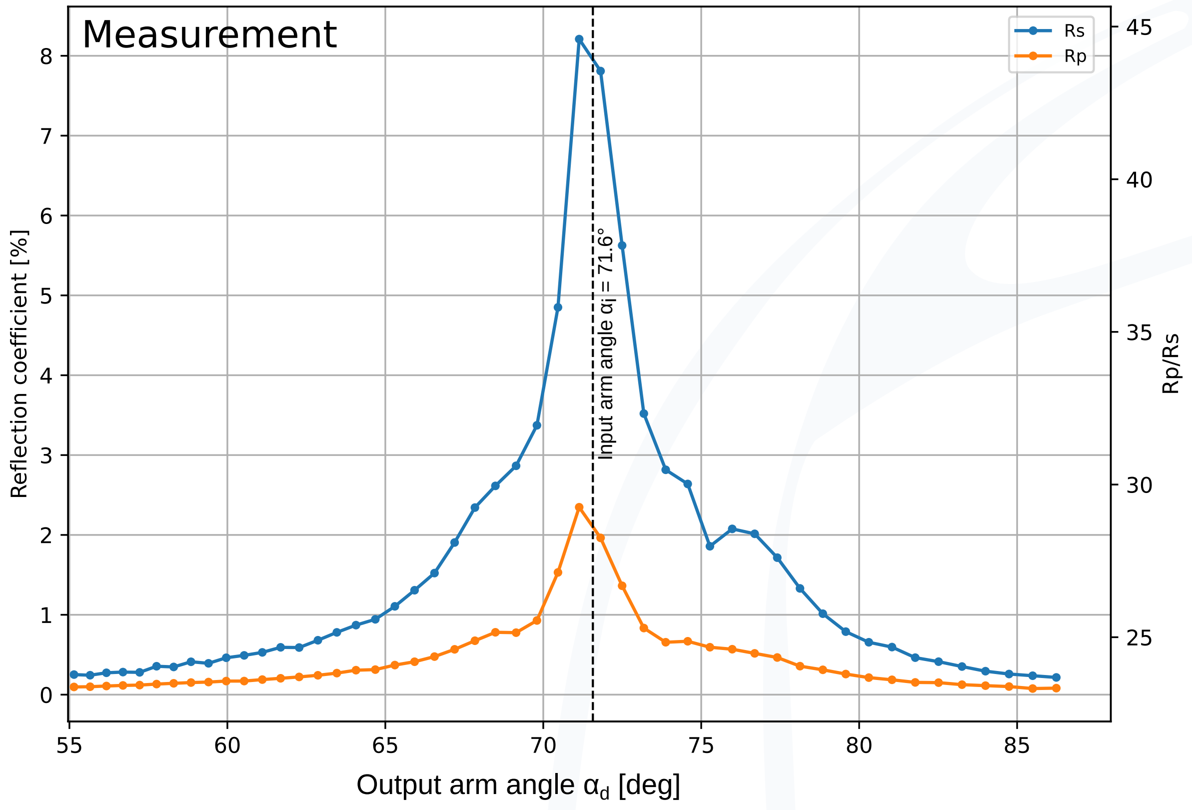

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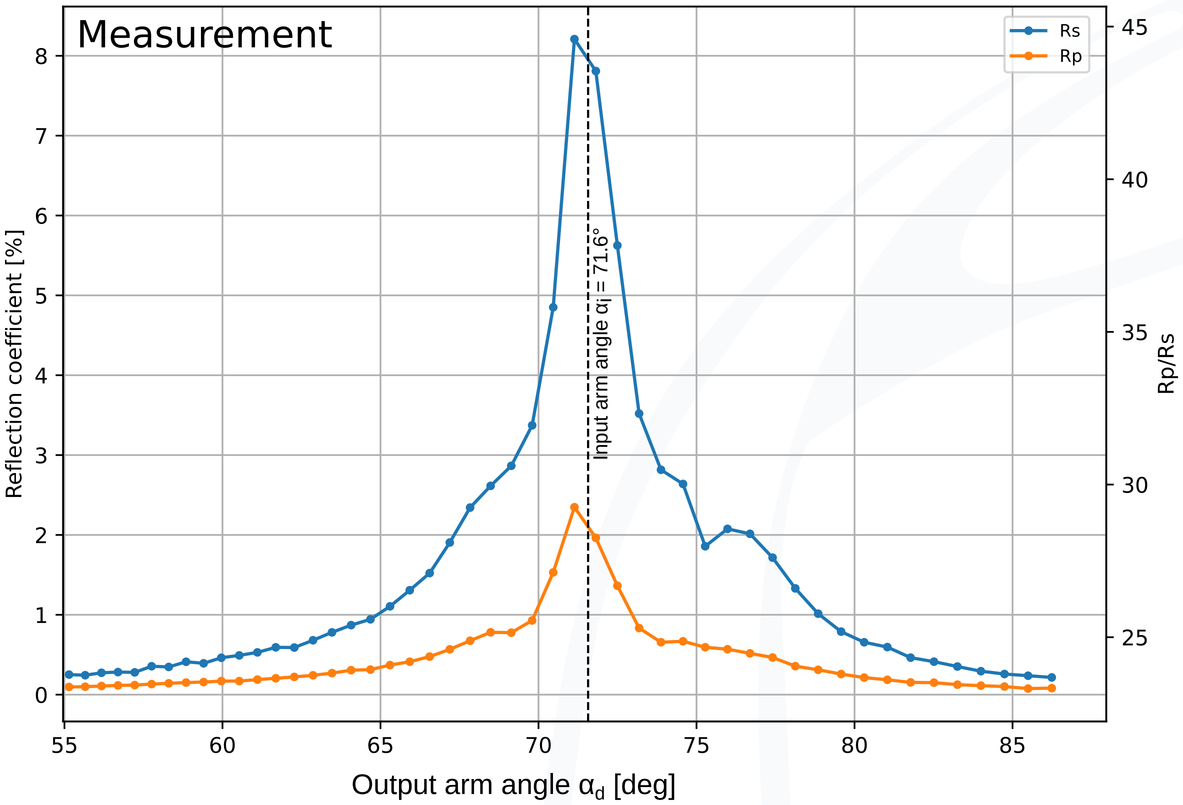

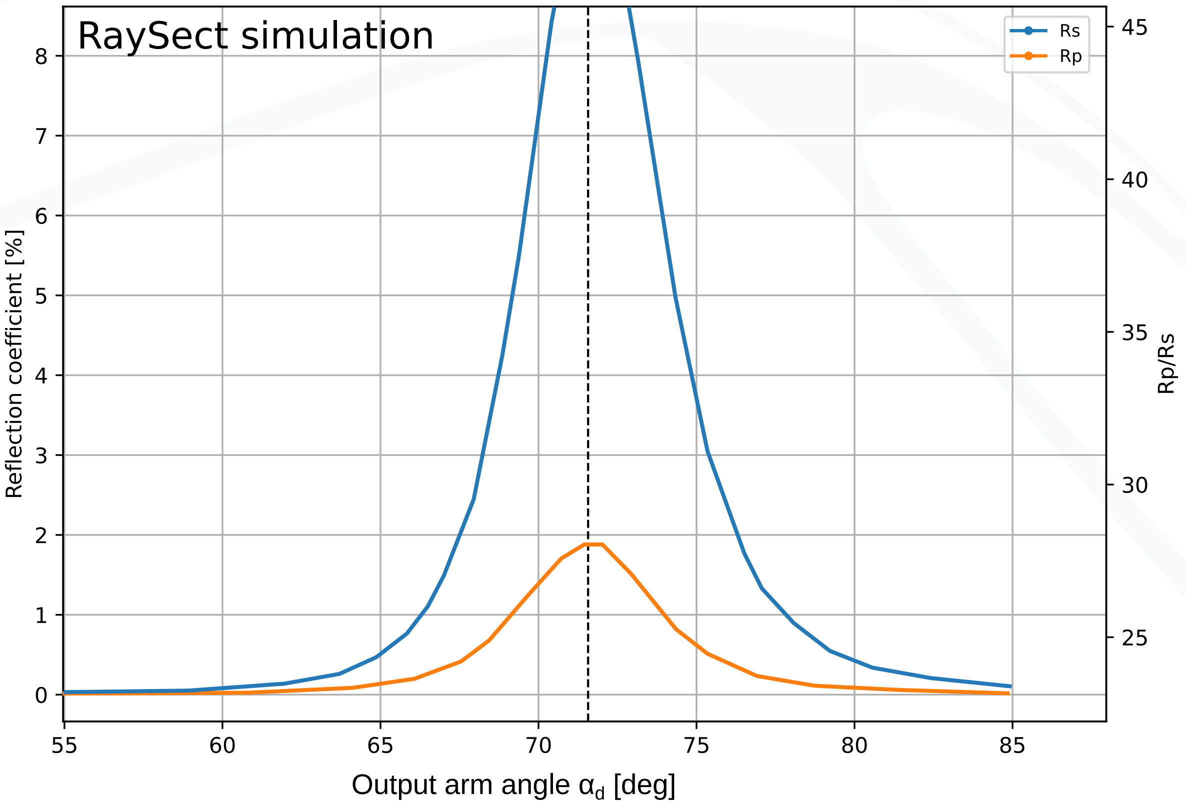

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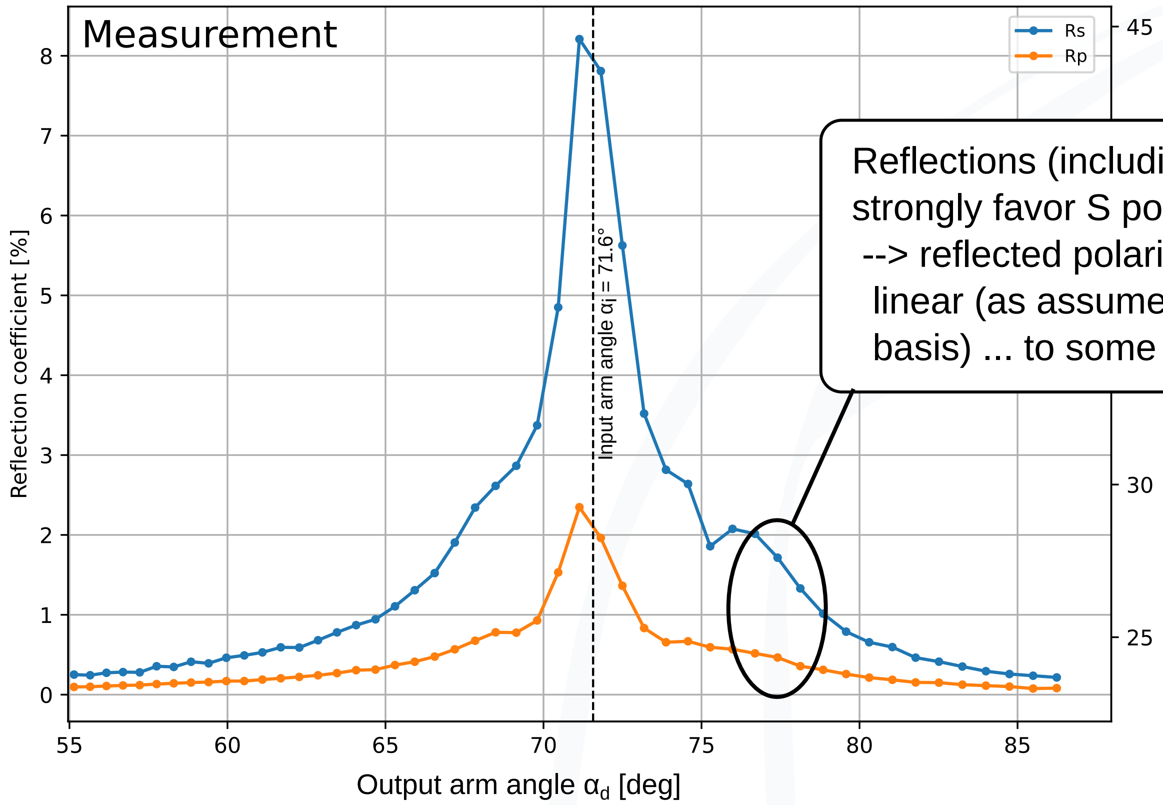

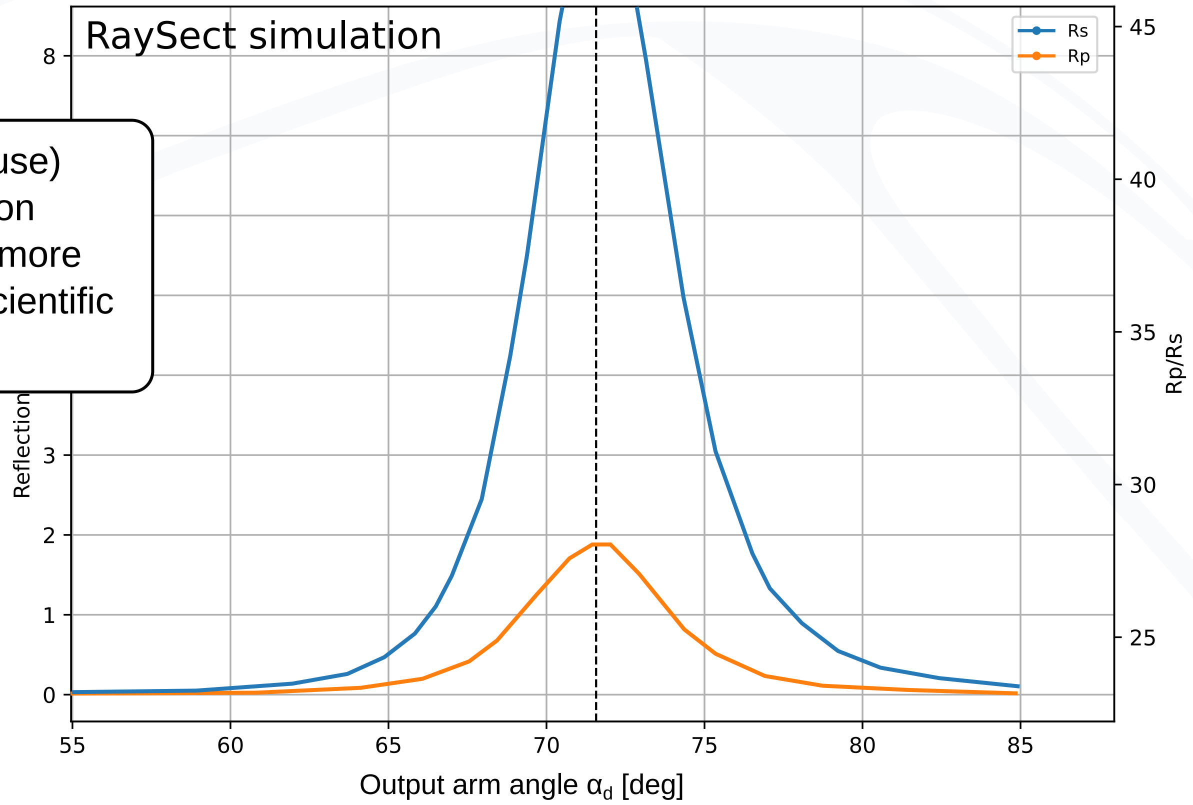

Reflections (including diffuse) strongly favor S polarisation
 --> reflected polarisation more
  linear (as assumed by scientific
  basis) ... to some extent.

