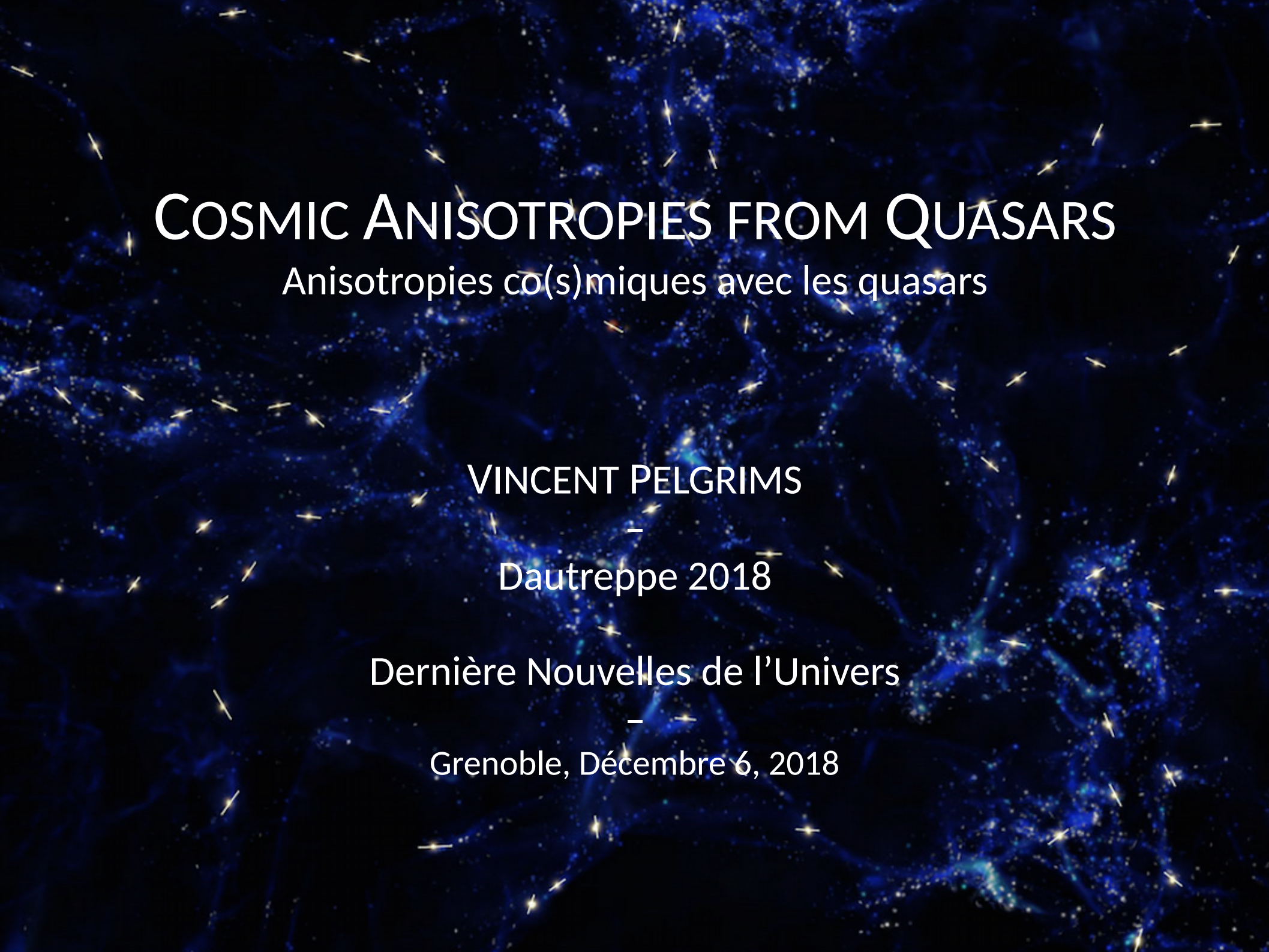


Cosmic Anisotropies from Quasars

Anisotropies co(s)miques avec les quasars

VINCENT PELGRIMS

–

Dautreppe 2018

Dernière Nouvelles de l'Univers

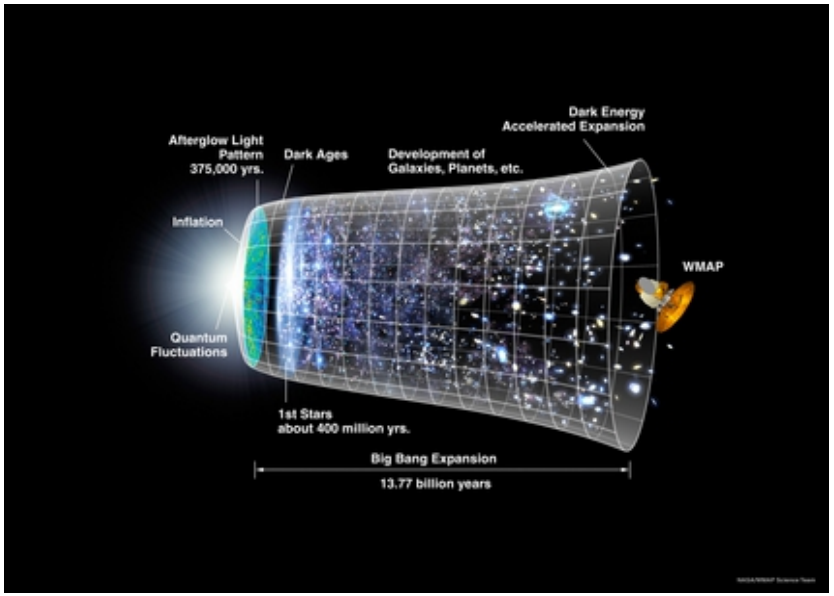
–

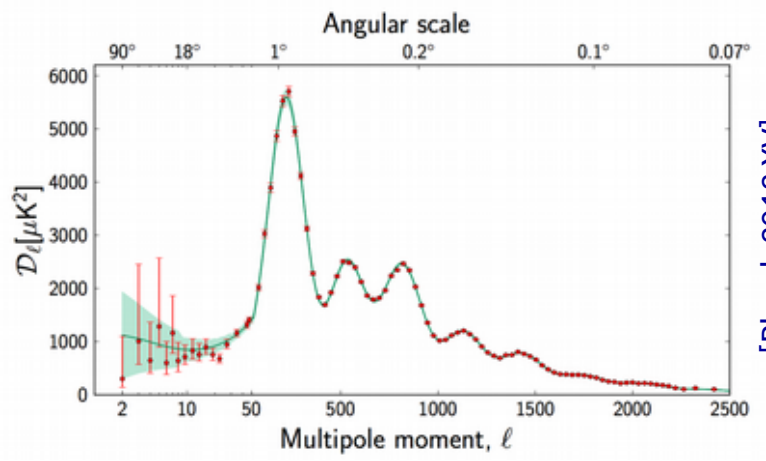
Grenoble, Décembre 6, 2018

Cosmological Principle

The ΛCDM: successful concordance model of cosmology

Cosmological principle + General Relativity → FLRW Universes [e.g Trodden & Carroll 2004]





[Planck 2013 XV]

Though, some *anomalies*:

- Low-*l* deficit in the TT angular power spectrum
- Small temperature variance
- Dipole and quadrupole alignment of moments
- Excess of Integrated Sachs-Wolfe effect signal
- …
- Departure from isotropic H_0 from SNIa
- Extreme-scale alignments of quasar (optical) polarization vectors
- …

Cosmological Principle

The Universe has to be **homogeneous** and **isotropic** when it is viewed at *sufficiently* large scale.

It requires/implies that the part of the Universe that we observe and study is a statistically representative sample of its entirety.

- Homogeneity = same observation can be made from wherever
- Isotropy = same observation can be made by looking in whatever direction
  - Isotropy for all observers implies homogeneity
  - Homogeneity for all does not imply isotropy
- Bianchi cosmological models that are homogeneous and anisotropic

Resurgent interests to explain some anomalies such as:

- Low-*l* deficit in the TT angular power spectrum
- Small temperature variance
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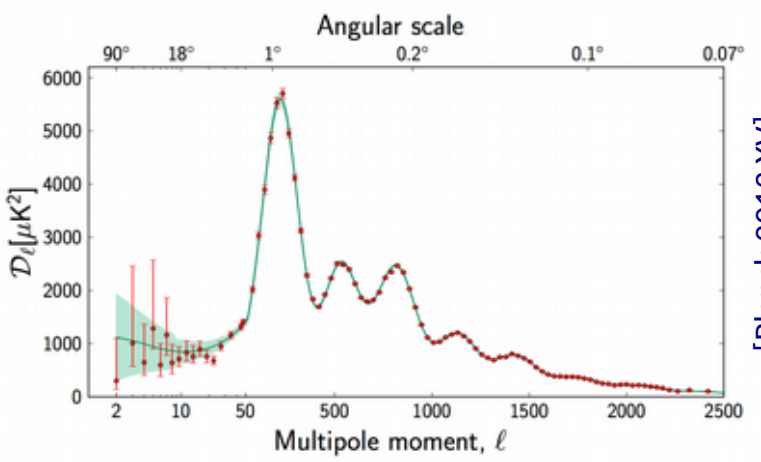
Isotropy appears to be questionable …



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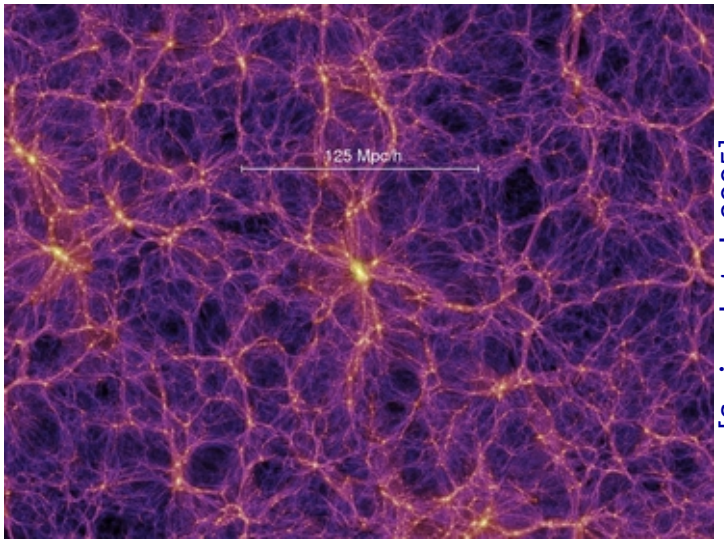
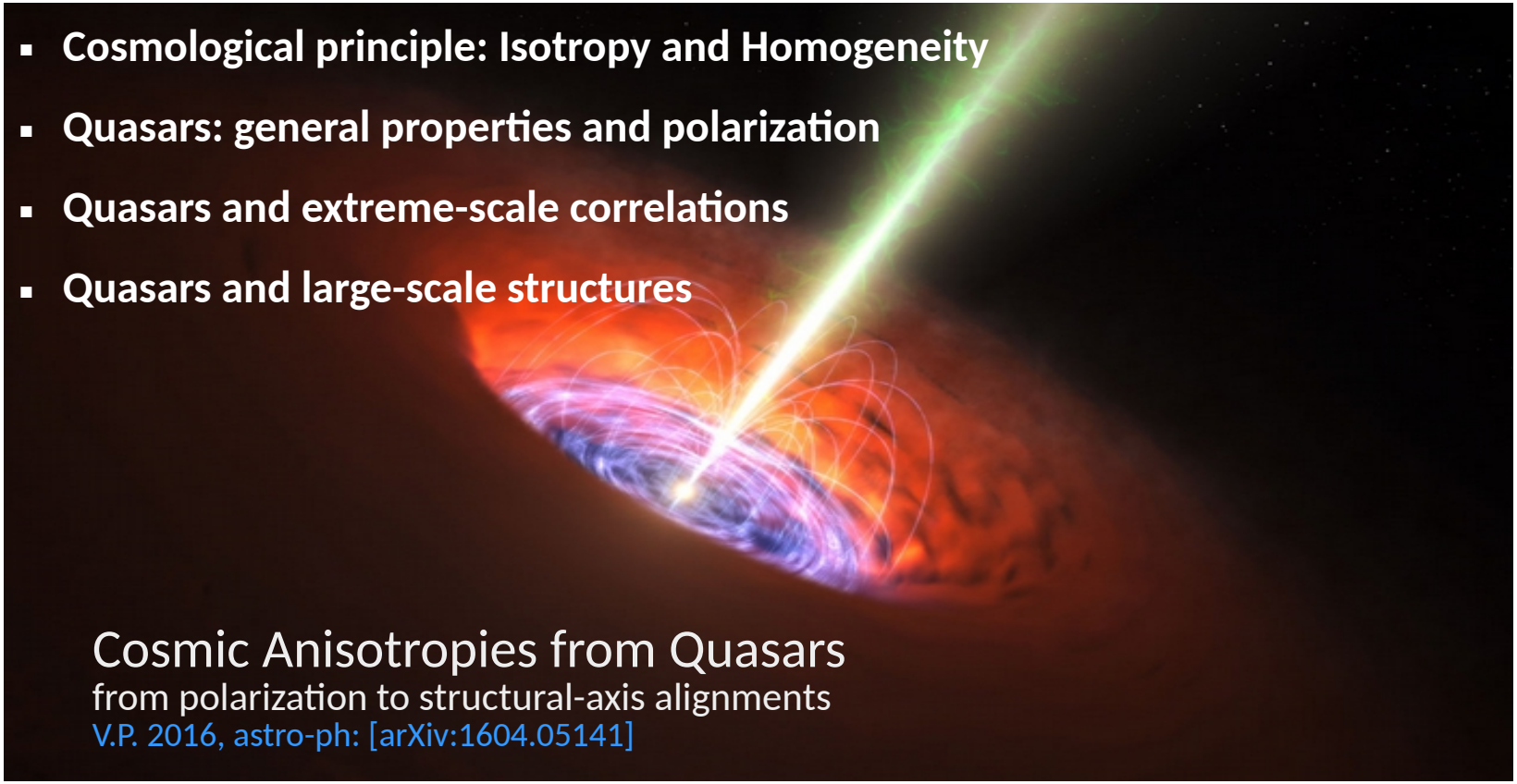
Isotropy appears to be questionable ...
Homogeneity as well, at least the value of the *homogeneity scale* has long been debated and most recently with quasars.



