*Curriculum Vitae* *Hum Chand*


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## *Academic History*

- **Present Position:** *Research Scholar*, IUCAA, Pune, India; *August 2001 to till date*
- **Ph. D :** IUCAA, University of Pune, Pune; *submission June, 2006.*
  **Title:** *Probing the Universe Using Absorption Lines Seen in the Spectra of Quasars.*
  **Supervisor:** *Prof. R. Srianand*
- **Master of Science:** *Physics*; In *First division*, from H.P University Shimla, *India, 1998-2000.*
- **Bachelor of Science:** *Physics*; In *First division*, from Govt. Degree College Karsog, *Himachal Pradesh, India, 1995-98.*

## *Awards and Distinctions*

- 2001: 2 year Junior Research Fellowship and 3 year Senior Research Fellowship awarded by Council of Scientific and Industrial Research (CSIR) Govt. of India.
- 2001: Qualify the all-India Joint Entrance Screening Test (JEST) with a percentile of 98.6, for admission to premier research institutes in India.

## *Main Research Interests*

- Probing the cosmological variation of fundamental constant, using QSOs absorption lines.
- To study the extra-galactic UV-radiation field and proximity effect around the QSOs
- Structure formation, semi-analytical modeling of IGM.
- Reionisation and the thermal history of universe.

# Cumulative list of publications

- *On the variation of fine-structure constant: Very high resolution HARPS spectrum of QSO HE 0515-4414*
  **Chand, H.**, Srianand, R., Petitjean, P. Aracil, B. Quast, R. Reimers, D.
  *Status:A&A in press* ; astro-ph/0601194

- *Probing the time-variation of the fine-structure constant: Results based on Si IV doublets from a UVES sample*
  **Chand, H.**; Petitjean, P; Srianand, R.; Aracil, B.
  A&A 430,47-58 (2005); astro-ph/0408200

- *The density structure around quasars from optical depth statistics*
  Rollinde,E.; Srianand, R.; T. Thenus, Petitjean, P.; **Chand, H.** *MNRAS 361, 1015-1029 (2005).*; astro-ph/0502284.

- *A new constraint on the time dependence of the proton-to-electron mass ratio. Analysis of the Q 0347-383 and Q 0405-443 spectra*
  Ivanchik, A.; Petitjean, P.; Varshalovich, D.; Aracil, B.; Srianand, R.; **Chand, H.**; Ledoux, C.; Boiss, P.
  *A&A 440, 45-52 (2005)*

- *Probing the cosmological variation of the fine-structure constant: Results based on VLT-UVES sample*
  **Chand, H.**, Srianand, R., Petitjean, P., Aracil, B.
  A&A,417,853-871 (2004); astro-ph/0401094

- *Limits on the Time Variation of the Electromagnetic Fine-Structure Constant in the Low Energy Limit from Absorption Lines in the Spectra of Distant Quasars*
  Srianand, R.; **Chand, H.**; Petitjean, P.; Aracil, B.
  PRL, 92, 121302 (2004); astro-ph/0402177

- *Time dependence of the proton-to-electron mass ratio*
  Patrick Petitjean, A. Ivanchik, Raghunathan Srianand , B. Aracil, D. Varshalovich ,**H. Chand**, Esther Rodriguez, C. Ledoux, Patrick Boiss
  *C. R. Physique 5, 411-415 (2004)*

- *Constraining the Time Variation of the Fine Structure Constant*
  Raghunathan Srianand, Patrick Petitjean, **Hum Chand**, Bastien Aracil
  *ESO Messenger N0-116 25-28 (2004)*

- *The Large Programme "Cosmic Evolution of the IGM"*
  J. Bergeron, P. Petitjean, B. Aracil, C. Pichon, E. Scannapieco, R. Srianand, P. Boisse, R. F. Carswell, **H. Chand**, S. Cristiani, A. Ferrara, M. Haehnelt, A. Hughes, T.-S Kim C. Ledoux, P. Richter, M. Viel
  *ESO Messenger N0-118, 40-44 (2004)*

# Paper(s) in preparation

- *Probing the density structure around QSOs and the physical state of IGM, using transverse proximity effect.*
  *Status: In preparation*

## *Short-term Projects*

- *Analytical model for Quasar luminosity and correlation function*; IUCAA, topical course, 2005
- *On the variation of fine-structure constant: New template method*; IUCAA graduate school project, 2002.