Ray-traced model

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  - Signal strong where lines of sight parallel to separatrix,
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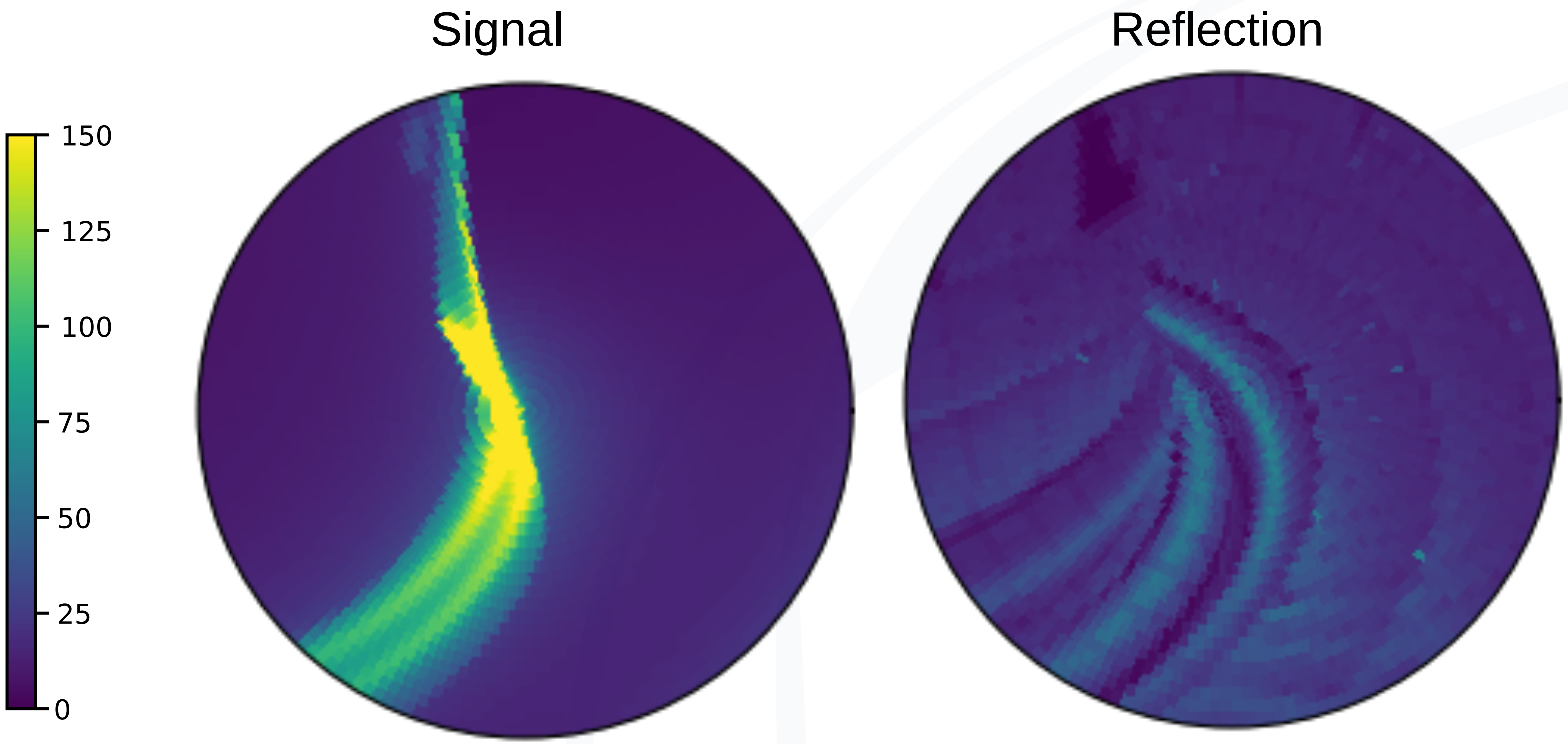

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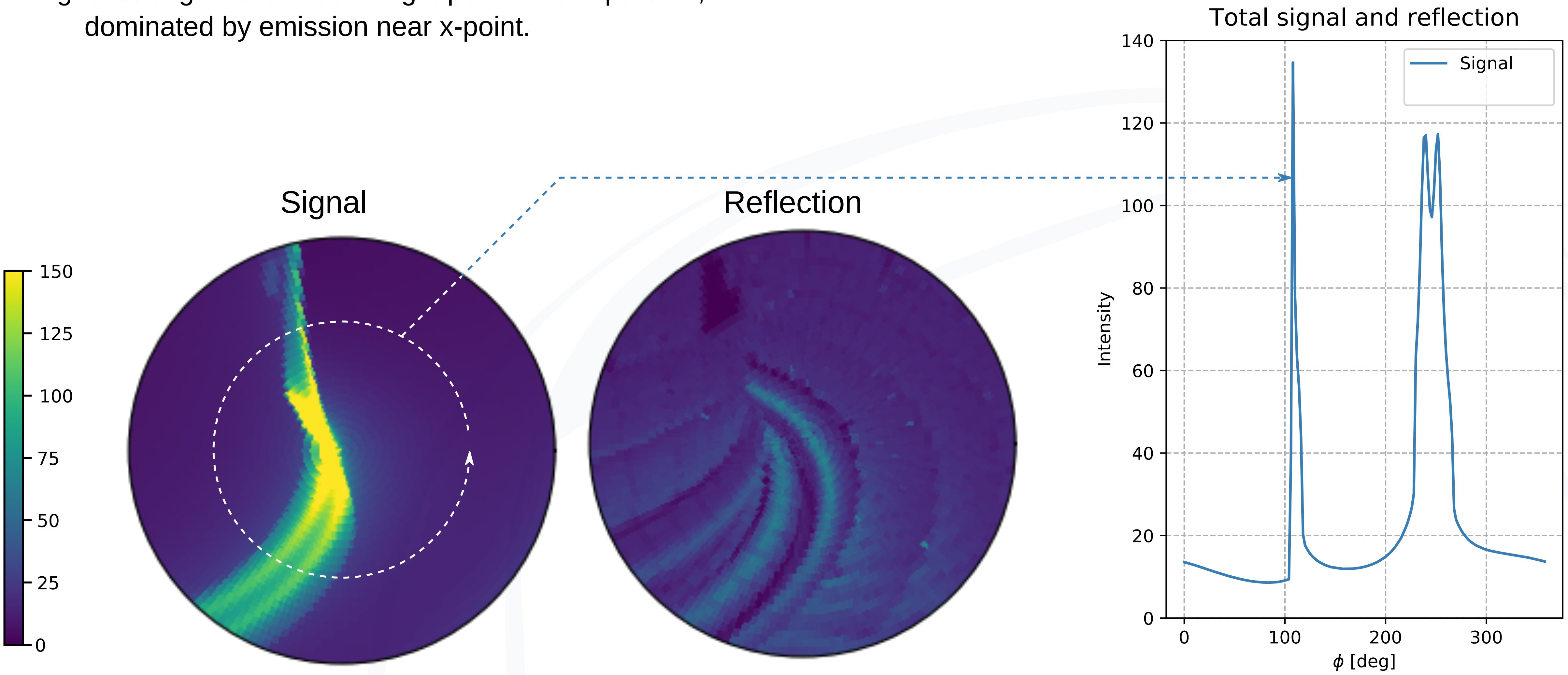

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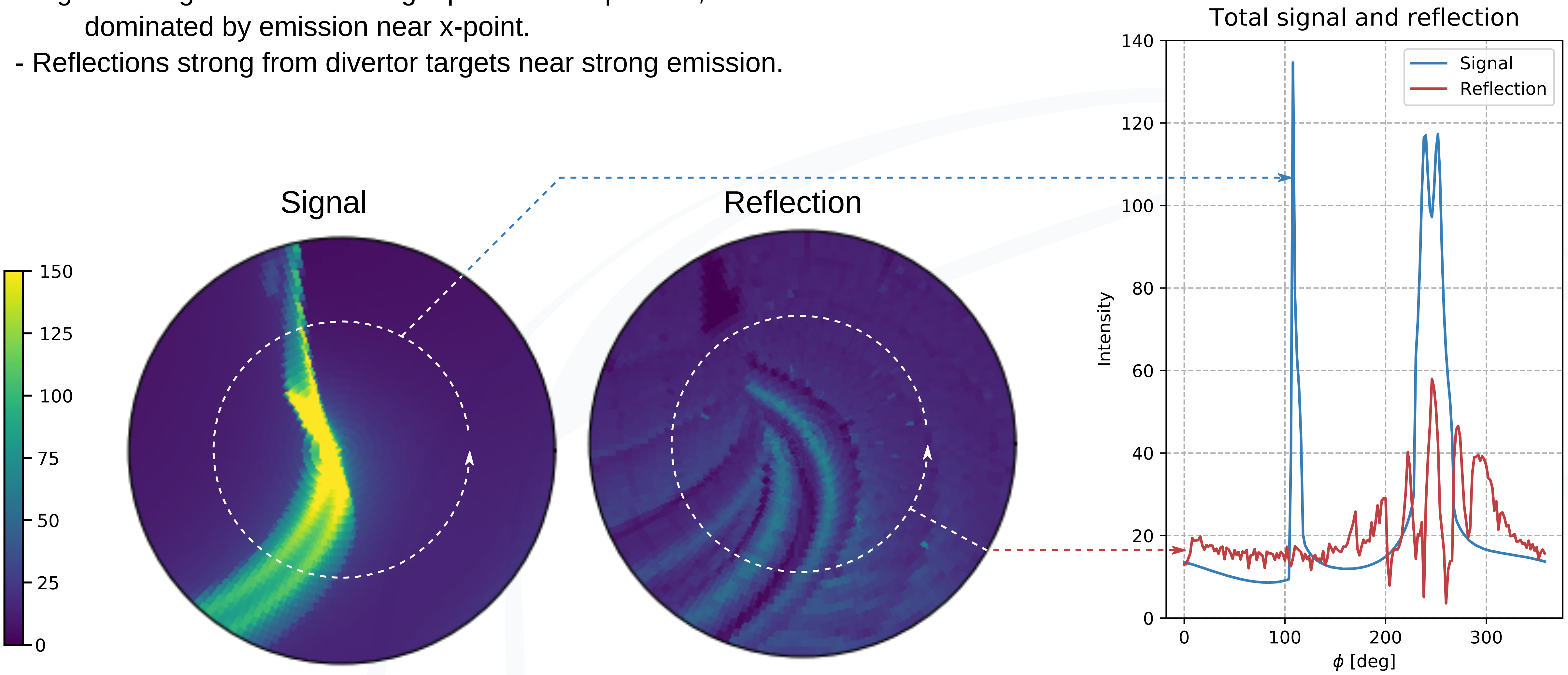