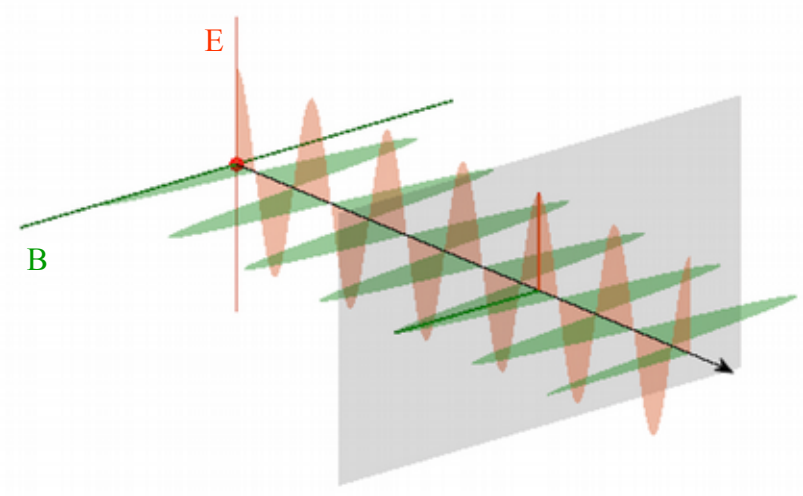
[Springel et al. 2005]

Quasars and Cosmology

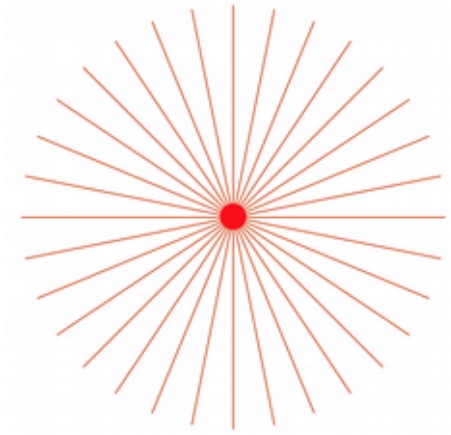
Large-scale alignments of quasar polarization vectors



Polarization of light



Un-polarized



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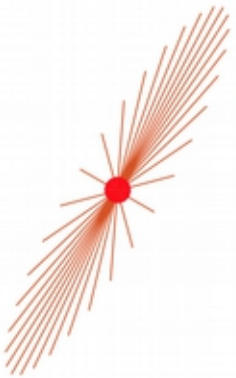

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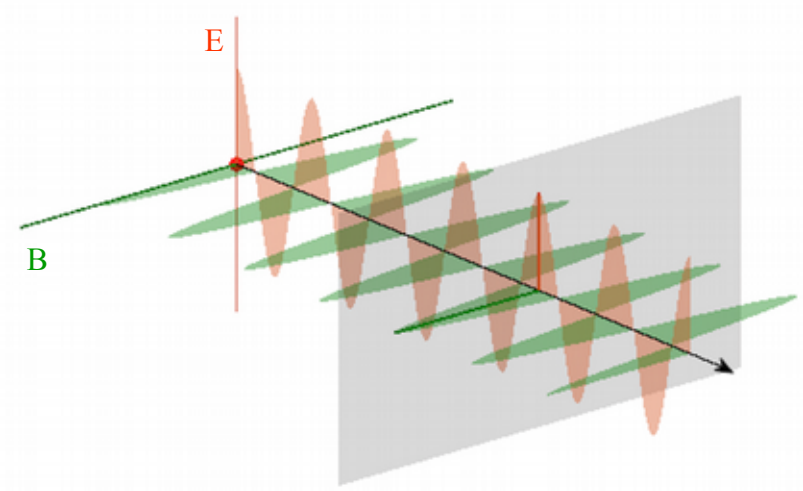

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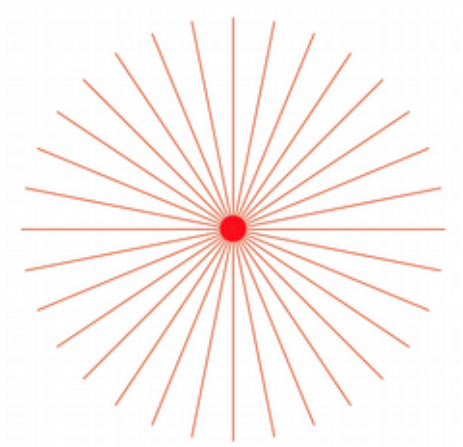
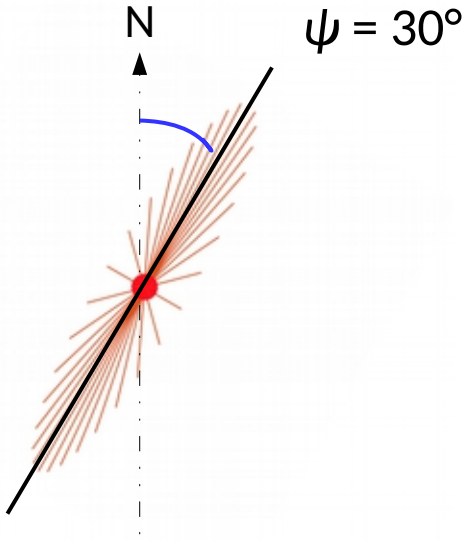


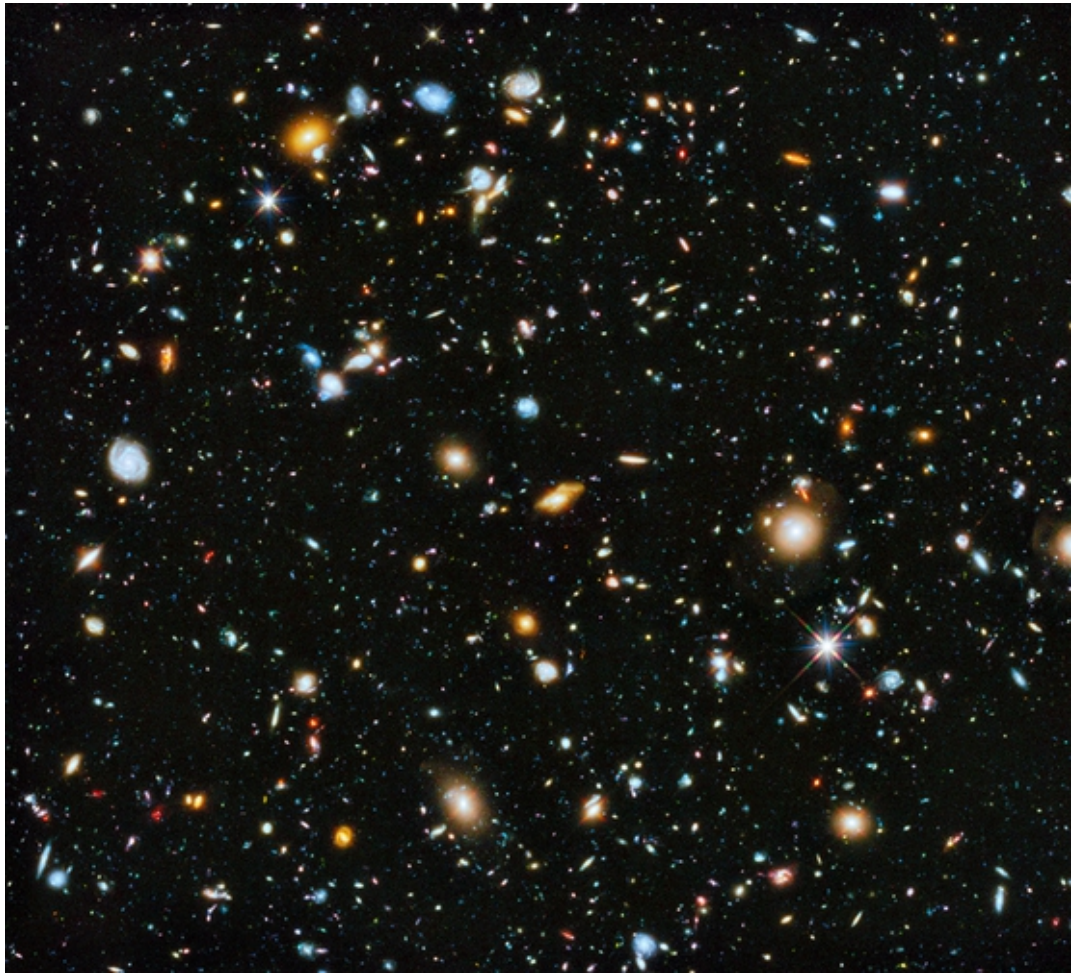
p_{lin} = 0 %

Polarized



p_{lin} >> 0 %

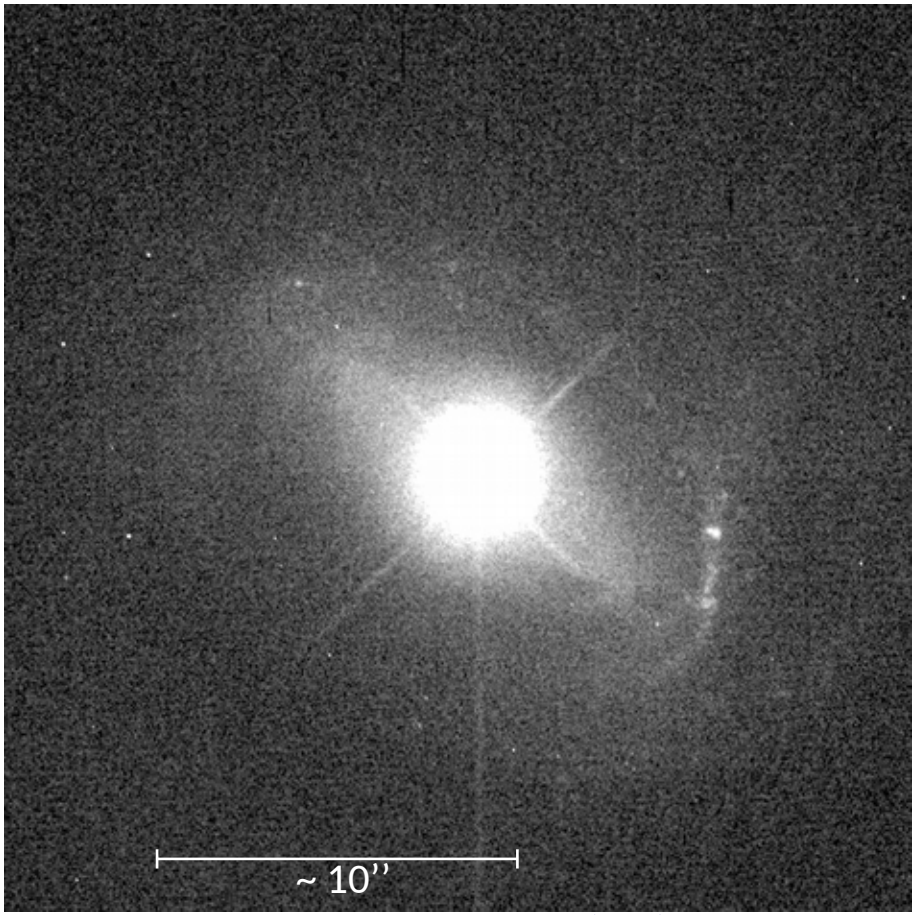
Quasars: bright point-like sources in the Universe