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## *Observing Experiences*

- **Three night** of observation using **UVES/VLT** at European Southern Observatory (ESO) - Paranal, *October 2004.*
- **Four night** of observation using **HARPS** at 3.6m telescope of European Southern Observatory (ESO) - La Silla, *December 2003.*
- **Two days** of radio observation using **GMRT** at Narayangoan, Pune *June, 2003*

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## *Computational Skill*

- Operating System — **Linux**, Unix, Solaris, Windows
- Programming Languages — **IDL**, Fortran77, C
- Scientific Computing — **Mathematica**, Maple
- Data Reduction — **MIDAS**, IRAF, IDL

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## *Teaching Experience*

- *Teaching assistant* for the graduate school course on **Inter Stellar Medium (ISM)** at IUCAA, Pune, March 2003.

## *School Workshop and Conferences*

- **IAU Colloquium 199 : Probing Galaxies Through QSO Absorption Line:** Shanghai Astronomical Observatory, Shanghai, China.
  *March, 14th to 18th, 2005.*
- **23$^{rd}$ Astronomical Society of India (ASI) Meeting:** ARIES, Nainital, INDIA.
  *21 - 24 Feb, 2005.*

- **Workshop on Supernovae and their connection to GRBs and pulsars:** Tata Institute of Fundamental Research, Mumbai 400 005, India.
*January, 20th to 23th, 2004.*

- **School on Radio Interferometry and Aperture Synthesis:** National Center for Radio Astronomy, Pune 411 007, India.
*June, 2-22, 2003.*

- **Symposium on Provocative Universe:** Pune, 411007 India, July 2003.

- **IUCAA-IfA (Hawaii) Workshop on Cosmology and High Redshift Universe,** Pune-411007, India, February, 2003.

- **The 22nd Meeting of the Indian Association for General Relativity and Gravitation,** IUCAA, Pune, December, 2002.

- **Annual Meet of the Astronomical Society of India,** Pune-411007, India, February 2002.

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## Talks and Presentations

- Talk presented: **Results on the variation of fine-structure constant, $\alpha = e^2/\hbar c$, based on UVES/VLT data sample,** *IUCAA SAC meeting, Pune, January, 2006*

- Poster presented: **On the variation of the fine-structure constant, using QSOs absorption lines,** at *IAU Colloquium 199, Shanghai, March, 2005.*

- Talk presented: **Does fine-structure constant vary ?**, at $23^{rd}$ ASI meeting, Nainital, India, February 2005

- Informal Discussion Group: **The Transverse Proximity Effect: A Probe to the Environment, Anisotropy, and Megayear Variability of QSOs,** November, 2004

# Research Proposal

## Probing the physical state of the IGM: tool of cosmology

There are at least two key cosmological questions for which QSOs absorption lines are key to the solution: UV-radiation field of the IGM and the constancy of dimensionless fundamental constant such as fine-structure constant($\alpha = e^2/\hbar c$) and ratio of electron and proton mass. The first is important to understand the physical condition of the IGM and the second is important for our basic knowledge of fundamental physics. Both require the use of ground based telescopes combined with SDSS/HST archival data.

Some of the unification theories such as SUSY GUT and Super-string theory suggest the possibility of the variation of the fine-structure constant, thus motivating an experimental search for such a variation. Such possible variation of $\alpha$ will also have tremendous consequence on our present understanding of cosmology, fine-structure constant being coupling constant between matter and radiation interaction. Quasar absorption lines serve as an important tool to test its variation as they allow one to measure its value at different redshift or look back time of around Gyrs.

On the other hand, the background mean UV-radiation field ($J_{21}$) plays important role in computing the elemental abundance and $\Omega_b$ along with the ionization state of the IGM. For instance, the origin of the elements: abundances of C and Si determined from IGM absorption lines can, in principle, help to define the origin of the first heavy elements, as being pre-galactic or post-galactic. For instance, C IV is observed in high z galaxies as well as in conjunction with the low density regions of Lyman-$\alpha$ forest lines. High quality QSOs spectra using 10m class telescope has made numerous, good determinations of the key absorption lines, but they are hard to interpret because of the lack of agreed upon knowledge of the $J_{21}$ and its dependence on redshift, in intergalactic space (Scott et al. 2000).