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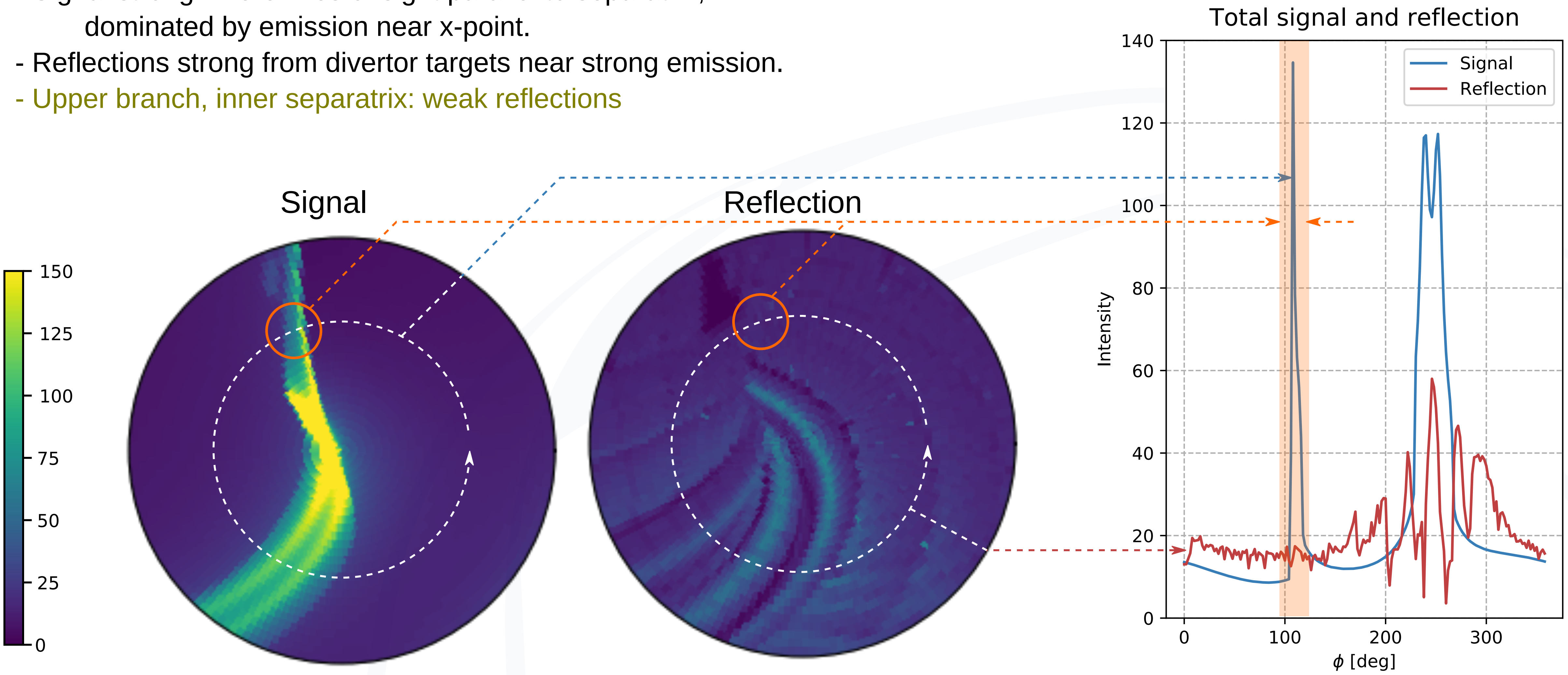

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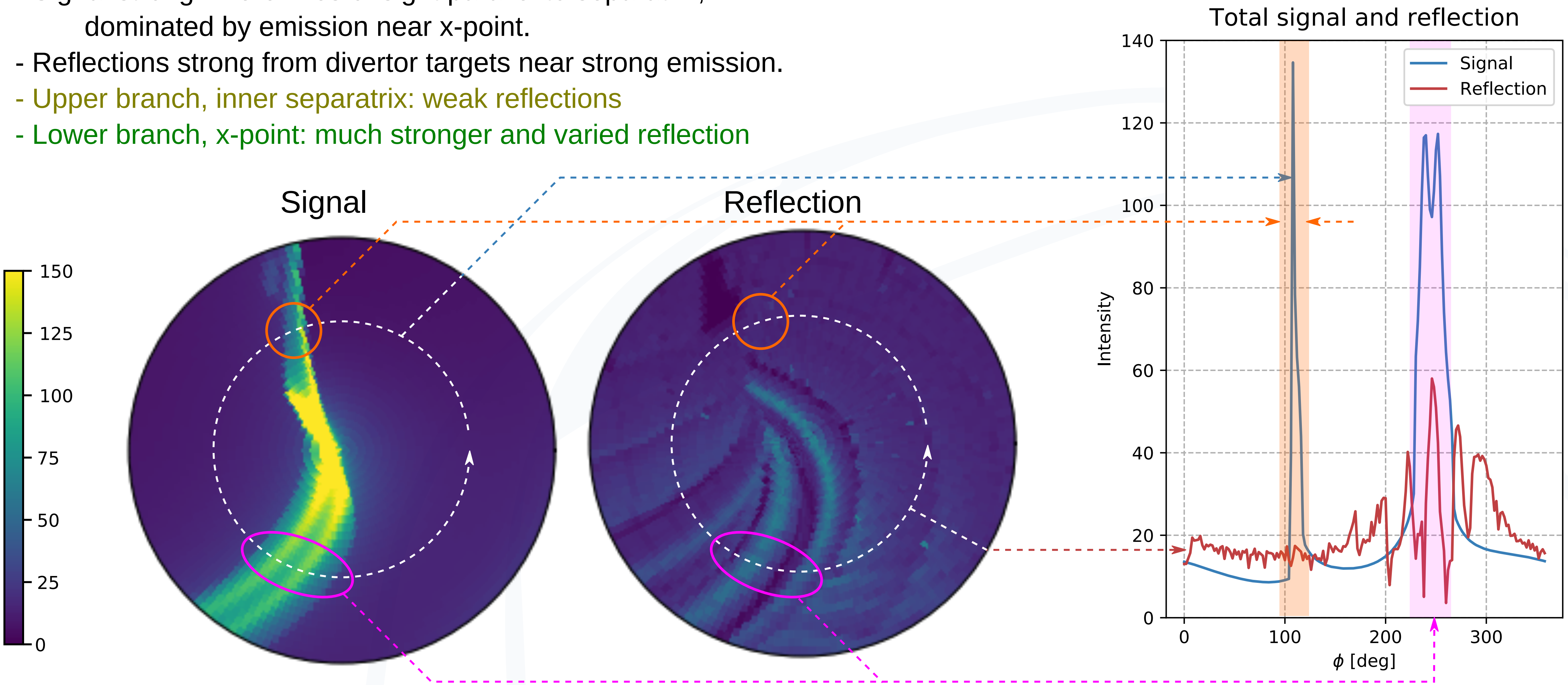
  - Upper branch, inner separatrix: weak reflections
  - Lower branch, x-point: much stronger and varied reflection



Emission model

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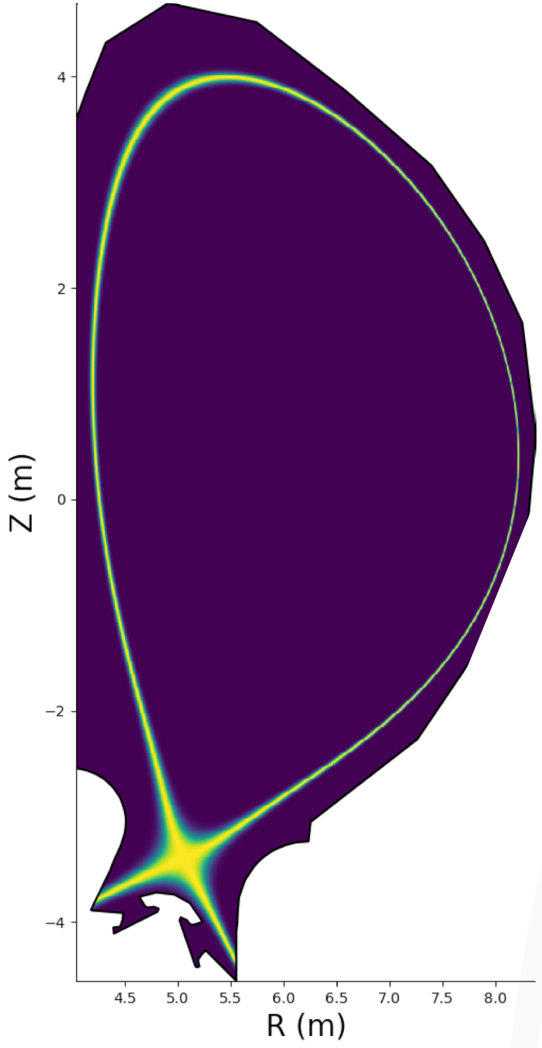
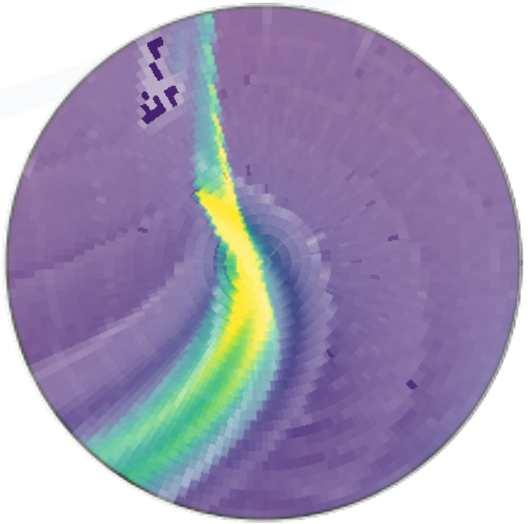
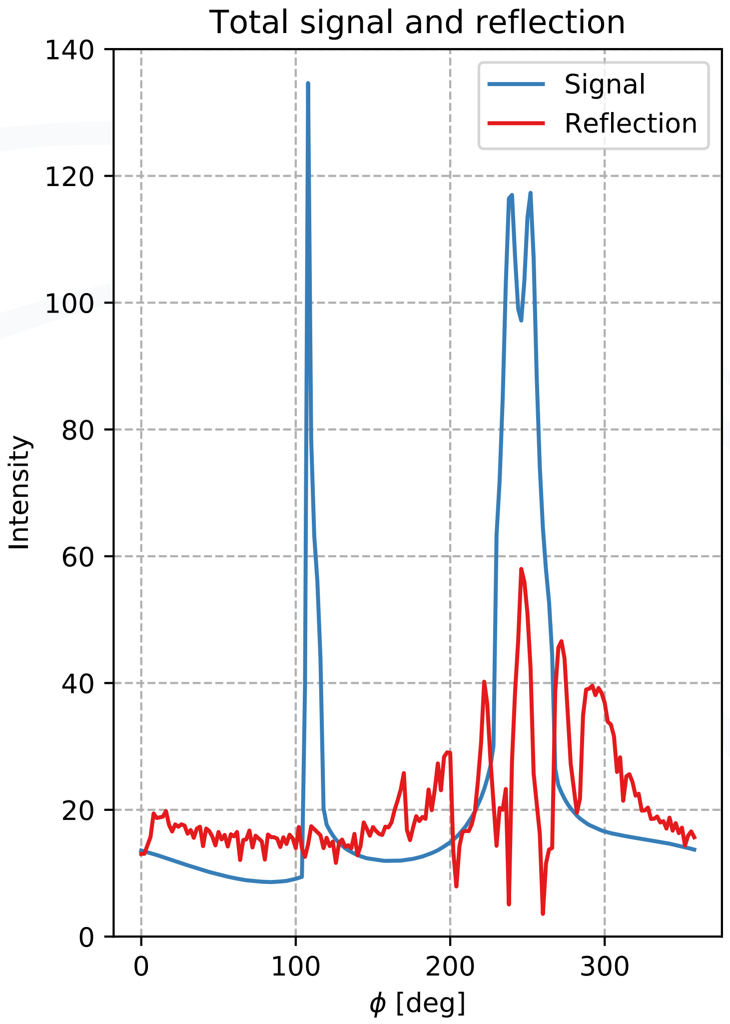


Most impurities viewed with CIS have low ionisation state and emit further down-stream (nearer target)





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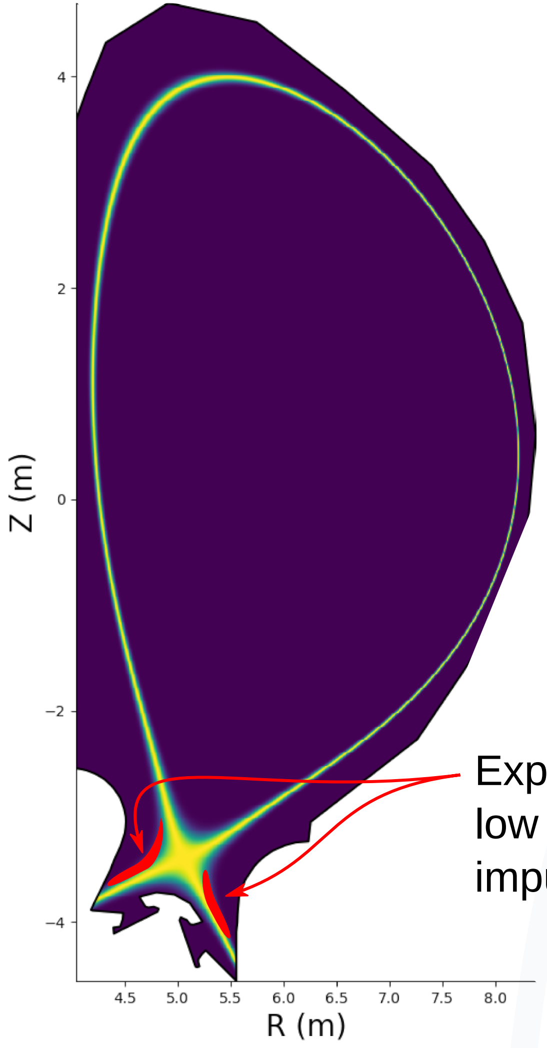

Expectation for low ionisation impurities

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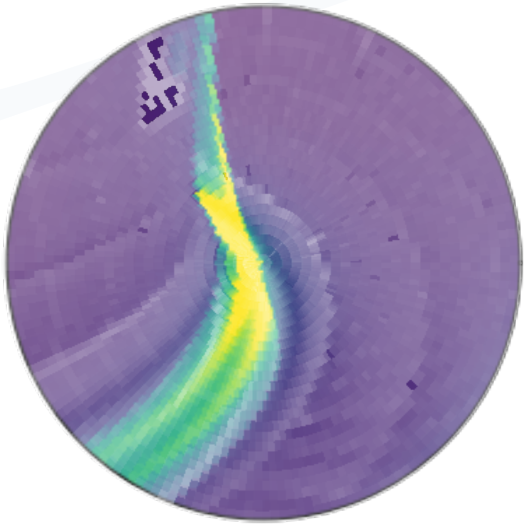