[Deep Field from Hubble Space Telescope]

Quasars: some properties

- Most luminous Active Galactic Nuclei
- Ultra-bright point-like sources
- Emit light in the whole spectrum
- Observable at the far reaches of the Universe
- Tiny region at the center of a Galaxy (~ 10^{-3} – 10^{-4} pc)
  → matter accretion onto a Super Massive Black Hole (>10^8 $M_\odot$)
- Light is polarized at various wavelengths
  → no spherical symmetry



[QSO 1229+204; Hutchings et al. 1994 (HST)]

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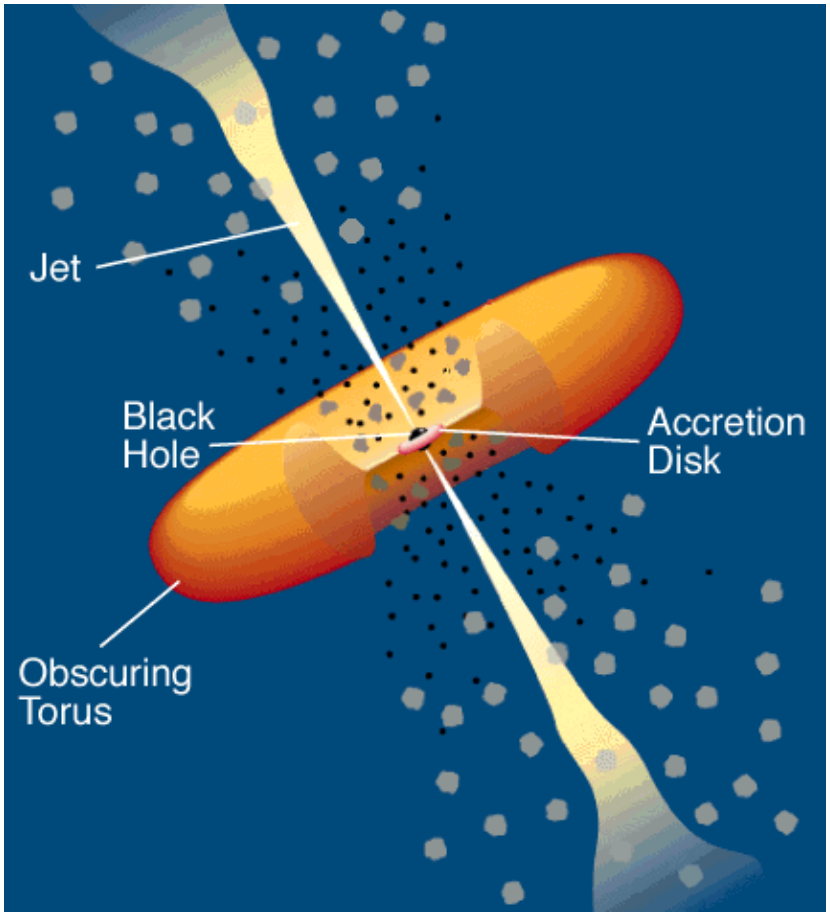

[Urry & Padovani; unified model]

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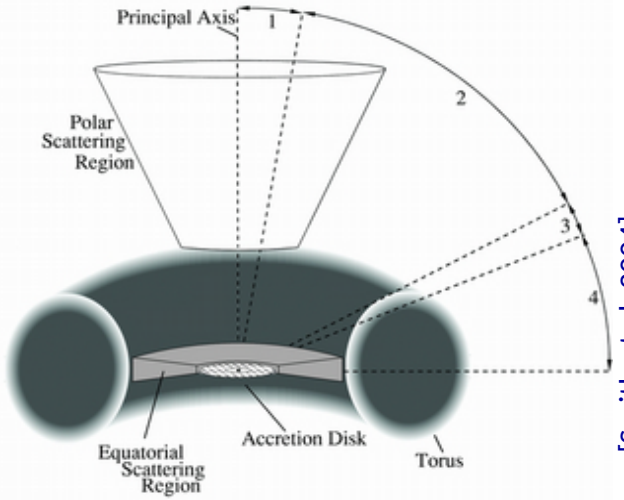
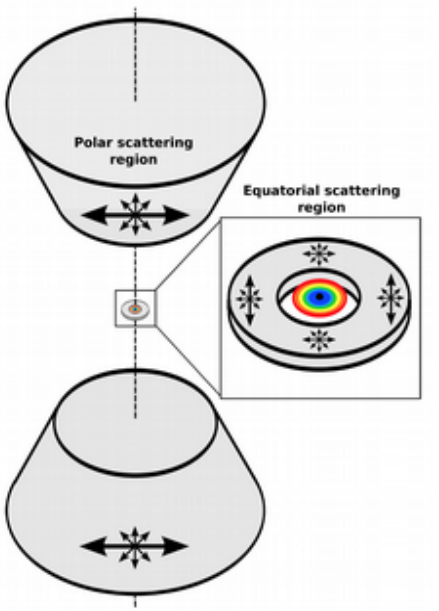
- Very-high resolution observations of a few showed the optical polarization orientation relates to structural axis of the source (blue/UV continuum or radio jet) [Borguet et al. 2005]
  → parallel or perpendicular to the spin axis at optical wavelength



[Smith et al. 2004]



[Hutsemékers et al. 2015]

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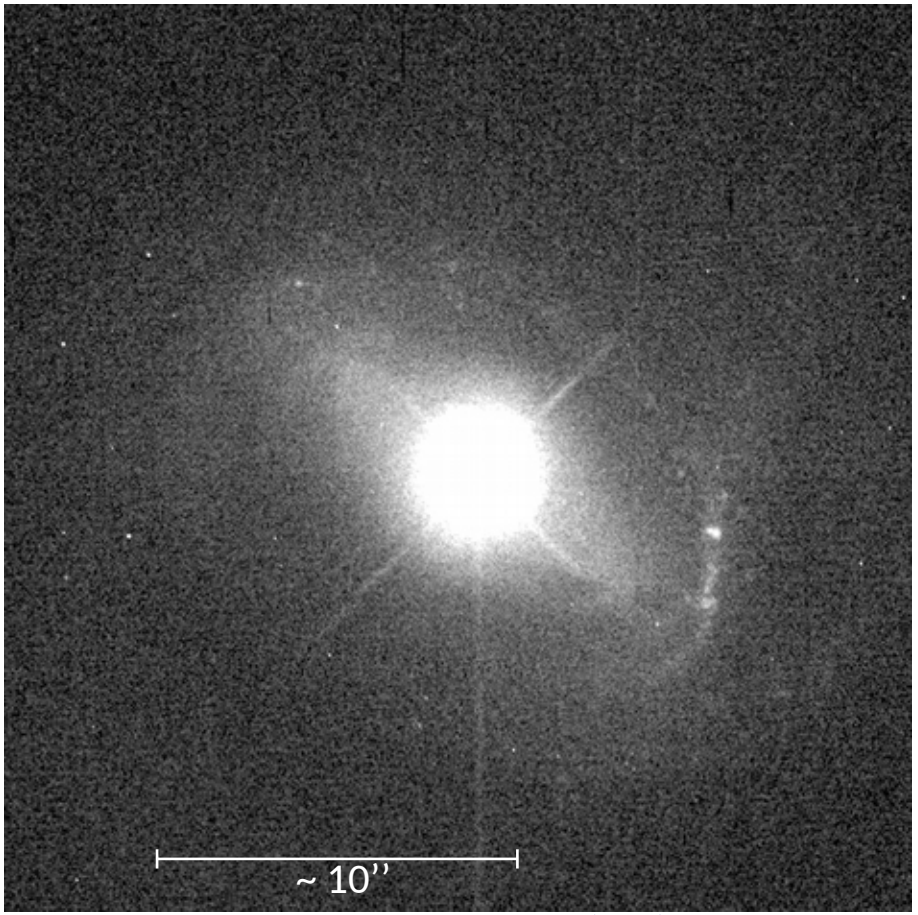
- Similar relation at other wavelength



[QSO 1229+204; Hutchings et al. 1994 (HST)]

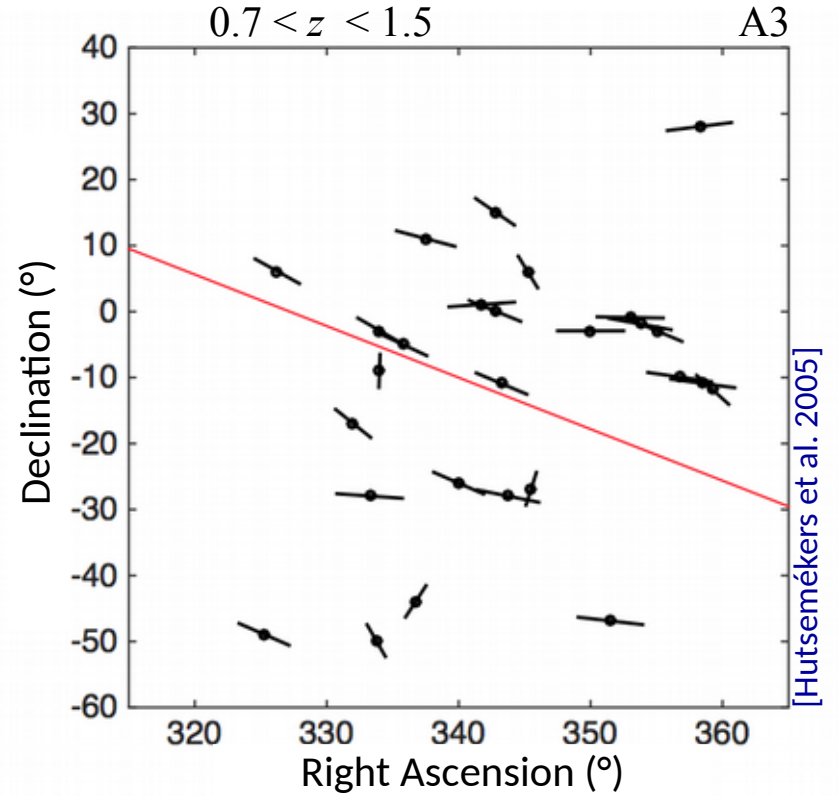
Quasars and extreme-scale correlations

Extreme-scale alignments of quasar optical polarization vectors

Originally discovered: [Hutsemékers 1998]

Confirmed with:

- new observations
  [Hutsemékers & Lamy 2001 ;
  Sluse et al. 2005]
- independent analyses
  [Hutsemékers & Lamy 2001 ;
  Jain et al. 2004 ;
  Cabanac et al. 2005 ;
  Hutsemékers et al. 2005 ;
  Pelgrims & Cudell 2012 ;
  Pelgrims 2018]



Probability of uniformity ~ $6\ 10^{-5}$

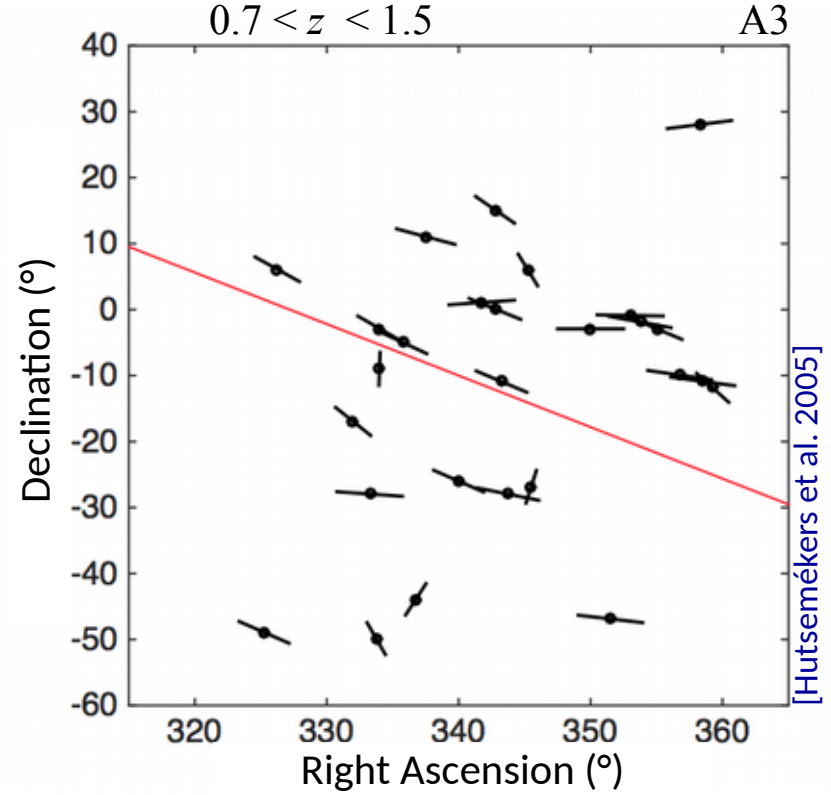
Quasars and extreme-scale correlations

Extreme-scale alignments of quasar optical polarization vectors

[Hutsemékers et al. 2005]

- Current sample:
  355 quasars with *reliable* opt. pol.

