Cosmic strings belong to the basic extremals of the K\"ahler action. The upper bound for string tension of the cosmic strings is $T\simeq .5\times 10^{-6}/G$ and in the same range as the string tension of GUT strings and this makes them very interesting cosmologically although TGD cosmic strings have otherwise practically nothing to do with their GUT counterparts.

\vm{\it 1. Basic ideas}\vm

The understanding of cosmic strings has developed only slowly and has required dramatic modifications of existing views.

\begin{enumerate}

\item Zero energy ontology implies that the energy and all quantum numbers of the Universe vanishes and physical states are zero energy states decomposing into pairs of positive and negative energy states localizable to the light-like boundaries of causal diamonds defined as intersections of future and past directed light-cones. Positive energy ontology is a good approximation under certain assumptions.

\item Dark matter hierarchy whose levels are labeled by gigantic values of gravitational Planck constant associated with dark matter is second essential piece of the picture.

\item The second variation of K\"ahler action vanishes for preferred extremals - at least the second variations associated with dynamical symmetries. This guarantees that Noether currents assignable to the K\"ahler-Dirac action are conserved. The properties of the preferred extremals suggest a dimensional reduction providing formulations of quantum TGD in terms of possibly dual slicings of space-time surface by string word sheets and partonic 2-surfaces. The localization of the modes of the K\"ahler-Dirac equation to 2-D surfaces - string world sheets and possibly partonic

2-surfaces)
suggests something similar although ot might be that both kind
of objects are necessary for a full description.

\item GRT limit of can be understood as an outcome of
the replacement of sheets of the many-sheeted space-time with single
sheet
endowed with effective metric given by the sum of Minkowski metric
and deviations
of the induced metrics of space-time sheets from Minkowski metric.
Gauge
theory limit can be understood in an analogous manner. Equivalence
Principle
in Einsteinian sense follows from Poincare invariance of TGD. The
additional
assumption made before a real understanding of GRT limit was that
the
the most important GRT space-times can be represented as
vacuum extremals of K\"ahler action. This assumption can be of
course questioned.

\item The basic question   whether one can model the exterior
region of
the topologically condensed cosmic string using   General
Relativity. The
exterior metric of the cosmic string corresponds to a small
deformation of
a vacuum extremal assuming the identification of the most important
GRT
space-times as vacuum extremals of K\"ahler action. The
angular defect and surplus associated with the exterior metrics
extremizing
curvature scalar can be much smaller than assuming vacuum Einstein's
equations. The conjecture is that the exterior metric of galactic
string
conforms with the Newtonian intuitions and thus explains the
constant
velocity spectrum of distant stars if one assumes that galaxies are
organized to linear structures along long strings like pearls in a
necklace.
\end{enumerate}

\vm{\it 2. Critical and over-critical cosmologies involve
accelerated
cosmic expansion}\vm

In TGD framework critical and over-critical cosmologies are unique
apart
from single parameter telling their duration and predict the
recently
discovered accelerated cosmic expansion. Critical cosmologies are
naturally
associated with quantum critical phase transitions involving the
change of

gravitational Planck constant. A natural candidate for such a transition is
the increase of the size of a large void as galactic strings have been
driven to its boundary. During the phase transitions connecting two
stationary cosmologies (extremals of curvature scalar) also determined
apart from single parameter, accelerated expansion is predicted to occur.
These transitions are completely analogous to quantum transitions at atomic
level.

The proposed microscopic model predicts that the TGD counterpart of the
quantity $\rho+3p$ for cosmic strings is negative during the phase
transition which implies accelerated expansion. Dark energy is replaced in
TGD framework with dark matter indeed predicted by TGD and its fraction is
.74 as in standard scenario. Cosmological constant thus characterizes
phenomenologically the density of dark matter rather than energy in TGD
Universe.

The sizes of large voids stay constant during stationary periods which
means that also cosmological constant is piecewise constant. p-Adic length
fractality predicts that $\Lambda $ scales as $1/L^2(k)$ as a function of
the p-adic scale characterizing the space-time sheet of void. The order of
magnitude for the recent value of the cosmological constant comes out
correctly. The gravitational energy density described by the cosmological
constant is identifiable as that associated with topologically condensed
cosmic strings and of magnetic flux tubes to which they are gradually
transformed during cosmological evolution.

\vm{\it 3. Cosmic strings and generation of structures}\vm

\begin{enumerate}

\item In zero energy ontology cosmic strings must be created from vacuum
as zero energy states consisting of pairs of strings with opposite

time
orientation and inertial energy.