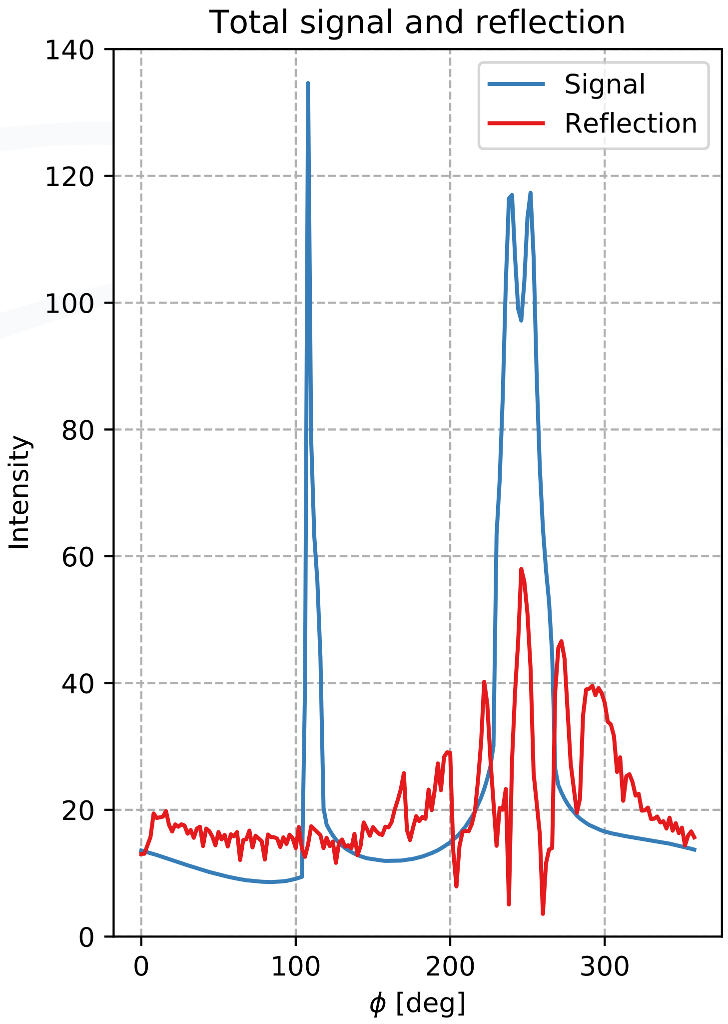

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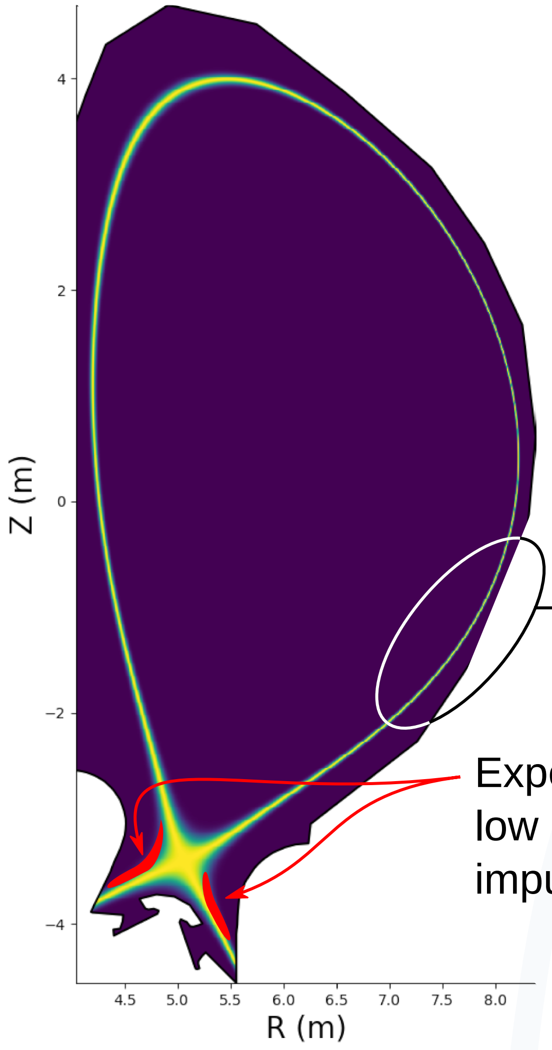

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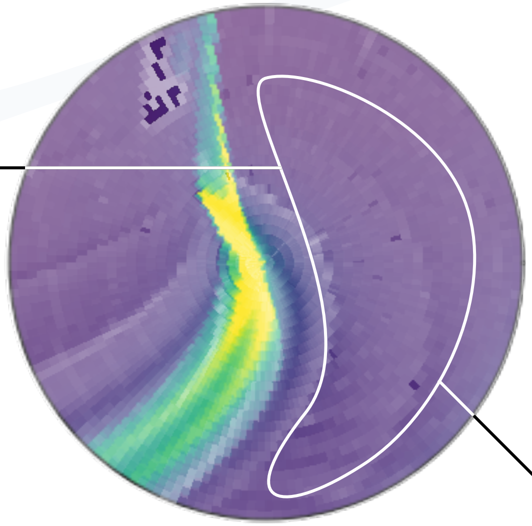

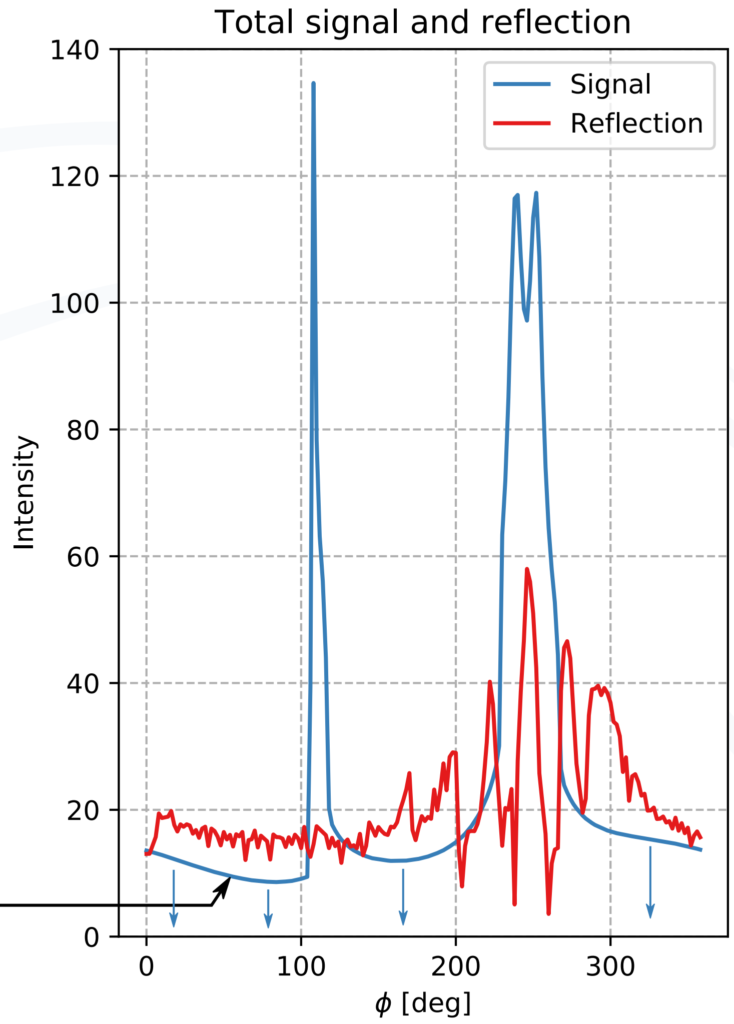

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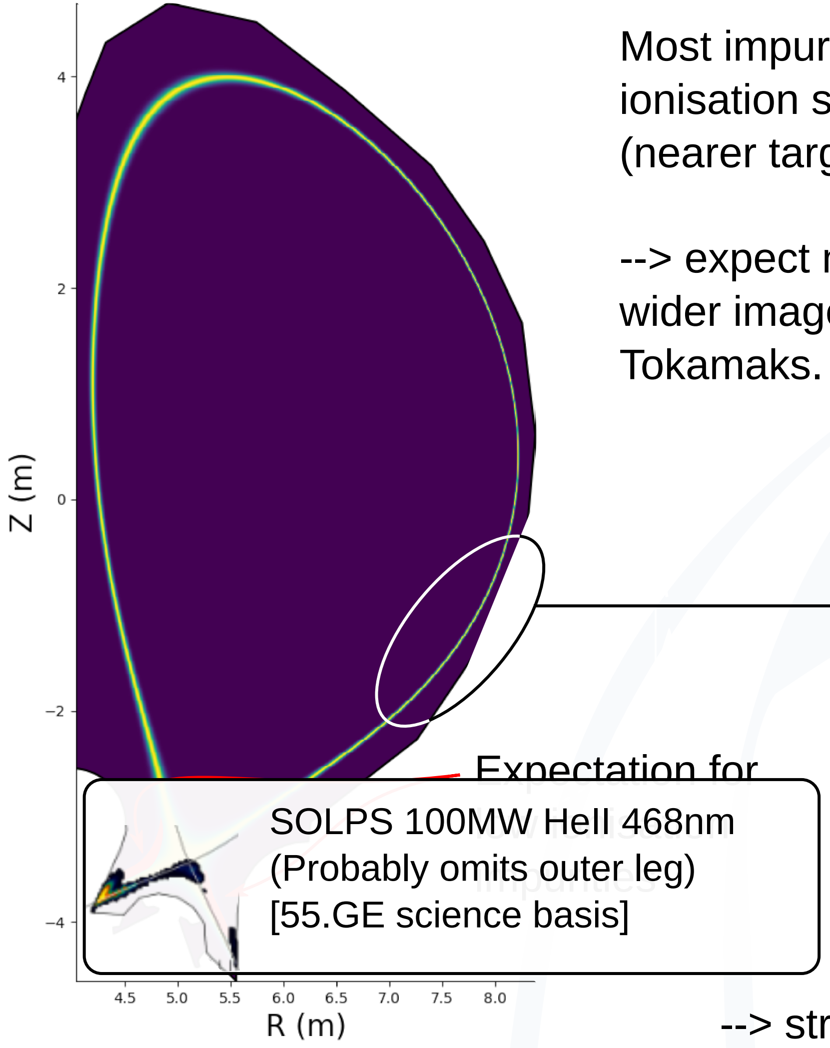

SOLPS 100MW HeII 468nm
(Probably omits outer leg)
[55.GE science basis]

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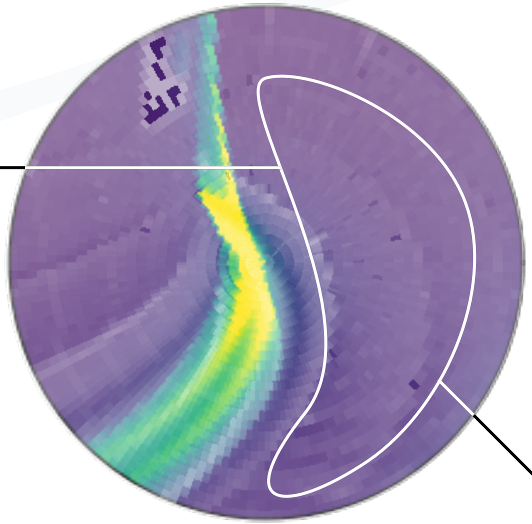