- Significant orientation correlations within few Gpc scale regions



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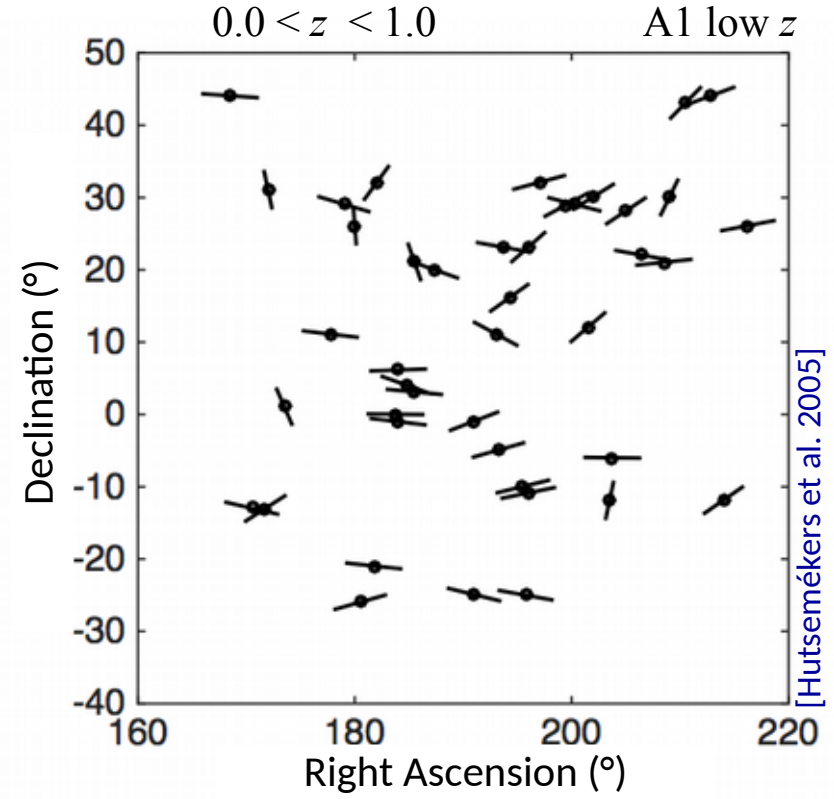

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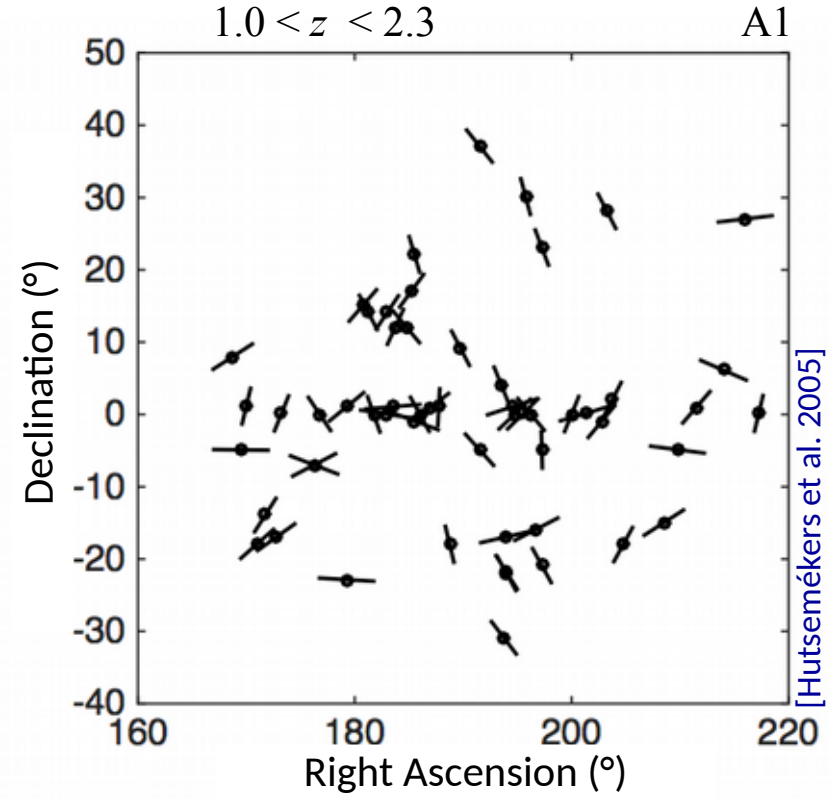

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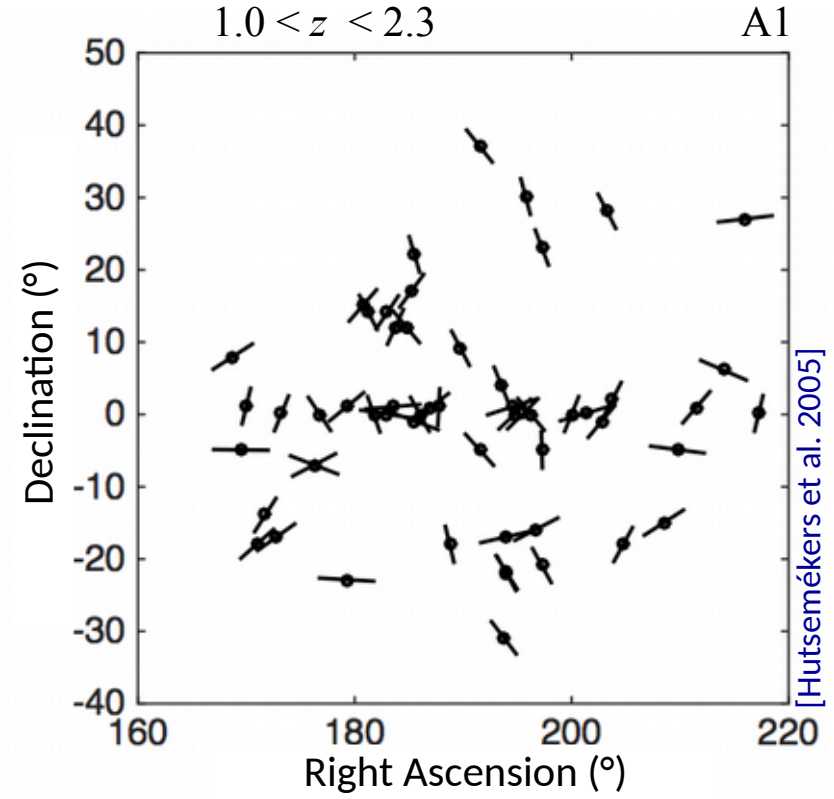

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Still *not* understood today !

No satisfactory explanation despite the various investigated scenarios

- Cosmic strings/loops
- Cosmological-scale magnetic field
- Axion-like Dark Matter particle
- Birefringence of the Universe
- **Anisotropic cosmological expansion**
- …

[V.P. & Cudell 2014 ; V.P. 2014]

- ✔ Confirmation of alignments with new and statistically independent methods
- ✔ Confirmation of redshift dependence but with no smooth and continuous rotation as suggested before

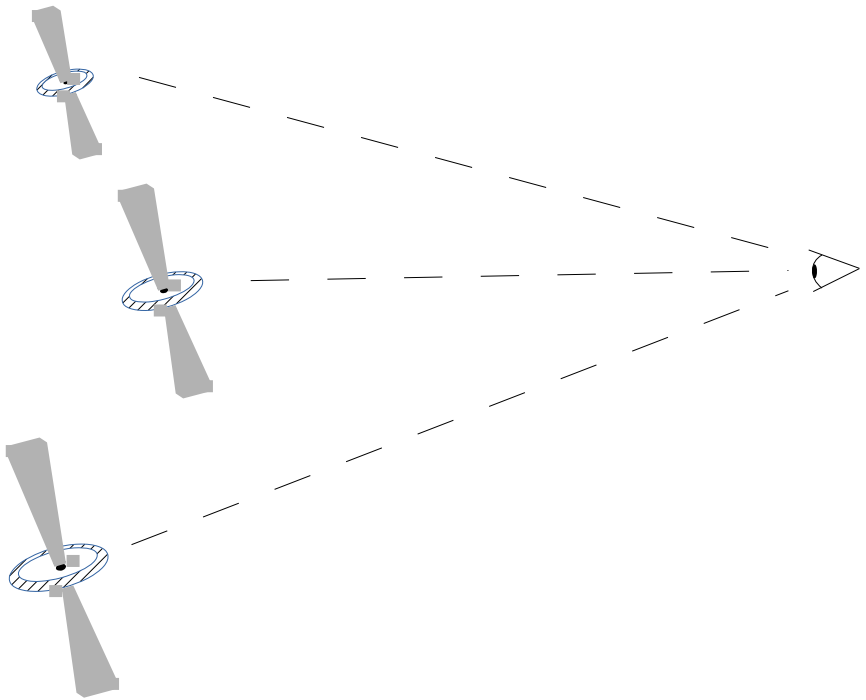
[V.P. 2018]

- ✔ Robustness of alignments regarding interstellar polarization contamination evaluated from *Planck* map
- ✔ But contamination is detected for ~ 30% of the sample

Quasars and extreme-scale correlations

Extreme-scale alignments of quasar optical polarization vectors

What can cause the polarization alignments ?