**1. Constraining mean UV-radiation field ($J_{21}$):** One independent way to measure $J_{21}$ is based on the proximity effect. This effect is the measure of the relative enhancement of the ionizing flux due to the local ionizing source (say QSO) compared to the $J_{21}$. Therefore by knowing the luminosity of the local ionizing source the value of $J_{21}$ can be statistically estimated (Bajtick el al. 1988). Such standard analysis of the proximity effect assumes that the density field of the QSOs is same as that of the normal IGM. This may not be a reasonable assumption in view of the recent studies showing evidence of excess clustering (Hennawi et al 2005). Schirber et al. (2004) have also found excess absorption in the spectrum of background QSOs around the region of ionizing foreground QSOs contrary to the expectation based on standard transverse proximity effect. Rollinde et al. (2005) have also shown explicitly that the standard analysis of proximity effect in the measurement of $J_{21}$ is degenerate with the density structure around the QSOs. Therefore in proximity effect analysis one should not completely ignore the effect of possible density structure around the ionizing source, while constraining the $J_{21}$ value, which form our first immediate objective.

The degeneracy between $J_{21}$ and density structure can be lifted by performing the analysis of proximity effect in different luminosity bins. The determination from high luminosity QSOs sample will be least affected by the density structure, while its effect will be dominant for the case of low luminosity QSOs. As a result the former can be used to better constrain the $J_{21}$ and then the latter one will allow to constrain the density structure. For this purpose we would like to make use of SDSS and HST data sets. The preliminary search using SDSS-DR3 listed a sample of around 100 QSOs pairs with separation of less then 3 arc minutes and redshift difference such that the foreground QSOs fall between the Lyman-$\beta$ and Lyman-$\alpha$ emission line of the background QSOs, as is required for the study of transverse proximity effect. The inclusion of SDSS-DR4 will enable to enhance the sample of such pairs by a factor of about 2-3, in order to do the good statistics in many luminosity and redshift bins. The pixel optical depth statistical method (Rollinde et al. 2005) will be very efficient for the analysis of such a large sample (see Figure 1). As we know from QSOs luminosity function that the probability of finding the faint QSOs along any sight line is larger, therefore we expect to find the faint QSOs around the line of sight of bright QSOs even with smaller angular separation, which will be more suitable for the study of transverse proximity effect. We will carry such search first by using the available photometric redshift data of faint QSOs and then propose the ground based observation using a larger telescope for spectroscopic confirmation of their redshift. The detailed analysis of such a large sample will also allow us to study the anisotropic emission (or life time) of QSOs beside constraining the measurements of $J_{21}$ and the density structure.

2 **Variation of fine-structure constant:** At present, the only theory that treats gravity and quantum mechanics in a consistent way is string theory. In the low energy limit, string theory reduces to general relativity with an important difference that string theory predicts the existence of a new interaction messenger (a four-dimensional scalar partner of the tensor Einstein graviton) called the dilaton. If the latter has a mass, then there is no macroscopic difference between string gravity and Einstein gravity. If the graviton remains massless however, all coupling constants and masses of elementary particles should be space and time dependent (see e.g. Chodos & Detweiler 1980; Damour & Polyakov 1994). Current laboratory constraints exclude any significant variation of the constants in the low-energy regime. However the variation over the cosmological time scale is not excluded. Savedoff (1956) first pointed out the possibility of using red-shifted atomic lines from distant objects to test the evolution of dimensionless physical constants such as fine-structure constant and proton to electron mass ratios.

The cosmological time variation of the fine-structure constant, $\alpha = e^2/\hbar c$, can be probed by measuring the separation in wavelength of two lines of the same doublet at different redshift. For instance, if $\lambda_1$ and $\lambda_2$ are the two wavelengths, of an alkali doublet then $(\lambda_1 - \lambda_2)/\bar{\lambda} \propto \alpha^2$. This method is commonly known as alkali-doublet (AD) method. Bahcall et al. (1967) were the first to apply AD-method to constrain the variation of $\alpha$ using alkali-doublets seen in QSO spectra. Since then several authors have used the alkali-doublet method (AD-method) to constrain the variation of $\alpha$. Recently Dzuba et al. (1999) have developed a new method called many multiplet method (MM-method), which is shown to improve the $\Delta\alpha/\alpha$ measurement by an order of magnitude compared to AD-method (Murphy et al. 2003). But unlike AD-method this method uses absolute wavelength measurements of numerous absorption lines from different species and assumes that they have same velocity structure. The application of MM-method using HIRES/KECK data sample has shown that the value of $\alpha$ was smaller in the past $\Delta\alpha/\alpha = (-0.57 \pm 0.10) \times 10^{-5}$ over the redshift range $0.2 \leq z \leq 3.7$ (Murphy et al. 2003). However our recent detailed study using the UVES/VLT data using a similar kind of method does not support this claim ($\Delta\alpha/\alpha = (-0.06 \pm 0.06) \times 10^{-5}$). In our study, we have used homogeneous and better quality data (S/N better by factor 2) with proper selection criteria. Although such precaution was not considered in the previous study (Murphy et al. 2003), one should consider the discrepancy between the two results seriously.