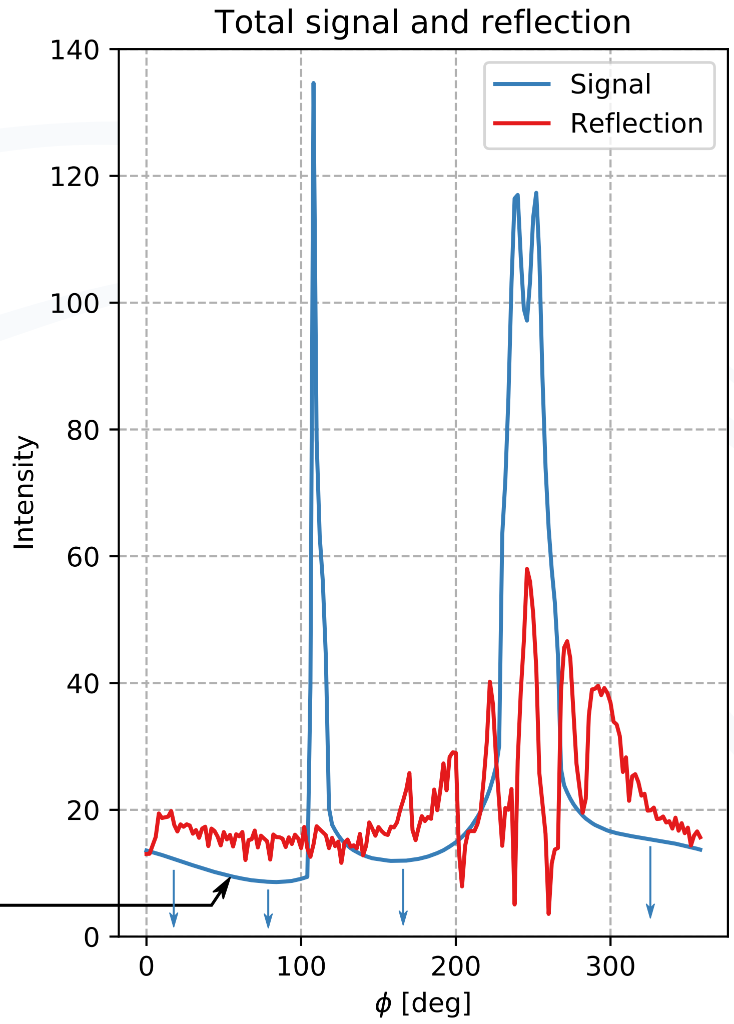

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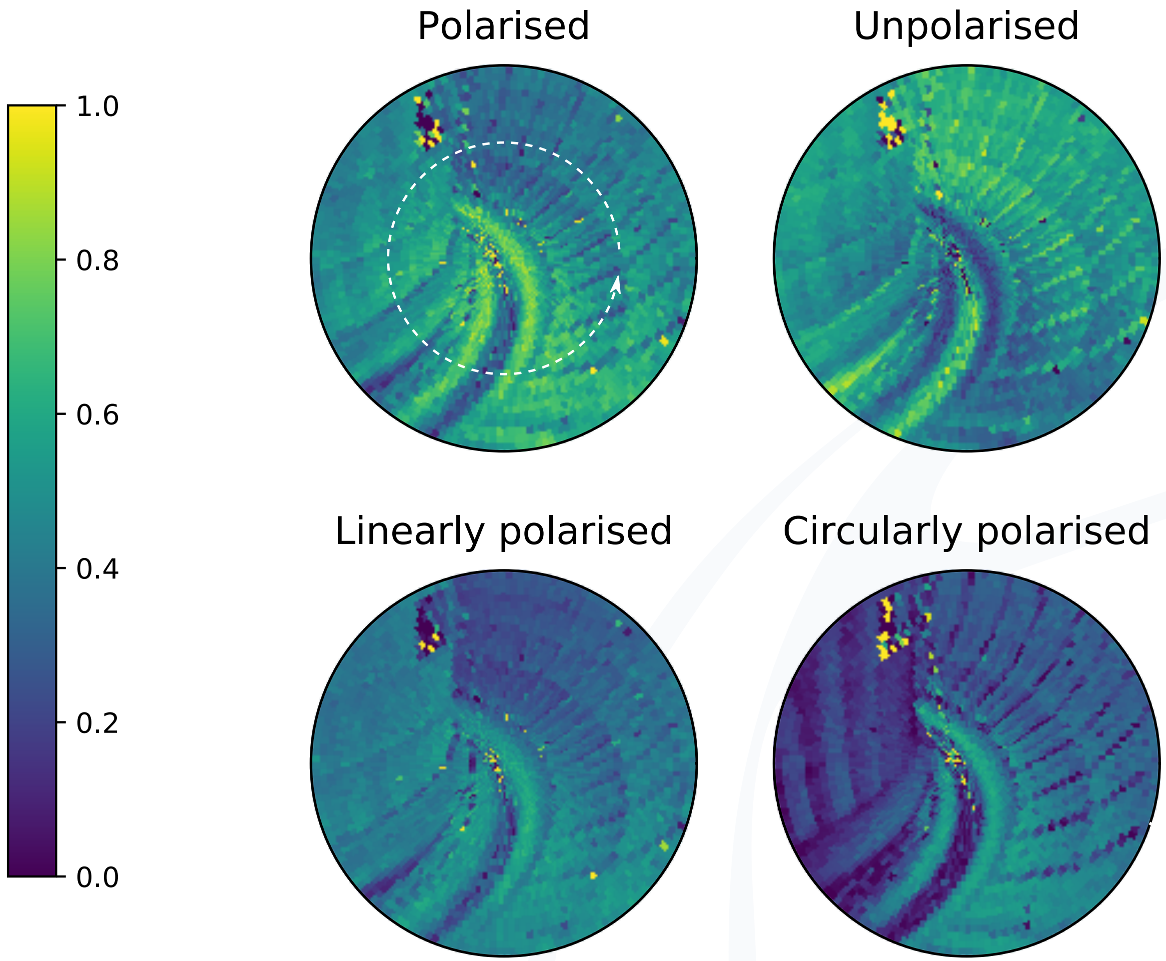

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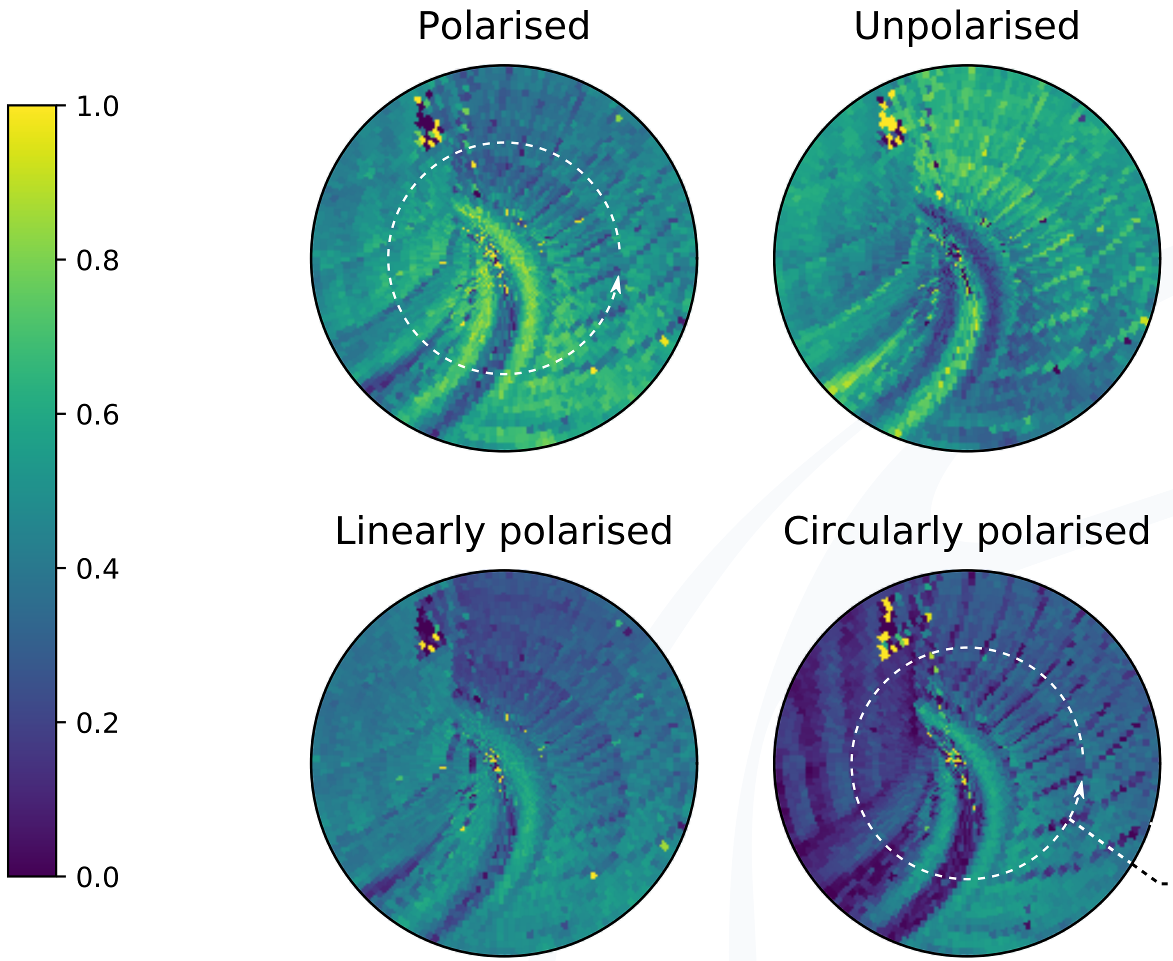

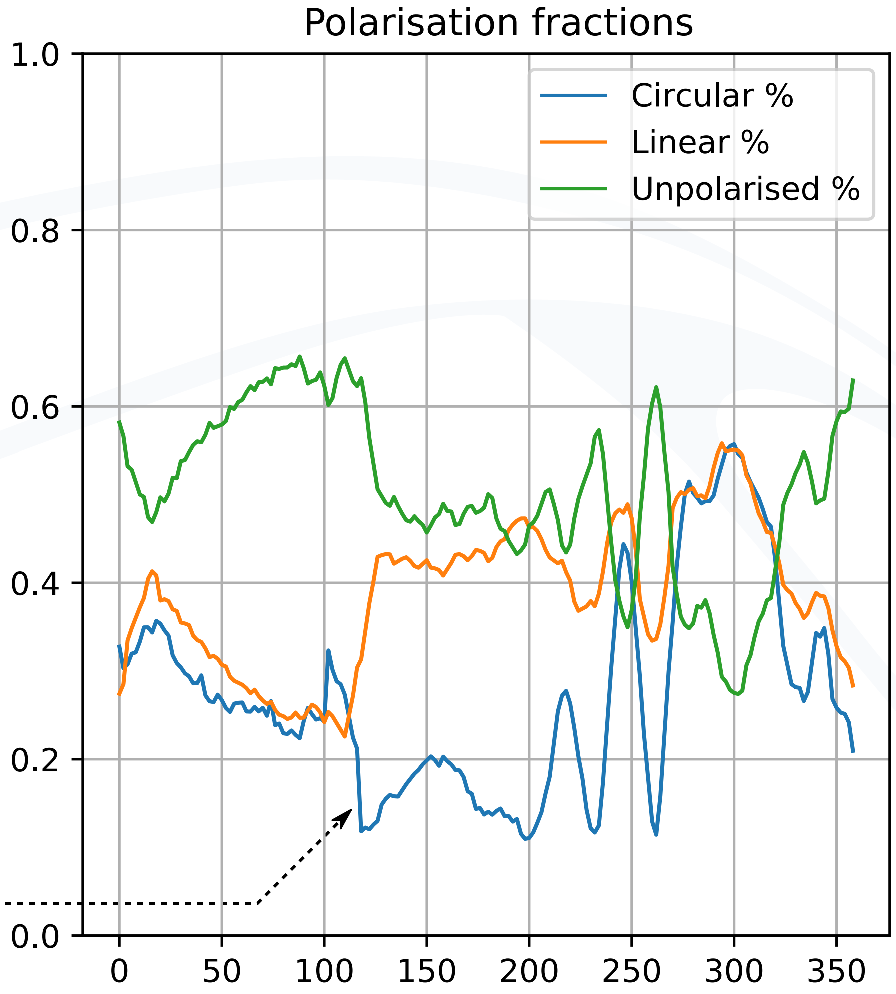

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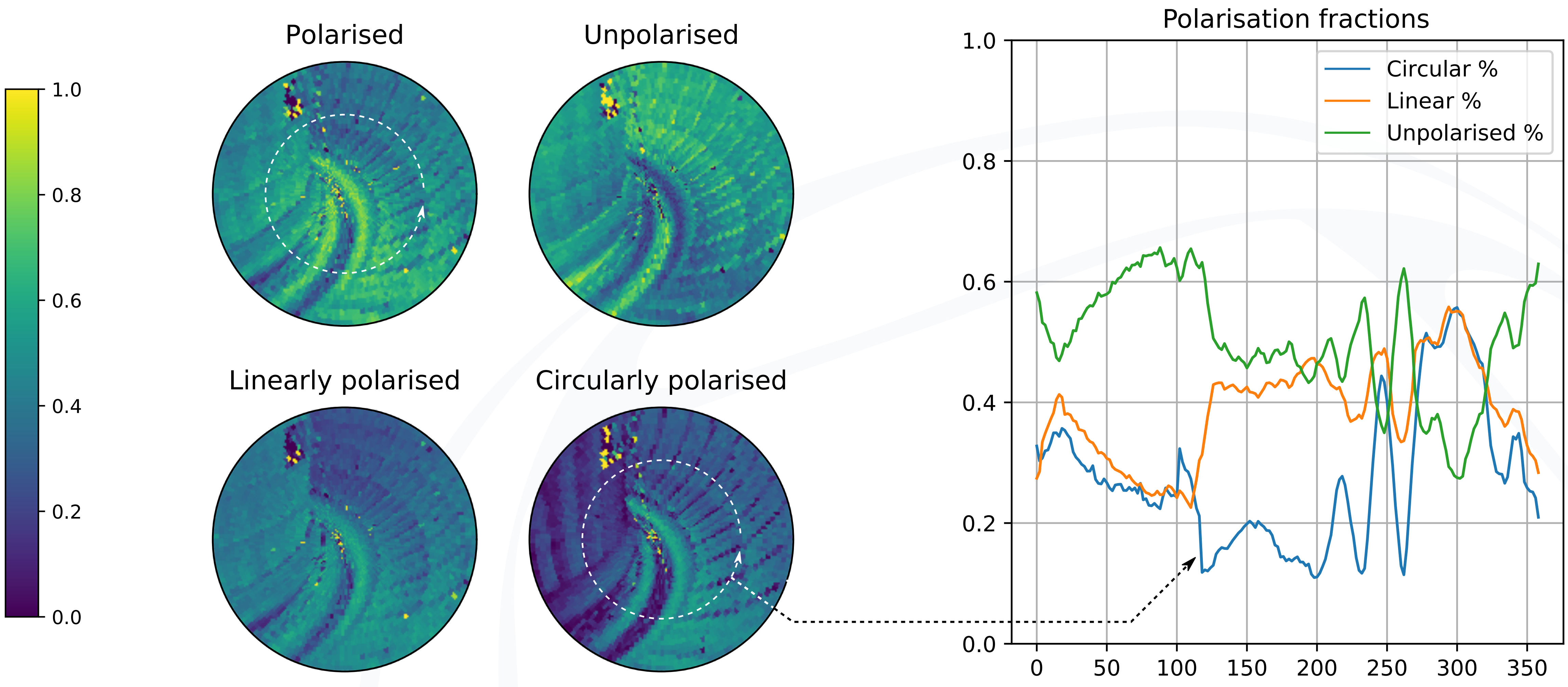

--> Not really, they seem to be a varied mixture of everything (linear, circular and unpolarised)

Suppression improvement

Reflections have between ¼ and ½ in each polarisation type.