- Photon path effects
  - Modulation of the polarization state
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Quasars and extreme-scale correlations

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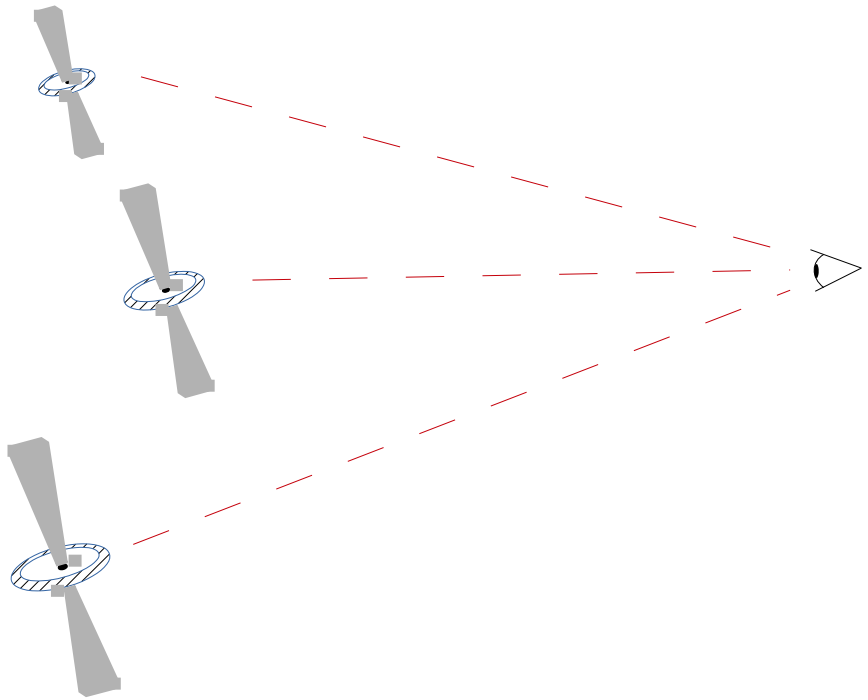

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Random — — — —?— — — —► Aligned

Quasars and extreme-scale correlations

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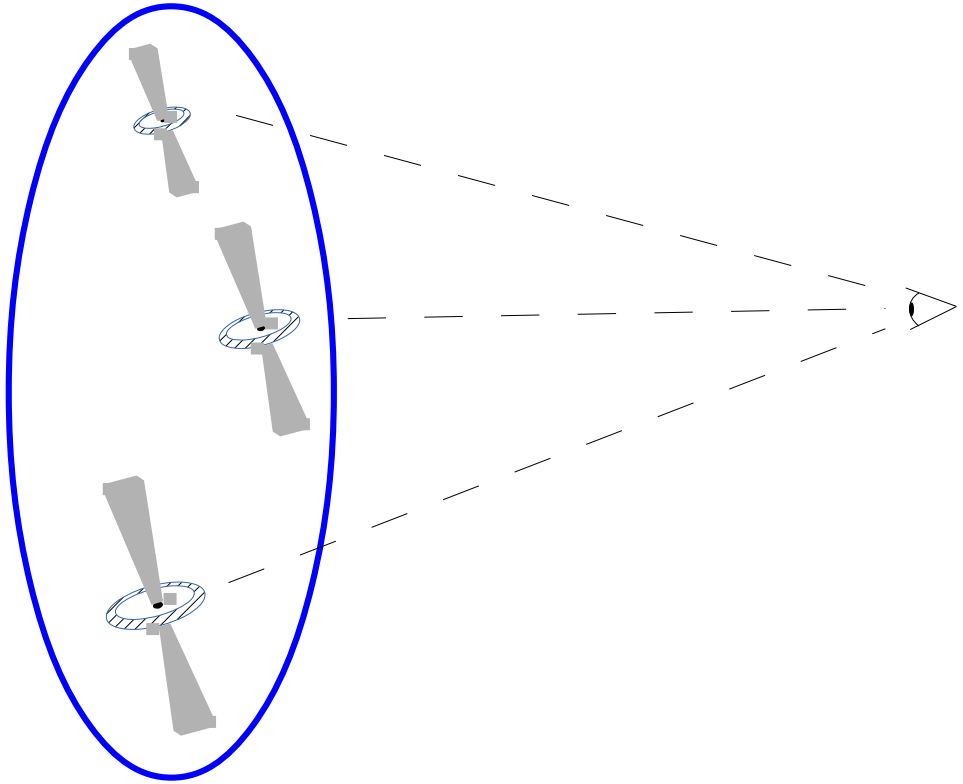

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Aligned — — — — — — — —► Aligned

?

Quasars and extreme-scale correlations

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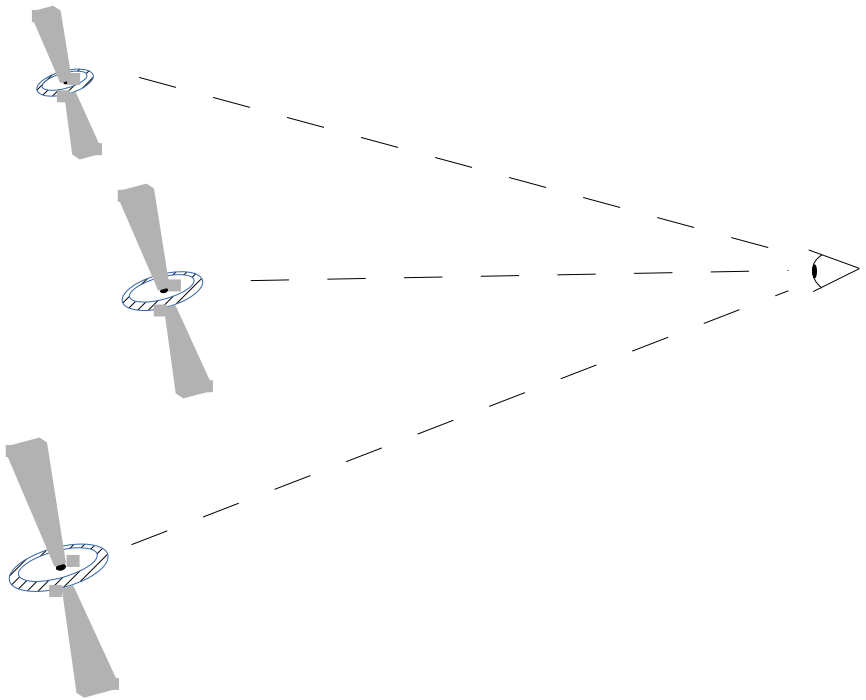

- Photon path effects
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These scenario have different observational signatures

Wavelength dependence of the alignments ?

Quasars and extreme-scale correlations

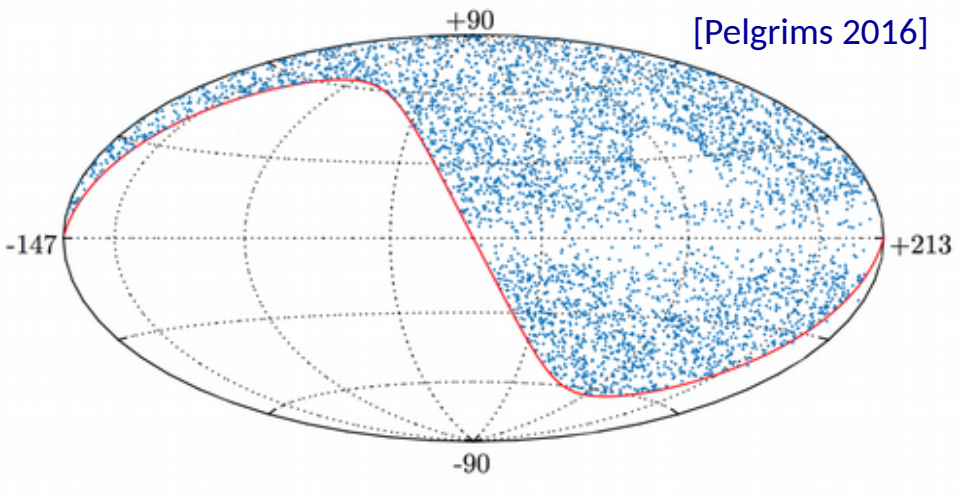
Quasar polarization alignments in JVAS/CLASS 8.4 GHz surveys

Based on JVAS/CLASS 8.4-GHz surveys
[Jackson et al. 2007]

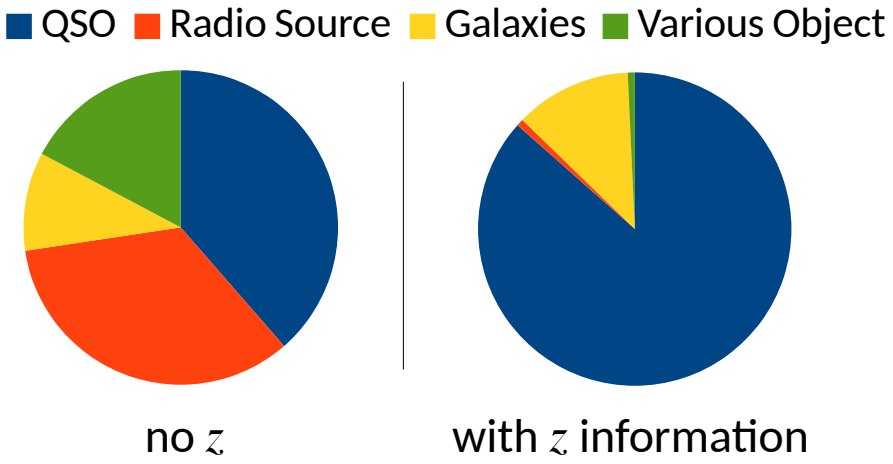
- Situation unclear from previous studies
  [Joshi et al. 2007 ; Tiwari & Jain 2013 ; Shurtleff 2014]
- Lack of consideration of the intrinsic properties of the sources (redshift, type, ...)

[V.P. & Hutsemékers 2015]

- Clear identification of 4155 Flat Spectrum Radio Sources with reliable polarization measurements
  (f_{pol} > 1 mJy ; $\sigma_\psi \leq 14°$)
- Nasa Extragalactic Database
  → redshift for 1531 sources
  → Classification in Object Types



[Pelgrims 2016]



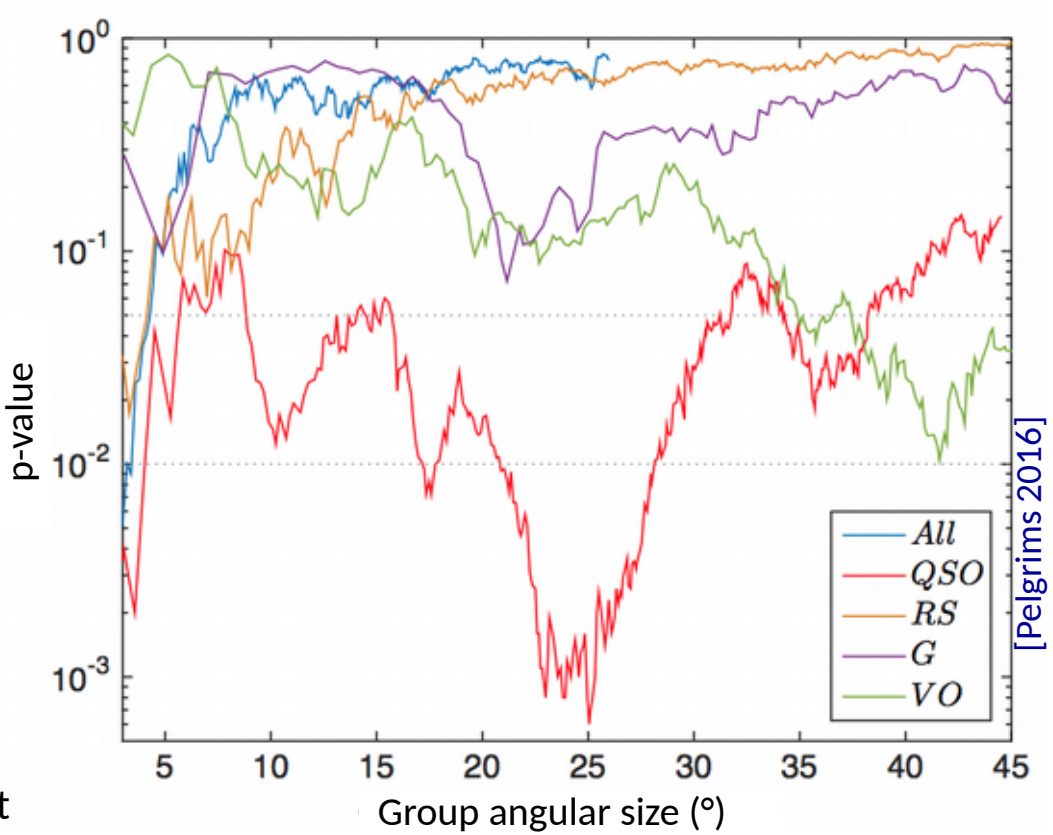
Quasars and extreme-scale correlations

Quasar polarization alignments in JVAS/CLASS 8.4 GHz surveys

[V.P. & Hutsemékers 2015]

- Evidence for alignment in one of the region of optical pol. alignment (~3σ)
- Stat. significant alignment features within the whole sample

  Dedicated global statistical tests:
  - comparison of polarizations in groups of nearest neighbors and averaged with the whole sample
  - 10^4 Monte Carlo simulations for random distribution
  - For any given size of groups of neighboring sources



→ 2D analysis with no restriction on the redshift

→ For a wide range of size of groups of neighboring sources

→ For all subsamples at hand

Quasars and extreme-scale correlations

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[V.P. & Hutsemékers 2015]