One of the possible uncertainties in MM-method study is due to its questionable assumption that the velocity structure is the same for different species. Although this is probably not a bad assumption in general especially for singly ionized species, but it is impossible to estimate the exact impact of the assumption on the measurements in this method. Therefore it becomes very important to have precise measurements which do *not* need this assumption.

The obvious choice will be to use only alkali doublets to avoid the above questionable assumption The best candidate among alkali doublets is Si IV, owing to its high sensitivity. The existing strongest constraint from Si IV doublet is $\Delta\alpha/\alpha = (+0.15 \pm 0.43) \times 10^{-5}$ (Chand et al. 2005). Even though this is consistent with no variation found by us, this does not rule out at high confidence level, the result of Murphy et al. (2003) showing the significant variation.

A better possibility is to use the Ni II absorption lines observed in damped Lyman-$\alpha$ (DLA) systems. There are three lines with very different sensitivity coefficients. The rest wavelength of Ni II$\lambda$1709 line is insensitive to minor variations in $\alpha$ thereby providing an anchor to measure the redshift, while the other two lines are very sensitive. Similarly Mn II has six absorption lines. Among them three have rest wavelength around $\lambda \approx$1200 and have opposite sensitivity compare to the other three lines having wavelength around $\lambda \approx$2600 (Dzuba et al. 1999). Our preliminary simulations (Figure 2) have shown that the sample of such sensitive lines consisting of about 15-20 best systems will be good enough to achieve the precision so as to rule out one of the above MM-results. Therefore we propose to make a sample of best Ni II and Mn II based on selection criteria from simulation. We will be using first the existing large data of QSOs (SDSS and HST) to make the sample and then will propose the observation of best candidates using large telescope for better data quality. This will allow us to resolve the issue of $\alpha$ variation beyond doubt.

I would like to carry my research at the Institut d'Astrophysique de Paris (IAP), as I feel that here I will benefit from the collaboration, experience and expertise of many people working in QSOs absorption line studies such as Prof. Patrick Petitjean and others. In addition from here the easy access to ESO telescope and the wealth of existing data gather using unique instruments such as UVES/VLT will also be very helpful for the successful completion of the above propose work, in case I am awarded the PGF post-doc fellowships there.

## Draft budget:

Following is the preliminary estimate of our money budget. For more accurate and realistic estimation/adjustments, we leave it up to the IAU secretariat:

- Livings expenses ≈ 27 000 USD.
- Travel: Scientific conferences and to carry the astronomical observations ≈ 6 900 USD.
- Other research expenses≈ 3 600 USD.