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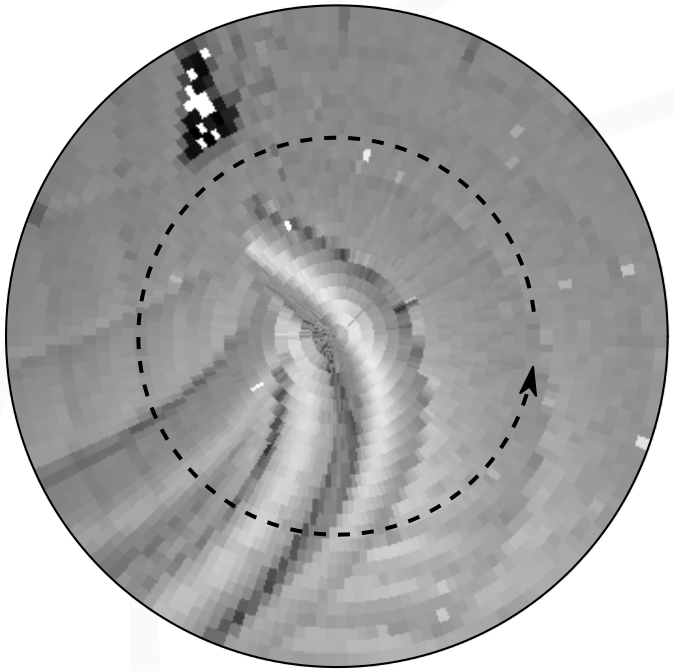

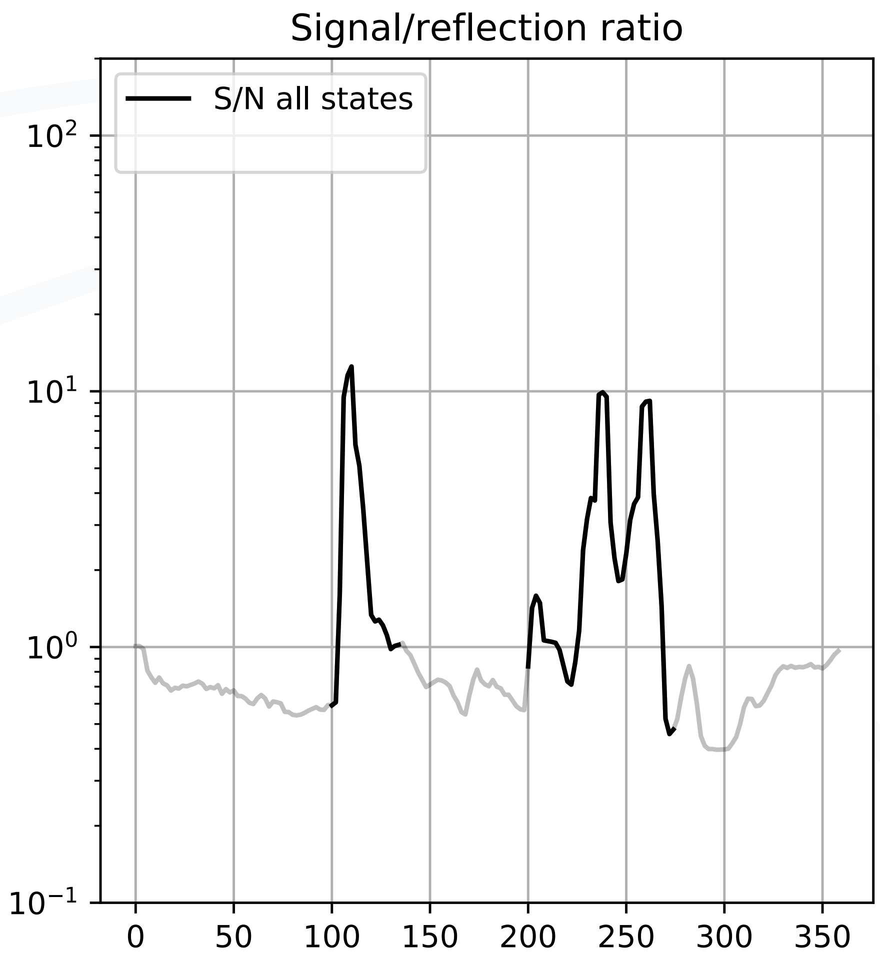

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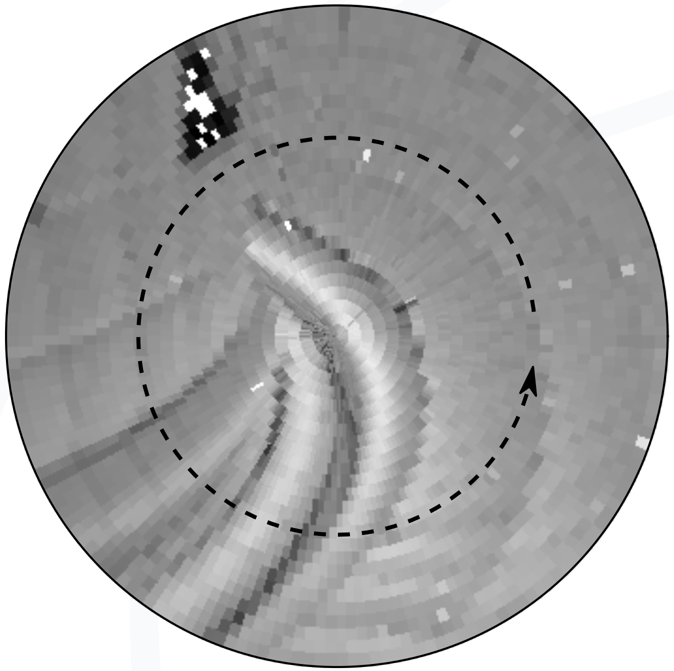

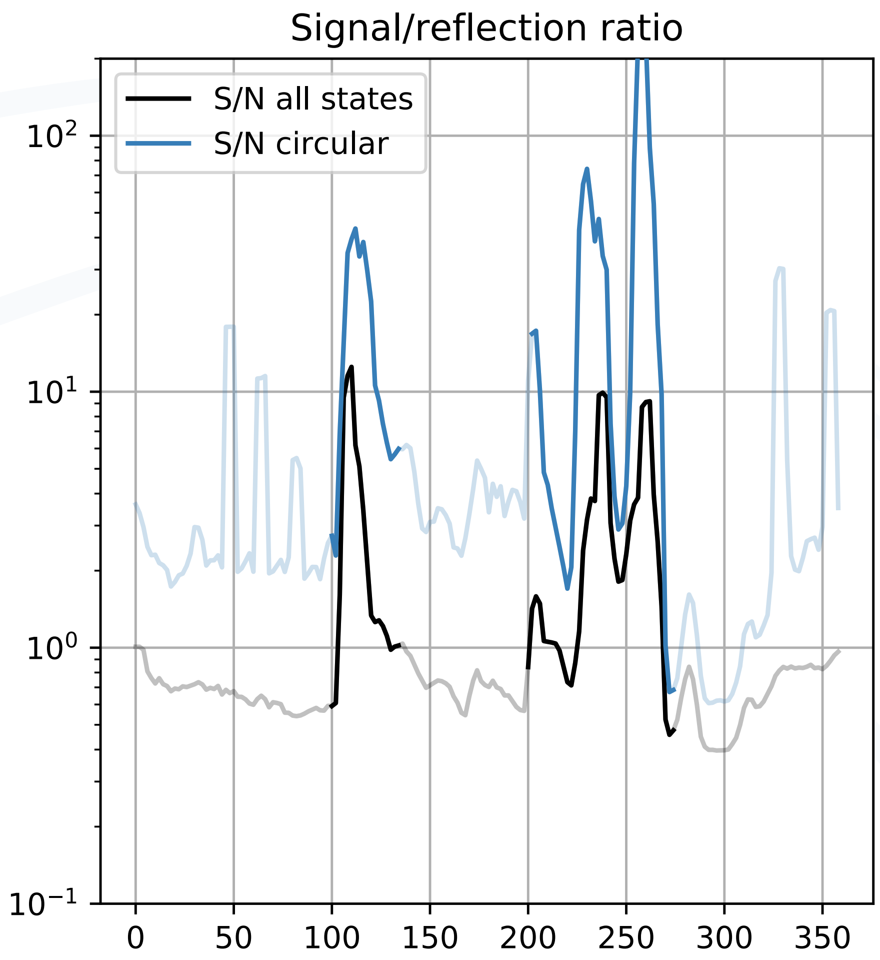

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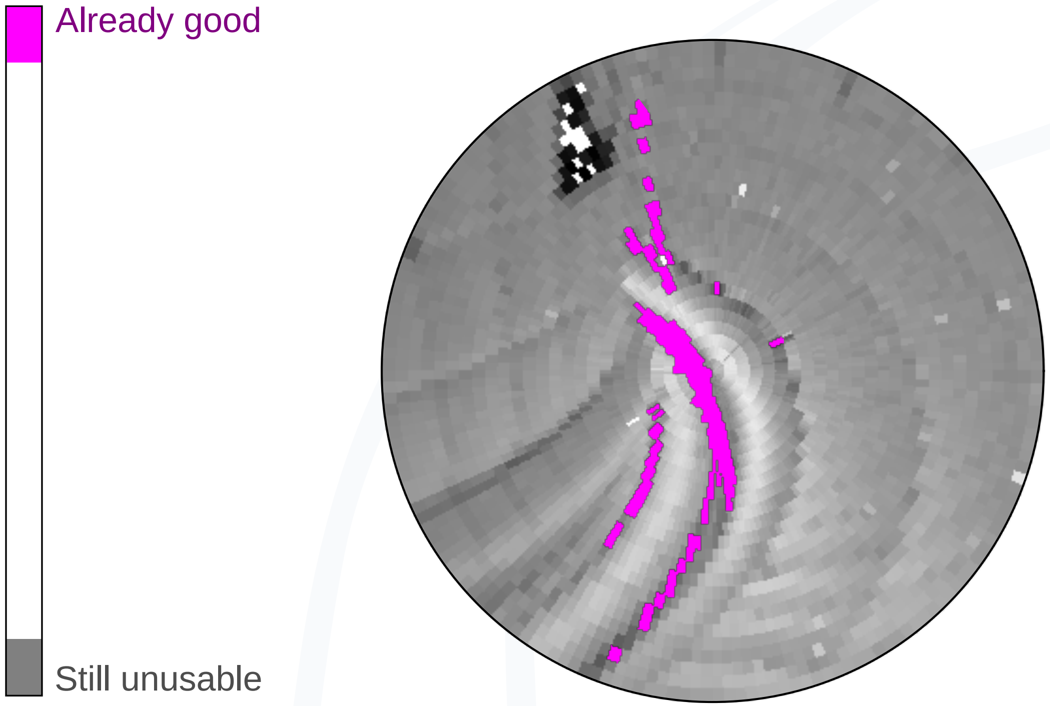