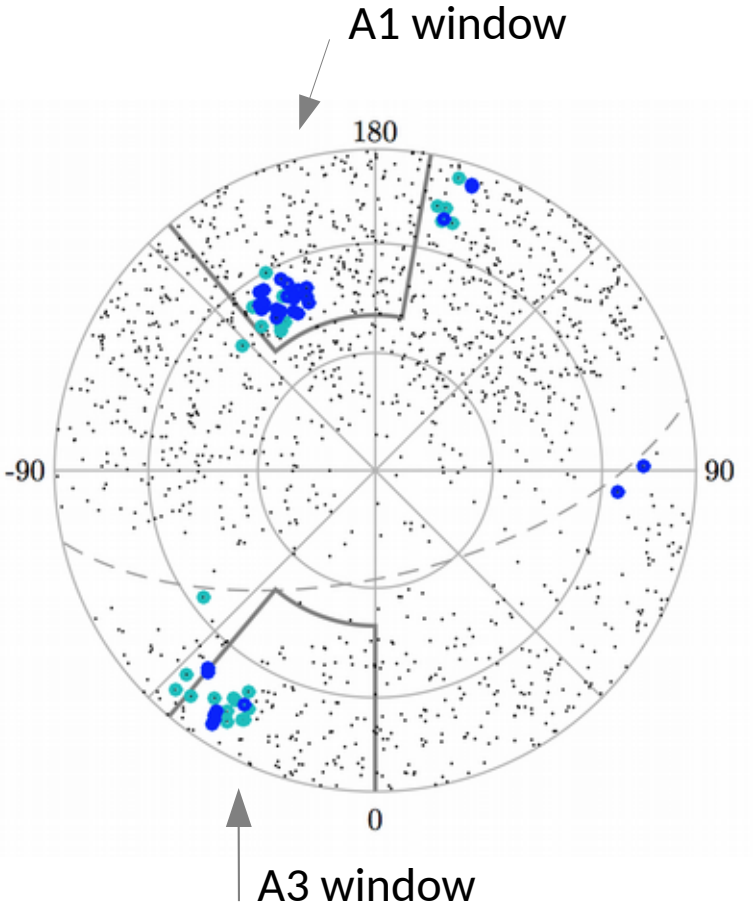
- Evidence for alignment in one of the region of optical pol. alignment (~3σ)
- Stat. significant alignment features within the whole sample

  Only for quasars!

- Identification of aligned groups

  clustered towards regions where quasar polarization vectors are aligned at optical wavelengths!

(A1 is roughly towards the same direction of the alignment of the CMB di.quadru.octo pole moments)



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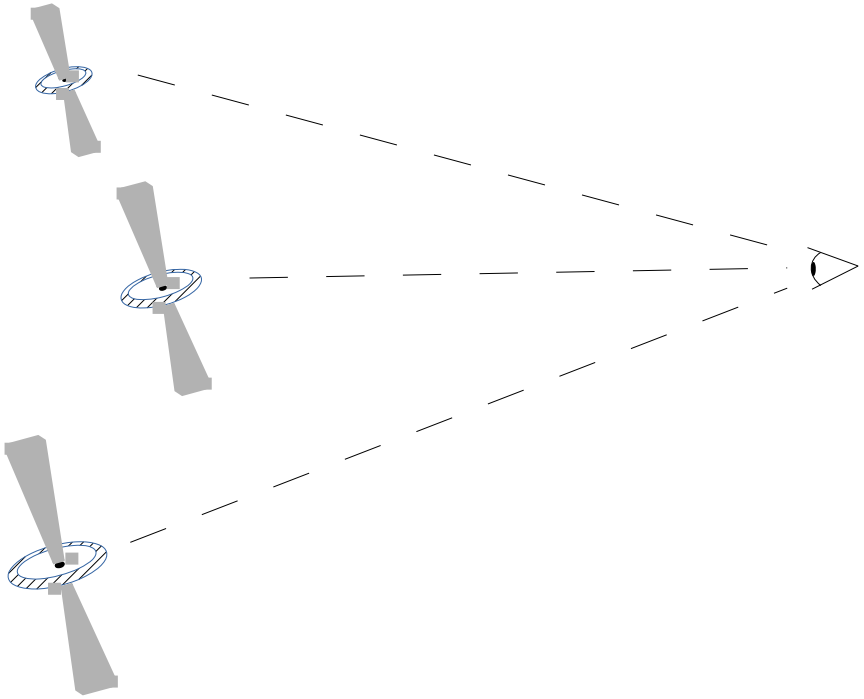

Radio wavelengths

- Photon path effects
  - Modulation of the polarization state
  - Asymptotic rotation of the polarization vectors
- Structural axis alignment

Quasars and extreme-scale correlations

Quasar polarization alignments: radio vs visible

Radio wavelengths

- Photon path effects
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Optical wavelengths

- Photon path effects
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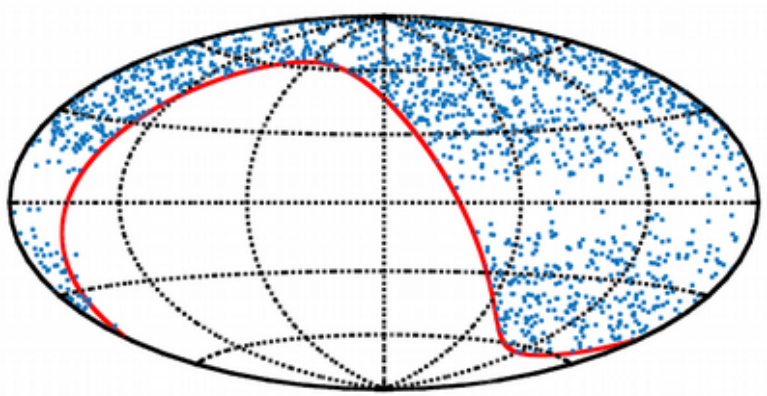
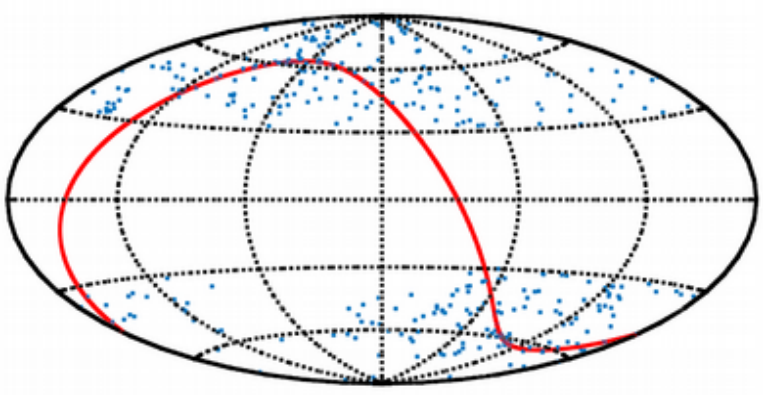
- Structural axis alignment

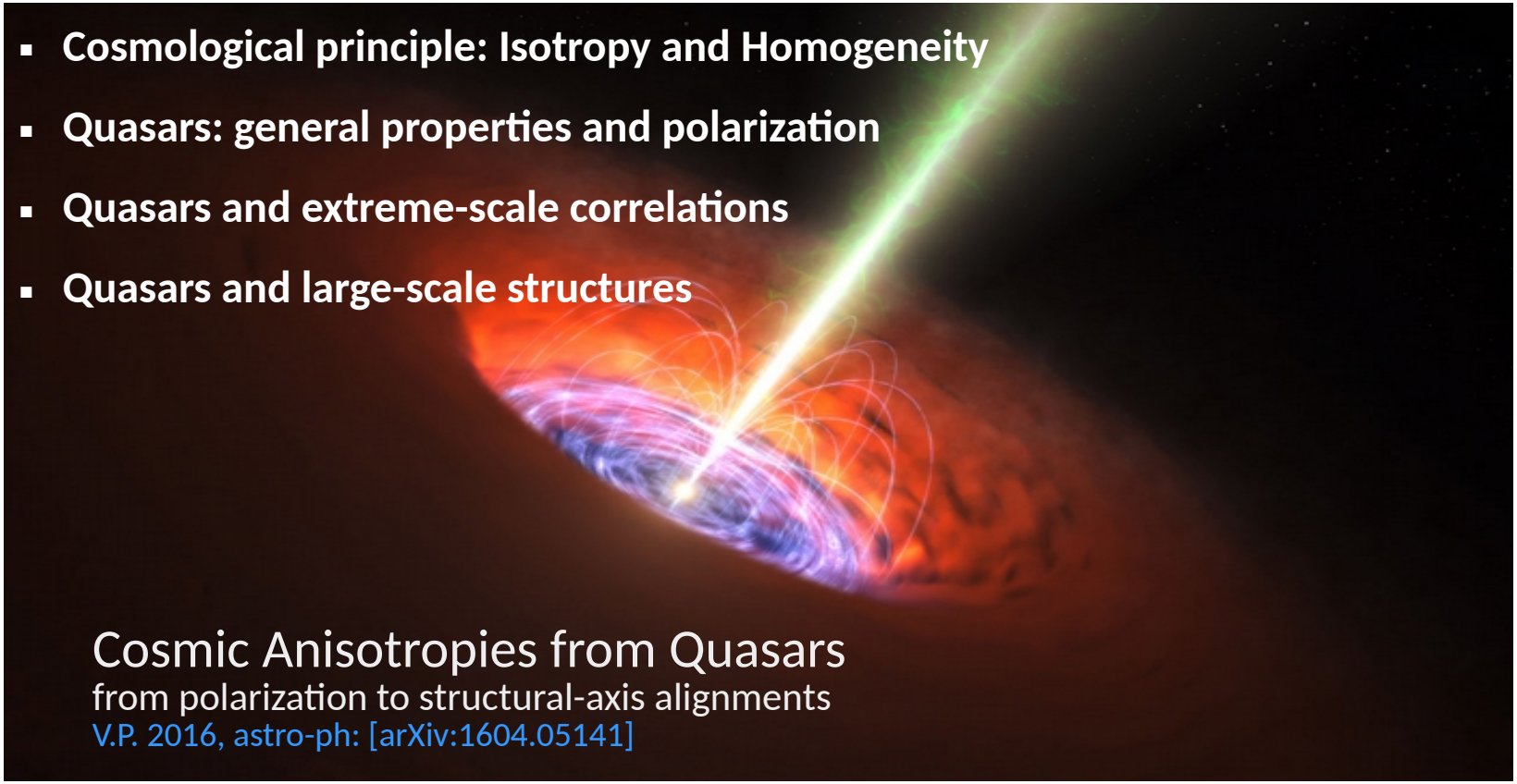
?!?