\item The counterpart of Hawking radiation provides a mechanism by which
cosmic strings can generate ordinary matter. The splitting of cosmic strings followed by a \blockquote{burning} of the string ends provides a second manner
to generate visible matter. Matter-antimatter symmetry would result if
antimatter is inside cosmic strings and matter in the exterior region. A
justification for CP asymmetry comes from basic quantum TGD. One can add to
K\"ahler function of the WCW an imaginary part defined by
instanton term $J\wedge J$. This term does not affect K\"ahler metric but
implies CP breaking.

\item Zero energy ontology has deep implications for the cosmic and
ultimately also for biological evolution (magnetic flux tubes paly a fundamental role in TGD inspired biology and cosmic strings are limiting
cases of them). The arrows of geometric time are opposite for the strings
and also for positive energy matter and negative energy antimatter. This
implies a competition between two dissipative time developments proceeding
in different directions of geometric time and looking self-organization and
even self-assembly from the point of view of each other. This resolves
paradoxes created by gravitational self-organization contra second law of
thermodynamics. So called super-symplectic matter at cosmic strings implies
large p-adic entropy resolves the well-known entropy paradox.

\item p-Adic fractality and simple quantitative observations lead to the
hypothesis that cosmic strings are responsible for the evolution of astrophysical structures in a very wide length scale range. Large voids
with size of order 10^8 light years can be seen as structures cosmic
strings wound around the boundaries of the void. Galaxies correspond to
same structure with smaller size and linked around the supra-galactic

strings. This conforms with the finding that galaxies tend to be grouped
along linear structures. Simple quantitative estimates show that even stars
and planets could be seen as structures formed around cosmic strings of
appropriate size. Thus Universe could be seen as fractal cosmic necklace
consisting of cosmic strings linked like pearls around longer cosmic
strings linked like... \end{enumerate}

\vm{\it 4. Cosmic strings, gamma ray bursts, and supernovae}\vm

During year 2003 two important findings related to cosmic strings were
made.

\begin{enumerate} \item A correlation between supernovae and gamma ray
bursts was observed.

\item Evidence that some unknown particles of mass $m\simeq 2m_e$ and
decaying to gamma rays and/or electron positron pairs annihilating
immediately serve as signatures of dark matter. These findings challenge
the identification of cosmic strings and/or their decay products as dark
matter, and also the idea that gamma ray bursts correspond to cosmic fire
crackers formed by the decaying ends of cosmic strings.

\end{enumerate}

This forces the updating of the more than decade old rough vision about
topologically condensed cosmic strings and about gamma ray bursts described
in this chapter. According to the updated model, cosmic strings transform
in topological condensation to magnetic flux tubes about which they
represent a limiting case. Primordial magnetic flux tubes forming
ferro-magnet like structures become seeds for gravitational condensation
leading to the formation of stars and galaxies. The TGD based model for
the asymptotic state of a rotating star as dynamo leads to the
identification of the predicted magnetic flux tube at the rotation axis of
the star as Z^0 magnetic flux tube of primordial origin. Besides Z^0
magnetic flux tube structure also magnetic flux tube structure exists at

different space-time sheet but is in general not parallel to the Z^0
magnetic structure. This structure cannot have primordial origin (the
magnetic field of star can even flip its polarity).

The flow of matter along Z^0 magnetic (rotation) axis generates
synchrotron radiation, which escapes as a precisely targeted beam along
magnetic axis and leaves the star. The identification is as the rotating
light beam associated with ordinary neutron stars. During the core collapse
leading to the supernova this beam becomes gamma ray burst. The mechanism
is very much analogous to the squeezing of the tooth paste from the tube.
The fact that all nuclei are fully ionized Z^0 ions, the Z^0 charge
unbalance caused by the ejection of neutrinos, and the radial compression
make the effect extremely strong so that there are hopes to understand the
observed incredibly high polarization of 80 ± 20 per cent.

The W fields experienced by fundamental fermions at 2-D surfaces at
which they are localized vanish by the well-definedness of em charge, and
one can also require that Z^0 fields vanish at least above weak scale.
The vanishing of effective weak fields is an obvious objection against
the model unless one allows the possibility of large values of
$h_{eff}=n\times h$ strongly suggested by the identification
$h_{eff}=h_{gr}$, where $h_{gr} GMm/v_0$ is the gravitational Planck
constant inspired by Nottale's considerations: here M and m would
correspond to masses of supernova and of microscopic system.

TGD suggests the identification of particles of mass $m\simeq 2m_e$
accompanying dark matter as lepto-pions formed by color excited leptons,
and topologically condensed at magnetic flux tubes having thickness of
about lepto-pion Compton length. Lepto-pions would serve as signatures of
dark matter whereas dark matter itself would correspond to the magnetic
energy of topologically condensed cosmic strings transformed to magnetic
flux tubes.

```
%\end{abstract}
```