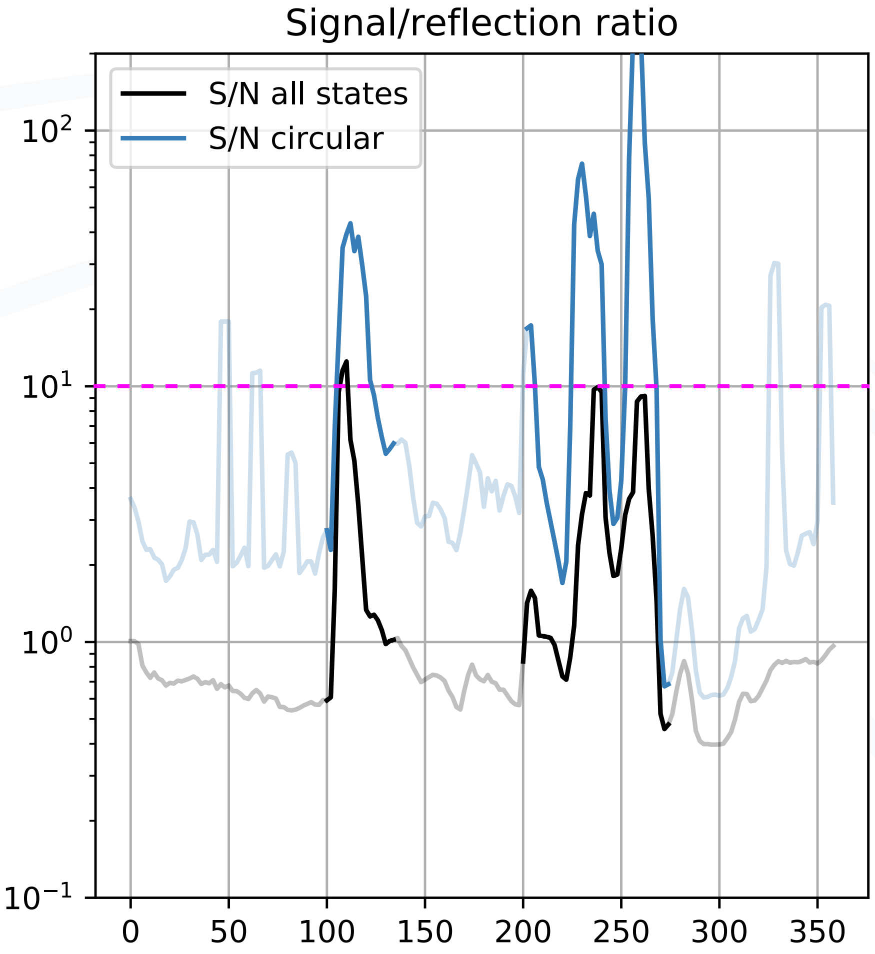

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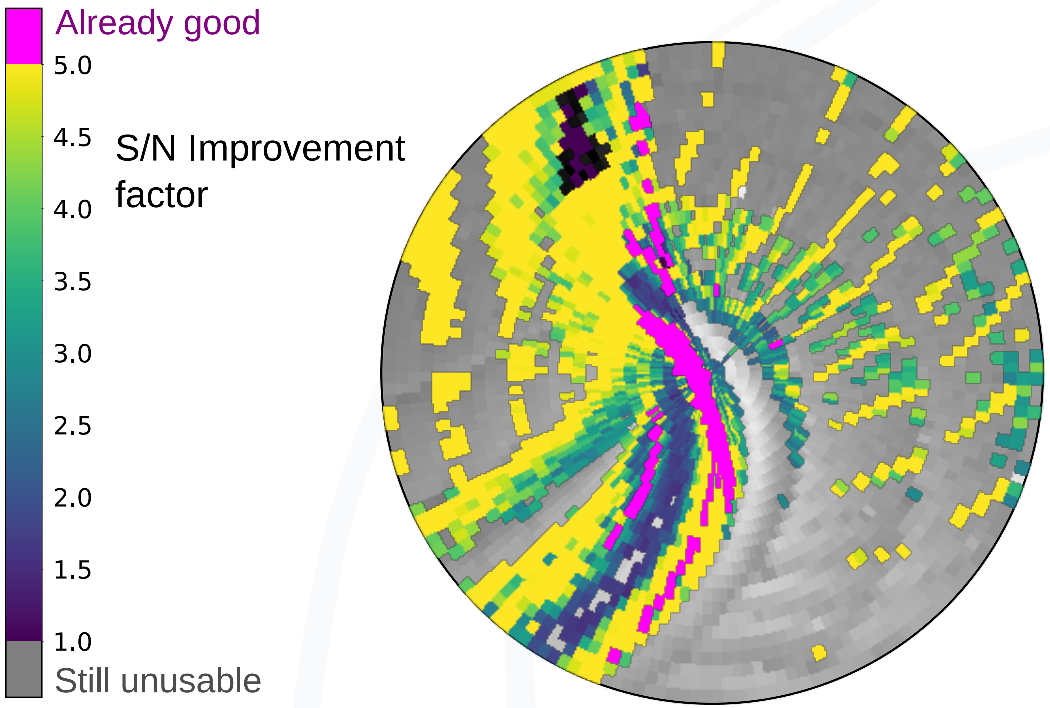

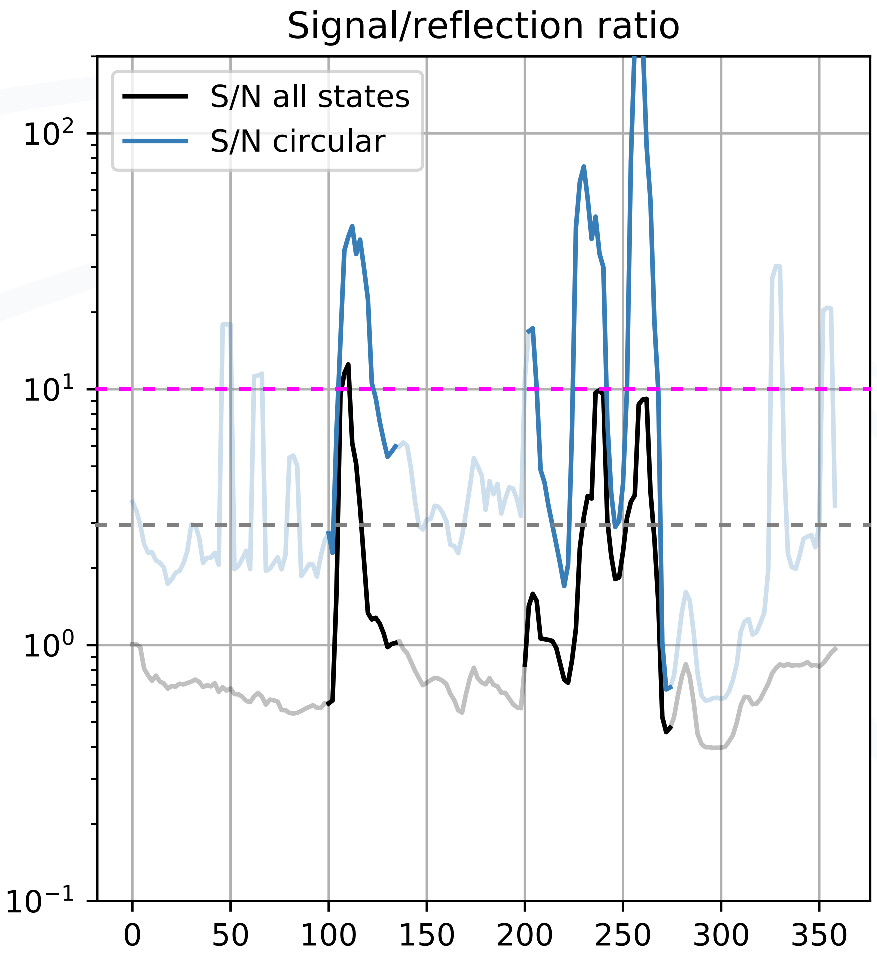

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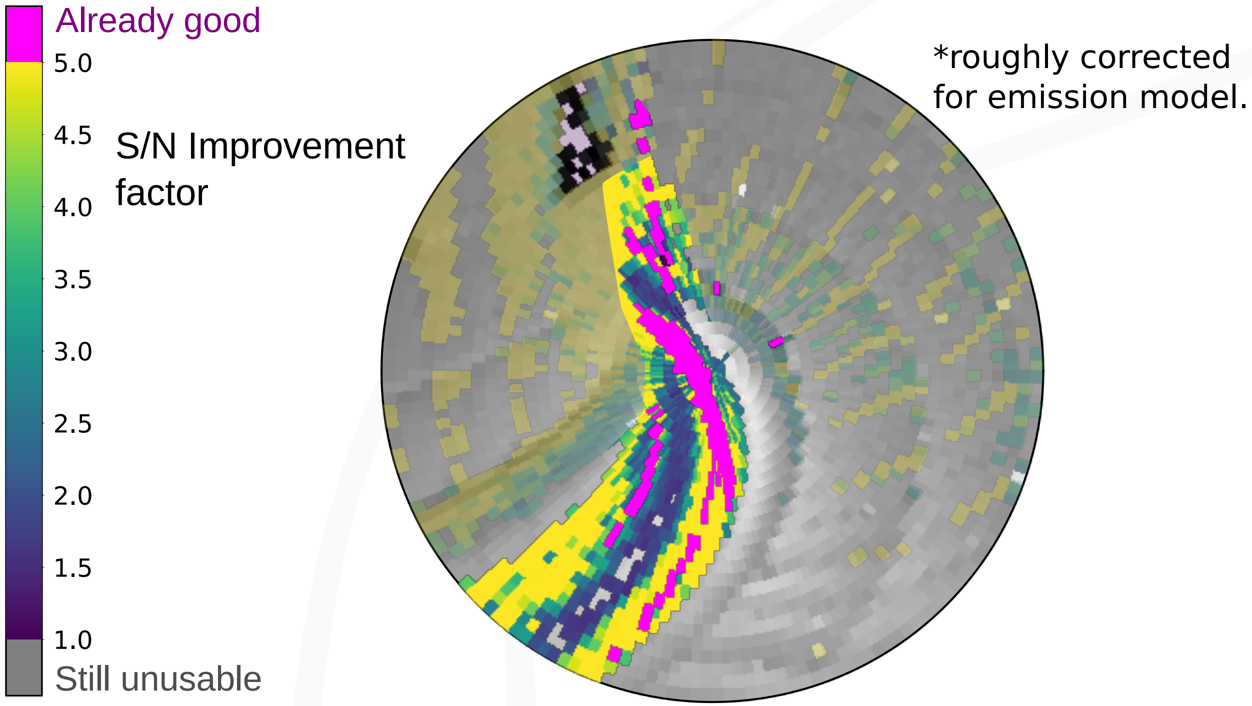

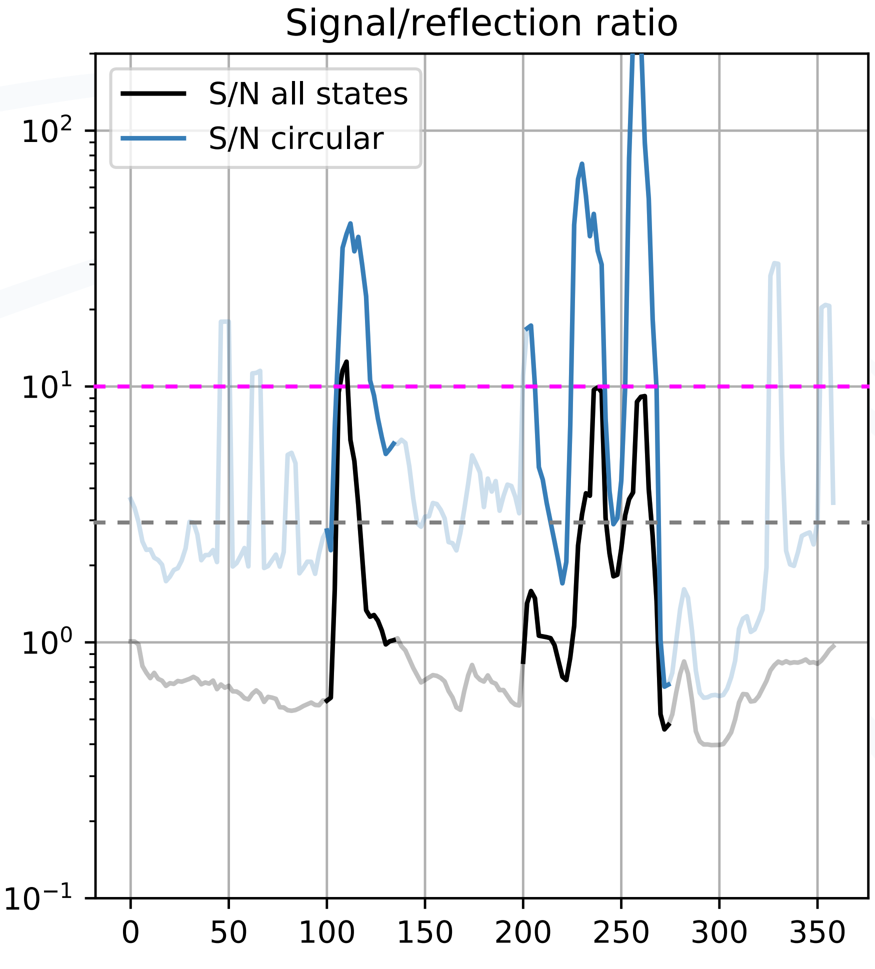

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- Emission location of each impurity line depends on unknown physics - Flux surfaces, T_i, n_Z, transport ...

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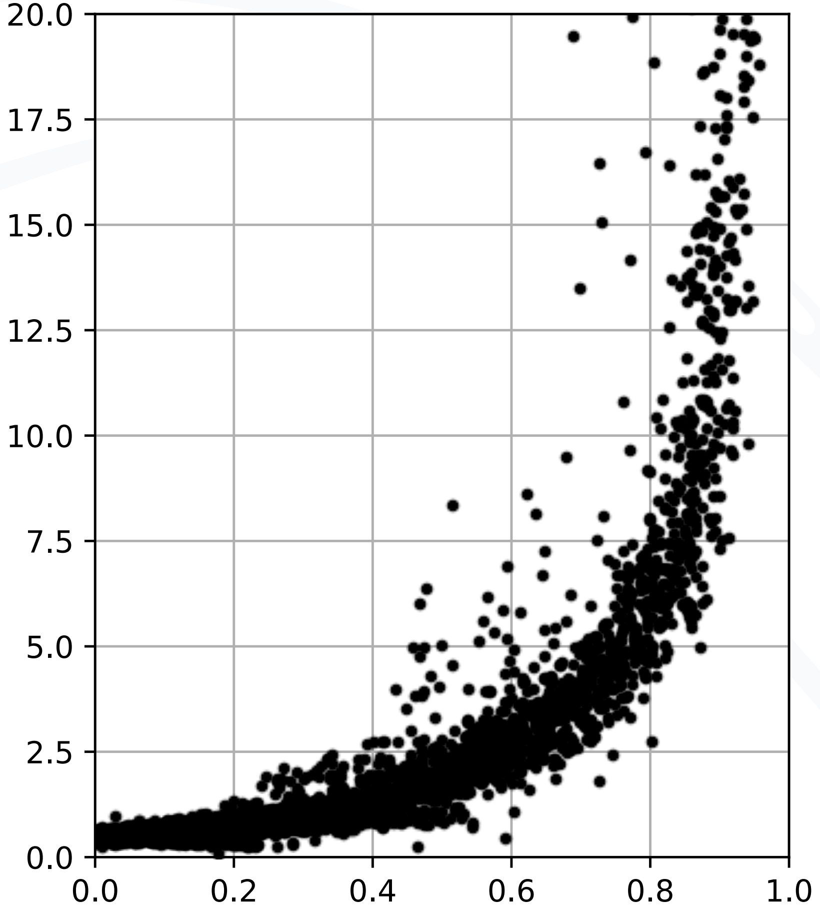