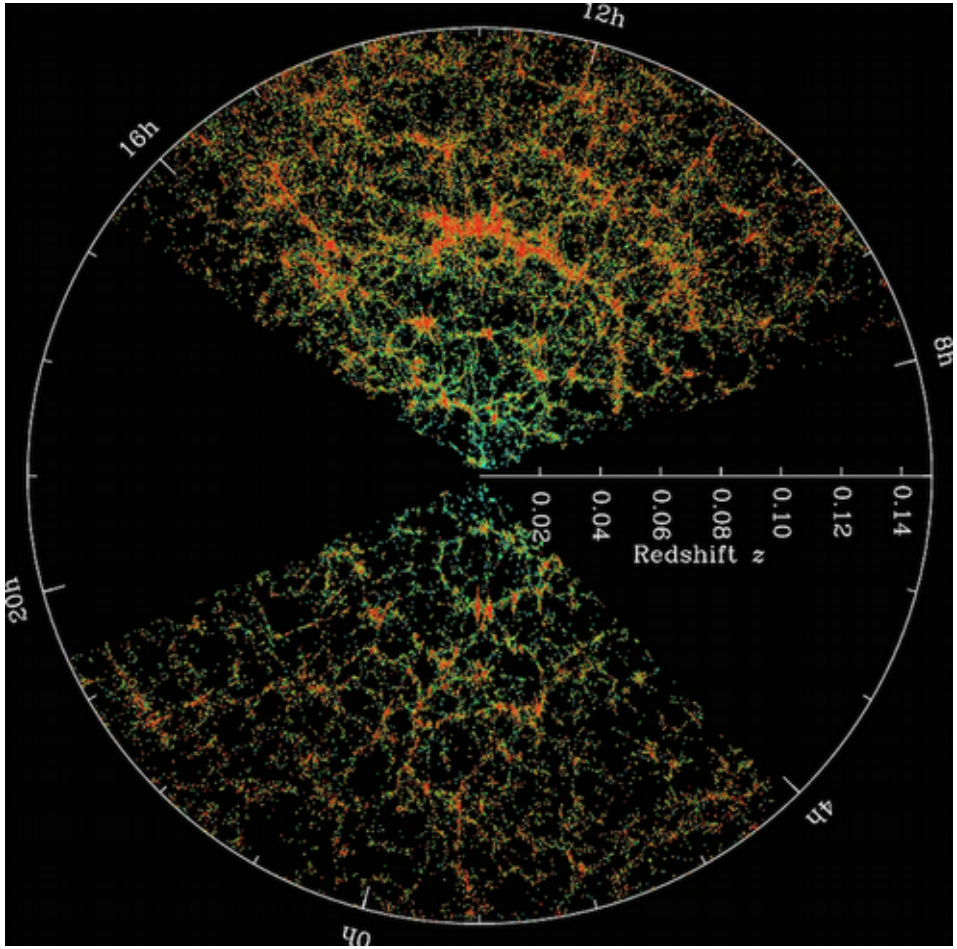


Quasars and Cosmology

Large-scale alignments of quasar polarization vectors



Quasars and large-scale structures

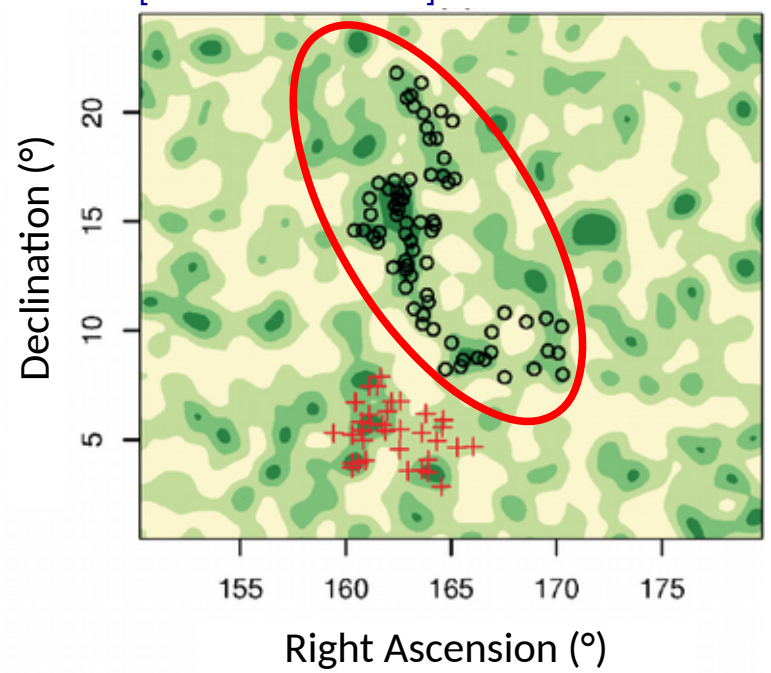


[SDSS Galaxies] a slice of our neighborhood

Quasars and large-scale structures

[Clowes et al. 2013] → discovery of a big inhomogeneity in the quasar distribution
the Huge-LQG, next to the CCLQG

[Clowes et al. 2013]



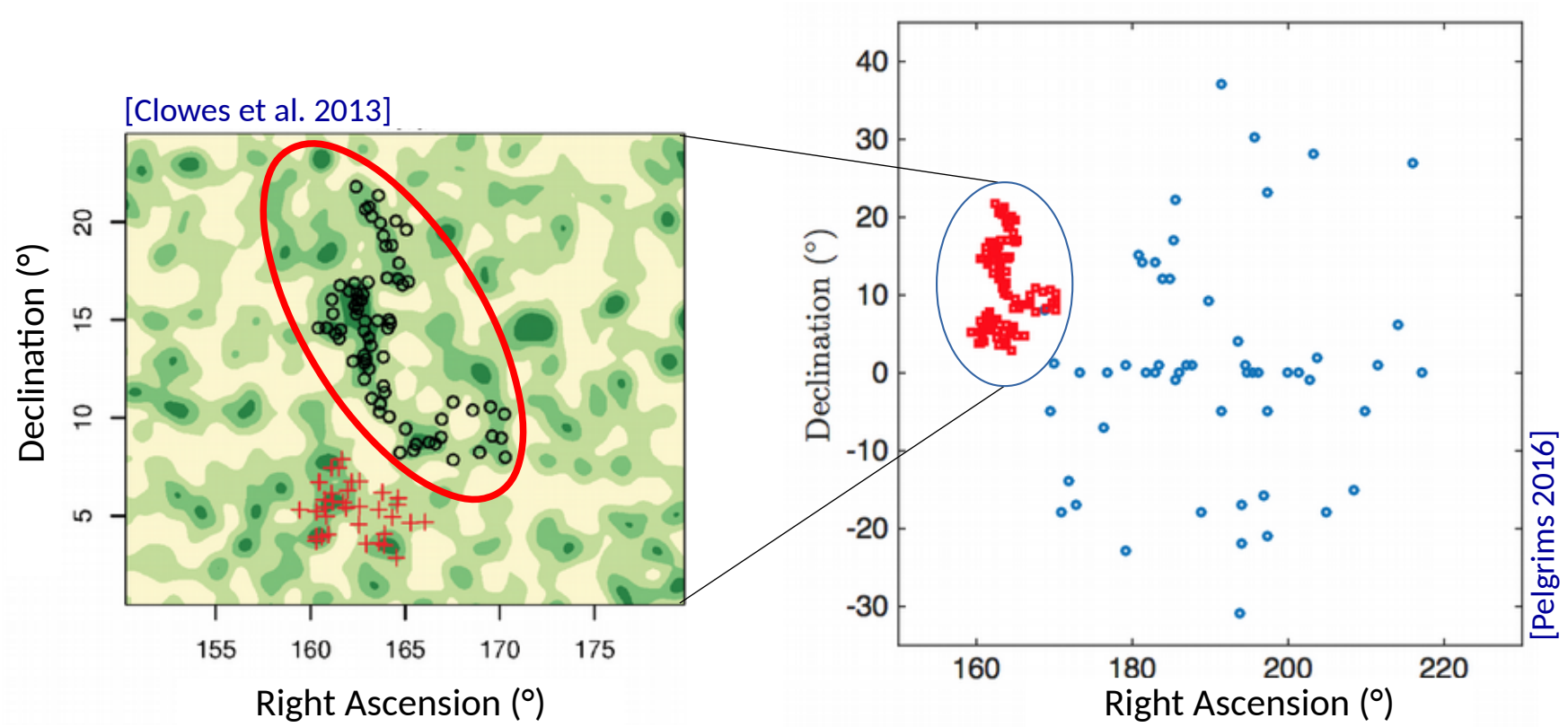
Huge-LQG

- z ~ 1.3
- 73 quasars
- elongation ~ 1 Gpc !

much bigger than the homogeneity scale of the Universe …
A problem that has finally been solved:
[see: Nadathur 2013 ; Einasto et al. 2014 ; Parkes et al. 2015 and finally [Marinello et al. 2016]

Quasars and large-scale structures

[Clowes et al. 2013] → discovery of a big inhomogeneity in the quasar distribution
the Huge-LQG, next to the CCLQG



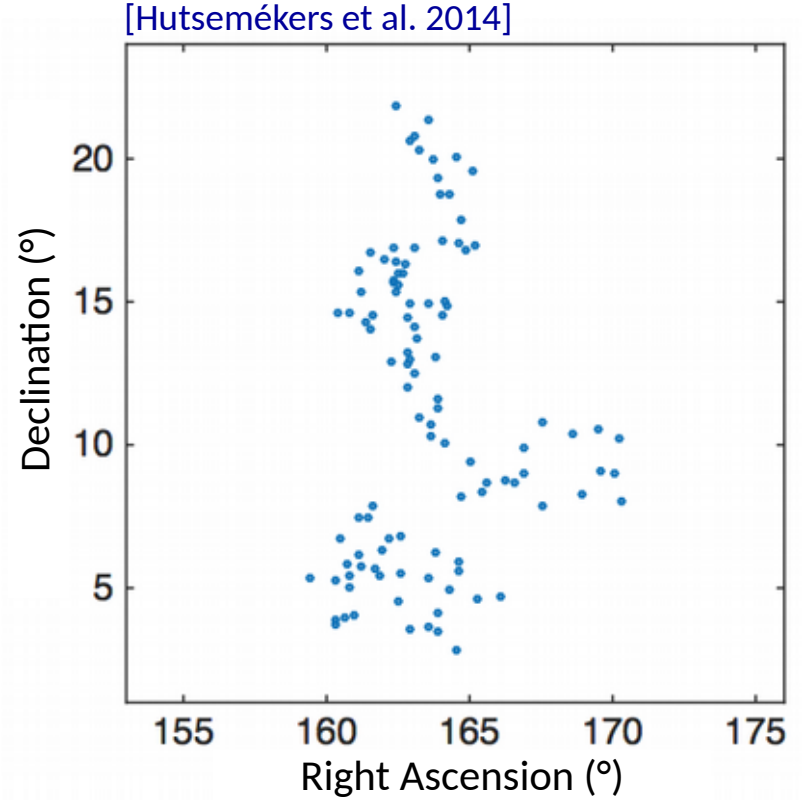
The Huge-LQG (and the CCLQG) is at the outskirt (3D) of one of
the regions of optical polarization alignments of quasars

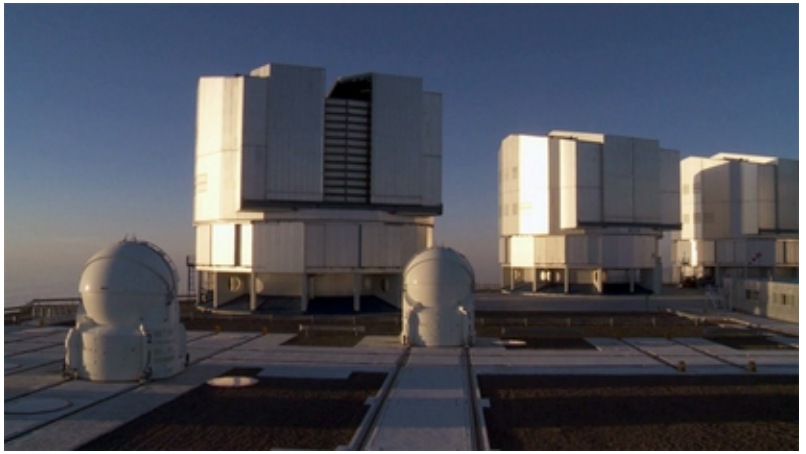
Quasars and large-scale structures

[Hutsemékers, Braibant, V.P., Sluse 2014]

- Polarization in the Huge-LQG and CCLQG

[Hutsemékers et al. 2014]



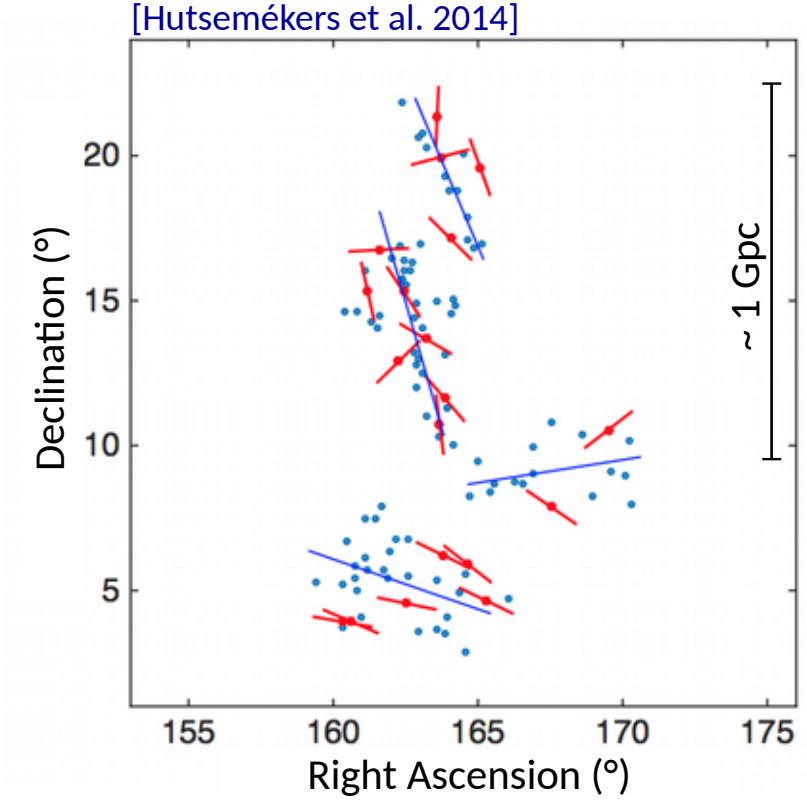


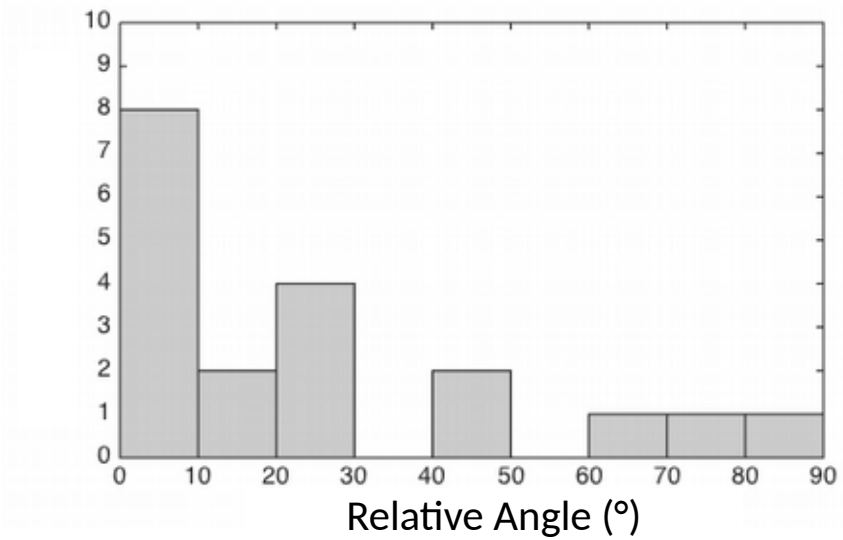
Quasars and large-scale structures

[Hutsemékers, Braibant, V.P., Sluse 2014]