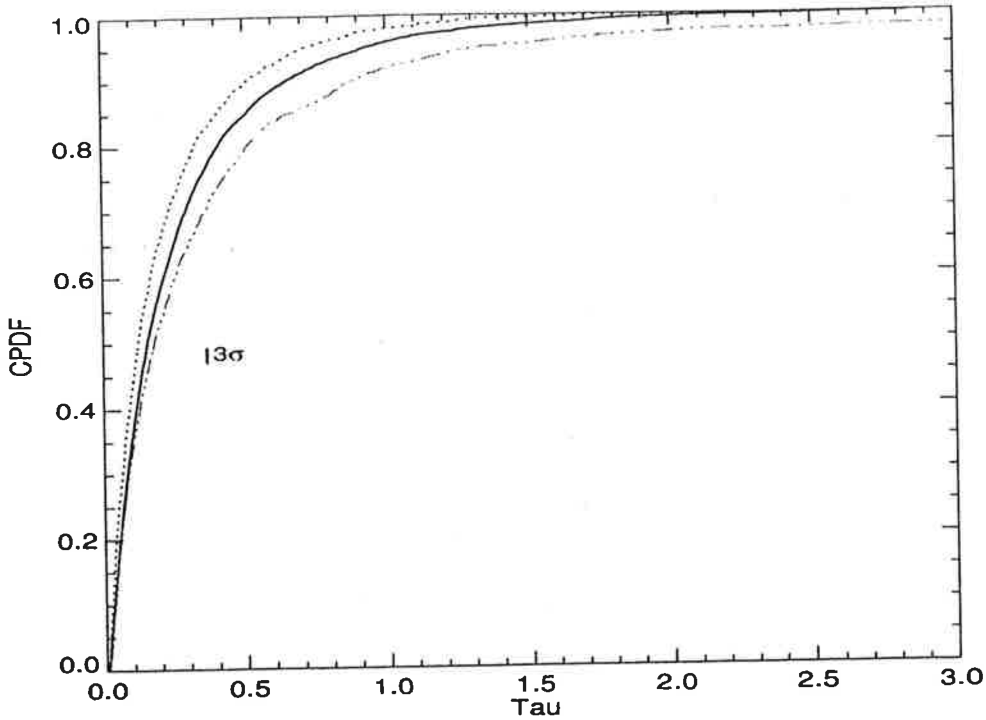


Figure 1: **Preliminary analysis of transverse proximity effect using 28 QOS pairs sample of FORS/VLT.** The solid line shows the cumulative probability distribution function (CPDF) of IGM and dot-dashed line refer to the CPDF obtain using the background QSOs spectra using the spectral region with $R < 10Mpc$(proper) from the foreground QSOs in the pair. The statistical significant departure between the two CPDF give the evidence of expected transverse proximity effect. The doted line refer to the CPDF after correcting for extra ionization by the foreground QSOs using J21 value obtain by using the longitudinal proximity region in the same data set. The disagreement between IGM CPDF (solid line) and the ionization corrected CPDF (dash doted line) in this preliminary analysis show the need for the detail investigation of the issues such as to consider the possible enhanced density around QSOs, anisotropy emission etc.

# References

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[3] Cowie & Songaila, 1995, ApJ 453, 596

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[5] Chand, H.; Petitjean, P; Srianand, R.; Aracil, B. A&A 2005, 430, 47

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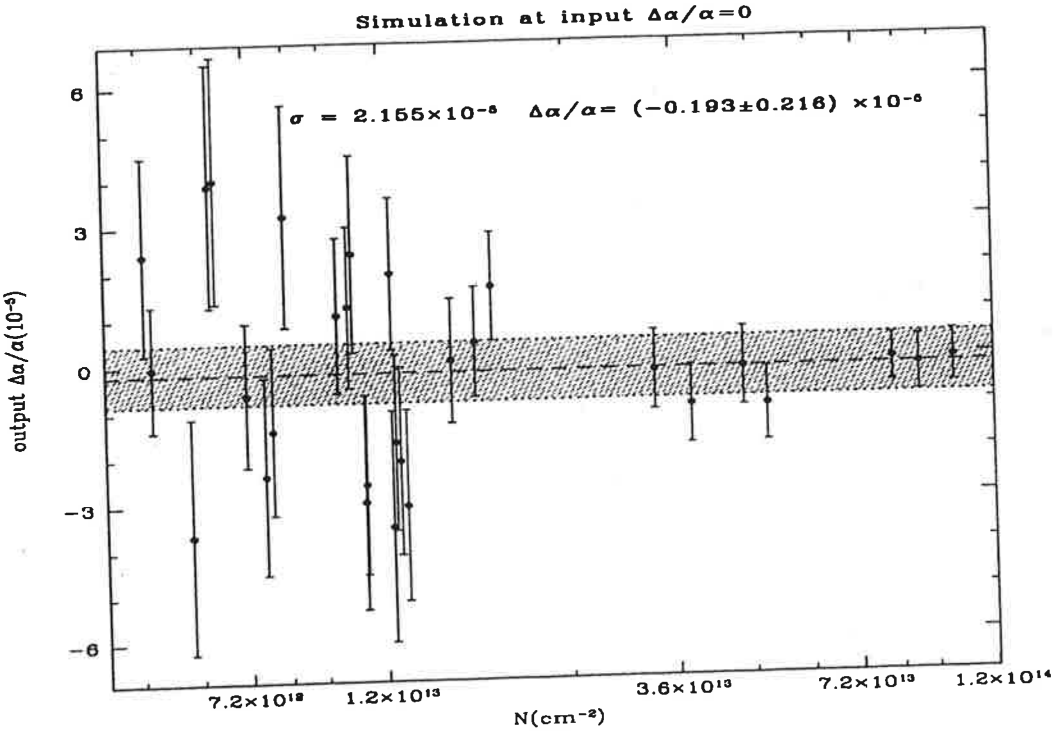


Figure 2: The figure shows the recovered $\Delta\alpha/\alpha$ versus the column density of the simulated Ni II absorption lines. The shadow region correspond to the $3\sigma$ uncertainly. It is clear that when we pick systems with log $N$(Ni II)$\geq$ 13 the uncertainties in the recovered value is low, hence illustrating the requirement of proper selection criteria. This preliminary simulation suggest that a sample of about 10-20 such best systems (e.g log $N$(Ni II)$\geq$ 13) can distinguish between the two contradictory results on $\alpha$ variation published in the literature.