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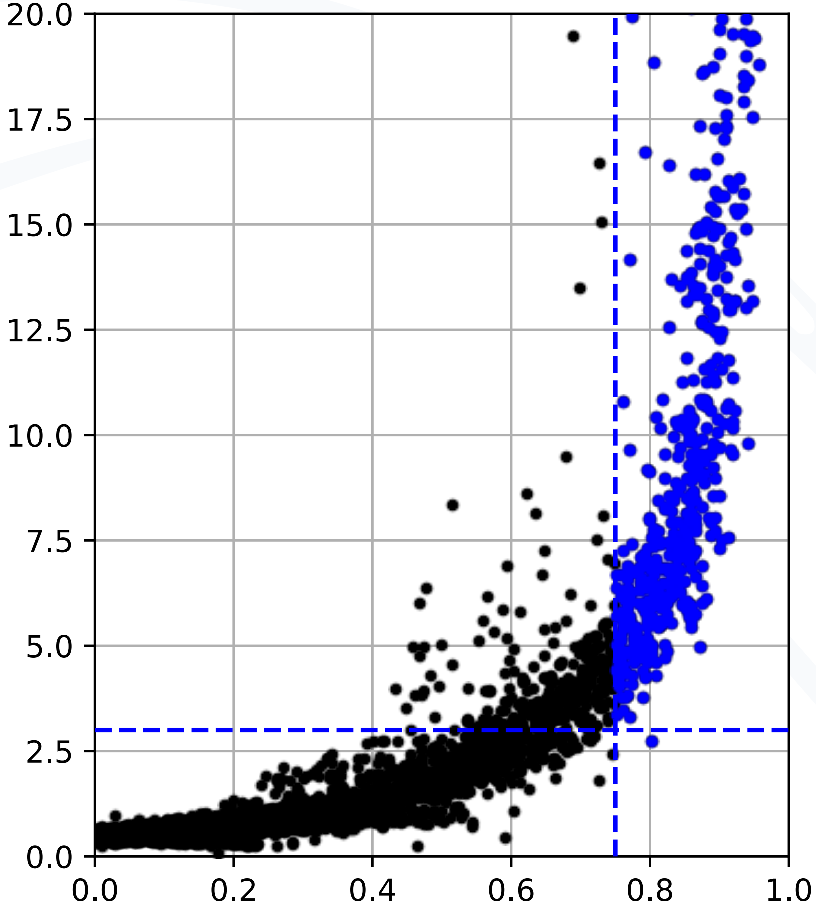

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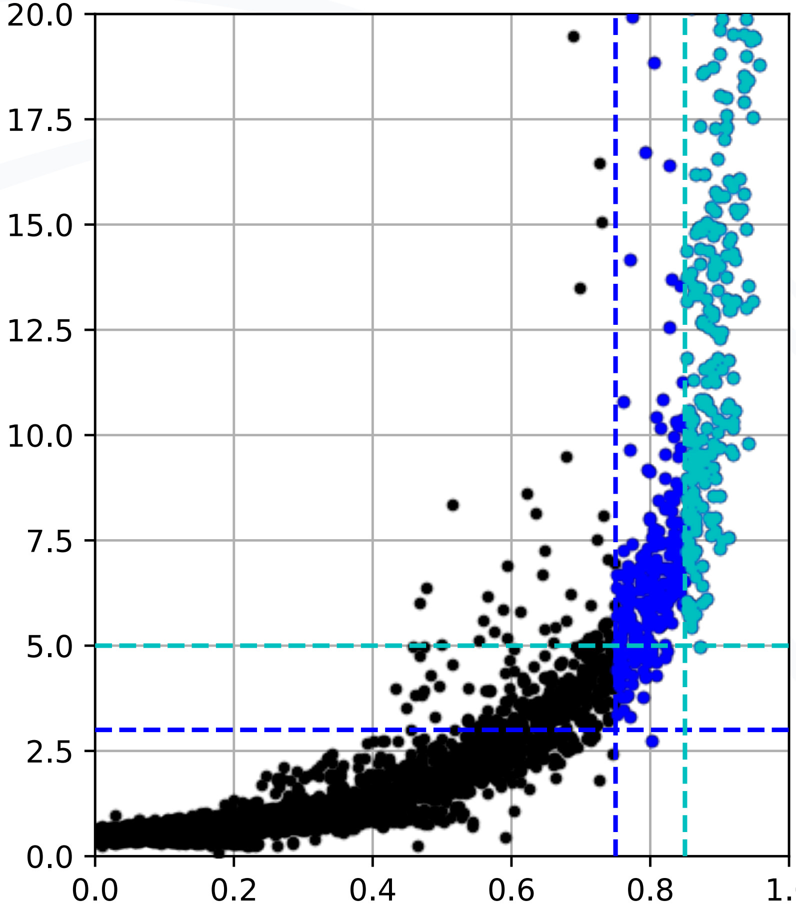

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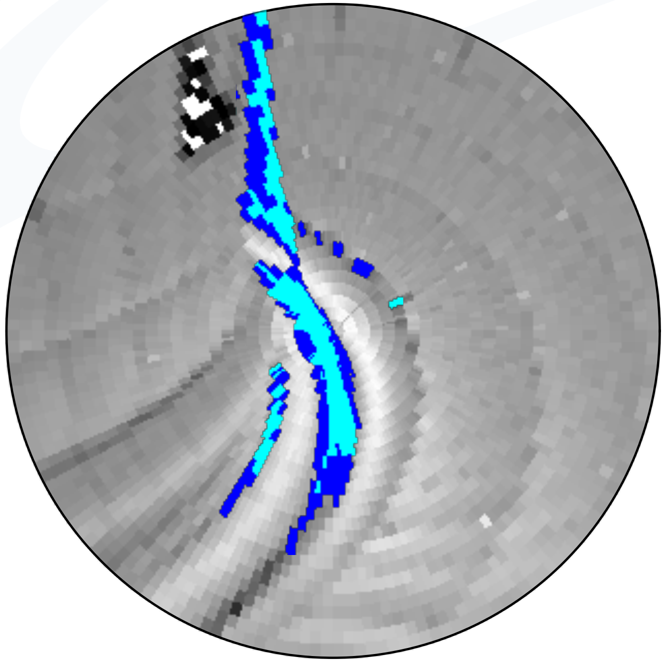

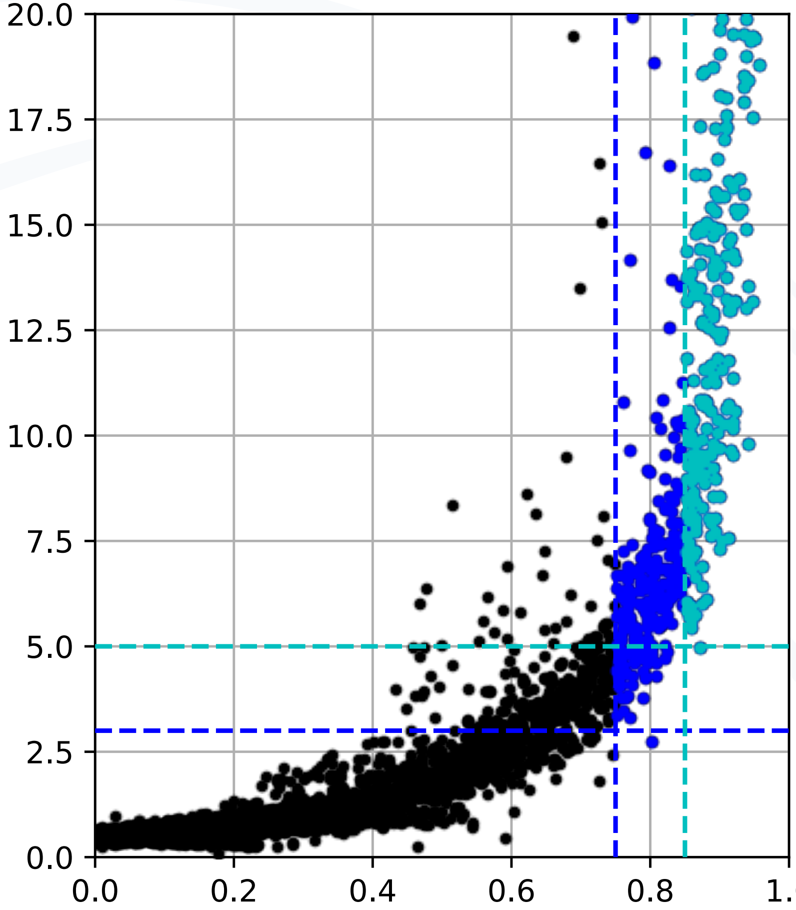

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- Some areas of the image will be good enough without polarisation selection.
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- Modelling shows the method could work well, but....
    - Polarisation information must be sufficiently well transferred to optical table and measured. (chits #14, #18)
    - Instrument must be able to simultaneously measure polarisation and doppler shift of nett-unpolarised multiplet.
      In practice very challenging - This method has not been tried in a fusion experimental environment before!

Absolute polarisation intensities

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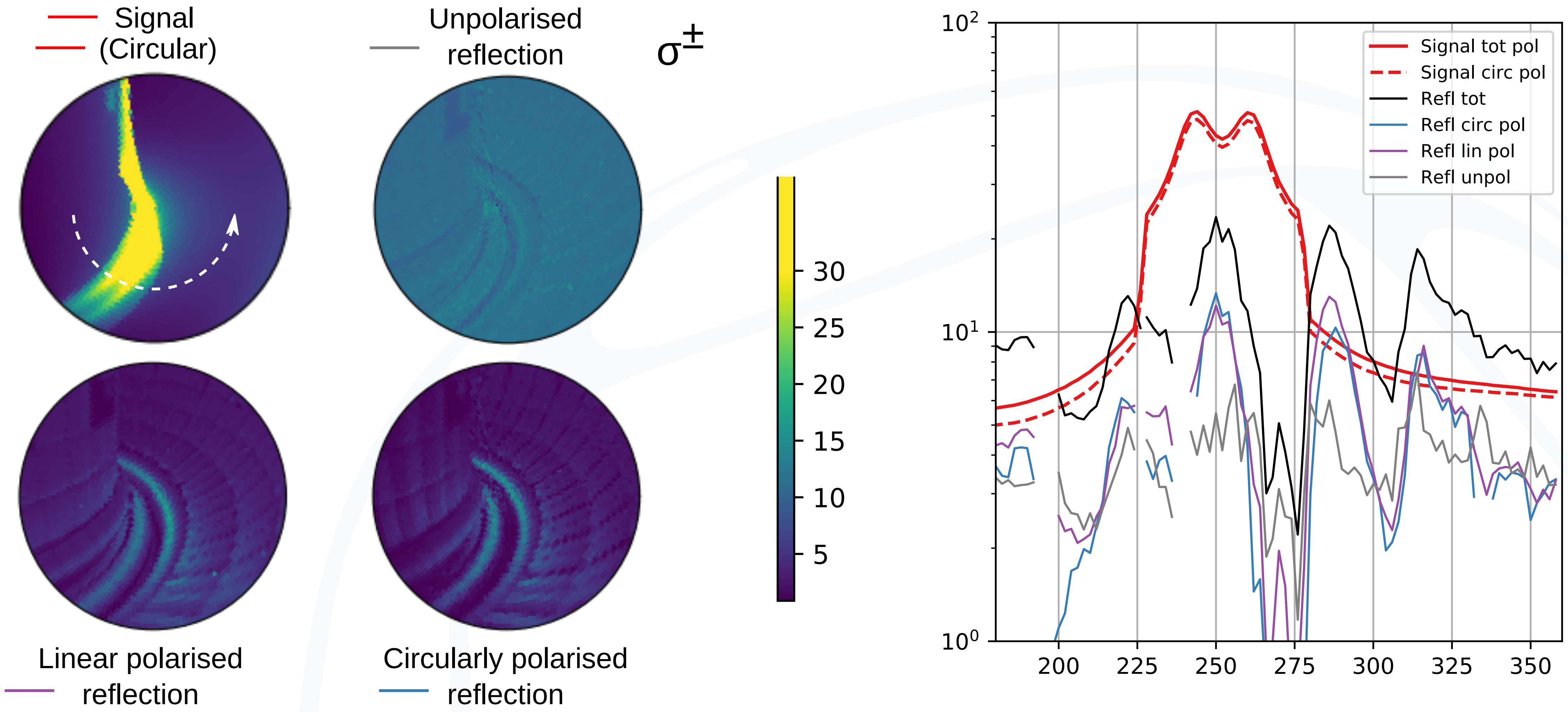
- Ignoring this for now... Are reflections mostly linearly polarised or unpolarised??
  --> Not really, they seem to be a varied mixture of everything (linear, circular and unpolarised)



All relevant chits

Signal is mostly circularly polarised. Reflection is mostly un-/linearly- polarised.
--> Measure polarisation and use it to discriminate and suppress reflections.

- CDR chit #12: **Is this principle valid and applicable for 55.GE view?**

The suppression of reflection is based on the idea that the majority of light reflected by the wall tiles comes from that emitted nearest to it, which necessarily comes perpendicular to the field and is therefore predominantly linearly polarised. This assumes: a) The diffuse reflection is dominant over specular, and b) reflected linear polarisation does not become circularly polarised. This should be shown for at least clean tungsten, but preferably also beryllium coated tungsten if at all possible.

If (a) is not true, specular reflection from lines of sight hitting tiles almost tangentially will contain a strong S3 component from the reflected continuation of that line of sight. If (b) is not true, the diffuse reflection of nearby plasma may be strongly circularly polarised due to phase shifts between the S and P reflected components.

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- CDR chit #14,18: **Does optic relay preserve enough of the polarisation information?**

#14: The polarisation modelling of the optical system should be repeated with realistic mirror/lens coatings to determine if the ideal relay system can be characterised by an invertible Müller matrix.
Faraday rotation in the vacuum window should also be modelled.
Stress-induced birefingence should be considered as far as possible since this may introduce a variable modification to the Müller matrix.

#18: ... more detailed analysis which directly assesses mixing in to S3, and whether the Mueller matrix of the system will be sufficiently invertible, needs to be performed since this is a crucial issue for the measurement scheme.