- Polarization in the Huge-LQG and CCLQG

[Hutsemékers et al. 2014]



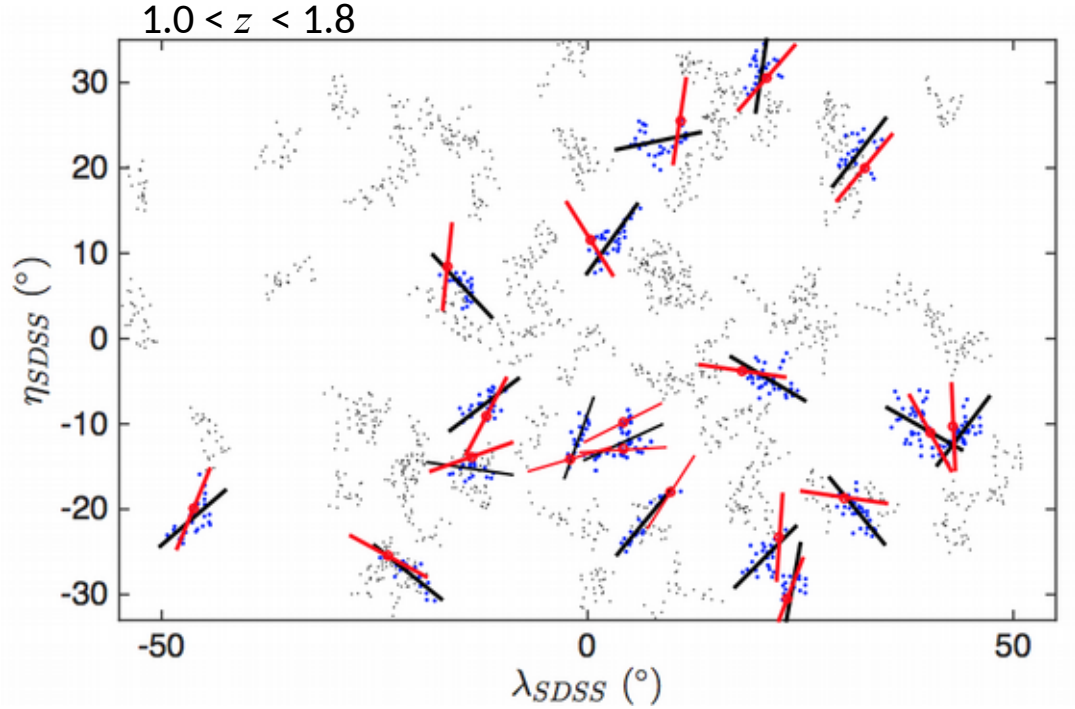


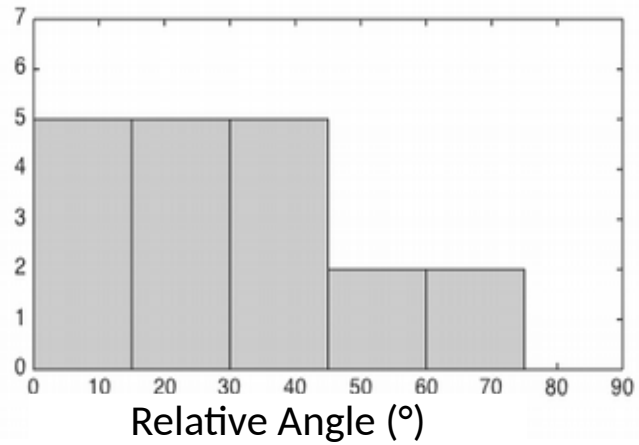
Quasar spin-axes align with
the large-scale structures at
z ~ 1.3 and over cosmological scales !

Quasars and large-scale structures

[V.P. & Hutsemékers 2016]

- Radio polarization in a large LQG sample
- Polarization (synchrotron) is preferentially $\perp$ to quasar spin axis [Joshi et al. 2007]





Quasar spin-axes preferentially parallel to the major axes of rich large quasar groups at *high redshifts* and *over large scales* !

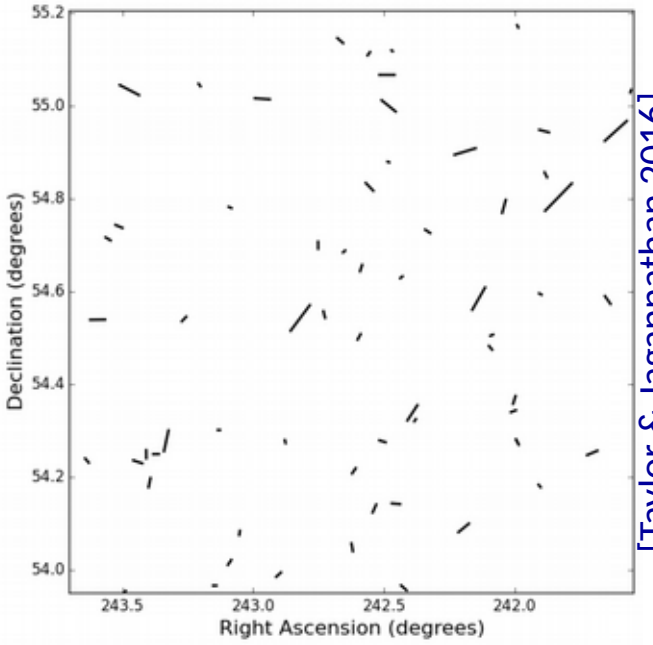
Quasars and large-scale structures

[Hutsemékers, Braibant, V.P., Sluse 2014 ; V.P. & Hutsemékers 2016]

- Made use of optical and radio polarization of quasars to infer their spin axes at *high redshift*
- Show quasar spin-axes correlate to the major axes of their host LQG

Corroborated by

- degree scale radio-jet axis correlations
  - [Taylor & Jagannathan 2016]
    → alignments in 1.4 deg^2 ELAIS N1 field
  - [Contigiani et al. 2017]
    → alignments at scale 1.5–2.5 deg in 7000 deg^2 FIRST+RadioGalaxyZoo sample (30 059 sources)
- degree scale radio-polarization correlations
  - [V.P. & Hutsemékers 2015]
    → alignments < 5 deg found in JVAS/CLASS 8.4GHz



[Taylor & Jagannathan 2016]

Explained through coevolution of galaxy spin axes within the cosmic web ?

Involved scales seem too large …

Take away

Quasar polarization alignments

There are evidences for extreme-scale alignments of the polarization of quasars when measured at optical and at radio wavelengths

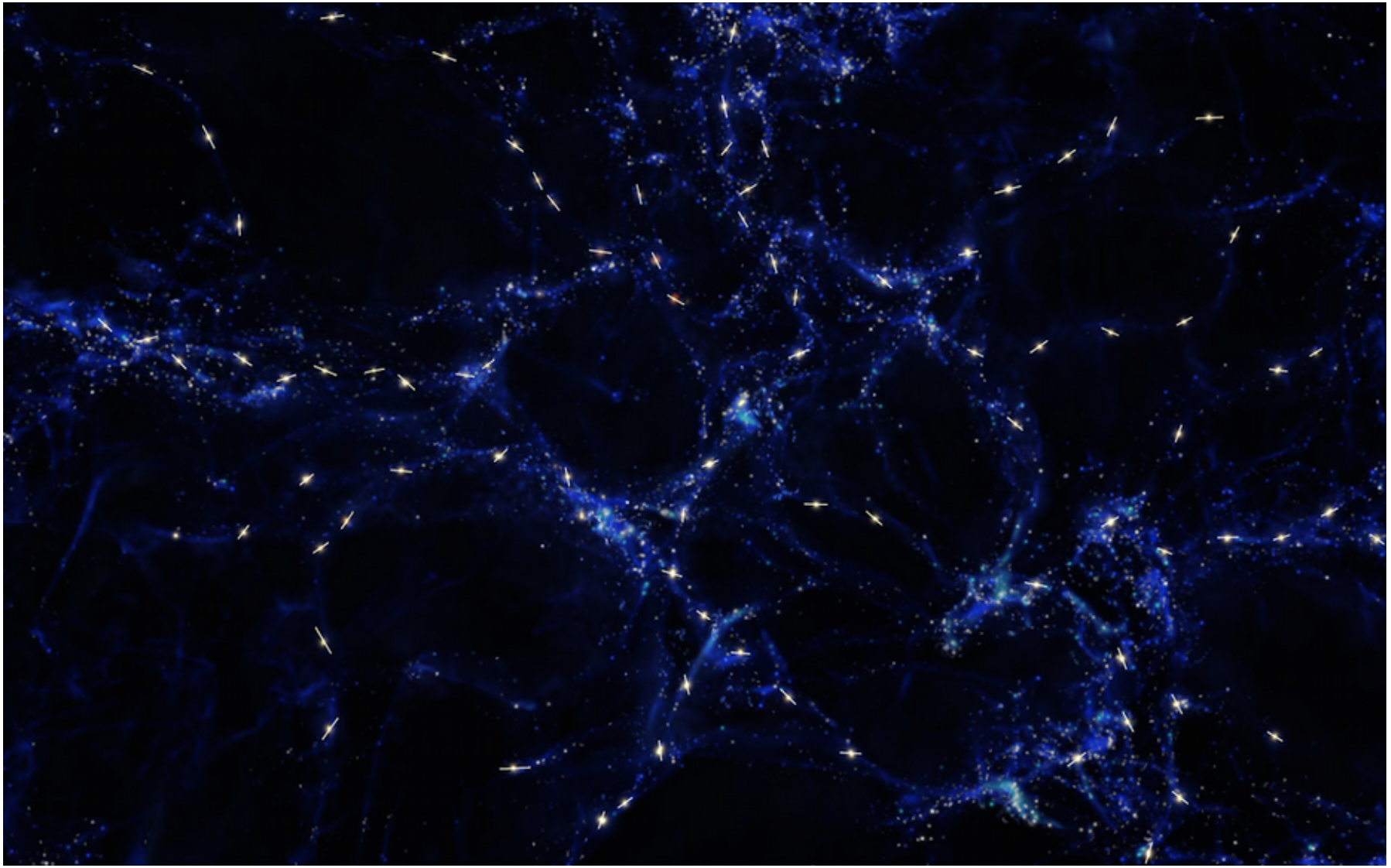
- Origin is still to be found
- Could indicate departure from isotropy of the Universe given the characteristic size of the correlation
- Difference between optical and radio signatures needs to be clarified

The large-scale correlation of quasar spin axes with and within large quasar groups

- Could be due to coevolution of black hole spins in LSS
- Typical size involved are way larger than expected
  → large-scale *intrinsic alignments* of galaxies ???

If true…

the two types of alignments could find the same origin assuming anisotropy in large-scale structure orientations



[Artist view of the “spooky” alignment Credit: ESO/M. Kornmesser]

Thank you

BACKUP